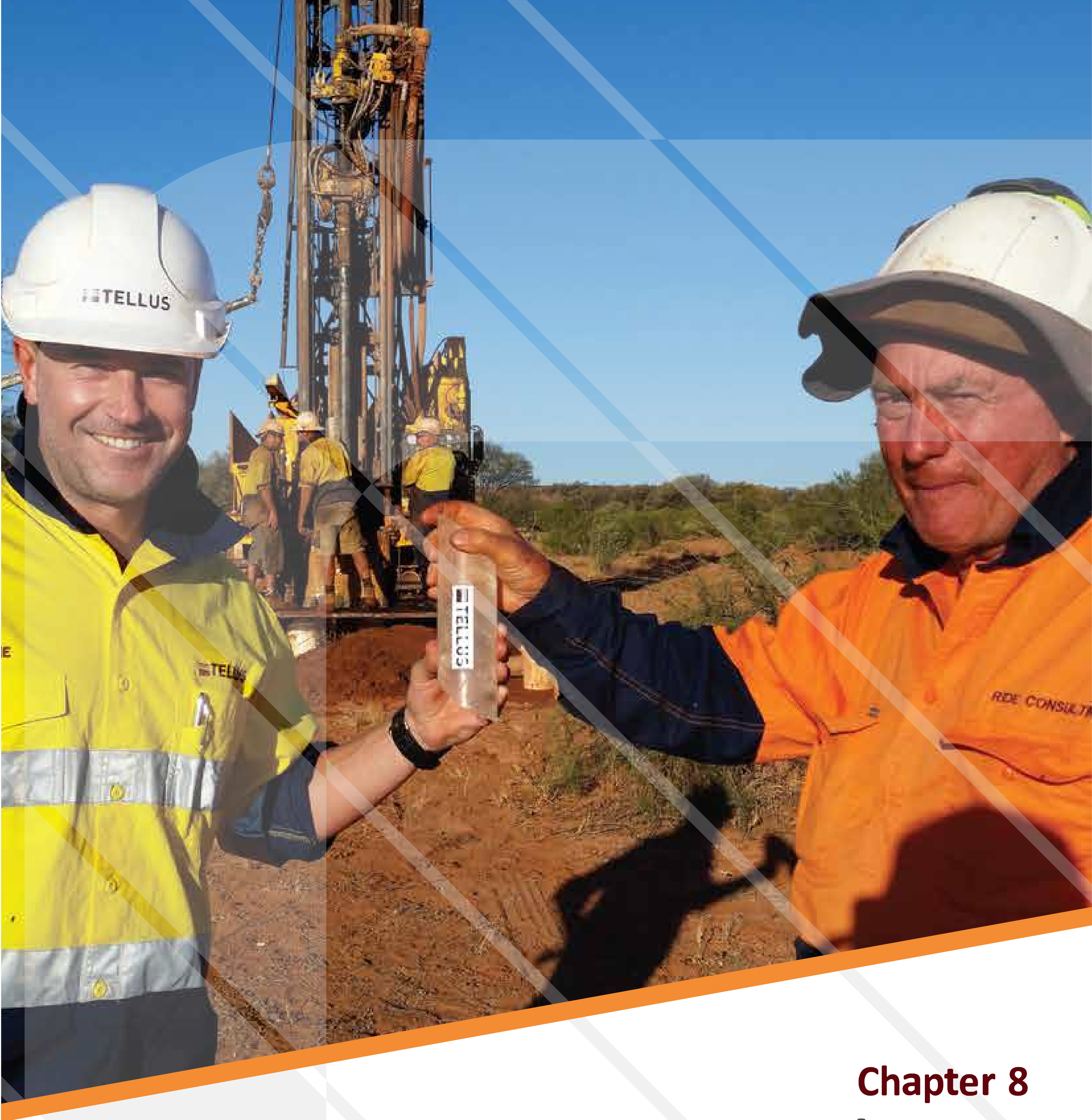

Chapter 8

Groundwater

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ABBREVIATIONS

AEMR	Annual Environmental Monitoring Report
AES	Alternate Evolution Scenario
AHD	Australian Height Datum
BGL	Below Ground Level
DENR	Department of Environment and Natural Resources
DLRM	Department of Lands and Resource Management
DPIR	Department of Primary Industry and Resources
EEC	Endangered Ecological Communities
EES	Expected Evolution Scenario
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
GAB	Greater Amadeus Basin
JORC	Joint Ore Reserves Committee
L/s	Litres per second
MAS	Mereenee Aquifer System
NT	Northern Territory
TDS	Total Dissolved Solids

8 GROUNDWATER

8.1 Introduction

This chapter provides a review of local and regional hydrogeology and groundwater resources that may be potentially affected by the construction, operation and closure of the Proposal. The review draws on the following (see Appendix P) that were undertaken to support the groundwater impact assessment for the Proposal:

- Geo 9 (2015).
- Atkins (2015).
- Quintessa (2016).
- EMM (2017).

Local and regional groundwater conditions are described. The potential impacts on local and regional groundwater resources, users and potential dependant ecosystems are assessed. Mitigation, management and monitoring measures are subsequently identified with the objective of reducing potential impacts during construction, operation and following closure of the Proposal. A draft Water Management Plan is also provided in Appendix Q.

The groundwater assessment has been prepared in accordance with the Terms of Reference (refer to Appendix A).

8.2 Methodology

This section describes the methodology used for the groundwater assessment. The methodology included a review of available literature, analysis of data collected from a groundwater monitoring network established within and around the Proposal area, conceptual groundwater modelling and groundwater impact assessment, mitigation and management strategy.

8.2.1 Literature review

A review of published geotechnical and hydrogeological reports was undertaken to collate information on the regional physical environment, including climate, topography, land use, surface water, geology, hydrogeology and water dependent ecosystems and other sensitive receptors.

The review has a focus on groundwater and surface water environments across the south-east of the Northern Territory and the north-west of South Australia. A summary of the critical information sources is included in Appendix N.

8.2.2 Groundwater monitoring and field investigations

Groundwater monitoring is an essential component in characterising the Proposal area baseline (pre-mining) hydrogeological and hydrological environments. Baseline water level and quality data collected from the various aquifers and watercourses is used to understand flow paths, recharge and discharge characteristics, and groundwater–surface water connectivity. The collection and analysis of field data was used to establish the conceptual (hydrogeological) model.

A dedicated groundwater monitoring network for the Proposal was designed and installed in May 2015 to investigate the local hydrogeological conditions across the proposed development footprint and vicinity. Following installation of the network, 15 months of groundwater monitoring data was collected at monthly intervals including baseline groundwater level and groundwater quality data.

The groundwater monitoring network (Figure 8-1) was designed to provide reasonable spatial coverage to investigate the main hydrogeological systems.

The groundwater monitoring network:

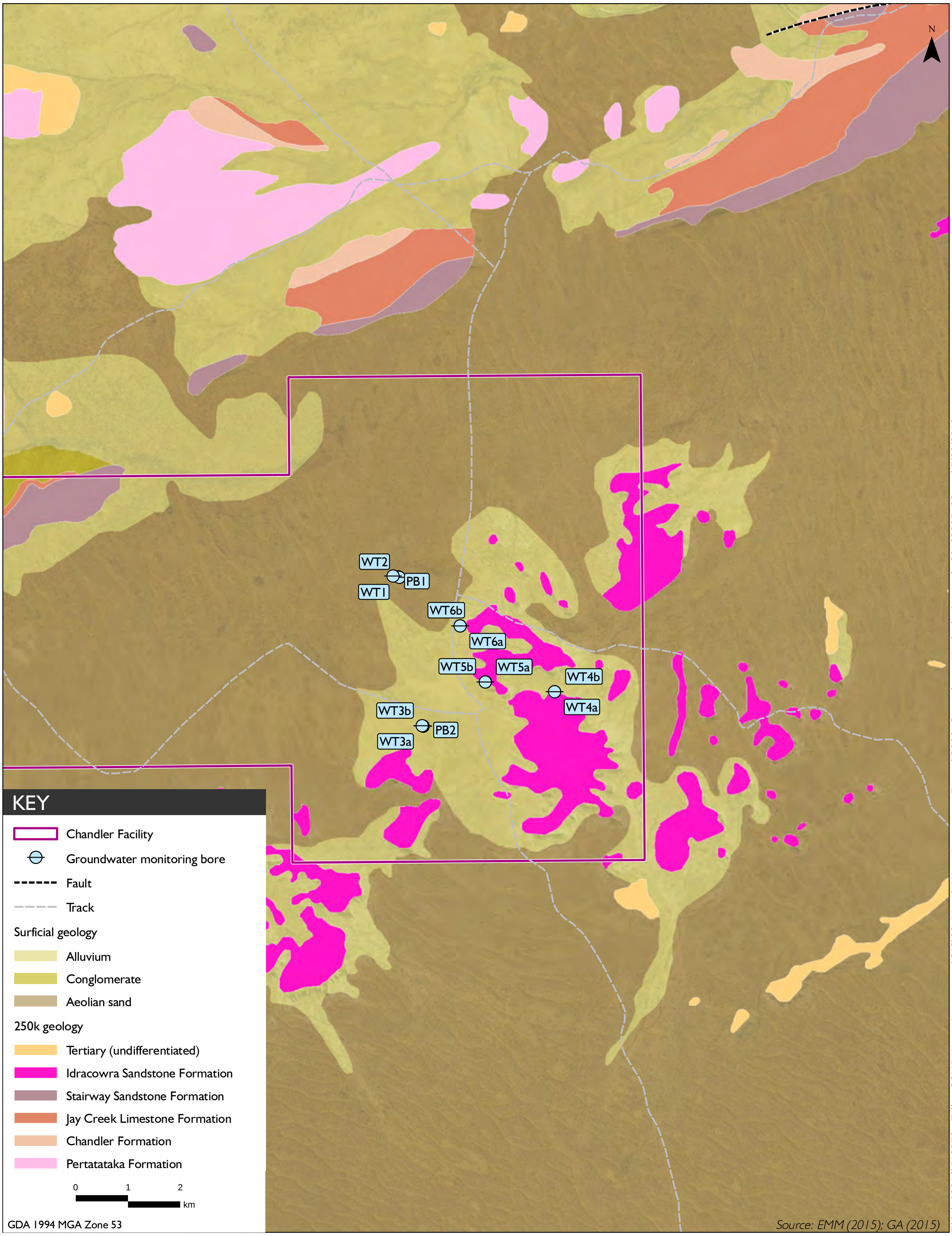
- Identifies and characterises water bearing units (aquifers) and aquitards in the Chandler Facility area, with focus on characterising groundwater flow and quality within the main groundwater bearing units, the Horseshoe Bend Shale Formation and the Langra Formation, which both overlie the Chandler Formation (salt deposit) by hundreds of metres.
- Provides spatial representation of pressure heads across the Chandler Facility area to investigate potential vertical hydraulic gradients and potential connectivity between water bearing units.

Groundwater quality data collected from the monitoring network was assessed using the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000). These guidelines describe requirements over a variety of marine and freshwater environments, aquatic ecosystems, primary industries, recreational water, drinking water and monitoring and assessment.

With the aim of further characterising the extent and hydraulic properties of the local groundwater environment, the assessment also included a review of data collected during a groundwater pumping test at the Proposal site, and a review of downhole and surface geophysical survey data.

Pumping tests are conducted by pumping water from a test bore at a constant rate and duration that stresses the aquifer and initiates a groundwater level response (drawdown) in monitoring bores. Tests are designed as a direct and reliable way to obtain estimates of aquifer properties including storativity, transmissivity and horizontal hydraulic conductivity. Pumping tests can also provide information on the extent and sustainability of the aquifer and the degree of connection with nearby surface water bodies if present.

Specialist groundwater assessments (Appendix P) provide details of the design, construction and installation of the groundwater monitoring network, and further details of the field investigations.



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Groundwater monitoring network
Chandler Facility
Figure 8.1

8.2.3 Groundwater modelling and water balance

The Terms of Reference included a requirement for: "A conceptual site model describing potential sources, pathways, receptors, and fate of any potentially contaminated waters. The model should be of sufficient detail for the general reader to understand the source(s) of potential contaminants, the mechanism(s) of their release, the pathway(s) for transport, and the potential for human and ecological exposure to these potential contaminants."

The *Australian Groundwater Modelling Guidelines* (NWC 2012) define a conceptual model in terms of a descriptive representation of a groundwater system that incorporates an interpretation of the geological and hydrological conditions consolidating the current understanding of the key processes of the groundwater system. The conceptual model assists in the understanding of possible future changes to the system and can be modified and refined as additional field data is collected.

Section 3 of the *Australian Groundwater Modelling Guidelines* provides guidance on conceptualisation, and specifies that development of the conceptual model should consider:

- Hydrogeological stratigraphy (including the occurrence and extent of aquifers)
- Aquifer properties.
- Conceptual boundaries.
- Stresses on the groundwater system.
- Groundwater flow processes and surface water groundwater interactions.

These criteria have been addressed throughout the Groundwater Assessment, and in the development of a conceptual (hydrogeological) model in accordance with the guideline and for the purpose outlined in the terms of reference.

An initial conceptual water balance was also completed for the Proposal based on the conceptual mine plan and provides an estimate of water inflows, outflows and storage within the system.

The conceptual model and water balance assist in the understanding of possible future changes to the system and are based on both qualitative and quantitative information derived from the literature review and groundwater monitoring and field investigations.

8.2.4 Groundwater impact assessment

The Groundwater Assessment includes an impact assessment which uses the conceptual model to assist in the assessment of potential impacts of the Proposal, specifically:

- Impacts from predicted changes in groundwater level and quality of groundwater, surface water, groundwater dependant ecosystems and landholder bores.
- Sources of potential contaminants, mechanisms of their release, pathways for transport, fate of any potentially contaminated waters, and the potential for human and ecological exposure to potential contaminants.

Hydro-stratigraphic and geo-mechanical impacts of the Proposal are also assessed in this review.

8.2.5 Risk management, mitigation and monitoring

In accordance with the Terms of Reference, a risk assessment matrix was used to quantify the level of risk (risk rating) based on the following: the likelihood of a potential impact occurring; and the consequence of a potential impact. Based on the risk ratings, the assessment includes the identification of management, mitigation and monitoring measures during the development, operation and closure of the Proposal.

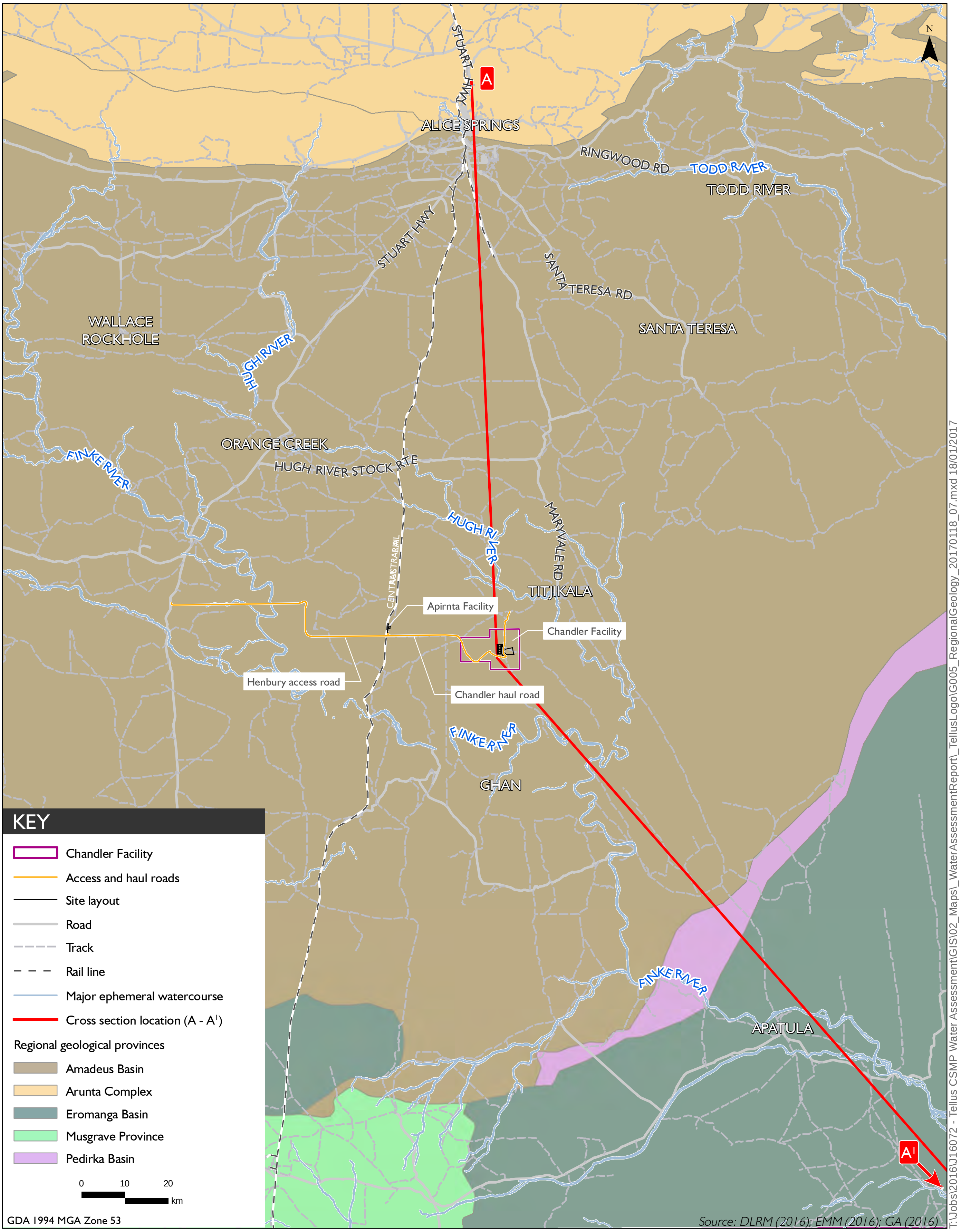
8.3 Existing environment

This section describes the regional geological and hydrogeological setting and sensitive receptors in the vicinity of the Proposal.

8.3.1 Regional geological setting

The regional geological setting in the vicinity of the Proposal in south-east NT and northern South Australia is dominated by three geological basins – the Amadeus Basin, Pedirka Basin, and the Eromanga Basin (Figure 8-2 and Figure 8-3). The Proposal is located within the Chandler Syncline sub-basin that forms part of the south-eastern extent of the Amadeus Basin, the most northerly of these three major basins.

The extent, depositional context and structure of the Amadeus Basin are described below. The Pedirka and Eromanga Basins are described in detail in the Groundwater Assessment (Appendix P).



