Surface Water 10

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10 SURFACE WATER

10.1 INTRODUCTION

This section provides a description of the surface water setting of the Eastern Leases Project (the project), the potential impacts on surface water and the water management strategies and systems proposed to manage these potential impacts. It draws on specialist studies undertaken for the Environmental Impact Statement (EIS), including the *Surface Water Drainage Report* (Appendix G), *Baseline Surface Water Monitoring Report* (Appendix H) and *Geochemistry Report* (Appendix A).

The Environmental Risk Assessment presented in Section 4 identifies all potential project risks in relation to surface water and determines the consequence and likelihood of each risk, and the overall risk rating. Risk ratings are provided for the risk both with and without the application of mitigation measures. The risk assessment has concluded that, with the application of the proposed mitigation measures, the majority of risks associated with surface water are low risks, and that there are no high or extreme risks. This section provides further detail on the impacts on surface water that have been identified for the project, as well as the mitigation measures that will be applied.

10.2 SURFACE WATER SETTING

This section describes the existing surface water setting of the project and provides a suitable baseline for the assessment of potential project impacts. It includes an overview of the regional catchment setting, and provides a detailed description of surface water drainage characteristics, environmental values and quality. This description draws upon watercourse monitoring data presented in the *Baseline Surface Water Monitoring Report* (Appendix H).

10.2.1 Regional Catchment Setting

The project site is located on Groote Eylandt, a 2,285 km^2 island in the Gulf of Carpentaria. The central areas of the island are characterised by elevated rocky outcrops that form hills and escarpments. The rocky outcrops limit the vegetation and soil cover within this central portion of the island. Between these hills and escarpments, the low-lying topography forms densely vegetated, gently sloping valleys that open into flat coastal plains. These hills and escarpments define the surface water catchments across the majority of the island. The relief of the landscape in the area surrounding the project site is shown in Figure 10-1 and Figure 10-2.

The Northern Eastern Lease (Northern EL) and the Southern Eastern Lease (Southern EL) (collectively termed the Eastern Leases) are located in the upper catchments of the Emerald River, Amagula River and Angurugu River (Figure 10-1). The Eastern Leases are located at the head of these catchments and site drainage is therefore highly ephemeral through the majority of the project site. Figure 10-2 shows the existing drainage features within the catchments. For the purposes of this section, all rivers and tributaries shown on Figure 10-2 are termed watercourses.

Regionally, the surface geology is naturally enriched in metals and depleted in minerals, and exhibits low soil erosion rates. This results in naturally low suspended sediment loads and elevated metals in watercourses.

The project site is undeveloped and the catchment setting is essentially undisturbed. Downstream regional land uses include the existing mine, rural Aboriginal settlements (termed “outstations”) and recreational areas (Figure 10-1 and Figure 10-2). Roads and associated watercourse crossings are present, most notably the Emerald River Bridge which crosses the lower Emerald River approximately 8.3 km downstream of the Northern EL (Figure 10-2).

10.2.2 Drainage Setting

Overview

The local drainage and catchment setting is shown in Figure 10-2 and Figure 10-3.

The majority of the project site drains towards the coast from elevated rock outcrops located at the periphery of the project site. The Emerald River and its tributary watercourses drain the majority of the Northern EL and the western area of the Southern EL. The Amagula River drains the eastern area of the Southern EL via the main channel and two tributary watercourses. The main channel of the Angurugu River does not traverse the project site.

Other drainage features include a network of minor gullies in the steeper topography associated with elevated outcrops, and overland flow paths in the lower lying areas. These drainage features coalesce to form regionally significant watercourses in the flatter areas of the project site. The main watercourses are typically channelised through the project site and characterised by narrow rocky channels and chains of pools.

Although the majority of watercourses within the project site are ephemeral, some sections of watercourses are predicted to receive groundwater inflows which contribute to surface water baseflow. Figure 10-4 shows the sections of watercourses that have been mapped as perennial, based on the results of the aquatic ecology impact assessment, the geomorphology study, groundwater modelling predictions and from general observations made from the baseline surface water quality monitoring program.

Watercourse Assessment Methodology

A detailed assessment has been undertaken to establish the physical characteristics of the watercourses that traverse the project site. The assessment included a watercourse geomorphology study and analysis of watercourse flow data.

The geomorphology study involved the review and interpretation of recent high resolution aerial photography and topographic information, review of published vegetation and geological mapping, and a multi-day field survey of 66 sites conducted in accordance with the *Australian River Assessment System: AusRivAS Physical Assessment Protocol* (AusRivAS Protocol) (Parsons *et. al.,* 2002). The watercourse geomorphology study and full results are presented in the *Baseline Surface Water Monitoring Report* (Appendix H).

A review of the NT Department of Land Resource Management (DLRM) Water Data Portal was undertaken to establish the baseline watercourse flow rates. This review identified two historical watercourse flow gauging stations which are relevant to describing the baseline drainage setting of the project. These gauging stations are located downstream of the project site on the Emerald River at the Old BHP Camp (Station G9290211) and the Amagula River at Ripplestone Gorge (Station G9290005), as shown on Figure 10-2. The Emerald River gauging station (G9290211) was in operation from 1963 to 1988, while the Amagula River gauging station (G9290005) was in operation from 1969 to 1983. Further details of these watercourse flow gauging stations and flow data analysis results are presented in the *Baseline Surface Water Monitoring Report* (Appendix H).

The drainage setting and geomorphic characteristics of the relevant watercourses and tributaries in the vicinity of the project are described in the following sections. Each watercourse is described in descending (i.e. upstream to downstream) order along the main channels.

Emerald River and Tributaries

The Northern EL is primarily drained by the upper reaches of the Emerald River and Emerald River – Tributary 1 (Figure 10-2).

Drainage from several incised gullies converges near the eastern upstream boundary of the Northern EL to form the Emerald River – Main Channel. The upstream catchment to this point is approximately 523 ha and is characterised by rock outcrops and relatively sparse vegetation. The main channel traverses the Northern EL east to west for 3.5 km in a gentle arc. The channel is typically well-defined for the majority of its length. The channel bedform and banks are largely controlled by exposed rock, with channel elevation falling 30 m across the project site as it follows the surface of the underlying rock.

Downstream of the Northern EL, the main channel continues to flow south-west. Approximately 2.3 km downstream of the Northern EL, the main channel loses definition and converges with the Emerald River – Tributary 1 and overland flowpaths and forms an alluvial fan.

The catchment area of the Emerald River – Tributary 1 is 645 ha. This represents approximately 25% of the Emerald River catchment upstream of the confluence of these watercourses. The catchment and drainage channel are comparable to the main channel, with the tributary transitioning from incised gullies to an alluvial fan over a similar distance.

Approximately 1.1 km downstream of the Emerald River – Tributary 1 confluence (and 3.4 km downstream of the Northern EL), Emerald River – Tributary 3 enters the main channel from the north. The main channel and the inflowing tributary are both ephemeral at this point. The Emerald River – Tributary 3 sub-catchment has an area of 780 ha and is closely bounded on three sides by elevated rock outcrops. This catchment area represents only 20% of the Emerald River catchment upstream of the confluence of these watercourses. The tributary comprises a shallow incised gully with a narrow rocky bed.

The main channel continues south-west from the Emerald River – Tributary 3 confluence. As the channel elevation decreases, groundwater baseflow supports perennial flow between pools connected by narrow rock chutes.

Emerald River – Tributary 2 enters the main channel 4.7 km downstream of Emerald River – Tributary 3. Emerald River – Tributary 2 has a catchment area of 2,393 ha. This sub-catchment contains the western portion of the Southern EL.

The Emerald River – Tributary 2 headwaters form in the western part of the Southern EL. Overland sheetflow follows unchannelised flowpaths west across the undulating elevated area that forms the Amagula River catchment divide. These flowpaths coalesce and become channelised as they flow north-west across the Southern EL. The channel transitions to an open network of slow moving perennial pools connected by narrow silted channels as it exits the northern boundary of the Southern EL.

The main channel continues 4.5 km south-west from the Emerald River – Tributary 2 confluence and enters the Gulf of Carpentaria approximately 12.6 km downstream of the Northern EL and 7 km downstream of the Southern EL (Figure 10-1). The estuarine reach of the Emerald River extends approximately 4 km upstream of the coastline.

Gauged flows in the lower reaches of the Emerald River are typically seasonal and range from 0.15 to 7.3 m^3/s.

The Strahler stream ordering system describes the size and complexity of a river network on a numerical scale from 1 to 12. Under the Strahler stream ordering system, small watercourses with a limited network of tributaries are assigned a low number, while significant rivers with a complex network of tributaries are assigned a high number. The stream order of a watercourse generally increases as tributaries combine and rivers approach their outfall. The Emerald River – Main Channel and Emerald River – Tributary 2 are small watercourses with limited tributaries and classed as 2^{nd} to 3^{rd} order streams, upstream of their confluence. These watercourses combine to form a slightly more complex tributary network. The Emerald River is considered as 3^{rd} to 4^{th} order stream downstream of this confluence.

Amagula River and Tributaries

The eastern area of the Southern EL is drained by the Amagula River and its tributaries Amagula River – Tributary 1 and Tributary 2 (Figure 10-2).

The Amagula River – Main Channel enters the Southern EL from the east and traverses the south-eastern corner of the Southern EL. The river flows approximately 0.8 km across the Southern EL and exits to the south. The upstream catchment of the Amagula River at this location is approximately 10,942 ha. The main channel is characterised by broad rocky pools connected by rock chutes and bounded by rock outcrops and rocky banks. The bed of these pools contains a thin layer of mud and silt. The main channel flows perennially through the Southern EL.

Amagula River – Tributary 2 flows ephemerally into the main channel at the boundary of the Southern EL. The Amagula River – Tributary 2 catchment comprises an area of 1,991 ha, which represents approximately 15% of the Amagula River catchment upstream of the confluence of these watercourses. The catchment is bounded by rock outcrops, with the channel geomorphically similar to the main river channel, albeit on a smaller scale.

From this confluence, the Amagula River – Main Channel flows west parallel to the Southern EL boundary. This reach of the main channel is characteristically rocky and receives inflows from overland flowpaths and a minor gully to the north.

Approximately 3 km downstream of the Amagula River – Tributary 2 confluence and 900 m south of the Southern EL, Amagula River – Tributary 1 flows perennially into the main channel from the north. The Amagula River – Tributary 1 catchment comprises 1,476 ha and is geomorphologically comparable to the Amagula River – Tributary 2.

A further 1.7 km downstream, the Amagula River – Main Channel becomes confined as it flows through an incised rock outcrop. As the river exits this area it becomes less confined, resulting in sediment deposition. A substantial sand bar has formed in this area on the inside of the main channel and forms part of the Leske Pools recreational area.

The Amagula River – Main Channel continues 17.4 km south and enters the Gulf of Carpentaria approximately 22 km downstream of the Southern EL (Figure 10-1). The estuarine reach of the Amagula River – Main Channel extends approximately 4 km upstream of the coastline and approximately 18 km downstream of the Southern EL.

Gauged flows in the Amagula River typically range from 0.09 to 7.1 m^3/s.

Under the Strahler stream ordering system, the Amagula River within the project site and upstream of the Amagula River – Tributary 2 confluence is a 4^{th} order watercourse. Downstream of the confluence the Amagula River is classed as slightly larger 5^{th} order watercourse.

Angurugu River

The Angurugu River catchment extends from the elevated rock outcrops present to the north and east of the Northern EL (Figure 10-3). A topographic saddle between these outcrops forms a catchment divide between the Emerald and Angurugu rivers in the north-east of the Northern EL.

The Angurugu River is located approximately 2 km north of the Northern EL and flows generally westward for 21.1 km from its headwaters in the centre of the island to its mouth at the coastline (Figure 10-1). The river mouth is located approximately 14 km north of the Emerald River estuary.

An area of 181 ha in the north-east of the Northern EL drains to the Angurugu River via minor drainage lines and overland sheetflow (Figure 10-3). This area will not be disturbed by project activities.

The existing mine operates an approved abstraction from the Angurugu River 13 km downstream of the Northern EL. Water abstracted by the existing mine is treated to potable standards at the abstraction point and used as potable water supply for Alyangula and Angurugu townships, and the mine.

10.2.3 Surface Water Use and Environmental Values

The surface water resources in the vicinity of the project site currently support a range of environmental values including aquatic ecosystems and human uses. The existing environmental values relevant to the project surface water setting have been identified from a review of local and downstream land uses, stakeholder consultation and through reference to published information (Harrison et al, 2009).

A detailed ecological assessment of the project site and catchment setting was undertaken as part of the *Aquatic Ecology Report* (Appendix D). This assessment indicates that the project site and its surroundings are considered to be ecologically undisturbed and of high conservation value.

The Leske Pools swimming hole is located 2.4 km to the south of the Southern EL and is frequently used by locals for day trips, overnight camping or camping over extended periods (Figure 10-2). The section of the Emerald River north of Yedikba Outstation and near the Emerald River Road bridge is another area popular for swimming (Figure 10-2).

Water quality values associated with farming or agriculture are not relevant because no farming or agricultural activities have been undertaken within the project site or surrounding area.

There are also two small, rural outstations located downstream of the project site (Figure 10-2). These outstations are not permanently occupied, with the level of use ranging from occasional visitation to sporadic residency. Although water supply bores are located at each outstation, untreated drinking water supply is understood to be sourced primarily from adjacent perennial watercourses.

The project site and catchment setting are considered to be environmentally and culturally sensitive. Specifically, the Emerald River and Amagula River are both known to be sensitive watercourses from a cultural perspective.

The NT *Water Act* provides a framework for the protection of environmental values. Under this framework, environmental values can be formalised through a process of statutory declaration. Environmental values formalised under the *Water Act* are known as beneficial uses. Beneficial uses have been declared for the Emerald River, Angurugu River and their receiving coastal waters west of Groote Eylandt. The declared beneficial uses for these waters are aquatic ecosystem protection, recreational water quality and aesthetics.

In summary, the surface water environmental values relevant to the project are:

- High conservation value aquatic ecosystems;
- Recreational use, including swimming and aesthetic values;
- Human consumption (i.e. drinking water); and
- Cultural values.

These environmental values and cultural sensitivities have been considered in determining the water management strategies for the project.

10.2.4 Surface Water Quality

Monitoring Program

The proponent has established a site-specific surface water monitoring program for the project. The surface water quality monitoring program comprises a total of eight monitoring sites, with three monitoring sites located in the Emerald River catchment and four monitoring sites in the Amagula River catchment. The distribution of these monitoring sites is shown on Figure 10-2.

The monitoring program was designed to establish the baseline surface water quality prior to commencement of the project, and allow the ongoing collection of water quality data over the life of the project. Monitoring sites were therefore located to provide long-term data from appropriate reference sites (i.e. upstream of proposed project activities or within equivalent undisturbed and high conservation value watercourses), within and downstream of areas potentially affected by project activities, and confluences where water quality is affected by mixing of watercourses. The rationale behind the selection of each representative monitoring site is explained in the *Baseline Surface Water Monitoring Report* (Appendix H).

A 12 month baseline dataset (January to December 2014 inclusive) is presented in the EIS, and data is continuing to be collected on an ongoing basis. The monitoring program includes field testing and laboratory analysis for a broad range of physico-chemical parameters. Parameters monitored include electrical conductivity (EC), pH, suspended solids, turbidity, ions, nutrients, total and dissolved metals and metalloids and total petroleum hydrocarbons.

