Appendix 3.

Hydrobiology (2013a) *Environmental Values Downstream of the Former Rum Jungle Mine site – Phase 1.* Prepared for the Department of Mines and Energy, Northern Territory Government.

Department of **Primary Industry and Resources**

Hydrobiology

Environmental Values Downstream of the Former Rum Jungle Minesite – Phase 1

Northern Territory - Department of Mines and Energy

April 2013

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Environmental Values Downstream of the Former Rum Jungle Minesite – Phase 1

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EXECUTIVE SUMMARY

Hydrobiology was commissioned by the Northern Territory Government Department of Mines and Energy to undertake a study of the environmental values downstream of the former Rum Jungle Mine. The purpose of the study was to describe the receiving environment in terms of its key ecological and geomorphological attributes, identify environmental values (EVs) and set appropriate water quality objectives (WQOs) in accordance with the ANZECC/ARMCANZ (2000) methodology. The Terms of Reference required this to be achieved in a two-stage process. The outcome of Stage 1 (this report) was the setting of EVs and WQOs (by river zone) with Stage 2 defining a monitoring plan.

Key elements of the methodology included assembling a team of recognised scientific experts covering the necessary range of relevant technical disciplines (including site experience). The team addressed the scope via a literature review, site visit, consultation with key stakeholders and a workshop. The literature review phase (supported by the fieldwork) showed that while a substantial amount of monitoring data had been collected over the years, there were also very substantial data gaps.

The East Branch of the Finniss River and Finniss River proper are dynamic in terms of flow and sediment processes, the key elements of which include monsoonal/season rainfall, high rates of sediment delivery from an eroding mine landscape, a sand-bearing geology and high groundwater connectivity. The rainfall record showed that the region had become wetter over recent decades and this, combined with climate change and the proliferation of Gamba grass, indicated that rates of erosion and sediment transport had probably increased and are likely to increase further in the future with particular implication for large stores of sand observed in the East Branch during the field trip.

Water and sediment quality on the mine site have been relatively well studied and it is well established that the rehabilitation of the mine site in the 1980s greatly improved the quality of discharges downstream and reduced contaminant loads delivered to the East Branch per annum by factors of three to seven. Nonetheless, water quality in the East Branch was still above levels that could cause environmental impact as late as the 2000s, and sediments along the East Branch have contaminant concentrations above the ANZECC/ARMCANZ (2000) sediment quality guidelines. However, there has been no reporting of the trends in continuing water quality monitoring data since reviews in the mid-2000s.

In terms of aquatic ecosystems, notable studies were undertaken during the 1990s that documented the status and recovery of water quality and aquatic organisms following commencement of rehabilitation in 1983, but there have been few studies that have included reference to riparian vegetation either during baseline, mine life or the post rehabilitation period, making quantitative impact assessment difficult although massive dieback is known to have occurred. Despite ecological recovery in the East Branch, elements of the ecosystem remain highly impacted although condition was better in the Finniss River. A range of terrestrial fauna species, including threatened species, have been recorded in the area.

Downstream, the Finniss River flows through the Finniss River Coastal Floodplain Site of Conservation Significance, that supports a number of listed threatened species.

An important part of the field visit was identifying cultural values via meetings with traditional Aboriginal owners (traditional owners) who willingly gave their time to assist the study and their assistance is gratefully acknowledged by the authors. The authors have attempted to identify the cultural values that need to be considered under the ANZECC/ARMCANZ (2000) method and these are described in the body of the report. The authors understand that the health of the river, its ability to flow freely, the abundance and wellbeing of Totem and other culturally and spiritually significant organisms and traditional foods are all particularly important to the traditional owners.

For the purposes of assigning EVs and WQOs, the downstream riverine receiving environment was divided into nine zones including four in the East Branch (between upstream of the mine and the Finniss River confluence), and five in the Finniss River (from upstream of the East Branch confluence to the estuary, including the site of conservation significance. This was undertaken because the condition, environmental values, recovery potential and therefore targets are variable along the river system. The values assigned were Aquatic Ecosystems, Wildlife Habitats, Primary Recreation, Secondary Recreation, Visual Recreation, Cultural/Spiritual, Industrial Usage, Aquaculture, Drinking Water, Irrigation, Stock Water and Farm Supply (not all values were relevant to each zone with the exception of Aquatic Ecosystems and Cultural/Spiritual, which were significant for every zone). Water quality objectives were developed for each zone for each water quality parameter by selecting the lowest trigger value identified for any environmental value for that zone. The results are contained in a series of tables in the main body of the report.

Environmental Values Downstream of the Former Rum Jungle Minesite – Phase 1

Northern Territory - Department of Mines and Energy

April 2013

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1 INTRODUCTION

1.1 Background

Hydrobiology was commissioned by the Northern Territory Government (Department of Mines and Energy) to undertake a study of the environmental values downstream of the former Rum Jungle mine site.

As described in the study Terms of Reference (ToR), the former Rum Jungle Mine site was mined in the 1950s-1970s then rehabilitated during the 1980s. Monitoring of landform stability and water quality has continued since that time. The current project (under a National Partnership Agreement between the Northern Territory and Commonwealth Governments) has tasked the Department of Mines and Energy (DME) with developing an improved rehabilitation strategy for the site in recognition of the ongoing environmental impacts from this site due primarily to acid and metalliferous drainage (AMD). In order to achieve this, the DME intends to apply the ANZECC/ARMCANZ (2000) water quality guidelines to:

- obtain a clear definition of environmental values, or uses;
- obtain a good understanding of links between human activity (including Indigenous uses) and environmental quality;
- set unambiguous management goals;
- identify appropriate water quality objectives, or targets; and
- develop an effective management framework, including cooperative, regulatory, feedback and auditing mechanisms.

Therefore (per the ToR), the purpose of this study is to:

- identify and define the receiving environment including the relevant environmental values of the receiving environment in accordance with ANZECC methodology. This will include assessment of the aquatic ecosystems as well as fluvial sediments downstream of the mine site; and
- determine appropriate water quality guidelines.This is a two stage study. The first stage of the study required that the study team:

- Undertake a literature and data review;
- Meet with DME and key stakeholders, including members of the Rum Jungle Working Group (RJWG) comprising experts from the Northern Territory and Commonwealth Governments and the Northern Land Council, and traditional owners of the site regarding the project, in order to gain a comprehensive understanding of cultural aspects important to traditional owners of the site, who in the past have used the river and its resources for their livelihood; and
- Conduct a visit of the mine site and receiving environment and while there, meet with relevant traditional owners and other stakeholders downstream of the mine site.

- Prepare a Stage 1 report (this report) detailing the relevant environmental values identified and water quality objectives recommended.

The second stage of the study will:

- Outline a detailed monitoring program which will enable the development of locally-derived water quality guidelines for the receiving environment.
- Recommend further activities necessary to address gaps in understanding the impacts on aquatic ecosystems downstream of the site, including possible surveys (i.e. aquatic surveys), project timelines and estimated costs.
- Prepare a Final report detailing all components of Stages 1 and 2.

2 METHODOLOGY

The study was undertaken by team of recognised scientific experts which included those with extensive experience of the Rum Jungle Mine, and of the biophysical and cultural characteristics of the region. For Stage 1, key members of the study team visited the mine, and sites on the Finniss River and East Branch.

Material for the desk-top study was sourced from the DME and NT Department of Land Resource Management (DLRM), internet searches, and personal libraries of reports and field notes. The on-line vegetation database of the Global Biodiversity Information Facility (GBIF) was accessed through the Atlas of Living Australia (ALA) portal and a list of floristic and faunal records was downloaded for the Finniss River area.

Meetings with traditional owner groups and other stakeholders in the receiving environment were held in Batchelor on 3rd October, Darwin on 7th and 9th October, and Palmerston on 10th October. Information on culturally important bush food species and other important plants and vegetation assemblages along the Finniss River was collated from the open discussion and from individual consultations following the meetings.

Site visits were conducted to both the upstream and downstream sections of the Finniss River, including adjacent billabongs and a significant tributary stream at Mount Burton Spring, on 5th, 8th and 16th October. A record was made of dominant canopy and significant understory species at selected fluvial sites. Aquatic macrophytes were also recorded where present.

The findings of the literature review, field visits and stakeholder meetings were discussed at a workshop on Thursday 18th October. Key outcomes of that meeting included:

- a review of information and identification of data gaps;
- a zone breakdown of the Finniss River; and
- draft Environmental Values.

The remainder of this report provides a description of Environmental Values, a description of the current status of ecosystem components, the adopted zone breakdown, and assignment of Environmental Values for each identified zone.

3 ENVIRONMENTAL VALUES

ANZECC/ARMCANZ (2000, Section 2.1.3) states that:

> *Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits.*

It specifically recognises the following environmental values in the guidelines:

- aquatic ecosystems;
- primary industries, including irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods;
- recreation and aesthetics (the former being divided into primary and secondary contact recreation in the guidelines, although primarily in terms of microbial water quality);
- drinking water;
- industrial water; and
- cultural and spiritual values.

The guidelines note further that:

> *Where two or more agreed environmental values are defined for a water body the more conservative of the associated guidelines should prevail and become the water quality objectives. It is essential that the needs and wants of the community be identified when environmental values are being defined to a particular water resource.*

For the purposes of this project and report, we have adopted the full suite of environmental values used by the guidelines, and have added a value of "Wildlife Habitat" to encompass the riparian habitats of the Finniss River system that are of particular importance for this project. Because the stakeholder consultation and site visits identified that the waters of the river system were being used for general farm/property use via offtake either directly from the river or via fluvial aquifers, the general water use sub-category of the guidelines' primary industries environmental value was re-named "Farm Supply" for this report. Therefore, the full set of environmental values considered in this report as used herein was:

- aquatic ecosystems;
- wildlife habitat;
- human consumer;
- primary recreation;
- secondary recreation;
- visual recreation;
- cultural/spiritual;
- industrial use;
- aquaculture;

- drinking water;
- irrigation;
- stock water; and
- farm supply.

4 CURRENT STATUS OF ECOSYSTEM COMPONENTS

4.1 Hydro-meteorology

4.1.1 Climate

The climate of the Rum Jungle area is described in numerous reports throughout the body of reviewed literature. In summary, the climate is tropical monsoonal with a mean rainfall of about 1500 mm (RGC 2010b). The variability of inter-annual rainfall totals is high and affected by the Southern Oscillation.

The historical rainfall record shows that the Northern Territory has become wetter since 1900 and the rate of change has increased since the 1950s, particularly for Nov-Apr totals (Hennessey *et al*, 2004). Further, since 1910, the intensity of heavy daily rainfall events has risen by 10%, (mainly due to increases after 1970 during March to August). Figure 4-1 shows a residual mass plot for annual rainfall totals, and demonstrates rainfall trends for Darwin Airport. The plot shows the cumulative deviation of the annual rainfall values from the overall mean of the dataset. Positive (upward-sloping) sections of the plot represent runs of above-average years, while negative (down-sloping) sections runs of below average years.

Rum Jungle was operational between 1952 and 1971, with rehabilitation occurring between 1982 and 1986 (RGC 2010b). The residual mass plot shows that the mine operated during a relatively dry phase, but conditions became wetter in the 1970s and again from the mid 1990s after rehabilitation.

Moreover, climate change predictions indicate that while regional rainfall is predicted to decline, the intensity of extreme events (including cyclones) will increase. However, changes to cyclone frequency (currently 1.8 and 2.0 per year for strong El Niño/La Niña phases respectively) are not known (Hennessey *et al*, 2004). This suggests that rates of erosion and sediment transport within the East Branch and Finniss Rivers may increase, and that changes to certain factors that affect flow and sediment processes (e.g. fire regime and vegetation) may also be expected. In short, it is reasonable to assume that the vigour of geomorphic processes (flow and sediment transport) has increased in recent decades, and is likely to increase further into the future. The relevance of this for environmental value in the Finniss River will be discussed in sections following.

Climate research also forecasts a sea level rise of between 10 and 50 cm by 2070 which could alter the tidal boundary of the Finniss River but the impact of this on ecological values is speculative.

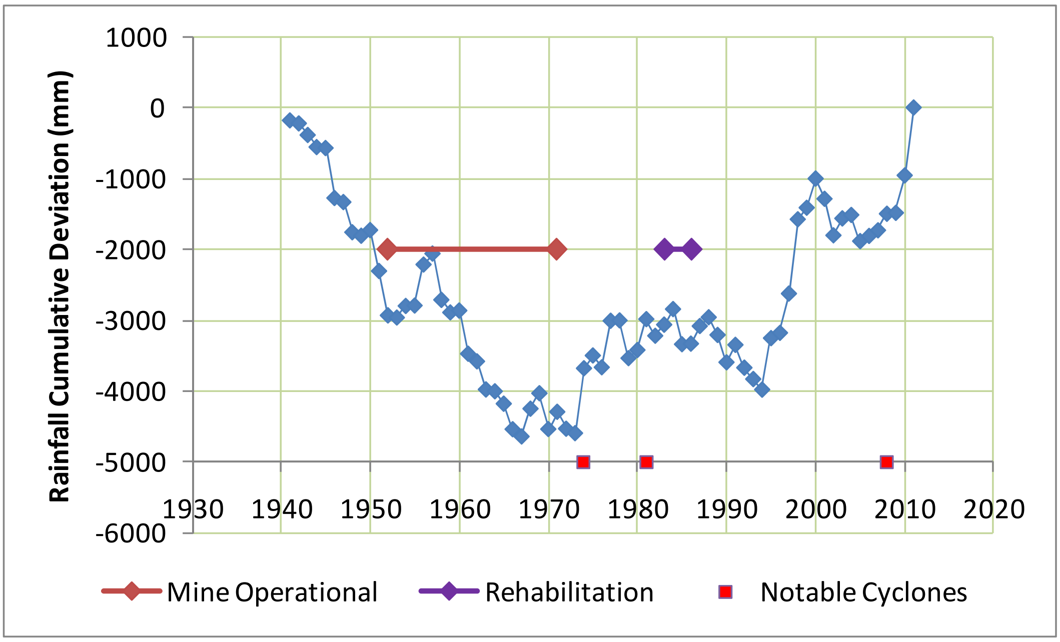

Figure 4-1 Rainfall residual mass plot (Darwin Airport)

4.1.2 Surface Hydrology

Streamflow patterns are seasonal and follow rainfall patterns. The East Branch has no flow from about July to December but the Finniss River has continuous flow from a point about 26 km above its junction with the East Branch (Watson 1975). The East Branch is classified as intermittent, as flows are comprised of both surface runoff and groundwater components. The first flows at gauge station 0097 usually occur three to four weeks after they are recorded at gauge station 0200 due to 'wetting up' of the dry river bed between the gauge stations (RGC 2010b). Pools of up to 300 m in length persist throughout the dry season in the East Branch (Taylor 2007).

There is some uncertainty over flow rates due to uncertainty in the stage-discharge rating curves at the key gauging stations (200 and 097). Taylor (2007) reported that 'a maximum annual discharge of 147 [cumecs] was recorded in 1977', presumably from water level records rather than by gauging, but Moliere *et al.*, (2007) reported discrepancies between load estimates (based on flow records) between gauge stations 200 and 097, and that hydrographs presented in that study (e.g. Figure 2) appeared to show discharges well in excess of 147 cumecs. Uncertainty associated with flow volumes as derived from gauge records is not unusual, particularly where mobile bed sediments may alter gauge control as is likely to be the case for the East Branch and (possibly), to a lesser extent, the Finniss River. Most of the large floods tend to occur at the end of the wet season when vegetation is well established and thus mitigating bank erosion to some degree (Morris 2005).

In terms of drainage patterns, the mine site area intersects the East Branch of the Finniss River and Fitch Creek with about two-thirds of the East Branch catchment upstream of the Mine (Davy 1975). Specifically the East Branch originally ran through the area now occupied by Main and Intermediate ore bodies so it was diverted. The Diversion Channel still carries the main flow of the East Branch but high flow waters are routed through the Main and Intermediate pitss, roughly following the original course of the river, then rejoins the East Branch via a spillway/outflow structure. To the north of the pits is the old tailings area subcatchment, which drains in a westerly direction through Old Tailings Creek and joins the East Branch at a point about 1.5 km downstream from the Intermediate pit outflow channel.

4.1.3 Hydrogeology

The East Branch is underlain by the Whites/Geolsec formations in its upper reaches, then by the highly permeable Coomalie Dolostone between the Mine and Old Tailings Creek confluence, and is then underlain by the Crater Formation in reaches downstream. The soils from the East Branch are primarily composed of alluvial sand and, overall, the geology is 'sand bearing' suggesting that sand bed deposits would likely have been a characteristic of the East Branch prior to mining.

Historic groundwater investigations and the current understanding of groundwater movements are well summarised in RGC (2010a, 2010b) and Wels *et al*, (2012). In summary, there are strong hydraulic connections beneath the mine area and towards the Finniss River valley, particularly via the highly fractured Coomalie Dolostone. RGC (2010a) suggested that half the Nov-March rainfall enters the sub-surface as recharge. Modelling results (Wels *et al*, 2012) suggested that mean annual losses from the Main and Intermediate pits total about 12 L/s, while annual groundwater discharge to the East Branch (downstream of gauge station 0200) is about 44 L/s, while a further 73 L/s is discharged to the various East Branch creeks and tributaries. Within the Finniss River valley, groundwater movement is primarily controlled by the permeable shallow soils and weathered bedrock, and at depth by fractures, faults and karstic features (RGC 2010a). The shallow alluvial aquifer underlying the East Branch and tributaries is deep in places (up to 20 m) facilitating significant groundwater transfers (RGC 2010b).

4.2 Fluvial Geomorphology

Aside from descriptions of geology, soils and surface hydrology, there appears to have been little by way of study of the fluvial geomorphology of the East Branch and Finniss Rivers. However, based largely on field observations and aerial imagery review for this study, it can be said that the East Branch exhibits a variety of morphological forms along its course. The river flows through incised reaches, between terraces of historic mine waste (including tails) along Old Tailings Creek, and zones of rock outcropping. Also present are wider alluvial reaches with compound cross section forms that are comprised of semi-permanent benches, sand drifts, raised terraces and off-channel flow paths including flood runners (Taylor 2007, figure 1).

Bed material ranges from boulder to sands and silts, with transient deposits of sand (point bars or medial bars) prevalent along the East Branch, particularly upstream from the Finniss River junction, but notable also nearer the mine (upstream of the Old Tailings Creek confluence). The Diversion Channel and Fitch Creek appear to be significant source areas although, as previously mentioned, instream sand deposits would be expected based on the characteristics of the local geology. There is little information available regarding erosion rates around the mine but Davy (1975) observed that about 1 cm of (bare) tails was eroded during an average 'wet' estimated to be 400 tonnes, while erosion from the overburden heaps was estimated at 0.3 cm/y before rehabilitation.

The Finniss River downstream of the junction with the East Branch is characterised by extensive pools and a variety of morphological features including in-stream woody debris, well-established riparian vegetation and sediment deposits.

The distribution and fate of contaminants in the fluvial system in inherently linked to the processes of flow and sediment transfer. Active areas of bank erosion in the East Branch (including the Diversion Channel) suggest that lateral migration (or at least channel widening) is occurring. Lateral migration causes 'fresh' fine sediments (and contaminants) to be incorporated into the floodplain (by, for example, accumulation on point bars) while, on the eroding bank, older sediments are released back to the watercourse. This process is known as lateral accretion. Vertical floodplain accretion occurs when sediment is deposited on top of floodplain surfaces by floodwaters.

For the East Branch, flow interaction with the floodplain is clearly important in terms of the lateral transfer of sediment to the floodplain during the wet season (vertical accretion), but also important is the effect of flood return water that can transport fine sediments back to the river channel. The return flow can cause erosion and gullying at the bank tops as water spills back to the channel. Davy (1975) estimated that about 100 km^2 of East Branch floodplain may be affected by sediment transfers by this process, but no supporting evidence was presented in that study. Mud drapes have been observed on bank tops in the East Branch (Taylor 2007) and are indicative of high rates of overbank deposition.

