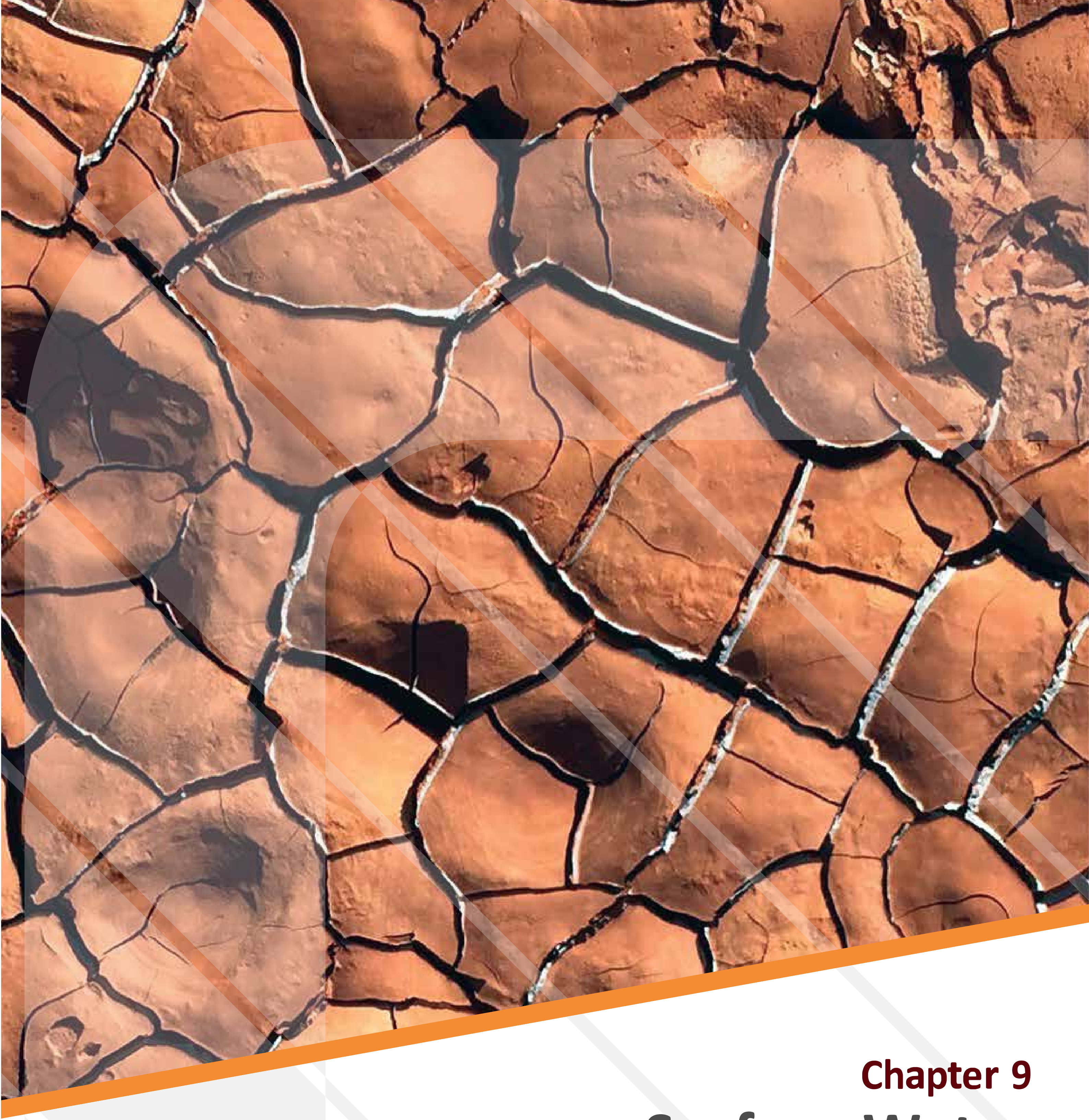


Chapter 9

Surface Water

This page has been left intentionally blank

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

ABBREVIATIONS

AHD	Australian Height Datum
ANZECC	Australian and New Zealand guidelines for fresh and marine water quality
APR87	Australian Rainfall and Runoff
ARI	Average Recurrence Intervals
BoM	Bureau of Meteorology
CDFM	Cumulative Deviation From The Mean
CUH	Clark Unit Hydrograph
DLRM	Department of Lands and Resource Management (now the NT Department of Environment and Natural Resources)
DoE	Department of Environment (now the Department of Environment and Energy)
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
HMTV	Hardness Modified Trigger Values
IFD	Intensity-Frequency-Duration
km^2	square kilometres
l/s	litres per second
mm	millimetres
m/s	metres per second
NT	Northern Territory
Sc	Storage coefficient
Tc	Concentration
TDS	Total dissolved solids
ToR	Terms of Reference
$\mu S\ cm^{-1}$	micro siemens per square centimetre
WOFS	Water Observations from Space
<	Less than

>	Greater than

9 SURFACE WATER

9.1 Introduction

An environmental impact statement (EIS) has been prepared to address specific requirements provided in the *Final Guidelines for the Preparation of an Environmental Impact Statement* for the Proposal application, issued on 23 September 2016.

This assessment has been prepared as part of the EIS to address the specific surface water requirements in the environmental assessment guidelines. Specifically, the assessment addresses the key requirements of the NT EPA and other NT Government agencies with jurisdiction over surface management.

The relevant requirements in the Final ToR relating to water are listed in Appendix A and include the section of this report and supporting documentation in Appendix N where they are addressed. The information presented in this Chapter summarises the main findings of specialist surface water investigations and reports to support the EIS (see Appendix R).

The objectives of this assessment are to:

- Identify and assess potential impacts on surface water from the development of the Proposal;
- Satisfy the Final ToR and other relevant agency requirements relevant to surface water impact assessment.
- Inform the wider community about the Proposal and its potential impacts on the local and regional water environments.

To achieve these objectives, the water assessment:

- Assesses the existing hydrological environment using a risk based approach, and baseline conditions within the Proposal area and its surrounding area.
- Identifies and quantifies the potential risks and impacts of the Proposal on the current surface waters.
- Proposes mitigation and management measures, and monitoring requirements for surface water.
- Discusses relevant legislation with respect to activities involving surface waters.

9.2 Methodology

9.2.1 Literature review

A literature review, drawing on a number of publicly available published reports has been undertaken to conceptualise the regional environment. The review has a particular focus on surface water environments across the south-east of the NT and the north-west of South Australia. A summary of the critical information sources is included in Appendix R.