The proponent also currently maintains a surface water monitoring program as part of the existing mining operations. This existing surface water monitoring program includes three monitoring locations on the lower and estuarine reaches of the Emerald River (EMP1 to EMP3). Monitoring data collected from the lower and estuarine reaches of the Emerald River over the duration of the project surface water quality monitoring program has been presented in the *Baseline Surface Water Monitoring Report* (Appendix H) for completeness. However, water quality data collected as part of the existing mine surface water monitoring program is not representative of the watercourses in the vicinity of the project site, given that the monitoring sites are well downstream of the project site in the estuarine and lower reaches of the Emerald River. Data from these three monitoring sites has not, therefore, been used to establish baseline conditions for the project.

Additional water quality data has been collected from within the project site as part of the preparation of the *Aquatic Ecology Report* (Appendix D). This data was generally consistent with the findings of the baseline surface water quality monitoring program presented in the following section.

Baseline Water Quality Assessment

The median baseline water quality is summarised in Attachment 10-1. Relevant guideline values for drinking water (NHMRC and NRMMC, 2011) and recreational use (ANZECC, 2000) are also quoted for reference.

The National Water Quality Management Strategy Paper 4: *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000) (ANZECC Guidelines) do not provide guideline values for the assessment of pristine aquatic ecosystems or systems with naturally enriched geology.

In general, the baseline water quality of the Amagula and Emerald Rivers is similar, reflecting the similar geology and catchment conditions across these catchments. The waters within both drainage networks are typically acidic and non-saline with low turbidity and suspended sediment. Locally elevated levels of sediment and salinity were recorded, although these instances generally coincided with low watercourse flows and remnant pools. This is consistent with the geomorphic assessment which confirmed deposited sediments within the drainage channels are generally localised to remnant pools.

Vegetation breakdown typically exerts an oxygen demand. The data shows sporadic decreases in dissolved oxygen concentrations that reflect this demand. These locally depleted oxygen concentrations are once again associated with remnant pools rather than flowing waters.

Long-term salinity (as electrical conductivity and total dissolved solids), pH, alkalinity and major ion levels are generally similar throughout the regional drainage network.

Naturally elevated concentrations of several metals are present including aluminium, copper, manganese and zinc. The presence of these metals reflects their enrichment in the underlying geology. All other metals and metalloid concentrations are at or below the applied limits of detection.

Baseline water quality was found to exceed relevant guideline values for drinking water and recreational use due to acidity and occasionally elevated metal concentrations (i.e. manganese), reduced oxygen saturation and water hardness.

10.3 MINE PLANNING AND SURFACE WATER MANAGEMENT

10.3.1 Project Overview

The project involves developing several quarries in the low-lying valleys of the Eastern Leases and construction of limited mine infrastructure to support the mining activities. The manganese ore is extensive throughout the valleys and underlies several watercourses traversing the project site (Figure 10-7). Manganese ore will be mined using open cut mining methods.

The manganese ore will be transported from the project site by truck on the new haul road connecting the site to the existing mine. The catchment setting of the project necessitates haul road crossings of watercourses within the project site and along the connecting haul road alignment.

10.3.2 Project Planning Process

The project planning process identified the Emerald and Amagula Rivers, and their tributaries, as being culturally and environmentally sensitive. Mine planning was cognisant of these sensitivities and a strategy for mining in the vicinity of these surface waters was developed over a period of approximately 18 months.

Mine planning, integrated with environmental impact assessment, was conducted to ensure the key watercourses traversing the project site will not be significantly impacted by the project. The proposed mine plan is designed to avoid any significant disturbance of the key watercourses, whilst still enabling efficient and economic access to the resource.

Key potential surface water impacts that were considered in the mine plan development included:

- The change in catchment areas resulting from the progression of the mine, which has the potential to result in downstream catchment yield impacts;
- Mining disturbance altering downstream drainage and potentially resulting in:
  - Changes to flood behaviour including flow paths, flood inundation areas and flow velocities; and
  - Geomorphic impacts on watercourses and drainage lines, including channel bed and bank instability.
- Sedimentation of downstream watercourses during construction and operations due to erosion from disturbed areas on the project site and increased sediment loads in site drainage water;
- Discharge of quarry water resulting in downstream water quality impacts on environmental values and water users; and
- Impacts of the final landform on surface drainage.

A detailed assessment of the potential surface water impacts has been conducted as part of the project planning and design process. Mitigation of any potential adverse impacts on surface water resources has been incorporated into the proposed mine plan, as far as is practical and economically feasible.

10.3.3 Mine Planning Design Principles

Features specifically incorporated into the mine design to manage these potential impacts are described in the following sections. Additional operational management and mitigation measures have been proposed to manage any residual risks of potential impacts to surface waters. These are summarised in Section 10.6.

Mining of Watercourses

The project has been designed to ensure that mining will not encroach on any of the significant watercourses traversing the project site (Figure 10-5). In particular, buffers have been defined around the main channels of the Emerald River, Amagula River and their tributaries. The mine plan and quarry extents were then designed to ensure no encroachment on the buffers, and to restrict mining to areas beyond the defined drainage channels and associated buffers.

The buffers were delineated by the predicted extent of the 1% Annual Exceedance Probability (AEP) (1 in 100 year) flood extents. The *Surface Water Drainage Report* (Appendix G) provides detail on the flood modelling that was undertaken to delineate the buffers.

Hydrology models were developed to calculate a range of design flood flows in the watercourses in the vicinity of the project site. The hydrology modelling results were validated against design flows estimated using the Rational Method in accordance with the procedures given in Australian Rainfall and Runoff (Pilgrim, 1998).

The hydrology model results for the 1% AEP (1 in 100 year) flood flow were used to develop a 2D TUFLOW hydraulic model that calculated the flooding behaviour along the Emerald and Amagula Rivers and their floodplains in the vicinity of the Eastern Leases. The hydraulic model calculated flow directions, depths and extents of flooding within the Eastern Leases. These extents were used to define the drainage buffers.

As determined by flood modelling, no watercourse diversions or flood control levees are therefore required as a result of the project and open cut mining is not anticipated to have any direct impact on watercourse geomorphology.

Post-Mining Landform Design

Project landform design will ensure that all quarries will be backfilled with overburden, creating a free draining landform that broadly replicates the pre-mining topography. Backfilling the quarries in this way will ensure that there will be no elevated overburden emplacements or final voids at the end of the mine life. It is much more common in the mining industry to have final landforms that include elevated overburden emplacements (i.e. free standing emplacements/stockpiles that may be tens of metres high) and final voids (i.e. deep quarries that are not backfilled and consequently accumulate water over time). The project has avoided the need for elevated overburden emplacements and final voids through careful mine planning and scheduling.

The post-mining landform is shown on Figure 3-15. The final landform design will ensure that there is no long-term reduction in downstream catchment yield.

The post-mining landform stability and flood behaviour was confirmed though detailed flood modelling under 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1,000 year) flood events. The *Surface Water Drainage Report* (Appendix G) provides detail on the flood modelling that was undertaken to assess the post-mining landform flood behaviour.

10.4 WATER MANAGEMENT STRATEGIES

The project will require the management of the following waters:

- Quarry water comprising:
  - Groundwater inflow to the quarries; and
  - Runoff from the quarry catchment.
- Runoff from areas disturbed by project activities including overburden emplacement areas and mine infrastructure areas; and
- Runoff from areas undisturbed by project activities.

The proposed management strategy for each type of water generated by the project is dependent on the quality of the water and is designed to prevent any adverse impacts on downstream surface water values identified in Section 10.2. Key water management objectives that were considered in the mine planning process included:

- Maximising the reuse of quarry water for water supply;
- Ensuring a reliable supply of water for the operations, whilst minimising the demand for external supply;
- Minimising the risk of discharge of any quarry water; and
- Minimising the generation of mine contact water (i.e. water that has been in contact with areas disturbed by mining activities).

The broad strategies for management of the waters that will be generated by the project are:

- Where possible, divert clean runoff from undisturbed areas around areas disturbed by mining activities and allow to drain from the site;
- Control suspended sediment in site drainage water in accordance with an Erosion and Sediment Control Plan. This will include collecting sediment-affected water, and directing it through sediment control structures to limit any potential downstream sedimentation; and
- Contain quarry water in on-site water storages for reuse as a water supply to the mine (i.e. mine water supply).

The proposed management strategies for each of the waters generated by the project are discussed in detail in the following sections. The staged site drainage plans and design principles are also described in the following sections and illustrated in Figure 10-6 to Figure 10-10.

The management of sewage effluent generated by the project is discussed separately in Section 17 – Non-mining Waste.

10.4.1 Quarry Water

Quarry pit water comprises groundwater inflow to the active quarries and runoff from quarry catchments.

Predicted groundwater inflow to the active quarries is discussed in detail in Section 9 – Groundwater. Groundwater inflows to the active quarries will predominantly occur from the shallow laterite aquifer. Groundwater inflow rates will fluctuate in response to seasonal changes in this aquifer, but will generally increase over the life of the project as the size of the quarry excavations increases. Groundwater inflows are predicted to peak at a rate of approximately 212 ML/a. A proportion of groundwater inflow will be lost to surface wetting, evaporation and infiltration to the quarry walls and floors. The residual peak groundwater inflow available for dewatering from the quarries is predicted to be 170 ML/a.

The quarry catchments are contained catchments that include the active quarry areas, as well as any areas of the overburden emplacement and areas above the highwall that cannot be drained around or away from the quarry pit. Temporary and permanent diversion drains will be constructed to isolate the contained catchments of the quarries and to divert runoff from undisturbed areas through the mining areas. This drainage strategy is designed to minimise the quarry catchment area over the life of the project.

Diversion drains will typically be contour drains constructed with sufficient capacity to convey runoff from the 1% AEP (1 in 100 year) critical storm event. The specific design capacity of each drain will be determined at the detailed design stage depending upon the contributing catchment, design life of the drain and overtopping risk. This design will minimise potential disruption to production due to flooding of the active quarries and also minimise the generation of large volumes of quarry water from rainfall runoff. This will result in a short-term reduction in the total catchment runoff from the project site compared to existing conditions and represents a negligible proportion of the overall receiving catchment areas. The conceptual quarry drainage strategy is illustrated in Figure 10-6 to Figure 10-10.

Quarry water quality will vary slightly depending on the relative contributions from groundwater inflow, seepage and runoff from in-pit overburden emplacements and rainfall runoff. As discussed in Section 9 - Groundwater, baseline groundwater quality is non-saline (i.e. freshwater) and contains low levels of metals that are leached from the natural geology. The *Geochemistry Report* (Appendix A) characterised overburden seepage and runoff as non-saline and typically low in metals, with the exception of naturally occurring manganese. This report also found that non-dispersive clay minerals (such as smectite and kaolinite) sporadically present within the excavated overburden material are not likely to significantly affect quarry water quality. Geochemical testing on these materials found that they are non-dispersive. Runoff from undisturbed quarry catchment areas is also likely to be non-saline and contain naturally occurring metals.

Quarry water will drain to collection sumps in the floor of the active quarries. This water will be pumped to dedicated on-site storage dams or available quarry pits and used as mine water supply. A single quarry water dam will be located in the Northern EL and two mine water dams will be constructed in the Southern EL (Figure 10-6 to Figure 10-10). The mine water dams will each have nil external catchment and will be operated with maximum operating storage levels and a freeboard to ensure nil overflow. Alternatively, available quarry pit voids may be used for quarry water storage. Dam design principles and operation are described in Section 10.5.

10.4.2 Runoff from Areas Disturbed by Mining Activities

Runoff from Overburden Emplacement Areas

The project will involve the progressive development and rehabilitation of overburden emplacement areas. The progressive development and rehabilitation of these areas is shown on Figure 10-6 to Figure 10-10.

Geochemical characterisation of the overburden material was completed as part of the *Geochemistry Report* (Appendix A). The geochemical assessment concluded that the bulk overburden material is likely to generate benign, non-saline runoff. Long-term geochemical testing of worst-case (i.e. fully oxidised and free-draining) leaching conditions demonstrated that metal and metalloid concentrations in overburden runoff will typically be less than laboratory limits of detection, with the exception of naturally elevated manganese. These results show that overburden runoff quality would fall within the range of natural background surface water quality and would therefore be suitable for passive drainage from site. In reality, the short contact duration between runoff and overburden materials and high levels of rainfall dilution would provide an additional factor of safety in the quality of water passive draining from these areas.

Runoff from active overburden emplacement areas may however contain elevated levels of suspended sediment. Runoff from these areas will be captured in collection drains and directed through sediment traps and sediment dams for control of suspended sediment prior to discharge from site. Collection drains will typically have sufficient capacity to convey runoff from 10% AEP (1 in 10 year) critical storm event. The collection drains will typically be contour drains. Longitudinal grades will be typically 1% and cross-section batters will be constructed to stable slopes and revegetated to minimise erosion. Any steeper sections will be constructed with velocity control structures or scour protection. Discharge points to natural drainage lines will be designed with energy dissipation measures, where necessary, to prevent any scouring and ensure stability.

Collected runoff will generally be directed to one or more sediment dams prior to draining from the site. In addition to sediment dams, a network of smaller sediment traps will also be installed close to any significant sources of sediment. This will effectively achieve a staged approach to removal of suspended sediment from site drainage water with coarser sediments being trapped close to the source and finer sediments trapped in the larger sediment dams. Sediment traps will be installed progressively over the life of the mine immediately downstream of any exposed overburden. They will generally be constructed as excavated pits at a size readily desilted by an excavator. The precise number and location of sediment traps will be determined during preparation of the detailed Erosion and Sediment Control Plan. Sediment dams will be designed and constructed generally in accordance with relevant engineering guidelines including the International Erosion Control Association Best Practice Erosion and Sediment Control Guidelines. The detailed design of each dam will be dependent on specific site conditions and the design life of the dam, but will typically be designed to manage inputs from the 10% AEP (1 in 10 year) critical storm event. All sediment traps and sediment dams will be regularly desilted to ensure their continued effective operation. The Erosion and Sediment Control Plan is discussed in more detail in Section 10.8.2.

Rehabilitation of the overburden emplacements will be undertaken progressively over the mine life and will be completed at the end of mining operations. Rehabilitation will involve establishment of a stable final landform that will promote surface runoff. Contour drains will be constructed on the rehabilitated final surface, where necessary, to prevent erosion of the final landform. Rehabilitated areas will generate clean runoff that will be allowed to drain passively to downstream overland flowpaths. Overburden emplacement area rehabilitation is discussed in detail in Section 6 – Mine Rehabilitation and Closure.

Runoff from Mine Infrastructure Areas

The project infrastructure is shown in Figure 10-6 to Figure 10-10 and is limited to:

- Unsealed haul roads.
- Dams and associated infrastructure including water fill points.

- A crib hut in each of the Northern EL and the Southern EL. The crib huts would be small demountable structures providing basic staff facilities (i.e. potable water, ablution facilities, dining area and kitchenette).
- Separate light and heavy vehicle parking areas, adjacent to the crib huts. These also include areas for basic servicing of vehicles and equipment.

Runoff from these infrastructure areas may contain elevated levels of suspended sediment. These infrastructure area catchments will be isolated with diversion drains and/or bunding, where necessary. Runoff from these areas will be intercepted by collection drains and directed through sediment traps and sediment dams for control of suspended sediment prior to discharge from site. Collection drains will typically be table drains with sufficient capacity to convey runoff from 10% AEP (1 in 10 year) critical storm event. These works will be designed and constructed in accordance with an Erosion and Sediment Control Plan.