A key observation from the field survey was that the sand slugs evident in the East Branch were not so noticeable in the Finniss River downstream from the confluence. While it appears likely that the sand from the East Branch is discharging to the Finniss River during the wet season (particularly during peak hydrograph conditions), the lower section of the East Branch (1 – 2 km) appears to be a temporary storage / deposition zone, seemingly with a net build-up of sediment occurring. Build-up of sediment on the bed of the East Branch could cause widening where erodible banks are present (the case for sections of the East Branch), and this was the interpretation of observations made during the field trip (R. Smith pers. comm.).

Work by Taylor (2007) and Morris (2005) showed that there was no clear pattern of the distribution of sediment associated metals along the East Branch channel and near bank areas, and was likely a function of local, reach-scale variations in channel geometry and geomorphology, which control sediment storage and transfer patterns.

4.2.1 Fluvial Sediments

Overall it is clear that there is active export of sediment from the extensive bare surfaces of the mine area, and that this is being transported downstream along the East Branch at a rate that appears to be high compared with historical levels, and may well increase further under the scenario of climate change in coming decades. The spread of Gamba grass at the mine site and along the river corridor has likely caused a change to the frequency of fires, and potentially higher rates of sediment export to the river from the erodible soils of the burned surfaces.

Within the riverine corridor of the East Branch, sediment deposition appears to be occurring (and, possibly, channel widening in some parts), particularly in its lower reaches near the junction of the Finniss River. This sediment is likely to be derived from both mine and floodplain sources.

The processes by which these sediments are deposited and then exported from the East Branch to the Finniss River are unclear, but it is assumed that the Finniss River has sufficient energy to transport this sand downstream without significant deposition near the junction. However, as previously discussed, increased rates of sediment export from the East Branch to the Finniss River may reasonably be expected into the future.

4.3 Water Quality/Sediment Quality

The quality, or at least contaminant loads, of waters leaving and on the Rum Jungle Mine site have arguably been the subject of greatest study of those aspects of the Rum Jungle site management that are directly relevant to this report. It is inappropriate here to provide a thorough review of that body of work, but the key issues are summarised in this section.

Following the cessation of mining at the site, the seasonal wet/dry cycle and active microbial oxidation of exposed (to oxygen) sulphidic materials resulted in the generation of metal rich acidic waters on the mine site that either flowed downstream into and through the East Branch or resulted in the evaporative formation of salt deposits that were subsequently available for re-solution and remobilisation into downstream waters in the wet season (Davy 1975 and detailed reports therein). These processes resulted in annual loads of contained metals in the East Branch of around 44 to 130 t of copper, 46 to 100 t of manganese, 16 to 40 t of zinc and 3300 to 13000 t of sulphate over the period 1969/70 to 1973/74 at concentrations up to ~30 mg/L of copper and manganese, 8 mg/L of zinc and 3000 mg/L of sulphate. This legacy of contaminant loading into the river system was the major reason for the rehabilitation of the site in the 1980s.

Following the rehabilitation, the contaminant loads in the East Branch were greatly reduced, but remained sufficiently elevated to impact the ecosystems of that watercourse (Kraatz 1998). Concentrations of copper, manganese and zinc in the East Branch waters remained two to three orders of magnitude above those in reference sites, and generally higher than recommended for drinking water and for protection of aquatic ecosystems. These reductions amounted to reductions in annual-cycle contaminant loads of sulfate, Cu, Zn, and Mn by factors of 3-7 (Jeffree *et al.* 2001) to around 2-15 t/a of copper, 1.6-7.5 t/a of zinc, 3.9-30.5 t/a manganese and 760-4800 t/z sulphate, depending on analysis method. Mean concentrations of these contaminants at gauge station GS8150200 (East Branch at the mine site access bridge) in 1991/92 were 0.74 mgCu/L, 0.48 mgZn/L, 1.25 mgMn/L and 1758 $mgSO_4/L$ with almost 90% of copper concentrations below 1 mg/L between 1990 and 1995 (Lawton in Kraatz 1998, Lawton and Overall in Pidsley 2002).

Brazier *et al.* (2005) found that aluminium, iron, manganese, cobalt, copper, nickel, zinc, cadmium, lead and uranium concentrations in the waters of the East Branch over the period of 2003-2005 were higher for both filtered and unfiltered samples than for the Finniss River upstream of the confluence, and that the wet season East Branch loads for copper, manganese and zinc remained comparable to those of the 90s discussed above. There have been few reported quantitative analyses and descriptions of water quality downstream of the mine site since that time, despite ongoing monitoring. An updated assessment is strongly recommended.

Taylor (2007) found that metal concentrations in sediments of the East Branch were highest in the mine site area, but that elevation above ANZECC/ARMCANZ (2000) sediment quality guidelines extended to the Finniss River downstream, specifically for arsenic, zinc and chromium in the <62.5 μm fraction and arsenic and zinc in the bulk fraction in stream bed sediments, and in bank sediments but not as far downstream. There were overall negative correlations of sediment metal concentration with distance downstream, but there was not a simple attenuation with distance, with local hydraulic and geomorphic conditions affecting the patterns of sediment deposition. Brazier *et al.* (2005) found that sediments from the East Branch were substantially elevated compared with the Finniss River upstream for the same list of parameters that they determined were elevated in waters. They also found that despite methodological differences, for at least one site (GS8150097, East Branch above Hannah's Spring) the concentrations of zinc, nickel iron, manganese and copper were comparable for the period 2003-2003 (whole sediment) as for the period 1988-1993 (<2 mm fraction) reported in Kraatz (1998).

Morris (2005) also found that East Branch sediment metal concentrations were above the ANZECC/ARMCANZ (2000) sediment quality guidelines, particularly copper, arsenic and lead, and particularly within the first four kms of the mine. He also determined that there was a partial inverse correlation between distance downstream and metal concentrations in sediments, but that zinc, thorium and barium exhibited no discernible diminution and no characteristic pattern of concentration downstream of the mine. In particular, thorium acted independently of other elements, showing a direct positive correlation with stream power. Again, there has been little reported on sediment metal concentrations downstream of the mine since that of Taylor (2007).

Kraatz (2003) noted that there was very little radiological evidence regarding the sediments of the East Branch. Therefore, it was difficult to be certain regarding potential for radiological issues downstream of the mine, but inferred from restricted locations of any radiological issues of note within the mine area that it would be unlikely that any downstream activities would be affected, although noted that this would need to be confirmed. Bollhöfer *et al.* (2007) used airborne gamma survey data to assess the current state and conditions of the land and water resources and to assess the need for restrictions for worker and other human access. Some anomalies were identified downstream of the site but it was not determined whether this was due to tailings deposits. They noted that the Acid Dam area was not suitable for residence during the dry season but that short stays would be acceptable for risk, that the mine site and the East Branch for ~five kms downstream would not be suitable for year-round habitat with a traditional lifestyle and that the waterways would not be suitable for year-round harvesting of fish and/or mussels. Hughes and Bollhöfer (2010) examined the earlier identified anomalies in more detail, and noted the following:

- three of four main gamma anomalies in the immediate mine site area were caused by tailings residues overlooked in the remediation works;
- the fourth was caused by residual mineralised waste rocks; and
- three of the downstream anomalies in the Mt Fitch area were similar geochemically and radiologically to the Rum Jungle anomalies, and therefore, mostly likely sourced from the mine, probably being buried tailings deposits, while the fourth was attributable to natural mineralisation in the Mt Fitch area.

4.4 Aquatic Ecosystems

Our knowledge of the contemporary status of the aquatic ecosystems of the Finniss River system relies heavily on field and experimental studies conducted during the 1990's, at least ten years after the commencement of the remediation of the Rum Jungle Mine site in 1983. During this post-remedial period, there were appreciable reductions in the annual loads of Cu, Zn, Mn and sulphate delivered into the Finniss River system via the East Branch as well as greater reductions in the maximum water concentrations of the metals and acidity in the East Branch and the Finniss River (see Section 4.3 above). It was against these appreciable improvements in water quality in the Finniss River system that a range of post-remedial studies were undertaken in the 1990's with the general objectives of:

- comparison of the post-remedial status of fish diversity and abundance with that measured in 1973/4 when unabated pollution from Rum Jungle had caused severe detriment to all of the East Branch downstream of pollution inflow from Rum Jungle and appreciable detriment in the main Finniss for 15 km downstream of its junction with the East Branch;
- assessment of existing impacts on aquatic algae and various groups of invertebrates, as previous studies of fish dietary composition had indicated such impacts had occurred;
- evaluation of the apparent adaptation of fishes to contaminant levels in the East Branch; and
- application of quantitative ecological risk assessment methodologies.

4.4.1 Finniss River

Assessment of the post-remedial status of fish communities was based on the relative abundances of seven fish species, sampled by enmeshing nets during two dry seasons (1992 and 1995). The post-remediation study (Jeffree *et al.* 2001) showed that prior to remediation, the impacted region of the Finniss River in 1974 had dissimilar and more heterogeneous fish communities, generally characterized by reduced diversity and abundance, compared with sites unexposed to elevated contaminant water concentrations. Following remediation, recovery in fish communities from the impacted region was indicated because they were not dissimilar from those sampled at contemporary unimpacted sites, which were also similar to pre-remediation unimpacted sites. Even though considerable contaminant loads were still being delivered to the impacted region of the Finniss River over the annual cycle in the 1990's, the recovery in fish diversity and abundances was consistent with (a) reductions of *in situ* contaminant water concentrations at the time of fish sampling, (b) reductions in annual-cycle contaminant loads of sulfate, Cu, Zn, and Mn by factors of 3-7, (c) greatly reduced frequencies of occurrence and magnitude of elevated contaminant water concentrations over the annual cycle, that was most pronounced for Cu, and (d) the absence of extensive observed fish-kills during the first-flushes of contaminants into the Finniss River proper at the beginning of the wet season, that were evident prior to remediation (Jeffree and Williams 1975).

During the fish sampling program in 1992, several specimens of a new species (and genus) of freshwater fish were taken in the Finniss at sites both upstream and downstream of its confluence with the East Branch (Jeffree, 2001). This species, now tentatively identified as *Pingalla lorentzi* according to museum records, has only been recorded in the Finniss River in the Northern Territory (*Pingalla lorentzi* is also known to occur in New Guinea (i.e. Papua New Guinea and West Papua), and Cape York and is listed as vulnerable (Northern Territory Parks and Wildlife 2012).

Prior to rehabilitation at the Rum Jungle Mine site, Allison and Simpson (1989) found no evidence of the freshwater mussel *V. angasi* in the East Branch downstream of the Rum Jungle Mine site or in the channel of the Finniss River downstream of the East Branch confluence. Although in the 1990's *V. angasi* were similarly not found in the East Branch downstream of the mine site, nor in the first ten kms of the Finniss River channel downstream of the East Branch confluence, Markich *et al.* (2002) reported, viable populations in the channel from 10 to 30 km downstream of the East Branch confluence. However, the longest-lived bivalves (ten years) found in this region of the river channel dated back to the end of rehabilitation (i.e. 1986) only. The maximum recorded ages of *V. angasi* at sites 8 and 9 (10 and 15 km downstream respectively) suggested an unfavourable environment for bivalve recruitment and/or survival prior to rehabilitation. In contrast, the oldest individuals at sites where there was no evidence of contamination by AMD, based on acceptably low concentrations of metals in sediment and surface water, ranged from 15 to 31 years , with viable populations existing prior to rehabilitation of the mine.

With regard to other biota Edwards (2001) found that communities of benthic macroinvertebrates in the Finniss in proximity to its confluence with the East Branch were modified in their composition by pollution from the Rum Jungle Mine site. However, the extent and nature of the effect of contaminants was difficult to discern at the level of sampling undertaken in that study.

4.4.2 East Branch

Field studies during the 1990's demonstrated the occurrence of five to seven fish species in the contaminated region of the East Branch. These species penetrated to varying degrees upstream along a gradient of contaminant water concentrations with one species, the black-striped rainbowfish (*Melanotaenia nigrans*) still abundant at very high metal concentrations in the stream waters (Jeffree and Twining, 2000; Twining, 2002). These occurrences indicated that varying degrees of tolerance to the contaminant water concentrations had developed among these fishes. An experimental study on this most tolerant fish species showed that copper accumulation in its tissues was reduced due to its diminished uptake via the gills, compared with a population unexposed to contaminants from Rum Jungle. The results of genetic studies were also consistent with natural selection for resistance to contaminants having occurred in this exposed population of fish (Gale *et al*., 2003).

Two species of decapod crustacean (freshwater crab and long claw prawn) were also observed in the East Branch during these field investigations. Although the number of fish and decapod crustacean species present did represent a recovery, compared with the pre-remedial status of the East Branch, it still fell well short of the potential diversity of up to 15-18 fish species and 5-6 species of macro-crustaceans that could be found in similar habitats elsewhere within the Finniss River system. Moreover, in the 1990's there were still areas of the East Branch where neither fish nor decapods were found (Twining, 2002).

Several investigations undertaken on the communities of benthic macro-invertebrates showed the following. Compared with unexposed reference sites the East Branch biota exposed to contaminants had fewer types and lower abundances of organisms, with the complete absences of many types of organisms know from previous studies to be sensitive to AMD (Jackson, 1993). There had also been no increase in the total number of families of organisms, compared with the pre-remedial baseline (Jeffree and Williams, 1975). However, there did appear to be some recolonisation occurring in the lower reaches of the East Branch. In a further study that encompassed one full annual cycle Edwards (2002) concluded that the invertebrate communities showed slight to severe modification of community structure when compared with unpolluted reference sites. The degree of impact varied both spatially and temporally over the annual cycle and some reduction in impact was found at the furthest distance downstream. It was noted that the assemblages sampled in the East Branch were dominated by Diptera (flies), with few PET (Plecoptera, Ephemeroptera and Trichoptera, or stoneflies, mayflies and caddisflies, generally regarded as being orders that are sensitive to pollution impacts) apart from Leptoceridae, indicating dominance by pollution tolerant forms. It was further noted that in the East Branch downstream of Hannah's Spring, the macroinvertebrate assemblages were close to reference condition, but as noted above the assemblages in the Finniss River downstream of the East Branch confluence differed from upstream of the confluence. This latter difference in the findings between the status of the lower East Branch and the Finniss River below the confluence may indicate that the intermittent nature of the East Branch masked an underlying pollutant stress in the East Branch below the spring.

In the first study of single-celled algae in the Finniss River system by Ferris *et al*. (2002), the changing diatom flora of the East Branch was found to relate to a gradient of AMD pollution that developed in the recessional flow period of the early dry season of 1995. The richness of the diatom flora varied from 30 to 45 species at the unpolluted reference sites and ranged from only a few species to 23 species along the gradient of acid-drainage affected sites.

This study found that changes in benthic diatoms did reflect the pollution gradient that develops in the East Branch during the early dry season. The East Branch, upstream from Hanna's Spring Creek, had not recovered to closely resemble reference sites by 1995.

4.5 Riparian Flora

4.5.1 Riparian Vegetation

Few published studies have included any reference to riparian vegetation in the Rum Jungle receiving environment during the life of the mine or during the periods of rehabilitation following. Revegetation studies are well reported in the literature (Cameron McNamara 1983, CCNT 1984, Dames and Moore 1983, Menzies & Mulligan 1997, Milnes *et al.* 1990, Ryan 1985, 1986a, 1986b) but they are restricted to the waste rock dumps and impacted land areas within the Rum Jungle Mine area. No baseline vegetation surveys are published for the catchment, and it would appear that a detailed analysis of the impact of off-site transportation of pollutants, particularly copper, on the plant biota in the receiving environment has never been attempted. This might seem surprising in the light of the massive die-back of mature White Paperbarks (*Melaleuca leucadendra*) known to have occurred during mining operations and the anecdotally reported mechanical removal of dead trees from the downstream river levees shortly thereafter.

Two reports associated with the Brown's Oxide Project, a mining operation immediately adjacent to the Rum Jungle Mine site currently in care and maintenance, contain desktop assessment of vegetation in the area including the riparian environments of the Finniss River. They consist of an Environmental Impact Assessment (EIA) compiled by Low (2001) and the unpublished Notice of Intent (NOI) for the Area 55 Oxide Project by HNC (Australia) Resources (Coffey Environments 2009).

For the EIA, Low (2001) searched NT Herbarium records and compiled a floristic list of 478 species occurring in a 20 minute square grid cell centred on the Brown's Oxide lease. He concluded that "recovery of the riparian habitat downstream from Rum Jungle following rehabilitation may result in habitat appropriate for several species of small understory plants that are likely to be classed as vulnerable by the NT Herbarium." These were listed as

Indigofera schultziana, *Habenaria elongata* and an undescribed *Helicteres* sp, but none of these three species are considered to be riparian in habit.

The unpublished Area 55 NOI reports flora and fauna surveys conducted during the dry season of 2007 and the wet season of 2008 using the standard NRETAS (now DNRM) survey methodology. Particular effort was devoted to the detection of threatened or vulnerable species, including those listed by Low (2001), but none were found during the surveys and the authors concluded that they are unlikely to be present on the Brown's Oxide lease. One species of cycad was listed as being of Territory significance and several occurrences of endemism were noted. However, none of these are specifically riparian in habitat preference and most are entirely absent from the Finniss River flood levees.

It should be noted that the map of NOI survey sites (Fig 5.2 in Coffee Environments 2009) indicates that most of the sites were not associated with fluvial landscapes. Only a single riparian site, on the main branch of the Finniss River where it first enters the lease, and two sites located on the flood levee above the East Branch confluence, recorded possible riparian plant assemblages.

For the current project, the NT Herbarium and other vegetation records were searched using the ALA portal to the Global Biodiversity Information Facility (GBIF) database. A list of 581 records was compiled but many of those records were repeat occurrences and a significant proportion of the species listed are not riparian or aquatic in nature. It is recommended that this search be repeated using more restricted spatial parameters constrained to the Finniss River levees and floodplains. However, it should be noted that much of the Herbarium collection was done prior to the widespread field use of GPS technology and the inaccuracies associated with recording general locations as Latitude/Longitude may not sustain this level of spatial analysis.

Records of canopy and woody understory species were made during visits to fluvial sites along the Finniss River, including the East Branch, several billabongs on the Finniss flood levee, and the stream emanating from Mount Burton Spring. The results are given in Appendix 1. Generally the results showed that the riparian vegetation assemblage was recovering well from the severe dieback resulting from the Old Tailings Dam failure and other unregulated pollution events during and immediately following the period of active mining. Mature White Paperbark trees were present and abundant in the main branch of the Finniss River both upstream and downstream of its confluence with the East Branch. Other species that might be considered vulnerable to heavy metal toxicity such as Leichhardt Trees (*Nauclea orientalis*), Freshwater Mangroves (*Barringtonia acutangula*), River Pandanus (*Pandanus aquaticus*) and Billabong Trees (*Carallia brachiata*) were also universally abundant.

Parts of the riparian zone of the Finniss River downstream from its confluence with perennial spring-fed tributary streams were infiltrated by monsoon species arising from spring jungles in the feeder-stream headwaters. The most common of these species were Beauty Leaf (*Calophyllum sil*) and the Understory Tree (*Helicea australasica*). The potentially measureable increase in floristic biodiversity in the vicinity of these localised inputs close to the East Branch confluence may be expected to mask the true effect of contaminant influx and subsequent riparian regeneration following planned rehabilitation.

The East Branch stood in stark contrast with the main branch of the river. Only the paperbark (*Melaleuca viridiflora*) and Black Wattle (*Acacia auriculiformis*) were recorded as present and abundant on the Rum Jungle Mine site and in the immediate downstream riparian zone.

Restricted occurrences of several other species were noted: the White Paperbark was successfully recolonizing the lower reaches; a single Cluster Fig (*Ficus racemosa*) was thriving at a spring in the Diversion Channel of the East Branch; several mature trees of *Terminalia sericocarpa* were present at the inflow from the secondary void (immediately downstream of site EB06) and a small stand of Billabong Trees at the confluence with Tailings Creek (site EB05) was unthrifty although probably affected by 'Gamba fire' rather than toxicology. A number of monsoon species were present immediately adjacent to the Hanna Spring outfall, including the riparian canopy species *T. sericocarpa*, *F. racemosa*, and *N. orientalis*.

Care is needed in interpretation of these observations as the East Branch is clearly intermittent in its flow regime whereas the main Finniss River branch is perennial or near-perennial. Nevertheless, it is likely that the higher concentrations of heavy metals and other contaminants in the system have limited or are limiting recolonisation by riparian species common to other seasonal braided streams in the western Top End.

