SECTION 4.4
HYDROLOGICAL PROCESSES
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4.4 Hydrological Processes

4.4.1. Introduction

This Section provides a description of the surface water and groundwater settings of the Project, the potential impacts and water management strategies and systems proposed to manage the potential impacts. It also draws on the specialist studies undertaken for the Water Management Plan (WMP) (Section 5).

Relevant legislation, policy and guidelines

- Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)
- Environmental Assessment Act (1982) (EA Act)
- Water Act; and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Hydrological and groundwater assessments have been undertaken for the Project (Appendix C5 and C6). The studies undertaken consisted of desktop assessments, hydrological and hydrogeological surveys and numeric modelling. This section presents findings from these studies in a structure that responds to the Terms of Reference.

The assessments undertaken demonstrate that with appropriate water management and mitigation measures in place, the potential impact of the Project on groundwater, surface flows and water quality in the receiving waters downstream of the Jervois Mine will be acceptable.

4.4.2. Existing environment

4.4.2.1. Regional surface water network

The Jervois Project area is in the upper catchment of the Hay River Basin, which ultimately feeds into Lake Eyre in the north of South Australia (Figure 4.4-1). 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 kilometres south-east of the Project area. Surface water in the Project area and surrounding region is ephemeral and the creeks hold water during and after rainfall events. Drainage lines originating in the Jervois Range, include Unca Creek. Unca Creek and its tributaries drain to the east through the Project area and north-east towards Arthur Creek, but flood out through the broad drainage plain to the south-east. Other watercourses in the surrounding area include: Daylight Creek 4 km south-west, Midnight Creek 7 km south and Bonya Creek 11 km south-west.
4.4.2.2. Local drainage network

The local drainage of the Jervois Project area is incised by a number of ephemeral drainage lines that hold water during and after rainfall events. Drainage lines in the Project area are shown in relation to proposed infrastructure in Figure 4.4 2.
Unca Creek is the only watercourse of note in the vicinity of the Jervois Project. Unca Creek has a catchment area of 21.8 km\(^2\) upstream of the Project area, with 17.1 km\(^2\) (78\%) of this catchment being captured by Jervois Dam. Downstream of the dam, Unca Creek runs in an easterly direction through the northern portion of the Project area before turning southeast and crossing Lucy Creek Access Road. A tributary of Unca Creek runs east through the southern portion of the Project area before joining the main creek channel approximately 1.5 km east of Lucy Creek Access Road. The southern Unca Creek tributary has a catchment area of 21.9 km\(^2\) upstream of the Unca Creek confluence.

The Unca Creek catchment upstream of Jervois Dam is steep and rocky, with poorly defined, sandy drainage features located along valley floors. Downstream of Jervois Dam, the catchment becomes flat and open, with wide expanses of sandy flats and spinifex grass, with scattered vegetation along the creek and drainage feature channels. The Unca Creek channel downstream of Jervois Dam is generally about 10 m wide and less than 1 m deep, with a sandy bed that would become mobile during flood events.

4.4.2.3. Jervois dam

Jervois Dam is an artificial water reservoir at the north-west corner of the Project area, which holds a substantial volume of water for several years following rainfall. It was constructed for previous mining operations in the early 1970’s and is the largest and most permanent surface water body in the Jervois Region. Jervois Dam currently has a storage capacity of 279 ML below the existing spillway level (367.38 mAH), and a catchment area of approximately 17.1 km\(^2\). The dam spillway is a narrow (less than 3 m 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. Faulty construction resulted in a pervious layer in the dam wall which allows seepage which provides long term irrigation for the area immediately east of the dam. It is planned to repair this leak to enable a larger quantity of water to be available for the mining process.

Analysis of dam level records (refer Appendix C5) indicates that:

- Jervois Dam generally fills up rapidly between December and February and then gradually decreases in volume during the remainder of the year via evaporation and/or seepage, but rarely empties completely
- During the period of record, the dam is at least 3.5\% full on 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; and
- The dam’s storage capacity to the spillway (274.8 ML) is exceeded on 3\% of all days in the period of record.

4.4.2.4. Flooding – existing conditions

A Unified River Basin Simulator (URBS) hydrological model and a TUFLOW two-dimensional hydraulic model were developed to simulate the flood behaviour of Unca Creek and its tributaries in the vicinity of the Project (refer Appendix C-5).

The models were used to estimate peak flood levels, depths and extents in the vicinity of the Project for the 10\% and 1\% AEP and the probable maximum flood (PMF) events under existing conditions (pre-mining).
Figure 4.4-2 Local drainage network
Figure 4.4-3 Peak flood depths and extents across the entire Project area, existing conditions, 1% AEP (100 year ARI) event.
Figure 4.4-4 Peak flood depths and extents near the Reward Pit and Processing Plant area, existing conditions, 1% AEP (100 year ARI) event.
Figure 4.4-5 Peak flood velocities across the entire Project area, existing conditions, 1% AEP (100 year ARI) event.
Figure 4.4-6 Peak flood velocities near the Reward Pit and Processing Plant area, existing conditions, 1% AEP (100 year ARI) event.
4.4.2.5. **Groundwater**

Groundwater availability on Jervois Station has always been a problem (Low Ecological Services P/L, 1985). Water from Palaeozoic sediments is frequently salty (Black, 1984), but fault and fracture lines in metamorphic and igneous rock may provide fresh water. Deep Quaternary beds through which major water courses flow can yield good supplies of fresh water. Unca Bore on the Project area is high in salt content at 3380 TDS.