Similarly, during construction, runoff from all disturbed mine infrastructure areas may contain elevated levels of suspended sediment. Runoff from these areas will be collected, allowed to settle and passively discharged as outlined for operational infrastructure areas. These works will be designed and constructed in accordance with a construction phase Erosion and Sediment Control Plan.

Infrastructure areas that are used for the basic servicing of vehicles and equipment will also be equipped with spill kits to manage any minor hydrocarbon spillage and prevent contamination.

Haul Road Watercourses Crossings

Haul roads are proposed to cross watercourses as shown on Figure 10-5, in the following locations:

- In the haul road corridor at one location on the Emerald River – Main Channel, and at one location on the Emerald River – Tributary 3;
- In the Northern EL at two locations on the Emerald River – Main Channel; and
- In the Southern EL at one location on the Amagula River Tributary 1.

All haul road crossings are located within ephemeral reaches of these watercourses.

Haul road crossings will be installed with low flow drainage culverts in the road formation. Culverts have been designed to allow unimpeded drainage of the 50% AEP (1 in 2 year) flood flow. Floods larger than the design event will be allowed to flow over the culvert to maintain drainage within these watercourses. These crossings will be constructed progressively as the operations expand over the life of the mine and once constructed will remain operational for the life of the mine. The crossings will be removed at the end of the mine life at the discretion of the Anindilyakwa Land Council and Traditional Owners.

10.4.3 Runoff from Areas Undisturbed by Mining Activities

Wherever possible, runoff from undisturbed areas will be diverted around (and away from) areas disturbed by mining activities and allowed to drain from site as discussed in the preceding sections. The locations of diversion drains for clean water diversion are shown in the staged drainage plans (Figure 10-6 to Figure 10-10).

A strategy for the specific management of quarry interaction with watercourses has been developed as an integral component of project planning. This strategy is described in detail in Section 10.3.

10.5 WATER MANAGEMENT SYSTEM

The project is an additional mining area that will be operated as part of the existing mine, rather than an independent mine.

The existing mine operates a water management system that includes all water supplies and demands associated with ore processing and tailings management. The project will not affect the supplies and demands on the water management system at the existing mine. The water management system within the existing mine is subject to existing environmental approvals, and no changes to these approvals or additional approvals are required for the existing mine as a result of the project. The project water management system will be separate and independent of the water management system at the existing mine.

Consequently, the proposed water management system for the project is straightforward and limited to the containment and reuse of quarry water for mine water supply (i.e. dust suppression). Quarry water is described in Section 10.4. The proposed water management system logic is consistent with the requirements of the Water Accounting Framework for the Minerals Industry (Minerals Council of Australia, 2014) and is presented in Diagram 10-1. Figure 10-11 illustrates the generation of water supplies, the containment of the water, and the project's water demands.

Diagram 10-1 Conceptual Water Management System

The water management system is described in the following sections along with the water balance for the proposed operations.

10.5.1 Water Supplies

Sources of water supply for the project are limited to quarry water, comprising:

- Variable groundwater dewatering volumes of up to approximately 170 ML/a; and
- Variable rainfall runoff to the quarry catchments.

Groundwater inflow is discussed in Section 9 – Groundwater. The rate of groundwater inflow to quarries generally increases as the quarry footprint and depth increases. The groundwater inflow volumes have been predicted using the numerical groundwater model described in the *Groundwater Report* (Appendix F).

Rainfall runoff volumes will be dependent on the contained quarry catchment areas and the rainfall.

Contained quarry catchment areas will vary as quarries are developed over the life of the mine. The staged development of these areas has been reflected in the water balance model in order to capture the variation in runoff contribution over the life of the mine. Key stages in the development of these areas are shown in Figure 10-6 to Figure 10-10.

Rainfall runoff captured as quarry water from all contributing catchment areas has been modelled based on daily rainfall data. Modelling and climate data are discussed in detail in Section 10.5.5.

External water supply will be sourced from excess water from the existing mine when insufficient quarry water supply is available at the project site.

10.5.2 Water Demands

The only project water demand is dust suppression water supply for haul roads, active quarry workings, and overburden emplacements. A demand of up to 780 ML/a is forecast. This demand will be preferentially supplied from stored quarry water.

Water losses for the project are typically variable over the life of the project and include evaporative losses from mine water storages.

Potable water supply for the project will be sourced from the existing water treatment plant located adjacent to the Angurugu River. Water is abstracted from the Angurugu River at the water treatment plant, and treated to potable standards through pH balancing and chlorination. The existing water treatment plant has sufficient capacity to accommodate the project demand for potable water supply. Potable water supply will be transported to the project site by tanker.

10.5.3 Mine Water Dams

Mine water dams will be constructed on the project site to collect and contain quarry water. Quarry water will be pumped to these dams via a pipeline from the adjacent quarries. These dams will be a primary source of dust suppression water supply. These dams will have nil external catchment and will be operated with a freeboard to ensure they do not overflow. In order to minimise the accumulation of runoff in the quarries during extended wet periods, quarry water will be transferred to these dams as a high priority and may accumulate in these dams during extended wet periods.

The location of these dams is shown in Figure 10-6 and Figure 10-10. All dams will be designed and constructed in accordance with relevant engineering design standards and licence requirements. Designs will adequately address the structural integrity of containment walls during climatic extremes, including drought and flood. The need for a liner will be determined during detailed design phase.

The dam sizings and containment performance have been determined by operational simulation modelling, as discussed in the following section.

10.5.4 Operational Modelling Method

An operational simulation model has been used to assess the project water balance across a range of climatic conditions over the life of the project. The model provides a dynamic simulation of water movement within the proposed water management system over the life of the project.

The modelling was undertaken using GoldSim software. GoldSim is an operational simulation program used for modelling both natural and industrial water resource systems. It is industry recognised and has been used extensively throughout the Australian resource sector and is ideally suited for application to the project water balance.

The water balance model has been used to assess:

- Appropriate sizing and location of dams to collect and store quarry water with a low probability for uncontrolled discharges;
- The availability of quarry water for dust suppression water supply and the volume of external water supply necessary for the project; and
- Frequency and volumes of any necessary controlled releases of excess quarry water to enable dewatering of the quarries following extended wet periods to avoid disruption to production and maintain a continued factor of safety for mine site personnel.

Modelling Logic and Assumptions

The operation of the water management system and the requirement for external water supply, or controlled discharge of any quarry water, will be dependent on numerous dynamic factors which will vary over the life of the mine. Consideration of static project stages in isolation over single wet or dry years will therefore not capture the full range of operational water management scenarios which may occur over the proposed mine life.

The operational performance of the water management system has therefore been dynamically simulated over the entire operational mine life. The operational mine life has been represented by detailed profiling of the progression of quarry development, groundwater inflows and catchment areas over the 13 years of mining activity, and has been assessed using a series of historical climate sequences. This approach has enabled the assessment of a broad range of water supply, water demand and management scenario combinations which could potentially occur over the mine life. The simulations are based on daily water balance iterations.

The performance of the water management system was simulated using consecutive 13-year climate sequences taken from the 124 years of historical climate records available for the project site. A total of 113 historical climate sequences were assessed and the model simulation consequently involved 113 x 13 climate sequences (a total of 1,469 years of mining). The performance of the water management system has therefore been evaluated for all possible combinations of mine development timing and climate sequences on record. This includes the worst-case combinations of mine development timing and high and low rainfall sequences.

For the purpose of the water balance model, a long-term climate dataset was acquired from the Bureau of Meteorology (BoM). The dataset comprised 124 complete years (1889 – 2014 inclusive) of rainfall and evaporation data interpolated from recorded meteorology data. The modelled dataset provided by the BoM deviates slightly from the recorded meteorology data presented in Section 11 – Climate. This is because the BoM dataset is modelled data for 124 years, compared to recorded data for 15 years. The dataset includes a 90th percentile annual rainfall of 1,696 mm and a 10th percentile annual rainfall of 709 mm. The average annual rainfall is 1,206 mm. The annual average evaporation is approximately 2,154 mm and exceeds average annual rainfall by 948 mm. Due to the tropical climate and seasonality, approximately 65% of average rainfall occurs between December and March. Conversely, only 7% of rainfall occurs between May and October.

Catchment runoff has been modelled using the Australian Water Balance Model (AWBM). The adopted AWBM parameters provided annual runoff coefficients between 31% and 48%. Runoff modelling parameters have been selected based on experience and a review of comparable mining operations in the NT, including the existing mine.

10.5.5 Water Balance

The representative long-term water balance for the project is represented by the overall median (i.e. 50th percentile) of model results for the water management system. A summary of the results for three discrete years of the mine life during median climatic conditions is shown in Table 10-1.

These modelling results show that median water supply demands over the life of the mine are generally significantly greater than the amount of quarry water that will be generated by the project in a given year. This indicates a significant overall water deficit for the project and the need for external water supply in certain years of operation.

Table 10-1 Median Annual Water Balance

SOURCE	MEDIAN ANNUAL WATER BALANCE (ML/ANNUM)		
	PROJECT YEAR 3[3]	PROJECT YEAR 9[4]	PROJECT YEAR 13[4]
Water Supplies			
Quarry Dewatering[1]	100	460	240
Quarry Water Storage	190	180	530
External Water Supply	490	140	10

SOURCE	MEDIAN ANNUAL WATER BALANCE (ML/ANNUM)		
	PROJECT YEAR 3[3]	PROJECT YEAR 9[4]	PROJECT YEAR 13[4]
Water Demands			
Dust Suppression [2]	780	780	780
Controlled Release	0	0	0

1 Reported as peak median volume during year

2 Assuming two water trucks operating full time

3 In Project Year 3 only the Northern EL will be operating

4 In Project Years 9 and 13 operations will occur in both the Northern EL and Southern EL

During extended rainfall periods the quarries will collect significant volumes of rainfall runoff and this will result in a net surplus of quarry water within the water management system. Following such events, in order to dewater the active quarries and allow continuing production, it will be necessary to transfer the accumulated water to quarry water storages. The storages have been designed to accommodate the surplus water generated during such extreme events without the need for discharge of quarry water from the site. A detailed assessment of the controlled discharge of quarry water is discussed below.

Dam Sizing

The model was used to derive dam capacities that would meet the management objective of low probability of discharge of quarry water (i.e. no modelled discharge based on 124 years of climate data). Modelling results presented in Table 10-2 show that each of the mine water dams will operate such that the design capacity will not be exceeded.

The dam design includes a further factor of safety in the form of an operating freeboard. A freeboard of 1.5 m has been nominally adopted for the proposed dams. This freeboard depth exceeds the long-term annual average rainfall (i.e. 1,206 mm).

Table 10-2 Dam Capacities

STORAGE DAM	OPERATING CAPACITY (ML)	MAXIMUM STORAGE CAPACITY (ML)	FREEBOARD (m)
Northern EL			
Mine Water Dam	900	900	1.5
Southern EL			
Mine Water Dam (West)	740	740	1.5
Mine Water Dam (East)	740	740	1.5
TOTAL	**2,380**	**2,380**	**N/A**

The size and construction of the dams will be based on the detailed mine design. However, the dam sizes presented in the EIS are worst case, and any changes in detailed design are likely to reduce the size of the dams.

Uncontrolled Discharge of Quarry Water

The modelling results predict that the maximum quarry water inventory for all modelled years was 2,380 ML, comprising 900 ML generated at the Northern EL and 1,480 ML generated at the Southern EL. Dams have been sized to accommodate the maximum predicted water inventories at the Northern and Southern ELs, as shown in Graph 10-1.

Graph 10-1 Probability of Quarry Water Release

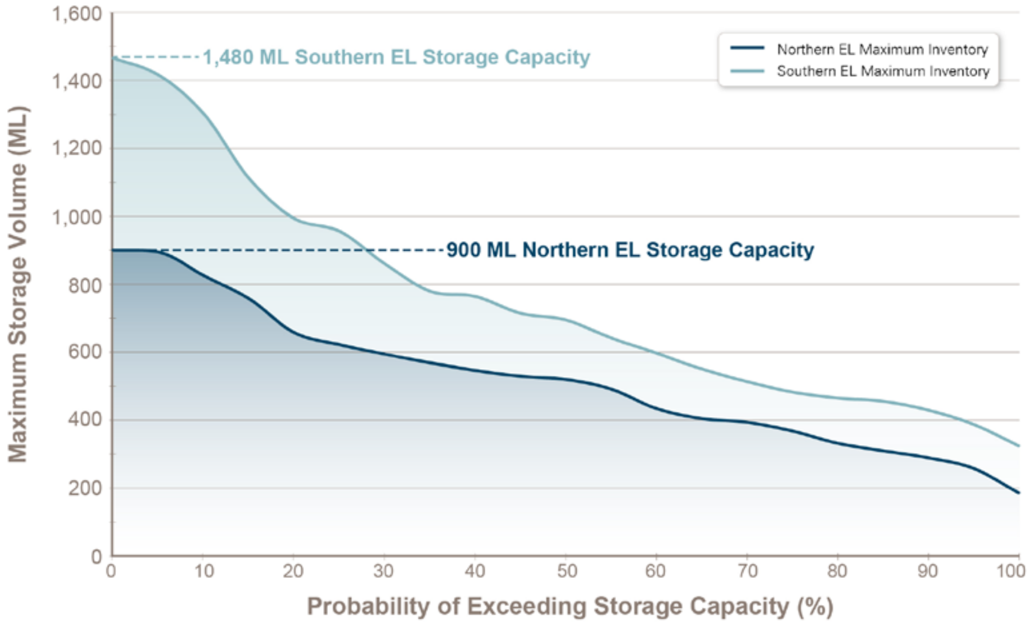
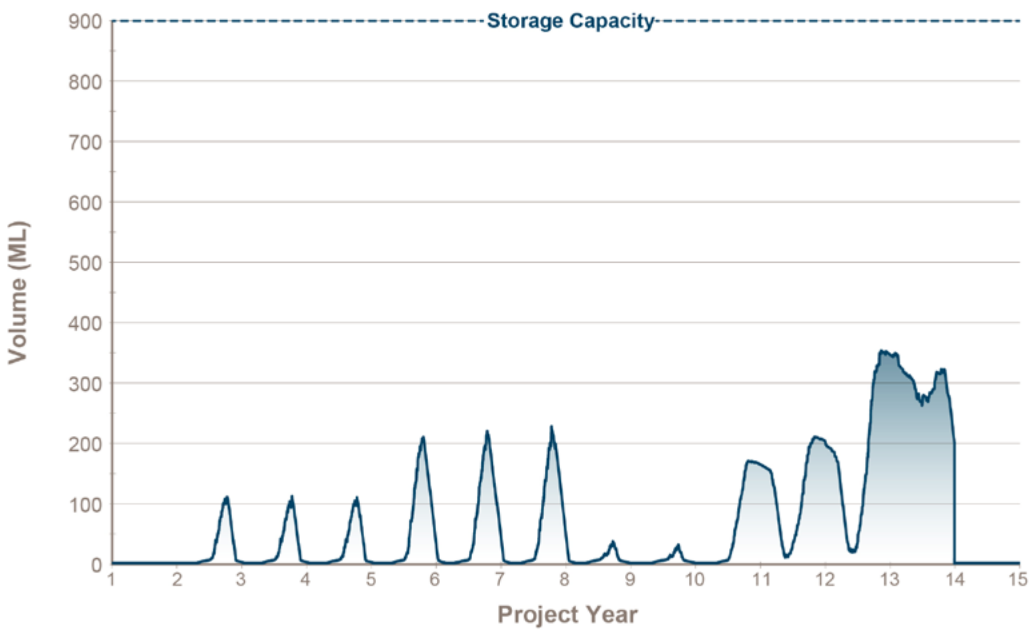


