SECTION 3.1
PHYSICAL ENVIRONMENT
3.1 Physical Environment

3.1.1 Weather and Climate

The Northern Territory has two distinct climate zones: the Red Centre and the Tropical Top End. Central Australia has quite low humidity with tropical rains unable to reach the south. The climate of the Project area can be categorised as a semi-arid desert environment with dry, hot summers and short, dry winters. Rainfall occurs predominantly during the summer months of November to April. The warmer months of October through to March have mean daily maximum temperatures over 33°C. Maximum average monthly temperatures are 38.4°C in January (Australian Government Bureau of Meteorology, 2018). The coolest months are June to September with mean minimum temperatures below 8°C. The minimum average monthly temperature in July is 5.4 °C (Australian Government Bureau of Meteorology, 2018). Relative humidity averages at 27.8% in the summer months and 38.5% during the winter months (Australian Government Bureau of Meteorology, 2018).

Table 3.1-1 provides a summary of temperature and humidity climatic data recorded at the Jervois Station, Alice Springs station (015540) and Ringwood station (015546).

<table>
<thead>
<tr>
<th>Location</th>
<th>Temperature (°C)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Minimal Temperature</td>
<td>Mean Maximum Temperature</td>
</tr>
<tr>
<td>Jervois Station (015602)</td>
<td>14.7</td>
<td>31.0</td>
</tr>
<tr>
<td>Ringwood Station (015540)</td>
<td>12.9</td>
<td>29.4</td>
</tr>
<tr>
<td>Alice Springs (015540)</td>
<td>12.8</td>
<td>28.6</td>
</tr>
</tbody>
</table>

Source: Bureau of Meteorology, Jervois (015602), Alice Springs (015540), Ringwood (015546) (BOM, 2018).

Rainfall records measured at Jervois Station since 1966 show a mean annual rainfall of 295.4 mm. Annual rainfall varies widely, with a range of 95.8 mm (2013) to 933.4 mm (2010) (Australian Government Bureau of Meteorology, 2018). Long-term rainfall trends show a pattern characteristic of the northern Australian arid zone, whereby long dry periods (rainfall around or below the annual average) are interrupted by short, large magnitude rainfall events lasting approximately 12 to 15 months. Most rainfall occurs between November and April, when flooding can occur following storm events (Low Ecological Services, 2018). Seasonal flooding can occur from river flows from Arthur Creek and the Georgina Basin. Table 3.1-2 shows the annual mean rainfall and mean number of rain days at the Jervois Station, Alice Springs station (015540) and Ringwood station (015546) located 245.0km and 155km from the Jervois Station.
### Table 3.1-2 Rainfall

<table>
<thead>
<tr>
<th>Location</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Mean rainfall (mm)</td>
</tr>
<tr>
<td>Jervois Station (015602)</td>
<td>290.8</td>
</tr>
<tr>
<td>Ringwood Station (015540)</td>
<td>302.6</td>
</tr>
<tr>
<td>Alice Springs (015540)</td>
<td>278.0</td>
</tr>
</tbody>
</table>

Source: Bureau of Meteorology, Jervois (015602), Alice Springs (015540), Ringwood (015546) (BOM, 2018).

The predominant wind direction is east and south-east although during storms and rainfall periods, the winds are predominantly from the west (Australian Government Bureau of Meteorology, 2018). The collected information for each station indicates that the wind speeds for 9am and 3pm local time are very similar and that the prevailing wind directions are predominantly toward the South West. The annual wind speeds of the Jervois, Rosewood and Alice Springs weather stations are summarised in Table 3.1-3. Wind roses for each weather station are also illustrated in Appendix C-3.

### Table 3.1-1 Wind speed and direction

<table>
<thead>
<tr>
<th>Location</th>
<th>Wind Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 9am wind speed (km/h)</td>
</tr>
<tr>
<td>Jervois Station (015602)</td>
<td>12.7</td>
</tr>
<tr>
<td>Ringwood Station (015540)</td>
<td>12.5</td>
</tr>
<tr>
<td>Alice Springs (015540)</td>
<td>10.9</td>
</tr>
</tbody>
</table>

Source: Bureau of Meteorology, Jervois (015602), Alice Springs (015540), Ringwood (015546) (BOM, 2018).

The Jervois Project lies within the Alice Springs Fire Management Zone. Vegetation in the Project area is predominantly sparse acacia shrubland with hummock grassland understorey. Fire occurs infrequently in the region, though a higher fire risk exists in years following seasons of good rains as vegetation growth increases available fuel loads. It is during these periods that an increased chance of large wildfire exists and corresponding risk to personnel and infrastructure within the Project area (SLR Consulting Australia, 2018). The Project area has had minimal bushfire impacts with one small isolated fire located at the Jervois Dam in 2011 (Low Ecological, 2017).

### Table 3.1-2 Fire History

<table>
<thead>
<tr>
<th>Year</th>
<th>Area sq km</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-2000</td>
<td>237.29</td>
<td>30.09</td>
</tr>
<tr>
<td>2001</td>
<td>40.33</td>
<td>5.11</td>
</tr>
<tr>
<td>2002</td>
<td>151.05</td>
<td>19.16</td>
</tr>
<tr>
<td>2011</td>
<td>267.22</td>
<td>33.89</td>
</tr>
<tr>
<td>2012</td>
<td>80.13</td>
<td>10.16</td>
</tr>
<tr>
<td>2017</td>
<td>12.54</td>
<td>1.59</td>
</tr>
</tbody>
</table>

3.1.2. Regional Topography and Geomorphology

Geomorphology is the study of the physical features of the surface of the earth and their relation to its geological structures. This section discusses the influence the underlying geology has on the region and Project area in terms of topography, land units and soils. The characteristics of water courses, which are also influenced by geology, are discussed in Section 3.7 Surface Water.

3.1.2.1. Regional

The Jervois Project area occurs within the Channel Country bioregion. This region extends across the Georgina Basin into Queensland and is characterised by red earths and shallow sandy soils over Cambrian sedimentary rocks. The region is typified by plains and low, rolling hills and braided river systems. Higher relief is provided by isolated ranges such as the Jervois and Toko Ranges (Baker et al, 2005).

The Alice Springs area has three land systems which can be described as Sonder land system, Bond Springs Land System and the Unca Land System (refer Section 3.6.1). The Sonder land system is identified as partially dissected, weather land surface, erosional containing partially beveled strike ranges, narrow strike valleys and transverse gorges. The Bond Springs land system is an erosional weathered surface within a hilly country with some narrow plains. The Unca land system is a lightly dissected peneplain, high surface erodibility and sandy valleys with open branching patterns.

The Jervois Range is approximately 250 m in height and composed of pre-Cambrian gneiss and schists, separating Central Australia from the plains to the east. The Jervois range runs through the northeast edge of the Project creating a drainage divide. This range is represented by the geology map unit p-Co and comprising the Bonya Schist formation Figure 3.1-1.

3.1.2.2. Local

The Project area is on the south-eastern ridge of the Jervois Range with bold sandstone ranges of the Sonder land system meeting the Bond Springs undulating plains and extending to the gently undulating, stony plains of the Unca land system (Low Ecological, 2017). The proposed mining activity is focused along the range of low hills and rises running approximately north to south through the middle of the Jervois Project area.

Across the undulating plains that dominate the Project area, scattered shear-sided, narrow and shallow gullies have been observed (VPS 2018). These gullies, which are likely to be the result of the long history of both cattle grazing and mining across the Project area, are considered reasonably stable at present as the floors of many of these gullies are grassed.