The nearest community water supply bores are:
- Maperte community (abandoned) water supply 17 km to the northeast of the mine site; and
- Orrtipa-Thurra (Bonya) Community water supply 17.5 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.

4.4.2.6. **Historic mining activities**

There is existing historical mine disturbance at the Project including tailings storage dams, a waste rock dump, processing plant equipment, an open cut mining pit, numerous prospecting trenches, a ROM pad area and some ore stockpiles.

The historic activities are having the following impact on water systems around the mine:
- Runoff from the existing processing plant area and ROM pad (including any remaining ore stockpiles) would drain north into Unca Creek
- Runoff from the existing tailings dams would collect in the base of the dams and evaporate or seep from the base of the dams potentially to Unca Creek
- Runoff from the existing waste rock dump drains south into the Tributary of Unca Creek
- Runoff from the existing Green Parrot Pit would collect in the base of the pit and evaporate or seep into the underlying rock. The existing pit is about 9m deep at its deepest point; and
- The prospecting trenches are generally located within the rocky outcrops in the southern portion of the Project area and would collect small amounts of runoff that would evaporate or seep into the underlying rock.

4.4.3. **Relevant activities**

Figure 4.4-7 shows the proposed infrastructure for the Project area, which are summarised below. For details refer to Section 2 – Project Description.

- **Reward infrastructure:**
  - A main open cut pit located across the main channel and floodplain of Unca Creek
  - A permanent diversion channel for Unca Creek
  - Three minor satellite pits located north of the main open cut pit
  - An underground mining operation with the portal located towards the base of the main open cut pit
  - A waste rock dump; and
  - Sediment dams to capture runoff from the water rock dump.
- **Bellbird infrastructure:**
  - Two main open cut pits referred to as Bellbird North Pit and Bellbird South Pit
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- Two minor satellite pits located close to the Bellbird South Pit
- An underground mining operation with the portal located towards the base of the Bellbird South Pit
- A waste rock dump; and
- Sediment dams to capture runoff from the water rock dump.

- Rockface infrastructure:
  - Underground mine and associated portal and haul roads.

- Jervois Dam repairs and increase in storage capacity.

- Processing Plant – to be constructed on site of existing plant:
  - Processing plant infrastructure
  - ROM and product stockpiles
  - Chemical storage
  - Hardstands; and
  - Process water dam (adjacent to Unca Creek diversion).

- Tailings storage facility; and
- Accommodation camp and administration.

The surface water management design incorporates the following components to control the discharge of run-off and sediment from the Project site:

- Raising of the existing Jervois Dam by approximately 1.5 m and strengthening of the dam wall.
- Repair of the spillway to the south of the main Jervois Dam embankment
- Construction of a diversion bund to the west of the proposed Marshall / Reward waste dump.
- Construction of a diversion channel to the east of the eastern perimeter of the TSF to divert water towards the catchment to the south
- Construction of a bund between the eastern face of the Marshall / Reward waste dump and the western perimeter of the Marshall / Reward pit
- Construction of a diversion channel at the northern end of the Marshall / Reward pit; and
- Construction of two sediment control dams.
Figure 4.4-7 Proposed infrastructure

Legend
- Stream Line
- Existing Roads
- Proposed Roads
- Weir Creek Diversion
- Dam
- Open cut pit
- Waste rock dump
- Tailings Storage Facility
- Process Plant Area
- Water storage
- Process Water Dam (PFD)
- Camp

Lease boundaries
- ML 30180 boundary
- ML 30182 boundary
- ML 30829 boundary
- EL 2542 boundary
- EL 28082 boundary

Jervois Project
Proposed Jervois Base Metal Project Components
Groundwater affecting activities:

- Process water supply - The process water supply comprises four planned bores abstracting up to 3.9 ML per day (45 L/s, 1.4 GL/year) for 10 years. Bores will be completed into the Georgina Basin Carbonate Aquifer at a site 10 km to the north of the mine site. The borefield is currently designed as 4 bores each equipped to pump 11-12 L/s

- Mine Pit Excavation - The excavation of the Mine pits will extend below the water table. The water table at the mine site has been measured at 320 - 330 mAH (20 – 30 m below ground level). The maximum pit depth at Bellbird is 100 m below ground surface and Reward is 140 m below ground surface approx. 261 mAH and 215 mAH respectively. Bellbird will intersect the water table at the end of year 6 and Reward will intersect the water table after the end of year 1

  The Bellbird and Reward underground mines will be constructed beneath the water table and can expect groundwater inflows at commencement of excavations. Rockface will commence decline construction above the water table, however, the excavation will intersect the water table in the first half of year 1 in the mine schedule

- Tailings handling - The mine operation tailings will be stored in a tailings storage facility (TSF) to the west of Reward pit. Some tailing liquor will seep from storage in the TSF to the groundwater table. This may result in some increase in groundwater level and change to the chemical composition of groundwater; and

- Spills - Spills of processing reagents and hydrocarbons (fuel, lubricants) present a risk of groundwater contamination, though the depth to the water table of 20 – 30 m provides a natural risk mitigation. Spills are considered a soil contamination risk rather than groundwater contamination

4.4.4. Potential impacts and risks

4.4.4.1. Site Water Demands

Water that will be used by the Project can be split into two quality types: potable water and process / dust suppression water.

**Potable water demands**

The predicted water demand rate to the Potable Water Treatment Plant is 3.8 T/h (0.1 ML/d or 36.5 ML/year). Based on a plant yield of 50%, 1.9 T/h (0.05 ML/d) of treated water from the Potable Water Treatment Plant will be used to supply potable water uses at the mine camp and the administration area. The remaining 1.9 T/h (0.05 ML/d) waste stream from the potable water treatment plant will be pumped to the processing plant to supply non-potable uses.