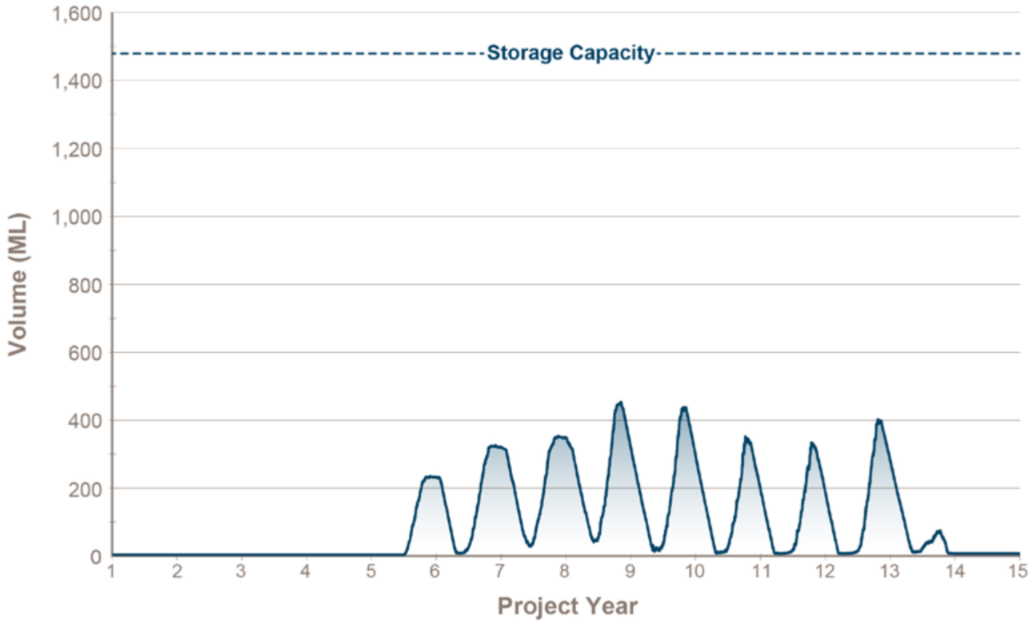
Table 10-2 demonstrates that there would be sufficient total storage capacity for containment of quarry water during the range of historical climate conditions over the life of the mine without the need for any discharge. Sufficient storage capacity is therefore available even during the most extreme climate conditions experienced in 124 years of climate data.

The maximum predicted inventory of each individual dam does not exceed the assigned design capacity. This means that each dam could operate during any climate extremes within the range experienced over the previous 124 years without the need for discharge of mine water. A freeboard of 1.5 m will provide additional contingency storage capacity within each dam given that the annual average rainfall is 1.2 m. This freeboard will ensure the dam will not overflow. Graph 10-2 and 10-3 show the quarry water inventories at the Northern EL and Southern EL under median rainfall conditions, respectively.

Graph 10-2 Median Quarry Water Inventory - Northern EL



Graph 10-3 Median Quarry Water Inventory - Southern EL



Climate change predictions indicate that the project site is unlikely to experience a long-term change in rainfall, although a minor increase in temperature could lead to a slight increase in evaporation (Northern Territory Government, 2008 & 2011). There is also potential for a decrease in the total number of cyclones, although this is countered by a potential increase in intensity of the remaining cyclones (Department of the Environment, 2014 & Northern Territory Government, 2011). The effects of these climate changes on the proposed water management system would be a potential minor reduction in the long-term accumulated rainfall runoff within the system, but an increase in short-term storm events.

Due to the robust nature and design of the proposed water management system, the relatively minor predicted changes in evaporation or rainfall intensity and frequency will not have a material impact on the effective operation of the water management system. In particular, any increase in runoff from higher intensity storm events would be accommodated by the conservatively sized dams (Table 10-2). These dams have been conservatively sized to contain prolonged runoff from the maximum rainfall conditions, with sufficient additional freeboard to accommodate an average year of rainfall. Any minor increase in external water demand due to increased evaporation could be sourced from the available water at the existing mine.

Controlled Releases of Quarry Water

Modelling of the proposed water management system indicates that there would be no requirement to discharge quarry water based on the 124 years of climate data including all extreme wet periods. This means that the probability that an uncontrolled discharge will occur is less than once in 124 years (i.e. the AEP of a discharge event is less than 0.8%).

However, it is possible, with a very low likelihood, that a sequence of prolonged rainfall events could occur that is more extreme than any within the modelled 124 years of rainfall data. The proponent will therefore request authorisation for discharge of quarry water, as a contingency measure. In the unlikely event that discharge of excess quarry water is required following an extreme rainfall event, this would be conducted in accordance with appropriate contingency discharge conditions and water quality limits.

Discharge water quality limits have been developed for key physical and chemical parameters, major ions and dissolved metals and metalloids. The proposed discharge limits are based on 12 continuous months of water quality monitoring data. The proposed discharge limits are presented in Table 10-3.

As discussed in Section 10.2, the project is located in a pristine, high conservation value setting in terms of aquatic ecosystems. The ANZECC Guidelines recommend that these ecosystems are afforded a high level of protection such that there is no detectable change in the ecosystem, beyond natural variability. The ANZECC Guidelines recommend that one standard deviation in the median baseline conditions is a suitably conservative marker of natural variation in water quality. Discharge water quality limits must therefore ensure that released water is within the limits of natural variation at the point of release to ensure that there is no detectable change in the baseline water quality and ecosystem values in the unlikely event of quarry water discharge.

The proposed discharge limits have been developed in accordance with these recommendations. Discharge limits have been developed for the Amagula River and Emerald River to ensure that the recorded variation in water quality between these two catchments is reflected in the discharge limits. Where there is significant variation in median water quality or deviation from the median across either catchment, the standard deviation in median water quality that provides the lowest discharge concentration has been adopted as the discharge limit. This represents a conservative approach to selection of discharge limits where significant natural variation has been recorded. For parameters that have not been detected at or above the limits of analytical reporting based on 12 continuous months of water quality monitoring data, the relevant limits of analytical reporting have been adopted as the discharge limit.

All proposed discharge limits will be updated once 24 continuous months of data is available and presented as part of the Mining Management Plan for the project.

Table 10-3 Contingency Discharge Water Quality Limits

PARAMETER	UNITS	DISCHARGE LIMITS	
		AMAGULA RIVER	EMERALD RIVER
Physical and Chemical Parameters			
Suspended Solids	mg/L	5.9	7.1
pH	pH units	4.7 (lower limit); 5.8 (upper limit)	5.4 (lower limit); 6.5 (upper limit)
Redox Potential	mV	198	204
Electrical Conductivity	µS/cm	68.1	81.9
Total Dissolved Solids	g/L	0.04	0.05
Dissolved Oxygen	% sat	38.4	45.5
Turbidity	NTU	4	8
Total Hardness	mg/L	1.0	2.4
Bicarbonate Alkalinity	mg/L	3.4	11.4
Carbonate Alkalinity	mg/L	1.0	1.0
Hydroxide Alkalinity	mg/L	1.0	1.0
Total Alkalinity	mg/L	3.4	11.4
Major Ions			
Total Anions	mg/L	0.39	0.42
Total Cations	mg/L	0.3	0.3
Sulfate	mg/L	1.4	1.5
Chloride	mg/L	10.8	11.4
Calcium	mg/L	1.0	1.0

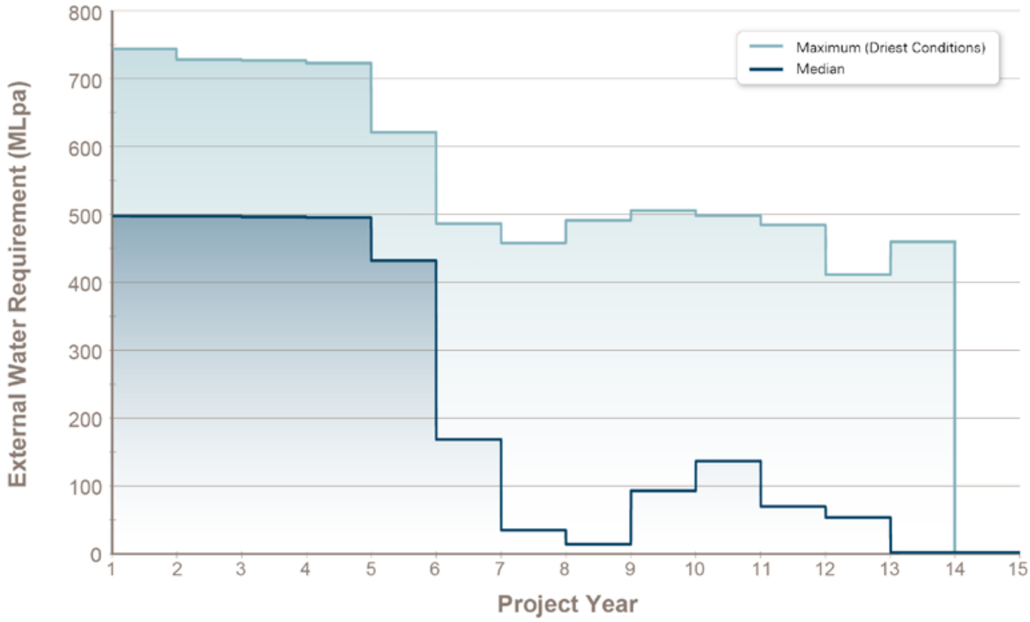
PARAMETER	UNITS	DISCHARGE LIMITS	
		AMAGULA RIVER	EMERALD RIVER
Magnesium	mg/L	1.0	1.0
Potassium	mg/L	1.0	1.0
Sodium	mg/L	6.7	7.8
Metals and Metalloids			
Aluminium	mg/L	0.01	0.01
Arsenic	mg/L	0.001	0.001
Barium	mg/L	0.004	0.008
Beryllium	mg/L	0.001	0.001
Boron	mg/L	0.05	0.05
Cadmium	mg/L	0.0001	0.0001
Chromium	mg/L	0.001	0.001
Cobalt	mg/L	0.001	0.001
Copper	mg/L	0.001	0.001
Iron	mg/L	0.07	0.07
Lead	mg/L	0.001	0.001
Manganese	mg/L	0.003	0.003
Mercury	mg/L	0.0001	0.0001
Nickel	mg/L	0.001	0.001
Selenium	mg/L	0.01	0.01
Uranium	mg/L	0.001	0.001
Vanadium	mg/L	0.01	0.01
Zinc	mg/L	0.005	0.005

Water Supply Reliability

The water management system is predicted to have a water deficit over the life of the mine. Modelling has indicated that additional external water supply is required in dry periods when the volume of quarry water stored in the project site is insufficient to meet project demands for dust suppression supply.

Graph 10-4 shows that the additional annual external water supply requirement will range from 0 to approximately 500 ML/a over the life of the mine under median conditions. Under the driest modelled conditions, the full project water demand of 780 ML would be required during the initial years of the project when contributing catchment areas and groundwater inflows are negligible. This requirement would decrease as groundwater inflows increase during later project years.

Graph 10-4 Annual External Water Supply Requirements



The proponent is proposing to use available mine water from the existing mine to address any water deficit for the project. The existing mine operates at a general water surplus that is sufficient to meet any additional requirements for the project, without compromising existing mine operations or dust suppression activities at the existing mine.

10.6 IMPACT ASSESSMENT

As discussed in Section 10.3, extensive design features have been incorporated into the project planning process to manage and mitigate potential impacts on surface waters. Further water management strategies were developed to manage each of the waters generated by the project (i.e. quarry water, runoff from areas disturbed by project activities and runoff from areas undisturbed by project activities).

Table 10-4 provides a summary of the potential surface water impacts of the project and the management measures proposed.

Table 10-4 Summary of Potential Surface Water Impacts and Management Measures

IMPACTS	DESCRIPTION	MANAGEMENT MEASURES
Contamination of watercourses	■ The project is an additional mining area that will be operated as part of the existing mine, rather than an independent mine. Consequently there are only limited activities being undertaken on the project site that may give rise to contamination. ■ Activities with the potential to give rise to surface water contamination include: – Refuelling of on-site equipment using mobile refuelling trucks and storage of small quantities of diesel and chemicals in small scale, portable containers; and – Basic maintenance works required on-site for equipment.	■ The proponent's refuelling procedures will be adopted to prevent and control any spills that may occur during vehicle and equipment refuelling. ■ Spill cleanup kits will be available on-site and located at strategic and easily accessible locations. All staff will be adequately trained in the use of these emergency kits. ■ Comprehensive maintenance involving mine vehicles and equipment will be undertaken at the heavy vehicle workshops located within the existing mine. ■ Basic maintenance undertaken at the project site will be restricted to designated hardstand areas, equipped with spill cleanup kits.
Surface water quality	■ The project may generate quarry water comprising groundwater inflows and contained rainfall runoff to quarry catchments. If this water were to be discharged to surface water in an uncontrolled manner, it would have the potential to affect the surface water quality in the receiving watercourses. ■ The project may also generate sediment-affected runoff from disturbed areas including overburden emplacements and infrastructure areas. If sediment-affected waters from disturbed areas were released to the environment, this would have the potential to affect surface water quality in the receiving watercourses. Specifically, increased levels of suspended sediment has the potential to increase turbidity in watercourses, thereby: – reducing photosynthesis, resulting in impacts to aquatic ecology; – reducing levels of visual amenity; and – rendering water less suitable for human consumption.	■ The project has been designed with sufficient quarry water storage capacity to allow containment of quarry water during the range of historical climate conditions over the life of the mine without the need for any discharge. ■ Contingency discharge limits have been developed to ensure that any release of quarry water would be within the natural range of water quality for the receiving riparian environment and avoid any impacts on surface water quality ■ Monitoring will be undertaken in accordance with a Water Management Plan. Monitoring will include: – Project water balance including water transfers, consumption and quarry water volumes; – Surface water quality monitoring and reporting; – Storage water quality monitoring and reporting; and – Discharge monitoring and reporting. ■ Sediment control works will be implemented. All work will be undertaken in accordance with the requirements of an Erosion and Sediment Control Plan. ■ Sediment control structures will be monitored in accordance with an Erosion and Sediment Control Plan.