9.2.2 Desktop gap analysis

Desktop gap analysis was completed in order to identify drainage channels and surface water features relevant to the Proposal prior to site visit and manipulate data collected during the site visit.

The desktop assessment included the following:

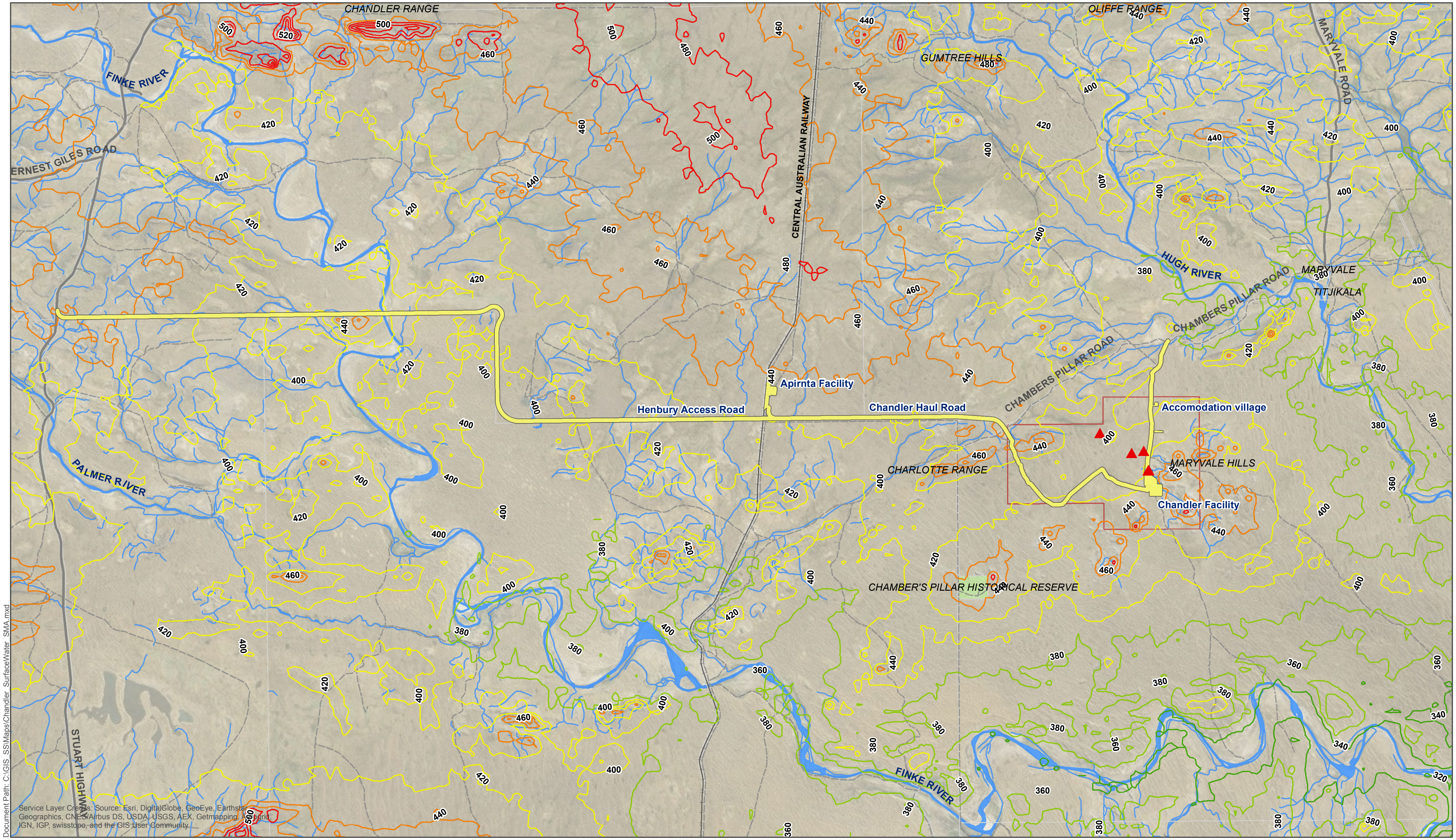
- Review of available literature and data relating to climate / hydrology, geology / soils, geomorphology and vegetation.
- Review of current Proposal baseline monitoring program.
- Review of topographic data to gain an understanding of key watercourse characteristics including bed slope, sinuosity, meander bend characteristics, channel widths / depths.
- Review of recent aerial photography to identify visible features relevant to watercourse geomorphology.
- The findings of the desktop assessment informed the development of a watercourse geomorphology field survey.

9.2.3 Field investigations

Field investigations for the preparation of this EIS were undertaken by the proponent over four years (2013 to 2016). Surface water field investigations continue in 2017 and would do so for the life of the Proposal.

The aim of field investigations was to describe and monitor baseline surface water systems associated with the Proposal. The proponent's existing surface water monitoring locations for the Proposal are shown in Figure 9-1.

Site locations for hydrological, geomorphological and sediment sampling were selected and are shown in Figure 9-2. Sites were located on a representative range of creeks both within and down gradient from the Proposal area and where land permissions could be obtained. Seven sites were selected where existing hydrographic stations were established (i.e. CS005013, CS005021, CS005031, CS005041) or where hydrographic stations are proposed in the near-future (i.e. GEOM01, GEOM2 and GEOM03).



4 2 0 4 Kilometers

N

Coordinate System: GDA 1994 MGA Zone 53

Legend

- Proposed development footprint
- Watercourse
- Pastoral boundaries
- Mining Lease Area
- Tellus Holdings hydrostations

Figure 9-1
Existing water monitoring stations

TELLUS

This document incorporates Data which is © Commonwealth of Australia (Geoscience Australia) 2006.
Data source: Geoscience Australia, 250K Topo base data, 2006; USGS, SRTM elevation, 2000; AUSURV SURVEYORS, detailed elevation data, 2016.
Created by:adrian.miller