Regional geological provinces

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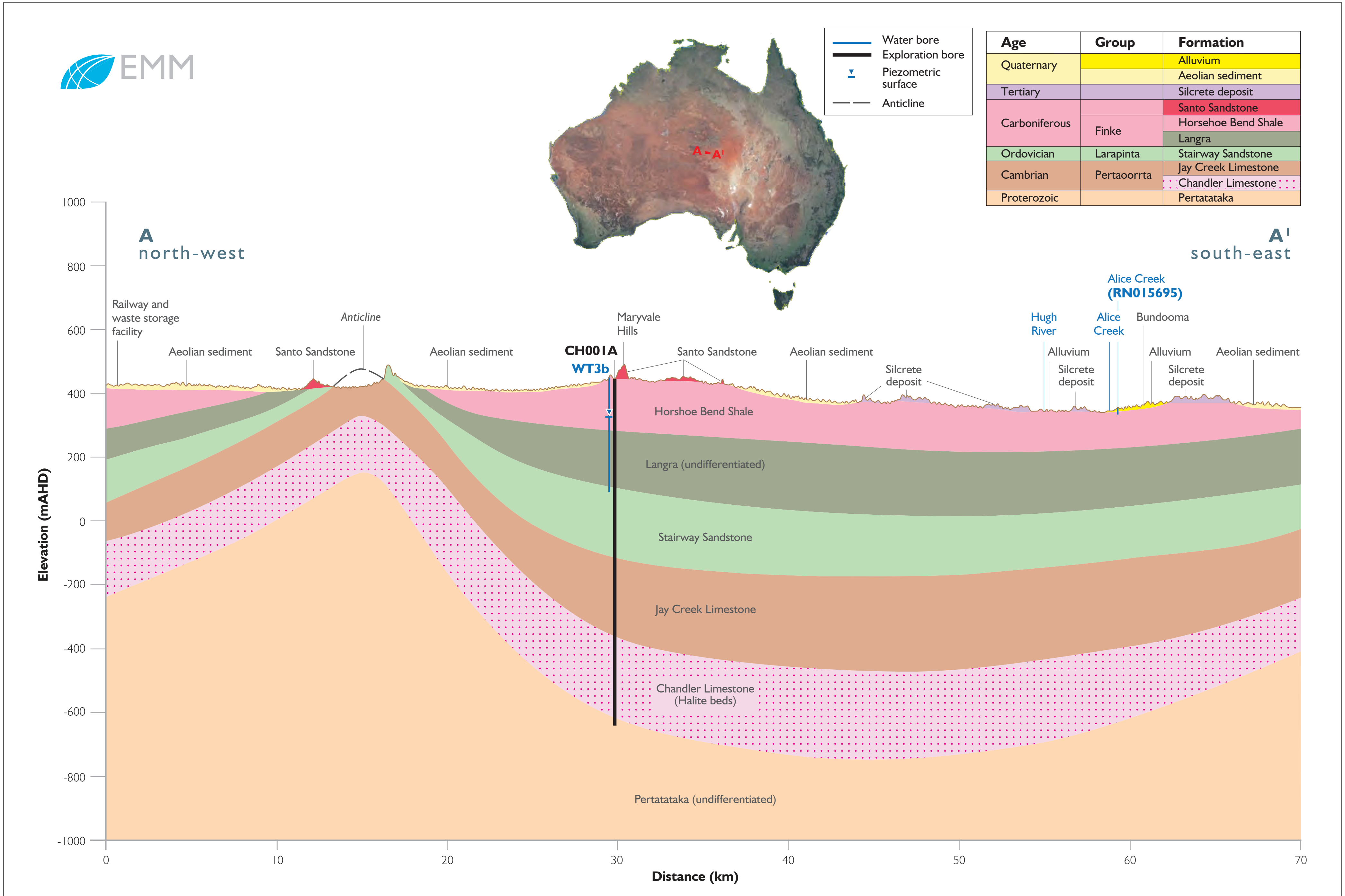
Figure 8-2



Age	Group	Formation
Quaternary		Alluvium
		Aeolian sediment
Tertiary		Silcrete deposit
Carboniferous		Santo Sandstone
	Finke	Horsehoe Bend Shale
		Langra
Ordovician	Larapinta	Stairway Sandstone
Cambrian	Pertaoorrta	Jay Creek Limestone
		Chandler Limestone
Proterozoic		Pertatataka

Amadeus Basin

The Proposal area lies within the Chandler Syncline sub-basin of the south-eastern extent of the Amadeus Basin. The Amadeus Basin is an extensive asymmetrical east-west trending, elongate sedimentary basin with an area of approximately 155,000 square kilometres (Lloyd and Jacobson 1987). The south-eastern extent of the Amadeus Basin abuts the Pedirka Basin about 80 kilometres south-east of the Proposal area (and close to the north-western extent of the Eromanga Basin – Figure 8-2). The land surface is structurally controlled to the north, east and west by a series of extensive Palaeozoic orogenies including Precambrian intrusive and metamorphic rocks (Lloyd and Jacobson 1987). Alluvial sediments dominate low lying areas.

The Basin comprises a series of synclinal sub-basins defined by numerous folds and thrust belts. The three predominant sub-basins are: the Northern Amadeus Sub-basin; the Orange Creek Syncline; and the Chandler Syncline. The Proposal lies within the southern-most Chandler Syncline sub-basin.

The predominant marine and terrestrial sedimentary sequences that form the Amadeus Basin were deposited about 500 million years ago (Alley and Gravestock 1995). The deposits include: dolostone, limestone, shale, sandstone, siltstone, quartzite, evaporite, diamicite and conglomerate (NT Department of Mines and Energy 2016). The sedimentary sequences reach a maximum thickness of around 8 kilometres, however the Chandler Syncline sub-basin depth extends to around 2 kilometres.

Several significant geological events have influenced the structure and geological composition within the Amadeus Basin. Sedimentation of dolomitic siltstones and sandstones in the Late Proterozoic was terminated by a period of mountain building, salt deposition, folding and thrusting, particularly in the north-western area of the basin (Wells et al. 1970). During the Cambrian period, continental sedimentation persisted in the north-west, while shallow marine shales, carbonates and evaporites were deposited in the north-east (Lloyd and Jacobson 1987). Ocean regression terminated marine deposition in the Late Ordovician period (Coffey 2012). The Alice Springs Orogeny, in the Carboniferous period, was a major mountain building period resulting in extensive folding and faulting in the Amadeus Basin (Lloyd and Jacobson 1987).

The stratigraphic summary and associated mountain building periods (orogenies) of the south-eastern extent of the Amadeus Basin observed across the Proposal area are shown in Table 8.1. The key geological units encountered by the Proposal are highlighted in different shades of orange.

Table 8-1 Stratigraphic summary of the south-eastern extent of the Amadeus Basin

Age	Group	Formation	Hydrogeology
Quaternary		Alluvium	Aquifer (perched)
		Aeolian sediment	Aquifer (perched)
Tertiary		Silcrete deposit	Aquatard (local)
Carboniferous		Idracowra Sandstone	Aquifer
Devonian			Aquifer
	Finke	Horseshoe Bend Shale	Aquifer
		Langra	Aquifer
Ordovician	Larapinta	Stairway Sandstone	Aquifer
Cambrian	Pertaoorrta	Jay Creek Limestone	Potential aquifer
		Giles Creek Dolostone	Potential aquifer
		Chandler	Not applicable
Proterozoic		Pertataka	Unknown

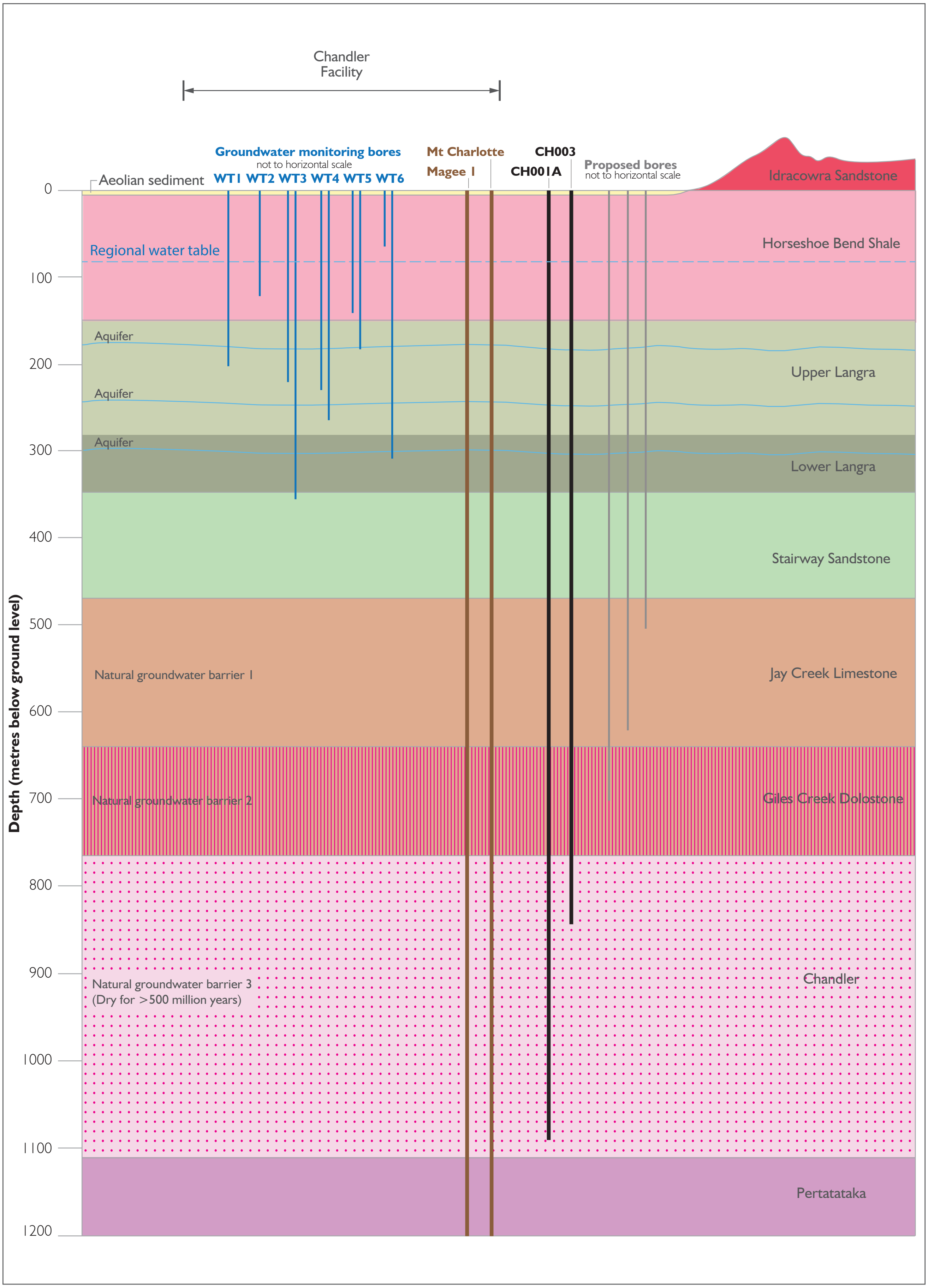
8.3.2 Local geological setting

The Proposal targets the Chandler Formation, a unit of the Pertaoorrta Group of Cambrian age (485-541 million years old) within the Chandler Syncline of the southern Amadeus Basin. Despite the complex history of the Amadeus Basin, the strata in the area of the Proposal are relatively flat lying and continuous.

The geological structure in the area of the Proposal has been investigated by some 2D seismic coverage in the area (reprocessed as part of the Tellus investigations), and sampled by four deep boreholes and nine shallower boreholes. The four deep boreholes reach the Chandler Formation; two were drilled by Tellus (CH001A and CH003), and two are pre-existing oil exploration wells (Mt Charlotte No. 1 and Magee) (see Figure 8-4).

CH001A lies at the northern margin of the underground footprint of the facility, while the other boreholes are outside the Chandler Facility footprint. Both CH001A and CH003 were drilled to the base of the salt for site investigation purposes and were subsequently fully sealed with cement grout. CH001A was fully cored. Additionally, 9 shallower boreholes, with depths of up to 360 metres, were drilled within the footprint of the facility during 2015 for the purpose of obtaining hydrogeological information.

The Chandler Formation is encountered between 755 and 811 metres below ground level. The Halite formation is up to 300 metres thick in places (Tellus exploration borehole CH001A). It occurs as an extensive evaporite unit comprising anhydritic siltstone to 825m and halite below that. Core from boreholes CH001A and CH003 show the salt to be almost pure halite (yellow to red brown, transparent and glassy) with very few marly beds (siltstone and claystone) or other impurities. The unit was formed when a relatively shallow water basin was repeatedly flooded and then subjected to subsequent evaporation, resulting in the deposition, desiccation and precipitation of evaporites (Coffey 2012).



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Chandler Facility Stratigraphy

The Chandler Facility would be located in the upper part of the Chandler salt formation. The upper halite bed in borehole CH001A is present in the depth interval 825 metres to 861metres (Joint Ore Reserves Committee (JORC) report (ERCOSPLAN 2014)). It is overlain by siltstone and underlain by a 10 metre thick bed of limestone/siltstone. Below this bed, the formation is dominantly halite with minor limestones and siltstones. Interpretation of the seismic data at this depth has identified the extent of the salt horizon and suggests that it is stable (i.e. the salt does not appear to be subject to any dissolution in the recent past and it is not migrating (RPS 2013)).

The target horizon is 35 metre thick in borehole CH001A and 34 metres thick in borehole CH003 (and at a slightly shallower depth in CH003). The facility is designed to allow for 20 metres of intact salt above the excavations, which implies that the facility would be at a depth of approximately 850 metres.

Overlying the Chandler Formation are deposits of siltstones and sandstones associated with the Pertaoorrta Group (Giles Creek Formation and Jay Creek Sandstone Formation), Larapinta Group (Stairway Sandstone Formation), Finke Group (Horseshoe Bend Shale Formation and Langra Formation) and the Idracowra Sandstone Formation (see Figure 8-4). Exploration drilling has characterised the overlying geological formations as follows (from shallow to deep):

- **Idracowra Sandstone Formation**: a kaolinitic sandstone that caps the Maryvale Hills across the Chandler Facility area and has a maximum thickness of 40 metres.
- **Horseshoe Bend Shale Formation**: a massive, red brown siltstone/very fine grained, soft to firm quartz sandstone with moderate mica. Contains occasional beds (up to 1 metre thick) of light brown, fine grained sandstone.
- **Langra Formation:** subdivided into three members: the upper, a very fine to coarse light brown sandstone; middle, a mottled red brown siltstone; and lower, a pale brown to orange very fine to fine sandstone with interbedded siltstone. The base of Langra formation is approximately 340 metres below ground level.
- **Stairway Sandstone:** a white coarse to medium grained sandstone with interbedded siltstone and minor shale. The base of the Stairway Sandstone is approximately 500 m below ground level.
- **Jay Creek Sandstone Formation:** comprises upper layers of siltstone with thin interbeds of dolomite and minor fine grained sandstone, and lower layers of shale, and laminated claystone and siltstone (Ride Consulting 2015). The base of the Jay Creek Formation is approximately 770 metres below ground level.
- **Giles Creek Dolomite Formation**: a fine-grained, massive, yellow-brown dolomitic limestone unit, with minor shale bands.

Underlying the Chandler Formation is the Pertatataka Formation (see Figure 8-4), a siltstone and shale formation with lenses of sandstone, dolomite, limestone and conglomerate (Bureau of Mineral Resources, Geology and Geophysics 1968).

To the south of the Proposal the overall formation deposition is mostly flat lying with localised deformation. West of the Proposal, associated with the Charlotte Ranges, is a major anticline, which causes the formations encountered at the Chandler Facility to dip towards the south-east. To the north-east of the Proposal, near the Hugh River, the geology is again deformed as it tilts upwards in what is assumed to be another major anticline.

8.3.3 Regional Hydrogeology

As described in Section 8.3.1., the geological composition and structure of the Amadeus Basin is highly complex, with the development of local and regional groundwater systems influenced by the complex depositional environment and structure of the area, namely the Alice Springs, James Ranges and Petterman Orogenies (refer to Table 8.1).

There are three main groundwater system types associated with the central and south-eastern NT within the Amadeus Basin, the:

- Mereenie Aquifer System (MAS)
- Fractured rock groundwater systems.
- Near surface sediment groundwater systems.

The extent and groundwater flow and recharge/discharge characteristics of each of these systems is summarised below and described in detail in Appendix P.

Mereenie Aquifer System

In the northern-central part of the Amadeus Basin, near Alice Springs, broad folds define three key aquifer systems, the Hermannsberg Sandstone, Mereenie Sandstone and the Pacoota Sandstone systems (Lloyd and Jacobson 1987). These aquifers are collectively termed the MAS (Jolly et al, 2005), and are associated with sediments deposited in the Carboniferous, Devonian and Early Ordovician periods. The MAS units occur within the Northern Amadeus sub-basin and Orange Creek Syncline, but do not occur within the Chandler Syncline (refer to cross-section A-A' in Figure 8-3).

Fractured rock groundwater systems

South of the Orange Creek Syncline and the Central Ridge (see Figure 8-3), a series of intense folding and faulting generated by the James Ranges and Ollife Range has given rise to the deposition of a series of fractured rock systems, including those within the Chandler Syncline. These are primarily Devonian to Ordovician age with some systems extending to the south-east partially dipping below the Pedirka Basin

Unlike the MAS to the north, groundwater within the fractured rock systems is unlikely to be extensive. Localised faulting and the deposition of claystones and siltstones form leaky aquitards throughout the area are likely to have resulted in the development of less extensive and more localised groundwater systems.

Groundwater storage and flow within these localised systems is likely to be restricted by their thickness and the permeability of the geology. Recharge is thought to occur through infiltration of overlying alluvial stream beds during flood events however, the reduced permeability influenced by the claystone aquitards is likely to restrict recharge to these deeper systems.

Discharge is understood to occur primarily via evapotranspiration and at springs along the Finke River to the south-east of the Proposal. Water quality within the localised groundwater systems is highly variable and generally considered to be brackish to saline (> 1,500 mg/L). The limited recharge and low permeability of the system is thought to contribute to long groundwater residence times, greater mineralisation of the local groundwater systems, and therefore reduced water quality.

Near surface sediment groundwater systems

The local near-surface sediment groundwater systems support the various ephemeral surface drainage features bisecting the Proposal. These surface drainage channels incise the bedrock, allowing sediment to partly fill the channel void and provide a medium for groundwater storage and flow. Sediment is typically characterised as moderately porous, poorly sorted and unconsolidated.

The main developed alluvial systems located across the south-eastern extent of the Amadeus Basin are associated with the Hugh River and Finke River. Recharge to these shallow systems primarily occurs during major flooding events.

Due to the shallow nature of these systems, the majority of natural discharge occurs via evapotranspiration. However, leakage to the underlying weathered bedrock is also expected to occur.

8.3.4 Local Hydrogeological setting

The assessment draws on published literature and field investigations including geophysical surveys and the establishment, testing and monitoring of groundwater levels and quality for the Proposal.

Proposal groundwater monitoring bores targeted the fractured sandstone aquifer present across the south-east of the Amadeus Basin. During the Proposal groundwater drilling campaign, inflows were first intersected in the Horseshoe Bend Shale Formation between 80 and 100 metres below ground level. Subsequent groundwater level monitoring has seen a rise in groundwater levels by up to 25 metres from the water intersections observed during drilling. This indicates the groundwater system is semi-confined with low primary porosity and permeability, and the groundwater level monitored is also considered to be the piezometric surface.

Groundwater flow is interpreted to be via fracture flow (secondary porosity), although some limited groundwater flow through primary porosity may also occur. The fundamental characteristic of fractured rock aquifers is the extreme spatial variability of groundwater occurrence, hydraulic conductivity and flow (Cook, 2003)[1]. During borehole drilling the lowest water intersections were observed in areas where the geology is fine grained and fractures are assumed to be absent (Ride Consulting 2015). Typically, geological units become more consolidated with depth, which is usually accompanied by less groundwater ingress. However, fracture frequency can also be maintained with depth, as evidenced by overall groundwater ingress increasing with depth during drilling through the sandstone/siltstone units.

Borehole water intersections in the relatively shallow Horseshoe Band Shale Formation were mostly comparable and ranged from 0.2 to 2 litres per second (L/s) (refer to Appendix P cross sectional figures {Ride Consulting 2015}); the highest yields were observed in the north-western extent of the Proposal. The next unit encountered was the Langra Formation, which exhibited a larger range of borehole water intersections, more typical of fractured rock groundwater flow. The average water yield for the upper Langra Formation was 4.2 L/s, the middle Langra Formation was 7.5 L/s and the lower Langra Formation was 11 L/s. A constant rate pumping test was conducted at bore PB1 in the upper Langra within the Chandler Facility area. The low pumping rate achieved (4 L/s) and the limited extent of drawdown (as observed at monitoring bore WT1) indicates that the local groundwater system is likely to have a low transmissivity and a limited extent.

Water yields for the next unit, the Stairway Sandstone, were recorded at two bores (between 15 and 20 L/s). Water yields observed during drilling typically over-estimate the sustainable yield from the Formation. A potential sustainable groundwater yield associated with the Stairway Sandstone is therefore likely to be significantly less and likely no greater than 5 L/s.

The Jay Creek Formation exhibits the potential for groundwater presence within the upper sequences of the Formation, as defined through the estimated porosity measurements of 30 % observed at the Mt Charlotte 1 exploratory bore. The Jay Creek Formation transitions into a calcareous dolomitic unit toward its basal extent, where it overlies the Giles Creek Formation. Groundwater potential is negligible within the extent of this unit, given its massive nature and the limited fracture potential.

The Chandler Formation halite deposit is hydro-geologically isolated from the overlying groundwater systems described above. If the water intersections observed in the overlying sedimentary units were indicative of enhanced aquifer permeability at depth, then associated groundwater flows would be expected to result in dissolution of the Chandler Formation, but there is no evidence for this. Basal shale layers in the Jay Creek and Giles Creek Formations are inferred to form an aquitard, preventing downwards groundwater flow. The uppermost regional aquifer is therefore confined to the sandstone and siltstone fractured units that overly the Chandler Formation.

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[1] *A guide to regional groundwater flow in fractured rock aquifers. Seaview Press, Adelaide, South Australia.*

Shallow aquifer mapping

An aquifer mapping survey[2] was undertaken by the proponent in September 2015 and the results analysed by Geo9 Pty Ltd (Geo9, 2015). The full report prepared by Geo9 is presented in Appendix N.

The dataset was used to indicatively model relative hydraulic conductivity using electroseismic tomography. The survey was undertaken within the proposed Mine Infrastructure Area and covered a 500 metre by 500 metre footprint to a maximum depth of about 390 metres below ground level (around 400 metre above the Chandler deposit).

Based on calibration with bore log data, the model results indicate there are three main aquifer zones within the saturated thickness of the sandstone aquifer, predominately between 140 and 350 metres below ground level, with minor small perched groundwater systems existing above the regional water table (inferred to be approximately 90 metres below ground level).

The main aquifer occurrences appear to be located in discrete horizontal zones of relatively high hydraulic conductivity which occur at varying depths throughout the Lower Langra Formation. The predicted zones of elevated hydraulic conductivity, which is a potential indicator of water within a geological unit, are depicted by the ‘spikes’ shown in Figure 8-5. The results of the shallow aquifer geophysical mapping correlate with bore log data.