IMPACTS	DESCRIPTION	MANAGEMENT MEASURES
Sedimentation of watercourses	■ Runoff from areas disturbed by construction or mining activities may contain elevated levels of suspended sediment. ■ If sediment-affected waters were released to the environment, this would potentially result in high sediment loads in receiving watercourses. ■ Suspended sediment may be deposited in slow moving sections of receiving watercourses, impacting watercourse geomorphology and flow regimes. ■ However, the project has been designed to ensure that all drainage from disturbed areas is managed to ensure that receiving waters are not impacted by sedimentation.	■ Sediment control works will be implemented. All work will be undertaken in accordance with the requirements of an Erosion and Sediment Control Plan. ■ Sediment control structures will be monitored in accordance with an Erosion and Sediment Control Plan.
Loss of downstream flow in watercourses	■ The development of the project will result in the capture and diversion of rainfall runoff, forming contained catchments. ■ The formation of contained catchments reduces the overall catchment area draining to watercourses, and has the potential to reduce watercourse flows. ■ Contained catchments that are typically formed by open cut mining include: – active mining catchments; and – residual final void catchments. ■ However, the project has been designed to ensure that a stable free-draining post-mining landform will be established with no final voids. The mine plan and mine schedule have been designed to ensure that all overburden will ultimately be placed in mined quarries, creating a final landform that is similar to the pre-mining landform. The final landform design will ensure that there is no long-term reduction in downstream catchment yield. ■ Drainage strategies have been developed which minimise the area of contained quarry catchments and maximise the diversion of catchment runoff to watercourses, thereby ensuring that there will be no significant loss of catchment runoff during the life of the project.	■ The design of the project mine plan avoids any long term reduction in catchment yield, and minimises the loss of catchment yield during mining operations. ■ During mining, this drainage arrangement will result in containment of up to approximately 40 ha of the Emerald River catchment (Project Year 3) and 110 ha of the Amagula River catchment. This will result in minor decreases (0.51% and 0.95%) in the respective watercourse catchments at historic gauged locations (Figure 10-1) and any resultant change in watercourse flow or level would be imperceptible downstream of the project site. ■ No additional management measures are proposed.

IMPACTS	DESCRIPTION	MANAGEMENT MEASURES
Impacts on watercourse geomorphology	■ In general, disturbance of watercourses and their floodplains by mining activities has the potential to change surface water flow and flood behaviour. These changes can change watercourse geomorphology through erosion and sedimentation, and can impact downstream water values. ■ However, the project has been designed to ensure that mining will not encroach on any of the watercourses traversing the project site. ■ Buffers have been defined around watercourses. The mine plan and quarry extents were designed to ensure no encroachment on the buffers, and to restrict mining to areas beyond the defined drainage channels and associated buffers. ■ The buffers were delineated by the predicted extent of the 1% AEP (1 in 100 year) flood extents. ■ Haul road crossings will be installed with low flow drainage culverts in the road formation. Floods larger than the design event will be allowed to flow over the culvert to maintain drainage within these watercourses. Haul road crossings are not anticipated to have any direct impact on watercourse geomorphology, including channel bed and bank stability.	■ The design of the project mine plan incorporates features, such as drainage buffers, designed to avoid potential adverse impacts on watercourse geomorphology. ■ Haul road crossings (culverts) of watercourses will be inspected throughout the construction period and as part of the commissioning phase, ensuring that any external batter slopes are stable and revegetated. ■ The inspections will also confirm that that appropriate erosion and sediment controls are in place.

IMPACTS	DESCRIPTION	MANAGEMENT MEASURES
Impacts on flooding behavior	■ In general, disturbance of watercourses and their floodplains by mining activities has the potential to change surface water flow and flood behaviour. ■ These changes can alter the natural extents and duration of flood inundation resulting in a range of impacts on vegetation and downstream land uses. ■ However, as discussed above, the project has been designed to ensure that mining will not encroach on any of the watercourses traversing the project site or the associated 1% AEP (1 in 100 year) flood extent. ■ During mining there is potential for minor redistribution of overland sheet flows as part of the proposed mine drainage arrangements. This is not predicted to have any significant impact on flood behaviour including flow paths, flood inundations areas and flow velocities. ■ As discussed above, the project has been designed to ensure that all overburden will ultimately be placed in mined quarries, creating a final landform that is similar to the pre-mining landform. ■ The final landform is not predicted to result in any significant post-mining impacts on flood behaviour.	■ The design of the project mine plan incorporates features, such as drainage buffers, designed to avoid any potential adverse impacts on flooding behaviour.
Impacts on aquatic ecology and riparian vegetation	■ The potential impacts of the project on riparian vegetation and aquatic ecology are discussed in Section 7 – Terrestrial Ecology and Section 8 – Aquatic Ecology.	

10.7 MONITORING

10.7.1 Water Management System Monitoring Program

Water management system monitoring for the project will include quarterly monitoring of water levels and quality in mine water dams. Parameters to be included in the monitoring program include pH, EC and turbidity. The monitoring program will include annual monitoring of a comprehensive suite of water quality parameters, including metals and metalloids.

Any controlled releases of quarry water will be monitored, as well as the receiving waters.

The site water balance including water transfers, consumption and dam storage volumes will be monitored monthly. The water management system will be monitored and managed in accordance with a Water Management Plan. The Water Management Plan is discussed in Section 10.8. The site water balance will be reviewed annually and the review will trigger modifications to the water management system, where necessary, to ensure the optimum operation of the system.

Sediment control structures will be managed in accordance with an Erosion and Sediment Control Plan. The Erosion and Sediment Control Plan will include an inspection plan for sediment control structures to ensure they are maintained and remain effective.

Haul road crossings (culverts) of watercourses will be inspected throughout the construction period and as part of the operations phase, ensuring that any external batter slopes are stable and revegetated. The inspections will confirm that that appropriate erosion and sediment controls are in place. Periodic inspections (i.e. monthly during the wet season) will be undertaken following construction to confirm that all culverts are operating effectively and not causing sedimentation of watercourses.

10.7.2 Receiving Environment Monitoring Program

The proponent has established a site-specific surface water monitoring program for the project. The surface water quality monitoring program is described in detail in the *Baseline Surface Water Monitoring Report* (Appendix H).

The existing baseline surface water quality monitoring program will continue on a monthly basis until at least 24 contiguous months of baseline data is available. The monitoring program will include field testing and sample analysis for the current range of physico-chemical parameters including EC, pH, suspended solids, turbidity, ions, nutrients, total and dissolved metals and metalloids and total petroleum hydrocarbons.

Upon completion of the baseline monitoring program, monitoring will continue on a quarterly basis. The data will be reviewed annually and will trigger modifications to the monitoring program to ensure that adequate data is collected for relevant parameters. In addition, the proponent is conducting a review of regional stream gauging data with the intent of upgrading or installing additional downstream gauging.

10.8 MANAGEMENT PLANS

10.8.1 Water Management Plan

A Water Management Plan will be prepared prior to commencement of the project. The plan will address water management for all stages of the project construction, operations and closure, as well as long-term post-mining water management requirements. This plan will include:

- A description of the existing setting including the surface water catchment and drainage setting, hydrogeology, and an overview of the existing surface and groundwater values, users and water quality.
- A description of the regulatory setting of the project.
- The water management objectives for the project.
- A description of potential project impacts on water.
- Control strategies including a description of the surface water drainage arrangements, water management system and water balance. This will include a discussion of options and alternatives for meeting the proposed water management objectives.
- A detailed description of the water management and monitoring measures to address each of the project impacts and maintain the effective operation of the control strategies.
- A description of the review process and remedial measures to address any impacts or potential water management issues identified through monitoring.

10.8.2 Erosion and Sediment Control Plan

An Erosion and Sediment Control Plan will be prepared prior to commencement of the project. The Erosion and Sediment Control Plan will be developed in accordance with the Department of Land Resource Management

(DLRM) Fact Sheets *Erosion and Sediment Control Plans for Rural Development* and *Model Erosion and Sediment Control Plans for Rural Development*.

The plan will be closely linked to (but distinct from) the Water Management Plan. In addition to meeting the requirements of the Water Management Plan, the Erosion and Sediment Control Plan will specifically include:

- A detailed description of the existing catchment and drainage setting in terms of the potential for erosion and sources of sediment.
- A description of the proposed drainage control measures for managing stormwater runoff and preventing gully and rill erosion. This will include design volumes, dimensions and grades for any drainage structures such as bunding and collection drains.
- A description of the erosion control measures proposed for protection of exposed soils and surfaces. This will include any engineered groundcover intended to stabilise haul road watercourse crossings and reduce the potential for channel erosion or instability in these areas.
- A description of the proposed sediment control measures for containing and settling any entrained sediments in stormwater runoff or site drainage. This will include design volumes, dimensions and sediment retention parameters for any sediment control structures such as sediment ponds and traps.
- Figures showing the pre-mining setting, areas of proposed disturbance and clearing, and an appropriate set of engineering plans for all erosion and sediment control measures.

All erosion and sediment control works will be constructed in accordance with the relevant NT *Erosion and Sediment Control Guidelines Technical Notes*.

10.9 WATER LICENSING

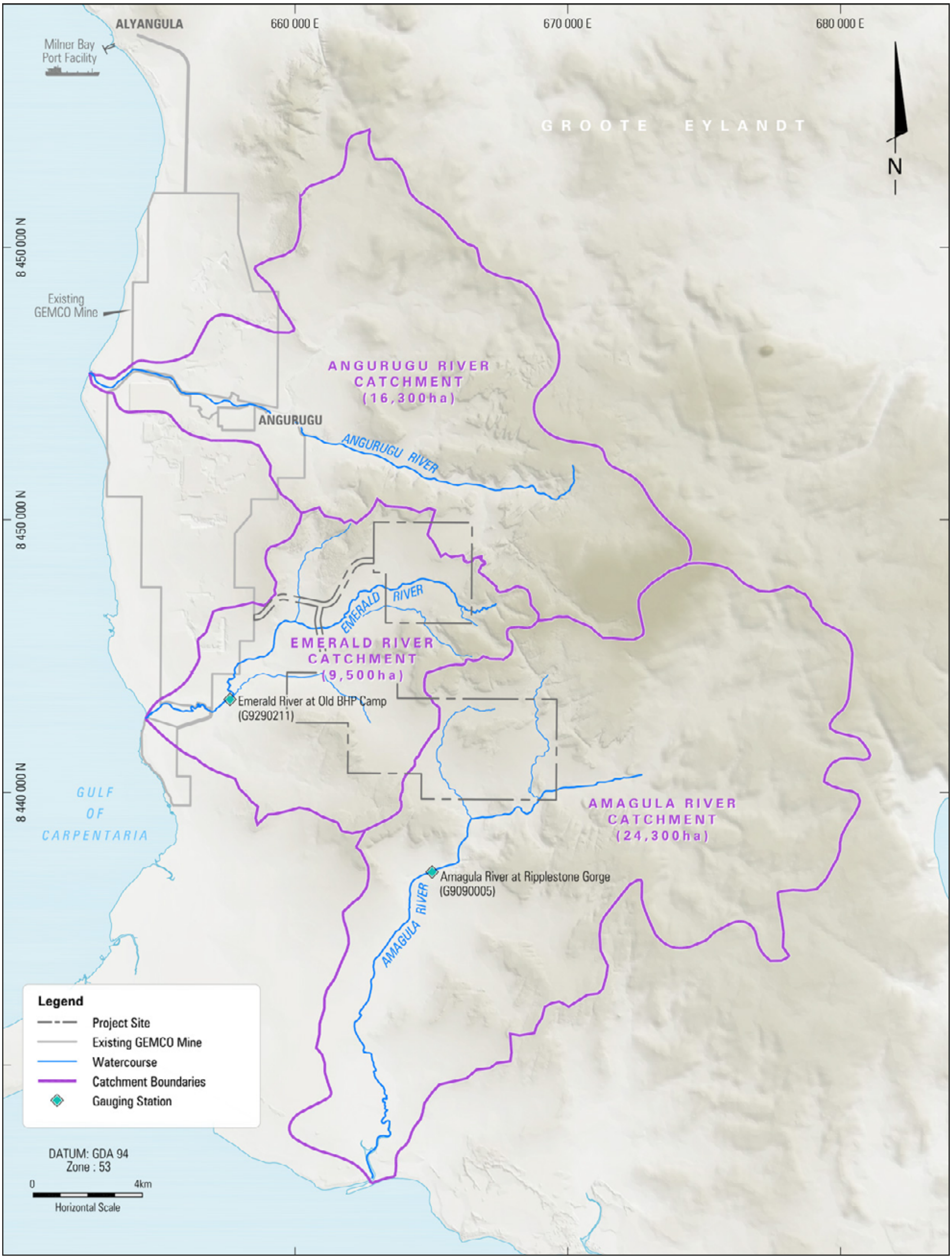
The *Water Act* and subordinate *Water Regulation* provide the legislative framework for water planning and entitlements for most water resources in the Northern Territory. The *Water Act* provides for the investigation, allocation, use, control, protection, management and administration of water resources and also defines the beneficial uses of surface water, as discussed in Section 10.2. However, these provisions of the *Water Act* do not apply to mining activities, given that they are managed under the *Mining Management Act*.

Although no routine discharges of quarry water are proposed, the proponent is proposing that discharge conditions are included in its Authorisation under the *Mining Management Act*. These discharge conditions are intended as a contingency measure only and the proposed discharge water quality limits are designed to ensure that discharges will not adversely impact downstream water quality, aquatic environments or other environmental values.

Site drainage infrastructure will be designed in accordance with relevant engineering guidelines and standards. Approval for dam structures will be applied for as necessary.

No watercourse diversions will be necessary for construction of the proposed water management system.

FIGURES



EASTERN LEASES PROJECT

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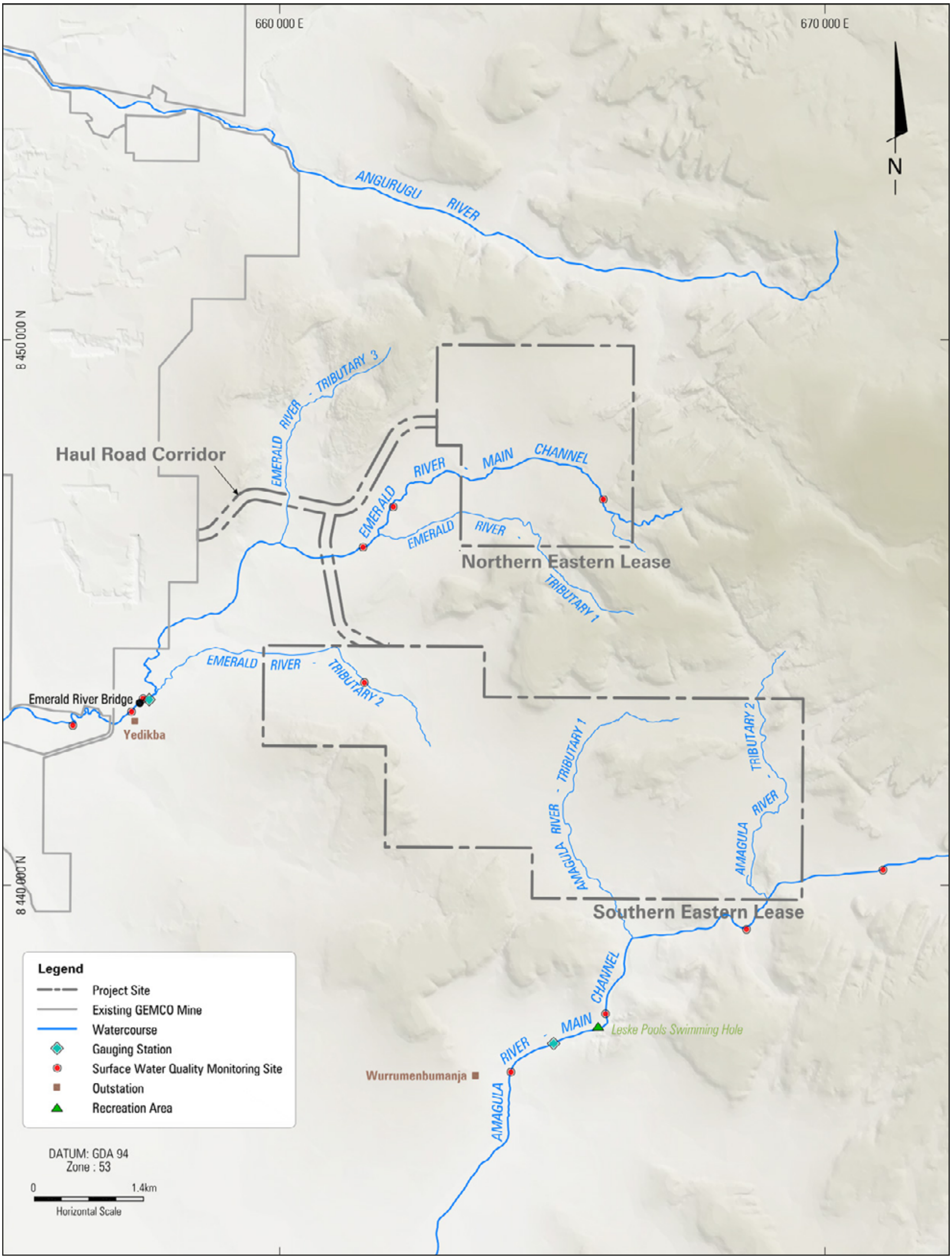
Regional Catchment Setting