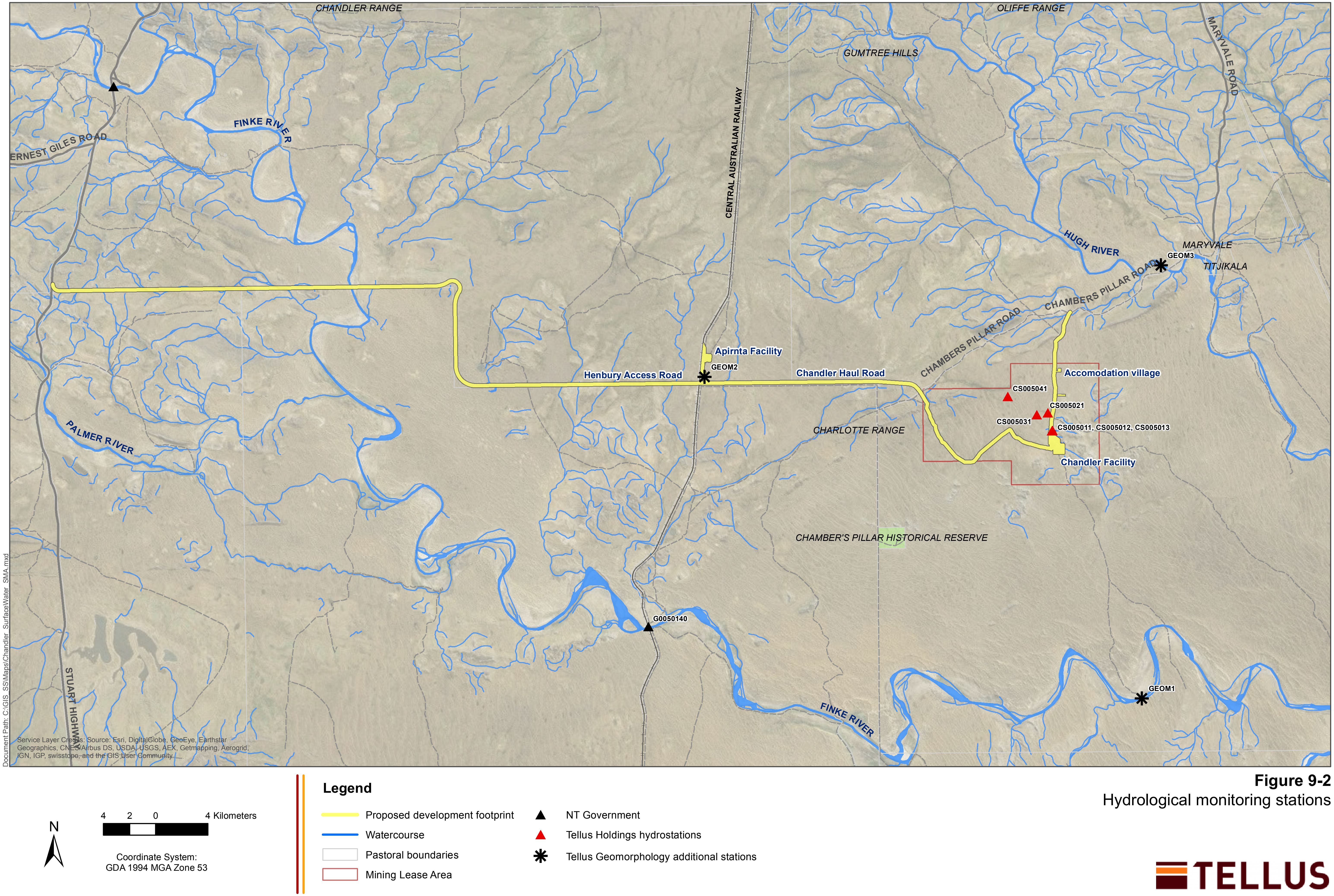


Figure 9-2
Hydrological monitoring stations

This document incorporates Data which is © Commonwealth of Australia (Geoscience Australia) 2006.
Data source: Geoscience Australia, 250K Topo base data, 2006; USGS, SRTM elevation, 2000; AUSURV SURVEYORS, detailed elevation data, 2016.
Created by:adrian.miller

Geomorphological conditions rapid walkover survey

A baseline geomorphology review was conducted at all seven sites to provide a snapshot of the current geomorphic conditions and capture the various channel types and characterise the main watercourses within the Proposal boundary. RiverStyles™ classification (Thompson et. al. 2005) was used to describe the main channel types identified in the assessment based on valley setting, channel continuity, river planform, geomorphic units and bed material texture.

Sediment testing

Bed sediment sampling was conducted on 16 and 17 May 2016. Further sediment samples were taken in recent rains but the results were not available at the time of submitting this EIS. Antecedent hydrological conditions immediately prior to the sampling event were wet; 53 mm of precipitation was recorded in the Hugh catchment for the two weeks preceding the site visit (NT Government 2016).

Bed sediment sub-samples were collected at 0, 20, 40, 60, 80 and 100 percentile width increments across the channel using a plastic scoop washed with deionized water to prevent cross-contamination. The six sub-samples were then combined into a composite sample by mixing, double-bagging and sent for the following analysis at a NATA accredited laboratory:

- Electrical conductivity (1:5 soil: water leach).
- Metals suite.
- Moisture content.
- Particle size distribution.
- Total organic carbon.

Quality assurance / quality control analysis was conducted on these samples including blank testing, duplicate testing and spike recovery. No analysis for nutrients or organic compounds (e.g. hydrocarbons, pesticides) was conducted because no significant sources of these chemicals were anticipated within the surface catchments and the Proposal was not expected to affect baseline conditions.

The monitoring of baseline conditions continues during the assessment of this EIS. The proponent is committed to continuing field investigations through the Proposal's detailed design, construction, operation, decommissioning and closure phases. Further data and discussion of baseline data is contained in the BECA report (see Appendix R).

9.2.4 Water quality guidelines

Australian and New Zealand guidelines for fresh and marine water quality

The Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ 2000) set out the framework for the application of water quality guidelines. These guidelines describe requirements over a variety of marine and freshwater environments, aquatic ecosystems, primary industries, recreational water, drinking water and monitoring and assessment.

The most appropriate guideline values to compare water quality data against were therefore considered to be national guidelines outlined in ANZECC 2000 Water Quality Guidelines for two conditions:

- The 95 % freshwater aquatic ecosystem protection.
- Primary industries livestock protection.

Adoption of the aquatic ecosystems guideline value was seen as a conservative approach, as the only possible aquatic systems supported in the Study Area were in the semi-permanent waterholes in the Finke River, which in turn has limited hydrological connectivity to the Proposal.

The only sub-catchment linked to the Finke is the Apirnta Creek to the west of the Study Area. As the study area has a small degree of human activity, the study area ecosystem was classified as slightly to moderately disturbed. A 95 % statistically-based protection level is most commonly applied to these ecosystems, and represent the 'no significant adverse effect' guidelines. The objectives of the aquatic ecosystem 95 % protection are to maintain the key ecological processes and diversity as comparable as possible to that of the existing natural habitats within the area.