The groundwater flow potential of the Horseshoe Bend Shale Formation, Langra Formation and Jay Creek Formation groundwater systems are likely to be dominated by secondary porosity as a result of the consolidated and deformed nature of the local geology (EMM 2016).

Based on the model data, Geo9 inferred that groundwater recharge does not appear to be strongly driven by local infiltration, with the majority of recharge most likely occurring remote to the site. The low hydraulic conductivity observed in shallower zones (less than 140 metres below ground level) and the depth of the piezometric surface (at about 90 metres below ground level) was interpreted to indicate that the near surface is relatively dry with little surface recharge to groundwater locally.

Geo9 concluded that, given the local arid climate and lack of apparent surface recharge, groundwater in the local system is likely to be ancient.

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[2] *Electroseismic and electrotelluric principles were used to complete the shallow aquifer mapping.*

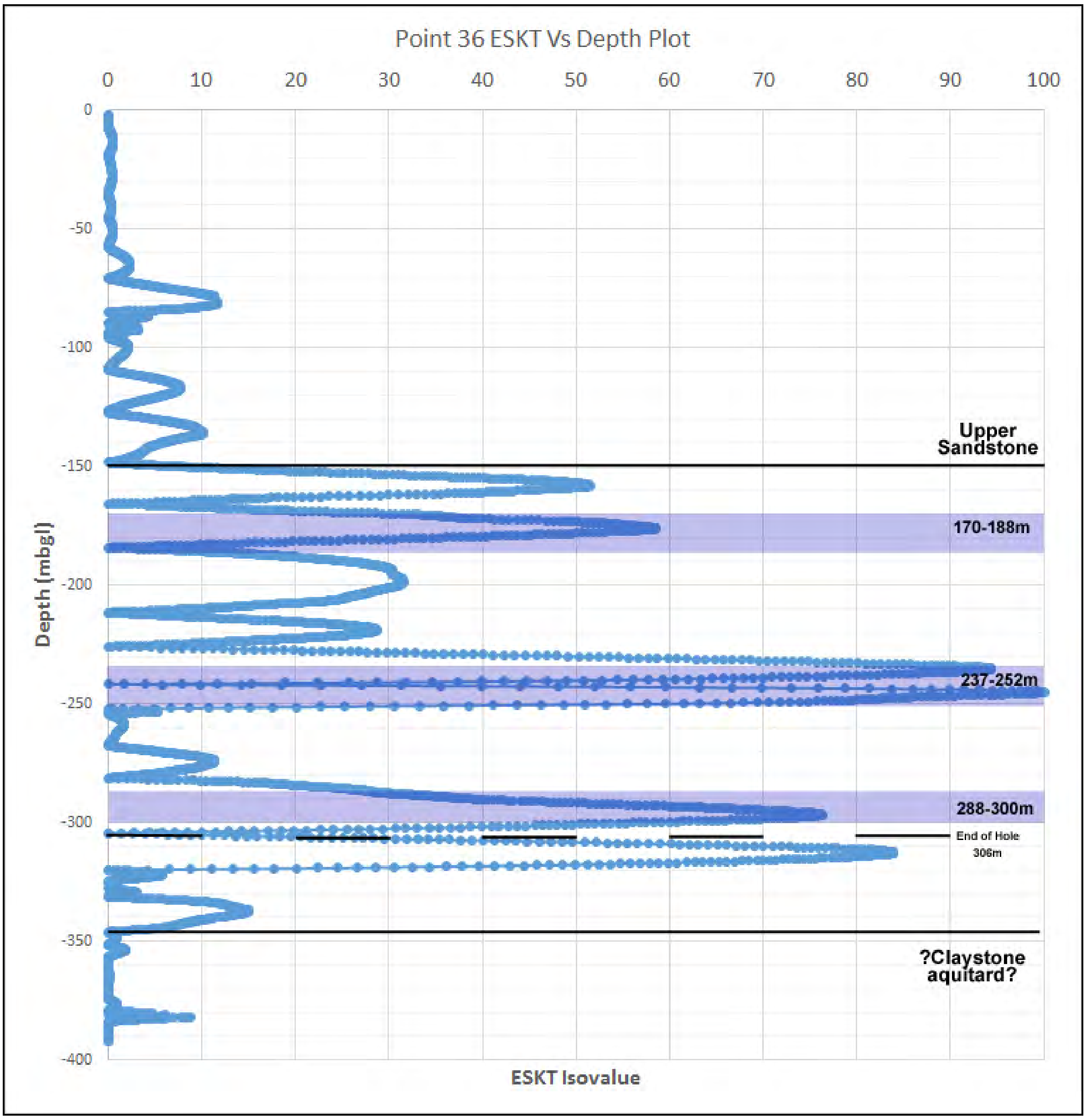


Figure 8-5 Electroseismic hydraulic conductivity tomography across the Proposal area (Geo9 2015)

Groundwater levels and flow

Hydrographs from the Proposal groundwater monitoring bores are presented in Figure 8-6, Figure 8- 7 and Figure 8-8. The hydrographs are plotted against daily rainfall to measure recharge potential within the targeted Horseshow Bend Shale and Langra Formations. The rainfall record comprised a composite dataset from Alice Springs Airport weather station (BoM station 015590) from 1 June 2015 to 6 November 2015, and the local Chandler Facility automated weather station data from 7 November 2015 onwards.

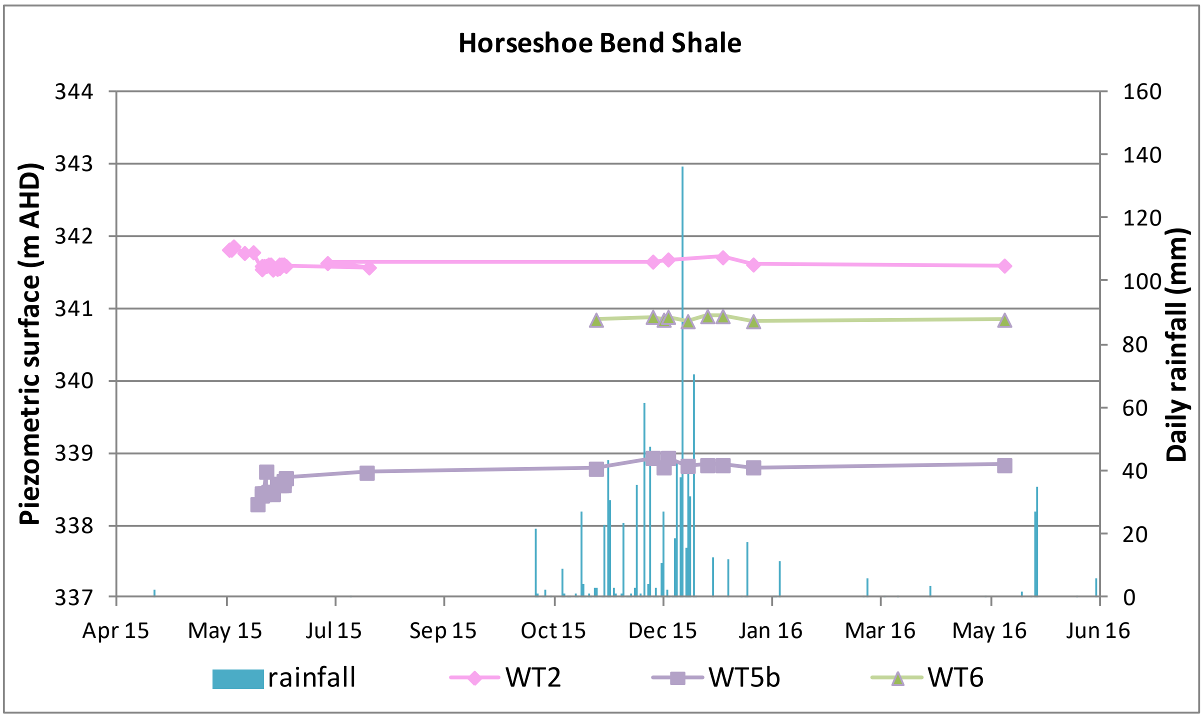


Figure 8-6 **Hydrograph for the Horseshoe Bend Shale Formation**

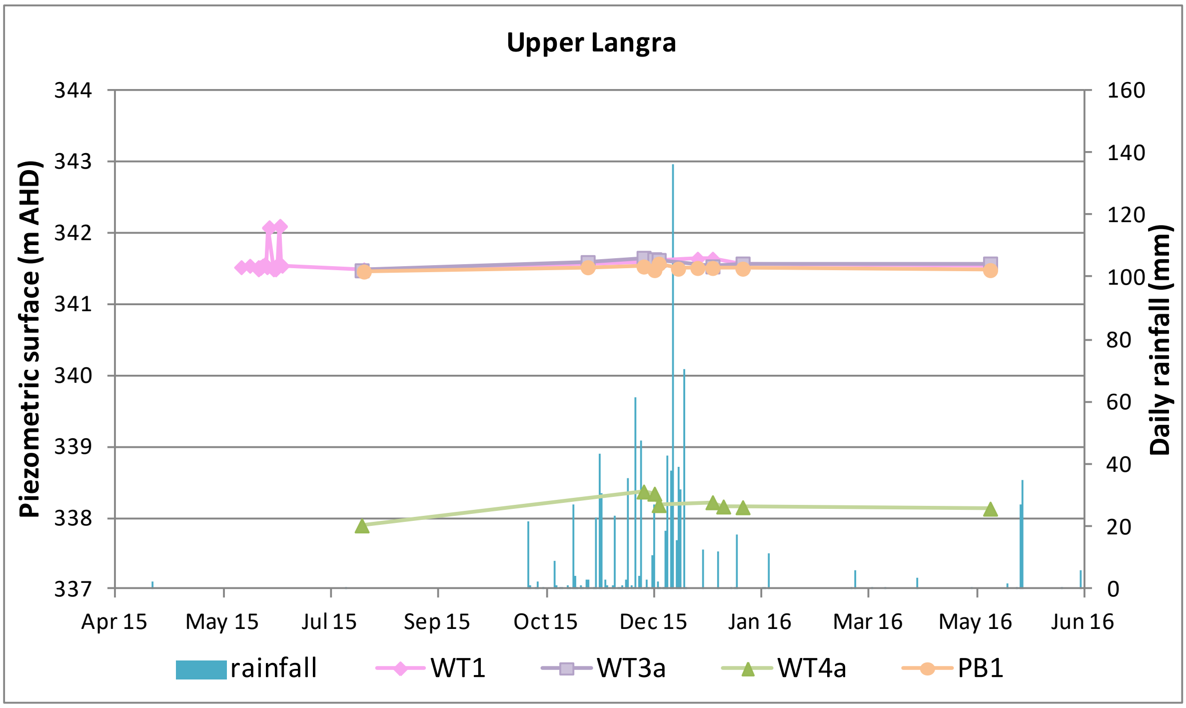


Figure 8-7 **Hydrograph for the Upper Langra Formation**

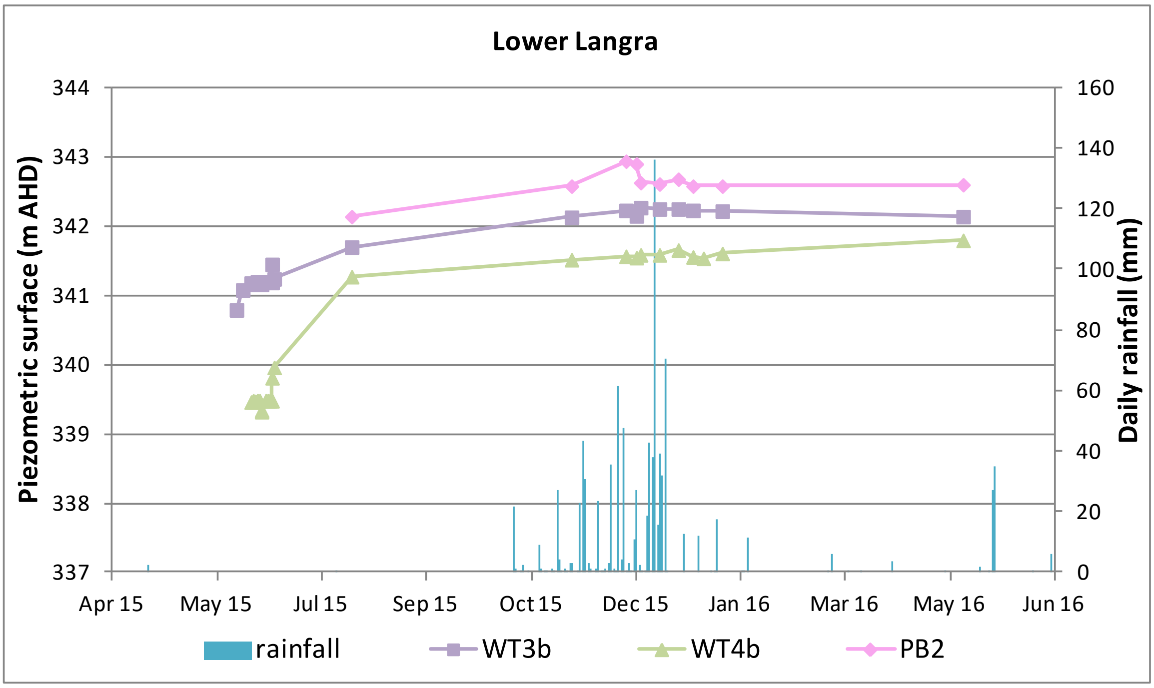


Figure 8-8 **Hydrograph for the Lower Langra Formation**

At the Chandler Facility the piezometric levels for the Horseshoe Bend Shale Formation and Langra Formation (Upper and Lower) are within a 5 metre range, between 338 and 343 metres Australian Height Datum (AHD). Recovery from drilling is relatively slow in the Lower Langra, as seen by the time taken for the piezometric surface to stabilise. This could be indicative of lower permeability and/or storage in this lower formation.

Overall, there is minimal response to rainfall recharge in the piezometric surfaces monitored, indicating the aquifer is dominated by lateral flow rather than vertical flow. In the uppermost formation, the Horseshoe Bend Shale Formation, there is a minor and delayed response (a 0.06 metre rise over 15 days) to rainfall recharge at WT2 and WT6a only.

The hydrographs for the Horseshoe Bend Shale Formation show a decline in piezometric surface (by up to 2 metres) from west to south-east, consistent with the regional groundwater flow direction. The relatively low piezometric surface in WT4b, in the east, compared to the western monitoring bores screening the Lower Langra Formation again confirms the regional west to south-east groundwater flow direction in the deeper unit. Comparable piezometric surfaces in the Upper Langra Formation indicate this unit is more confined than the overlying and underlying groundwater units.

The piezometric surfaces for the Upper Langra Formation are comparable, with the exception of WT4a. The level at WT4a, in the east of the Chandler Facility area, is lower than the piezometric surface at WT4b, targeting the Lower Langra Formation at this location. This indicates an upward vertical gradient within the Langra Formation in this location, likely influenced by local fracturing.

Analysis of the regional groundwater piezometric surfaces indicates that groundwater flows from the west of the Chandler Facility, where it is heavily controlled by topographic gradients, towards the south-east (refer to Figure 8-9). Beyond the Charlotte Ranges the groundwater flow direction shifts from easterly to south-easterly.

Groundwater recharge and discharge

The main groundwater flow mechanism for the fractured sandstone aquifer is considered to be rainfall recharge to outcropping units to the west and north-west of the Chandler Facility driving lateral flow in the units overlying the Chandler deposit. Secondary recharge is possible through regional through flow to the east and south-east.

As monthly average evaporation exceeds monthly average rainfall by up to 11 times, recharge is event-based and episodic, occurring only during high rainfall events that cause flooding of the overlying local alluvial groundwater systems adjacent to watercourses.

However, across the mine infrastructure area, groundwater level changes were observed to be muted or negligible in response to rainfall as indicated by observations and records at each groundwater monitoring bore.

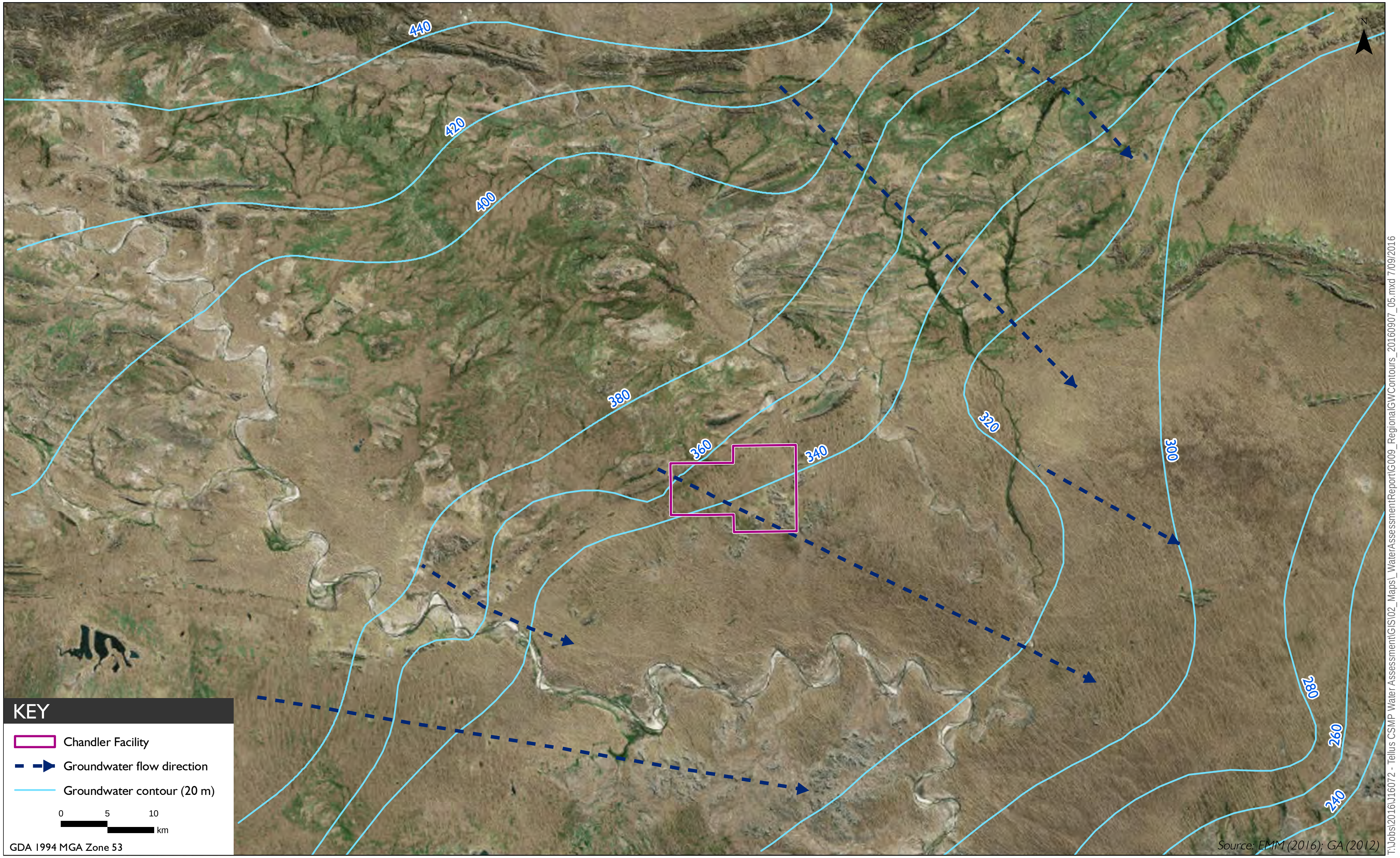
Relic flat basins to the west of the Proposal area are interpreted to have been historic areas of discharge. However, discharge now occurs to the east to the northern Eromanga Basin (Lloyd and Jacobson 1987). This is considered consistent with the regional groundwater flow direction observed from the Proposal groundwater monitoring bores and the standing water levels within regional landholder bores.

On the downstream hydraulic gradient of the proposed Chandler Facility, five groundwater springs are observed to be discharging at the banks of the Finke River to the south and south-east. These include Horseshoe Bend Spring, Black Hill Spring, Polly's Spring, Micks Soak and Pascoes Spring. All springs other than Pascoes Spring (c. 20 km south) are located greater than 50 km south-east of the Chandler Facility and are likely to be discharging from the shallow alluvial groundwater system, which would not be intercepted by the Proposal.

The groundwater flow direction at the Horseshoe Bend Spring location is oriented west/east, whereas the flow from the Proposal area is oriented north-west/south-east. This indicates that groundwater discharges at the Horseshoe Bend spring area are likely to be sourced from a separate groundwater system to the south of the Finke River.

Groundwater quality

Groundwater quality results collected between May 2015 and May 2016 are presented as an average for each sampling location in the Groundwater Assessment (Appendix N).



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Regional groundwater contours

Chandler Salt Mine Project
Water Assessment

Figure 8.9

The groundwater quality results are reasonably comparable between the different target Formations. The groundwater is slightly alkaline (averaging pH 8) and saline (electrical conductivity ranged between 12,600 and 21,000 microSeimens per centimetre (µS/cm)).