**Processing plant demands**

Modelling shows the Processing Plant is Projected to require a constant water demand rate of 86.1 T/h (2.05 ML/d) over the life of the Project, which includes:

- 55 T/h (1.3 ML/d or 475 ML/year) of raw water (plant standard); and
- 31 T/h (0.75 ML/d or 274 ML/year) of process water (mine affected water or sediment laden water).
The above water demand rate has accounted for all internal recycling of processed water within the processing plant and tailing storage facility. If insufficient mine affected or sediment laden water is available to supply the process water demand to the plant, raw water will be used to supply the plant demand.

**Dust suppression**

Dust suppression demand rates were calculated based on the predicted surface area (waste rock dump, open cut pits, haul roads and access roads) to be wetted, and the average daily evaporation rate for during dry days (refer Appendix C5). Table 4.4-1 shows the adopted dust suppression demand rates over the Project life. It is expected that dust suppression water can be sourced from lower quality water (via the Process Water Tank), such as harvested surface runoff and groundwater collected in-pit.

<table>
<thead>
<tr>
<th>Project year</th>
<th>Area requiring dust suppression (ha)</th>
<th>Total dust suppression demand (kL/d)</th>
<th>Estimated annual average dust suppression demand (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mining Pit</td>
<td>Waste rock dump</td>
<td>Haul roads / access roads</td>
</tr>
<tr>
<td>EOY0 to EOY4</td>
<td>16.2</td>
<td>33.4</td>
<td>41.6</td>
</tr>
<tr>
<td>EOY4 to EOY5</td>
<td>25.3</td>
<td>50.8</td>
<td>41.6</td>
</tr>
<tr>
<td>EOY5 to EOY6</td>
<td>25.3</td>
<td>44.1</td>
<td>41.6</td>
</tr>
<tr>
<td>EOY6 to EOY7</td>
<td>25.3</td>
<td>37.4</td>
<td>41.6</td>
</tr>
<tr>
<td>EOY7 to EOY8</td>
<td>25.3</td>
<td>30.8</td>
<td>41.6</td>
</tr>
<tr>
<td>EOY8 to EOY10</td>
<td>25.3</td>
<td>15.4</td>
<td>41.6</td>
</tr>
</tbody>
</table>

**Underground mining equipment demand**

A maximum nominal underground mining demand rate of 100 kL/d has been adopted when all three underground mines (Rockface, Bellbird and Reward) are operating i.e 33.3 kL/d for each operating underground mine.
Table 4.4-2 shows the adopted underground mine demand rates over the Project life. It is assumed that underground mining equipment demands can be supplied from raw water (plant standard), mine affected water and sediment laden water if necessary. If insufficient water is available from the above sources, raw water (potable standard) will be used.
Table 4.4-2 Underground mining water demand

<table>
<thead>
<tr>
<th>Project year</th>
<th>Marshall / Reward operations</th>
<th>Bellbird operations</th>
<th>Rockface operations</th>
<th>Underground mine demand (kL/d)</th>
<th>Underground mine demand (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOY0 to EOY4</td>
<td>open cut only</td>
<td>none</td>
<td>underground only</td>
<td>33.3</td>
<td>12.2</td>
</tr>
<tr>
<td>EOY4 to EOY5</td>
<td>open cut + underground only</td>
<td>open cut only</td>
<td>underground only</td>
<td>66.7</td>
<td>24.3</td>
</tr>
<tr>
<td>EOY5 to EOY6</td>
<td>underground only</td>
<td>open cut only</td>
<td>underground only</td>
<td>66.7</td>
<td>24.3</td>
</tr>
<tr>
<td>EOY6 to EOY7</td>
<td>underground only</td>
<td>open cut + underground</td>
<td>underground only</td>
<td>100.0</td>
<td>36.5</td>
</tr>
<tr>
<td>EOY7 to EOY8</td>
<td>underground only</td>
<td>open cut + underground</td>
<td>none</td>
<td>66.7</td>
<td>24.3</td>
</tr>
<tr>
<td>EOY8 to EOY10</td>
<td>underground only</td>
<td>underground only</td>
<td>none</td>
<td>66.7</td>
<td>24.3</td>
</tr>
</tbody>
</table>

Figure 4.4-1 shows the total (combined) annual modelled demand for raw water from Jervois Dam and the groundwater bore fields over the Project life. The results indicate the following:

- External water supply is required in all years to satisfy demand
- The peak annual demand for external raw water occurs in year 1 of Project life
- Demand for external raw water decreases rapidly to less than 100 ML/year by year 7 of Project life (due to increased groundwater inflows); and
- The predicted demand includes significant dust suppression demand. During the first four years of the Project life it should be possible to rationalise dust suppression demands to reduce the amount of external water imported to the site.
4.4.4.2. Water Supply Sources

There are four primary water sources for the Project:

- Rainfall runoff (excluding Jervois Dam)
- Dewatered groundwater inflows
- Jervois Dam; and
- Supply from borefield.

The Process Water Dam will be the primary water storage of mine-affected water on site. Runoff and any groundwater seepage (mine affected water) collecting in the Reward and Bellbird open cut pits will be collected in sumps before being pumped out the process water dam. Groundwater that seeps into the underground mining operations will be pumped to a collection sump at the portal of each mine before being pumped back to the underground dewatering dam. Groundwater that seeps into the underground mining operations is expected to be of good quality i.e. suitable for use to supply raw water demands in the processing plant.