Chemical and physical indicators (or trigger values) for aquatic ecosystem 95 % protection guidelines are outlined in the BECA report (see Appendix N).

The above guidelines provide an authoritative guide for setting water quality objectives for natural and semi-natural water resources in Australian and New Zealand sustaining current or likely future environmental values (uses). The guidelines were used when assessing the baseline water quality for the Proposal.

NT Government water quality data

NT government has several water quality monitoring stations located within the Study Area. The water quality samples collected at each NT station were compared against the trigger levels for 95 % freshwater aquatic ecosystem protection and primary industries livestock protection (See BECA Report in Appendix R).

The following water features included in this analysis are not within the study area but were included to provide an indication of dam / tank water quality due to limited records within the Proposal area dams:

- Dead Bird Tank.
- Dead Horse Dam.
- Four Winds Tank.
- One Tree Hill Dam.
- River Tank.
- Soakage Dam.
- Top Soak Dam.

Water quality in these dams and tanks is likely to be similar to Charlotte Range Lookout and Robinson Dams. The most appropriate guideline values to compare water quality data against were therefore considered to be national guidelines outlined in ANZECC 2000 Water Quality Guidelines for two conditions:

1. The 95 % freshwater aquatic ecosystem protection; and
2. Primary industries livestock protection.

Adoption of the aquatic ecosystems guideline value was seen as a conservative approach, as the only possible aquatic systems supported in the study area were in the semi-permanent waterholes in the Finke River, which in turn has limited hydrological connectivity to the Proposal. The only sub-catchment linked to the Finke is the Apirnta Creek to the west of the study area. As the study area has a limited degree of human activity, the study area ecosystem was classified as slightly to moderately disturbed.

A 95 % statistically- based protection level is most commonly applied to these ecosystems, and represent the 'no significant adverse effect' guidelines. The objectives of the aquatic ecosystem 95 % protection are to maintain the key ecological processes and diversity as comparable as possible to that of the existing natural habitats within the area.

Chemical and physical indicators (or trigger values) for aquatic ecosystem 95 % protection guidelines are outlined in Table 9-1.

Table 9-1 Chemical and physical stressor trigger values for aquatic ecosystem 95% protection

Chemical / physical stressor	Trigger value
Aluminium (µg/L)	55
Ammonia (µg/L)	6
Arsenic (µg/L)	24
Boron (µg/L)	370
Cadmium* (µg/L)	0.2
Chromium* (µg/L)	1
Copper* (µg/L)	1.4
EC (µS/cm)	20 -250
Dissolved oxygen (%)	90-120
Manganese (µg/L)	1900
Lead* (µg/L)	3.4
Nickel* (µg/L)	11
Nitrate (µg/L)	700
Mercury (µg/L)	0.6
pH	6.0 – 77.57.5
Phosphate (µg/L)	5
Selenium (µg/L)	11
Silver (µg/L)	0.05
TSS (mg/L)	2-200
Turbidity (NTU)	2-15
Zinc* (µg/L)	8.0

* Site-specific HMTVs were applied to these selected metals based on a hardness correction factor

Good water quality is essential for the livestock production, where contaminates in drinking water can adversely affect animal production. The scope of the guidelines for livestock protection, include biological, chemical and radiological characteristics that may affect animal health. Chemical and physical trigger values for livestock protection are outlined in Table 9-2.

Table 9-2 Chemical and physical stressor trigger values for livestock protection

Chemical / physical stressor	Trigger value
Aluminium (mg/L)	5
Arsenic (mg/L)	0.5
Boron (mg/L)	5
Calcium (mg/L)	1000
Cadmium* (mg/L)	0.01
Cobalt (mg/L)	1
Chromium* (mg/L)	1
Copper* (mg/L)	1
Fluoride (mg/L)	2
Lead* (mg/L)	0.1
Mercury (mg/L)	0.002
Molybdenum (mg/L)	0.12
Nickel* (mg/L)	1
Nitrate (mg/L)	400
Selenium (mg/L)	0.02
Uranium (mg/L)	0.2
Sulfate (mg/L)	1000
TDS (mg/L)	4000-5000
Zinc* (mg/L)	20

* Site-specific HMTVs were applied to these selected metals based on a hardness correction factor

In Table 9-1 and Table 9-2, the bioavailability of cadmium, chromium, copper, lead, nickel and zinc is related to the hardness of the water. If the water found onsite was determined to be hard, hardness modified trigger values (HMTVs) would be developed, as outlined by the ANZECC guidelines, to better represent a site-specific trigger value. The hardness of the water quality data was evaluated against the ANZECC guidelines values outlined in Table 9-3.

Table 9-3 Hardness categories for ANZECC guidelines

Hardness category	Values (mg/l)
Soft	0
Medium	60 to 119
Hard	120 to 400

Water quality naturally changes temporally and spatially in dryland rivers. This makes developing and applying site-specific water quality guidelines and trigger levels very difficult for these rivers (Miles *et al.*, 2015). One possible solution is to develop guidelines for both the no-flow and flowing phases. This could be done by collecting and interrogating monitoring data and developing conceptual, probabilistic and/or numerical models that incorporate flow, catchment and in-stream influences.

Such an understanding would assist in guiding the sustainable use and management of watercourses surrounding the Chandler Facility area, Apirnta area and wider study area. This site-specific system would be developed during detailed design and as part of the Water Management Plan once more data has been collected on site.

Desktop studies following site visit

Metal concentrations are generally higher in < 0.063 millimetre fraction than the bulk sediment fraction. Normalisation is a procedure to correct or adjust contaminant concentrations for the influence of the natural variability in sediment composition; in particular for grain size.

In this study, bulk sediment samples have been collected and analysed for metal concentrations and percentage < 63 µm grain size. In this instance, a very simple form of normalisation was suitable whereby bulk sediment concentration data (expressed as mg/kg dry weight) was divided by the percentage '< 63 µm % passing' (expressed as a decimal) (Simpson *et. al.* 2013). Bulk metal concentrations for the current dataset can then be compared on a spatial basis in order to evaluate sediment enrichment, independent of differences in particle size in different creeks.

The ANZECC interim sediment quality guideline values for Aquatic Ecosystem Health (ANZECC 2000) and Queensland guideline reference median range values (DoE 1998) were assessed against both the raw and normalised data. The latter dataset was used in the absence of any NT guidelines (refer to Table 9-4.