In summary, a meaningful assessment of the environmental values for riparian flora in the Rum Jungle receiving environment, including potential biodiversity targets, is hampered by the lack of baseline data for naturally-occurring plant assemblages in the Finniss River catchment. It is recommended that a comprehensive baseline vegetation survey be planned and implemented as soon as possible to address this serious shortfall.

4.5.2 Aquatic Macrophytes

Studies including aquatic macrophytes in the Finniss River downstream of the Rum Jungle Mine site are essentially absent from the literature. Site visits by the authors during October 2012 confirmed that aquatic macrophytes were rare or absent in the main stream-bed of the Finniss River, both upstream of the confluence with the East Branch, and downstream.

A small number of species were found to be present in billabongs on the Finniss River levee and floodplains, and one species was recorded in a riverine waterhole well above the East Branch confluence. Billabong environments along the Finniss River levee supported small populations of the White Fringe Lily *Nymphoides indica*, and the Purple Water Lily *Nymphaea violacea*. Possibly due to the extreme seasonality of these water bodies, the populations were not extensive, being restricted to a small number of individual plants scattered around the shallower margins of the waterholes. It is likely that more extensive occurrences of these and other species of aquatic macrophytes would be found in the larger permanent billabongs on the lower Finniss floodplain and may develop at the sites inspected in the late wet season and earlier in the dry season.

A species of Spike Rush (*Eleocharis* sp.) was also present in a few billabong locations associated with paperbark (*Melaleuca* spp.) swamps. However, the reed-beds comprised of this species were generally restricted to a few square metres in area at the time of visitation (late dry season).

Only two species of submerged aquatic macrophytes were recorded during site visits to the Finniss River catchment. The Hornwort *Ceratophyllum demersum* was recorded at a single location in a slow-flowing section of the main branch of the Finniss near Meneling Crossing, approximately 18km upstream of the East Branch confluence, and an unidentified algal Stonewort (*Charophyceae*) was observed in several shallow billabongs along the Finniss River levee well downstream of the confluence.

It is strongly recommended that a comprehensive survey of aquatic macrophytes in the Finniss River and associated water bodies be undertaken as a matter of priority, preferably early in the dry season when optimal conditions for such a survey are more likely.

4.6 Riparian Fauna

Historically, the Finniss River was known to be well stocked with fish and freshwater crocodiles (Davy, 1975). In addition to the freshwater crocodiles (*Crocodylus johnstoni*), the Finniss River is also well known for being the original home of "Sweetheart", the large saltwater crocodile (*Crocodylus porosus*) responsible for attacking boats in the 1970's (Stringer, 2003). Unfortunately, "Sweetheart" was deemed a menace and was accidentally killed during his capture and subsequently ended up being the most popular exhibit at the Northern Territory Museum and Art Gallery in Darwin.

While numerous surveys and monitoring have been conducted on the Rum Jungle Mine site, mining began there before any formal requirement for environmental impact assessment (Low, 2001). Despite a substantial amount of literature on fish (see Section 4.4), there does not appear to be any other vertebrate work apart from crocodile monitoring (Manolis *et al.* 2002a; 2002b), a few incidental freshwater turtle captures (Jeffree & Twining 1992), a desktop fauna and flora survey of Browns Oxide (Low, 2001), and a fauna survey of the Area 55 Oxide project (Coffey Environments 2009).

4.6.1 Desktop Review

Due to a lack of published fauna studies a desktop review was initiated for East Branch of the Finniss River downstream of the former Rum Jungle Mine (Figure 4-2). Specifically this review examined the distribution and status of aquatic terrestrial vertebrates that may be present on the Rum Jungle Mine site area and also within the riparian sections of the Finniss River. The data enquiry included the existing fauna records, known distributions and preferred habitats, as well as the current protection status of all terrestrial vertebrates that may be present. The resources used are referenced in each subsection.

Terrestrial vertebrate fauna data was compiled from the following sources:

- a review of known fauna assessments in the area;
- Northern Territory Fauna Atlas (Department of Land Resource Management) (LRM); and
- Atlas of Living Australia (www.ala.org.au) (ALA).

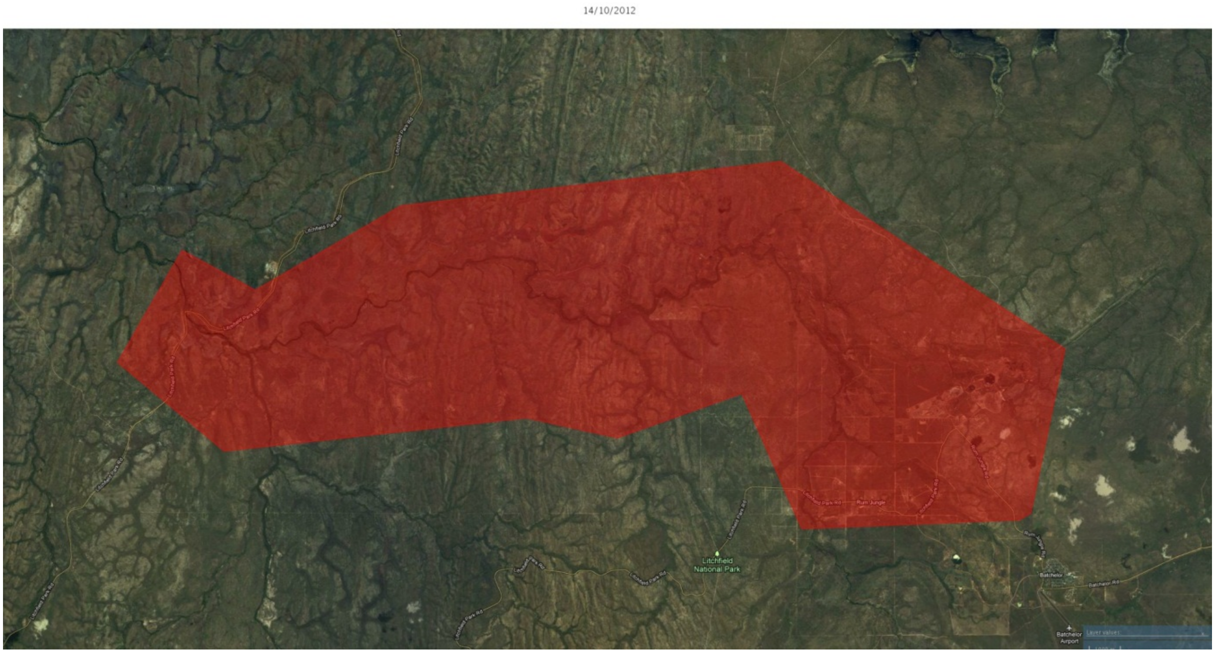

Figure 4-2. Area used for the ALA search of fauna records.

4.6.2 Consultation with Traditional Owners

A range of traditional owner groups were visited in October 2012 to determine what fauna they used for bush tucker and also ceremonial purposes. Through in depth discussion and referral to known species in the area a list was compiled.

4.6.3 Bioregion

Bioregions in Australia are covered under The Interim Biogeographic Regionalisation for Australia (IBRA). This work divides Australia into areas of similar landform and biodiversity (Baker *et al.* 2005). The search area fell within the Pine Creek Bioregion.

This large bioregion is located to the west of the Arnhem Land sandstone massif and covers an area of approximately 28,456 km^2. Much of the bioregion consists of foothill environments dominated by tall open Eucalypt forest. The dominant species being *Eucalyptus miniata* and *E. tetrodonta* but small patches of monsoon forest are also present along riparian areas. At the bottom of the foothills there are also large tracts of tussock grassland. This bioregion is well populated due to its proximity to Darwin and hence has an increased fire regime with some patches burnt annually (Baker *et al.* 2005).

At least twenty threatened species have been recorded in the bioregion, including the critically endangered Northern Quoll (*Dasyurus hallucatus*), endangered Gouldian Finch (*Erythrura gouldiae*) and vulnerable Yellow Spotted Monitor (*Varanus panoptes*).

This bioregion is also very important in that it contains the catchments of parts of the Adelaide River, Daly River, Mary River, Roper River, South and East Alligator Rivers, Wildman River, and the Finniss River.

4.6.4 Sites of Conservation Significance (SOCS)

Within the Northern Territory, 67 Sites of Conservation Significance (SOCS) have been identified as having national or international significance for biodiversity (Ward & Harrison, 2009). A search of these listed sites in Harrison *et al*. (2009) shows that the search area does not occur within a SOCS. However, The Finniss River further downstream does flow through the Finniss River Coastal Floodplain (SOCS). This SOCS is recognized as it supports very large populations of native water birds (Chatto, 2000) and supports the following listed threatened species:

- Australian Bustard (*Ardeotis australis*).
- Red Goshawk (*Erythrotriorchis radiatus*).
- Partridge Pigeon (*Geophaps smithii smithii*).
- Masked Owl (Northern) (*Tyto novaehollandiae kimberli*)
- Yellow-spotted Monitor (*Varanus panoptes*).

4.6.5 Terrestrial Fauna

Based on existing records and a review of the biology of the state and federally listed threatened species, approximately 165 terrestrial vertebrate species are known to inhabit the area (Appendix 5). Specifically 15 threatened species could exist at the proposed site (Appendix 5). Additionally two proposed state listed threatened species; Fawn Antechinus (*Antechinus bellus*), and Mulga Snake (*Pseudechis australis*), are also recorded from the area. Of these species, 47 are known to reside in or prefer aquatic habitats (Table 4-1)

4.6.6 Birds

A large diversity of birds has been recorded from the area with 145 species present, including the Gouldian Finch (*Erythrura gouldiae*) (endangered), Red Goshawk (*Erythrotriorchis radiates*) (vulnerable), Emu (*Dromaius novaehollandiae*) (vulnerable), Partridge Pigeon (*Geophaps smithii*) (vulnerable) and Masked Owl (*Tyto novaehollandiae kimberli*) (vulnerable) (Appendix 5). As birds can cover large areas in search of food and shelter it is hard to quantify their habits, but a search of the general biology of the present birds determined that 24 species are either aquatic or prefer these areas (Table 4-1). Traditional owners mentioned that they utilised adult Magpie Goose (*Anseranas semipalmata*) and their eggs as well as Green Pygmy Geese (*Nettapus pulchellus*) for food. Additionally various species of ducks, presumably Wandering Whistling Ducks (*Dendrocygna arcuata*), Plumed Whistling Ducks (*Dendrocygna eytoni*) and Rajah Shelduck (*Tadorna radjah*) were also used for food. Emu (*Dromaius novaehollandiae*) was also mentioned as being eaten and seen drinking from the river. Traditional owners also expressed concern over whether it was safe to eat these particular species.

4.6.7 Mammals

Approximately 18 species of mammal have been recorded from the area including the Northern Quoll (*Dasyurus hallucatus*) (critically endangered), Brush-tailed Phascogale (*Phascogale pirata*) (vulnerable) and Black-footed tree-rat (*Mesembriomys gouldii*) (vulnerable) (Appendix 5). Only one species is known as being aquatic (Table 4-1) but most species would forage in riparian habitats and traditional knowledge recorded this. Traditional owners mentioned the Antilopine Wallaroo (*Macropus antilopinus*) and Agile Wallaby (*Macropus agilis*) were also important food items that were regularly seen drinking from the river. Flying fox collected as a food item was also seen as riparian in contexts.

4.6.8 Frogs/Amphibians

Thirteen species of frog have been recorded for the area along with the introduced Cane Toad (*Rhinella marina*) (Appendix 5). As all amphibians require water to facilitate reproduction they have all been listed as aquatic in the context of this report. All of the species present are listed as "least concern" (Table 4-1).

4.6.9 Reptiles

Thirty four species of reptiles have been recorded from the area including the introduced Asian House Gecko (*Hemidactylus frenatus*) (Appendix 5). Of these species, eight are known to be aquatic or prefer aquatic habitats (Table 4-1). Two of the aquatic species, the Floodplain Monitor (*Varanus panoptes*) and Mitchell's Water Monitor (*V. mitchelli*) are listed as vulnerable in the Northern Territory (Table 4-1). All aquatic species present were also recorded as having cultural significance to traditional owners in the area. During meetings with traditional owners, frequent mention was made of the use of "turtle" or "freshwater tortoise", primarily for food, but also as a totem animal and in ceremony. The long-neck species, presumably the Northern Long-necked Turtle (*Chelodina rugosa*) was collected during the dry season, dug up from the mud when in a state of aestivation. The short-neck species was caught in billabongs by fishing, or by actively searching shallow waters and areas beneath floating grass. This turtle is either the Northern Snapping Turtle (*Elseya dentata*) or Northern Yellow Faced Turtle (*Emydura tanybaraga*). Two pythons were mentioned, the 'Yellow-belly' Water python, presumably (*Liasis fuscus*) and the 'plain' one, presumably Olive python (*Liasis olivaceus*). Arafura File Snakes (*Acrochordus arafurae*) are usually caught by hand in shallow water. Use of both Freshwater (*Crocodylus johnstoni*) and Saltwater Crocodiles (*Crocodylus porosus*) was inferred from discussion that use is infrequent and opportunity based. Both species were not actively sought by the groups in discussion, but were important items as totems and use in ceremony. Lastly traditional owners mentioned a lack of big goannas, inferred to be Yellow Spotted Monitors (*Varanus panoptes*), but also stated that the smaller Water Goanna, presumable Merten's Water Monitor (*Varanus mertensi*) could still occasionally be seen at creek crossings.

Table 4-1 Aquatic Terrestrial Vertebrates that occur in the project area.

Species	Common Name	TPWC
BIRDS		
Anhinga novaehollandiae	Australasian Darter	LC
Anseranas semipalmata	Magpie Goose	LC
Ardea ibis	Cattle Egret	LC
Ardea intermedia	Intermediate Egret	LC
Ardea modesta	Eastern Great Egret	LC
Ardea pacifica	White-necked Heron	LC
Ardea sumatrana	Great-billed Heron	LC
Butorides striata	Striated Heron	LC
Ceyx azureus	Azure Kingfisher	LC
Ceyx pusilla	Little Kingfisher	LC
Dendrocygna arcuata	Wandering Whistling-Duck	LC
Dendrocygna eytoni	Plumed Whistling-Duck	LC
Egretta novaehollandiae	White-faced Heron	LC
Haliaeetus leucogaster	White-bellied Sea-eagle	LC
Ixobrychus flavicollis	Black Bittern	DD
Microcarbo melanoleucos	Little Pied Cormorant	LC
Nettapus pulchellus	Green Pygmy Goose	LC
Nycticorax caledonicus	Nankeen Night Heron	LC
Pelecanus conspicillatus	Australian Pelican	LC
Phalacrocorax sulcirostris	Little Black Cormorant	LC
Phalacrocorax varius	Pied Cormorant	LC
Tadorna radjah	Radjah Shelduck	LC
Todiramphus macleayii	Forest Kingfisher	LC
Todiramphus sanctus	Sacred Kingfisher	LC
MAMMALS		
Hydromys chrysogaster	Water Rat	LC
FROGS		
Austrochaperina adelphe	Northern Territory Frog	LC
Litoria australis	Giant Frog	DD
Litoria bicolor	Northern Dwarf Tree-frog	DD
Litoria caerulea	Green Tree-frog	LC
Litoria inermis	Peters' Frog	LC
Litoria nasuta	Rocket Frog	LC
Litoria pallida	Pale Frog	LC
Litoria rothii	Roth's Tree-frog	LC
Litoria rubella	Red Tree-frog	LC
Litoria tornieri	Tornier's Frog	LC
Limnodynastes convexiusculus	Marbled Frog	LC
Platyplectrum ornatus	Ornate Burrowing Frog	DD
Uperoleia inundata	Floodplain Toadlet	LC
REPTILES		
Acrochordus arafurae	Arafura File-snake	LC
Chelodina rugosa	Northern Snake-necked Turtle	LC
Crocodylus johnstoni	Freshwater Crocodile	LC
Crocodylus porosus	Saltwater Crocodile	LC

Species	Common Name	TPWC
Elseya dentata	Northern Snapping Turtle	LC
Emydura tanybaraga	Northern Yellow-faced Turtle	LC
Liasis fuscus	Water Python	LC
Varanus mertensi	Merten's Water Monitor	VU
Varanus panoptes	Floodplain Monitor	VU

4.6.10 Threatened Fauna

Based on the desktop review, two aquatic threatened vertebrate species are present in the area (Table 4-1). Likelihood of occurrence was determined based on the criteria listed below which was gleaned from available records and ecological knowledge of the area:

- Likely – these species are listed if suitable habitat and records exist for near the area.
- May – these species are listed is suitable habitat and records for the bioregions exist.
- Unlikely – these species are listed if no suitable habitat was present, are unknown from the area, or are locally extinct.

4.6.10.1 Floodplain Monitor (*Varanus panoptes*) (Likely)

This species occurs in a broad range of habitats from riparian woodlands to tropical savannahs (Schultz & Doody 2004). Currently the species has been found across the top of northern Australia from North Queensland, Top End of the Northern Territory, and the Kimberley and Pilbara regions of Western Australia (Schultz & Doody 2004). Unfortunately, this species experiences significant declines due to Cane Toad poisoning (Doody *et al.* 2009).

4.6.10.2 Merten's Water Monitor (*Varanus mertensi*) (Likely)

This species occurs on the edges of watercourses and is never far from water (Christian 2004). Currently the species is known to range from the western side of Cape York, Top End of the Northern Territory, and the Kimberley region in Western Australia (Christian 2004). Unfortunately, this species also experiences significant declines due to Cane Toad poisoning (Griffiths & McKay 2005; Doody *et al.* 2009).

4.6.11 Summary and Recommendations

Studies on the aquatic terrestrial vertebrates downstream of the former Rum Jungle Mine appear to be almost non-existent. Despite a large number of database records there does not appear to have ever been any studies looking at the distribution and abundance of aquatic terrestrial vertebrates downstream. The overall area included in the search found a large number of species present with at least 15 threatened species recorded as present in the area. Consultation with traditional owners highlighted the cultural importance of the aquatic reptiles that are present in the riparian areas of the Finniss River. Due to a lack of knowledge the following is recommended:

1. A detailed terrestrial vertebrate fauna survey downstream of the former Rum Jungle Mine should be undertaken. This survey should be conducted in both the wet and dry

season in order to account for any seasonal changes in the fauna structure. Secondly this survey should focus on determining which threatened species are present in the area. This survey should provide opportunities for traditional owner involvement.

2. A detailed survey of all the culturally significant aquatic reptiles downstream of the former Rum Jungle Mine to gain an understanding of species abundance and secondly to determine distribution in relation to the former Rum Jungle Mine. This survey should provide opportunities for traditional owner involvement.
3. A detailed report on these recommended surveys should be produced for distribution to traditional owners in the area highlighting the findings.

4.7 Indigenous Values

Cultural and spiritual values are an important component of setting water quality objectives under the ANZECC/ARMCANZ (2000) framework. In the case of the Rum Jungle Mine rehabilitation, cultural and spiritual values are of high importance to the traditional owners and to other Indigenous people living in or utilising the Finniss River receiving environment. While these values may be difficult to quantify empirically, it is crucial to the success of any proposed rehabilitation process that their value to the traditional owners and other affected Indigenous groups be given due consideration in setting environmental values. Nonetheless, it was beyond the scope of this project to undertake a comprehensive assessment of cultural and spiritual ties of all individuals, clans and groups with connection to 'country' downstream of the mine. The authors were extremely grateful for the time taken and openness displayed by the traditional owners and affected groups that we were able to meet during the field visits and meetings undertaken for the project in discussing these values. The section below aims to convey the essence if not the detail of those discussions in order to provide a wider audience with some understanding of these cultural and spiritual values in the context of setting water quality objectives. Any fault in the overview of these values in the following text will be the fault of the authors and should not be taken to imply any limitation of those consulted to convey their aquatic and riparian values. However, in any brief assessment it would be impossible to collate and convey the complexities of the cultural and spiritual connection Indigenous people have with the Finniss River system waterways.