Jervois Dam is the primary source of raw water (potable standard) and secondary source of raw water (plant standard) for the site. The existing Jervois dam will be repaired and enlarged.

A new borefield, consisting of bores completed into the Georgina Basin Carbonate Aquifer, will be developed at a site 10 km to the north of the mine site.

4.4.4.3. Water Balance

The performance of the water management system (WMS) was assessed using the OPSIM water balance model. OPSIM is a computer-based operational simulation model that has been developed to
assess the dynamics of the water balance under varying rainfall and catchment conditions throughout the development of the Project.

The OPSIM model dynamically simulates the operation of the WMS and keeps complete account of all site water volumes and representative water quality on a daily time step. Full details of the configuration and calibration of the Jervois OPSIM model, including input assumptions, are provided in Appendix C5.

The Jervois OPSIM model was used to predict the performance of the following:

- **Overall water balance** - the average inflows and outflows of the WMS for a number of representative realisations
- **Mine water inventory** – the risk of accumulation of water in the mining pits and underground mines and the Process Water Dam
- **External water demand** – the risk and associated volumes of requiring imported external water (via the bore fields) to supplement mine site water demands; and
- **Uncontrolled releases (spillway discharges)** – the risk of uncontrolled releases from the surface water storages to the receiving environment.
Table 4.4-3 provides a summary of the long-term average annual inflows and outflows based on the model. Key outcomes from the water balance are:

- There is no accumulation of water predicted during the first six years of mining (EOY0 to EOY6) as the total water supply is equal to or exceeded by the total site demand.
- Groundwater inflows into the underground mines continuously increase until they peak during EOY6 to EOY7 when all three underground mines are operating simultaneously. From EOY7, groundwater inflows gradually decrease towards the end of the Project in EOY10.
- The average external water supply requirements vary over the life of the Project.
- There were no modelled uncontrolled releases (spillway overflows) from the Process Water Dam over the life of the Project; and
- There are minor uncontrolled releases (spillway overflows) from the sediment dams (about 3 ML/yr) during EOY0 to EOY4 (refer Appendix C5). The predicted uncontrolled releases are larger from EOY4 towards the end of the concept mine plan as water stored in the sediment dams is no longer pumped back to the mine water management system. The water balance model does not account for the potential controlled release of water from the waste rock sediment dams. The average annual volume of sediment dam uncontrolled releases varies between 8.0 and 9.8 ML/yr from EOY4 to the end of the concept mine plan (EOY10).
### Table 4.4-3 Annual site water balance (average annual volumes)

<table>
<thead>
<tr>
<th>Component</th>
<th>Process</th>
<th>Volume (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EOY0 to EOY4</td>
</tr>
<tr>
<td>Inflows</td>
<td>Rainfall runoff (excluding Jervois Dam)</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Dewatered Groundwater inflows</td>
<td>669</td>
</tr>
<tr>
<td></td>
<td>Supply from Jervois Dam</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>Supply from bore field</td>
<td>1,353</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,237</td>
</tr>
<tr>
<td>Outflows</td>
<td>Evaporation (excluding Jervois Dam)</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>Processing Plant demand</td>
<td>761</td>
</tr>
<tr>
<td></td>
<td>Dust suppression</td>
<td>1,328</td>
</tr>
<tr>
<td></td>
<td>Underground mine demand</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Potable water demand</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Releases from Sediment Dams</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Releases from Process Water Dam</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,239</td>
</tr>
<tr>
<td>Change in Site Water Inventory</td>
<td></td>
<td>-2</td>
</tr>
</tbody>
</table>

#### Proposed changes to the movement of surface waters

For surface water management purposes, the surface water that is generated and/or managed at the Project is divided into five classes based on water quality:

- **Undisturbed runoff**: runoff from catchments unaffected by mining
- **Raw water (potable standard)**: raw water suitable for use in supplying the potable water treatment plant. Raw water (potable) standard will not have been in contact with any areas disturbed by mining, or any ore bodies. Raw water (potable standard) is typically sourced from Jervois Dam or the external borefield
- **Raw water (plant standard)**: water suitable for use in the raw water streams of the processing plant. Raw water (plant standard) will have suitably low levels of TSS to prevent clogging of machinery nozzles but may have elevated levels of metalloids. Raw water (plant standard) is typically sourced from groundwater dewatered from the underground mining operations
- **Sediment laden water**: sediment laden runoff from waste rock dumps. Sediment laden water is suitable for use as make-up process water in the plant, and for dust suppression. May be suitable for release to the environment dependant on long term water quality monitoring results; and
- **Mine affected water**: runoff from areas where chemicals, contaminants or oxidised ore may be present. Includes runoff that collects from the processing plant, ROM and product stockpiling areas, open cut mining pits and tailings storage facilities. Suitable for use as
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make up process water in the plant and for dust suppression. Unlikely to be suitable for release to the environment.

4.4.4.5. Surface Water Impacts

Flooding

A Unified River Basin Simulator (URBS) hydrological model and a TUFLOW two-dimensional hydraulic model were developed to simulate the flood behaviour of Unca Creek and its tributaries in the vicinity of the Project (refer Appendix C5).

The models were used to estimate peak flood levels, depths and extents in the vicinity of the Project for the 10% and 1% AEP and the probable maximum flood (PMF) events under existing conditions (pre-mining), operational conditions (during mining) and final landform conditions (post-mining). The model results for the 10% and 1% AEP events were used to assess the flood impacts of the Project. The model results for the 0.1% AEP event were used to size the proposed Unca Creek diversion and the crest heights of proposed flood protection bunds under operational mining conditions. The model results for the PMF event were used to assess the immunity of the final void under the final landform conditions.
Model outputs for the more significant 1% AEP (100 year ARI) events are provided here.
Figure 4.4-3 and Figure 4.4-4 show the peak flood depths and extents in a 1% AEP event, while Figure 4.4-5 and Figure 4.4-6 show the peak velocities in 1% AEP event under existing conditions. Figures showing 10% AEP (10 year ARI) events are contained in Appendix C5.