Table 9-4 Sediment guideline values to compare to raw and normalised chemical data

Parameter	Sediment guideline values (all mg/kg)			
	ANZECC 2000 ISQG - Low	ANZECC 2000 ISQG - High	Qld RMR - Low	Qld RMR - High
Antimony	2	25	NS	NS
Arsenic	20	70	NS	NS
Cadmium	1.5	10	0.5	1.5
Chromium	80	370	15	240
Copper	65	270	10	64
Lead	50	220	5	20
Mercury	0.15	1	NS	NS
Nickel	21	52	5	40
Silver	1.0	3.7	NS	NS
Uranium	300*	600*	NS	NS
Zinc	200	410	29	130

* Reported in Hardford *et. al.* (2013); NS = No standard

The trigger value that was the lower of the two for each parameter was applied when the ANZECC, Queensland guidelines differed. For antimony, arsenic, silver and mercury only ANZECC guidelines were found.

Proposal water quality guidelines

Existing water quality stations are shown in Figure 9-1. The data collected from these station were compared against the trigger values for 95 % freshwater aquatic ecosystem protection (Table 9-1) and primary industries livestock protection (Table 9-2). Due to the hardness of the water sample data, hardness modified trigger values (HMTVs) for cadmium, chromium, copper, lead, nickel and zinc were developed as outlined against the ANZECC guidelines. These HMTVs better represent the site-specific bioavailability of these metals in surface water onsite.

Proposal sediment quality data

The Proposal contaminant limits and trigger levels were compared for samples taken at the existing monitoring stations. The results are shown in Table 9-5.

Table 9-5 Comparison of sediment contaminant concentrations to guideline values

Sample code	Chemical concentrations (all mg/kg)										
	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Uranium	Zinc
CS005013	<7	<4	<0.4	4	1	2	<0.1	<1	<1	0.1	2
CS005021	<7	<4	<0.4	9	4	3	<0.1	2	<1	0.2	10
CS005041	<7	<4	<0.4	11	4	3	<0.1	2	<1	0.2	9
GEOM02	<7	<4	<0.4	9	3	3	<0.1	2	<1	0.2	5
GEOM03	<7	<4	<0.4	5	2	3	<0.1	2	<1	0.2	7

Key

< = Less than practical quantifiable limit

Below guideline value/s	Equal to guideline values	Exceeding guideline values

9.2.5 Flooding and flood flow hydrographs

Overall approach

The mine site, haul road and railhead lie in the catchments of the Finke and Hugh Rivers. As noted in the Surface Water Baseline Report (Appendix R), flows on both rivers are recorded at the Stuart Highway crossings (as is the Palmer, a tributary of the Finke) and the flows on the Finke are also recorded at the rail crossing.

The Chandler Haul Road crosses the Finke River about 22.8 kilometres east of the Stuart Highway, but west of the railhead. The topographic gradient suggests that water from the mine site would generally drain towards the Hugh River near Titjikala. However, site reconnaissance has shown that hydraulic connectivity between the mine site and the Hugh River is unlikely.

Flood hydrographs have been defined for the catchments draining towards the project infrastructure (mine site, haul road and railhead) using the Australian Rainfall and Runoff (hereafter referred to as

ARR87) guide to flood estimation and HEC-HMS hydrological modelling software. The resulting flood estimates have been verified with reference to the flood frequency of the major rivers. The ARR87 approach requires:

- Catchment areas, lengths and slopes to be defined.
- Design rainfall.
- Storm depth.
- Aereal reduction.
- Profile.
- Lossess.
- Method of the transforming effective rainfall into a flow hydrograph. This includes calculating the Time of Concentration (Tc).

The input parameters for the hydrological modelling are listed in Tables B.1 to B.5 in Appendix B of the Chandler Facility Flood and Hydrology Assessment in Appendix R. The calculated peak flows are in Table B.5 in Appendix B of the same report.

Catchment Delineation

This was done using a 30 metre grid Digital Elevation Model (DEM), catchment delineation shape files from previous studies (though at a larger catchment scale) and aerial photographs. GIS files were produced showing the catchments draining to each low point along the haul road, and for those catchments discharging across the mine site, as shown in Figure 9-3.

The limited DEM information was used to calculate average catchment slopes, which were in the range of 0.2 % to 1.1 %. The location where the watercourse (flow line) crossed the haul road was identified by its distance from the Stuart Highway. For example, the Finke River crossing is at 22.8 kilometres. In the absence of named watercourses, this nomenclature has been retained throughout the report.

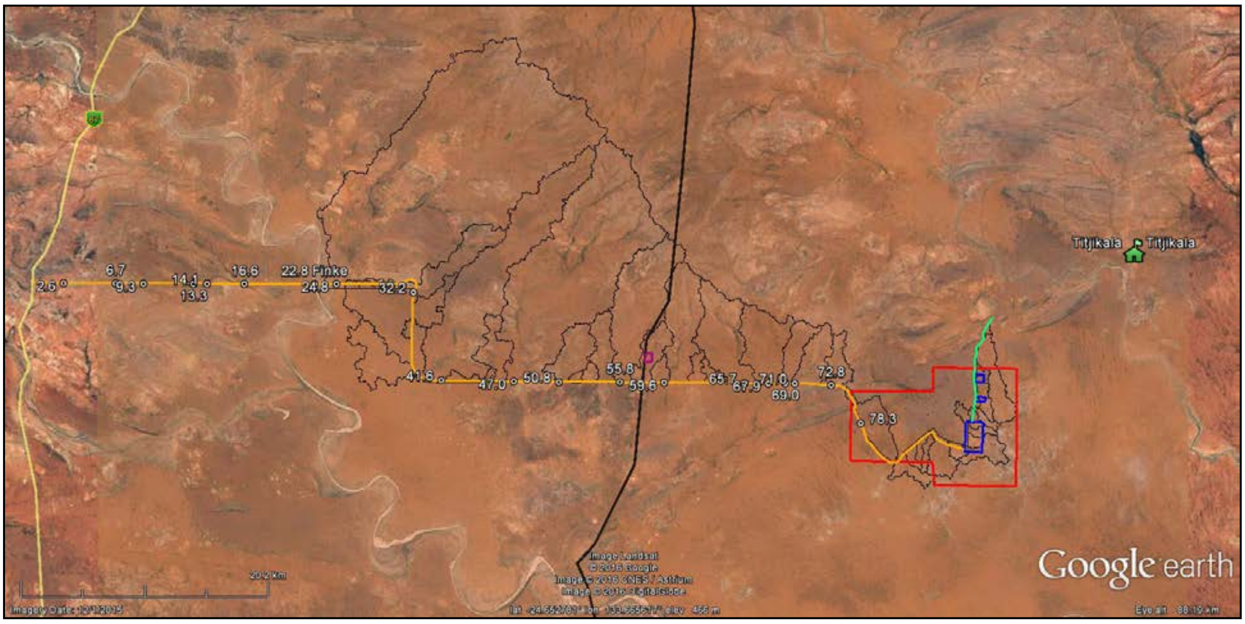


Figure 9-3 Catchment delineation

9.2.6 Design rainfall

Storm depth

Rainfall depths for design storms up to the 100-year Annual Recurrence Interval (ARI) event were taken from a Bureau of Meteorology (BoM) Rainfall Intensity-Frequency-Duration (IFD) table generated for the rail crossing at the Finke River (refer to Figure 2.2 in Appendix R). Values from the same table were used for all catchments relating to the project, as a comparison with IFD tables for the mine site and western end of the haul road (at the Stuart Highway).