4.7.1 Cultural Values

The overriding cultural value of the riparian environment downstream from the Rum Jungle Mine site stems from the widely-held belief that the health and well-being of a particular group of Aboriginal people, as well as that of individuals within the group, is inextricably linked to the general health and well-being of 'country'. Central to this belief in the local context is the health status of the Finniss River itself, the main 'arterial' river system flowing through the region. For some, it is the source of all life in the catchment, the life-blood of 'country', and hence the source of both spiritual and physical good health for all Indigenous people living along its length. Indeed, the ability of the waters to 'flow freely" was indicated by some to be an important expression or component of the health of the river system, akin to the free flow of blood through the body and a way for connection to 'country' to be spread from a point of initial contact with the river system. As an extension of this belief, springs in the headwaters of the East Branch, near the Rum Jungle Mine, have a particular birthing significance for the traditional owners of the mine site.

In that context, any 'sickness' or perceived decline in the health of the river system downstream from the Rum Jungle Mine site is likely to result in a strong sense of apprehension amongst the traditional owners. This was said to be the case in the past when unregulated discharges from the Old Tailings Dam resulted in fish kills and paperbark die-back well down the main branch of the Finniss River. A manifestly 'healthy' waterway unaffected by mine runoff is considered paramount to those who depend on the river system for their cultural and spiritual strength.

In terms of spiritual utilisation of the local waters *per se*, some traditional owners disclosed that the ceremonies for introduction to country (among others) conferred spiritual connection to the subject via the water. The current contamination levels in the vicinity of the mine site precluded this practice because the waters' spiritual nature had been degraded, and there was uncertainty about human health effects the practice might trigger. The means that for this area, spiritual conference of cultural rights is regarded as potentially hazardous.

Whilst primarily relating to animal species or groups, the recognition of one or more spiritual totems by individuals or kinship groups is also an important cultural consideration in the Rum Jungle Mine receiving environment. The abundance and general well-being of totem organisms such as 'redclaw', barramundi, crocodile, and 'turtle' is seen as highly desirable, and any noticeable decline or poor health of totem organisms may be considered ominous.

The only riparian plant species discussed in a spiritual context was the White Paperbark, *Melaleuca leucadendra*, mature specimens of which were said by one Indigenous group to be a manifestation of the spirits of ancestral beings keeping station along the river. It is likely that other important riparian or aquatic plant species also have specific cultural values arising from spiritual beliefs not enunciated in open discussion.

The same assumptions can be reliably upheld for the value to Indigenous groups of certain riparian plant and aquatic vertebrate and invertebrate species for 'ceremony'. The importance of healthy populations of certain plants and/or animals was discussed in general terms without specific details of the spiritual context of individual subjects. However, it was made clear that any decline in the abundance or general well-being of the subject organisms could have a negative impact on the spiritual value of these important cultural activities.

4.7.2 Traditional Foods

Those traditional bush food items, known commonly as 'bushtucker', consist primarily of plant species with edible fruit, seeds or vegetative parts. A significant proportion of the native plant species utilised by traditional owners and other Indigenous groups in the receiving environment are riparian in habit, and hence are regarded as being part of the river system and important to this project's assessment. A list of the most important traditional bush foods and the aquatic or riparian species from which they are derived was compiled from consultation with Indigenous groups from the area, including site visits with traditional owners. The list is given in Appendices 2 and 3.

Two primary concerns arising from potential impact of mine runoff were enunciated by the Indigenous groups in the Finniss River region: potential reduction in the distribution or abundance of important food species, and potential toxicity of food items due to heavy metal and/or radiological contamination. It is strongly recommended that these concerns be addressed in any consultation with downstream people as it is seen to be a high priority environmental value for all Indigenous groups in the Rum Jungle receiving environment.

In this context it should be noted that traditional owner patterns of consumption of animals tends to be more complete than that of most other Australians, with almost all body parts that are edible consumed. Studies that focus on just edible muscle or compare contaminant concentrations against standard FSANZ (2012) assumptions of food items "as prepared for consumption" and consumption frequencies may not be adequately comprehensive for consideration of traditional owner consumption patterns in the Finniss River system.

4.7.3 Other Traditional Uses

A number of riparian species in the Finniss River catchment downstream from the Rum Jungle Mine site are used for traditional purposes other than food. Appendix 4 lists those species said to be highly valued as sources of timber for tools and weapons, dye, soap, medicines, fish poison, bark for construction, fibre for string, and other domestic uses. It is important to those living in the catchment and other indigenous users of the river system that these species should also be considered in any assessment of the traditional values of the receiving environment.

4.7.4 Weeds

Mention was made by a number of traditional owners and other Indigenous groups that the presence of weeds such as Gamba grass (*Andropogon gayanus*), Mission grass (*Pennisetum polystachion*) and Mimosa (*Mimosa pigra*) was undesirable as it detracted from the normal traditional utilisation of the riparian environment. There was a perception that better weed control on the Rum Jungle Mine site, particularly for Gamba and Mimosa, might result in improved outcomes for control in the receiving environment.

Given the extensive current distribution and wind dispersal propagation of the two grasses mentioned, this is probably not realistic, but Mimosa control on the Finniss floodplain has been relatively successful and an expectation of better Mimosa control outcomes along the river itself is justified. Strong inference was made by Indigenous stakeholders that a weed-free environment should be considered to be an important environmental value in the context of mine-site rehabilitation.

There is a known endemic infestation of Mimosa on the Rum Jungle Mine site in a borrow pit that ultimately directs storm-water flows into the East Branch of the Finniss River. Although regular attempts are made by DME to control this infestation, eradication should be afforded short-term priority. It is presumed that a reduction of Gamba on the waste rock dumps and other impacted areas on the mine site would be desirable to reduce the detrimental effect of fire on woody revegetation.

Olive hymenachne (*Hymenachne amplexicaulis*) was recorded along the East Branch upstream and downstream of the Rum Jungle Mine during site visits. This species was not mentioned by Indigenous stakeholders other than in the context of stock feed on pastoral land bordering the Finniss River floodplain, where it was said not to be preferred over other improved pasture grass species such as the Tully cultivar of *Brachiaria humidicola*.

Snakeweed (*Stachytarpheta australis*) was widespread in the area on moist soils in disturbed or heavily grazed areas and along drainage lines. It was mentioned only by one non-Indigenous occupant of the catchment.

5 FINNISS RIVER ZONE BREAKDOWN

In light of the knowledge gleaned by the technical panel during the literature review and the site inspection, a zone breakdown of the Finniss River system was developed during the Phase I Technical Workshop on 18 October. A zone system was necessary in order to allow for different environmental values and water quality objectives in different parts of the river system.

The breakdown that was developed was based in part on known historic and current patterns of effects on water and sediment quality downstream of the mine, the separation of fresh and estuarine waters, which under the ANZECC/ARMCANZ framework warrant different water quality trigger values, and taking into account the position of the Finniss River SOCS. The breakdown agreed to was as follows (Figure 5-1):

1. East Branch and tributaries upstream of the Rum Jungle Mine;
2. East Branch within the mine site area to the junction with Old Tailings Creek;
3. East Branch from Old Tailings Creek to Hannah's Spring;
4. East Branch from Hannah's Spring to the junction with the Finniss River;
5. Finniss River upstream of the East Branch;
6. Finniss River from the East Branch to Florence Creek;
7. Finniss River from Florence Creek to the upstream boundary of the SOCS;
8. Finniss River SOCS from the upstream boundary to the fresh water/sea water interface; and
9. Finniss River estuary to the mouth.

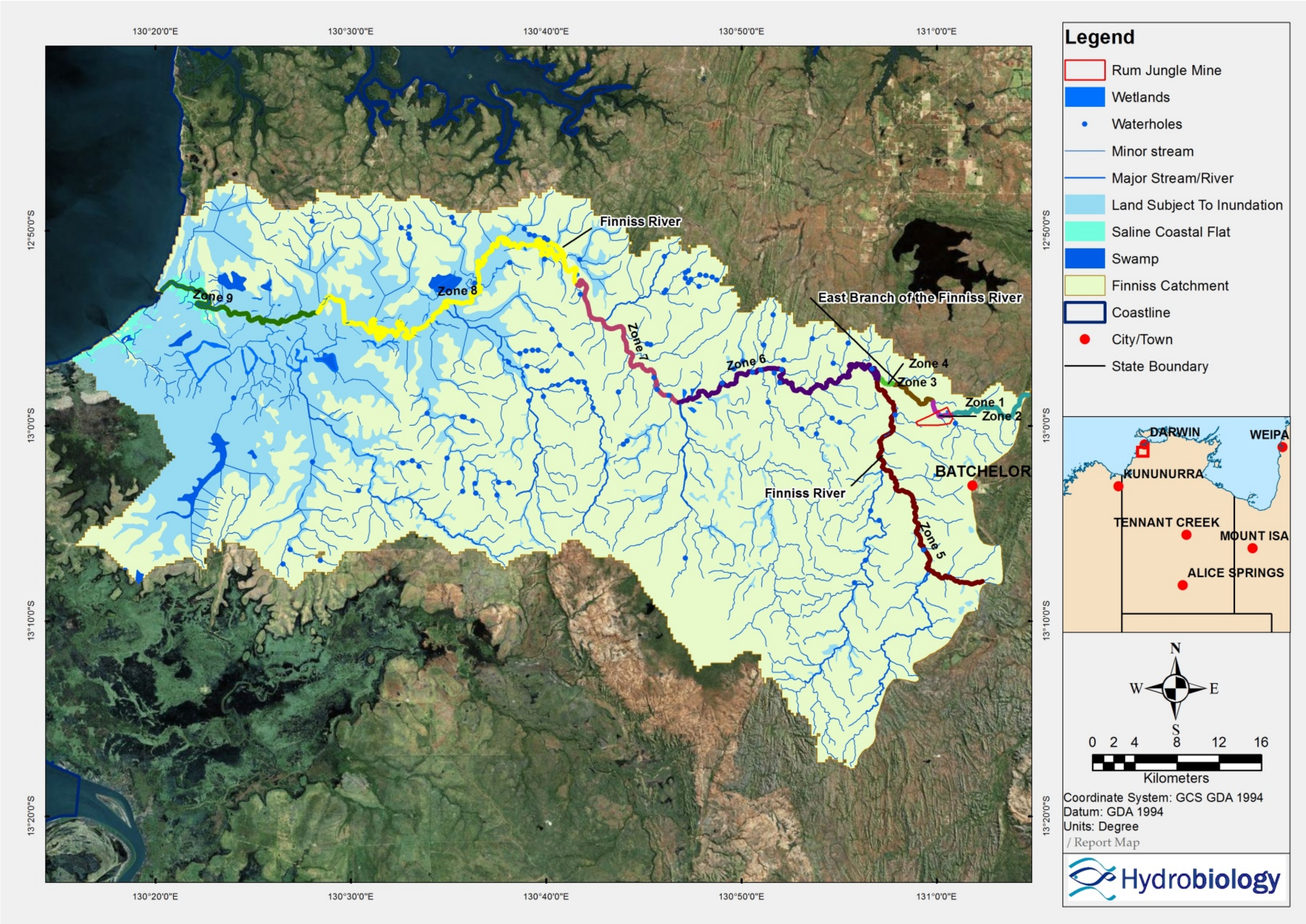

Figure 5-1 Map of Finniss River showing zone breakdown

6 ENVIRONMENTAL VALUES BY ZONE

6.1 Allocation of Environmental Values by Zone

Environmental values were assigned to each zone by the project team during the Phase I technical workshop on 18 October, based on: the collective understanding of the characteristics of the zones, stakeholder uses, values and aspirations for each reach and conservation values assigned by the Northern Territory Government. The assigned environmental values for each zone are shown in Table 6-1.

Table 6-1 Environmental values assigned to each zone.

Reach	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	SMD	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
2. East Branch within mine site to Old Tails Ck	H <80%	✓											
3. East Branch Old Tails Ck to Hannah Spring	H-80%PC	✓	✓				✓						
4. East Branch below Hannah Spring	H-90%PC	✓	✓	✓	✓	✓	✓					✓	
5. Finniss U/S EB	SMD	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
6. Finniss EB to Florence Ck	SMD	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
7. Finniss Florence Ck to SOCS	SMD	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
8. SOCS upstream limit to FW/SW interface	HCV	✓	✓	✓		✓	✓			✓	✓	✓	✓
9. Finniss Estuary	HCV	✓	✓	✓		✓	✓						

✓indicates value is assigned to that zone. For aquatic ecosystems, SMD indicates value assigned for classification of Slightly-Moderately Disturbed ecosystems, H-x%PC indicates value assigned for classification of Highly Disturbed ecosystem with an x% protective concentration recommended, HCV indicates value assigned for classification of High Conservation Value ecosystems.

6.2 Allocation of Water Quality Trigger Values and Objectives

For Zone 2 (East Branch within mine site area to the junction with Old Tailings Ck), a protective concentration designation was not confirmed during the technical workshop, except that a value less than 80% was deemed appropriate. The reason for this was that it was assumed that even after further rehabilitation, to a large extent, water courses in this zone would primarily serve the purpose of water transport and management, and have only incidental values as aquatic ecosystems. The more relaxed protection level assigned to this zone was also considered to be more pragmatic than a more aspiration goal of higher aquatic ecosystem protection, given its prehistory and the extent of impact from AMD within it. Although a level of protection was not specified by the project team for this zone, a level of 70% was adopted for developing the water quality objectives discussed below.

For this zone, it was further assessed that use of waters for human contact or drinking, irrigation, stock watering, wildlife and human collection of aquatic foods would not apply, but it was assessed that cultural and spiritual values would apply (see discussion of this value below). Note that even at these lesser levels of protection, the aquatic ecosystem trigger values for most of the parameters of concern are at or below the human contact trigger values.

For Zone 3 (East Branch from Old Tailings Creek to Hannah's Spring), wildlife habitat and visual recreation values were added, while in Zone 4 (East Branch from Hannah's Spring to the junction with the Finniss River) human consumption of aquatic foods, recreational use and stock watering were also added.

The attribution of these values to the East Branch aspired to provide for the stated stakeholder objectives for rehabilitation of the East Branch, while including some pragmatic acceptance that improvement of water quality in that tributary would require the development of management systems to do so that would to some extent impact on the state of the watercourse themselves, and that achieving water quality equivalent to that of slightly-moderately disturbed ecosystem status would be impractical on and near the mine site in the near future. Nonetheless, the resulting water quality objectives from this approach (see below) would require a very large improvement in water quality over the current condition (typically several orders of magnitude for the main parameters), and associated considerable improvement in aquatic ecosystem condition.

For Zones 1, 5, 6, 7, 8, and 9 (all Zones other than the East Branch within the mine site area to the junction with the Finniss River) the default water quality guidelines for aquatic ecosystem protection for slightly to moderately disturbed ecosystems were used except for the two zones covering the Finniss River Site of Conservation Significance (Zones 8 and 9), for which trigger values for high conservation significance ecosystems were used.

For each zone, trigger values for each parameter evaluated were extracted from the ANZECC/ARMCANZ (2000) guidelines. In the following tables, "NA" indicates that no trigger value is provided by the guidelines for that parameter for that value. For the aquatic ecosystem value, for parameters that require hardness correction, both the default soft water trigger value and the hardness modified trigger value for moderately hard waters (using the modification factor from table 3.4.4 of the guidelines) are provided. Note that this hardness correction may need to be revisited when more reference site hardness data become available. Also, the following assumptions/modifications were made for the following parameters:

Al trigger values were provided on the assumption that the pH of the water in each zone would be above 6.5, because this was the target for pH for most zones and the low reliability trigger value for pH below 6.5 could not be used to derive different values for different levels of protection;

Fe as the low reliability trigger value for aquatic ecosystems could not be used to derive different values for different levels of protection, for the two zones currently most affected by AMD a requirement for a reduction in the iron concentration was specified;

Mn as the ANZECC/ARMCANZ (2000) trigger value for protection of aquatic ecosystems for this metal is high and considered to need revision, the WHO (2004/2005) figure was used in preference. The WHO assessment used the ANZECC/ARMCANZ methodology to develop a trigger value, but used an updated international toxicity database as input. However, it was necessary to reconstruct the species sensitivity distribution to derive the trigger values for level of protection other than 95%, and when this was done it was found that there was a discrepancy between the calculated end-points in the table (Table A-2 in WHO 2004/2005) and the plotted values in the figure (Figure A-3 in WHO 2004/2005). For the purpose of setting trigger values for the various levels of protection for this report, the end-point values in WHO's Table A-2 were used and a species sensitivity distribution fitted using the same method used by WHO;

Co As for iron (Fe), there was only a low reliability trigger value for cobalt, and so for the two zones currently most affected by AMD a requirement for a reduction in the cobalt concentration was specified;

U An update on the ANZECC/ARMCANZ (2000) trigger value for uranium for aquatic ecosystems developed by Iles (2005) was used for this parameter because it improved on the fitting of the probability distribution for the species sensitivity distribution and included additional toxicity data, despite being developed as a site specific trigger value for Magela Ck. As the waters of Magela Ck are much softer than those of the Finniss River, this trigger value is likely to be over-protective, despite being considerably higher than the current ANZECC/ARMCANZ (2000) default value;

pH, EC, TSS The first two of these parameters have default trigger values for tropical Australia provided by ANZECC/ARMCANZ (2000), but these trigger values do not have mechanisms for adjustment for different levels of protection. Reference site 20 and 80%ile values were also calculated for the Finniss River upstream of Mount Burton for March to October 2012 (the only reference data available for a Finniss River site outside the previous zone of impact). Reference site single measurements were also available for the East Branch upstream of Dyson's Overburden Heap and Fitch Creek at the boundary of Section 2968 (the maximum rounded up (and minimum rounded down for pH) was used as representative of unimpacted East Branch sites above Hannah's Spring) and Hannah's Spring upstream of the East Branch (used as potentially representative of the lower East Branch below Hannah's Spring after rounding up with the Finniss River above Mount Burton 20%ile for pH used as a lower trigger value). These values were used to set interim aquatic ecosystem trigger values for each zone, but they should be revised as additional reference site data become available. There were no reference data available for TSS (Total Suspended Solids) and so reference is made in the table to the requirement that the median of monitoring data should not exceed the 80%ile of appropriate reference site data. Such reference site data would need to be collected in order to apply this trigger value; and

Radionuclides No aquatic ecosystem protection guidelines were available for these parameters in ANZECC/ARMCANZ (2000), but trigger values were found for irrigation water, stock water, drinking water and human recreation.

As not all environmental values have designated trigger values, the following approaches were used to derive trigger values from those applicable to the other values:

Wildlife Habitat — On the assumption that the habitat structure component of this environmental value would be protected by the aquatic ecosystem and irrigation water trigger values, it was concluded that the remaining key component requiring protection was provision of drinking water for wildlife. This was accounted for by application of the lowest of the appropriate stock drinking water trigger values in the absence of specific trigger values being available for local wildlife species. Note that the stock water trigger value for cattle was applied for the stock watering environmental value because cattle are the dominant type of stock in the Finniss River catchment

Irrigation — trigger values for long term irrigation use were used for this value;

Industrial Use — No industrial uses other than primary industries were identified as being important for the Finniss River catchment so no trigger values were developed for this environmental value;

Aquaculture — No commercial aquaculture operations were identified for the Finniss River catchment and it was assumed that the aquatic ecosystem protection trigger values would also be protective of recreational and commercial fisheries operations so no trigger values were developed for this environmental value;

Human Consumer

ANZECC/ARMANZ (2000) does not provide water quality objectives specifically for this environmental value, but does for aquaculture and for aquatic ecosystems. It was assumed that the aquatic ecosystems trigger values would be protective of this environmental value in general, but for those parameters for which FSANZ (2012) provides health-based maximum residue limits for appropriate food types note was made of those limits;

Farm Supply

This environmental value was assumed to be protected by the lowest of the trigger values for Primary or Secondary Recreation, Irrigation and Stock Water. Note that human drinking water trigger values were not applied to this environmental value because it was considered that the selection of farm drinking water supplies was commonly a separate decision from the decision to obtain general farm water supply. Protection of the use of river water for human drinking water is specifically covered as a separate environmental value;

Visual Recreation

A trigger value for this environmental value is provided in ANZECC/ARMCANZ (2000) for visual clarity of the water, and this was applied for TSS. Otherwise, it was assumed that the lowest trigger values for the environmental values of Aquatic Ecosystems and Wildlife Habitat would be protective of this environmental value; and

Cultural/Spiritual

It was very evident from our discussions with traditional owners of the Finniss River system that all zones had substantial cultural and spiritual significance. Although the specifics of these values varied between groups, as much as such matters could be conveyed to the project team, it was clear that these values were intrinsically linked to the integrity of the fluvial system and the health and function of the aquatic and riparian ecosystems dependent upon it and the ability of the traditional owners to access and use the waters for cultural purposes.