Several ephemeral gullies and deeply etched creeks drain into the area from the Jervois Range contributing to the Plenty and Marshall Rivers, which flow into the Georgina Basin. Arthur creek provides the main drainage from north and west of the Jervois Range, which also drains into the Georgina Basin (Lindsay-Park, 2005). No evidence of sedimentation of the natural streams and drainage lines was observed during detailed site assessments undertaken for the EIS.
Figure 3.1-1 Percent slope across Jervois Project area
3.1.3. Regional Geology

3.1.3.1. Regional Geology

The Jervois Range lies within the eastern part of the Arunta Region, which forms part of the North Australian Craton. To the north is the Georgina Basin, the largest of the intracratonic Neoproterozoic-Palaeozoic basins formed on the North Australian Craton. Sedimentary rocks of the Georgina Basin are typically unmetamorphosed and have a generally flat-lying, angular unconformity contact with the underlying basement (Greene 2010 in Reno 2013).

The Jervois Range area is dominated by polymetamorphic and polydeformed basement rocks of the Arunta Region. The Arunta Region extends over an area of approximately 200,000 km² and has a complex stratigraphic, structural and metamorphic history spanning the Palaeoproterozoic through to the Palaeozoic. The Arunta Region can be subdivided into three geological provinces: Aileron, Warumpi (not present in Jervois Range) and Irindina, each with distinct protolith (original, unmetamorphosed rock) ages and stratigraphic and tectonic evolution. The Aileron Province in Jervois Range is overlain in part by the Georgina Basin.

Metasedimentary successions in the Aileron Province are believed to have been deposited within the interval 1860-1740 Ma and the majority of the magmatism occurred in the interval 1820-1700 Ma (Scrimgeour 2013. The Aileron Province experienced three major tectonometamorphic and magmatic events in the Palaeoproterozoic: the Stafford Event; the Yambah Event; and the Strangways Event. The Strangways Event is restricted to the eastern and south-eastern Aileron Province. Multiple structural events, stages of metamorphism and pulses of magmatism are interpreted to have occurred during the Strangways Event (Scrimgeour 2013a in Reno 2013).

The oldest known unit exposed in Jervois Range is the Bonya Metamorphics. The Bonya Metamorphics is a high-temperature, low-pressure package of metasedimentary rocks with protoliths interpreted to be equivalent to the lower Strangways Metamorphic Complex (Reno 2015). The Bonya Metamorphics is unconformably overlain by Neoproterozoic sediments of the Georgina Basin that forms a prominent ridge on the western edge of the Project area (Figure 3.1-2). The Bonya Metamorphics (formerly “Bonya Schist”) crop out extensively in the Bonya Hills in western Jervois Range and in the vicinity of the Jervois Mine area (Figure 3.1-3).
Figure 3.1-2 Simplified regional surface geological map derived from 1:250000 sheet
Table 3.1-3 Geological units identified in Figure 3.1-2

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Lithology</th>
<th>Symbol</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>A10</td>
<td>Harts Range Group: Migmatitic metapelite, metabasite, gneiss, calc-silicate, marble, quartzite</td>
<td>D</td>
<td>Dulcie Sandstone: Sandstone, shale</td>
</tr>
<tr>
<td>A5</td>
<td>Cackleberry, Deep Bore Metamorphics, Mascotte Gneiss Complex Bonya Metamorphics Parenti Metamorphics: Felsic and mafic gneiss, metavolcanics, metapelitie</td>
<td>Pd</td>
<td>Gabbro, dolerite and other basic intrusive rocks.</td>
</tr>
<tr>
<td>-C1</td>
<td>Mount Baldwin to Arthur Creek Formation: Sandstone, conglomerate</td>
<td>Pg</td>
<td>Granite.</td>
</tr>
<tr>
<td>-C2</td>
<td>Limestone, shale</td>
<td>K</td>
<td>-</td>
</tr>
<tr>
<td>-C3</td>
<td>Arrinthrunga Formation to Nora Formation: Dolostone, limestone, sandstone</td>
<td>O</td>
<td>Toko Group: Sandstone, shale, dolostone</td>
</tr>
<tr>
<td>-CO</td>
<td>Sandstone, shale, dolostone</td>
<td>-Pa</td>
<td>Elkera Formation: Sandstone, dolostone, limestone, diamicrite</td>
</tr>
<tr>
<td>Cz</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Geological Structures**

The region has experienced a long and complex structural history and detailed structural mapping has revealed three major deformational events in the Jervois area. Bennett (2015) has described three main deformational events that have occurred in the Project and surrounding areas (Bennett, 2015). These include:

- **D1** – Large westward closing recumbent fold
- **D2** – foliation is sub-parallel to bedding and formed in an east-west, isoclinal folding due to repetitions of the mineralised horizons across the strike

At the Project area, sediments of the Lower Proterozoic Bonya Schist Formation have been strongly deformed and display a well-developed foliation. The sediments have been folded to form a J-shaped, near isoclinal and steeply north-plunging, synform (Figure 3.1-8). The more resistant lithologies crop out as a series of hills that prominently define the J-structure on aerial photographs and satellite images. This distinctive J-shape of the Bonya Schist outcrop in the Project area has been interpreted as the result of re-folding of pre-existing folds and also as a drag feature to a regional fault that lies to the west.

There are a series of faults in the region, with the three closest to the site are the Jervois Fault, the Bonya Fault and the Lucy Creek Fault (Figure 3.1-5 and Figure 3.1-6)
Jervois Fault Zone
The Jervois Fault is located to the north of the Jervois Mine site and represents a major break in the basement rocks across a NNE extension of the Bonya Fault. The fault coincides with the eastern limit of the sedimentary rocks of the Georgina Basin to the NW of the Jervois Mine. Further northwards the extension of the Jervois Fault may be represented by a line of disruption within the sedimentary rocks in the Jervois Range.

Bonya Fault
The Bonya Fault is located to the west of the Jervois Mine and separates the Bonya Metamorphics to the SW and the Cambrian sediments of the Georgina Basin to the NE.

Lucy Creek / Mount Playford Fault Zone
The Lucy Creek and Mount Playford faults are related northwest-striking, steeply west-dipping, west-side-up reverse faults extending into and displacing the sediments of the Georgina Basin near Lucy Creek homestead. The Lucy Creek Fault is greater than 75 km in length and has had a minimum vertical displacement of about 700 m, with an actual displacement possibly exceeding 1000 m (Greene, 2010). The shorter Mount Playford Fault appears to curve into and terminate against the Lucy Creek Fault in a ‘J-hook’ relationship (Kruse, Dunster, & Munson, 2013).

Figure 3.1-3 Geological cross-section through the study area showing the relationship between the Cambrian sediments, Bonya Metamorphics and Runta rocks. Jervois Mine offset along strike. (source: CloudGMS 2018)

3.1.3.1 Local Geology
The site lies on the eastern side of the Jervois Fault with largely crystalline rocks of the Arunta Orogenic domain (schists, granites and gabbros) to the south-east of the fault and sediments of the Georgina Basin Sequence to the east and north (Figure 3.1-3).

The geology of the area has been mapped by the Bureau of Rural Sciences, 1991. The north western portions of Jervois are made up of sedimentary sandstone, limestone and conglomerate of the Jervois range, while the remaining area overlies felsic and mafic intrusives such as schist and granites. The Bonya Metamorphics (formerly “Bonya Schist”) crop out extensively in the vicinity of the Jervois mine (Figure 3.1-7). The economically prospective lithologies within the tenement are within the Bonya Metamorphics.
Bedrock over much of the area is covered by soil and shallow alluvium with outcrop restricted to the low hills (Figure 3.1-7). The calc-silicate and carbonate-rich lithologies in particular, tend to be silicified and more resistant to weathering and erosion. Rapid changes in rock types and tight isoclinal folding add to the difficulties of geological mapping and only broad correlations are possible within the Project area.

At Jervois, the Bonya Metamorphics is dominated by quartz-muscovite schist representing metamorphosed siltstone and mudstone. The schist is interbedded with fine to medium grained beds of metasandstone that typically vary from 1 cm to 30 cm but much thicker beds and lenses of metasandstone have been mapped at the surface. The Bonya Schist is interpreted to be derived from a thick sequence of argillaceous to arenaceous sediments with intercalations of limestone that suggest a shallow marine environment of deposition.