Storm profile

The critical storm durations for the catchments were initially defined by the calculation of the catchment time of concentration as being from 1.5 to 24 hours, depending on the catchment size and shape.

Areal Reduction Factor

Design rainfall information for flood estimation is generally made available to designers in the form of point rainfall intensities. However, most flood estimates are required for catchments of significant size and would thus require a design estimate of the areal average rainfall intensity over the catchment.

The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and annual exceedance probability (AEP), is called the areal reduction factor (ARF). It allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area (Engineers Australia, 2013).

Therefore, a factor is applied to the rainfall depth. The factor, which varies according to catchment size and the storm duration, was taken from ARR87 for IFD Zone 5.

Rainfall losses

ARR87 suggests that rainfall losses should be accounted for by applying an Initial Loss (Ia) to the rainfall and then an Ongoing Loss (OL) for the duration of the storm. For 'Central Australia' parts of the Northern Territory, Table 3.8 of ARR87 Book 2 directs the user to the losses for 'Arid Zone' parts of South Australia, which are given in Table 3.4 of ARR87 Book 2. Two combinations of Initial and Ongoing losses are provided; Initial Loss of 15 mm or 40 mm, and Ongoing Loss of 4 mm/h or 1-3 mm/h.

Storm runoff is sensitive to the choice of appropriate rainfall losses. Using an Initial Loss of 40 mm with the BoM IFD rainfall depths would result in no runoff for the majority of design events of 5 years ARI or less.

While selecting a higher Ongoing Loss would result in no effective rainfall from much of the longer-duration storm profiles. Through a combination of professional judgement and verification against storm hydrographs for the Hugh and Finke rivers, the following rainfall losses have been used:

- Initial Loss: 20 millimetres.
- Ongoing Loss: 1 millimetres per hour.

Rainfall flow transformation

The Clark Unit Hydrograph (CUH) method has been used to transform the effective rainfall hyetographs for each catchment into flow hydrographs. The CUH method requires the Time of Concentration (Tc) and CUH Storage Coefficient (Sc) to be calculated using the following equations:

$Tc = 0.76 * Area^{0.38}$	*where:*	*Tc = Time of Concentration (hours)*
		Area = Catchment area (km^2)
$Sc = Tc * ratio/(1-ration)$		*Sc = CUH Storage Coefficient (hours)*
		ratio = 0.65 for flat rural catchments

9.2.7 Risk assessment

The assessment of risks on surface water associated with the Proposal was undertaken using the risk assessment approach described in Chapter 6 and Appendix N. The potential risks arising on surface water environments as a result of the Proposal include:

- Soil erosion leading to excess sedimentation in watercourses.
- Vegetation removal.
- Altered hydrology.

- Flooding.
- Contaminated surface water runoff off-site.
- Salt dissolution and transport off-site.
- Contamination of regional surface waters (Hugh and Finke Rivers) through loss of containment.

Discussion of potential impacts associated with these identified risks is discussed in Sections 9.4, 9.5 and 9.6.

9.3 Existing environment

9.3.1 Topography

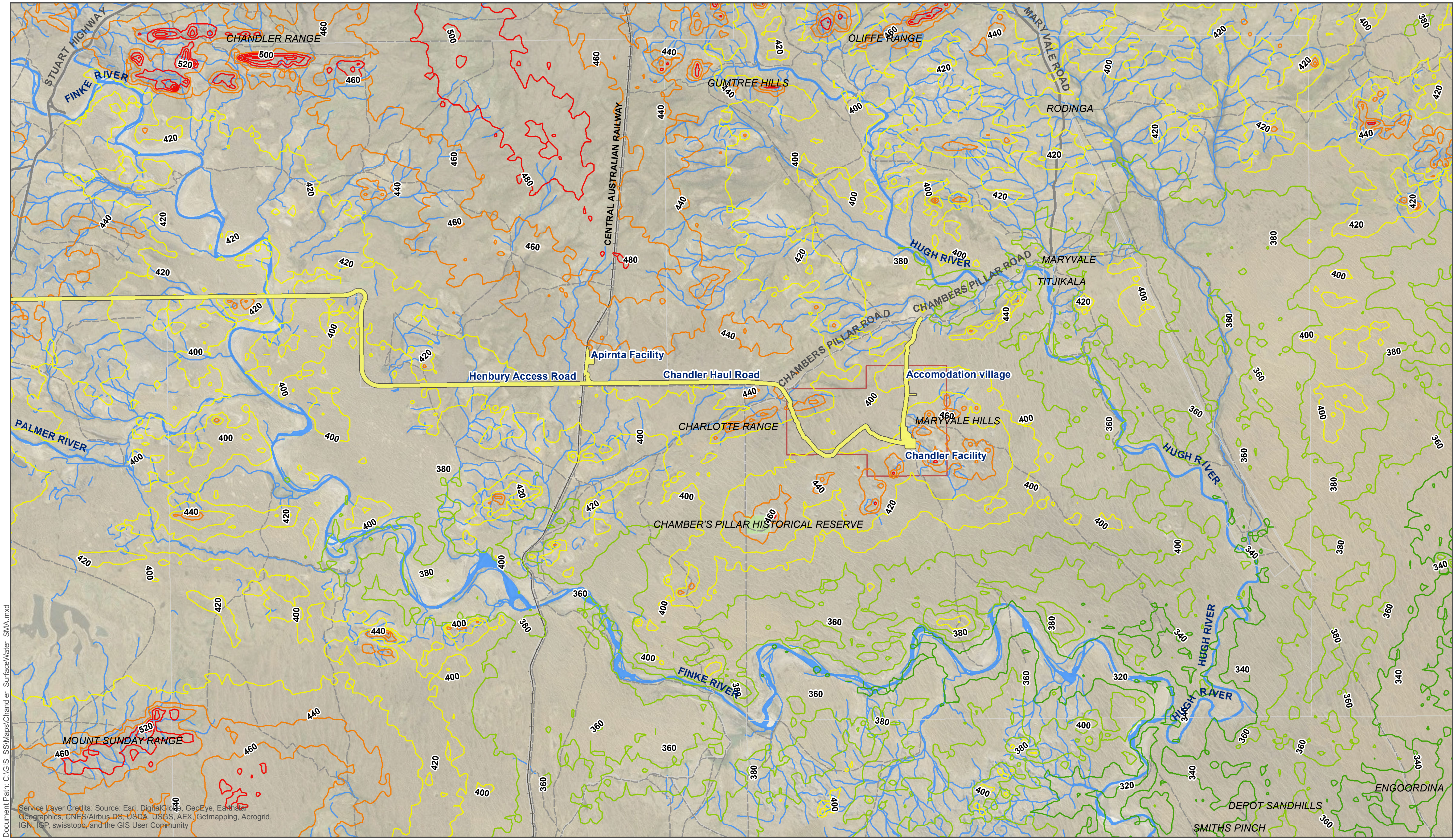
The topography of the Proposal is characterised by rolling hills and dunes, and sand ridges. However, the general area of the Proposal is bisected by a number of large hills that were created by tectonic activity hundreds of millions of years ago to the north, east and west.