The model results indicate that the proposed infrastructure for the Project are generally located outside of the 1% AEP flood extent except for the proposed Reward Pit, which traverses the Unca Creek channel and floodplain. The proposed Reward and Bellbird waste rock dumps appear to be located across existing overland flow paths, however the dumps will not be affected by flooding from Unca Creek and the Unca Creek tributary. Clean and dirty water diversion drains will be used to manage overland flows around the waste rock dumps.

The following changes are proposed between the existing conditions and the operational conditions:

- The Jervois Dam spillway will be raised and widened. This will change the behaviour of spills from the dam and affect design discharges in Unca Creek upstream of the Reward operational area. The URBS hydrologic model was modified to incorporate the raised dam spillway. The updated URBS model was then used to derive updated design discharge hydrographs for the TUFLOW model; and
- The proposed Unca Creek diversion will divert all Unca Creek flows around the proposed Reward Pit for all events up to and including the 0.1% AEP event. The TUFLOW hydraulic model was modified to incorporate this diversion.

Flood impacts of operating mine

The predicted impacts of the Project are summarised below:

- There are no predicted increases in peak flood levels and velocities along the watercourses traversing the Project area, except in Unca Creek
- The Jervois Dam spillway will be raised and widened under operational conditions, increasing the peak outflow discharge from the spillway by about 10%, resulting in minor increases in peak flood levels and velocities along Unca Creek downstream of Jervois Dam
- Increases in peak flood levels of up to 0.1 m are predicted in Unca Creek downstream of Jervois Dam for the 10% AEP and 1% AEP events. The average increase in flood levels along Unca Creek is about 0.05 m for the 10% AEP event and about 0.08 m for the 1% AEP event. These increased flood levels are not expected to have any material impact on existing land uses downstream of the Project area
- There are minor predicted increases in peak velocities of up to 0.2 m/s in Unca Creek downstream of Jervois Dam for the 10% AEP and 1% AEP events. The average increase in peak velocities along Unca Creek is about 0.07 m/s for the 10% AEP event and about 0.11 m/s for the 1% AEP event. Given that the average peak flood velocities along Unca Creek under existing conditions are about 0.9 m/s for the 10% AEP event and 1.3 m/s for the 1% AEP event, the minor predicted increases in peak velocities due to the Project are not considered significant; and
- If Jervois Dam was removed (the pre-dam case), the 1% AEP peak discharge in Unca Creek downstream of the dam sit would be approximately 58.4 m$^3$/s. The 1% AEP peak discharge downstream of the existing dam is 27.6 m$^3$/s, and this will increase to 35.1 m$^3$/s after the dam is upgraded. Therefore, the predicted increase in flood levels and velocities following the dam upgrade would be closer to the pre-dam flooding conditions.
Impact of final voids

A water balance model was used to assess the long-term behaviour of the final voids post mine closure. The final void water balance model (Appendix C5) indicates that:

- All voids will typically have a small volume of surface water runoff stored in the base of the void
- The stored water depth in each void is predicted to typically vary between 10 m and 15 m deep, however this may increase to as much as 30 m deep during extended wet periods; and
- The water surfaces in the final voids are generally between 40 m and 100 m below surrounding ground levels.

Final landform hydraulic modelling indicated that the final voids will be protected from flooding from Unca Creek and its tributaries for all events up to and including the PMF.

The pits will act as groundwater sinks, i.e. there will be some drawdown associated with them, this combined with evaporation from the pit lake and pit surfaces, suggests that there will be negligible groundwater inflows to the final voids. Therefore, the only water that collects in the final voids will be surface water runoff from the pit catchments. This runoff will collect in the base of the pits and evaporate over time. The final landform for the Project will ensure that the remnant surface water catchments that drain into the final voids are limited to the voids themselves.

Therefore, the final voids will have no significant impact on surface water.

Impacts on Water Quality

The Project has the potential to impact on water quality in Unca Creek and its tributaries due to controlled and uncontrolled releases of water.

The results of the water balance model show that no uncontrolled releases are predicted from the process water dam in any of the water balance model simulations. Therefore, the Project will not release any mine affected water or dewatered groundwater to the environment.

The water balance model indicates that there is approximately a 10% chance of uncontrolled releases of water from the waste rock sediment dams in the first four years of Project life.

The water balance model predicts an increase in uncontrolled releases from the sediment dams beyond Year 4 of Project life, as groundwater inflows increase and water captured in the sediment dams is no longer pumped back to the WMS. The water balance model does not consider the potential for controlled releases of water from the waste rock sediment dam from year 5 onwards (pending suitable water quality), which would reduce the amount of uncontrolled releases.

It is considered that the predicted uncontrolled releases from the waste rock sediment dam are unlikely to have any impact of significance on water quality in Unca Creek, as they will occur when there is likely to be some flow in the receiving watercourses, and the uncontrolled releases are likely to be of similar quality to background water quality.
Changes to streamflow in Unca Creek

The proposed upgrade to Jervois Dam will potentially result in changes to the existing conditions streamflow regime in Unca Creek. It should be noted that the existing dam has already altered the streamflow regime of Unca Creek significantly.