Within the fine grained schistose beds there are broad belts with distinctive cordierite and/or andalusite porphyroblasts that give the rock a knotted appearance. Beds of marble and calc-silicate rock occur throughout the Jervois Project area, but have poor strike continuity due to flattening and attenuation during deformation.

Although minor in extent, narrow beds of finely bedded quartz-tourmaline and fine to coarse grained volcanic/volcaniclastic rocks of rhyolitic composition have been mapped. The Jervois sequence has been intruded by several phases of pegmatite and an amphibolitic rock interpreted to correlate with the Attutra Metagabbro (ca 1786 Ma).
Figure 3.1-4 Surface geology of the Jervois Project Area
Table 3.1-4 Summary of geology map units of Jervois Project (NT Geological Survey data) referenced in Figure 3.1-4

<table>
<thead>
<tr>
<th>Unit</th>
<th>Rock Group</th>
<th>Unit Age</th>
<th>Unit Name</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qa</td>
<td>Sedimentary</td>
<td>Quaternary</td>
<td>Soil, silty or sandy, alluvial and aeolian; includes other Quaternary units locally</td>
<td></td>
</tr>
<tr>
<td>Qc</td>
<td>Sedimentary</td>
<td>Quaternary</td>
<td>Colluvium; scree</td>
<td></td>
</tr>
<tr>
<td>Clb</td>
<td>Sedimentary</td>
<td>Early Cambrian</td>
<td>Mount Baldwin Formation</td>
<td>Quartz arenite, medium to coarse-grained, thin to thick-bedded, dusky red</td>
</tr>
<tr>
<td>Pak</td>
<td>Sedimentary</td>
<td>Adelaideon</td>
<td>Elkera Formation</td>
<td>Siltstone to sandstone, micaeous, laminated to thin-bedded, blue-grey to dusky red; dolostone horizons, some stromatolitic</td>
</tr>
<tr>
<td>Pag</td>
<td>Sedimentary</td>
<td>Adelaideon</td>
<td>Grant Bluff Formation</td>
<td>Quartz arenite to quartz-wacke, fine-grained, fissile and undulose-laminated; lesser coarse-grained, cross-bedded, ripple-marked, quartz arenite: grey</td>
</tr>
<tr>
<td>Pda</td>
<td>Igneous</td>
<td>Proterozoic</td>
<td>Altutra Metagabbro</td>
<td>Gabbro; dolerite; rare norite: all altered; magnetite rock</td>
</tr>
<tr>
<td>p-Co</td>
<td>Metamorphic</td>
<td>Proterozoic</td>
<td>Bonya Schist</td>
<td>Muscovite, biotite and two-mica schists, some with andalusite, sillimanite or garnet; calc-silicate rock; metapelitic and meta-acid volcanic rocks; amphibolite; skarn-like rock; magnetite quartzite; rare migmatisite</td>
</tr>
</tbody>
</table>

Mineral Resource

The economically prospective lithologies within the tenement are considered to be contained within the Bonya Metamorphics.

The style of mineralisation at Jervois remains controversial and is subject to research programs by the Northern Territory Geological Survey (NTGS) and Commonwealth Scientific and Industrial Research Organisation (CSIRO). Previous exploration companies have described the mineralisation as having affinity to iron oxide copper-gold deposits (IOCG) of the Cloncurry region, Volcanic Massive Sulphide (VHMS), Sediment-hosted Exhalative (SEDEX), Broken Hill Type and skarn. Recent work suggests that at least part of the copper-lead-zinc mineralisation is stratigraphic in nature, probably relating to the discharge of base metal-rich fluids in association with volcanism or metamorphism or dewatering of the underlying rocks at a particular time in the geological history of the area. Importantly, it occurred within a single stratigraphic horizon and is near-contemporaneous with the sediments that enclose it.

The Project consists of a series of narrow, structurally controlled, sub-vertical sulphide / magnetite-rich deposits hosted by Proterozoic-aged, amphibolite grade metamorphosed sediments of the Arunta Inlier. A total of five deposits comprise the Project, namely Marshall-Reward, Green Parrot, Bellbird including Bellbird North, Rockface, and Cox’s Find (Figure 3.1-5).
Figure 3.1-5 Interpreted bedrock geology and mineral resources
The base metal mineralisation at Jervois is stratabound and contained within steeply dipping lenticular bodies (lodes) of calc-silicate, garnet-chlorite-magnetite rock and garnet-magnetite quartzite, within a thick succession of spotted andalusite-cordierite schist and quartz-sericite-magnetite schist. The mineralized sequence has a strike length of some 12 km and a stratigraphic thickness up to about 600 m. Within this sequence there is a broad zonation, best demonstrated on the eastern flank of the synform. From the west the mineralized zone contains calc-silicate units with scheelite-bearing skarns, below which a group of lead, lead-copper and scheelite lodes occur together with several marble beds. Stratigraphically below and to the east is a unit of quartz-magnetite-garnet schist containing the main copper lodes. Farther east, there are at least three other zones containing copper lodes in quartz-magnetite-garnet rock and less commonly copper-bearing skarns.

Lead-silver (zinc-copper) sulphide mineralisation (e.g. Green Parrot deposit) is typically hosted in the calc-silicate rock types, whereas the copper mineralisation (e.g. Bellbird deposit) is best developed in the garnet-chlorite-magnetite quartzite unit. Where exposed at the surface, the mineralisation is represented by siliceous gossans with boxworks after the sulphides and by the widespread development of secondary copper minerals. The dominant primary mineral phases are chalcopyrite, galena, sphalerite, bornite and pyrite. A copper-gold-silver mineral association has been reported from deep drill intersections in the Marshall / Reward deposit, copper-gold mineralisation occurs at Bellbird and lead-silver-gold mineralisation is present at Green Parrot. The main gangue mineral assemblage to magnetite and sulphide mineralisation is chlorite, quartz and white mica with subordinate biotite and carbonate.

Small pegmatite intrusions, quartz veins and amphibolite bodies (possibly mafic intrusions) are not common but locally disrupt the lodes. Core from several diamond drill holes in the Marshall /Reward deposit showed evidence of brecciation of the lode with remobilized and recrystallized sulphides infilling fractures. Two cross-cutting faults displace the mineralisation at the Marshall /Reward deposit.

The internal geometry of the Reward, Marshall, and Green Parrot lodes is complex and imperfectly understood. Contacts are generally gradational and correlation of individual intercepts between drill holes is often difficult. Figure 3.1-6 shows a section through the most extensively drilled Marshall /Reward deposit where a system of steeply dipping shoots can be interpreted within the relatively well defined lode structure. The limits of the shoots are defined by 1.0 m at 1% copper cut-off boundaries. The axis of the lode plunges north.

By comparison, the geometry of the main lode at the Bellbird deposit is relatively straightforward; copper mineralisation occurs in a steeply dipping tabular body (Figure 3.1-7).
Figure 3.1-6 Marshall-Reward cross section 74946N
In May 2018, an updated Mineral resource estimate for the Project was announced. Total contained copper has increased to 384,800 tonnes. The overall copper grade has increased to 1.53% from the previous resource estimate, with a higher cut-off grade of 1%. The resource estimate for the Project, associated with the known deposits are summarised in Table 3.1-6 below.
Table 3.1-7 Jervois Resource Estimate