ANZECC/ARMCANZ (2000, Box 2.2 in Section 2.1.3) notes that:

> *"At this stage no water quality guidelines have been developed for the protection of cultural and spiritual values in either New Zealand or Australia. Because of the lack of such guidelines, in the water management framework, cultural values can be taken into account through the process of establishing the specific water quality objectives for a particular water resource (see figure 2.1.1).*

> *Until further work is undertaken to better define cultural and spiritual values for users in both Australia and New Zealand, managers in both countries, in full consultation and co-operation with indigenous peoples, will need to decide how best to account for cultural values within their management frameworks."*

> The consultation undertaken for this project is compliant with those recommendations in terms of developing sufficient understanding to propose appropriate water quality trigger values, but further consultation will be required to discuss those trigger values and reach agreement on appropriate water quality objectives.

> Nonetheless, in the course of the consultation traditional owners did state that although their preference was for a system devoid of any mine signature, an end result that gave compliance to the ANZECC/ARMCANZ guidelines would be acceptable within the confines of practicability.

> Given the range of values that traditional owners identified, it was assessed that their cultural and spiritual values would be protected by whichever trigger value was the lowest for the Aquatic Ecosystem, Wildlife Habitat, Human Consumer, Primary and Secondary Recreation and Drinking Water values, as these values encompassed the cultural and spiritual values of health and function of the ecosystems dependent on the river waters, consumption of aquatic and riparian foods, and human contact with and consumption of river waters (at least for the parameters of relevance to the Rum Jungle Mine).

The trigger values that were derived for each parameter for each environmental value are listed in Table 6-2 to Table 6-19 for each parameter for each zone. A Water Quality Objective was developed for each zone for each parameter by selecting the lowest trigger value identified for any environmental value for that zone, and these WQOs are also provided in the tables.

Reference data will be derived using samples collected from a suite of sites in the Finniss River (upstream of the East Branch Confluence) and the East Branch upstream of the former mine. These subcatchments are considered likely to be more representative of baseline conditions within the mineralised catchment, compared with other catchments unimpacted by the former Rum Jungle mine but with different geological characteristics.

It is acknowledged that the nature and extent of mineralisation in the currently available upstream reference sites may differ from that which existed in the East Branch prior to mining. Nonetheless, the use of a suite of sites will provide a range of concentrations of the key parameters that are characteristic of the catchment in the absence of mine drainage under current landscape conditions and hence a reasonable water quality rehabilitation target.

Table 6-2 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Aluminium (Al) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	55	Lowest	5000	NA	200	200	Lowest			200	5000		200	55
2. East Branch within mine site to Old Tails Ck	236	Lowest												236
3. East Branch Old Tails Ck to Hannah Spring	150	Lowest	5000				Lowest							150
4. East Branch below Hannah Spring	80	Lowest	5000	NA	200	200	Lowest					5000		80
5. Finniss U/S EB	55	Lowest	5000	NA	200	200	Lowest			200	5000	5000	200	55
6. Finniss EB to Florence Ck	55	Lowest	5000	NA	200	200	Lowest			200	5000	5000	200	55
7. Finniss Florence Ck to SOCS	55	Lowest	5000	NA	200	200	Lowest			200	5000	5000	200	55
8. SOCS upstream limit to FW/SW interface	27	Lowest	5000	NA		200	Lowest			200	5000	5000	200	27
9. Finniss Estuary	0.5	Lowest		NA		200	Lowest							0.5

Table 6-3 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Cadmium (Cd) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	0.2 / 0.54	Lowest	10	Mussels ≤2 mg/kg	5	5	Lowest			2	10		5	0.54
2. East Branch within mine site to Old Tails Ck	1.6 / 4.3	Lowest												4.3
3. East Branch Old Tails Ck to Hannah Spring	0.8 / 2.16	Lowest	10				Lowest							2.16
4. East Branch below Hannah Spring	0.4 / 1.08	Lowest	10	Mussels ≤2 mg/kg	5	5	Lowest					10		1.08
5. Finniss U/S EB	0.2 / 0.54	Lowest	10	Mussels ≤2 mg/kg	5	5	Lowest			2	10	10	5	0.54
6. Finniss EB to Florence Ck	0.2 / 0.54	Lowest	10	Mussels ≤2 mg/kg	5	5	Lowest			2	10	10	5	0.54
7. Finniss Florence Ck to SOCS	0.2 / 0.54	Lowest	10	Mussels ≤2 mg/kg	5	5	Lowest			2	10	10	5	0.54
8. SOCS upstream limit to FW/SW interface	0.06/ 0.16	Lowest	10	Mussels ≤2 mg/kg		5	Lowest			2	10	10	5	0.16
9. Finniss Estuary	0.7	Lowest		Mussels ≤2 mg/kg		5	Lowest							0.7

Table 6-4 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Cobalt (Co) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	2.8	Lowest	1000	NA	NA	NA	Lowest			NA	50		50	2.8
2. East Branch within mine site to Old Tails Ck	Reduction	Lowest												R
3. East Branch Old Tails Ck to Hannah Spring	Reduction	Lowest	1000				Lowest							R
4. East Branch below Hannah Spring	2.8	Lowest	1000	NA	NA	NA	Lowest					1000		2.8
5. Finniss U/S EB	2.8	Lowest	1000	NA	NA	NA	Lowest			NA	50	1000	50	2.8
6. Finniss EB to Florence Ck	2.8	Lowest	1000	NA	NA	NA	Lowest			NA	50	1000	50	2.8
7. Finniss Florence Ck to SOCS	2.8	Lowest	1000	NA	NA	NA	Lowest			NA	50	1000	50	2.8
8. SOCS upstream limit to FW/SW interface	2.8	Lowest	1000	NA		NA	Lowest			NA	50	1000	50	2.8
9. Finniss Estuary	0.005	Lowest		NA		NA	Lowest							0.005

Table 6-5 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Copper (Cu) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	1.4 / 3.4	Lowest	400	NA	1000	1000	Lowest			2000	200	1000	200	3.4
2. East Branch within mine site to Old Tails Ck	3.2 / 8.0	Lowest												8
3. East Branch Old Tails Ck to Hannah Spring	2.5 / 6.25	Lowest	400				Lowest							6.25
4. East Branch below Hannah Spring	1.8 / 4.5	Lowest	400	NA	1000	1000	Lowest					1000		4.5
5. Finniss U/S EB	1.4 / 3.4	Lowest	400	NA	1000	1000	Lowest			2000	200	1000	200	3.4
6. Finniss EB to Florence Ck	1.4 / 3.4	Lowest	400	NA	1000	1000	Lowest			2000	200	1000	200	3.4
7. Finniss Florence Ck to SOCS	1.4 / 3.4	Lowest	400	NA	1000	1000	Lowest			2000	200	1000	200	3.4
8. SOCS upstream limit to FW/SW interface	1.0 / 2.5	Lowest	400	NA		1000	Lowest			2000	200	1000	200	2.5
9. Finniss Estuary	0.3	Lowest		NA		1000	Lowest							0.3

Table 6-6 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Iron (Fe) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	300	Lowest	NA	NA	300	300	Lowest			300	200		300	200
2. East Branch within mine site to Old Tails Ck	Reduction	Lowest												0
3. East Branch Old Tails Ck to Hannah Spring	Reduction	Lowest	NA				Lowest							0
4. East Branch below Hannah Spring	300	Lowest	NA	NA	300	300	Lowest					NA		300
5. Finniss U/S EB	300	Lowest	NA	NA	300	300	Lowest			300	200	NA	300	200
6. Finniss EB to Florence Ck	300	Lowest	NA	NA	300	300	Lowest			300	200	NA	300	200
7. Finniss Florence Ck to SOCS	300	Lowest	NA	NA	300	300	Lowest			300	200	NA	300	200
8. SOCS upstream limit to FW/SW interface	300	Lowest	NA	NA		300	Lowest			300	200	NA	300	200
9. Finniss Estuary		Lowest		NA		300	Lowest							300

Table 6-7 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Manganese (Mn) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	140	Lowest	NA	NA	100	100	Lowest			500	200		100	100
2. East Branch within mine site to Old Tails Ck	759	Lowest												759
3. East Branch Old Tails Ck to Hannah Spring	443	Lowest	NA				Lowest							443
4. East Branch below Hannah Spring	228	Lowest	NA	NA	100	100	Lowest					NA		100
5. Finniss U/S EB	140	Lowest	NA	NA	100	100	Lowest			500	200	NA	100	100
6. Finniss EB to Florence Ck	140	Lowest	NA	NA	100	100	Lowest			500	200	NA	100	100
7. Finniss Florence Ck to SOCS	140	Lowest	NA	NA	100	100	Lowest			500	200	NA	100	100
8. SOCS upstream limit to FW/SW interface	63	Lowest	NA	NA		100	Lowest			500	200	NA	100	63
9. Finniss Estuary	86	Lowest		NA		100	Lowest							86

Table 6-8 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Nickel (Ni) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	11 / 27.5	Lowest	1000	NA	100	100	Lowest			20	200		100	20
2. East Branch within mine site to Old Tails Ck	22 / 55	Lowest												55
3. East Branch Old Tails Ck to Hannah Spring	17 / 42.5	Lowest	1000				Lowest							42.5
4. East Branch below Hannah Spring	13 / 32.5	Lowest	1000	NA	100	100	Lowest					1000		32.5
5. Finniss U/S EB	11 / 27.5	Lowest	1000	NA	100	100	Lowest			20	200	1000	100	20
6. Finniss EB to Florence Ck	11 / 27.5	Lowest	1000	NA	100	100	Lowest			20	200	1000	100	20
7. Finniss Florence Ck to SOCS	11 / 27.5	Lowest	1000	NA	100	100	Lowest			20	200	1000	100	20
8. SOCS upstream limit to FW/SW interface	8 / 20	Lowest	1000	NA		100	Lowest			20	200	1000	100	20
9. Finniss Estuary	7	Lowest		NA		100	Lowest							7

Table 6-9 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Lead (Pb) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	3.4 / 13.6	Lowest	100	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	50	50	Lowest			10	2000		50	10
2. East Branch within mine site to Old Tails Ck	12.9 / 51.6	Lowest												51.6
3. East Branch Old Tails Ck to Hannah Spring	9.4 / 37.6	Lowest	100				Lowest							37.6
4. East Branch below Hannah Spring	5.6 / 22.4	Lowest	100	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	50	50	Lowest					100		22.4
5. Finniss U/S EB	3.4 / 13.6	Lowest	100	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	50	50	Lowest			10	2000	100	50	10
6. Finniss EB to Florence Ck	3.4 / 13.6	Lowest	100	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	50	50	Lowest			10	2000	100	50	10
7. Finniss Florence Ck to SOCS	3.4 / 13.6	Lowest	100	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	50	50	Lowest			10	2000	100	50	10
8. SOCS upstream limit to FW/SW interface	1.0 / 4.0	Lowest	100	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg		50	Lowest			10	2000	100	50	4
9. Finniss Estuary	2.2	Lowest		Mussels ≤2 mg/kg Fish ≤0.5 mg/kg		50	Lowest							2.2

Table 6-10 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Zinc (Zn) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	8.0 / 20	Lowest	20000	NA	5000	5000	Lowest			3000	2000		2000	20
2. East Branch within mine site to Old Tails Ck	57 / 142.5	Lowest												142.5
3. East Branch Old Tails Ck to Hannah Spring	31 / 77.5	Lowest	20000				Lowest							77.5
4. East Branch below Hannah Spring	15 / 37.5	Lowest	20000	NA	5000	5000	Lowest					20000		37.5
5. Finniss U/S EB	8.0 / 20	Lowest	20000	NA	5000	5000	Lowest			3000	2000	20000	2000	20
6. Finniss EB to Florence Ck	8.0 / 20	Lowest	20000	NA	5000	5000	Lowest			3000	2000	20000	2000	20
7. Finniss Florence Ck to SOCS	8.0 / 20	Lowest	20000	NA	5000	5000	Lowest			3000	2000	20000	2000	20
8. SOCS upstream limit to FW/SW interface	2.4 / 6	Lowest	20000	NA		5000	Lowest			3000	2000	20000	2000	6
9. Finniss Estuary	7	Lowest		NA		5000	Lowest							7

Table 6-11 Water quality trigger values (µg/L) for each environmental value and overall water quality objective for Uranium (U) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	18.9	Lowest	200	NA	NA	NA	Lowest			20	10		10	10
2. East Branch within mine site to Old Tails Ck	96	Lowest												96
3. East Branch Old Tails Ck to Hannah Spring	62	Lowest	200				Lowest							62
4. East Branch below Hannah Spring	32.9	Lowest	200	NA	NA	NA	Lowest					200		32.9
5. Finniss U/S EB	18.9	Lowest	200	NA	NA	NA	Lowest			20	10	200	10	10
6. Finniss EB to Florence Ck	18.9	Lowest	200	NA	NA	NA	Lowest			20	10	200	10	10
7. Finniss Florence Ck to SOCS	18.9	Lowest	200	NA	NA	NA	Lowest			20	10	200	10	10
8. SOCS upstream limit to FW/SW interface	6	Lowest	200	NA		NA	Lowest			20	10	200	10	6
9. Finniss Estuary	NA	Lowest		NA		NA	Lowest							

Table 6-12 Water quality trigger values for each environmental value and overall water quality objective for pH for each zone. Shading indicates trigger values should be refined after more reference data become available.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	6.5-8.0	Lowest	6.0-8.0	NA	6.5-8.5	6.5-8.5	Lowest			6.5-8.5	6.0-9.0		6.0-9.0	6.5-8.0
2. East Branch within mine site to Old Tails Ck	Improved	Lowest												mproved
3. East Branch Old Tails Ck to Hannah Spring	Improved	Lowest	6.0-8.0				Lowest							6.0-8.0
4. East Branch below Hannah Spring	Improved	Lowest	6.0-8.0	NA	6.5-8.5	6.5-8.5	Lowest					6.0-9.0		6.5-7.5
5. Finniss U/S EB	6.5-7.5	Lowest	6.0-8.0	NA	6.5-8.5	6.5-8.5	Lowest			6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.5-7.5
6. Finniss EB to Florence Ck	6.5-7.5	Lowest	6.0-8.0	NA	6.5-8.5	6.5-8.5	Lowest			6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.5-7.5
7. Finniss Florence Ck to SOCS	6.5-7.5	Lowest	6.0-8.0	NA	6.5-8.5	6.5-8.5	Lowest			6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.5-7.5
8. SOCS upstream limit to FW/SW interface	6.5-7.5	Lowest	6.0-8.0	NA		6.5-8.5	Lowest			6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.5-7.5
9. Finniss Estuary		Lowest		NA		6.5-8.5	Lowest							

Table 6-13 Water quality trigger values (µS/cm) for each environmental value and overall water quality objective for electrical conductivity (EC) for each zone. Shading indicates trigger values should be refined after more reference data become available.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	126	Lowest	2985	NA	NA	NA	Lowest			746	1440		1440	126
2. East Branch within mine site to Old Tails Ck	Improved	Lowest												Improved
3. East Branch Old Tails Ck to Hannah Spring	Improved	Lowest	2985				Lowest							2985
4. East Branch below Hannah Spring	427	Lowest	2985	NA	NA	NA	Lowest					5970		427
5. Finniss U/S EB	374	Lowest	2985	NA	NA	NA	Lowest			746	1440	5970	1440	374
6. Finniss EB to Florence Ck	374	Lowest	2985	NA	NA	NA	Lowest			746	1440	5970	1440	374
7. Finniss Florence Ck to SOCS	374	Lowest	2985	NA	NA	NA	Lowest			746	1440	5970	1440	374
8. SOCS upstream limit to FW/SW interface	374	Lowest	2985	NA		NA	Lowest			746	720	5970	1440	374
9. Finniss Estuary		Lowest		NA		NA	Lowest							0

Table 6-14 Water quality trigger values (mg/L) for each environmental value and overall water quality objective for total suspended solids (TSS) for each zone. Shading indicates trigger values should be refined after more reference data become available.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	80%ile	no more than 20% change in clarity	NA	NA	NA	NA	no more than 20% change in clarity			5 NTU Turbidity	NA		NA	0
2. East Branch within mine site to Old Tails Ck	Improved	no more than 20% change in clarity												0
3. East Branch Old Tails Ck to Hannah Spring	Improved	no more than 20% change in clarity	NA				no more than 20% change in clarity							0
4. East Branch below Hannah Spring	80%ile	no more than 20% change in clarity	NA	NA	NA	NA	no more than 20% change in clarity					NA		0
5. Finniss U/S EB	80%ile	no more than 20% change in clarity	NA	NA	NA	NA	no more than 20% change in clarity			5 NTU Turbidity	NA	NA	NA	0
6. Finniss EB to Florence Ck	80%ile	no more than 20% change in clarity	NA	NA	NA	NA	no more than 20% change in clarity			5 NTU Turbidity	NA	NA	NA	0
7. Finniss Florence Ck to SOCS	80%ile	no more than 20% change in clarity	NA	NA	NA	NA	no more than 20% change in clarity			5 NTU Turbidity	NA	NA	NA	0
8. SOCS upstream limit to FW/SW interface	80%ile	no more than 20% change in clarity	NA	NA		NA	no more than 20% change in clarity			5 NTU Turbidity	NA	NA	NA	0
9. Finniss Estuary	80%ile	no more than 20% change in clarity	NA	NA		NA	no more than 20% change in clarity							0

Table 6-15 Water quality trigger values (Bq/L) for each environmental value and overall water quality objective for Radium-226 (^{226}Ra) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	NA	Lowest	5	NA	NA	NA	Lowest			investigate if β or α level exceeded	5		5	5
2. East Branch within mine site to Old Tails Ck	NA	Lowest												0
3. East Branch Old Tails Ck to Hannah Spring	NA	Lowest	5				Lowest							5
4. East Branch below Hannah Spring	NA	Lowest	5	NA	NA	NA	Lowest					5		5
5. Finniss U/S EB	NA	Lowest	5	NA	NA	NA	Lowest			investigate if β or α level exceeded	5	5	5	5
6. Finniss EB to Florence Ck	NA	Lowest	5	NA	NA	NA	Lowest			investigate if β or α level exceeded	5	5	5	5
7. Finniss Florence Ck to SOCS	NA	Lowest	5	NA	NA	NA	Lowest			investigate if β or α level exceeded	5	5	5	5
8. SOCS upstream limit to FW/SW interface	NA	Lowest	5	NA		NA	Lowest			investigate if β or α level exceeded	5	5	5	5
9. Finniss Estuary	NA	Lowest		NA		NA	Lowest							0

Table 6-16 Water quality trigger values (Bq/L) for each environmental value and overall water quality objective for Radium-228 (^{228}Ra) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	NA	Lowest	2	NA	NA	NA	Lowest			investigate if β or α level exceeded	2		2	2
2. East Branch within mine site to Old Tails Ck	NA	Lowest												0
3. East Branch Old Tails Ck to Hannah Spring	NA	Lowest	2				Lowest							2
4. East Branch below Hannah Spring	NA	Lowest	2	NA	NA	NA	Lowest					2		2
5. Finniss U/S EB	NA	Lowest	2	NA	NA	NA	Lowest			investigate if β or α level exceeded	2	2	2	2
6. Finniss EB to Florence Ck	NA	Lowest	2	NA	NA	NA	Lowest			investigate if β or α level exceeded	2	2	2	2
7. Finniss Florence Ck to SOCS	NA	Lowest	2	NA	NA	NA	Lowest			investigate if β or α level exceeded	2	2	2	2
8. SOCS upstream limit to FW/SW interface	NA	Lowest	2	NA		NA	Lowest			investigate if β or α level exceeded	2	2	2	2
9. Finniss Estuary	NA	Lowest		NA		NA	Lowest							0

Table 6-17 Water quality trigger values (Bq/L) for each environmental value and overall water quality objective for Gross Beta radiation excluding Potassium-40 (Beta) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5		0.1	0.1
2. East Branch within mine site to Old Tails Ck	NA	Lowest												0
3. East Branch Old Tails Ck to Hannah Spring	NA	Lowest	0.5				Lowest							0.5
4. East Branch below Hannah Spring	NA	Lowest	0.5	NA	0.1	0.1	Lowest					0.5		0.1
5. Finniss U/S EB	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5	0.5	0.1	0.1
6. Finniss EB to Florence Ck	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5	0.5	0.1	0.1
7. Finniss Florence Ck to SOCS	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5	0.5	0.1	0.1
8. SOCS upstream limit to FW/SW interface	NA	Lowest	0.5	NA		0.1	Lowest			0.5	0.5	0.5	0.1	0.1
9. Finniss Estuary	NA	Lowest		NA		0.1	Lowest							0.1

Table 6-18 Water quality trigger values (Bq/L) for each environmental value and overall water quality objective for Gross Alpha radiation (Alpha(for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply	WQO
1. East Branch & tributaries U/S of the Mine	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5		Y	0.1
2. East Branch within mine site to Old Tails Ck	NA	Lowest												0
3. East Branch Old Tails Ck to Hannah Spring	NA	Lowest	0.5				Lowest							0.5
4. East Branch below Hannah Spring	NA	Lowest	0.5	NA	0.1	0.1	Lowest					0.5		0.1
5. Finniss U/S EB	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5	0.5	Y	0.1
6. Finniss EB to Florence Ck	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5	0.5	Y	0.1
7. Finniss Florence Ck to SOCS	NA	Lowest	0.5	NA	0.1	0.1	Lowest			0.5	0.5	0.5	Y	0.1
8. SOCS upstream limit to FW/SW interface	NA	Lowest	0.5	NA		0.1	Lowest			0.5	0.5	0.5	Y	0.1
9. Finniss Estuary	NA	Lowest		NA		0.1	Lowest							0.1

Table 6-19 WHO (2011) Drinking water guidelines for selected radionuclides of relevance to the Rum Jungle Mine site.