The upgraded dam will require a greater volume of catchment runoff to fill the dam before the spillway is activated and flow leaves the dam. Further, the dam will be relied upon as a source of raw water, particularly during the first four years of operations (before groundwater inflows to the underground increase). Therefore, the volume of water stored in the dam will be drawn down after a runoff event more rapidly than under existing conditions. Overall, the proposed upgrade to the dam will potentially reduce the magnitude and number of overflows from the dam, particularly in the first four years of concept mine plan.

The water balance model was used to assess the change in flows in Unca Creek immediately downstream of the dam following the upgrade. Figure 4.4-9 shows the existing conditions and predicted post-upgrade (for year 1 of Project life and post-mine closure) flow duration curves for Unca Creek immediately downstream of the dam for the first four years of Project life.

Figure 4.4-9 Impact of upgraded Jervois Dam on downstream Unca Creek flows

Further, the dam is situated in an arid catchment, where it would not be unusual for the dam not to overflow for several years. Water balance modelling indicates that the existing dam on average only overflows in every fourth year. The upgraded dam is predicted to overflow on average every 11 years under the year 1 scenario, and every 9 years under the post-mine closure scenario.
Increase in Jervois Dam lake extent

The proposed repairs and upgrade to Jervois Dam (increased spillway level) will result in an increase in the area inundated by the lake behind the dam wall. Figure 4.4-10 shows the extent of inundation from the lake at full supply level under both existing conditions and post-mining conditions. The area of inundation at full supply will increase from about 16 ha under existing conditions to about 36 ha under the upgraded dam case. The increased inundation extent does not affect any existing structures or sensitive environmental or cultural heritage areas.
The water balance model (Appendix C5) assessed the frequency of inundation. The proposed dam upgrade will result in an increase to the frequency of inundation; water levels in the upgraded dam are predicted to exceed the existing full supply level approximately 27% of the time.

**Flooding**

Modelling of flood events under operational conditions (mine operating) were undertaken for 10% AEP (10 year ARI) and 1% AEP (100 year ARI) events. The results for the more extreme 1% AEP events are shown in Figure 4.4-11 and Figure 4.4-12 (flood depths and extents), and Figure 4.4-13, and Figure 4.4-14 (velocities).

The predicted impacts of the Project are summarised below:

- There are no predicted increases in peak flood levels and velocities along the watercourses traversing the Project area, except in Unca Creek.
- The Jervois Dam spillway will be raised and widened under operational conditions. This has the effect of increasing the peak outflow discharge from the spillway by about 10%. In turn, the increased discharges from the dam spillway results in minor increases in peak flood levels and velocities along Unca Creek downstream of Jervois Dam.
- There are minor predicted increases in peak flood levels of up to 0.1 m in Unca Creek downstream of Jervois Dam for the 10% AEP and 1% AEP events. The average increase in flood levels along Unca Creek is about 0.05 m for the 10% AEP event and about 0.08 m for the 1% AEP event. These minor increases in peak flood levels are not expected to have any material impact on existing land uses downstream of the Project area.
- There are minor predicted increases in peak velocities of up to 0.2 m/s in Unca Creek downstream of Jervois Dam for the 10% AEP and 1% AEP events. The average increase in peak velocities along Unca Creek is about 0.07 m/s for the 10% AEP event and about 0.11 m/s for the 1% AEP event. Given that the average peak flood velocities along Unca Creek under existing conditions are about 0.9 m/s for the 10% AEP event and 1.3 m/s for the 1% AEP event, the minor predicted increases in peak velocities due to the Project are not considered significant; and
- The relatively minor increases in peak flood levels and velocities in Unca Creek due to the upgrade to Jervois Dam are not considered significant. The increased flood levels and velocities are typically confined to the Unca Creek channel and do not affect any existing structures or property. The peak flood levels, discharges and velocities in Unca Creek with the upgraded dam in place will also be below the ‘pre-dam’ scenario.
Figure 4.4-11 Peak flood depths and extents across the entire Project area, operational conditions, 1% AEP (100 year ARI) event.
Figure 4.4-12 Peak flood depths and extents near the Reward pit and processing plant area, operational conditions, 1% AEP (100 year ARI) event.
Figure 4.4-13 peak flood velocities across entire Project area, operational conditions, 1% AEP (100 year ARI) event.
Figure 4.4-14 Peak flood velocities near the Reward pit and processing plant, operational conditions, 1% AEP (100 year ARI) event.
4.4.4.6. Groundwater

Numerical groundwater modelling was used to investigate the likely impacts of groundwater abstraction for the mine process water supply and dewatering of mine excavations on existing users.

**Drawdown at Receptors**

The closest pastoral bores (RN010717) and the bores near Lucy Creek homestead, which is about 10 km from the planned mine supply borefield. The borefield for Orttipa-Thurra Community represented by RN018072 is located about 18 km from the planned mine site.

The results from the drawdown analysis indicate that, for the 10 years scheduled life of mine, a maximum drawdown of 3 m can be expected at the closest pastoral bores (RN011101, RN011102 & RN013274), while the bores at Lucy Creek Station (RN013381 and RN018943) show a drawdown of less than 0.5 m (Figure 4.4-15).

No drawdown is observed at the Orttipa-Thurra community borefield represented by RN018072. Following closure of the mine the groundwater levels at the borefield recover to 90% of their pre-pumping levels in less than 5 years and almost completely recover after 20000d (55 years) (Appendix C6).

Groundwater modelling (Appendix C6) forecasts that the drawdown impacts around the mine as shown in Figure 4.4-16. The 0.5 m drawdown at the end of mining extends approximately 1 km beyond the mining lease to the south of Rockface underground mine.