The water type at all locations was dominated by sodium and chloride, with minor calcium and sulfate ions. Total iron and zinc measurements were typically two to three orders of magnitude higher than the other total metal analytes.

Regional water quality monitoring conducted by the NT Government indicates that salinity is comparable (ie moderately saline) for other monitoring locations targeting the Langra Formation. Regional mean electrical conductivity (11,307 µS/cm) is slightly lower than observed within the proposed Chandler Facility area but remains within a saline category. Regional monitoring in the Stairway Sandstone, underlying the Langra Formation, has comparable pH and electrical conductivity results (mean electrical conductivity: 16,578 µS/cm) to the Langra Formation at the Chandler Facility. Regional water type for the Langra Formation and Stairway Sandstone is also dominated by sodium and chloride. The water is generally suitable only for industrial uses.

It is important to note that:

- All the aquifers (Horseshoe Bend Shale, Upper Langra, Lower Langra and Stairway Sandstone) contain water with salinity significantly in excess of the salinity of potable water. Were water from these aquifers to be used for human consumption it would need to be diluted to < 1000 mg/L and more likely < 6 00 mg/L (e.g. WHO 2011).
- The highest salinity groundwaters occur in the Stairway Sandstone (approximately 15,000 mg/L). The Jay Creek Formation (approximately 40,000 mg/L) and the underlying Gillen Member (of about 318,000 mg/L).
- The highest salinities are all less than any water that is saturated with respect to (in equilibrium with) halite. Such a water at 25 °C would equal about 360,000 mg/L.

If any of these groundwaters were to be used in future for human consumption or for agriculture, they would need to be diluted significantly on account of their high salinity. This dilution would also reduce the concentrations of any contaminants that could potentially mobilise in the groundwater systems through construction, operational, or post closure activities (which is assessed to be very unlikely, refer to Section 8.6.2).

The relatively low salinity of the groundwater within the upper part of the Chandler Formation is very unlikely to be due to upwards flow of halite solute because:

- Such a process would be expected to result in dissolution of the halite in the upper part of the Chandler Formation, for which there is no evidence (e.g. RPS 2012).
- On lithological grounds the upper part of the Chandler Formation is interpreted to have very low permeability, inhibiting rapid groundwater flow.

- Groundwater fluxes are interpreted to be very slow, based on the low interpreted rates of recharge and low hydraulic gradients.

In view of these points, the steep salinity gradient that must exist between the top of the Chandler Halite and the upper lithologies (Horseshoe Bend Shale, Upper, Middle and Lower Langra, and Santo Sandstone) where groundwater samples were obtained, implies that if natural transport of solutes did occur in an upwards direction from the Chandler Halite, it must be extremely small (i.e. it has no material effect on the salinity of the overlying formations).

Similar arguments to these also support the conclusion that any natural fluxes of groundwater and solutes upwards from the Chandler Formation to the Stairway Sandstone Formation must be very small.

The density contrast between the deeper saline water near to the Chandler Halite and the shallower, less saline water within the overburden would also tend to act against upwards flow of groundwater. For example, the salinity of the water in the Stairway Sandstone implies a density of about 1,015 kg/m^3. In contrast, water in the Chandler Formation that has dissolved halite to the point of saturation would have a salinity of about 360,000 mg/L, equivalent to a density of about. 1,360 kg/m^3.

Water use - Landholder bores

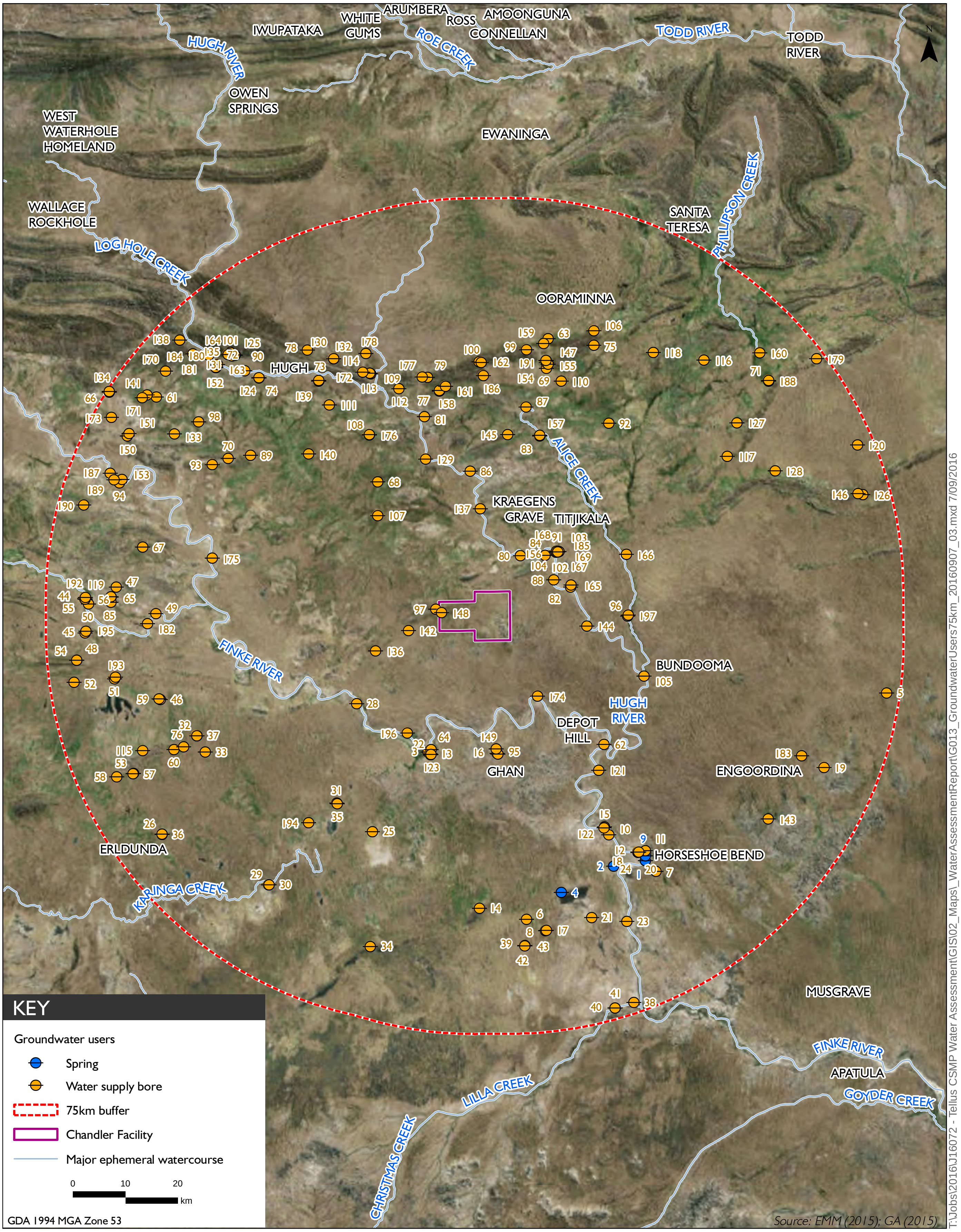
The Amadeus Basin hosts numerous groundwater supply bore fields across central and south-eastern NT. Regionally, the Roe Creek and Rocky Hill Borefield, located approximately 100 km north of the Proposal provide the potable supply to Alice Springs. Both bore fields are located within the Orange Creek Syncline and target the Mereenie Aquifer System which is distinctly separate to the Chandler Syncline system.

Elsewhere, closer to the Proposal and within the south-east extent of the Amadeus Basin, numerous landholder bores target the shallow near-surface sediment groundwater systems along the Finke and Hugh Rivers. Other bores target deeper groundwater within the Idracowra and Stairway Sandstone.

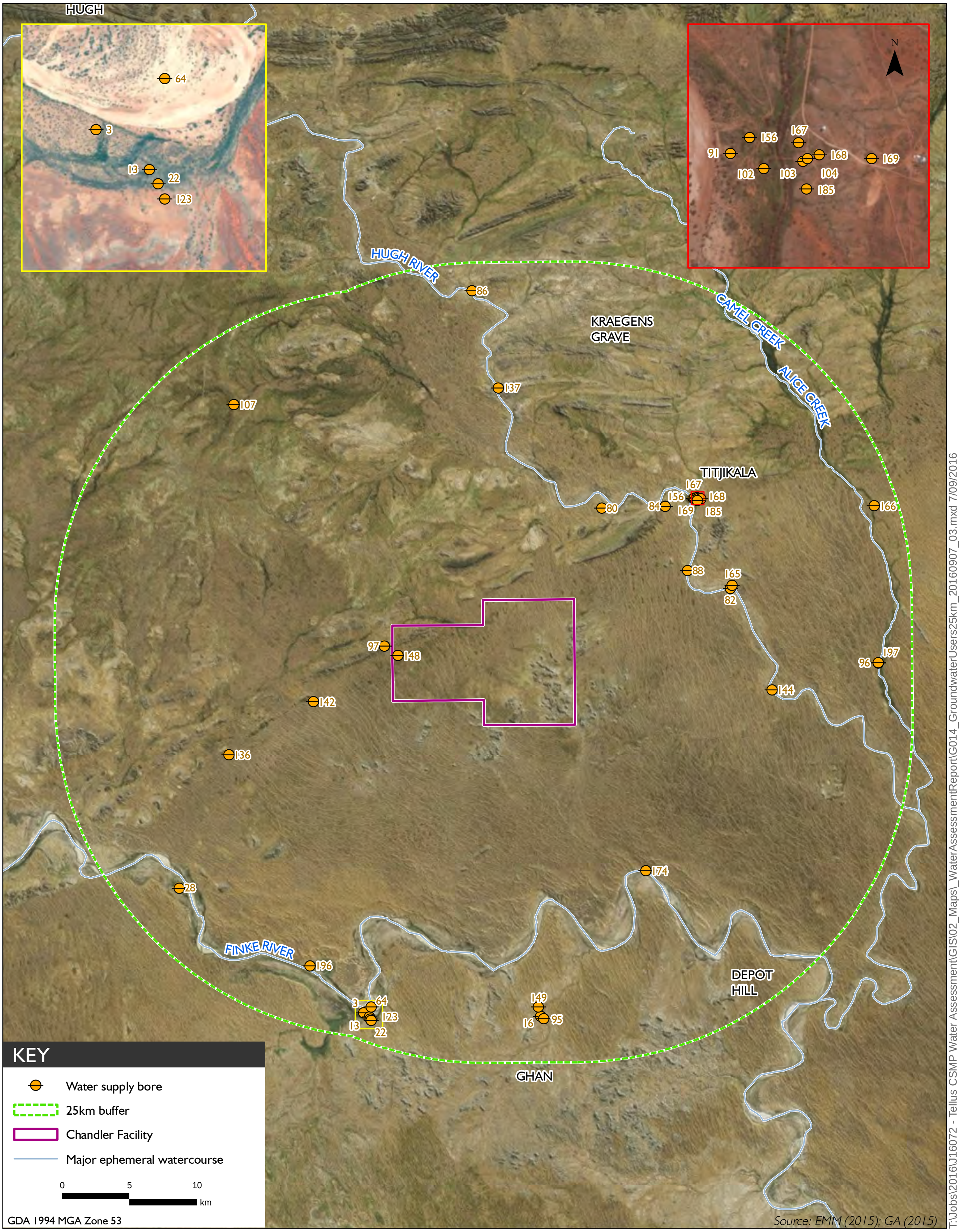
A search for landholder bores registered for ‘production’ has been undertaken. A 75 kilometre and 25 kilometre spatial buffer around the Chandler Facility was prepared (refer to Figure 8-10 and Figure 8-11).

Landholder bores located within the 25 kilometre spatial buffer have been tabulated in the Groundwater Assessment (Appendix P). Also included in Appendix P are groundwater levels, predicted flow direction and interpreted water quality from these bores as well as a complete list of bores located within the 75 kilometre spatial buffer.

In total, 36 landholder production bores were identified within the 25 kilometre spatial buffer (including the Titjikala groundwater bore) and 193 were identified within the 75 kilometre spatial buffer.



Groundwater users within 75 km of the project area
Chandler Salt Mine Project
Water Assessment
Figure 8.10



Groundwater users within 25 km of the Chandler Facility

Chandler Salt Mine Project

Water Assessment

Figure 8.11

EMM

The groundwater levels within the 25 kilometre spatial buffer were mostly relatively shallow with a range between 6.44 and 18.4 metres below ground level. It is noted that landholder bores are generally located in lower lying creek lines and areas of the landscape that typically intercept localised groundwater in alluvial/colluvial sediment and weathered bedrock (i.e. Idracowra Sandstone and Stairway Sandstone).

Elsewhere, for bores targeting the deeper groundwater associated with the Stairway Sandstone, groundwater levels ranged between 31 and 88.4 m below ground level (shallow by comparison with the Chandler Formation at 800 m below ground level).

Groundwater levels, once converted to a common elevation datum ranged between 409.9 metres AHD and 306.6 m AHD, which demonstrates a wide range of about 100 metres. The shallower level (306.6 m AHD) measures the piezometric surface within the Stairway Sandstone down hydraulic gradient along the eastern boundary of Alice Creek. The higher level (409.9 m AHD) is measured to the west of the proposed Chandler Facility along the Charlotte Range.

The shallowest levels were observed at Top Soak Bore–RN12534 (5.2 m below ground level) along the southern boundary of the ephemeral Finke River at an elevation of 345.1 metres AHD. The inferred geology at this location comprised shallow Cainozoic alluvials underlain by Idracowra Sandstone.

Groundwater quality results, where available, for the landholder bores indicate the groundwater conditions within the shallow local groundwater systems are highly variable, ranging from fresh (bores targeting the shallow Titjikala aquifer) to saline (bores targeting the deeper Stairway Sandstone and the Idracowra Sandstone).

The major ion chemistry of the shallow (< 20 m deep) and deep landholder bores (> 20 m deep) within the 25kilometre spatial buffer displayed highly variable water types. The majority of shallow landholder bores targeting the alluvium and tertiary sediment were dominated by calcium, chloride and bicarbonate, whereas water types within the deeper landholder bores targeting the Stairway Sandstone, Idracowra Sandstone and Titjikala aquifer were more closely associated with sodium, chloride and bicarbonate.

Springs

Five groundwater springs are located within a 75 kilometre radius of the Chandler Facility (Figure 8- 12), the nearest (Pascoes Spring) being approximately 20 kilometre south-west of the proposed Chandler Facility. The remaining four springs (Horseshoe Bend Spring, Black Hill Spring, Polly's Spring, and Micks Soak) are all located approximately 50 kilometre south-east of the Chandler Facility, situated along the Finke River.

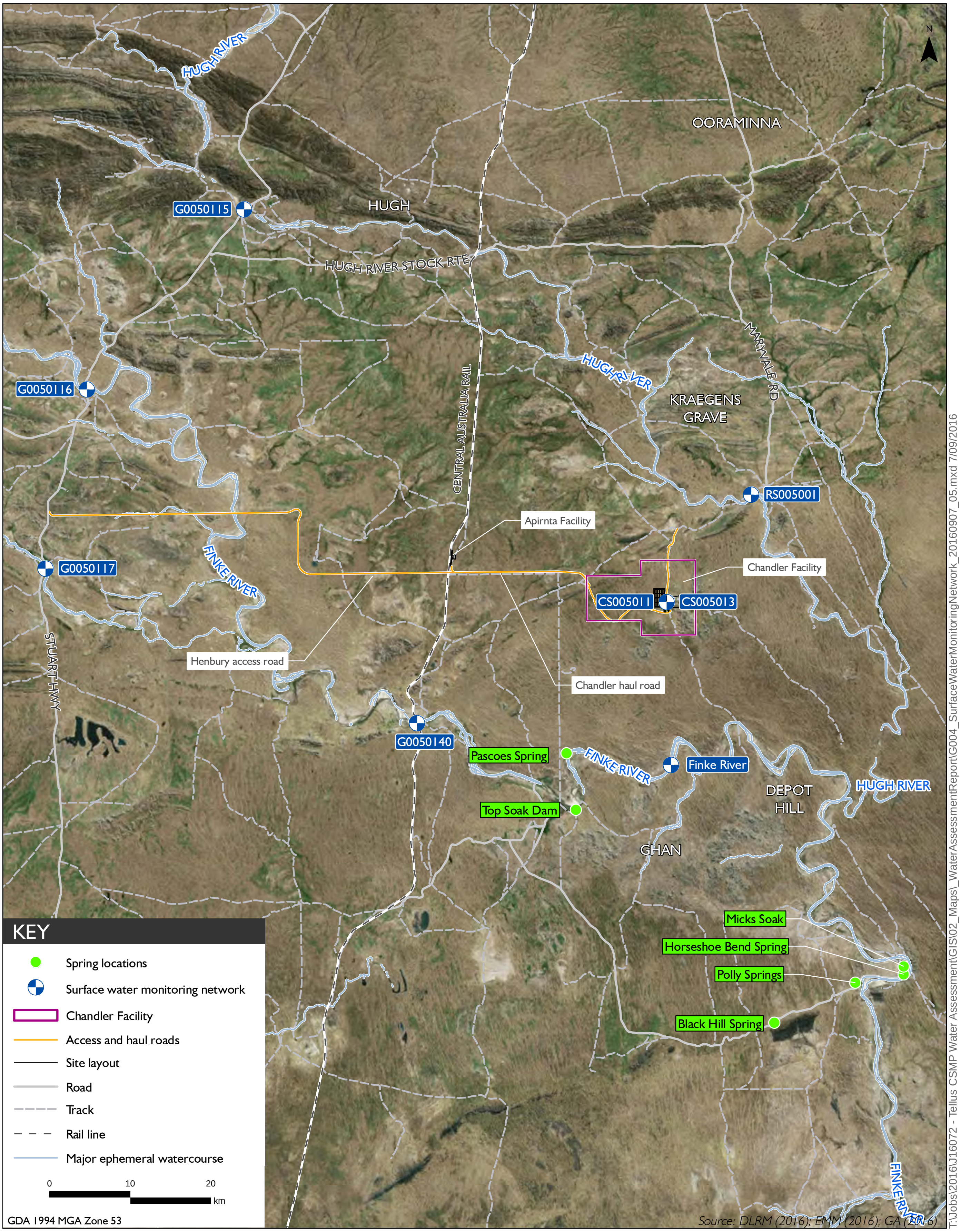
Riparian vegetation communities consisting predominantly of River Red Gum and Coolabah are likely to be partially sustained through intermittent baseflow provided by these four groundwater springs. However, the majority of water sustaining these ecological communities is thought to be provided through flooding events.

Approximately 230 kilometres south-east of the Chandler Facility the Dalhousie Spring complex emanates in an area underlain by the Lake Eyre Basin, western Eromanga Basin and the Pedirka Basin, but beyond the south-eastern boundary of the Amadeus Basin. The Dalhousie Spring complex is considered in the Groundwater Assessment as it is an important ecological and cultural asset. The Dalhousie Spring complex is attributed as a discharge feature of the Eromanga Basin and is also supported in part by discharge from the Crowne Point Formation, a key groundwater system within the Pedirka Basin (Wohling et al, 2013). There is no evidence for any hydraulic connectivity with the Amadeus Basin or the Chandler Syncline sub-basin.

Groundwater dependant ecosystems

Two ecological communities (Eucalyptus camaldulensis var. Obtuse and Eucalyptus coolabah subsp. Arida) have been identified by DLRM to persist within the riparian corridors of the Finke and Hugh Rivers. These communities are commonly identified in the Bureau of Meteorology's Atlas of Groundwater Dependent Ecosystems (BoM 2016) as having a moderate potential for groundwater interaction. The root structure is considered to be shallow (less than 15 metres) and may potentially receive a source of water from perched shallow groundwater systems (i.e. alluvial sources) associated with ephemeral creeks. Neither of these ecological communities has been listed as endangered ecological communities.

A complete list of key sensitive groundwater receptors identified during the desktop study, their source of water and the potential impact are listed later in this Chapter (Table 8-5).



Surface water monitoring network

Chandler Salt Mine Project

Water Assessment

Figure 8.12

8.4 Site conceptual model

This section presents the site conceptual (hydrogeological) model of the proposed development footprint and vicinity. A conceptual (hydrogeological) model is a simplified representation of the physical hydrological and hydrogeological setting and understanding of the system. This includes the identification and description of the geologic and hydrologic frameworks, recharge to the system, groundwater flow dynamics and surface-groundwater interaction processes.

The model is used in subsequent sections of this chapter to describe potential sources, pathways, receptors, and fate of any potentially contaminated waters from the Proposal.

8.4.1 Groundwater systems

The Proposal area is within the Chandler Syncline (sub-basin) located within the south-eastern extent of the Amadeus Basin. The Chandler Syncline hosts various local groundwater systems, all of which have minor confining layers and permeability barriers to groundwater flow. The basal unit overlying the target salt resource of the Chandler Formation is the Giles Creek Dolostone Formation, comprising predominantly dolomitic calcareous shales and sand and silt sediment. The Giles Creek Dolostone is an aquitard, unsaturated, and acts as a barrier to groundwater flow.