FIGURE 10-1



EASTERN LEASES PROJECT

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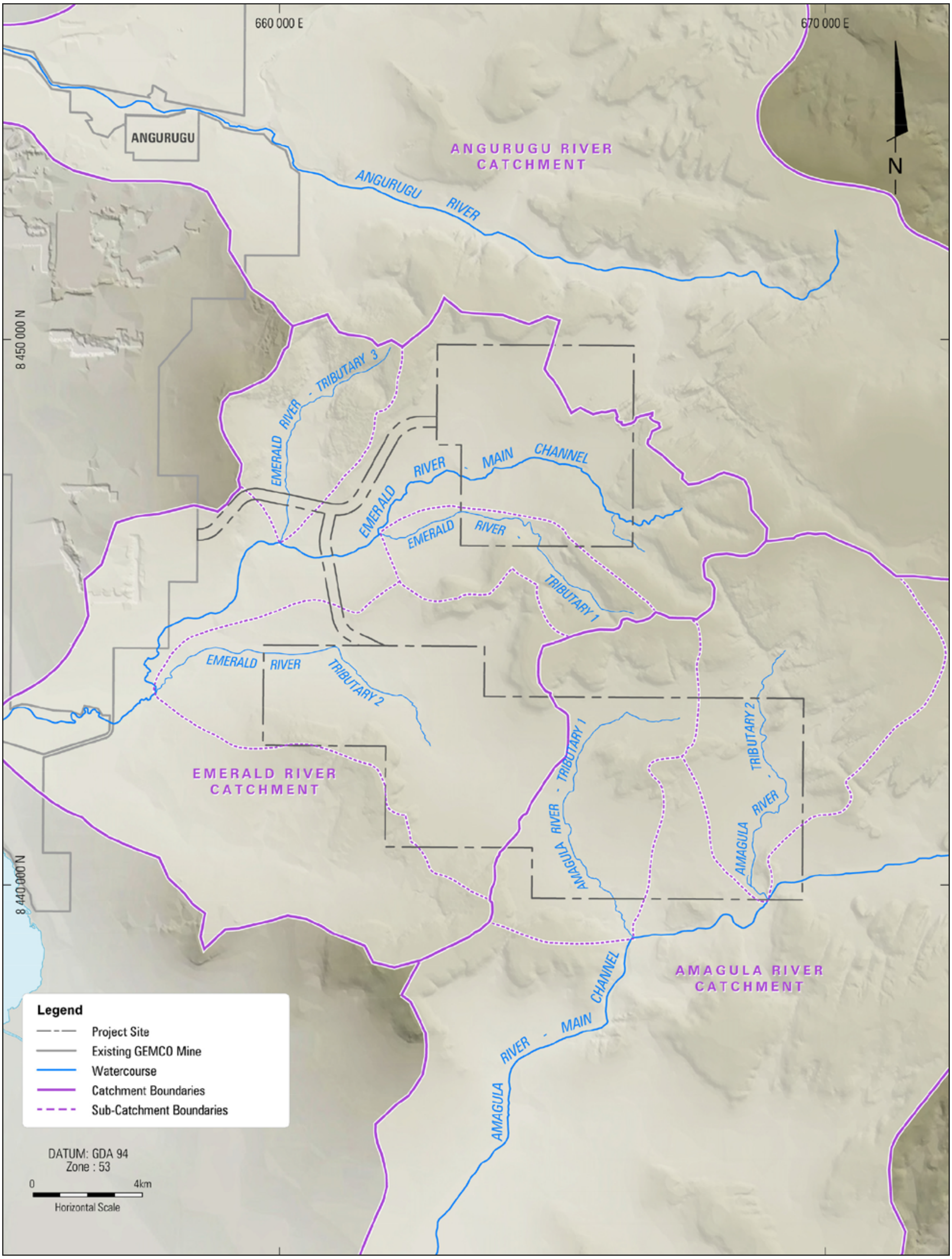
Local Drainage Setting

FIGURE 10-2



EASTERN LEASES PROJECT

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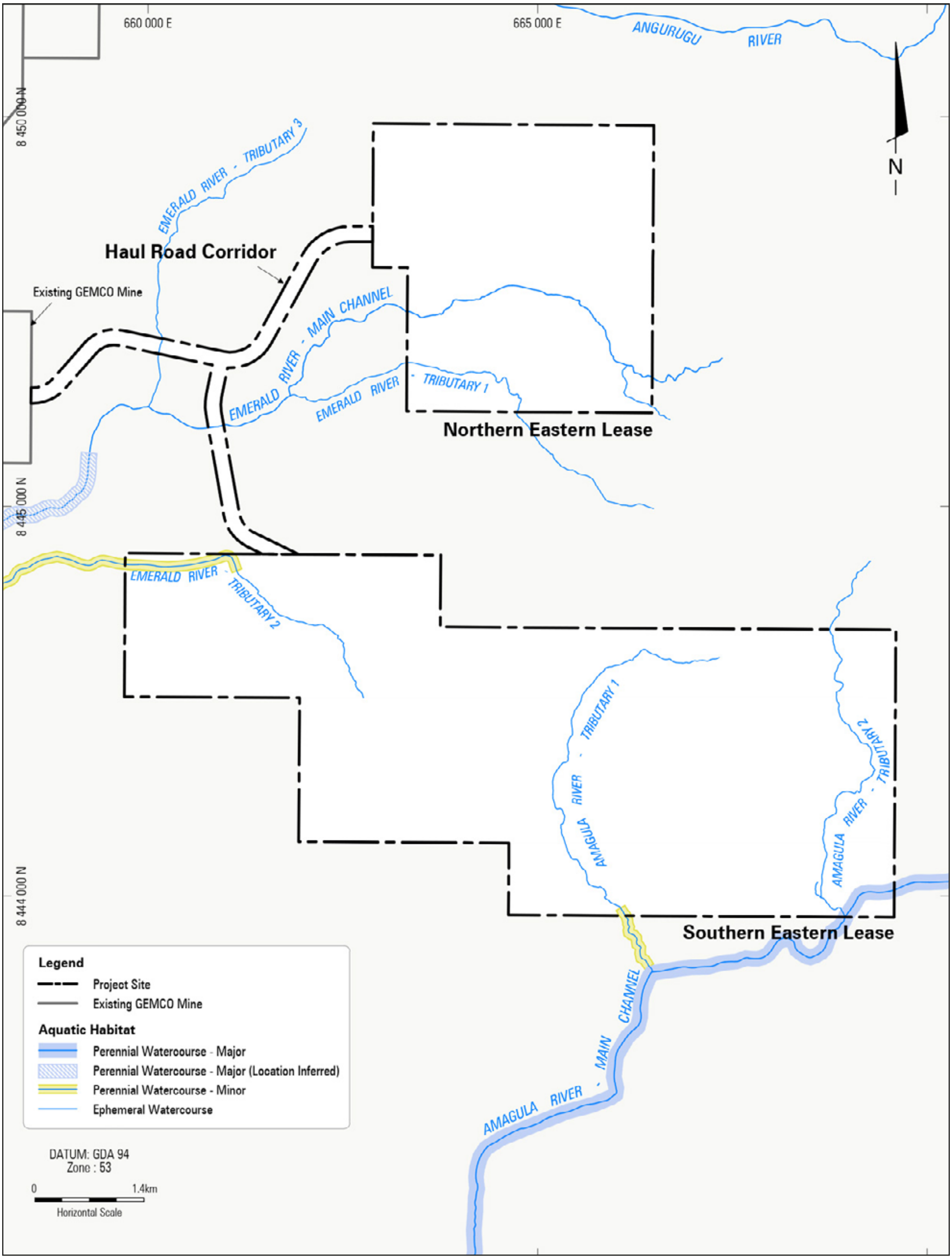
Local Catchment Setting

FIGURE 10-3



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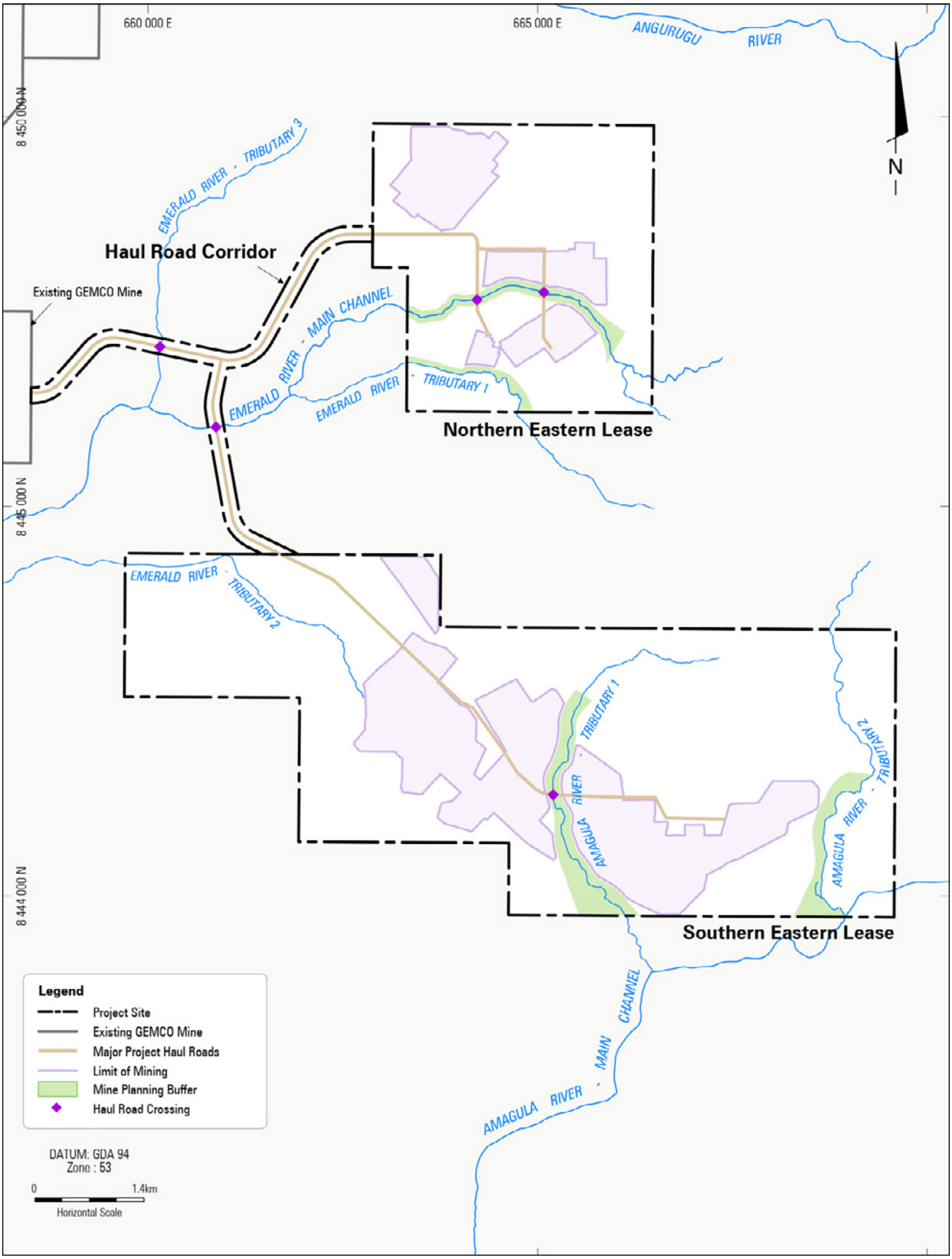
Existing Site Drainage

FIGURE 10-4



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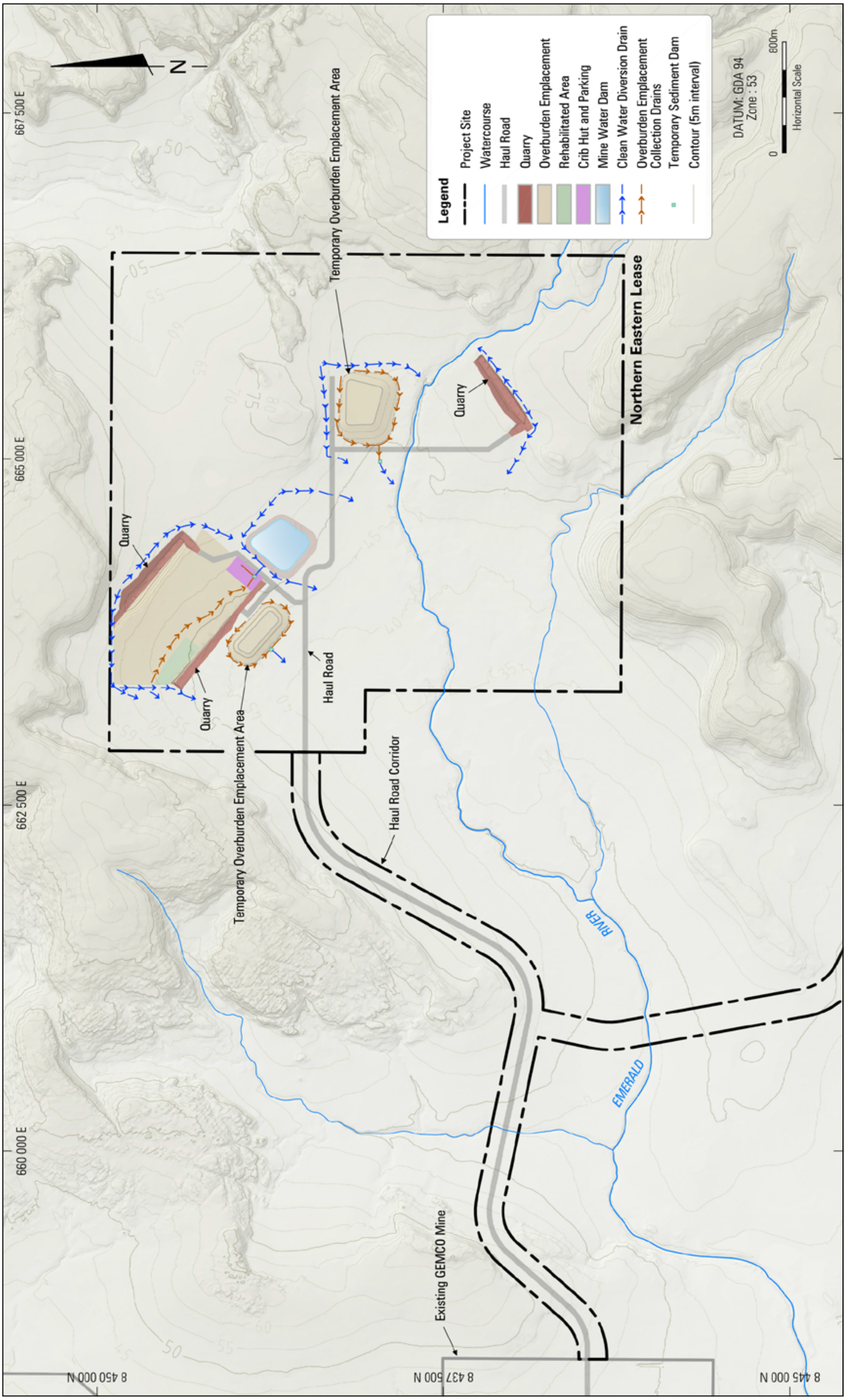
Watercourse Drainage Design