**Life of mine inflows**

Inflows to the pits and underground mines have been determined during the life of mine (Appendix C6). Inflows into pits increase from commencement of mining and reach a peak during year 3 at about 0.2 ML/d (1.8 L/s). Inflows to the underground mines increase from commencement of mining and reach a peak during year 7 at about 6.3 ML/d (74 L/s).

**Contamination from TSF**

The mine operation tailings will be stored in a tailings storage facility (TSF) to the west of Reward pit. Without proper control some tailings liquor will seep from storage in the TSF to the groundwater table. This may result in some increase in groundwater level and change to the chemical composition of groundwater. Random walk particle tracking indicates that in the long-term the particles sourced from the areas beneath the TSF will be captured by the formation of a pit-lake at Reward pit.

**Groundwater Dependant Ecosystems**

There are no identified groundwater dependant ecosystems (GDE’s) within at least 40 kilometres of the process water supply borefield and the depth to groundwater generally precludes ecosystem use. A single waterhole is mapped to the southeast of the mine site, although generally groundwater levels in the mine site are generally greater than 20 metres below ground level suggesting that this feature is likely to be disconnected from the regional groundwater system. Two sites show groundwater levels less than 5 m below ground level and are associated with Unca Creek.
There is no evidence of stygofauna at the Project site (although there presence is possible). The impact on potential stygofauna for this Project is dewatering of the aquifer habitat in proximity to the borefield. Any potential impact must be assessed in the context of habitat reduction, however, as the mine water supply will result in a water table drawdown of less than 10 m (total aquifer thickness in basin over 100 m) over a small area relative to the total Georgina Basin extent, although possible the impact would be minimal. Therefore, the risk of impact to stygofauna from groundwater drawdown is low.

Figure 4.4-15 Modelled drawdown after 10 years of groundwater abstraction from the process water supply borefield
4.4.5. Mitigation and monitoring

4.4.5.1. Mitigation

The mitigation measures put in place to safeguard surface and groundwater resources and their environmental values, to ensure the protection and resilience of water dependent ecosystems include:

- Water management systems to keep different types of water separate
- Controlled waste stockpiling (waste rock and tailings)
- Sediment dams to capture sediment and reduce turbidity
• Standard storage and handling protocols (bunded storage, spill kits etc) for processing reagents and hydrocarbons will be implemented
• Construction of low bunds at the crest of each batter to assist with surface water control on batters
• Deep ripping on the contour to assist with water management and minimisation of erosion
• Shaping the upper surface to most appropriately mangle surface water; and
• Deep ripping on the contour to assist with water adsorption and surface water control.

Water Management

The Water Management Plan (refer Section 5) provides control strategies, including a description of the surface water drainage arrangements, water management system and water balance and a discussion of options and alternatives for meeting the proposed water management objectives.

Based on the ANZECC & ARMCANZ (2000) guideline, the condition of the watercourses in the vicinity of the Project is considered as Condition 2: slightly to moderately disturbed ecosystem. The ANZECC & ARMCANZ (2000) water quality objectives (WQO) for aquatic ecosystems are considered to be the most appropriate. Where no aquatic ecosystem WQO value is available for a certain parameter, a WQO has been sourced from alternative EVs e.g. WQOs for pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), sulphate and iron were sourced from ANZECC & ARMCANZ (2000) guidelines for either livestock drinking water or recreation.

Although the water balance model suggests that managed releases will not be required from the Project, a WDL will be required to ensure flexibility for water management at the Project and to define the requirements for monitoring at the site to ensure relevant EVs are protected. A WDL will be acquired for the Project. Under a WDL, managed releases from an authorised discharge point are permitted only when the managed release will not contribute to the exceedance of water quality trigger levels specified in the WDL.

The key objectives of the Project’s water management system are:

• To protect environmental values of the receiving waters downstream of the Project during the operational period and post-closure; and
• To ensure that the Project has sufficient water available for operations during dry times.

To achieve the water management objectives and strategies, mine water is managed based on quality using the mine water quality classification system (refer section 4.4.4):

• Undisturbed Areas
• Water Storage Surfaces
• Runoff from ROM and product stockpiles (mine affected water)
• Runoff from processing plant area (mine affected water)
• Runoff from pit areas (mine affected water); and
• Waste rock dumps (sediment laden water).

The adopted principles for management of water on the site are summarised as follows:

• Existing surface water drainage patterns will be maintained where practical to do so
- Water from different sources will be managed separately
  - Undisturbed runoff will be diverted around disturbed areas where practical
  - Mine affected water collected in-open cut pits, and in the process water dam will be managed using temporary in-pit sumps and re-used within the water management system
  - Sediment-laden runoff from the proposed waste rock dumps will be captured in dedicated sediment dams and re-used within the water management system
  - Raw water (plant standard) dewatered from the open cut pits and underground mines will be reused within the water management system
- Water will be selected for use based on water quality considerations; and
- Water collected on site as part of mining operations will be used preferentially in order to reduce demand on external water sources. Water for mine operating purposes (excluding supplying potable water) will be sourced preferentially as follows:
  - Mine affected water
  - Sediment laden water
  - Raw water (plant standard), dewatered from the underground mines
  - Raw water (potable standard), sourced from Jervois Dam; and
  - Raw water (potable standard) sourced from the external borefield.