Overlying the Giles Creek Dolostone Formation is the Jay Creek Limestone Formation, comprising predominantly of marine shale, silt and sand sediments and thin beds of dolomite. The Jay Creek Formation is a potential water bearing zone.

Overlying the Jay Creek Limestone Formation is the Stairway Sandstone Formation, a thick geological sequence comprising predominantly continental coarse to medium grained sandstone within interbedded minor silt and shale beds. The Stairway Sandstone is a water bearing zone and supports numerous landholder bores within the region at shallow depths (<100 metres below ground level).

Overlying the Stairway Sandstone Formation is the Langra Formation, a geological unit subdivided into three member units, represented at depth by interbedded silt and shale beds, gradually transitioning into extensive fine to medium grained sand.

Overlying the Langra Formation is the Horseshoe Bend Shale Formation, a massive siltstone and quartzitic sandstone deposit. Both the Langra and Horseshoe Bend Shale Formations are water bearing zones and contain brackish to saline groundwater.

Directly above the Horseshoe Bend Shale Formation and partially eroded at surface across the Proposal area is the Idracowra Sandstone, a kaolinitic sandstone represented across the Maryvale Hills and discontinuous across the Proposal area. The Idracowra Sandstone supports numerous groundwater users within a 25 km radius of the Proposal. Groundwater is typically saline and as such is used locally as a stock supply. The Idracowra Sandstone Formation would not be intercepted by the Proposal mining.

Locally in the vicinity of the Proposal area, there is limited recharge from direct rainfall and minor recharge is expected to occur via infiltration from overlying alluvial systems during major flooding events. Minor direct rainfall recharge may occur locally, but the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the middle and lower members of the Langra Formation is likely to result in the formation of perched localised groundwater systems in the upper Langra Formation and Horseshoe Bend Shale Formation.

The inferred piezometric surface ranges between 60 and 90 metres below ground level across the Chandler Facility.

Consistent with topographic gradients, hydraulic gradients are very gentle in the south-eastern extent of the Amadeus Basin, and the broad flow direction in all groundwater systems is generally from north-west to south-east.

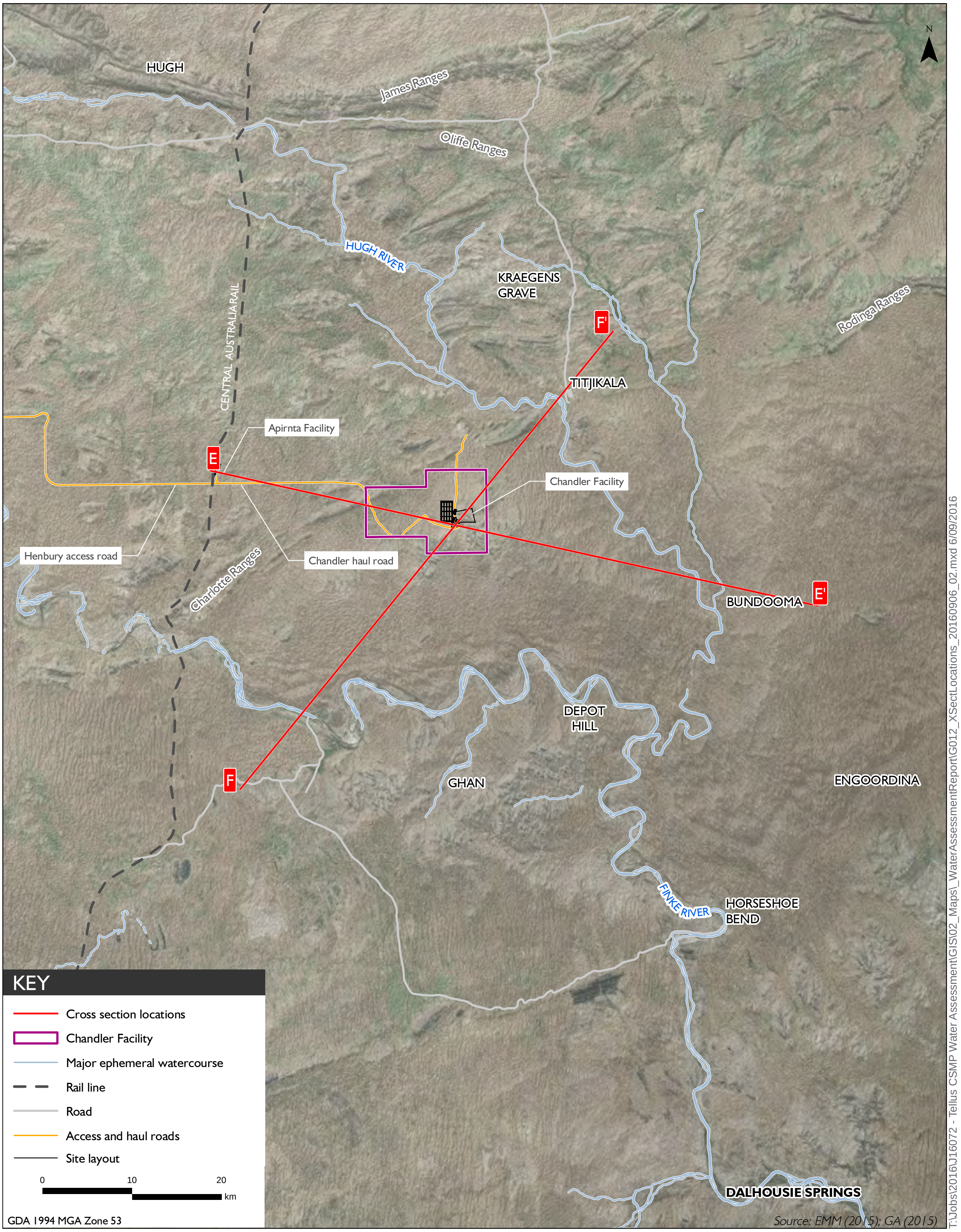
Two cross sections were drawn across the Chandler Facility (refer to Figure 8-13). The basement structure (typically associated with folding) influences the groundwater flow direction in certain areas. The horizontal hydraulic conductivity in geological units is highly variable, due to the depositional environments and volume of clay; substantial lateral flow through formations is therefore not expected.

There is an upwards hydraulic gradient from the Langra Formation to the Horseshoe Bend Shale Formation based on pressure head differences observed through groundwater monitoring, but there is no evidence of substantial flow volumes between these units. Elsewhere, within the 25 kilometre spatial buffer around the Chandler Facility, landholder bores located within the shallow alluvium report shallow groundwater levels which are likely to be perched systems, with very little connectivity to the underlying Idracowra Sandstone Formation and Horseshoe Bend Shale Formation.

The saline groundwater quality within the Chandler Syncline differs markedly from the potable water quality reported for the Mereenie Aquifer System about 100 kilometres north within the Northern Amadeus Basin.

The Chandler Syncline system is a separate groundwater system entirely and therefore, not connected to the groundwater sources utilised for the Alice Springs Water Supply. The evidence confirms that the Chandler Syncline system is distinct and separate from the Mereenie Aquifer System in terms of geological structure, lithological units, groundwater flow properties, hydraulic gradients and hydro-geochemistry.

Water quality within shallow alluvial groundwater accessed by landholder bores to the north and west of the Chandler Facility, particularly at Titjikala, is potable. By comparison, groundwater quality observed within the Horseshoe Bend Shale and Langra local groundwater systems at the Chandler Facility is poor and saline. Salts originating from the marine depositional environment, and the enhanced climatic nature of the environment (i.e. low precipitation/high evaporation), coupled with long groundwater residence times is likely to contribute to the poor groundwater quality observed within the Chandler Syncline.



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Location of the cross-sections

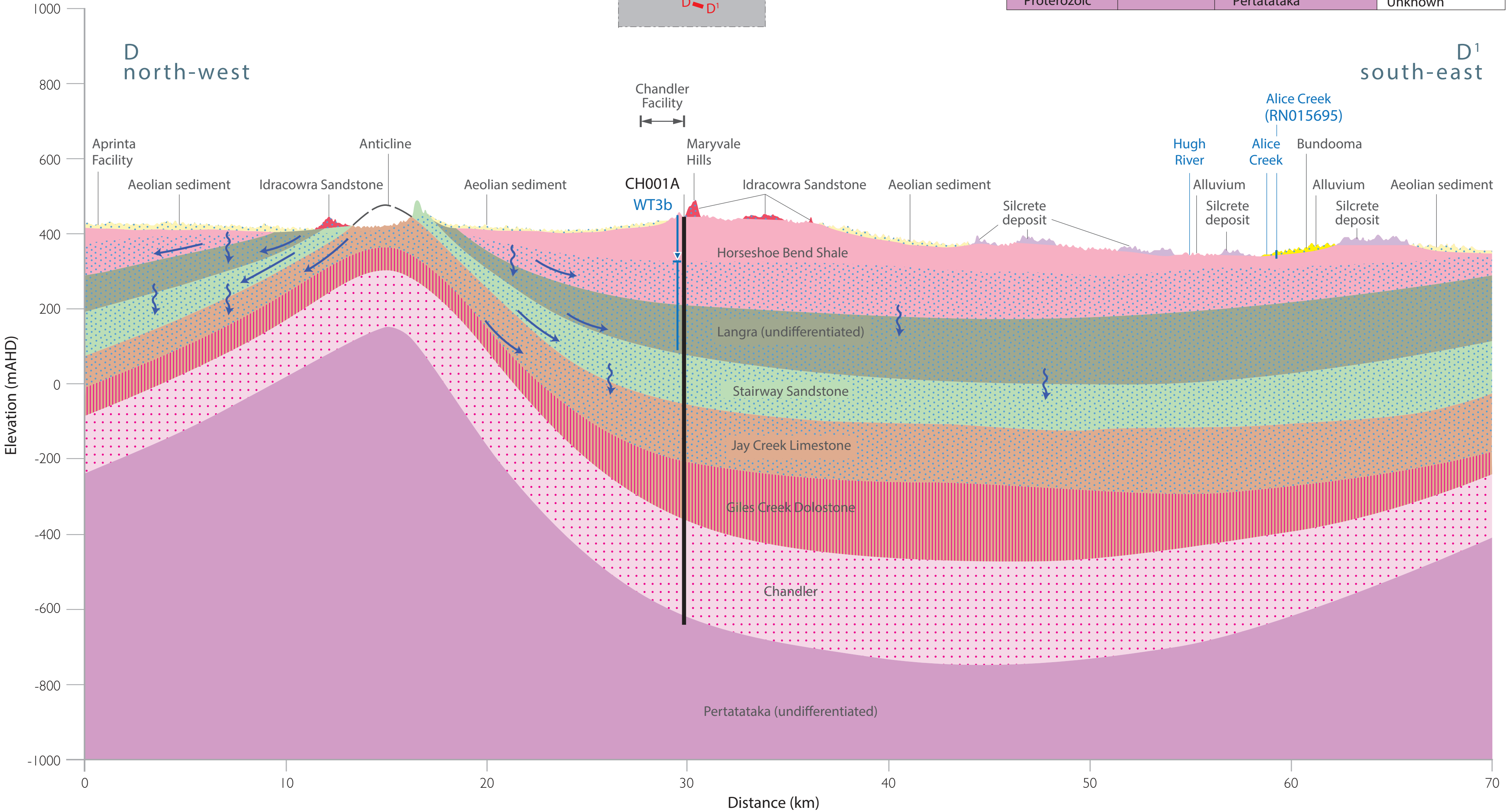
Chandler Salt Mine Project
Water Assessment

Figure 8.13

TELLUS

- Water bore
- Exploration bore
- Piezometric surface
- Saturated zone
- Groundwater flow

Age	Group	Formation	Hydrogeology
Quaternary		Alluvium	Aquifer (perched)
		Aeolian sediment	Aquifer (perched)
Tertiary		Silcrete deposit	Aquitard (local)
Carboniferous		Idracowra Sandstone	Aquifer
Devonian	Finke	Horseshoe Bend Shale	Aquifer
		Langra	Aquifer
Ordovician	Larapinta	Stairway Sandstone	Aquifer
Cambrian	Pertaoorrta	Jay Creek Limestone	Aquifer
		Giles Creek Dolostone	Aquitard
		Chandler	Aquitard
Proterozoic		Pertatataka	Unknown



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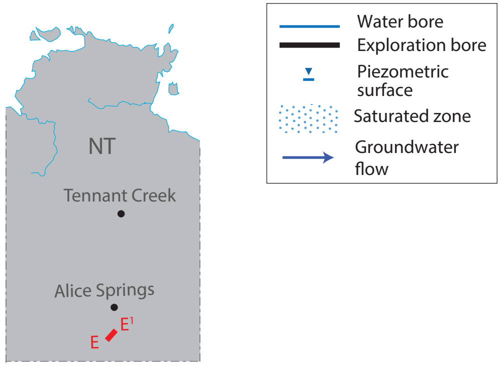
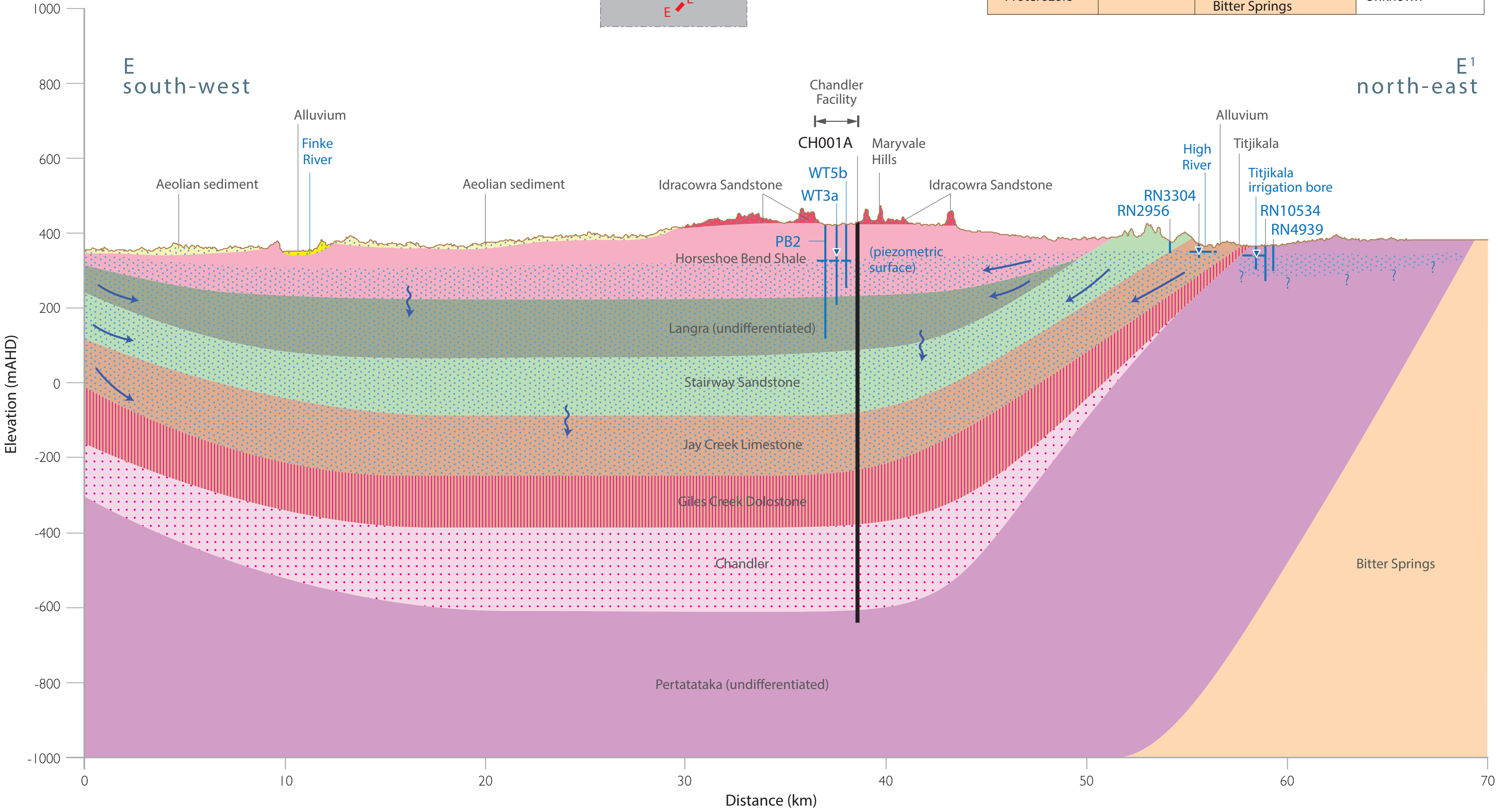
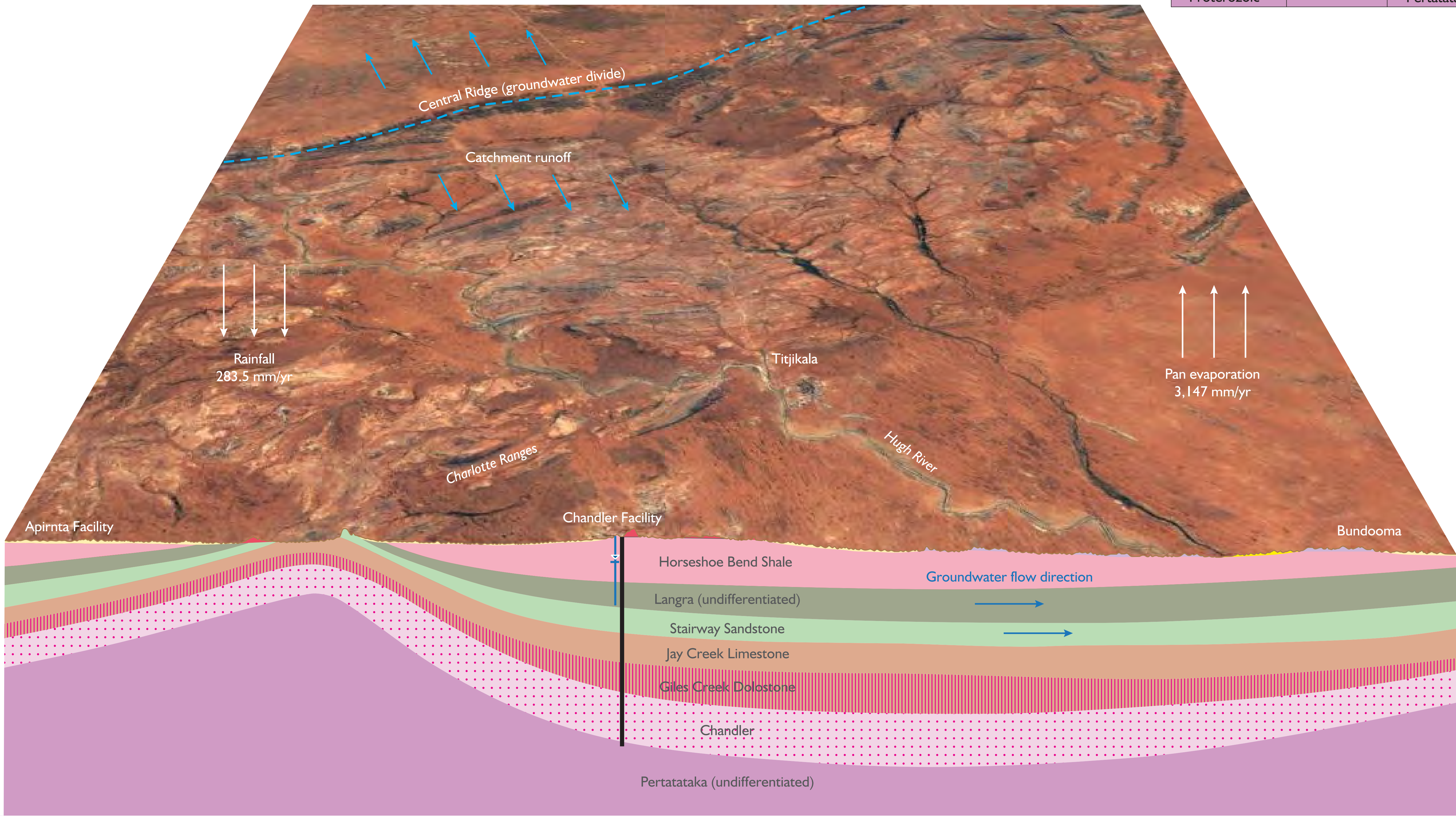


Age	Group	Formation	Hydrogeology
Quaternary		Alluvium	Aquifer (perched)
		Aeolian sediment	Aquifer (perched)
Tertiary		Silcrete deposit	Aquitard (local)
Carboniferous		Idracowra Sandstone	Aquifer
Devonian	Finke	Horseshoe Bend Shale	Aquifer
		Langra	Aquifer
Ordovician	Larapinta	Stairway Sandstone	Aquifer
Cambrian	Pertaoorrta	Jay Creek Limestone	Aquifer
		Giles Creek Dolostone	Aquitard
		Chandler	Aquitard
Proterozoic		Pertatataka	Unknown
		Bitter Springs	



Water bore
Exploration bore
Piezometric surface

Age	Group	Formation
Quaternary		Alluvium
		Aeolian sediment
Tertiary		Silcrete deposit
Carboniferous		Idracowra Sandstone
Devonian	Finke	Horseshoe Bend Shale
		Langra
Ordovician	Larapinta	Stairway Sandstone
Cambrian	Pertaoorrta	Jay Creek Limestone
		Giles Creek Dolostone
		Chandler
Proterozoic		Pertatataka



8.4.2 Surface water and groundwater connectivity

The widespread absence of permanent surface water features across the Proposal area indicates that the groundwater and surface water systems are not connected in the vicinity of the Chandler Facility or the Apirnta Facility. However, shallow groundwater levels and gradients within the alluvium groundwater system indicate some potential for connectivity to the south-east along the Finke River about 20 km from the Chandler Facility.