FIGURE 10-5



EASTERN LEASES PROJECT

Stage Drainage Plan - Northern Eastern Lease
Project Year 3

FIGURE 10-6

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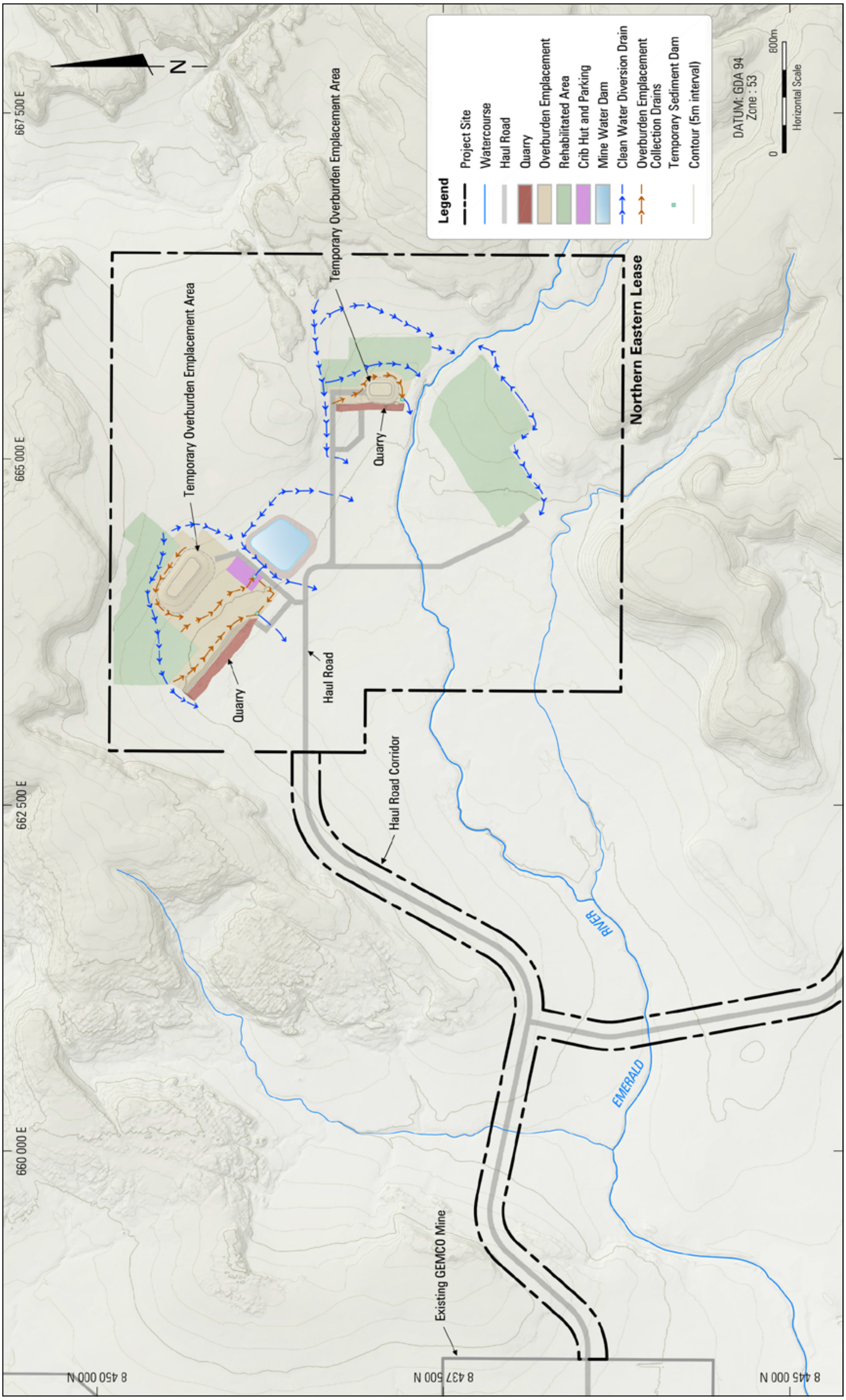

EASTERN LEASES PROJECT

Stage Drainage Plan - Northern Eastern Lease
Project Year 9

FIGURE 10-7

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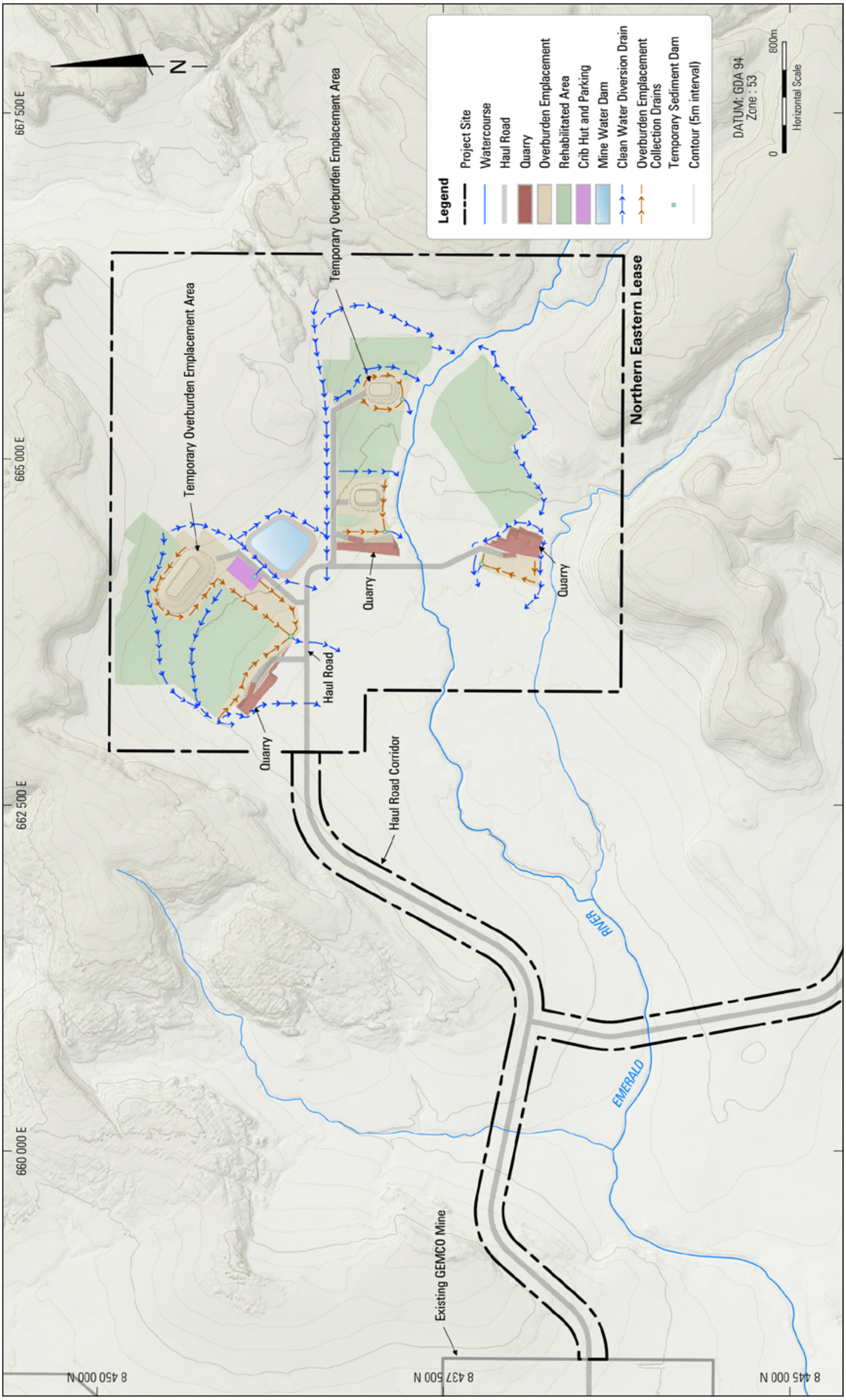

EASTERN LEASES PROJECT

Stage Drainage Plan - Northern Eastern Lease
Project Year 13

FIGURE 10-8

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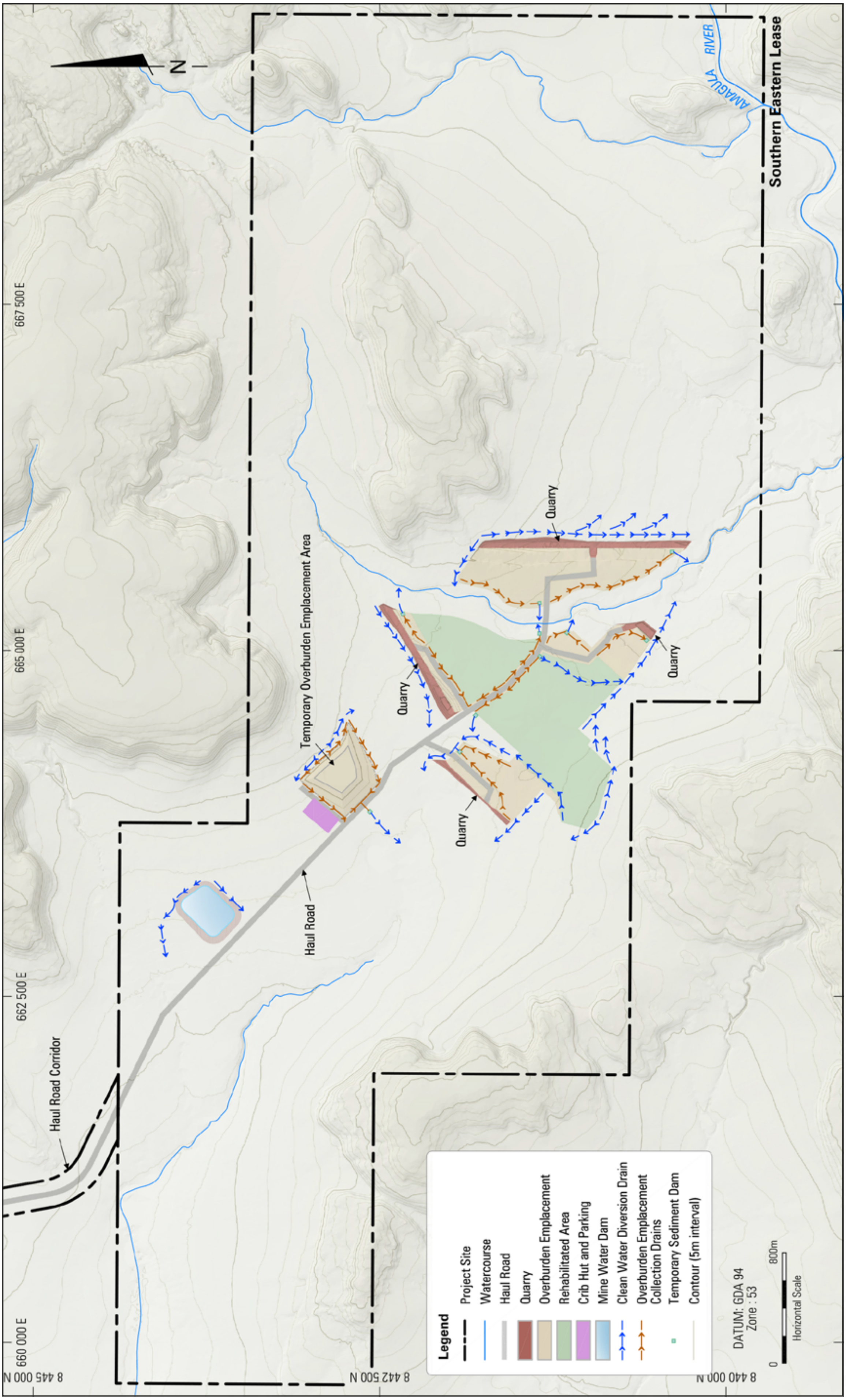

EASTERN LEASES PROJECT

Stage Drainage Plan - Southern Eastern Lease
Project Year 9

FIGURE 10-9

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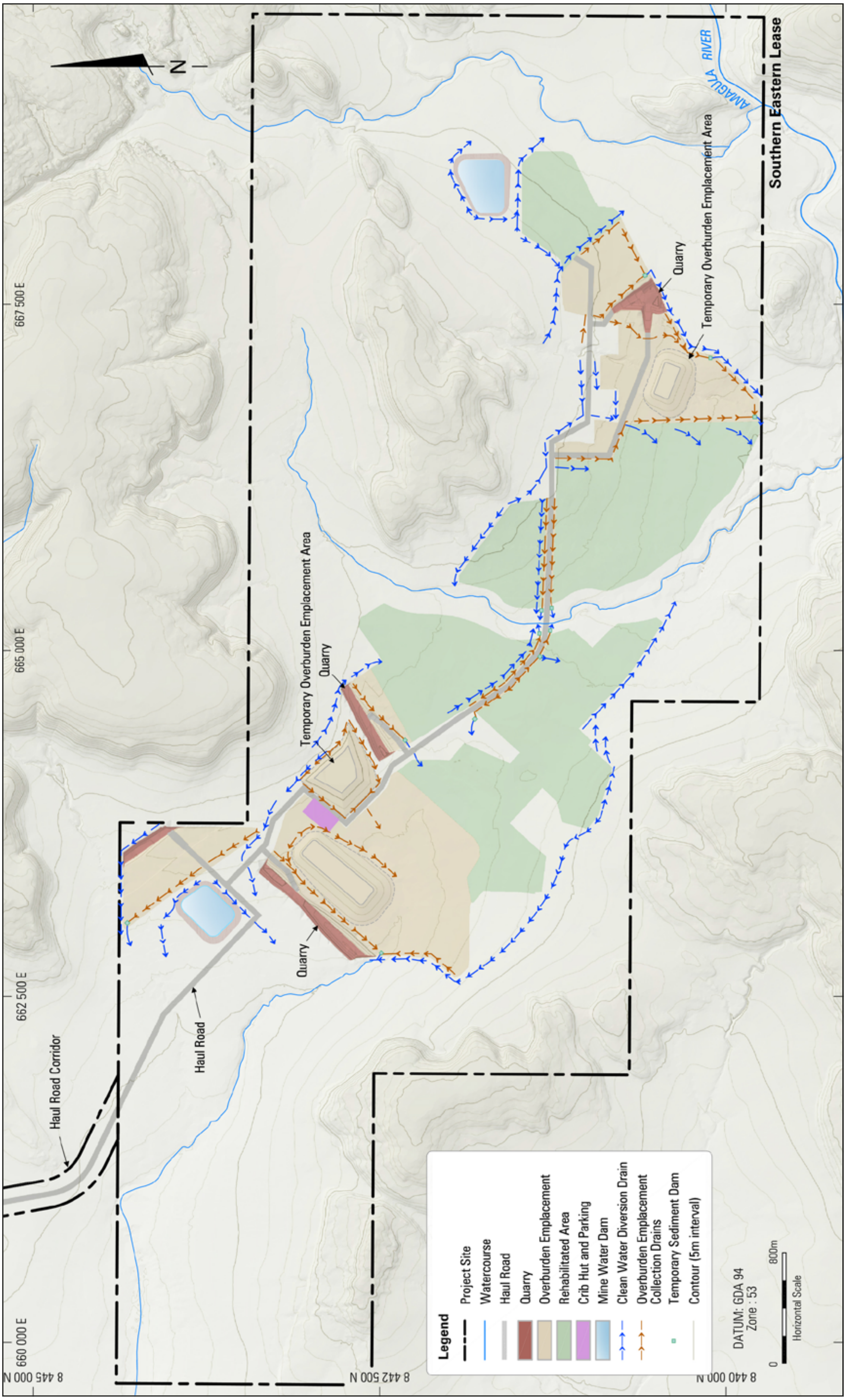