Radionuclide	Guidance Level (Bq/L)
U-238	10
Ra-226	1
RA-228	0.1
Th-232	1
Pb-210	0.1
Po-210	0.1

NB $$\sum \frac{C_i}{GL_i} \leq 1$$

C=activity concentration of radionuclide I and GL=guideline for radionuclide i

6.3 Allocation of Sediment and Soil Quality Criteria

Not all parameters that were assessed for water quality were able to be assessed for sediment and soil quality, as National or Territory criteria have not been published for all.

For metals, the ANZECC/ARMCANZ (2000) sediment quality guidelines were used to assign quality criteria for protection of aquatic ecosystems for arsenic, cadmium, copper, lead, nickel and zinc, while the National Assessment Guidelines for Dredging (NAGD, Commonwealth of Australia 2009) were used to assign criteria for radionuclides. For the metals, the interim sediment quality guidelines-low (ISQG-Low) were used for most zones, but the ISQG-High values were used for the East Branch zones from the mine to the junction with the Finniss River. It should be noted that these guidelines apply to the bioavailable fraction of the sediment metals, and while they conservatively predict low likelihood of effects on aquatic biota for concentrations below the ISQG-Low, concentrations above that guideline and indeed the ISQG-High, require further investigation to assess the likelihood of toxicity. That is, the guidelines are not good predictors of the likelihood of effects occurring in sediments above the guideline, as the form of the contaminant, exposure pathways and co-occurring factors that affect toxicity are not fully taken into account. For a more detailed discussion of the limitations of these guidelines and the types of assessment that should be triggered by measurements above the guidelines, see Simpson *et al.* (2005).

For consideration of wildlife habitat (and riparian vegetation) and crop growing, the draft National Environment Protection (Assessment of Site Contamination) Measure (NEPM) (2011) guidelines for soil quality (Schedule B_{5c}) were used for the elements considered in that draft (i.e. copper, lead, nickel and zinc) for aged soil contamination. These guidelines are for additional contaminant levels (ACL), not total concentrations, and should be added to the background concentrations for the soils to determine the total metal concentration guideline. That was not possible for this assessment, so only the ACL values are provided (and shaded in the tables). Additionally, for those elements that should be normalised for soil pH and/or cation exchange capacity (CEC), it was assumed that the generally sandy soils of the fluvial system of the Finniss River would be low in CEC and neutral in pH. An advantage of these draft guidelines is that they provide for different uses of soils, including for high ecological value areas (applied to the Site of Conservation Significance zones), urban residential/public open space (applied to most other zones) and commercial/industrial land use (applied to the East Branch zones from the mine downstream).

For elements not included in NEPM (2011), the older NEPM (1999) guidelines for investigation level for soil and groundwater (Schedule B_1) were used. For wildlife habitat values, the interim urban ecological investigation levels were used, while for recreational values the Health Investigation Level E (HIL-E, for parks, recreational open spaces and playing fields) was used. For irrigation and general farm usage the HIL-A (for "standard" residential with garden/accessible soils) was used. For visual and cultural/spiritual values the lowest of these criteria was adopted. No applicable guidelines were available for stock access (although levels suitable for vegetation growth would at least maintain food availability for them) and sediment criteria are not applicable for drinking water. For human consumption of aquatic foods, as for water quality there were no specific guidelines available, but it was assumed that sediment quality sufficient for aquatic ecosystems would provide protection for availability of these foods. Note was made for relevant food standards for particular elements (arsenic, cadmium and lead), as for the water quality trigger values.

For the East Branch zones from the mine to the junction with the Finniss River, where there is no default trigger value for highly disturbed or industrial use areas for a parameter, an objective greater than the default trigger value is recommended, but is not quantified. Zone specific objectives should be developed for these parameters from soil or sediment sampling within those zones.

In addition to the ecosystem protection limits for radionuclides from the NAGD for the aquatic ecosystem environmental value, the approach used by Hughes and Bollhöfer (2010) was applied for the human recreation and farm use values. This approach was based on the International Commission on Radiological Protection (ICRP) recommended reference level of 1-20 mSv/a for the restriction of dose or risk, above which it is judged inappropriate to plan to allow exposures to occur. Note that that this approach sets a limit on dose to humans over the course of a year from presence in an area, and is not equivalent to the guideline value for contaminant concentration in sediments from the NAGD. We selected the mid-point of the ICRP range, 10 mSv/a, as recommended by the ICRP. This was also applied to the East Branch zones for secondary recreational use, as it was considered appropriate that a radiological objective was applied to use of these areas by humans. It was also applied to the visual recreation and cultural/spiritual values of all zones, because these values also require facilitation of the presence of humans in the vicinity of soils and sediments.

It is worth noting that because the soil/sediment quality objectives apply variously to stream sediments, riparian soils, and soils more generally depending on the environmental value of concern, no overall quality objective is provided. However, in general terms the aquatic ecosystem sediment quality trigger values would apply to stream sediments and the lowest of the other environmental values' objectives to soils.

The sediment/soil quality objectives that were derived are presented in Table 6-20 to Table 6-28.

Table 6-20 Sediment and soil quality objectives (mg/kg) for each environmental value for Arsenic (As) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	20	Lowest	3	Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg	200	200	Lowest			NA	100		100
2. East Branch within mine site to Old Tails Ck	70	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	70	Lowest	>3				Lowest						
4. East Branch below Hannah Spring	70	Lowest	>3	Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg	200	200	Lowest					NA	
5. Finniss U/S EB	20	Lowest	3	Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg	200	200	Lowest			NA	100	NA	100
6. Finniss EB to Florence Ck	20	Lowest	3	Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg	200	200	Lowest			NA	100	NA	100
7. Finniss Florence Ck to SOCS	20	Lowest	3	Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg	200	200	Lowest			NA	100	NA	100
8. SOCS upstream limit to FW/SW interface	20	Lowest	3	Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg		200	Lowest			NA	100	NA	100
9. Finniss Estuary	20	Lowest		Crustacea and Fish Inorganic As ≤2 mg/kg, Mussels ≤1 mg/kg		200	Lowest						

Table 6-21 Sediment and soil quality objectives (mg/kg) for each environmental value for cadmium (Cd) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	1.5	Lowest	3	Mussels ≤2 mg/kg	40	40	Lowest			NA	20		20
2. East Branch within mine site to Old Tails Ck	10	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	10	Lowest	>3				Lowest						
4. East Branch below Hannah Spring	10	Lowest	>3	Mussels ≤2 mg/kg	40	40	Lowest					NA	
5. Finniss U/S EB	1.5	Lowest	3	Mussels ≤2 mg/kg	40	40	Lowest			NA	20	NA	20
6. Finniss EB to Florence Ck	1.5	Lowest	3	Mussels ≤2 mg/kg	40	40	Lowest			NA	20	NA	20
7. Finniss Florence Ck to SOCS	1.5	Lowest	3	Mussels ≤2 mg/kg	40	40	Lowest			NA	20	NA	20
8. SOCS upstream limit to FW/SW interface	1.5	Lowest	3	Mussels ≤2 mg/kg		40	Lowest			NA	20	NA	20
9. Finniss Estuary	1.5	Lowest		Mussels ≤2 mg/kg		40	Lowest						

Table 6-22 Sediment and soil quality objectives (mg/kg) for each environmental value for cobalt (Co) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	NA	Lowest	NA	NA	200	200	Lowest			NA	100		100
2. East Branch within mine site to Old Tails Ck	NA	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	NA	Lowest	NA				Lowest						
4. East Branch below Hannah Spring	NA	Lowest	NA	NA	200	200	Lowest					NA	
5. Finniss U/S EB	NA	Lowest	NA	NA	200	200	Lowest			NA	100	NA	100
6. Finniss EB to Florence Ck	NA	Lowest	NA	NA	200	200	Lowest			NA	100	NA	100
7. Finniss Florence Ck to SOCS	NA	Lowest	NA	NA	200	200	Lowest			NA	100	NA	100
8. SOCS upstream limit to FW/SW interface	NA	Lowest	NA	NA		200	Lowest			NA	100	NA	100
9. Finniss Estuary	NA	Lowest		NA		200	Lowest						

Table 6-23 Sediment and soil quality objectives (mg/kg) for each environmental value for copper (Cu) for each zone. NEPM (2011) ACL values are shaded.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	65	Lowest	50	NA	2000	2000	Lowest			NA	50		50
2. East Branch within mine site to Old Tails Ck	270	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	270	Lowest	80				Lowest						
4. East Branch below Hannah Spring	270	Lowest	80	NA	2000	2000	Lowest					NA	
5. Finniss U/S EB	65	Lowest	50	NA	2000	2000	Lowest			NA	50	NA	50
6. Finniss EB to Florence Ck	65	Lowest	50	NA	2000	2000	Lowest			NA	50	NA	50
7. Finniss Florence Ck to SOCS	65	Lowest	50	NA	2000	2000	Lowest			NA	50	NA	50
8. SOCS upstream limit to FW/SW interface	65	Lowest	15	NA		2000	Lowest			NA	50	NA	50
9. Finniss Estuary	65	Lowest	15	NA		2000	Lowest						

Table 6-24 Sediment and soil quality objectives (mg/kg) for each environmental value for manganese (Mn) for each zone.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	NA	Lowest	500	NA	3000	3000	Lowest			NA	1500		1500
2. East Branch within mine site to Old Tails Ck	NA	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	NA	Lowest	>500				Lowest						
4. East Branch below Hannah Spring	NA	Lowest	>500	NA	3000	3000	Lowest					NA	
5. Finniss U/S EB	NA	Lowest	500	NA	3000	3000	Lowest			NA	1500	NA	1500
6. Finniss EB to Florence Ck	NA	Lowest	500	NA	3000	3000	Lowest			NA	1500	NA	1500
7. Finniss Florence Ck to SOCS	NA	Lowest	500	NA	3000	3000	Lowest			NA	1500	NA	1500
8. SOCS upstream limit to FW/SW interface	NA	Lowest	500	NA		3000	Lowest			NA	1500	NA	1500
9. Finniss Estuary	NA	Lowest		NA		3000	Lowest						

Table 6-25 Sediment and soil quality objectives (mg/kg) for each environmental value for nickel (Ni) for each zone. NEPM (2011) ACL values are shaded.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	21	Lowest	85	NA	600	600	Lowest			NA	85		85
2. East Branch within mine site to Old Tails Ck	52	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	52	Lowest	160				Lowest						
4. East Branch below Hannah Spring	52	Lowest	160	NA	600	600	Lowest					NA	
5. Finniss U/S EB	21	Lowest	85	NA	600	600	Lowest			NA	85	NA	85
6. Finniss EB to Florence Ck	21	Lowest	85	NA	600	600	Lowest			NA	85	NA	85
7. Finniss Florence Ck to SOCS	21	Lowest	85	NA	600	600	Lowest			NA	85	NA	85
8. SOCS upstream limit to FW/SW interface	21	Lowest	6	NA		600	Lowest			NA	85	NA	85
9. Finniss Estuary	21	Lowest	6	NA		600	Lowest						

Table 6-26 Sediment and soil quality objectives (mg/kg) for each environmental value for lead (Pb) for each zone. NEPM (2011) ACL values are shaded.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	50	Lowest	530	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	600	600	Lowest			NA	530		530
2. East Branch within mine site to Old Tails Ck	220	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	220	Lowest	940				Lowest						
4. East Branch below Hannah Spring	220	Lowest	940	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	600	600	Lowest					NA	
5. Finniss U/S EB	50	Lowest	530	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	600	600	Lowest			NA	530	NA	530
6. Finniss EB to Florence Ck	50	Lowest	530	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	600	600	Lowest			NA	530	NA	530
7. Finniss Florence Ck to SOCS	50	Lowest	530	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg	600	600	Lowest			NA	530	NA	530
8. SOCS upstream limit to FW/SW interface	50	Lowest	170	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg		600	Lowest			NA	530	NA	530
9. Finniss Estuary	50	Lowest	170	Mussels ≤2 mg/kg Fish ≤0.5 mg/kg		600	Lowest						

Table 6-27 Sediment and soil quality objectives (mg/kg) for each environmental value for zinc (Zn) for each zone. NEPM (2011) ACL values are shaded.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	200	Lowest	230	NA	14000	14000	Lowest			NA	230		230
2. East Branch within mine site to Old Tails Ck	410	Lowest											
3. East Branch Old Tails Ck to Hannah Spring	410	Lowest	360				Lowest						
4. East Branch below Hannah Spring	410	Lowest	360	NA	14000	14000	Lowest					NA	
5. Finniss U/S EB	200	Lowest	230	NA	14000	14000	Lowest			NA	230	NA	230
6. Finniss EB to Florence Ck	200	Lowest	230	NA	14000	14000	Lowest			NA	230	NA	230
7. Finniss Florence Ck to SOCS	200	Lowest	230	NA	14000	14000	Lowest			NA	230	NA	230
8. SOCS upstream limit to FW/SW interface	200	Lowest	50	NA		14000	Lowest			NA	230	NA	230
9. Finniss Estuary	200	Lowest	50	NA		14000	Lowest						

Table 6-28 Sediment (Bq/g) and soil quality (mSv/a) objectives for each environmental value for radionuclides for each zone. Sediment quality objectives are for aquatic ecosystem protection and are for the sum of gross α and gross β. Soil quality objectives are provided where appropriate for other environmental values and are annual doses on the assumption of permanent residence.

Zone	Aquatic Ecosystems	Cultural/Spiritual	Wildlife Habitat	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Industrial Use	Aquaculture	Drinking Water	Irrigation	Stock Water	Farm Supply
1. East Branch & tributaries U/S of the Mine	35	10	NA	NA	10	10	10			NA	NA		10
2. East Branch within mine site to Old Tails Ck	>35	10				10							
3. East Branch Old Tails Ck to Hannah Spring	>35	10	NA			10	10						
4. East Branch below Hannah Spring	>35	10	NA	NA	10	10	10					NA	
5. Finniss U/S EB	35	10	NA	NA	10	10	10			NA	NA	NA	10
6. Finniss EB to Florence Ck	35	10	NA	NA	10	10	10			NA	NA	NA	10
7. Finniss Florence Ck to SOCS	35	10	NA	NA	10	10	10			NA	NA	NA	10
8. SOCS upstream limit to FW/SW interface	35	10	NA	NA		10	10			NA	NA	NA	10
9. Finniss Estuary	35	10		NA		10	10						

7 SUMMARY AND CONCLUSIONS

A review of available literature and data, and the findings of visits to the mine and receiving environments, and meetings and consultation with key stakeholders has shown that while a substantial body of knowledge exists with regard to historic and contemporary biophysical processes, there exists substantial data gaps. However, the information obtained and reviewed by the study team has enabled EVs and WQOs to be set according to the ANZECC/ARMCANZ (2000) protocol for nine separate zones of the East Branch and Finniss Rivers. Despite the apparent lack of trend analysis for key metrics of the receiving environment since the mid-2000s, it is clear that while the condition of the East Branch has improved in the years since the commencement of the rehabilitation program, it is still substantially impacted. Of some concern was the finding that rainfall has steadily increased over the period of record, and that climate change predictions suggest that the intensity of climatic events will also increase. As surface and groundwater flows are the key transport mechanisms for mine contaminants, it may reasonably be expected that the rate of contaminant transport and mixing in both the East Branch and Finniss Rivers will increase, with ecological consequences. Therefore, it is important that steps are taken (via revised/expanded monitoring and further data analysis) that will allow the information gaps to be filled, and thereby better inform the ongoing rehabilitation that will be necessary in order for the WQOs to be achieved.

The authors are particularly grateful for the inputs provided by the traditional owners which have been incorporated into the EVs and subsequent WQOs in accordance with the ANZECC/ARMCANZ (2000) methodology.

8 REFERENCES

ANZECC/ARMCANZ (Australia and New Zealand Environment and Conservation Council)/(Agriculture and Resource Management Council of Australia and New Zealand) (2000a). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. (Agriculture and Resource Management Council of Australia and New Zealand: Canberra).

Allison, H. E.; Simpson, R. D. (1989). Element Concentrations in the Freshwater Mussel, Velesunio angasi, in the Alligator Rivers Region; Technical Memorandum 25; Australian Government Publishing Service: Canberra, p 249.

Atlas of Living Australia (ALA), online portal to the Global Biodiversity Information Facility (GBIF): http://www.ala.org.au/.

Baker, B., Price, O., Woinarski, J.C.Z., Gold, S., Connors, G., Fisher, A. & Hempel, C. (2005). Northern Territory Bioregions – Assessment of Key Biodiversity Values and Threat. Department of Natural Resources, Environment and The Arts, Palmerston, Northern Territory.

Bollhöfer, A., Pfitzner, K., Ryan, B., Esparon, A., and Brazier, J. (2007). Radiological Assessment of Rum Jungle Mine, Northern Territory. Environmetal Research Institute of the Supervising Scientist and Department of Enviornment and Water Resources, Darwin.

Brazier, J., Munksgaard, N. and Parry, D. (2005) Sediment and Water Quality of the East Branch of the Finniss River, Northern Territory 2003-2005. Charles Darwin University, Darwin.

Cameron McNamara Pty. Ltd (1983). Specification for Darwin: Rum Jungle rehabilitation - Stage 2 Reshaping, Drainage and Revegetation of Whites Overburden Heap.

Chatto, R. (2000). Waterbird Breeding Colonies in the Top End of the Northern Territory. Technical Report 69, Parks and Wildlife Commission of the Northern Territory, Darwin.

Christian, K. (2004). Varanus mertensi. In: Pianka, E.R., King, D.R. & King, R.A. (eds). Varanoid Lizards of the World. Indiana University Press. Bloomington. Indianapolis.

Coffey Environments Pty Ltd (2009) Notice of Intent: HNC (Australia) Resources Pty Ltd: Area 55 Oxide Project. (unpublished).

Commonwealth of Australia (2009) National Assessment Guidelines for Dredging. Commonwealth of Australia, Canberra.

Conservation Commission of the Northern Territory (1984). Review of Revegetation Operations and Monitoring Rum Jungle. October 1983 - October 1984. Conservation Commission of the Northern Territory. Darwin, NT.

Davy, D., (1975), Rum Jungle Environmental Studies. Australian Atomic Energy Commission report.