It is difficult to at this stage to gain a comprehensive understanding of connectivity in areas along the Finke River as there are no groundwater monitoring bores located directly adjacent to the Finke River and screened within the deeper groundwater systems (i.e. Idracowra Sandstone, Horseshoe Bend Shale or Langra Formation). However, characterisation of the water type of the springs located along the Finke River to the south and south-east of the Chandler Facility suggest the source of water from these springs is likely to be derived from the perched shallow alluvial sediment and not the deeper groundwater system connected to the Chandler Facility approximately 50 km away. This implies a lack of connectivity, which would mean that any potential drawdown impacts in the deeper groundwater systems arising from Proposal dewatering through abstraction or mining activities would not impact surface water resources.

It should also be noted that the drawdown impacts arising from the Proposal would be of such low magnitude and extent that they would not reach the spring areas (refer to Section 8.4.3). This is due to the low rate of groundwater pumping throughout the Proposal life (1.7 L/s, which is broadly consistent with stock and domestic rates), and also the limited extent of drawdown due to the relatively low permeability aquifer units, and the intervening aquitard units.

8.4.3 Groundwater modelling of drawdown impacts

The De Glee (1930) analytical model of steady state drawdown in leaky aquifer systems has been applied to investigate the pumping and drawdown relationship, based on site specific hydrogeological data and the site hydrogeological conceptual model. The de Glee model has been used in northern South Australia to investigate the drawdown effects due to extractions in the Eromanga Basin as part of the Far North Water Allocation Plan.

Based on results obtained through the Proposal drilling and monitoring program, a groundwater drawdown rate of 0.2 metres has been calculated at a distance of 1 kilometre from a bore continuously pumping in excess of the project water demand of 1.7 L/s (refer to Figure 8-17).

Source: EMM (2017); GeoScience Australia (2016); LPI (2011)

TELLUS

Project-related drawdown

Chandler facility
Water assessment

This distance drawdown relationship was calculated using the de Glee equation:

$$s_m = Q/(2\pi KD)\ K_0(r/L)$$

Table 8-2 defines the variables used in the above solution.

Table 8-2 Aquifer parameters

Variable ID	Parameter	Unit	Adopted value
s_m	Drawdown and radial distance	m	-
Q	Well discharge	m^3/day [1]	172.8
L	Leakage factor	m	447
c	Hydraulic resistance	~	20,000
D'	Saturated thickness	m	20
K'	Hydraulic conductivity	m/d	0.001
$K_0(x)$	Bessel function	~	0.085

Notes: 1.m^3/day = cubic metres per day

The de Glee analytical modelling method is consistent with the Proposal conceptual model (semi-confined or leaky aquifer conditions). Water take through mine dewatering and groundwater abstraction has been calculated and the result (0.2 metre drawdown) is likely to have a limited and very localised drawdown impact, primarily confined to the defined Project area.

Further detailed analytical interpretation would be completed following the implementation of additional monitoring and pumping tests within stage two groundwater drilling works following approval of the Proposal.

8.4.4 Water balance

A water balance involves the estimation of the storage and flow of water in a defined area, during a given timeframe. A mass balance equation is used in which the change of water stored within an open (natural) hydrological system is equal to the inputs to the system minus the outputs from the system (Todd and Mays 2005):

$$\text{Change in storage } (\Delta S) = \text{Inflows} - \text{Outflows}$$

A water balance combining the mine water management system, abstracted saline and potable groundwater, and saline water intercepted during construction has been prepared for the construction and operations phases.

The water balance is based on the conceptual mine plan and would be updated following the completion of detailed design. The results of the updated water balance would be carried through into the Proposal's Water Management Plan (refer to Appendix O).

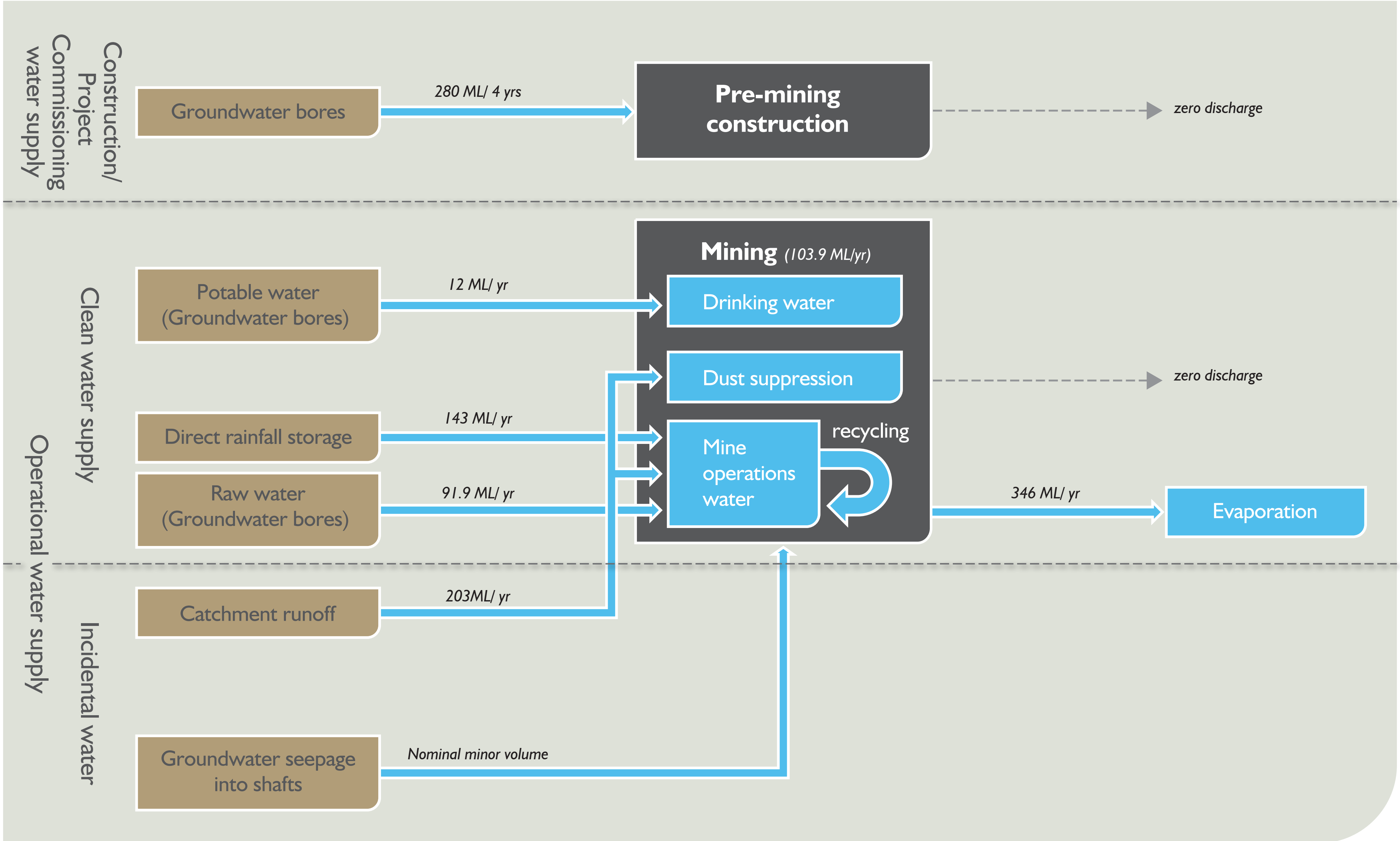
The conceptual water balance is presented in Figure 8-18 and indicates marginal net change in total site water inventory during the operation phase.

Table 8-3 Water balance (average rainfall per year)

Parameter	Construction (ML/y)	Operation – Year 1
Inflows to water management system		
Groundwater inflow into shafts	0	0
Catchment runoff	203	203
Direct rainfall on water storage areas	143	143
Raw water supply for processing / dust suppression	54	54
Potable water supply	16	12
TOTAL INFLOW	**416**	**412**
Outflows from water management system		
Net site water management system	70	99
Uncontrolled release	0	0
Evaporation	346	346
TOTAL OUTFLOW	**416**	**445**
Net change in total site water inventory	**0**	**33**

Notes: 1. ML/year = mega litres per year.

The water management system maximises the capture and reuse of mine affected water. The majority of water would be sourced from groundwater abstraction with make-up water supplied via on-site sources (i.e. rainfall runoff). Mine affected water would be reused to the supply the processing plant and water dust suppression demands in addition to groundwater abstraction which would target the Langra and Stairway Sandstone Formations.



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Water balance schematic

Chandler Salt Mine Project
Water Assessment

8.5 Assessment of risk during construction

This section presents the potential impacts (both direct and indirect) on groundwater during construction of the Proposal. Mitigation measures to avoid or reduce these impacts are discussed in Section 8.8. Changes to groundwater levels, groundwater chemistry and the hydrogeology itself are considered in respect of the sensitive receptors that were identified earlier in Section 8.3. Specifically, the significance of change and subsequent impact is considered.

When considering the potential environmental impacts of the Proposal during development, operation and post operational phases on regional groundwater water resources, the management of natural resources within the study area must be considered.

In respect to potential effects on groundwater, existing land and water resource users within the region have an interest. Where there are no potential adverse effects, individuals, communities, interested organisations and relevant government agencies have an interest in why there are no potential impacts on the water resources in their area, town or community.

This means that the regional area studied must be much larger than the local area in which the Proposal would take place.

8.5.1 Direct impacts

Overview

Direct impacts on groundwater during construction may include groundwater abstraction resulting in localised drawdown. Potential impacts from abstracting groundwater are discussed below.

Groundwater abstraction would service potable and raw water supply demands across the Proposal. A maximum groundwater demand of approximately 70 mega litres per year would be required over the four-year construction/commissioning period.

Groundwater abstraction during construction would service the following primary activities.

- Raw water supply.
- Potable water supply.
- Building the Apirnta Facility.
- Building the Chandler Facility.

Raw water supply

Raw water would be abstracted during construction to service key activities including:

1. Chandler Facility dust suppression, drilling and construction demands.
2. Chandler Haul Road dust suppression, wash-down and construction demands.
3. Apirnta Facility dust suppression and construction demand.

A borefield would be sited to the north-east of the decline entrance and would target the Langra groundwater system at a depth of approximately 150 metres below ground level. Bores would be spaced at a distance of approximately 200 metres and connected to electro-submersible pumps. Abstracted water would be gravity fed to a water storage retention dam as shown in Figure 3-1..

A series of production bores would be sited at approximately 8 kilometres intervals along the Chandler Haul Road, with two additional production bores, one at each end of the Chandler Haul Road. Based on site investigation works undertaken to date and the results of the site conceptual model (refer to Section 8.4), bore depths would target the Langra Formation.

Bores would be operated on a throttled float system to pump groundwater to above-ground storage tanks when the water level in the storage tanks drops below 50 % capacity. Water carts would connect to the storage tanks as required along the Chandler Haul Road.

Potable water supply

To meet the accommodation village and drinking water demand, two large diameter production bores (approximately 250 millimetres in diameter) would be constructed.

Extracted groundwater would be piped to a site water treatment plant. Water would then be treated to Australian Drinking Water Guidelines (NHMRC 2011). The system would likely comprise the following treatment processes:

- Staged microfiltration.
- Reverse osmosis (or dilution).
- Carbon filtration.
- Chlorination.
- Water softening.
- Ultra violet disinfection.

Treated water would then be stored in two enclosed steel tanks with a combined capacity of 40,000 L. Following use, grey water would be reticulated back through the water treatment plant. The proponent has set a 50 % recycled water target.

The construction water demands for the Proposal are summarised in Table 8-4.

Table 8-4 Construction phase water demands

Demand	Water type	Average volume (ML/year)	Source
Dust suppression			
Overburden/ ore removal	Saline	43	Various lithologies
Chandler haul road and Henbury access road	Saline		Horseshoe Bend Shale / Langra Formation / Stairway Sandstone Formation
Internal roads	Saline		Horseshoe Bend Shale / Langra Formation
Process water			
Other process demand	Saline	9	Langra Formation
Washdown bays	Non-saline	2	Horseshoe Bend Shale / Langra Formation
Workforce consumption			
Personnel – potable	Potable	16	Horseshoe Bend Shale / Langra Formation
Personnel – ablutions and non-potable	Non-saline	Reticulated	Horseshoe Bend Shale / Langra Formation
Saline demand		54	
Potable demand		14	
TOTAL CONSTRUCTION DEMAND		70	

Notes: 1.ML/year=mega litres per year.

Chandler Facility and accommodation village

Two production bores would be located adjacent to the decline portal within the mine infrastructure area of the Chandler Facility. They would target the Langra groundwater system (140 to 220 metres below ground level). Water supply would be used for construction ahead of mining. The potential impact of drawdown associated with this activity have been modelled. The results discussed in Section 8.4.3 indicate there is a low risk of drawdown (0.2 metres within a one kilometre).

Chandler Haul Road, Henbury Access Road and Apirnta Facility

Four production bores sited along the Chandler Haul Road would target the Langra and Stairway Sandstone groundwater systems at depths of between 50 and 150 metres below ground level and would meet dust suppression and construction water demands along the Chandler Haul Road and at the Apirnta Facility.

Impacts are minor, with only minor localised drawdown predicted as a result of extraction from these bores (i.e. 0.2 metres drawdown within 1 kilometre, based on the de Glee analytical model calculation; refer to Section 8.4.3). Landholder bores (RN10082 and RN14584) abstracting water from the Stairway Sandstone groundwater system are both located greater than 300 metres from the Chandler Haul Road and are not considered to be adversely impacted by abstraction demands.

Discussion of drawdown impacts

A pumping test undertaken at the existing production bore (PB1) at a sustained abstraction rate of 4 L/s resulted in negligible drawdown within the Langra groundwater system, with nearby observation bores (WT1 and WT2) not influenced by dynamic head changes in the piezometric surface. This is consistent with the site conceptual model and the de Glee analytical model calculations of Section 8.4.3.

The proposed abstraction rate (approximately 2 L/s) required for construction and operation water demands is considered to result in very minor changes to the local piezometric surface (i.e. 0.2 metres drawdown within 1 kilometre). A similar dynamic response in groundwater levels is expected within the Stairway Sandstone along the Chandler Haul Road, with abstraction demands for dust suppression likely to result in minor localised drawdown.

As discussed in Section 8.4.3., potential for drawdown impacts arising from the Proposal would be of such low magnitude and localised extent that they would not reach the spring areas listed in Table 8- 5.

Elsewhere, the relatively minor drawdown associated with Proposal-related abstraction is of such a low magnitude and localised extent that is unlikely to cause any impacts of concern to those sensitive receivers listed in Table 8-5 is not explored further as a potential impact.

Contamination of borefield aquifer from site activities

Site activities have the potential to contaminate the groundwater resource through actions such as spills, equipment failure or accidents. For groundwater bores, this would relate to drilling activities. If a potential contamination incident were to occur, appropriate emergency actions would be undertaken (refer to Section 8.9).

Measure that would be taken to avoid direct impacts on groundwater resources during drilling are detailed in Section 8.8.

Summary of direct impacts

Potential direct impacts of groundwater abstraction on local water users, receiving environments and groundwater quality during construction are listed in Table 8-5, noting the drawdown modelling results in section 8.4.3 (0.2 metres drawdown within 1 kilometre, based on the de Glee analytical model calculation).

Table 8-5 Key sensitive receptors and their water source

Receptor	Water source	Potential impacts
Groundwater supplies		
Rocky Hill borefield	Mereenie Aquifer System	• Contamination of drinking water supply due to derailment of train carrying hazardous wastes. • Groundwater drawdown.
Roe Creek borefield	Mereenie Aquifer System	• Contamination of drinking water supply due to derailment of train carrying hazardous wastes. • Groundwater drawdown.
Titjikala water supply	Titjikala bore	• Contamination of drinking water supply due to truck overturning carrying hazardous wastes. • Contamination arising from hazardous waste storage. • Groundwater drawdown.
Idracowra stock water supply	Alluvium	• Contamination arising from hazardous waste storage. • Groundwater drawdown
Springs		
Pascoes spring	Amadeus Basin	• Reduced groundwater flows due to construction and operation dewatering impacts. • Contamination arising from hazardous waste storage leakage.
Horseshoe Bend spring		
Polly's spring		
Black Hill spring		
Mick's spring		
Riparian vegetation		
River Red Gum woodland (Eucalyptus camaldulensis var. obtusa)	Alluvium – combination of interflow and perched groundwater	• Contamination of alluvial groundwater systems via infiltration of mine surface water runoff. • Dewatering of shallow groundwater systems.
Coolabah woodland (Eucalyptus coolabah subsp. arida)		

8.5.2 Indirect impacts

Construction may indirectly impact vegetation within the vicinity of the proposed development footprint that may be partially dependent on groundwater.

Groundwater dependent ecosystems

There are no known groundwater dependant ecosystems within the vicinity of the Proposal. There is the potential for low to moderate impacts to River Red Gum and Coolabah vegetation proximal to the Proposal area, as these ecosystems are considered to be partially dependent on groundwater.

As discussed in Section 8.3, two ecological communities (*Eucalyptus camaldulensis* var. *Obtuse* and *Eucalyptus coolabah* subsp. *Arida*) have been identified by DENR to persist within the riparian corridors of the Finke and Hugh Rivers. The root structure is considered to be shallow (less than 15 metres) and dependent on the perched shallow groundwater systems (i.e. near-surface alluvial sources) associated with ephemeral creeks, rather than the water table at about 80 metres depth.

The Proposal is unlikely to impact storage within the alluvium, with mining and groundwater abstraction targeting the deeper (220 plus metre area) hard rock groundwater systems. The surface water assessment presents information on any surface water related impacts.

8.6 Assessment of risks during operation

This section presents the potential impacts (both direct and indirect) on groundwater during operation of the Proposal. Mitigation measures to avoid or reduce these impacts are discussed in Section 8.8.

8.6.1 Direct impacts

Direct impacts on groundwater during operation may include groundwater abstraction resulting in drawdown and impacts to private landholder bores. These impacts are discussed below.

Groundwater abstraction would service potable and raw water supply demands during operation of the Proposal (refer to Table 8-6). A maximum groundwater demand of approximately 113 mega litres per year would be required during operation of the Proposal. Abstraction would service the following primary activities and by doing so, may give rise to impacts on local groundwater resources:

- Raw water supply
    - Chandler Facility and accommodation village.
    - Hydraulic backfill processing.
    - Chandler Haul Road.
    - Apirnta Facility.
    - Henbury Access Road.
- Potable water supply.

Raw water supply

During operation, raw water would be abstracted to service three key activities:

1. Mining operations.
2. Chandler Facility dust suppression, drilling and construction demands.
3. Chandler Haul Road/Apirnta Facility dust suppression, wash-down and construction demands.

Potable water supply

There would be no change between construction and operation water supply. Raw water during operations would still need to meet the requirements of the accommodation village and drinking water demand. It is anticipated that two large diameter production bores (approximately 250 mm diameter) would be constructed.

Extracted groundwater would be piped to a site water treatment plant. Water would then be treated to Australian Drinking Water Guidelines (NHMRC 2011).

Table 8-6 Operation raw water demands

Demand	Water type	Average volume (ML/year)	Source
Dust suppression			
Overburden/ ore removal	Saline	43	Various lithologies
Chandler haul road and Henbury access road	Saline		Horseshoe Bend Shale / Langra Formation / Stairway Sandstone Formation
Internal roads	Saline		Horseshoe Bend Shale / Langra Formation
Process water			
Process water (hydraulic backfill)	Saline	45	Re-use from hydraulic backfill process and Langra Formation
Other process demand	Saline	9	Langra Formation
Washdown bays	Non-saline	2	Horseshoe Bend Shale / Langra Formation
Workforce consumption			
Personnel – potable	Potable	14	Horseshoe Bend Shale / Langra Formation
Personnel – ablutions and non-potable	Non-saline	Reticulated	Horseshoe Bend Shale / Langra Formation
Saline demand		**99**	
Potable demand		**14**	
TOTAL OPERATION DEMAND		**113**	

Mining

The Proposal would intercept groundwater during the construction of the mine decline and the two ventilation shafts. Three localised groundwater systems are expected to be intercepted during the construction phase of the Proposal. These are understood to be:

- The Horseshoe Bend Shale Formation.
- The Langra (Upper and Lower) Formation.
- The Stairway Sandstone Formation.