<table>
<thead>
<tr>
<th>Resource</th>
<th>Category</th>
<th>Mt</th>
<th>Cu%</th>
<th>Ag g/t</th>
<th>Cu/t</th>
<th>Ag Moz</th>
<th>Cu% cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall</td>
<td>Indicated</td>
<td>1.4</td>
<td>1.45</td>
<td>35.6</td>
<td>20.1</td>
<td>1.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Marshall</td>
<td>Inferred</td>
<td>0.3</td>
<td>0.9</td>
<td>20.2</td>
<td>2.6</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Reward OP</td>
<td>Indicated</td>
<td>3.3</td>
<td>1.11</td>
<td>27.7</td>
<td>37</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Reward OP</td>
<td>Inferred</td>
<td>0.4</td>
<td>1.01</td>
<td>20.5</td>
<td>3.8</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Reward UG</td>
<td>Indicated</td>
<td>0.7</td>
<td>2.68</td>
<td>43.1</td>
<td>18.3</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
<td>Reward UG</td>
<td>Inferred</td>
<td>3.6</td>
<td>1.9</td>
<td>32.8</td>
<td>67.6</td>
<td>3.8</td>
<td>1</td>
</tr>
<tr>
<td>Reward E OP</td>
<td>Indicated</td>
<td>0.5</td>
<td>0.78</td>
<td>6.6</td>
<td>3.8</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Reward E UG</td>
<td>Inferred</td>
<td>0.7</td>
<td>1.45</td>
<td>12.9</td>
<td>10.3</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>Bellbird OP</td>
<td>Indicated</td>
<td>3.9</td>
<td>1.19</td>
<td>8.6</td>
<td>46.5</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Bellbird OP</td>
<td>Inferred</td>
<td>1.3</td>
<td>0.98</td>
<td>36.5</td>
<td>13</td>
<td>1.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Bellbird UG</td>
<td>Indicated</td>
<td>0.2</td>
<td>1.84</td>
<td>12</td>
<td>3.9</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Bellbird UG</td>
<td>Inferred</td>
<td>1.9</td>
<td>2</td>
<td>12.7</td>
<td>37.6</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td>Rockface UG</td>
<td>Indicated</td>
<td>0.5</td>
<td>3.57</td>
<td>19.3</td>
<td>19.3</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>Rockface UG</td>
<td>Inferred</td>
<td>2.7</td>
<td>2.77</td>
<td>16.3</td>
<td>73.5</td>
<td>1.4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Jervois Copper 2018</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indicated</td>
<td></td>
<td>10.1</td>
<td>1.44</td>
<td>21.6</td>
<td>145.1</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Inferred</td>
<td></td>
<td>11.3</td>
<td>1.88</td>
<td>22.9</td>
<td>212.1</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>21.3</td>
<td>1.67</td>
<td>22.3</td>
<td>357.2</td>
<td>15.3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Jervois Lead/Zinc 2015</th>
<th>Category</th>
<th>Mt</th>
<th>Cu%</th>
<th>Ag g/t</th>
<th>Pb%</th>
<th>Zn%</th>
<th>Cu kt</th>
<th>Ag Moz</th>
<th>Pb kt</th>
<th>Zn kt</th>
<th>Cu% cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reward</td>
<td>Indicated</td>
<td>0.5</td>
<td>0.74</td>
<td>70.7</td>
<td>6.8</td>
<td>0.9</td>
<td>3.6</td>
<td>1.1</td>
<td>33.6</td>
<td>4.4</td>
<td>none</td>
</tr>
<tr>
<td>Lead/Zinc</td>
<td>Inferred</td>
<td>0.8</td>
<td>0.51</td>
<td>0.9</td>
<td>8.6</td>
<td>1.2</td>
<td>4.1</td>
<td>2.3</td>
<td>69.4</td>
<td>9.4</td>
<td>none</td>
</tr>
<tr>
<td>Green Parrot</td>
<td>Indicated</td>
<td>0.5</td>
<td>0.99</td>
<td>64.0</td>
<td>0.9</td>
<td>0.6</td>
<td>5.1</td>
<td>1.1</td>
<td>4.7</td>
<td>3.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Lead/Zinc</td>
<td>Inferred</td>
<td>1.4</td>
<td>0.81</td>
<td>78.0</td>
<td>4.8</td>
<td>0.9</td>
<td>11.1</td>
<td>3.4</td>
<td>24.4</td>
<td>12.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Bellbird North</td>
<td>Inferred</td>
<td>0.7</td>
<td>0.57</td>
<td>17.9</td>
<td>1.7</td>
<td>2.5</td>
<td>3.8</td>
<td>0.4</td>
<td>11.3</td>
<td>16.7</td>
<td>0.2</td>
</tr>
<tr>
<td>2018 lead Zinc Resource</td>
<td>Indicated</td>
<td>1.0</td>
<td>0.87</td>
<td>67.3</td>
<td>3.8</td>
<td>0.8</td>
<td>8.7</td>
<td>2.2</td>
<td>38.3</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Inferred</td>
<td></td>
<td>2.8</td>
<td>0.67</td>
<td>67.6</td>
<td>3.7</td>
<td>1.4</td>
<td>18.9</td>
<td>6.2</td>
<td>105.1</td>
<td>38.9</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>3.8</td>
<td>0.72</td>
<td>67.5</td>
<td>3.7</td>
<td>1.2</td>
<td>27.7</td>
<td>8.3</td>
<td>143.4</td>
<td>46.5</td>
<td></td>
</tr>
</tbody>
</table>

3.1.3.4 Seismic stability

The Northern Territory has two distinct sources of earthquakes: local intraplate earthquakes and large, tsunamigenic earthquakes on the nearby plate boundary to the north. As the Project is a considerable distance from the coast, it is the intraplate earthquakes that are most relevant.

Large intraplate earthquakes, magnitude 6 or more, occurred near the NT/SA border, in 1941 and 1986, near the NT/WA border in 1970 and at Tennant Creek in 1988. The largest known earthquakes in the Territory were in a remarkable sequence near Tennant Creek that included three large earthquakes of magnitude 6.3, 6.4 and 6.7 in a twelve-hour period on 22nd January 1988. Thousands of aftershocks have since been recorded, and whilst the rate has decreased it has not yet, returned to its pre-1987 level which was just about zero for the previous 20 years apart from a nearly year-long precursory sequence of earthquakes that initiated in January 1987 (McCue, 1993).

Figure 3.1-8 (left) shows the recorded earthquakes of magnitude 3 or more in the Northern Territory between 1901 and 2011. The Tenant Creek hotspot events are all post-1986. Figure 3.1-8 (right) is a
graphic representation of earthquake hazard. It indicates that there is negligible hazard in the vicinity of the proposed Jervois Project.

Figure 3.1-8 Left - Seismicity of the Northern Territory from the Geoscience Australia earthquake database, epicentres from 1901 to 2011, magnitude 3 and above. Right - Earthquake hazard assessed by Geoscience Australia (Burbidge, 2012) Source: (McCue, 1993)

3.1.3.4 Exploration and Mining History at the Site

The Jervois Project area has been sporadically explored by numerous companies for a variety of commodities for almost 90 years (refer Section 2.1.3).

Copper was discovered at Jervois in 1929 during a muster of stray cattle on a track leading from Tobermorey on the Northern Territory-Queensland border. Small scale mining commenced and a small mining settlement was located at Jervois in the 1930s. In the 1950s, Kurt Johannsen acquired leases over the area and mined copper carbonate on a small scale for the fertiliser industry and later as a flux for the smelting process in Mt Isa.

Since then, numerous companies have owned the Project and conducted exploration and mining activities (refer Section 2.1.3). The first modern exploration was conducted by New Consolidated Goldfields (Australasia) Pty Ltd from 1961 – 1965. Exploration continued sporadically through to 1980 when the Project was acquired by Plenty River Mining.

In the 1982 Plenty River Mining commenced mining high-grade lead and-silver ore from the Green Parrot open pit, processing it in a treatment plant commissioned in April that year. However, a sharp fall in the lead price resulted in the closure of the operation within a year.