The James Ranges and the Oliffe Ranges, a series of west-east trending ridgelines, rise to 788 metres Australian Height Datum (AHD) and 428 metres AHD respectively to the north of the Proposal area. These ridgelines lie at the southern edge of the Orange Creek Syncline and are predominantly composed of basement rock.

To the east of the Proposal area lies the Rodinga Ranges and the Pillar Range, a series of south-west to north-east trending ridgelines that rise to a maximum height of 350 metres AHD. The Charlotte Range and the Maryvale Hills lie directly west of the proposed Chandler Facility. These topographic highs interrupt the low lying areas dominated by sand dunes and flood plain deposits.

Figure 9-4 shows contours across the study at 20 metre intervals. There is little to no change in elevation at the location of the proposed mine infrastructure area and accommodation village (i.e. 400 metres AHD). The two geological outcrops surrounding the mine infrastructure area, namely Maryvale Hills and Charlotte Range, are both approximately at 440 metres AHD. The area surrounding the proposed Apirnta Facility is approximately 420 metres AHD. Plate 9.1 shows the low lying floodplain comprising alluvial and aeolian sediment, while the Maryvale Hills and the Charlotte Range may be distinguished in the distance.

Plate 9-1 View south-west toward the Maryvale Hills and Charlotte Range from the proposed Chandler Facility



N

4.5 2.25 0 4.5 Kilometers

Coordinate System:
GDA 1994 MGA Zone 53

Legend

- Proposed development footprint
- Watercourse
- Pastoral boundaries
- Mining Lease Area

Figure 9-4

Local topography within the study area

TELLUS

Soil mapping

The Northern Territory Natural Resources Map (NT Government 2015) shows that the study area is dominated by two soil types: Aeolian sands (soil type code Qs) over the flood-out and dune areas and Alluvial Gravel, Sand and Silt (soil type code Qa) along drainage line and creek valleys (Figure 9- 3). A small parcel of Conglomerate Sedimentary soil (soil type code Qc) is present on the northern fringe of the Charlotte Range.

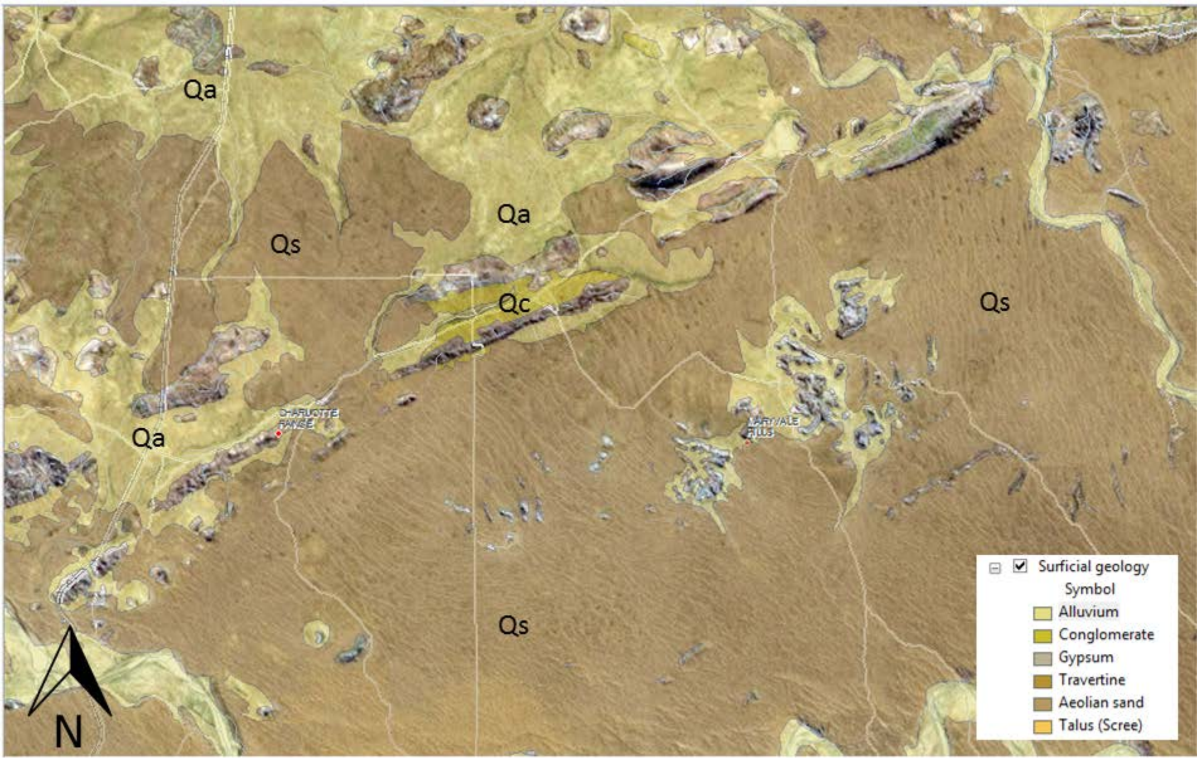


Figure 9-5 Surficial geology in the study area

Soil survey

A soil survey was undertaken in September 2013 (Low Ecological 2013). The spatial extent of the survey was limited to eight locations within the EL29018 area to the west of the Maryvale Hills. This area is characterised by low gradients. The soils in the exploration lease EL29018 fall within soil classes B43 (Rudosols), Nb19 (Sodosols), Nb25 (Sodosols) and LD1 (Calcarosols).