Subject to further drilling within the mine infrastructure area, a fourth localised system may be encountered, namely the Jay Creek Limestone Formation.

The limited extent of these fractured rock groundwater systems as identified by the extensive surface and downhole geophysical surveys and detailed in the site conceptual model, is likely to result in limited groundwater storage.

This is further evidenced by the pumping test at the existing production bore (PB2), where transmissivity and sustainable yield both indicated the Langra groundwater system was only capable of supporting small groundwater yields. Therefore, any groundwater inflows to the decline and ventilation shafts are expected to be easily managed using standard underground mine sealing techniques during construction and operation of the Proposal.

Any groundwater intercepted during construction is likely to result in the dewatering of the localised groundwater systems. Due to the limited extent of these systems and the stratified nature of the geology, dewatering impacts arising from mining operations are not expected to impact those sensitive receivers identified in Table 8-5.

The proponent would construct multiple engineering barriers to prevent groundwater inflow during the construction of subsurface works to limit the extent of dewatering. Details of mitigation/control measures, notably including shot-creting of any significant inflow areas along the decline and/or mine path, are provided in Section 8.7.1.

Impacts to private landholder bores

Registered private landholder bore details were obtained from DENR in July 2016. Within a 25 kilometres radius of the Proposal area there are 36 private landholder bores, predominantly utilising groundwater for stock and domestic purposes. Only one bore is used for community and domestic supply i.e. Titjikala bore, located 25 kilometres north-east of the Proposal area.

The majority of the bores are screened in the alluvium and local Titjikala groundwater systems, however deeper bores to the west and east of the proposed Chandler Facility are known to intercept the Stairway Sandstone and Idracowra Sandstone.

As described above and illustrated in Figure 8-17, dewatering impacts arising from the construction of subsurface works are expected to be localised and are not likely to impact the landholder bores identified in this assessment.

Groundwater abstraction within the Stairway Sandstone associated with the operation of the Chandler Haul Road borefield may also result in localised drawdown. Impacts are minor, with only minor localised drawdown predicted as a result of extraction from these bores (i.e. 0.2 metres drawdown within one kilometre of a bore pumping at 2 L/s, based on the de Glee analytical model calculation; refer to Section 8.4.3). Landholder bores (RN10082 and RN14584) abstracting water from the Stairway Sandstone groundwater system are both located greater than 300 m from the Chandler Haul Road and are therefore not considered to be potentially impacted by abstraction demands.

Water resource impacts to the Alice Springs water supply bore fields (Roe Creek borefield and Rocky Hill borefield) arising from Proposal-related dewatering and/or groundwater abstraction is not expected as demonstrated through the conceptual model (refer to Section 8.4).

8.6.2 Indirect impacts

Potential indirect impacts on groundwater resources during operation may include:

- Groundwater dependant ecosystems.
- Groundwater quality
- Hydro-stratigraphy and geo-mechanics (including earthquake risk).

These impacts are discussed below.

Groundwater dependent ecosystems

The Proposal would not target storage or water abstraction within the alluvium zone (up to 40 metres below ground level). Mining and groundwater abstraction would target the deeper groundwater systems (between 140 and 220 metres below ground level). At this depth, the potential for adverse impacts on riparian vegetation or groundwater dependent ecosystems has been assessed as having an unlikely likelihood of occurring with negligible consequence.

Groundwater quality

The Chandler Facility would receive and store hazardous wastes below ground in isolation over the 25-year mining life. The final inventory of waste product to be received is yet to be agreed. An indicative waste inventory to be accepted at the proposed Chandler Facility is provided in Appendix F.

Waste would be transported by rail and temporarily stored above ground within shipping containers at the Apirnta Facility, where it would then be transported by road train and eventually transported down the decline shaft for storage in the Chandler Facility's waste storage repository.

Contamination of groundwater arising from the storage of waste in the underground repository has been quantitatively assessed during operation and post-closure.

The mine's ongoing management of groundwater inflows and surface water flooding at the decline portal is critical to avoid potential contamination. The proponent would implement a multi-barrier approach to the safe storage of wastes over geological time. This would involve a combination of natural (the halite formation) and engineered barriers (decline and shaft seals) to protect the environment and groundwater sources from risks of contamination during construction, operation and post closure.

Contamination of groundwater arising from the storage of waste in the underground repository is unlikely to pose a groundwater contamination risk given the natural impermeability of the Chandler Formation halite resource. In addition, the depth of the proposed Chandler salt mine and deep geological repository in comparison to known groundwater systems provides a vertical separation and barrier of about 400 metres. This comprises low permeability overburden material between the waste repository and the nearest overlying groundwater system.

During construction and operation, it is anticipated that geophysical surveying would be used to identify faults/features of interest up to several hundred metres ahead of and prior to excavation with the mine layout subsequently adjusted to avoid such structures. The Proposal is not expected to be intersected by any geological faults or features that could be a pre-existing pathway to the overlying formations or groundwater resources.

Hydro-stratigraphy and geo-mechanical risks

The mining process would result in localised alteration to the physical structure and distribution (i.e. stratigraphy) of the Horseshoe Bend Shale, Langra, Stairway Sandstone, Jay Creek Limestone, Giles Creek Dolostone and Chandler Formations.

On a regional scale the current hydro-stratigraphy and associated aquifer properties are not expected to change.

Due to the proposed mining method (room and pillar) and the subsequent commitment to backfilling the mining void with waste material and salt rejects, the potential for subsidence, and alterations to the overlying stratified geology, is not considered a risk. In addition, the proponent has undertaken a detailed geo-mechanical risk assessment of the Chandler Formation and concluded no material risks are likely (refer to Appendix K). A summary of the geo-mechanical assessment is provided below.

Preliminary investigations of the geo-mechanical behaviour of the Proposal were carried out by Douglas Partners (2015) and Atkins (2016). Since relevant data are not available for the Chandler Formation and overlying rocks within the footprint of the facility, the following information was used:

- The geometry of the planned mine layout (i.e. corresponding depth, dimensions and shape of the room and pillar layout).
- Groundwater quality.
- The results of the analyses concerning the non-soluble material of the Chandler Halite (Terra Search 2014).
- Core photographs from the exploratory borehole CH001A (ERCOSPLAN 2014).
- Generic salt mechanics data and results from in situ measurements, derived from previous geo-mechanical studies carried out by Atkins.

Geo-mechanical modelling was undertaken using the finite difference method to analyse the geo- mechanical response of the Chandler Formation and overlying rocks to the excavation and operation of the Proposal over a period of 30 years. The studies employed engineering judgement to analyse the results of the geo-mechanical modelling. Established experience and knowledge enabled the use of appropriate parameters concerning the strength and the constitutive response of the Chandler Formation. The geometry and in-situ geostatic stresses and the boundary conditions that characterise the planned room and pillar mine layout were analysed.

The studies showed that, provided the Chandler Facility is designed and operated appropriately, the excavated cavities would remain stable throughout the operational phase of the facility. In particular, roof spans are required to be sufficiently small to ensure that unacceptable creep convergence of the rooms can be avoided.

A significant influence on the strain that would be undergone by the Chandler Halite is the c. 270 m thick Jay Creek Limestone, which overlies the Chandler Formation. Provided that there are no major faults or discontinuities within it, the Jay Creek Limestone would act as thick plate that is expected to contribute significantly to the stability of the planned excavations in the halite formation.

At the time of closure, there would be voidage present within the underground geological repository which has been estimated to be in the range 20%-40% (Atkins 2016). This voidage consists of:

- Pore space within solid wastes.
- Pore space between the grains of the salt backfill that surrounds the solid wastes.
- Pore space within the hydraulic backfill rooms.
- Voids between the solid wastes / backfill and the walls of the caverns (because 100 % filling is unattainable).
- Voids between hydraulic backfill and the walls of the caverns (because 100 % filling is unattainable in practice).

Due to the natural properties of salt 'creep', much of this pore space would be reduced, until eventually the waste and backfill provide sufficient support to the salt that creep ceases. It is expected that most of the void space within the wastes and backfill would not be reduced by creep because the waste / backfill material would become grain-supported well before all the voids are lost.

Creep typically occurs in three stages: primary, or Stage I; secondary, or Stage II and tertiary, or Stage III (Figure 8-19).

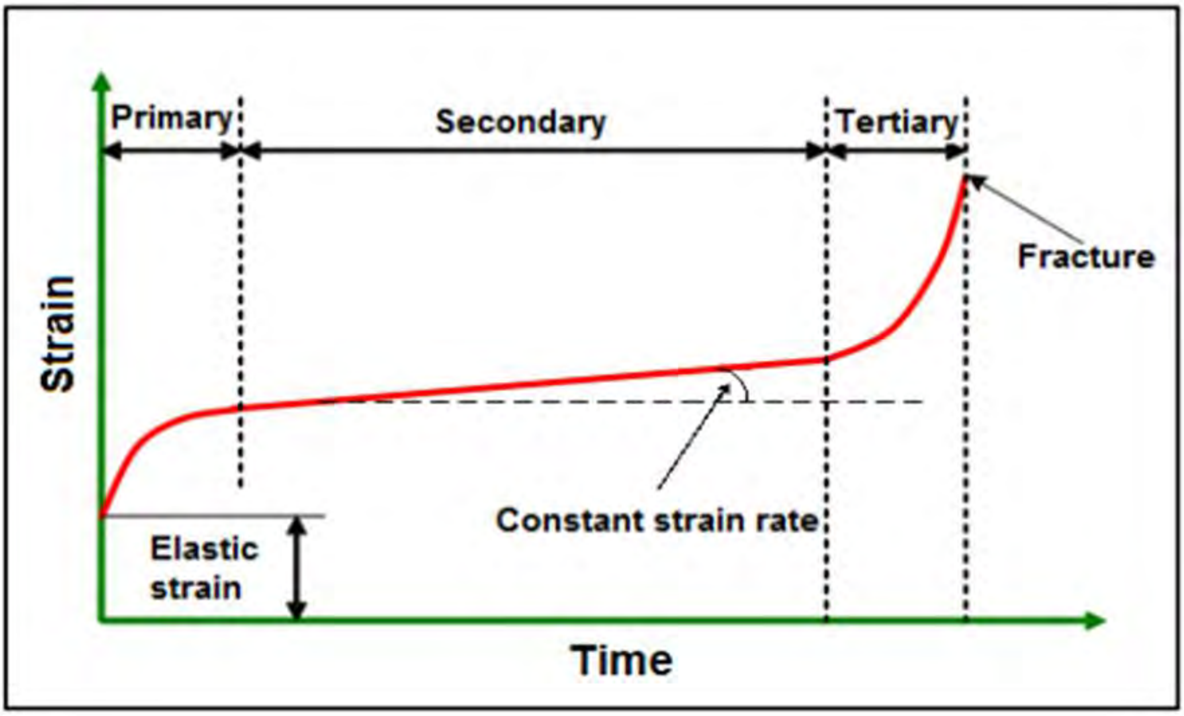


Figure 8-19: The idealised strain-time curve for a creep test - Atkins (2016).

Initially, as load is applied there is virtually instantaneous elastic strain, but over time, under constant stress, the strain rate decreases. With increasing strain, the strain rate continues to decrease. The time interval over which this decelerating strain-rate occurs is the period of *primary creep*.

The *secondary creep* phase is reached when resistance to creep increases and the strain rate reaches a near-constant, minimum value. This stage is often termed a “steady state creep” period. At the end of Stage II, the strain rate exponentially increases with strain, and the creep rate begins to accelerate, resulting in the initiation of a creep fracture process. This final stage of accelerating deformation that leads to a rapid material failure is called Stage III, or *tertiary creep*.

The rate of convergence of the excavated rooms would be decreased by the presence of waste and/ or backfill. Provided the waste is suitably emplaced, backfilling can be done to prevent long-term convergence. The smaller the residual void volume after backfilling, the lower the convergence rate. Rapid waste emplacement and backfilling would allow more control on creep and consequently, there would be accelerated room convergence.

When waste materials that flow are used (hydraulic backfill) they should be emplaced in a manner that minimises unfilled spaces at the level of the roof and improves significantly the support provided by the stored waste. For solid, packaged waste material and the surrounding salt backfill, the initial reduction in the closure rate of the excavated rooms is anticipated to be between 20 % and 25 %. Well-compacted hydraulically backfilled waste materials are expected to result in an initial reduction in the rate of closure between 35 % and 40 %.

Based on geo-mechanical analyses for other facilities (e.g. WIPP; Committee on the Waste Isolation Pilot Plant, National Research Council 1996; USDOE 2014), it is believed that if creep were to persist into Stage III (i.e. brittle failure occurs), the fractures developed would re-seal such that the halite would remain essentially impermeable and therefore, risks to groundwater resources several hundred metres above the Chandler Formation would not be at risk of contamination.

Earthquakes

The Proposal is located in the eastern part of the Amadeus Basin, within a tectonically stable plate interior, thousands of kilometres from the nearest tectonic plate boundaries that are characterised by frequent seismicity and on-going intense deformation (refer to Figure 8-20).

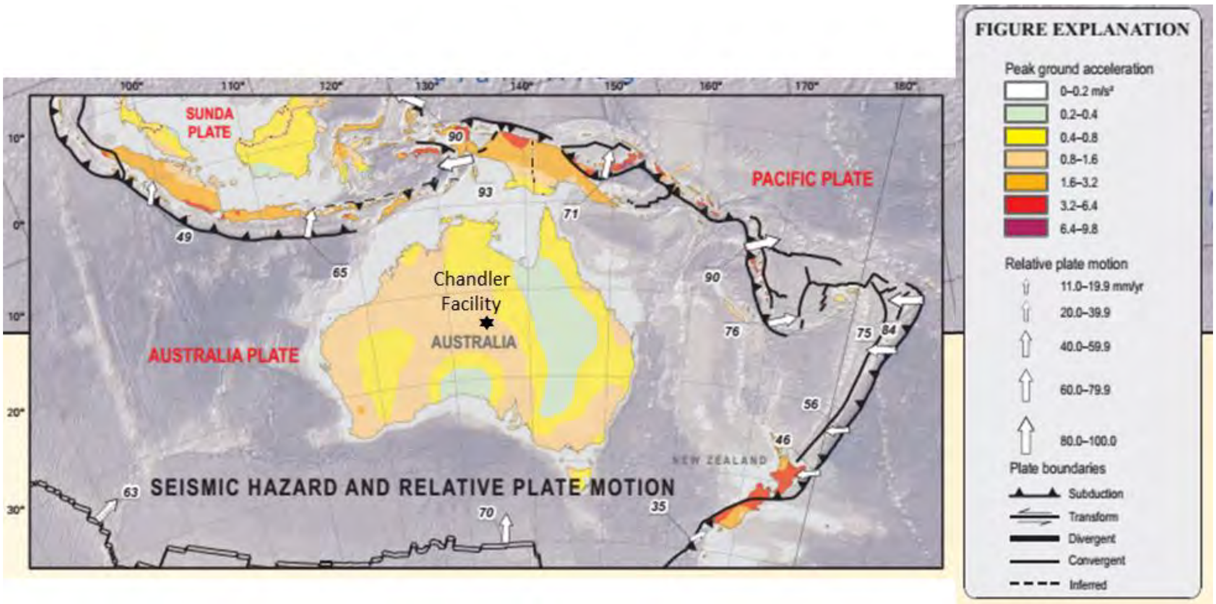
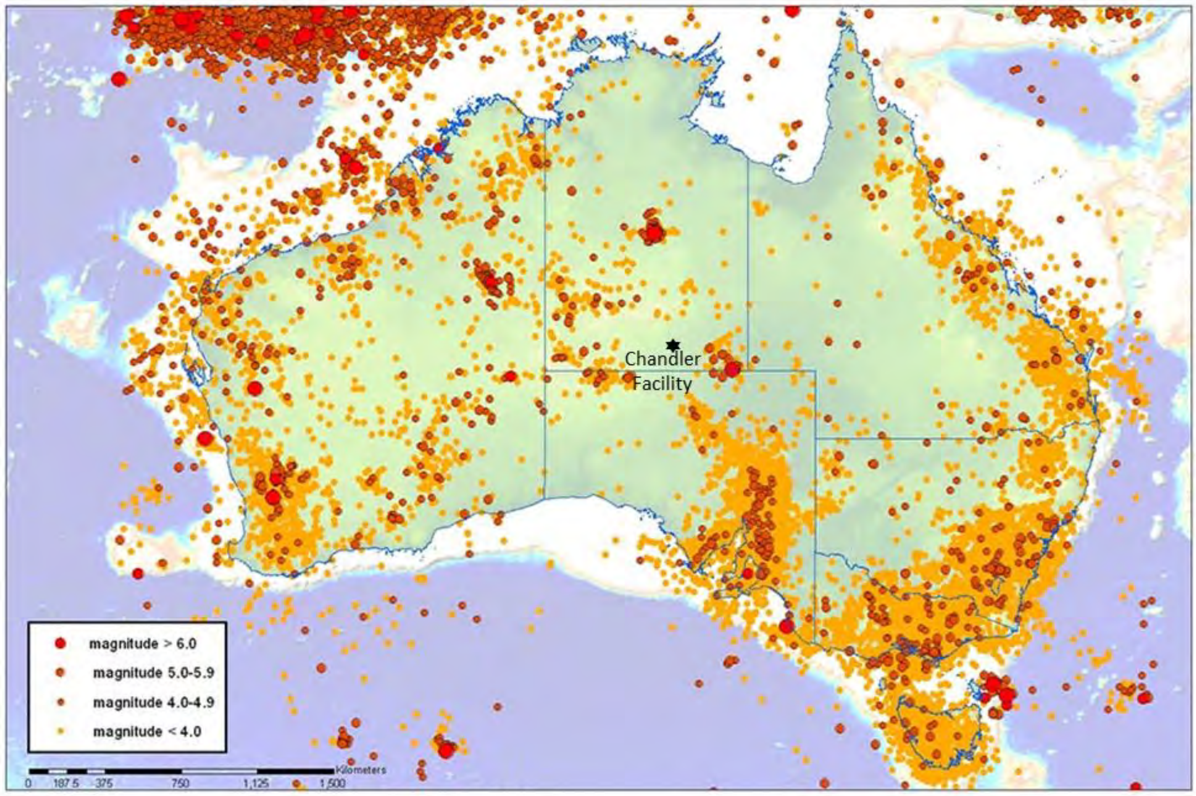


Figure 8-20: Location of the Chandler Facility in the stable interior of the Australian tectonic plate (after Benz et al. 2011).

Nevertheless, earthquakes do occur in stable continental interiors and there have been several earthquakes of magnitude up to 6.6 (the largest recorded in Australia) within the NT (refer to Figure 8-21). However, there have been no recorded large earthquakes within the immediate vicinity of the Proposal.

In the unlikely event earthquakes were to occur, the underground facilities would not be affected significantly, since damaging vibrations occur only at the earth's surface. Extensive research in Japan, a far more seismically active country than Australia, has established the feasibility of siting geological disposal facilities for high level radioactive waste at depths comparable to those proposed for the Chandler Facility (JNC 2000). Seismic vibrations are attenuated rapidly and would be very unlikely to be felt at 850 metres below ground level, the target depth for hazardous waste emplacement (see for example the dataset from Kamaishi Mine, Japan; JNC 2000).



All Australian earthquakes located up to 2011

Source: http://www.ga.gov.au/scientific-topics/hazards/earthquake/basics/where

Figure 8-21 All recorded Australian earthquakes up to 2011. After Geoscience Australia

Earthquakes would only be of concern to the safety of a deep geological facility if the moving fault that causes the earthquake were to intersect the facility. However, under the stress regime in central Australia, new faults are not expected to form. Furthermore, seismic surveys have revealed no faulting within the footprint of the Proposal, or its surroundings (RPS 2013). On this basis, it can be assumed that if any faults do occur, they must be too small to be resolved (displacements likely less than 10 metres).

Since there is a well-established correlation between the sizes (displacements) of existing faults and the magnitude of earthquakes that are likely to occur along them (Wells and Coppersmith 1994), it follows that the risk of movements of existing faults within the Proposal causing significant seismic events is not a concern for the Proposal.

8.7 Assessment of risk during closure and rehabilitation

This section presents the potential impacts (both direct and indirect) on groundwater during closure and rehabilitation of the Proposal. Mitigation measures to avoid or reduce these impacts are discussed in Section 8.8.

8.7.1 Direct impacts

The potential for direct impacts on groundwater during closure and rehabilitation of the Proposal are considered negligible because there would be no requirement to draw on groundwater resources during this period and all surface facilities would have been decommissioned and rehabilitated.

8.7.2 Indirect impacts

The potential for indirect impacts on groundwater during closure and rehabilitation have been quantitatively assessed by Quintessa and Atkins (refer to Appendix H and K, respectively).

Potential indirect impacts from geo-mechanical failure and earthquakes are discussed above in Section 8.6.2 and conclude no operational (including during backfill) indirect impacts on groundwater resources that lie several hundred metres above the Chandler (Halite) Formation.