Between 1999 and 2001 MIM Exploration farmed into the Project and conducted an induced polarisation survey followed by diamond drilling but withdrew because of the perceived limited size potential. In 2004, the Project was acquired by Reward Minerals who sold it to Jinka Minerals in 2011. Kentor Gold Ltd, now KGL Resources Ltd, acquired the Project in 2011 with the takeover of Jinka Minerals.
KGL has conducted drilling programs each year since the acquisition and has steadily increased the resource. Between 2011 and 2015 KGL has completed over 100,000m of drilling, conducted geophysical and geochemical surveys, detailed geological mapping and supported research on the deposit by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Northern Territory Geological Survey (NTGS). Exploration by KGL initially focused primarily on the copper resources at Jervois, but the discovery of new high grade lead-zinc lenses in 2014 and a steady increase in the gold and silver resource has highlighted that Jervois is polymetallic (Cu-Pb-Zn-Ag-Au). The increasing lead-zinc resource prompted a reassessment of the deposit style that had never been adequately resolved in the past. The research by the NTGS and CSIRO has proposed that Jervois is a ‘hybrid SEDEX-VMS deposit’ that has undergone substantial modification during deformation and metamorphism.

The current Jervois copper resource is 21.3Mt at 1.67% Cu, 22.3g/t Ag and a lead-zinc resource of 3.8Mt at 3.7% Pb, 1.2% Zn, 0.72% Cu, 67.5g/t Ag.
3.1.4. Soil Types and Land Units

3.1.4.1. Land Units

Land system mapping is also available from DENR at 1:250 000 scale (Jervo_250) (Figure 3.1-9 and Table 3.1-8). This mapping shows the land systems across the Jervois Project area comprises four land systems – Bond Springs, Sonder, Kanandra and Woodduck (very minor). This mapping reflects the major landscape features (hills, rises) visible on higher resolution imagery and DTM.

Figure 3.1-9 Land systems across Jervois Project area (1:250,000) (land system data from DENR)
### Table 3.1-8 Description of 1:250 000 scale Land Systems across the Jervois Project area (VPS 2018)

<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Land System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bs-1</td>
<td>Bond Springs One</td>
<td>Ridges and hills with rocky outcrops of schist and gneiss. Sparse mulga, witchetty bush and cassia over woolly oat and oat grasses, mulga grass and mountain wanderrie.</td>
</tr>
<tr>
<td>Bs-2</td>
<td>Bond Springs Two</td>
<td>Low hills and gravely plains with occasional schist outcrops growing mulga grass and woolly oat grass beneath scattered cassias. Watercourses and creeks with tea-tree and ghost gums over silky browntop and golden beard grass.</td>
</tr>
<tr>
<td>Kn</td>
<td>Kanandra</td>
<td>Broad sandy to sandy loam plains growing ironwood and witchetty bush over woolly oat, mulga and kerosene grasses and mixed forbs. Sandier areas adjacent to watercourses and creeks have ironwood, corkwood and whitewood over golden beard grass, woolly oat and annual herbage.</td>
</tr>
<tr>
<td>So</td>
<td>Sonder</td>
<td>Bold sandstone and quartzite ranges, mainly bare rock with pockets of shallow soil growing sparse shrubs and low trees over spinifex.</td>
</tr>
<tr>
<td>Wo</td>
<td>Woodduck</td>
<td>Flood-outs with red clayey sands supporting mixed woodland of beefwood, ghost gum, whitewood and ironwood over a variety of palatable grasses and herbage.</td>
</tr>
</tbody>
</table>

### 3.1.4.1 Soils

Low (2000) described the soils in the general Jervois Project area as shallow and stony in the ranges with alluvial loams at the base of the hills and sandy or clayey loams in the extensive undulating plains. The Jervois tenure is mapped in the BA30 unit in the Digital Atlas of Australian Soils (DAFF 2012), which consists of shallow sands and loams (Table 3.1-9).

### Table 3.1-9 Characteristics of soil map unit BA30 (BRS 1991)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
<th>Chief soils</th>
<th>Minor soil components</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA30</td>
<td>Low but bold rocky hills on gneiss and schist with intervening valley plains.</td>
<td>Shallow red sands and loams with frequent rock outcrops.</td>
<td>Red earths, earthy sands and deep red soils in the valleys; and red duplex soils, red earths and calcareous sands on foot slopes</td>
</tr>
</tbody>
</table>

A detailed soil-landscape assessment was undertaken for the Project (VPS 2018 – Appendix C-4). The soil survey identified and mapped 6 soil-landscape units (Figure 3.1-10 and Table 3.1-10). Soil textures on the site are of low to moderate clay throughout the soil profile and loamy and clayey sands on the surface. Based on The Australian Soil Classification (Isbell 2002), the dominant soils across the site are Rudosols on the hills and rises, with Red Kandosols and Red-orthic Tenosols on the gently undulating plains.
Figure 3.1-10 Soil map units across Jervois Project area (VPS 2018)
Table 3.1-10 Summary of soil-landscape map units across Jervois Project area based on detailed survey (VPS 2018)

* Acid is used to assess for the presence of calcareous segregations within the soil layer. Nil reaction indicates that no segregations are present.

The Dryland Salinity Hazard Map of the Northern Territory (Tickell 2002) indicates that the Jervois Project area lies within an area of Low to Very low risk of dryland salinity. Soils across the Jervois Project area comprise well drained, light to moderately textured soils (maximum clay content 20-30%) with low EC values and low fertility (low CEC) (Perry *et al* 1962), therefore the risk of sodicity (and hence dispersibility) within the soils across the site is expected to be low (VPS 2018).

### 3.1.4.2 Land Contamination

The Jervois mine site is a brownfield/disturbed site. The area is part of a historic mining district and has been mined sporadically for almost 90 years. Modern mining started in 1982, with open pit mining at Green Parrot and a newly commissioned treatment plant designed to treat Green Parrot lead-zinc-copper-silver ore. A combination of technical difficulties and a sharp decline in reduced global metal prices, the plant was placed on care and maintenance in December 1983 and has not operated since. There is a substantial amount of existing disturbance for the Jervois Project site as a result of the historical activities within the area. Historic mining disturbance includes tailings storage facilities, waste rock dumps, decommissioned processing plants and equipment, pits, prospecting trenches, ROMs, water storages and evaporation ponds, an exploration camp, exploration disturbances, roads and tracks. Potential sources of land contamination include the TSF, ROMs, processing plant and the possible milled ore at the processing plant, pits, underground shafts, prospecting trenches and old plenty river mining camp.

The proposed mining operation will be located over the existing disturbance area to minimize disturbance. Re-handling of the historic mine materials and potential contamination sources will be managed to demonstrate isolation from the receiving environment.
3.1.4.3 Land Use

The Jervois mine site is a brownfield site, acquired by KGL in 2011. An overview of the site history is provided in Sections 1 and 3.4.

The Project is located approximately 380 km north-east of Alice Springs, with the nearest communities being Bonya, approximately 17 km to the south-west, and Maperte which is mostly unoccupied, 16km to the north-east. These communities are described further in Section 3.4 and in Appendix C-9 – Social Impact Assessment.

The main long-term economic activity in the area is the pastoral industry of beef cattle grazing. The current land use within the Project boundary is predominately cattle grazing and some small scale historical mining practices. The site is currently an abandoned mine that lies within the Jervois Station pastoral lease. The extent of the historic mining and exploration activities limits the potential for the Project area for beef cattle grazing. The Project is expected to disturb approximately 0.35% of the Jervois Pastoral Lease.

The proposed Project represents a continuation of the use, i.e. mining, which has occurred on site for almost 90 years. The Project footprint will be largely contained within existing disturbed areas, so in relative terms there will be little change in the land use of the site.

3.1.5 Surface Water

3.1.5.1 Introduction

Management of water is crucial for successful operations and closure at Jervois Mine. The Project requires water for various site activities including industrial uses, environmental uses, and potable water.

This chapter describes the characteristics of surface water associated with the Jervois Mine Project as required by the Terms of Reference.