EASTERN LEASES PROJECT

Stage Drainage Plan - Southern Eastern Lease
Project Year 13

FIGURE 10-10

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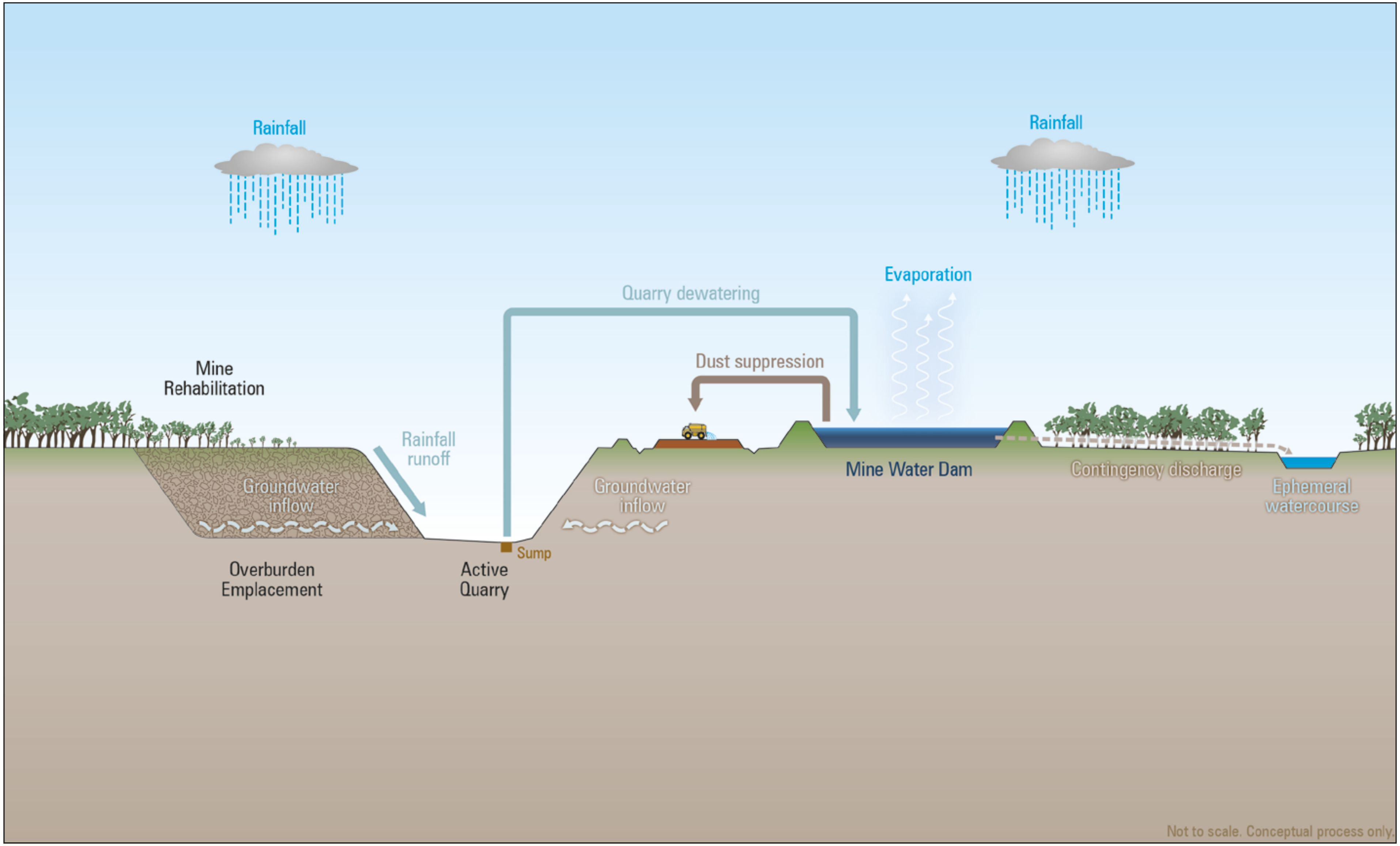

EASTERN LEASES PROJECT

Conceptual Water Management Schematic

FIGURE 10-11

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ATTACHMENTS

10-1 Summary of Baseline Surface Water Quality

Table 1 Baseline Surface Water Quality – Emerald River

PARAMETER	UNITS	LIMIT OF REPORTING	DEFAULT GUIDELINE VALUES		EMERALD RIVER			
			DRINKING WATER[1]	RECREATION[2]	MINIMUM VALUE[4]	MINIMUM MEDIAN[3]	MAXIMUM MEDIAN[3]	MAXIMUM VALUE[4]
Physical and Chemical Parameters								
pH[5]	pH units	0.1	6.5 – 8.5[a]	6.5 – 8.5	**4.9**	**5.8**	**6.1**	6.7
Redox Potential	mV	1	N/V	N/V	33	141	158	305
Electrical Conductivity	µS/cm	1	N/V	N/V	37.5	59.7	71.7	219.5
Total Dissolved Solids	g/L	0.01	0.6[a]	1	0.02	0.039	0.047	0.14
Dissolved Oxygen[6]	% sat	0.1	85[a]	80	**15**	**73.7**	**77.3**	100
Turbidity	NTU	1	5[a]	N/V	2.9	2.9	3.7	**58.5**
Suspended Solids	mg/L	5	200[a]	N/V	5	5	5	48
Total Hardness	mg/L	1	200[a]	500	1	1	1	38
Bicarbonate Alkalinity	mg/L	1	N/V	N/V	1	5.5	9.0	72
Carbonate Alkalinity	mg/L	1	N/V	N/V	1	1	1	1
Hydroxide Alkalinity	mg/L	1	N/V	N/V	1	1	1	1
Total Alkalinity	mg/L	1	N/V	N/V	1	5.5	9.0	72
Major Ions								
Total Anions	mg/L	0.01	N/V	N/V	0.28	0.37	0.44	0.65
Total Cations	mg/L	0.01	N/V	N/V	0.22	0.26	0.30	0.65
Sulfate	mg/L	1	250[a] / 500[h]	400	1	1	1	16
Chloride	mg/L	1	250[a]	400	7	10	12	22
Calcium	mg/L	1	N/V	N/V	1	1	1	7
Magnesium	mg/L	1	N/V	N/V	1	1	1	5
Potassium	mg/L	1	N/V	N/V	1	1	1	4
Sodium	mg/L	1	180[a]	300	5	7	9	17
Dissolved Metals and Metalloids								
Aluminium	mg/L	0.01	0.2[a]	0.2	0.01	0.01	0.01	0.08
Arsenic	mg/L	0.001	0.010[h]	0.050	0.001	0.001	0.001	0.001
Barium	mg/L	0.001	2[h]	1	0.001	0.004	0.0065	0.17
Beryllium	mg/L	0.001	0.06[h]	N/V	0.001	0.001	0.001	0.001
Boron	mg/L	0.05	4[h]	1	0.05	0.05	0.05	0.07
Cadmium	mg/L	0.0001	0.002[h]	0.005	0.0001	0.0001	0.0001	0.0001
Chromium	mg/L	0.001	0.05[h]	0.05	0.001	0.001	0.001	0.001
Cobalt	mg/L	0.001	N/V	N/V	0.001	0.001	0.001	0.003
Copper	mg/L	0.001	1[a] / 2[h]	1	0.001	0.001	0.001	0.001
Iron	mg/L	0.05	0.3[a]	0.3	0.05	0.07	0.125	**2.03**
Lead	mg/L	0.001	0.01[h]	0.05	0.001	0.001	0.001	0.001
Manganese	mg/L	0.001	0.1[a] / 0.5[h]	0.1	0.002	0.0665	**0.396**	**11.3**
Mercury	mg/L	0.0001	0.001[a]	0.001	0.0001	0.0001	0.0001	0.0001

PARAMETER	UNITS	LIMIT OF REPORTING	DEFAULT GUIDELINE VALUES		EMERALD RIVER			
			DRINKING WATER[1]	RECREATION[2]	MINIMUM VALUE[4]	MINIMUM MEDIAN[3]	MAXIMUM MEDIAN[3]	MAXIMUM VALUE[4]
Nickel	mg/L	0.001	0.02[h]	0.1	0.001	0.001	0.001	0.001
Selenium	mg/L	0.01	0.01[h]	0.01	0.01	0.01	0.01	0.01
Uranium	mg/L	0.001	0.017[h]	N/V	0.001	0.001	0.001	0.001
Vanadium	mg/L	0.01	N/V	N/V	0.01	0.01	0.01	0.01
Zinc	mg/L	0.005	3[a]	5	0.005	0.005	0.005	0.005

1 Guidelines for human drinking water supply derived from NHMRC Guidelines (2011)

2 Guidelines for recreational use derived from Section 5.2.3 of the ANZECC Guidelines

3 Minimum and maximum of the median value calculated independently from EMP4, EMP6 and EMP7 datasets

4 Minimum and maximum recorded values derived from combined EMP4, EMP6 and EMP7 datasets

5 pH upper and lower limits presented

4 Dissolved oxygen lower limits presented

Non-detections have been reported as the analytical limit of reporting

Bold denotes water quality exceeds the default guideline value for drinking water and/or recreation

N/V Default guideline value not available for parameter

a Drinking water guideline (aesthetic)

h Drinking water guideline (health)

Table 2 Baseline Surface Water Quality – Amagula River

PARAMETER	UNITS	LIMIT OF REPORTING	DEFAULT GUIDELINE VALUES		AMAGULA RIVER			
			DRINKING WATER[1]	RECREATION[2]	MINIMUM VALUE[4]	MINIMUM MEDIAN[3]	MAXIMUM MEDIAN[3]	MAXIMUM VALUE[4]
Physical and Chemical Parameters								
pH[5]	pH units	0.1	6.5 – 8.5[a]	6.5 – 8.5	**4.5**	**4.8**	**5.5**	6.0
Redox Potential	mV	1	N/V	N/V	74	149	201	331
Electrical Conductivity	µS/cm	1	N/V	N/V	2.4	56.15	59.8	112.9
Total Dissolved Solids	g/L	0.01	0.6[a]	1	0.002	0.036	0.039	0.073
Dissolved Oxygen[6]	% sat	0.1	85[a]	80	**12**	**50.3**	91.45	98.3
Turbidity	NTU	1	5[a]	N/V	1.06	2.73	3.33	**19.1**
Suspended Solids	mg/L	5	200[a]	N/V	5	5	5	32
Total Hardness	mg/L	1	200[a]	500	1	1	1	1
Bicarbonate Alkalinity	mg/L	1	N/V	N/V	1	2	3	6
Carbonate Alkalinity	mg/L	1	N/V	N/V	1	1	1	1
Hydroxide Alkalinity	mg/L	1	N/V	N/V	1	1	1	1
Total Alkalinity	mg/L	1	N/V	N/V	1	2	3	6
Major Ions								
Total Anions	mg/L	0.01	N/V	N/V	0.29	0.36	0.40	0.45
Total Cations	mg/L	0.01	N/V	N/V	0.17	0.26	0.26	0.35
Sulfate	mg/L	1	250[a] / 500[h]	400	1	1	1	3
Chloride	mg/L	1	250[a]	400	8	10	12	13
Calcium	mg/L	1	N/V	N/V	1	1	1	1
Magnesium	mg/L	1	N/V	N/V	1	1	1	1
Potassium	mg/L	1	N/V	N/V	1	1	1	1
Sodium	mg/L	1	180[a]	300	4	6	7	8
Dissolved Metals and Metalloids								
Aluminium	mg/L	0.01	0.2[a]	0.2	0.01	0.01	0.01	0.07
Arsenic	mg/L	0.001	0.010[h]	0.050	0.001	0.001	0.001	0.001
Barium	mg/L	0.001	2[h]	1	0.002	0.003	0.004	0.007
Beryllium	mg/L	0.001	0.06[h]	N/V	0.001	0.001	0.001	0.001
Boron	mg/L	0.05	4[h]	1	0.05	0.05	0.05	0.05
Cadmium	mg/L	0.0001	0.002[h]	0.005	0.0001	0.0001	0.0001	0.0001
Chromium	mg/L	0.001	0.05[h]	0.05	0.001	0.001	0.001	0.001
Cobalt	mg/L	0.001	N/V	N/V	0.001	0.001	0.001	0.001
Copper	mg/L	0.001	1[a] / 2[h]	1	0.001	0.001	0.001	0.003
Iron	mg/L	0.05	0.3[a]	0.3	0.05	0.05	0.1	0.14
Lead	mg/L	0.001	0.01[h]	0.05	0.001	0.001	0.001	0.001
Manganese	mg/L	0.001	0.1[a] / 0.5[h]	0.1	0.001	0.002	0.022	0.088
Mercury	mg/L	0.0001	0.001[a]	0.001	0.0001	0.0001	0.0001	0.0001
Nickel	mg/L	0.001	0.02[h]	0.1	0.001	0.001	0.001	0.001

PARAMETER	UNITS	LIMIT OF REPORTING	DEFAULT GUIDELINE VALUES		AMAGULA RIVER			
			DRINKING WATER[1]	RECREATION[2]	MINIMUM VALUE[4]	MINIMUM MEDIAN[3]	MAXIMUM MEDIAN[3]	MAXIMUM VALUE[4]
Selenium	mg/L	0.01	0.01[h]	0.01	0.01	0.01	0.01	0.01
Uranium	mg/L	0.001	0.017[h]	N/V	0.001	0.001	0.001	0.001
Vanadium	mg/L	0.01	N/V	N/V	0.01	0.01	0.01	0.01
Zinc	mg/L	0.005	3[a]	5	0.005	0.005	0.005	0.011

1 Guidelines for human drinking water supply derived from NHMRC Guidelines (2011)

2 Guidelines for recreational use derived from Section 5.2.3 of the ANZECC Guidelines

3 Minimum and maximum of the median value calculated independently from EMP4, EMP6 and EMP7 datasets

4 Minimum and maximum recorded values derived from combined EMP4, EMP6 and EMP7 datasets

5 pH upper and lower limits presented

4 Dissolved oxygen lower limits presented

Non-detections have been reported as the analytical limit of reporting

Bold denotes water quality exceeds the default guideline value for drinking water and/or recreation

N/V Default guideline value not available for parameter

a Drinking water guideline (aesthetic)

h Drinking water guideline (health)