The long-term, Post-Closure Risk Assessment, quantitatively assessed risks to the environment, including groundwater, that may arise following closure of the facility. The period covered by quantitative calculations undertaken during the risk assessment is sufficiently long to ensure that maximum risks have been considered (i.e. considering longer periods would not cause greater maximum risks to be estimated at a point in the future). Calculations were undertaken for periods of up to one million years.

The overall approach to the Long-term Post-Closure Risk Assessment followed best international practice[3], in accordance with the requirements of Australian and international regulations, and successful assessments of underground facilities in countries other than Australia, such as hazardous waste and gas storage facilities in the United Kingdom, and radioactive waste disposal facilities in Canada, Finland and Sweden.

In practice the assessment was carried out in a "top-down" fashion, such that the starting point was identifying the main threats to the environment posed by the Proposal during the post-closure phase. The most probable scenario for the future evolution of the Proposal is that the facility behaves as planned and no contamination leaves it following closure (the Expected Evolution Scenario, EES).

To assess the risks of the Proposal unexpectedly not behaving as designed (i.e. the EES not being realised), Alternative Evolution Scenarios (AES) were assessed and included:

- AES1, Connected porosity through the halite roof of the Proposal.
- AES2, Collapsed roof of the Proposal, with the variant:
    - AES2a, Collapsed roof in the Operational Phase.
    - AES2b, Collapsed roof in the Post-Closure Phase.

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[3] *Here "best practice" refers to the well-established approaches and methodologies that are widely applied throughout the world for assessing the performance and safety of various kinds of underground waste disposal and storage facilities. These approaches and methodologies have been developed over several decades during many projects, including ones concerned with radioactive waste disposal, CO_2 storage, natural gas storage, and hazardous waste disposal. No single document describes this best practice, but rather the approaches and methodologies are documented in numerous reports by international agencies such as the International Atomic Energy Agency (IAEA), Nuclear Energy Agency (NEA), International Energy Agency (IEA), International Standards Organisation (ISO), national regulators, and project implementers.*

- AES3, Impaired shaft seal.
- AES4, Accidental human intrusion.

The assessment provides confidence that, for the proposed categories of wastes and with appropriate facility design, there would be no significant risks arising from the Proposal in terms of environmental safety or risks to groundwater resources on a local or regional basis during post closure.

8.8 Mitigation and monitoring

8.1.1 Managing groundwater during construction

During construction, the risk assessment identified potential impacts from accidental spills and/or leaks from drilling machinery. These types of impacts could unintentionally contaminate groundwater resources during the construction of mine shafts and the decline. To avoid and minimise these risks, the drilling program would implement shaft sealing techniques as shown in Figure 8-22 and Figure 8-23.

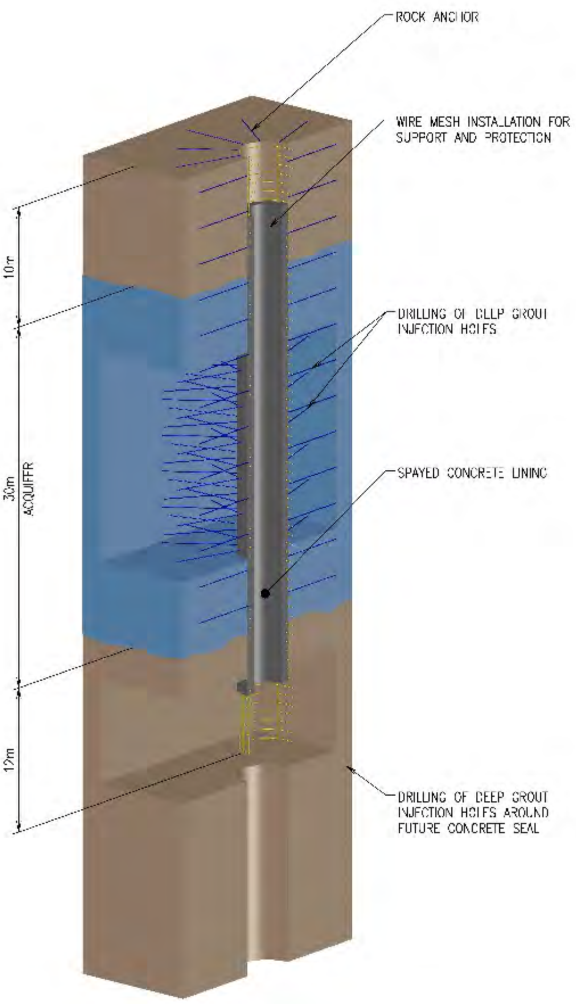

Figure 8-22 Shaft sealing techniques during construction

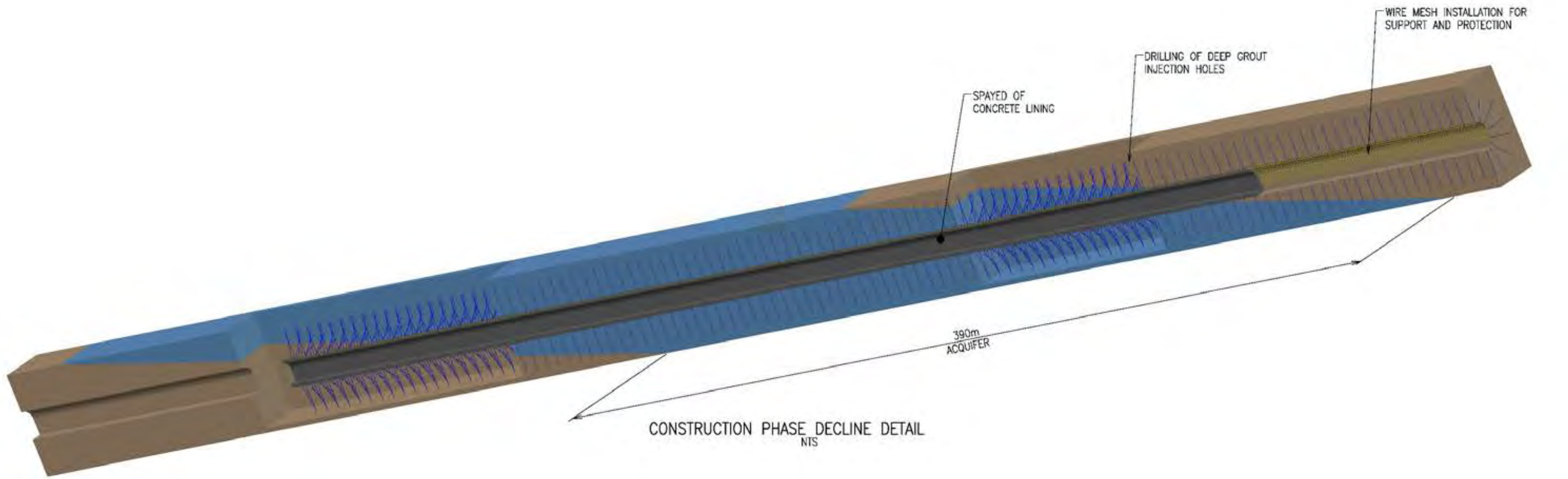

Figure 8-23 Decline sealing techniques during construction

8.1.2 Managing groundwater during operation and post closure

During operation, the risk assessment identified potential impact from leaking shaft /decline seals. These types of impacts could unintentionally contaminate groundwater resources during the operation of the Proposal.

To avoid and minimise these impacts, the drilling program would implement shaft sealing techniques similar to those shown in Figure 8-22 and Figure 8-23. Refer to Table 8-8 for more information on the detail behind the management measures that would be implemented during construction to protect groundwater resources.

8.1.3 Groundwater monitoring

Monthly groundwater level monitoring has been carried out on the existing monitoring network since June 2015 to establish a detailed groundwater baseline. Groundwater quality data has been taken on intermittently during the same period. The established monitoring network would be used for ongoing monitoring during construction and operation to assess groundwater level and water quality trends. Monitoring data would be used to verify predictions during construction and operations based on the preliminary baseline dataset.

Ongoing groundwater quality monitoring would ensure early detection of any change in groundwater quality or possible groundwater contamination.

Ongoing groundwater level and quality monitoring would include:

- Monitoring of targeted groundwater elevations on at least a quarterly basis.
- Targeted groundwater quality sampling on a quarterly basis sampling suite provided in Table 8-7.

Table 8-7 Groundwater quality sampling suite

Analysis / classification	Parameter
In-field analysis	
Depth to groundwater	Metres below top of casing
Chemical properties	pH, dissolved oxygen
Physical properties	Temperature, electrical conductivity, total dissolved solids
Laboratory analysis	
Hydrocarbons	TPH, BTEX, PAH[1]
Dissolved metals	Antimony, arsenic, boron, cadmium, chromium, copper, iron lead, mercury, molybdenum, nickel, selenium, strontium, zinc
Total metals	Antimony, arsenic, boron, cadmium, chromium, copper, iron lead, mercury, molybdenum, nickel, selenium, strontium, zinc
Major ions	Alkalinity, bicarbonate, calcium, carbonate, chloride, hydroxide, magnesium, potassium, sodium, sulfate
Nutrients	Total nitrogen, total phosphorus, nitrite, nitrate, ammonia

Notes: 1. TPH=total petroleum hydrocarbons; BTEX=benzene, toluene, ethylbenzene and xylenes; PAH=polycyclic aromatic hydrocarbons.

The existing and proposed groundwater monitoring program would be revised in consultation with the DENR and NT EPA via the Water Management Plan (Appendix Q).

Additional monitoring locations may be required to monitor drawdown in deeper groundwater systems and drawdown extent during mining at key locations between active groundwater users (including environment) and the mine areas such as:

- Monitoring site(s) in the Langra, Stairway Sandstone and/or Jay Creek Limestone within the Chandler Facility surface infrastructure area.
- Monitoring site(s) between the mine and the Finke River (specifically Horseshoe Bend Spring).
- Monitoring site(s) between the mine and active groundwater users.
- Additional shallow monitoring bore(s) would be installed adjacent to the Apirnta Facility.

Field based physicochemical water quality monitoring of any groundwater dewatered from the mine would occur on a regular basis. Any water dewatered from the mine would be metered to ensure the water management system accurately represents total inflows and outflows across the site.

The draft Water Management Plan contains details for the proposed construction and operation groundwater monitoring program. It would also include the establishment of groundwater level and quality triggers, actions and contingencies that would be implemented in the event that monitoring indicates an adverse impact on groundwater quality.

This process would also comprise the ongoing evaluation of monitoring data and the redefinition of triggers, actions and contingencies if required, in consultation with DENR and NT EPA.

8.1.4 Summary of mitigation and monitoring measures

An overall summary of all proposed groundwater mitigation and monitoring measures are listed in Table 8-8.

Table 8-8 Proposed groundwater mitigation and management measures

ID	Outcome	Mitigation / management measure	Timing
GW.1	Sustainable use of groundwater reserves	Apply for water abstraction licences and permits under the NT *Water Act.*	Pre-construction
GW.2	Avoid groundwater contamination	Grout and seal production bores during construction, operation and post closure (as indicated in Sections 8.1.1 and 8.1.2).	Pre-construction
GW.3	Monitor and record groundwater drawdown	Ensure localised depressurisation of groundwater systems are monitored with data loggers in monitoring bores to ascertain potential of the Proposal to impact local groundwater users. Ensure groundwater level data is reviewed and reported in an Annual Environmental Monitoring Report (AEMR).	Pre-construction, construction, operations, post-closure
GW.4	Develop of detailed groundwater quality database	Report groundwater quality results to the DPIR and the NT EPA every four months (April, August and December) to compare seasonal data against project activities.	Seasonal (on a rolling basis over the life of the mine).
GW.5	Consultation to develop a local groundwater database	Undertake a hydro-census (condition) survey of local groundwater users prior to construction to ascertain bore condition and current status of the bores located within a 25 kilometre spatial buffer around the proposed Chandler Facility. Involve consultation with local groundwater users, with an end purpose of establishing baseline conditions of existing local groundwater users.	Pre-construction
GW.6	Develop a detailed groundwater database	Construct four additional water monitoring sites (as nested sites) to observe shallow groundwater and to monitor deeper systems predicted to be intercepted through mining activities. Monitor groundwater levels and quality near Titjikala, the Finke River, and within the deeper groundwater systems (Stairway Sandstone and Jay Creek Formations) near the proposed mine portal. Undertake shallow monitoring of ephemeral groundwater in aeolian/alluvial sediments at the Chandler Facility and Apirnta Facility to monitor any pollutant losses into the sub-surface.	Pre-construction
GW.7	Develop a detailed groundwater database	Complete a groundwater isotope study for monitoring bores prior to construction to confirm the relationship between shallow and deeper groundwater systems, and to confirm the origin and residence time of groundwater.	Pre-construction
GW.8	Develop a detailed groundwater database	Despite there being no known groundwater dependent ecosystems in the immediate vicinity of the Proposal, potential groundwater dependent ecosystems should be monitored and modelled through detailed design if identified to be potentially impacted by the Proposal. Establish a monitoring program if potential groundwater dependent ecosystems are identified to be impacted through the construction, operation or closure and rehabilitation of the Proposal.	Pre-construction (detailed design)
GW.9	Avoid groundwater contamination	Ensure that the management of groundwater and surface water inflow into the mine portal and ventilation shafts, including the design and capture of this water is undertaken in consultation with the DPIR who administer the Mine Management Plan.	Construction
GW.10	Sustainable use of groundwater reserves	Ensure preference is given to re-use groundwater inflows over potable water for construction activities, where reasonable and feasible.	Construction
GW.11	Develop a more detailed understanding of local groundwater network	Refine or further develop the groundwater model to verify the predictions within the EIS (if water level variations outside of the natural range are observed). Ensure modelling is consistent with established guidelines, which allow for analytical or numerical modelling if appropriate for the project context and risks, subject to discussion and agreement with government agencies.	Operations
GW.12	Develop a detailed groundwater database	Monitor groundwater abstraction in production bores. Fit a cumulative flow meter to each production bore, and install pressure transducers in each bore to monitor groundwater drawdown at source.	Construction, operations, post-closure

8.9 Summary of risk assessment

A summary of the risk assessment undertaken for groundwater during construction, operation, closure and rehabilitation of the Proposal is provided in Table 8-8.

Table 8-9 Summary of groundwater risk assessment

Hazard	Pre-mitigated risk			Post-mitigated risks			Risk outcome
	Likelihood	Consequence	Risk ranking	Likelihood	Consequence	Risk ranking	
Changes to groundwater levels	Almost certain	Minor	High	Possible	Minor	Medium	Risk reduced
Changes to groundwater chemistry	Possible	Minor	Medium	Remote	Minor	Low	Risk reduced
Changes to groundwater flow (direction)	Possible	Moderate	Medium	Remote	Minor	Low	Risk reduced
Contamination of Horseshoe Bend Shale aquatards from drilling activities	Remote	Major	Medium	Eliminated	Major	Eliminated	Risk reduced
Contamination of Langra aquifer from drilling activities	Remote	Major	Medium	Eliminated	Major	Eliminated	Risk reduced
Contamination of Hermannsberg Formation groundwater from drilling activities	Remote	Major	Medium	Eliminated	Major	Eliminated	Risk reduced
Contamination of Stairway Sandstone groundwater from drilling activities	Remote	Minor	Low	Eliminated	Minor	Eliminated	Risk reduced
Contamination of Jay Creek Limestone groundwater from drilling activities	Remote	Minor	Low	Eliminated	Minor	Eliminated	Risk reduced
Contamination of Titjikala water supply through loss of containment	Eliminated	Catastrophic	Eliminated	Eliminated	Catastrophic	Eliminated	Risk same
Contamination of Alice Springs aquifer through loss of containment	Eliminated	Catastrophic	Eliminated	Eliminated	Catastrophic	Eliminated	Risk same
Contamination of Great Artesian Basin through loss of containment	Eliminated	Major	Eliminated	Eliminated	Major	Eliminated	Risk same
Contamination of livestock through loss of containment	Eliminated	Major	Eliminated	Eliminated	Major	Eliminated	Risk same

Uncontrolled inflow of groundwater during construction	Unlikely	Minor	Low	Remote	Minor	Low	Risk reduced
Uncontrolled inflow of groundwater during operations	Remote	Catastrophic	Medium	Remote	Major	Medium	Risk reduced
Engineered uses of naturally occurring corrosive groundwater	Almost certain	Major	Extreme	Almost certain	Minor	High	Risk reduced
Over abstraction of groundwater leading to local or regional drawdown	Remote	Minor	Low	Eliminated	Minor	Eliminated	Risk reduced
Lack of groundwater for supply	Remote	Major	Medium	Eliminated	Minor	Eliminated	Risk reduced

8.10 Conclusion

The Proposal area is within the Chandler Syncline, itself within the south-eastern extent of the Amadeus Basin. The Chandler Syncline hosts various local groundwater systems, all of which have minor confining layers and permeability barriers to groundwater flow.

The depth to groundwater at Chandler is about 90 metres, and the groundwater is saline. The basal unit overlying the Chandler Formation and target salt resource is the Giles Creek Dolostone Formation, comprising predominantly of marine shale, silt and sand sediments and thin beds of dolomite at a depth of about 830 metres. The Giles Creek Dolostone does not host groundwater.

Overlying the Giles Creek Dolostone is the Jay Creek Limestone Formation, a 170 metres thick geological unit comprising predominantly shale, silt and sand. Overlying the Jay Creek Limestone Formation is the Stairway Sandstone Formation, a thick sequence comprising predominantly continental coarse to medium grained sandstone within interbedded minor silt and shale beds. The Stairway Sandstone supports numerous landholder bores within the region at shallower depth (<100 metres BGL).

Overlying the Stairway Sandstone Formation is the Langra Formation, subdivided into three member units, represented at depth by interbedded silt and shale beds, gradually transitioning into extensive fine to medium grained sand. Overlying the Langra Formation is the Horseshoe Bend Shale Formation, a massive siltstone and quartzitic sandstone deposit. Both the Langra and Horseshoe Bend Shale Formations host brackish to saline groundwater.

The inferred piezometric surface ranges between 60 and 90 metres BGL across the Chandler Facility. Directly above the Horseshoe Bend Shale Formation and partially eroded at surface across the Proposal area is the Idracowra Sandstone, a kaolinitic sandstone represented across the Maryvale Hills and discontinuous across the Proposal area. The Idracowra Sandstone supports numerous groundwater users within a 25 kilometre radius of the mine. Groundwater is typically saline and as such is used locally as a stock supply. The Idracowra Sandstone Formation will not be intercepted by mining.

Locally in the vicinity of the Proposal area, there is very low recharge from direct rainfall, but minor recharge is expected to occur via infiltration from overlying alluvial systems during major flooding events.

Minor direct rainfall recharge may occur locally, but the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the middle and lower members of the Langra Formation is likely to result in the formation of perched localised groundwater systems in the upper Langra Formation and Horseshoe Bend Shale Formation. The underlying Stairway Sandstone Formation and Jay Creek Limestone Formation are likely to receive negligible recharge where the two geological units outcrop at surface along the Charlotte Ranges to the west of the Chandler Facility due to their limited outcrop extent and distant location from ephemeral creek lines.

Consistent with topographic gradients, hydraulic gradients are very gentle in the south-eastern extent of the Amadeus Basin, and the broad flow direction in all groundwater systems is generally from north-west to south-east, however, the basement structure influences the groundwater flow direction in certain areas. The structural influences are typically associated with folding.

The horizontal hydraulic conductivity in geological units is highly variable, due to the depositional environments and volume of clay; groundwater flow through Formations is therefore not expected.

There is an upwards hydraulic gradient from the Langra Formation to the Horseshoe Bend Shale Formation based on pressure head differences observed through groundwater monitoring. Elsewhere, within the 25 kilometre spatial buffer around the Chandler Facility, landholder bores located within the shallow alluvium associated with ephemeral creeks report shallow groundwater levels which are likely to be perched systems, with low rates of vertical leakage to the underlying Idracowra Sandstone Formation and Horseshoe Bend Shale Formation.

The saline groundwater quality within the Chandler Syncline differs markedly from the potable water quality reported for the Mereenie Aquifer System about 100 kilometre north within the Northern Amadeus Basin (the MAS is utilised for the Alice Springs Water Supply). The Chandler Syncline is a separate groundwater system entirely, given that the MAS units occur within the Northern Amadeus sub-basin and Orange Creek Syncline, but do not occur within the Chandler Syncline. The evidence confirms that the Chandler Syncline is distinct and separate from the Mereenie Aquifer System in terms of geological structure, lithological units, groundwater flow properties, hydraulic gradients and water chemistry.

Water quality within shallow alluvial groundwater accessed by landholder bores to the north and west of the Chandler Facility, particularly at Titjikala can be characterised as potable. Whereas groundwater quality observed within the Horseshoe Bend Shale and Langra local groundwater systems are poor and equivalent to seawater. Salts originating from the marine depositional environment, and the enhanced climatic nature of the environment (i.e. low precipitation/high evaporation), coupled with long groundwater residence times is likely to contribute to the poor groundwater quality observed within the Chandler Syncline.