3.1.5.2 Regional Drainage Characteristics

The Jervois Project area is in the upper catchment of the Hay River Basin, part of the Lake Eyre basin, which ultimately feeds into Lake Eyre in the north of South Australia (Figure 3.1-11). The Hay Rivers rises in the Harts and Dulcie Ranges and flows south-east towards the Simpson Desert. The Plenty River drains roughly parallel to the Hay River, about 50km apart, and the two converge at the southern edge of the Simpson Desert before feeding into Lake Eyre. The Plenty River usually seeps into the ground in the eastern part of the Simpson Desert after about 340 km, however in particularly wet years, it flows into the Hay River. The total catchment area of the Hay River basin upstream of Lake Eyre (including the Plenty River catchment) is approximately 100,000 km².
Figure 3.1-11 Lake Eyre Basin

The Hay River catchment is bounded by the Georgina River catchment to the north and northeast, and by the Todd and Finke rivers catchments to the west. Figure 3.1-12 shows the drainage network of the Hay River catchment and its major tributaries, including the Plenty River, the Marshall River and Arthur Creek. The catchment is sparsely populated with isolated communities. Land use is typically rural throughout the catchment, with some evidence of historical mining activities in small areas, particularly near the Project area.

The Project is located adjacent to Unca Creek, a tributary of Arthur Creek in the upper headwaters of the Hay River catchment. Arthur Creek and the Marshall River converge into the Hay River approximately 60 km southeast of the Project.

The drainage lines that intersect the Project area feed into the Marshall River to the south and Arthur Creek to the north, which in turn converge into the Hay River, approximately 60 km south-east of the Project area.

Figure 3.1-12 Hay River basin drainage network
3.1.5.3 Local Drainage Characteristics

General

The hard rock catchments of the Jervois Range are high yielding. The Project area is incised by a number of ephemeral streams that generally flow only during runoff-producing rainfall events (Figure 3.1-13).

Major creeks include:
- Unca Creek, which flows through the mine site
- Bonya Creek including tributaries Daylight Creek; and
- Many unnamed creeks.

The only watercourse of note in the vicinity of Jervois Project is Unca Creek. Unca Creek originates about nine kilometres upstream of the Project and joins Arthur Creek approximately 45 km southeast of the Project. The proposed Marshall/Reward components of the Project, including the Process Plan and most of the Tailings Storage Facility (TSF) are located within the Unca Creek floodplain. Unca Creek has a catchment area of 21.8 km\(^2\) upstream of upstream of the Project area, with 17.1 km\(^2\) (78\%) of this catchment being captured in Jervois Dam upstream of the Project area.

The proposed Bellbird components of the Project and part of the TSF are located within the catchment of a southern tributary to Unca Creek. This tributary drains in a westerly direction and joins Unca Creek approximately 4.5 km downstream of the Project. The southern Unca Creek tributary has a catchment area of 21.9 km\(^2\) upstream of the Unca Creek confluence.

The Unca Creek floodplain upstream of Jervois Dam is bounded by steep hills but the main channel is generally poorly defined. Downstream of Jervois Dam, the Unca Creek floodplain is characterised as relatively flat and open, with the main channel generally poorly defined. The Unca Creek channel downstream of Jervois Dam is generally about 10m wide and less than 1m deep, with a sandy bed that...
would become mobile during flood events (Figure 3.1-14 and Appendix C-5). Loose rock is evident in the bed of the Unca Creek channel at locations where depths and flow velocities increase (i.e. at constrictions or bends in the channel). The Unca Creek channel and floodplain is sparely vegetated, with only scattered bushes lining the channel banks.

![Figure 3.1-14 Unca Creek channel at the proposed Reward Pit location](image)

**Jervois Dam**

Jervois Dam (Figure 3.1-15), located in Unca Creek about two kilometres upstream of the Project, was constructed for previous mining operations and is the largest and most permanent surface water body in the Jervois region (MBS, 2013). Jervois Dam currently has a storage capacity of 279 ML below the existing spillway level (367.38 mAHD), and a catchment area of approximately 17.1 km². The dam spillway is a narrow (less than 3m wide) rock chute that has been cut through the ridge at the northern end of the dam wall. The existing spillway chute is about 4 m below the crest of the existing dam wall.

The structural stability of the existing dam wall is unknown, however it appears that there is significant leakage through the dam wall, as there is strong vegetation growth and signs of sodden ground along the southern side of the valley downstream of the dam wall (WRM 2018).

Water quality analysis indicates that the water in the dam is fresh and close to rainwater in quality (Knight Piésold 2012).
3.1.5.4 Surface Water Flows

The Northern Territory Government operated a water level gauge (Gauge No. R0070009) in Jervois Dam between 1972 and 2010. Recorded sub-daily water level data at the Jervois Dam gauge were obtained from the Northern Territory (NT) Government water portal for the period of record. The recorded water level data was converted to stored volumes using a stage-storage relationship (Appendix C-5) Table 3.1-11 shows a statistical summary of daily maximum stored volumes in during the period of record.

Table 3.1-11 Statistical summary of daily maximum recorded volumes in Jervois Dam (WRM 2018)

<table>
<thead>
<tr>
<th>Percent of days</th>
<th>Volume exceeded (ML)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>99%</td>
<td>3.7</td>
<td>1.4% full</td>
</tr>
<tr>
<td>90%</td>
<td>9.6</td>
<td>3.5% full</td>
</tr>
<tr>
<td>50%</td>
<td>59.0</td>
<td>21.5% full</td>
</tr>
<tr>
<td>10%</td>
<td>210.0</td>
<td>76.4% full</td>
</tr>
<tr>
<td>3%</td>
<td>274.8</td>
<td>Full storage level (FSL)</td>
</tr>
<tr>
<td>1%</td>
<td>315.</td>
<td>Dam spilling</td>
</tr>
</tbody>
</table>

The data indicates that:

- Jervois Dam generally fills up rapidly during the wet season (between December and February) and then gradually decreases in volume during the remainder of the year via evaporation and seepage, but it rarely empties completely.
- During the period of record, the dam is at least 3.5% full in 90% of all days, at least 21.5% full in 50% of all days and at least 76.4% full in 10% of all days.
- The dam’s storage capacity below the spillway (274.8 ML) is exceeded in 3% of all days in the period of record.
3.1.5.5 Surface Water Quality

The character of surface water quality is influenced by land use and the mineral composition of soils and near-surface geology. The absence of a sustained baseflow contribution to watercourses is likely to limit the influence of deeper bedrock geology on surface water quality.

Water Quality Data

There are 11 surface water quality monitoring sites across the Project area: one monitoring site in Jervois Dam and 10 monitoring sites in the watercourses downstream of Jervois Dam (Figure 3.1-16). Few samples are available for each monitoring site (generally between one and four), while no data is available for the JSW03 monitoring site. The available samples were obtained following a total of four rainfall events which occurred between 2015 and 2018, except for one sample for Jervois dam which was obtained in January 1991. Appendix C-5 provides details of the water quality data from the monitoring sites.

Water quality data can be grouped into two groups:

- **Group A** – This group consists of 8 samples obtained from monitoring sites located in the undisturbed areas within the Unca Creek Tributary catchment (sites JSW04, JSW05, JSW07 and JSW08).

- **Group B** – This group consists of 3 samples obtained from monitoring sites located in the undisturbed areas in Unca Creek immediately downstream of Jervois Dam (sites JSW02 and JSW06).

The data shows that water quality of Group B is similar to that observed in Jervois Dam, with pH close to neutral, low EC, TSS and turbidity as well as low concentrations of metals. Contaminant concentrations in Group A are significantly higher than Group B, particularly TSS and metals. The Group A monitoring sites are located in the mineralised zone within the Project area, which likely contributes to the high concentrations of metals at these monitoring sites. The increased turbidity and TSS at the Group B locations is due to the flat, sandy nature of the channel and floodplain at those sites, compared to the rock catchment prevalent around the Group A sites.