Dames and Moore (1983). Options for Reshaping and Revegetation. White's Heap and Contaminated Surrounds, Rum Jungle, Northern Territory. Northern Territory Government Department of Transport and Works, Darwin NT.

Doody, J.S., Green, B., Rhind, D., Castellano, C., Sims, R. & Robinson, T. (2009). Population-Level Declines in Australian Predators Caused by an Invasive Species. Animal Conservation. 12:46-53.

Edwards, C. A. (2002). Effects of Acid Rock Drainage from the Remediated Rum Jungle Mine on the Macroinvertebrate Community Composition in the East Finniss River, Northern Territory. MSc thesis, University of Technology, Sydney, pp. 208.

Ferris J.M., Vyverman W, Gell P and Brown P L (2002). Diatoms as Biomonitors in two Temporary Streams Affected by Acid Drainage from Disused Mines, in Proceedings of the Finniss River Symposium, August 23-24, 2001, Darwin, eds. S. J. Markich and R. A Jeffree, ANSTO E/748, pp. 26-31.

Food Standards Australia New Zealand (2012) Standard 1.4.4 Contaminants and Natural Toxicants. (http://www.foodstandards.gov.au/foodstandards/foodstandardscode.cfm accessed 23/10/12).

Gale S. A., Smith S. V., Lim R. P., Jeffree R. A., and Petocz P. (2003). Insights into the Mechanisms of Copper Tolerance of a Population of Black-banded Rainbowfish (Melanotaenia nigrans) (Richardson) Exposed to Mine Leachate, using $^{64/67}$Cu. Aquatic Toxicology, 62 (2), 135 – 153.

Griffiths, A.D. & McKay, J.L. (2005). Monitoring the Freshwater Goanna Varanus mertensi After the Arrival of Cane Toads using Site Occupancy Models. Report to Parks and Wildlife Service NT. (Charles Darwin University, Darwin).

Harrison, L., McGuire, L., Ward, S., Fisher, A., Pavey, C., Fegan, M. & Lynch, B. (2009). An Inventory of Sites of International and National Significance for Biodiversity Values in the Northern Territory. Department of Natural Resources, Environment, The Arts and Sport, Darwin, NT.

Hennessy, K., Page, C., McInnes, K., Walsh, K., Pittock, B., Bathols, J. and Suppiah, R. (2004), Climate Change in the Northern Territory, CSIRO report.

Hughes, A. & Bollhöfer, A. (2010). Radiological Investigations in the Rum Jungle and East Finniss River areas 2009. Supervising Scientist Division, Darwin.

Iles, M. (2005). Application of national water quality guidelines in mine regulation at Ranger mine, Australia. Proceedings of the 9th International Mine Water Congress, Oviedo, Spain.

Jackson S. (1993). An Investigation of Macroinvertebrate Community Composition in the Polluted East Branch of the Finniss River, Northern Territory, Following Remediation of the Rum Jungle Mine. MSc thesis, University of Technology, Sydney, pp. 96.

Jeffree R. A. (2001). Degree of Recovery of Fish Biodiversity in the Finniss River System, NT, Following Remediation of the Rum Jungle U/Cu Mine Site. Proceedings of 26th Annual Minerals Council of Australia Enviromental Workshop, Adelaide, NSW, 14-18 October, 2001, pp. 124-128.

Jeffree, R. A., Markich, S. J., Twining, J. R. and Gale, S. (2006). Tolerance of Fish to Contaminated Habitats: Underlying Mechanisms Probed with Isotopic Tracers.

Jeffree, R. A. & Twinning, J. R. (1992). An Investigation on Fish Diversity and Abundance in the Finniss River Following Remediation of the Rum Jungle Mine Site. Environmental Science Program. Sydney Australian Nuclear Science and Technology Organisation (ANSTO).

Jeffree, R. A., Twining, J., Ewing, B. & Jackson, D. (1992). Enhanced Fish Diversity and Abundance in the Finniss River, NT, Australia, Following Remediation of the Rum Jungle Mine Site Menai, NSW/Palmerston, NT, ANSTO and Conservation Commission of the Northern Territory.

Jeffree R. A and Twining J. R. (2000).n Contaminant Water Chemistry and Distribution of Fishes in the East Branch, Finniss River, following Remediation of the Rum Jungle Uranium/Copper Mine Site. Proc. 2000 Contaminated Site Remediation Conference, Melbourne, 4-8 December, 2000, pp. 51-56.

Jeffree R. A., Twining J. R. and Thompson J. (2001). Recovery of Fish Communities in the Finniss River, Northern Australia, Following Remediation of the Rum Jungle Uranium/Copper Mine Site. Environ. Sci. Technol., 35, 2932-2941.

Jeffree R.A. & Williams N.J. (1975). Biological Indications of Pollution of the Finniss River System, Especially Fish Diversity and Abundance. Chapter 7 in D. R. Davy, editor. Rum Jungle environmental studies. Australian Atomic Energy Commission/ E365, Lucas Heights.

Jeffree R.A. & Williams N.J. (1980). Mining Pollution and the Diet of the Purple Striped Gudgeon Mogurnda Mogurnda Richardson (Eleotridae) in the Finniss River, Northern Territory, Australia. Ecological Monographs, 50 (4), 457-485.

Kraatz, M. (Ed) (1998). Monitoring Report 1988-1993 Rum Jungle Rehabilitation Project. Northern Territory Department of Lands, Planning and Environment, Darwin.

Kraatz, M. (2004). Rum Jungle Rehabilitation Scoping Study Environmental Issues and Considerations for Future Management. M4K Environment Consulting, Casaurina.

Low, W. A. (2001). Flora and Fauna of the Brown's Oxide Region, NT, a Desk Top Assessment of Information Available and Required for Environmental Impact Assessment of Brown's Polymetallic Project for NSR Environmental Consultants P/L Melbourne and Compass Resources NL Sydney. Low Ecological Services P/L, Alice Springs, NT.

Manolis, S. C., Webb, G.J.W. & Britton, A.R.C. (2002a). Crocodiles and Other Reptiles: Bioindicators of Pollution. Pp. 65-69 in The Finniss River; a Natural Laboratory of Mining Impacts - Past, Present and Future. ANSTO: Sydney.

Manolis, S.C., Webb, G.J.W., Britton, A.R.C. Jeffree, R.A. & Markich, S.J. (2002b). Trace Element Concentrations of Wild Saltwater Crocodile Eggs. Pp. 58-61 in the Finniss River; A Natural Laboratory of Mining Impacts - Past, Present and Future. ANSTO: Sydney.

Markich S. J., Jeffree R. A. and Burke, P. J. (2002). Freshwater Bivalve Shells as Archival Indicators of Metal Pollution from a Copper-Uranium Mine in Tropical Northern Australia. Environ. Sci. Technol., 36, 821-832.

Menzies, N. W. and Mulligan, D. R. (1997). Vegetation Dieback on Dyson's Open Cut. Implications, Casual Mechanisms and Options for Remediation. The Queensland University.

Milnes, A. R., Reddell, P., Playfair, L. A. and Frazey, P. G. (1990). Elemental Composition of Rock Samples, Mine Soils and Plant Species Colonizing the Waste Rock Dump (Area 6), Rum Jungle Creek South. CSIRO, Darwin, NT.

Moliere, M., Brazier, J., and Jones, D, (2007), Discrepancies Between Pollutant Loads From on-site Sources and Pollutants Loads Downstream of Rum Jungle, ERISS report.

Morris, O., (2005), The role of Physical and Chemical Transport Mechanisms in the Dispersion of Heavy Metals and Arsenic in the Seasonally-Wet Tropical, East Branch of the Finniss River, Northern Territory, Australia. University of Lancaster honours thesis.

National Environment Protection (Assessment of Site Contamination) Measure (NEPM) (1999). Schedule B(1) Guideline on the Investigation Levels for Soil and Groundwater. National Environment Protection Council, Canberra.

National Environment Protection (Assessment of Site Contamination) Measure (NEPM) (2011). Schedule B_{5c} Guideline on Soil Quality Guidelines for Arsenic, Chromium (III), Copper, DDT, Lead, Naphthalene, Nickel and Zinc. National Environment Protection Council, Canberra.

Parks and Wildlife Commission Northern Territory (2012). Threatened Species of the Northern Territory Lorentz Grunter *Pingalla lorentzi*. (http://lrm.nt.gov.au/__data/assets/pdf_file/0004/10894/Lorentzs_Grunter_VU.pdf accessed 26/10/12).

Pidsley, S.M. (2002). Rum Jungle Rehabilitation Project Monitoring Report 1993-1998. Department of Infrastructure, Planning and Environment, Darwin.

RGC (2010a), Hydrogeological Study of Rum Jungle Mine Site, Initial Review and Data Gap Analysis. Consultant's report to the Northern Territory Government.

RGC (2010b), Phase 2 Report, Detailed Water Quality Review & Preliminary Contaminant Load Estimates, Rum Jungle Mine Site, Northern Territory. Consultant's report to the Northern Territory Government.

Ryan, P. (1985). Review of Revegetation Operations and Monitoring. Rum jungle Rehabilitation Project. October 1984 - August 1985. Conservation Commission of the Northern Territory Darwin, NT.

Ryan, P. (1986a) Tree Colonisation on Compacted Soil Layers at Rum Jungle, Darwin, NT. Conservation Commission of the Northern Territory, Darwin, NT.

Ryan, P. (1986b). Rum Jungle Rehabilitation Project. Summary of Revegetation. Monitoring and Recommendations. Conservation Commission of the Northern Territory. Darwin, NT.

Schultz, T. & Doody, S. (2004). Varanus mitchelli. In: Pianka, E.R., King, D.R. & King, R.A. (eds). Varanoid lizards of the world. Indiana University Press. Bloomington. Indianapolis.

Simpson, S.L., Batley, G.E., Charlton, A.A., Stauber, J.L., King, K.K., Chapman, J.C., Hyne, R.V., Gale, S.A., Roach, A.C., and Maher, W.A. (2005). Handbook for Sediment Quality Assessment. CSIRO, Bangor, NSW.

Stringer, C. (2003). The Saga of Sweetheart. Phoenix Offset Printers. Hong Kong, China.

Taylor, M., (2007), Distribution and Storage of Sediment-associated Heavy Metals Downstream of the Remediated Rum Jungle Mine on the East Branch of the Finniss River, Northern Territory, Australia. Journal of Geochemical Exploration, 92, 55-72.

Twining J.R. (2002). Post Remedial Ecological Recovery in the East Branch of the Finniss River: Fish and Decapods, in Proceedings of the Finniss River Symposium, August 23-24, 2001, Darwin, eds. S. J. Markich and R. A Jeffree**,** ANSTO E/748, pp 35-38.

Ward, S. & Harrison, L. (2009). Recognising Sites of Conservation Significance for Biodiversity Values in the Northern Territory. Department of Natural Resources, Environment, The Arts and Sport, Darwin, NT.

Watson (1975), Rum Jungle Environmental Studies Summary Report, Australian Atomic Energy Commission report.

Wels, C., Ferguson, P., and Fawcett, M., (2012), Numerical Groundwater Flow Modelling at the Historic Rum Jungle Mine Site, Northern Australia. Proceedings of the IMWA 2012 conference, Bunbury, Western Australia.

WHO (2004/2005). Manganese and its Compounds: Environmental Aspects. (including corrigenda to April 2005). WHO, Geneva.

WHO (2011). Guidelines for Drinking-water Quality. Fourth Edition. WHO, Geneva.

APPENDIX 1 CANOPY AND MID-LAYER SPECIES RECORDED DURING SITE VISITS TO THE FINNISS RIVER RIPARIAN ZONE

1. FR6: Meneling Crossing, Finniss River ~18km upstream of the East Branch confluence.	
Canopy Species	**Woody Understory**
Melaleuca leucadendra (dominant)	*Pandanus aquaticus* (co-dominant)
Nauclea orientalis	*Barringtonia acutangula* (co-dominant)
Bambusa arnhemica	*Glochidion* sp
Lophostemon grandiflorus	*Exocarpos latifolius*
Acacia auriculiformis	*Smilax australis*
Timonius timon	*Erythrina vespertilio*
Syzygium armstrongii	
Vitex glabrata	
2. FR5: Finniss River ~6km upstream of the East Branch confluence	
Canopy Species	**Woody Understory**
Melaleuca leucadendra (dominant)	*Helicea australasica*
Nauclea orientalis	*Pandanus aquaticus*
Bambusa arnhemica	*Maranthes corymbosa*
Terminalia sericocarpa	*Vitex glabrata*
Syzygium armstrongii	*Cyclophyllum schultzii*
Timonius timon	*Barringtonia acutangula*
Buchanania arborescens	
Myristica insipida	
Lophostemon grandiflorus	
3. FR4: Finniss River ~1km downstream of the East Branch confluence.	
Canopy Species	**Woody Understory**
Syzygium armstrongii (co-dominant)	*Pandanus aquaticus* (co-dominant)
Melaleuca leucadendra (co-dominant)	*Barringtonia acutangula* (co-dominant)
Melaleuca argentea (co-dominant)	*Vitex glabrata*
Nauclea orientalis	*Leptospermum longifolium*
Terminalia sericocarpa	*Strychnos lucida*
Acacia auriculiformis	*Flagelaria indica*
Bambusa arnhemica	*Eleocarpus arnhemicus*
	Caolphyllum sil
	Cupaniopsis anacardioides
4. FR3: Finniss River ~4km downstream of the East Branch confluence.	
Canopy Species	**Woody Understory**
Syzygium armstrongii (co-dominant)	*Pandanus aquaticus* (co-dominant)
Melaleuca leucadendra (co-dominant)	*Barringtonia acutangula* (co-dominant)
Melaleuca argentea (co-dominant)	*Carallia brachiata*
Nauclea orientalis	*Leptospermum longifolium*

Terminalia sericocarpa	*Strychnos lucida*
Acacia auriculiformis	*Flagelaria indica*
Bambusa arnhemica	*Eleocarpus arnhemicus*
	Caolphyllum sil
	Helicea australasica
5. FL1 and FL2: Finniss River ~16km downstream of the East Branch confluence.	
Canopy Species	**Woody Understory**
Syzygium armstrongii (co-dominant)	*Pandanus aquaticus* (co-dominant)
Melaleuca leucadendra (co-dominant)	*Barringtonia acutangula* (co-dominant)
Melaleuca argentea (co-dominant)	*Carallia brachiata*
Nauclea orientalis	*Leptospermum longifolium*
Terminalia sericocarpa	*Strychnos lucida*
Acacia auriculiformis	*Flagelaria indica*
Bambusa arnhemica	*Eleocarpus arnhemicus*
	Caolphyllum sil
	Cupaniopsis anacardioides
6. FR1: Finniss River ~30km downstream of the East Branch confluence.	
Canopy Species	**Woody Understory**
Syzygium armstrongii (co-dominant)	*Pandanus aquaticus* (co-dominant)
Melaleuca leucadendra (co-dominant)	*Barringtonia acutangula* (co-dominant)
Bambusa arnhemica	*Carallia brachiata*
Melaleuca argentea	*Leptospermum longifolium*
Terminalia sericocarpa	*Carpentaria acuminata*
Acacia auriculiformis	*Flagelaria indica*
Nauclea orientalis	*Mimosa pigra* (weed)
7. FL4 (adjacent): Billabongs on Finniss River levee ~5km downstream of the East Branch confluence.	
Canopy Species	**Woody Understory**
Melaleuca leucadendra (co-dominant)	*Pandanus aquaticus* (co-dominant)
Acacia auriculiformis (co-dominant)	*Barringtonia acutangula* (co-dominant)
Nauclea orientalis	
	Aquatic Macrophytes
	Nymphaea violacea
	Nymphoides indica
	Eleocharis sp
	Chara sp
8. EB2: East Branch ~1km upstream of Rum Jungle Mine-site	
Canopy Species	**Woody Understory**
Melaleuca viridiflora	*Pandanus spiralis*
Acacia auriculiformis	
Lophostemon grandiflorus	
9. EB Dysons: East Branch immediately upstream of Rum Jungle mine-site	

Canopy Species	Woody Understory
Melaleuca viridiflora (co-dominant)	
Acacia auriculiformis (co-dominant)	
10. Spring: East Branch at the Rum Jungle Mine site, adjacent to the Main void.	
Canopy Species	**Woody Understory**
Melaleuca viridiflora	
Acacia auriculiformis	
Ficus racemosa	
11. EB06: East Branch at the Rum Jungle Mine site, adjacent to the secondary void.	
Canopy Species	**Woody Understory**
Melaleuca viridiflora	*Pandanus spiralis*
Acacia auriculiformis	
Melaleuca leucadendra	
Terminalia sericocarpa	
12. GS0097: East Branch ~6km downstream of the Rum Jungle Mine site.	
Canopy Species	**Woody Understory**
Acacia auriculiformis	*Barringtonia acutangula*
Melaleuca viridiflora	*Mimosa pigra* (weed)
Melaleuca leucadendra	
13. Hannah's Spring: East Branch ~7km downstream of the Rum Jungle Mine site.	
Canopy Species	**Woody Understory**
Acacia auriculiformis	*Barringtonia acutangula*
Melaleuca leucadendra	*Mimosa pigra* (weed)
Nauclea orientalis	*Calophyllum sil*
Terminalia sericocarpa	*Carallia brachiata*
Ficus racemosa	*Mimosa pigra* (weed)
Carpentaria acuminata	

APPENDIX 2 TABLE OF NOMINATED INDIGENOUS BUSH FOOD PLANTS IN THE FINNISS RIVER RIPARIAN ZONE

Species	Common Name	Use
Amorphophallus paeoniifolius	**Cheeky Yam**	tuber eaten after roasting, peeling
Ampelocissus frutescens	**Wild Grape**	fruit edible raw
Antidesma ghesaembilla	**Black Currant**	fruit eaten raw
Bambusa arnhemica	**Bamboo**	edible shoots, cut off below ground when ~30cm tall
Bombax ceiba	**Red Kapok Tree**	seeds edible after removing kapok
Brachystelma glabriflorum	**Bush Potato**	edible tuber, cleaned and eaten raw
Buchanania arborescens	**Plum**	Black fruit eaten raw.
Carallia brachiata	**Ruby Red**; **Plum Tree**	Red fruit eaten raw when almost black
Cartonema spp.	**Yam**	edible tuber, sun-dried and lightly roasted
Carpentaria acuminata	**Carpentaria Palm**	edible 'cabbage' eaten raw
Cyclophyllum schultzii	**Cherry**	Ripe fruit eaten raw
Dioscorea bulbifera	**Cheeky Yam**	edible tuber cooked and peeled
Eleocharis spp.	**Water Chestnut**	edible small tubers (nuts) lightly roasted
Eriosema chinense	**Bush Potato**	edible tuber peeled and eaten raw or cooked
Exocarpos latifolius	**Wild Cherry**	pedicel eaten raw when red
Ficus hispida	**River Fig**	edible fruit ripe figs eaten raw
Ficus racemosa	**Cluster Fig**	edible fruit ripe figs eaten raw
Ficus virens	**Banyan**	edible fruit ripe figs eaten raw
Flueggea virosa	**White Currant**	ripe fruit eaten raw
Melaleuca leucadendra	**White Paperbark**	edible nectar; leaves to flavour fish, turtle
Morinda citrifolia	**Rotten Cheese Fruit**	fruit eaten raw, medicinal value
Nauclea orientalis	**Leichardt Tree**	edible fruit, but not well liked
Nelumbo nucifera	**Red Lily**; **Lotus**	edible seeds
Nymphaea violacea	**Waterlily**	flower-stem eaten after peeling, tubers roasted, seeds eaten raw or cooked
Smilax australis	**Native Grape**	edible berry or 'grape'
Syzygium armstrongii	**White River Cherry**	fruit edible raw
Syzygium eucalyptoides bleeseri	**White Apple**	fruit edible raw
Syzygium suborbiculare	**Red Apple**; **Lady Apple**	fruit edible raw
Vitex glabrata	**Black Plum**; **Mulama**	ripe fruit edible raw

APPENDIX 3 TABLE OF NON-FLORISTIC INDIGENOUS BUSH FOODS IN THE FINNISS RIVER RIPARIAN ZONE

Aquatic Vertebrates

Aquatic Vertebrate	Use
1: Turtle	Frequent mention was made of the use of "turtle" or freshwater tortoise, primarily for food, but also as a totem animal and in ceremony. The long-neck species (*Chelodina rugosa)* was collected during the dry season, dug up from the mud when in a state of aestivation. The short-neck species (*Emydura* spp) were caught in billabongs by fishing or by actively searching shallow waters and areas beneath floating grass.
2: Water python	Two forms were mentioned: the 'Yellow Belly' water python, presumably *Liasis fuscus*, and the 'Plain' one presumably Olive python or *Liasis olivaceus*.
3: File snake	The Arafura file snake (*Acrochordus arafurae*) is usually caught by hand in shallow water but may be speared.
4: Water snake	Smaller snake, in and around water. No specifics given, possibly the Keelback (*Tropidonophis mairii*).
5: Water rat	The Water rat (*Hydromys chrysogaster*) is hunted for food - no details given of capture method or preparation.
6: Magpie goose	Adult birds (*Anseranas semipalmata*) and eggs utilised for food - adults acquired by shooting.
7: Other waterfowl	Ducks, pygmy geese, etc. (various spp.). - acquired by shooting.
8: Crocodile	Inferred from discussion that use of crocodilians (*Crocodylus porosus* and *C. johnstoni*) as food is infrequent and opportunity based. Not actively sought by the groups in discussion. Important for totem and ceremony.