The proposed water management system (WMS) schematic for the Project is shown in Figure 4.4-17. The WMS layout for the Reward operations is shown in Figure 4.4-18 and Figure 4.4-19. Reference source not found. for the Bellbird operations.
Figure 4.4-17 Water management system (WMS) schematic
Figure 4.4-18 Proposed water management system (WMS) layout for the Reward mining operations
Figure 4.4-19 Proposed water management system (WMS) layout for the Bellbird and Rockface mining operations
Changes to streamflow in Unca Creek
There are three proposed bunds along the Unca Creek Diversion are required to prevent water overflowing from the diversion channel into the existing creek channels (and then into the Reward pit). The most upstream bund will double as the embankment wall for the Process Water Dam. Excessive velocities are not predicted in the Unca Creek diversion channel, and therefore excessive erosion (beyond what naturally occurs in streams at the Project) is unlikely to occur. Nevertheless, the diversion channel will be inspected following flow events to identify any locations where erosion is occurring and identify remediation works.

The proposed upgrade to the dam will potentially reduce the magnitude and number of overflows from the dam, particularly in the first four years of the concept mine plan. However, the existing dam has already altered the streamflow regime of Unca Creek significantly and the dam is situated in an arid catchment where it would not be unusual for the dam not to overflow for several years. While the changed streamflow within the Project area will be significant, downstream of the Project they will be insignificant and therefore no specific mitigation measures are proposed. Consideration will be given to lowering the spillway at the end of the concept mine plan.

Increase in Jervois Dam Lake Extent
The spillway level will ensure that the sacred site located upstream of the dam will not be inundated by standing water. However, the mine closure plan for Jervois Dam could include the upgraded dam remaining in place, reduction in spillway level to the pre-mining level, or complete removal of the dam, depending on whether maintaining the dam is beneficial to the post-mining landholder.

Waste Dumps
The material placed in the waste rock dumps and the proposed dump construction methods will ensure that runoff from the dumps is generally of similar quality to background runoff from undisturbed catchments within the Project site, and will not be contain acid rock drainage or significantly elevated concentrations of metalloids (beyond background values).

Final voids
The proposed final landform ensures that the only water that collects in the final voids will be surface water runoff from the pit catchments.
The final landform also provides the final voids with immunity from flooding for events up to and including the Probable Maximum Flood (PMF) event.

Water Quality
Controlled releases of water will only take place from the waste rock dump sediment dams after year 4 of Project life, provided the quality of runoff from the waste rock dumps has been proven to be equal to or better than background water quality in undisturbed drainage features within the Project area, or agreed WQOs. No controlled releases of water to the receiving environment are proposed from the process water dam.
Flooding

The Project will not have any significant impact on flooding downstream. The Jervois Dam repair and Unca Creek diversion and bunds are proposed to mitigate the potential impact of flooding on planned mine infrastructure.

Post-mining the height of the Unca Creek diversion and Process Water Dam bunds would be increased to ensure that the Reward Pit final void is protected from floodwater for the Probable Maximum Flood (PMF) event.

Emergency and contingency plan

Emergency responses to specific incidents will be carried out as per the Emergency Response Plan and Crisis Management Manual for the mine. With respect to water management, the Emergency Response Plan is implemented for a range of potential emergency scenarios:

- Exceedance of design rainfall events
- Failure of containment structures
- Loss of electrical supply; and
- Supply of critical equipment and spare parts.

Water storages at the mine will be operated in accordance with the Trigger Action Response Plan (TARP) for each structure.

4.4.5.2. Monitoring

Monitoring of surface water and groundwater quality will be ongoing as part of the Project, both for background water quality locations (undisturbed by mining), the surface water storages proposed as part of the Project, the bore field and onsite monitoring bores, as well as in receiving environments downstream of the Project area.

The Water Management Plan (refer Section 5) details a description of the water management and monitoring measures to address each of the Project impacts and maintain the effective operation of the control strategies.

Background and receiving water monitoring will continue to take place following runoff events at the monitoring locations shown on Figure 4.4-20. The proposed storages at the Project (process water dam, Jervois Dam, underground dewatering dam and waste rock sediment dams) will be monitored at least quarterly (and daily during or following significant runoff events). The proposed suite of monitoring parameters and recommended monitoring frequency is given in Table 4.4-4 Proposed surface water storage monitoring parameters and frequenciesTable 4.4-4.
Table 4.4-4 Proposed surface water storage monitoring parameters and frequencies

<table>
<thead>
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<th>Parameter</th>
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<td>Quarterly / during significant runoff events</td>
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<tr>
<td>Electrical conductivity</td>
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<tr>
<td>Total dissolved solids</td>
<td>Quarterly / during significant runoff events</td>
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<tr>
<td>Turbidity</td>
<td>Quarterly / during significant runoff events</td>
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<tr>
<td>Dissolved oxygen</td>
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<td>Sulphate</td>
<td>Quarterly / during significant runoff events</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Quarterly / during significant runoff events</td>
</tr>
<tr>
<td><strong>Metals and metalloids (filtered, unless otherwise stated)</strong></td>
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<tr>
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<td>Quarterly / during significant runoff events</td>
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<tr>
<td>Arsenic</td>
<td>Quarterly / during significant runoff events</td>
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<tr>
<td>Cadmium</td>
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<td>Zinc</td>
<td>Quarterly / during significant runoff events</td>
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4.4.6. Conclusion

The assessments undertaken demonstrate that with appropriate water management and mitigation measures in place, the potential impact of the Project on groundwater, surface flows and water quality in the receiving waters downstream of the Jervois Mine will be acceptable.

The Project is able to meet the NT EPA’s objective related to surface water and groundwater to: “maintain the hydrological regimes of groundwater and surface water so that environmental values are protected both now and in the future”.
Figure 4.4-20 Locations for surface water monitoring program