![Figure 3.1-16 Locations of baseline surface water quality monitoring sites](image-url)
In summary, water quality at the Project area is characterised as follows:

- Across the Project area, pH is slightly acidic, while salinities (ECs) are low.
- Water stored in Jervois Dam has low turbidity as well as low concentrations of TSS, TDS and metals. This was expected as the catchment upstream of the dam is located outside of the mineralised region of the Project area. Water quality immediately downstream of Jervois Dam (monitoring sites JSW02 and JSW06) is consistent with the observed water quality in the dam.
- In the undisturbed areas along the Unca Creek Tributary (monitoring sites JSW04, JSW05, JSW07 and JSW08), turbidity is relatively high, while concentrations of TSS and metals are also relatively high. The catchment upstream of these monitoring sites is located within the mineralised region of the Project area. This likely resulted in the elevated metal concentrations observed here despite the absence of mining disturbance in the contributing catchment.
- Downstream of the Project area (monitoring sites JSW01, JSW09 and JSW10), contaminant concentrations are consistent with those observed in the undisturbed areas along the Unca Creek Tributary. Runoff from the mineralised zone within the Project area reports to these monitoring sites. It is possible that runoff from existing mining disturbance in the catchment of Unca Creek and its tributary may have also contributed to the elevated contaminant concentrations observed here.

### 3.1.5.6 Surface Water and Groundwater Interaction Mechanisms

This section briefly describes the key mechanisms that facilitate interaction between groundwater and surface water at Jervois. A schematic of these mechanisms is provided in Figure 3.1-17.

![Figure 3.1-17 Surface water and groundwater interaction mechanisms](image)

**Rainfall Runoff**

During and following rainfall, water that lands on the surface within the Jervois area will either infiltrate into the soil or rock as recharge (see Recharge below) or flow towards drainage lines as runoff. Surface water runoff is diverted and managed depending on the material that the water interacts with and derived suspended solids.

**Recharge/Infiltration**

During and following rainfall, some of the water that lands on or flows onto the surface (including in creeks and rivers) can soak into the soil or rock. The water that infiltrates the surface and does not evaporate or transpire through plants back into the atmosphere is known as groundwater recharge.
Groundwater recharge is the mechanism by which the groundwater levels within the hydrogeological units at Jervois are fed additional water. Two mechanisms provide recharge to the aquifers of the study area:

- Direct (or diffuse) recharge; and
- Indirect (or local) recharge.

Recharge in this environment is generally via direct infiltration to outcropping or thinly covered aquifers such as the fractured rock aquifers outcropping in the Jervois Range and the Watt, Spring, and Tomohawk Ranges. Riverbed recharge during heavy rainfall events also occurs.

**Toe and Basal Seepage**

Seepage is a general term used to describe the water that has infiltrated a body of material and under the influence of gravity, is moving. This can be in the form of basal seepage (bottom of a facility) or toe seepage (at the edge of a facility). Seepage from non-benign material will be collected and returned to the process water dam. Groundwater modelling has demonstrated that the Reward pit acts as a sink to capture any minor seepage that may escape from TSF or WRD.

Seepage through benign material may only require sediment management into the groundwater. Basal seepage may report to surface water systems distant from the source (refer Baseflow below). Toe seepage and can be collected in drains and sumps as required.

**Baseflow**

Baseflow describes the discharge of groundwater into the surface water system. At Jervois no groundwater reports to the surface. Groundwater levels are approximately 20-15m below ground level.

**Evaporation**

Evaporation is the loss of water from the surface (land or water) to the atmosphere. When evaporation is assisted by vegetation (either natural or revegetated surfaces on mine affected areas), it is termed evapotranspiration. This term is mainly used when describing water loss from the shallow soil via vegetation.

At Jervois, the average evaporation rate is much greater than the rate of rainfall. The evaporation rate is high throughout the year, with the highest evaporation rates occurring in the months between October and March. Evaporation is generally much higher than rainfall in all months of the year.

**3.1.5.7 Water Users**

**Environment**

Environmental water use is constrained by the sporadic nature of rainfall and surface runoff. Vegetation and fauna are either capable of surviving in between rainfall events or are able to access shallow groundwater.

Jervois Dam is the largest and only permanent water near the site available to fauna, all other watercourses are ephemeral, therefore aquatic flora and fauna will be limited. River red gums (Eucalyptus camaldulensis) at the Jervois dam have flourished since the dam was built. There is a moderate to high likelihood that the E. camaldulensis community along Unca Creek (north) and the major tributary to Unca Creek (south) is dependent on groundwater within the alluvial soils. Similarly, along Arthur Creek near Lucy Creek Homestead it is possible that the riparian vegetation is accessing groundwater due to the depth to groundwater.
Pastoral Water Supply
Lucy Creek Station, Arapunya Station and the northern portion of Jervois Station use bores completed in the Georgina Basin Carbonate aquifer for stock and domestic purposes. Lucy Creek Station utilises groundwater from the Georgina Basin Carbonate aquifer and is located approximately 10 km away. The closest stock bores to the process water supply bores are approximately 1.5 km from the closest production bore.

Community Water Supply
The nearest community water supply bores are: Maperte community water supply 16 km to the northeast of the mine site; and Orrtipa-Thurra (Bonya) Community water supply 17 km to the southwest of the mine site. Orrtipa-Thurra (Bonya) Community water supply and Jervois Station utilise groundwater from the Fractured Rock aquifer and is located more than 30 km and 50 km from the planned process water supply borefield respectively.

3.1.6. Groundwater

3.1.6.1 Introduction
This section provides a general description of the groundwater environment in the Project area. It identifies the major groundwater bearing rock units, discusses general groundwater flow patterns across the site and the quality of groundwater within the system. Further details are contained within the specialist groundwater assessment (Appendix C-6).

Regional and local geology has been described in Section 1.3. The following focuses on geological units relevant to groundwater, i.e. the hydrogeology.

3.1.6.2 Major Groundwater Bearing Units
The hydrogeology of the study area can be separated into two distinct groundwater systems:
- the Georgina Basin, typified by karstic and fractured sedimentary rocks which host regionally extensive groundwater resources; and
- the Arunta Region (hosting the Jervois Mine ore bodies), typified by fractured and weathered metasediments with minor groundwater resources.

Figure 3.1-18 shows the hydrological units, classified by aquifer types.
Figure 3.1-18 Hydrogeological units classified by aquifer type (CloudGMS 2018).
Hydrogeology of the Georgina Basin

The Georgina Sedimentary Basin commences immediately west of the mine site in the adjacent Jervois Range. Limited aquifers are known to occur in the Formations that form this range. The first Formation known to contain significant aquifers outcrops 20 km to the north-west of the Jervois Range.

Groundwater resources capable of meeting the water demand for the process water supply (45 L/s) are most likely located within the Georgina Basin in the regionally extensive fractured and karstic rocks of the Arrinthrunga Formation, Steamboat Sandstone and Arthur Creek Formation. The Southern Georgina Basin Carbonate Aquifer is part of the regionally extensive Georgina Basin that underlies approximately one quarter of the Northern Territory and extends beneath the northwest of Queensland. The aquifer system is a regional scale, extensive and transmissive aquifer. Estimated drainable groundwater volume of 160 – 320 cubic kilometres.

The carbonate aquifer system of the Georgina Basin comprises carbonates; limestone, dolomite, dolostone and sandstone. Regionally the aquifer is unconfined and the entire basin is understood to comprise a connected aquifer system. Previous studies of the system indicate that regionally it shows unconfined characteristics with a specific yield of about 0.01 to 0.04 (Jolly, 2002; Jolly et al., 2004; Knapton, 2006).

Carbonate formations in other regions of the Georgina Basin have recorded significant bore yields (50 L/s) in areas where weathering has led to dissolution features and karst development (i.e. cavernous limestone) within the limestone/dolostone sequence and significant secondary porosity. Where these features are absent, the Arrinthrunga Formation/Arthur Creek Beds display relatively poor yield potential (< 2 L/s). Groundwater resources are also present in intergranular sedimentary formations (Tomahawk Beds, Eurowie Sandstone), but supplies are typically less than 5 L/s.