Other vertebrate species mentioned as important riverine food sources were antilopine wallaroo (*Macropus antilopinus*), Agile wallaby (*Macropus agilis agilis*) and emu (*Dromaius novaehollandiae)* drinking at the river. as well as feral pigs (*Sus scrofa*) in the riparian environment. Flying fox (*Pteropus alecto* and *P. scapulatus)* collected as a food item was also seen as riverine in context.

Aquatic Invertebrates

Aquatic Invertebrate	Use
1: Mussels (*Velesunio angasi*)	These are collected and eaten along the Finniss, its tributaries and billabongs and in Rum Jungle Creek South pit.
2: Redclaw (*Cherax quadricarinatus*)	Important food item - taken in traps (pots) or speared at night.
3: Cherabin or freshwater prawn (*Macrobrachium rosenbergii*)	Trapped (potted) or caught amongst paperbark roots and weedbeds.
4: Other Freshwater prawns (*Macrobrachium australiense*)	Utilised for food - mainly trapped (potted).
5: Freshwater crab	Unspecified *Austrothelphusa* sp. - these are gathered when available and roasted or boiled to eat or make a soup. No capture details given.

Several other invertebrate species utilised as food were seen as riverine in context, such as green ant and a 'witchetti grub' of unknown species from rotten logs in monsoon forest.

APPENDIX 4 TABLE OF NOMINATED INDIGENOUS PLANT USE, OTHER THAN FOOD IN THE FINNISS RIVER RIPARIAN ZONE

Species	Common Name	Use
Nauclea orientalis	**Leichhardt Tree**	'bum fodder' (toilet paper), bush medicine (fruit)
Ampelocissus acetosa	**Native Grape**	'bum fodder' (toilet paper), dye
Barringtonia acutangula	**Freshwater Mangrove, Itchy Tree**	fish poison
Acacia auriculiformis	**Black Wattle**	fish poison, timber for tools, weapons, soap
Alphitonia excelsa	**Soap Tree, Red Ash**	Soap, crushed leaves, bark etc. are medicinal
Calophyllum sil	**Beauty Leaf**	timber for spear shafts
Melaleuca leucadendra	**White Paperbark**	sheet bark for roofing, wrapping food
Melaleuca viridiflora	**Broad-leaved Paperbark**	sheet bark for wrapping food
Canarium australianum	**Cedar**	timber for dugout canoes
Flueggea virosa	**White Currant**	fibre for bush string
Smilax australis	**Native Grape**	dye for basket weaving, fabrics, medicinal
Corymbia spp.	**Bloodwood**	ash for bush medicines
Morinda citrifolia	**Rotten Cheese Fruit**	fruit is medicinal for sore throat, coughs etc

APPENDIX 5 SUMMARY OF TERRESTRIAL VERTEBRATE SPECIES THAT OCCUR WITHIN THE SEARCH AREA AND THEIR CURRENT STATUS.

BIRDS

Species	Common name	Aquatic	TPWC*	EPBC*
Acanthizidae				
Gerygone albogularis	White-throated Gerygone		LC	
Gerygone chloronota	Green-backed Gerygone		LC	
Gerygone magnirostris	Large-billed Gerygone		LC	
Smicrornis brevirostris	Weebill		LC	
Accipitridae				
Accipiter cirrocephalus	Collared Sparrowhawk		LC	
Accipiter fasciatus	Brown Goshawk		LC	
Accipiter novaehollandiae	Grey Goshawk		LC	
Aquila audax	Wedge-tailed Eagle		LC	
Aviceda subcristata	Pacific Baza		LC	
Erythrotriorchis radiatus	Red Goshawk		VU	VU
Haliaeetus leucogaster	White-bellied Sea-eagle	Yes	LC	
Haliastur sphenurus	Whistling Kite		LC	
Hamirostra melanosternon	Black-breasted Buzzard		LC	
Hieraaetus morphnoides	Little Eagle		LC	
Lophoictinia isura	Square-tailed Kite		NT	
Milvus migrans	Black Kite		LC	
Aegothelidae				
Aegotheles cristatus	Australian Owlet-nightjar		LC	
Alcedinidae				
Ceyx azureus	Azure Kingfisher	Yes	LC	
Ceyx pusilla	Little Kingfisher	Yes	LC	
Anatidae				
Dendrocygna arcuata	Wandering Whistling-duck	Yes	LC	
Dendrocygna eytoni	Plumed Whistling-duck	Yes	LC	
Nettapus pulchellus	Green Pygmy Goose	Yes	LC	
Tadorna radjah	Radjah Shelduck	Yes	LC	
Anhingidae				
Anhinga novaehollandiae	Australasian Darter	Yes	LC	
Anseranatidae				
Anseranas semipalmata	Magpie Goose	Yes	LC	
Apodidae				
Apus pacificus	Fork-tailed Swift		LC	

Species	Common name	Aquatic	TPWC*	EPBC*
Ardeidae				
Ardea ibis	Cattle Egret	Yes	LC	
Ardea intermedia	Intermediate Egret	Yes	LC	
Ardea modesta	Eastern Great Egret	Yes	LC	
Ardea pacifica	White-necked Heron	Yes	LC	
Ardea sumatrana	Great-billed Heron	Yes	LC	
Ardeidae				
Butorides striata	Striated Heron	Yes	LC	
Egretta novaehollandiae	White-faced Heron	Yes	LC	
Ixobrychus flavicollis	Black Bittern	Yes	DD	
Nycticorax caledonicus	Nankeen Night Heron	Yes	LC	
Artamidae				
Artamus cinereus	Black-faced Woodswallow		LC	
Artamus leucorynchus	White-breasted Woodswallow		LC	
Artamus minor	Little Woodswallow		LC	
Cracticus nigrogularis	Pied Butcherbird		LC	
Cracticus tibicen	Australian Magpie		LC	
Cracticus torquatus	Grey Butcherbird		LC	
Burhinidae				
Burhinus grallarius	Bush Stone-curlew		NT	
Cacatuidae				
Cacatua galerita	Sulphur-crested Cockatoo		LC	
Cacatua sanguinea	Little Corella		LC	
Calyptorhynchus banksii	Red-tailed Black-cockatoo		LC	
Eulophus roseicapilla	Galah		LC	
Nymphicus hollandicus	Cockatiel		LC	
Campephagidae				
Coracina novaehollandiae	Black-faced Cuckoo-shrike		LC	
Coracina papuensis	White-bellied Cuckoo-shrike		LC	
Coracina tenuirostris	Cicadabird		LC	
Lalage leucomela	Varied Triller		LC	
Lalage sueurii	White-winged Triller		LC	
Caprimulgidae				
Caprimulgus macrurus	Large-tailed Nightjar		LC	
Casuariidae				
Dromaius novaehollandiae	Emu		VU	
Charadriidae				
Vanellus miles	Masked Lapwing		LC	
Ciconiidae				
Ephippiorhynchus asiaticus	Black-necked Stork		LC	

Species	Common name	Aquatic	TPWC*	EPBC*
Cisticolidae				
Cisticola exilis	Golden-headed Cisticola		LC	
Climacteridae				
Climacteris melanura	Black-tailed Treecreeper		LC	
Columbidae				
Chalcophaps indica	Emerald Dove		LC	
Ducula bicolor	Pied Imperial-pigeon		LC	
Geopelia cuneata	Diamond Dove		LC	
Geopelia humeralis	Bar-shouldered Dove		LC	
Geopelia striata	Peaceful Dove		LC	
Geophaps smithii	Partridge Pigeon		VU	VU
Petrophassa rufipennis	Chestnut-quilled Rock-pigeon		NT	
Phaps chalcoptera	Common Bronzewing		LC	
Ptilinopus regina	Rose-crowned Fruit-dove		LC	
Coraciidae				
Eurystomus orientalis	Dollarbird		LC	
Corvidae				
Corvus orru	Torresian Crow		LC	
Cuculidae				
Cacomantis pallidus	Pallid Cuckoo		LC	
Cacomantis variolosus	Brush Cuckoo		LC	
Centropus phasianinus	Pheasant Coucal		LC	
Chalcites basalis	Horsfield's Bronze-cuckoo		LC	
Chalcites minutillus	Little Bronze-cuckoo		LC	
Eudynamys orientalis	Eastern Koel		LC	
Dicruridae				
Dicrurus bracteatus	Spangled Drongo		LC	
Estrildidae				
Erythrura gouldiae	Gouldian Finch		EN	EN
Lonchura castaneothorax	Chestnut-breasted Mannikin		LC	
Neochmia phaeton	Crimson Finch		LC	
Poephila acuticauda	Long-tailed Finch		LC	
Poephila personata	Masked Finch		LC	
Taeniopygia bichenovii	Double-barred Finch		LC	
Eurostopdidae				
Eurostopodus argus	Spotted Nightjar		LC	
Falconidae				
Falco berigora	Brown Falcon		LC	
Falco cenchroides	Nankeen Kestrel		LC	
Halcyonidae				

Species	Common name	Aquatic	TPWC*	EPBC*
Dacelo leachii	Blue-winged Kookaburra		DD	
Todiramphus macleayii	Forest Kingfisher	Yes	LC	
Todiramphus sanctus	Sacred Kingfisher	Yes	LC	
Hirundinidae				
Petrochelidon nigricans	Tree Martin		LC	
Jacanidae				
Irediparra gallinacea	Comb-crested Jacana		LC	
Maluridae				
Malurus melanocephalus	Red-backed Fairy-wren		LC	
Megaluridae				
Megalurus timoriensis	Tawny Grassbird		LC	
Megapodiidae				
Megapodius reinwardt	Orange-footed Scrubfowl		LC	
Meliphagidae				
Cissomela pectoralis	Banded Honeyeater		LC	
Conopophila albogularis	Rufous-banded Honeyeater		LC	
Conopophila rufogularis	Rufous-throated Honeyeater		LC	
Entomyzon cyanotis	Blue-faced Honeyeater		LC	
Lichenostomus unicolor	White-gaped Honeyeater		LC	
Lichmera indistincta	Brown Honeyeater		LC	
Manorina flavigula	Yellow-throated Miner		LC	
Melithreptus albogularis	White-throated Honeyeater		LC	
Myzomela erythrocephala	Red-headed Honeyeater		LC	
Myzomela obscura	Dusky Honeyeater		LC	
Philemon argenticeps	Silver-crowned Friarbird		LC	
Philemon citreogularis	Little Friarbird		LC	
Ramsayornis fasciatus	Bar-breasted Honeyeater		LC	
Meropidae				
Merops ornatus	Rainbow Bee-eater		LC	
Monarchidae				
Grallina cyanoleuca	Magpie-lark		LC	
Myiagra alecto	Shining Flycatcher		LC	
Myiagra inquieta	Restless Flycatcher		LC	
Myiagra rubecula	Leaden Flycatcher		LC	
Nectariniidae				
Dicaeum hirundinaceum	Mistletoebird		LC	
Oriolidae				
Oriolus flavocinctus	Yellow Oriole		LC	
Oriolus sagittatus	Olive-backed Oriole		LC	
Sphecotheres vieilloti	Australasian Figbird		LC	

Species	Common name	Aquatic	TPWC*	EPBC*
Pachycephalidae				
Colluricincla harmonica	Grey Shrike-thrush		LC	
Colluricincla megarhyncha	Little Shrike-thrush		LC	
Pachycephala rufiventris	Rufous Whistler		LC	
Pachycephala simplex	Grey Whistler		LC	
Pardalotidae				
Pardalotus striatus	Striated Pardalote		LC	
Pelecanidae				
Pelecanus conspicillatus	Australian Pelican	Yes	LC	
Petroicidae				
Microeca flavigaster	Lemon-bellied Flycatcher		LC	
Phalacrocoracidae				
Microcarbo melanoleucos	Little Pied Cormorant	Yes	LC	
Phalacrocorax sulcirostris	Little Black Cormorant	Yes	LC	
Phalacrocorax varius	Pied Cormorant	Yes	LC	
Phasianidae				
Coturnix ypsilophora	Brown Quail		LC	
Pittidae				
Pitta iris	Rainbow Pitta		LC	
Podargidae				
Podargus strigoides	Tawny Frogmouth		LC	
Pomatostomidae				
Pomatostomus temporalis	Grey-crowned Babbler		LC	
Psittacidae				
Aprosmictus erythropterus	Red-winged Parrot		LC	
Platycercus venustus	Northern Rosella		LC	
Psitteuteles versicolor	Varied Lorikeet		LC	
Trichoglossus haematodus	Rainbow Lorikeet		LC	
Ptilonorhynchidae				
Ptilonorhynchus nuchalis	Great Bowerbird		LC	
Rhipiduridae				
Rhipidura dryas	Arafura Fantail		LC	
Rhipidura leucophrys	Willie Wagtail		LC	
Rhipidura rufiventris	Northern Fantail		LC	
Strigidae				
Ninox connivens	Barking Owl		LC	
Ninox novaeseelandiae	Southern Boobook		LC	
Ninox rufa	Rufous Owl		LC	
Threskiornithidae				
Plegadis falcinellus	Glossy Ibis		LC	

Species	Common name	Aquatic	TPWC*	EPBC*
Threskiornis molucca	Australian White Ibis		LC	
Threskiornis spinicollis	Straw-necked Ibis		LC	
Tytonidae				
Tyto javanica	Eastern Barn Owl		LC	
Tyto novaehollandiae kimberli	Masked Owl (North Australia)		VU	VU

* Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (ED), Critically Endangered (CR) and Introduced (Int).

FROGS

Species	Common name	Aquatic	TPWC*	EPBC*
Bufonidae				
Rhinella marina	Cane Toad	Yes	(Int)	
Hylidae				
Litoria australis	Giant Frog	Yes	DD	
Litoria bicolor	Northern Dwarf Tree-frog	Yes	DD	
Litoria caerulea	Green Tree-frog	Yes	LC	
Litoria inermis	Peters' Frog	Yes	LC	
Litoria nasuta	Rocket Frog	Yes	LC	
Litoria pallida	Pale Frog	Yes	LC	
Litoria rothii	Roth's Tree-frog	Yes	LC	
Litoria rubella	Red Tree-frog	Yes	LC	
Litoria tornieri	Tornier's Frog	Yes	LC	
Limnodynastidae				
Limnodynastes convexiusculus	Marbled Frog	Yes	LC	
Platyplectrum ornatus	Ornate Burrowing Frog	Yes	DD	
Microhylidae				
Austrochaperina adelphe	Northern Territory Frog	Yes	LC	
Myobatrachidae				
Uperoleia inundata	Floodplain Toadlet	Yes	LC	

* Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (ED), Critically Endangered (CR) and Introduced (Int).

MAMMALS

Species	Common name	Aquatic	TPWC*	EPBC*
Dasyuridae				
Antechinus bellus	Fawn Antechinus		DD	
Dasyurus hallucatus	Northern Quoll		CR	EN
Phascogale pirata	Northern brush-tailed Phascogale		VU	
Sminthopsis virginiae	Red-cheeked Dunnart		DD	
Emballonuridae				

Species	Common name	Aquatic	TPWC*	EPBC*
Saccolaimus flaviventris	Yellow-bellied Sheath-tailed Bat		LC	
Taphozous kapalgensis	Arnhem Sheath-tailed Bat		NT	
Leporidae				
Oryctolagus cuniculus	Rabbit		(Int)	
Macropodidae				
Macropus agilis	Agile Wallaby		LC	
Macropus antilopinus	Antilopine Wallaroo		LC	
Muridae				
Melomys burtoni	Grassland Melomys		LC	
Mesembriomys gouldii	Black-footed Tree-rat		VU	
Pseudomys calabyi	Kakadu Pebble-mouse		NT	
Pseudomys nanus	Western Chestnut Mouse		NT	
Rattus tunneyi	Pale Field Rat		NT	
Peramelidae				
Isoodon macrourus	Northern Brown Bandicoot		LC	
Phalangeridae				
Trichosurus vulpecula, arnhemensis	Common Brushtail Possum (Top End)		LC	
Pteropodidae				
Pteropus scapulatus	Little Red Flying-fox		LC	
Tachyglossidae				
Tachyglossus aculeatus	Echidna		LC	
Vespertilionidae				
Pipistrellus adamsi	Forest Pipistrelle		LC	

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REPTILES

Species	Common name	Aquatic	TPWC*	EPBC*
Agamidae				
Chlamydosaurus kingii	Frilled/Frill-necked Lizard		LC	
Diporiphora bilineata	Two-Lined Dragon		LC	
Acrochordidae				
Acrochodrus arafurae	Arafura File-snake	Yes	LC	
Agamidae				
Diporiphora magna			LC	
Chelidae				
Chelodina rugosa	Northern Snake-necked Turtle	Yes	LC	
Elseya dentata	Northern Snapping Turtle	Yes	LC	
Emydura tanybaraga	Northern Yellow-faced Turtle	Yes	LC	

Species	Common name	Aquatic	TPWC*	EPBC*
Crocodylidae				
Crocodylus johnstoni	Freshwater Crocodile	Yes	LC	
Crocodylus porosus	Saltwater Crocodile	Yes	LC	
Elapidae				
Acanthophis praelongus	Northern Death Adder		NT	
Brachyurophis roperi	Northern Shovel-nosed Snake		(NL)	
Cryptophis pallidiceps	Northern Small-eyed Snake		DD	
Pseudechis australis	Mulga Snake		NT	
Gekkonidae				
Gehyra australis	Northern Dtella		LC	
Gehyra nana	Northern Spotted Rock Dtella		LC	
Hemidactylus frenatus	Asian House Gecko		(Int)	
Heteronotia binoei	Bynoe's Gecko		LC	
Oedura rhombifer	Zig-zag Gecko		LC	
Pygopodidae				
Lialis burtonis	Burton's Legless Lizard		LC	
Pythonidae				
Liasis fuscus	Water Python	Yes	LC	
Liasis olivaceus	Olive Python		LC	
Scincidae				
Carlia amax	Two-spined Rainbow Skink		LC	
Carlia gracilis	Slender Rainbow Skink		LC	
Carlia munda	Striped Rainbow Skink			
Carlia rufilatus	Red-sided Rainbow Skink		LC	
Cryptoblepharus plagiocephalus	Arboreal Snake-eyed Skink		LC	
Ctenotus essingtonii	Port Essington Ctenotus		LC	
Ctenotus hilli	Hill's Ctenotus		LC	
Ctenotus inornatus	Plain Ctenotus		LC	
Glaphyromorphus darwiniensis	Darwin Skink		LC	
Glaphyromorphus douglasi	Douglas' Skink		LC	
Morethia ruficauda	Red-tailed Snake-eyed Skink		LC	
Tiliqua scincoides	Common Blue-tongued/Blue Tongue Lizard		DD	
Varanidae				
Varanus mertensi	Merten's Water Monitor	Yes	VU	
Varanus panoptes	Floodplain Monitor	Yes	VU	

* Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (ED), Critically Endangered (CR) and Introduced (Int).