Key local groundwater observations in the Arrinthrunga Formation are as follows:

- Lucy Creek Oil Well located 45 km north-east of the Jervois mine intersected a full sequence of the Arrinthrunga Formation (700 m) and airlifted approximately 60L/s of groundwater during drilling. Ride (1971) drilled several investigation holes along the oil bore access road, two bores were pumped at rates of 5 and 6 L/s, one of which recorded a “cavern” at a depth of 190 m. Bores drilled closer to Lucy Creek Station along the access track had less success.
- BMR Huckitta 8 was a stratigraphic core hole drilled by the NTGS located 35 km north-west of the Jervois mine. The hole was abandoned at a depth of 80 m in the Arrinthrunga Formation due to a lack of water supply for drilling. Circulation loss was experienced from 17 m and a total of 300,000 L of drilling water was lost downhole, this suggested significant porosity in the top 80 m of the sequence.

Hydrogeology of the fractured rocks (Arunta Region)

Numerous local minor aquifers occur within the granites, pegmatites and other basement formations of the Arunta Region. Groundwater yield and storage within these aquifers relies on fractures and jointing, they typically form marginal aquifers that are only suitable for stock and minor domestic supply.

Local aquifers are also present in shallow alluvial deposits (e.g. Paradise Bore 15 km north-east of the mine). Tertiary alluvial sequences (palaeovalleys) form significant groundwater resources in other locations in central Australia (e.g. Ti-tree basin, Tennant Creek), however, previous investigation drilling (Ride, 1971) suggests that these deposits have a limited extent and thickness.
Groundwater resources in the Jervois Mine area are very poor due to the limited open fracturing and lack of primary porosity of the Proterozoic rock, with recorded flows of 0.5 to 1.6 L/sec. Higher yielding areas are related to localised zones of more intense fracturing and jointing.

The groundwater system in the mine area is within the fractured and weathered rocks of the Bonya Metamorphics. The Bonya Metamorphics have been mapped as having very poor (minor) groundwater resources due to the “tight” nature of the Proterozoic rock.

Groundwater occurs in the Bonya Metamorphics Complex in fractures at about 25 m below ground surface (M.I.M Exploration, 2001). Metamorphic rocks such as schist and gneiss have low permeabilities and generally contain small amounts of groundwater, which is commonly brackish to saline. Information on the hydrogeology of the fresh rocks at greater depths is limited. The Bonya Schist is typical of metamorphic rocks and has a poor record of successful groundwater exploration (Berry & Matthews, 1992).

3.1.6.3 Groundwater Flows
This section provides a brief discussion of groundwater flows within the major hydrogeological units in the Project area.

Although there is limited groundwater elevation data in the study area, groundwater levels were obtained from 309 bores and provide a reasonable spread across the study area (Figure 3.1-19). The water table through the area generally mirrors the topography - flowing generally from northwest to southeast and locally from areas of higher topography to areas of lower topography such as drainage features and discharging as small seepages adjacent to the rivers and lowlands.

Water levels measured in wells referenced to datum (mAHD), provide information regarding the water table elevation for unconfined aquifers, or the potentiometric pressure for confined aquifers. This data can then be used to infer groundwater flow regimes.

The potentiometric surface indicates that there is a groundwater flow divide associated with the contact between the Fractured Rock and Georgina Basin groundwater systems (Figure 3.1-19). To the north of the divide, groundwater flows into the Georgina Basin and northeast toward the Queensland border. South of the divide groundwater flows within the Fractured Rock groundwater system to the south.

3.1.6.4 Groundwater Surface Connections
Groundwater from the Georgina Basin Carbonate Aquifer does not discharge to surface within the study area. The water table ranges from 20 to 80m below ground surface and there are no springs, soaks, wetlands or salt lakes associated with the aquifer. Groundwater flows from the Southern Georgina Basin, eastward into the broader regional Georgina Basin for eventual discharge many hundreds of kilometres from the study site.

Groundwater discharge to surface features will be low as the Bonya Metamorphics has a low hydraulic conductivity.

3.1.6.5 Recharge
Two mechanisms provide recharge to the aquifers of the study area:

- Direct (or diffuse) recharge – this is defined as the water added to the groundwater in excess of soil moisture deficits and evapotranspiration, by direct vertical percolation of precipitation through the unsaturated zone and is typically distributed over large areas; and
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- Indirect (or local) recharge – this results from the percolation of water to the water table following runoff as ponding in low-lying areas or through the beds of surface watercourses (Lerner et al., 1990).

Recharge in the mine site environment is generally via direct infiltration to outcropping or thinly covered aquifers, such as the Fractured rock aquifers outcropping in the Jervois Range to the South of the Southern Georgina Basin, and the Watt, Spring, and Tomohawk Ranges to the South. Focussed (indirect) recharge occurs at stream flood-outs, where ephemeral streams flow from the ranges onto the plains after heavy rainfall events, for instance at the Oorotippra Creek, Tomohawk Creek, Arthur Creek Flood-Out to the south of the Project site. The potentiometric surface, which exhibits a gradient from the ranges toward the Georgina Basin, indicates that these ranges are recharge areas. Likewise the string of low salinity stock bores along the Sandover River indicate riverbed recharge along this watercourse.

Recharge rates are difficult to measure. Recharge for the Jervois Project, based on a chloride mass balance method, is estimated to be approximately 1.5mm/year for an average annual rainfall of 350 mm/year (CloudGMS 2018).

![Figure 3.1-19 Groundwater potentiometric surface and inferred groundwater flow directions.](image-url)
3.1.6.6 Groundwater Quality

A regional groundwater quality dataset was obtained from DENR NR Maps. The distribution of water quality as TDS across the study area is shown in Figure 3.1-20. Groundwater is generally fresh to brackish (500-3000 mg/L TDS). Most bores report water suitable for stock watering, but less than 40% are suitable for potable use (salinity <1000 mg/L).

Around the mine site, groundwater quality is constrained to Pastoral (Stock) uses due to elevated nitrate, boron and fluoride. Groundwater at the borefield site (Georgina Basin Carbonate Aquifer) can support potable use in most instances and is typically suitable for Pastoral (Stock) use.

Groundwater samples collected in the vicinity of the Jervois Mine from the Proterozoic Basement rocks exhibit Pastoral (stock) water quality with a mixed chemical composition dominated by Na-Mg-HCO₃-Cl. The water is not potable due to elevated fluoride, nitrate and boron.

Groundwater from bores in the Georgina Basin exhibit marginal to non-potable water suitable for pastoral use. The water exhibits a chemical composition similar to the Proterozoic Basement Aquifer, however elevated in Ca, Mg and SO₄, indicative of equilibration with carbonates; calcite (CaCO₃) dolomite (CaMg(CO₃)₂) and Gypsiferous rock (CaSO₄).

Figure 3.1-20 Groundwater quality (TDS) distribution (source DENR NR Maps, CloudGMS 2018).
3.1.6.7 Existing Groundwater Users

Third party users include pastoral bores used for stock watering and station water supplies, and community water supplies. Pastoral bores, community water supply bores are presented in Figure 3.1-21 and include:

- Arapunya Station stock and domestic bores
- Jervois Station stock and domestic bores
- Lucy Creek Station stock and domestic bores
- Maperte community (abandoned) water supply 16 km to the northeast; and
- Orrtipa-Thurra (Bonya) Community water supply 17 km to the southwest.

Lucy Creek Station, Arapunya Station and the northern portion of Jervois Station use bores completed in the Georgina Basin Carbonate aquifer for stock and domestic purposes.

Lucy Creek Station utilises groundwater from the Georgina Basin Carbonate aquifer and is located 10 km from the proposed process water supply borefield. Orrtipa-Thurra (Bonya) Community water supply and Jervois Station utilise groundwater from the Fractured Rock aquifer and is located more than 30 km and 50 km from the planned process water supply borefield respectively.

The closest stock bores to the process water supply bores are RN011102 and RN013274, which are approximately 1.5 km from the closest production bore.
Figure 3.1-21 Distribution of existing groundwater users in the Project area