The site survey found that B43 dominates the investigation sites within Proposal area EL29018. Localized water erosion was occurring at sites CNP03, S11-grasslands and S08 indicating a potential for further erosion with disturbance. Linear structures within the sand dunes and hill slopes which were present across EL29018 would have the potential to cause erosion. The drill site soils (CNP01, CNP02 and CNP03) have high rain splash protection due to generally high soil cover (30-50 %) with moderate below ground contributions (10-20 %) from basal and canopy cover. The ground is also covered with more than 10 % to 50 % litter. S04, S08, S10, and S11 have less ground protection and would be more susceptible to erosional forces.

Alluvial sediments and aeolian sand dominate low lying areas of the Proposal. Deposition of the alluvium is likely to have occurred in the early to mid-Cainozoic with the development of various fluvial systems, notably the Finke and Hugh Rivers. During the Tertiary, the persistence of continental conditions established a period of persistent aridity across Central Australia, prompting the development of extensive hard crusts.

Ongoing aridity into the Quaternary lead to the development of sand dunes across the south-eastern extent of the basin and ultimately the modern day environment (Lloyd and Jacobson 1987). A more detailed assessment on soil conditions in the Proposal can be found in a previous Soils Investigation Report (Low Ecological Services 2013). The implications of soil type to erosion potential and increased sediment loads in down-gradient watercourses is covered in Section 0.

9.3.2 Vegetation

The Proposal area contains 17 different vegetation formations, including forests, woodlands, shrublands, palmlands, grasslands, forblands and an inland salt lake. Forty-two different vegetation types occur across the 17 vegetation formations (DLRM 2011). The dominant vegetation type across much of the Proposal area is Hard Spinifex (*Trioda basedowii*), Low Open Hummock Grassland with an open shrubland of Desert Cassia (*Senna artemisiodes* subsp. *filifolia*), Mulga (*Acacia aneura*), Witchetty Bush (*Acacia kempeana*), *Aristida holathera* and *Allocasuarina decaisneana* (DLRM 2011) (see Plate 9.2 and Plate 9.3).

Plate 9-2 *Trioda basedowii*

Plate 9-3 *Acacia aneura*

Several ephemeral creeks (refer to Section 9.4.8) intersect the Proposal area and are lined by riparian woodlands, comprising:

- River Red Gum (*Eucalyptus camaldulensis* var. *obtusa*) Woodland, containing Coolabah (*Eucalyptus coolabah* subsp. *arida*) with an understorey of Couch (*Cynodon dactylon*), Silky Browntop (*Eulalia aurea*) and Spiny Sedge (*Cyperus gymnocaulos*); and
- Coolabah Woodland, with an understorey of Lignum (*Muehlenbeckia florulenta*), Mulga, Desert Cassia, Water Clover (*Marsiliea spp.*), Couch and Buffel Grass (*Cenchrus ciliaris*).

Given their proximity to waterways, and the presence of River Red Gum and Coolabah, it is likely that these vegetation communities could be partially dependent on the subsurface presence of shallow groundwater.

9.3.3 Climate

Southern NT is characterised by a semi-arid to arid climate with hot dry summers and mild winters (Coffey 2012). Historic rainfall, temperature and evaporation data for the general area was acquired from the Bureau of Meteorology (BoM) for the Alice Springs Airport weather station (BoM: 015590), which is located 113 kilometres north of the Proposal area. The monthly rainfall and temperature dataset extends from January 1940 to July 2016. The mean daily evaporation record extends from 1959 to 2016.

The proponent also owns and operates an Automated Weather Station at the proposed Chandler Facility. However, this meteorological dataset is limited to 12 months and is therefore, not used to define long term or seasonal climatic trends but does provide valuable baseline information for the Proposal area.

9.3.4 Rainfall

The Bureau of Meteorology (BoM) rainfall gauges in the general area are listed in Table 9-6. The nearest rainfall gauge to the Proposal area is located at Maryvale, approximately 21 kilometres north-east of the Chandler Facility. The record at Maryvale and adjacent sites contains a significant proportion of data gaps (> 20% of missing data).

Data from BoM stations within 25 kilometres of the mine site, namely Maryvale and Idracowra indicates that long term mean annual rainfall at the proposed mine site is likely to be approximately 204 millimetres (mm) (Table 9-6). Annual rainfall totals are highly variable from year to year and almost 50 percent of annual rainfall can occur within a single month, with rainfall greatest during monsoon months (November to March) and below regional averages during dry months (April to September).

The total annual rainfall recorded at the Alice Springs Airport weather station (BoM 015590) ranges from 76 mm to 782 mm (over the 74-year monitoring period), with an annual mean of 283.5 mm.

Table 9-6 Rainfall gauge data

Gauge number	Name	Latitude	Longitude	Record start	Record end	Record length (years)	Distance from Chandler (km)[1]	Mean annual rainfall (mm)[2]
15519	Palmer Valley	24.75	133.23	1953	Open	63	74	253.5
15524	Idracowra	24.99	133.79	1950	Open	66	25	203.6
15536	Maryvale	24.67	134.07	1948	Open	68	21	205.3
15532	Henbury	24.55	134.25	1897	Open	129	77	224.2
15590	Alice Springs Airport	23.80	133.89	1940	Open	76	113	283.5
	Tellus AWS			2015	Open	1.5	0	136.4

Meteorological monitoring has been performed at the Proposal site since 31 May 2015. An automatic weather station (AWS) collects precipitation data on a continuous basis. Hourly average data collected between 5 November 2015 and 31 January 2017 have been reviewed with a discussion provided below.

The Proposal site received at total of 991 mm of rainfall between 5 November 2015 and 31 January 2017. The distribution of rainfall is presented in Figure 9-6. Distribution of rainfall by season is presented in Table 9-7. Maximum daily rainfall of 136 mm was observed during December 2015, with the average rainfall during the summer months being the highest of all seasons. Lowest maximum and daily average rainfall was observed during the winter months at the Proposal site.

Table 9-7 Observed daily maximum and average rainfall at Chandler - 5 November 2015 to 31 January 2017

Season	Daily rainfall (mm)	
	Maximum	Average
Annual	136.4	2.4
Spring	43.6	1.26
Summer	136.4	5.48
Autumn	34.8	0.89
Winter	19.4	0.60

[1] *Bureau of Meteorology, 2016*
[2] *mm = millimetres*

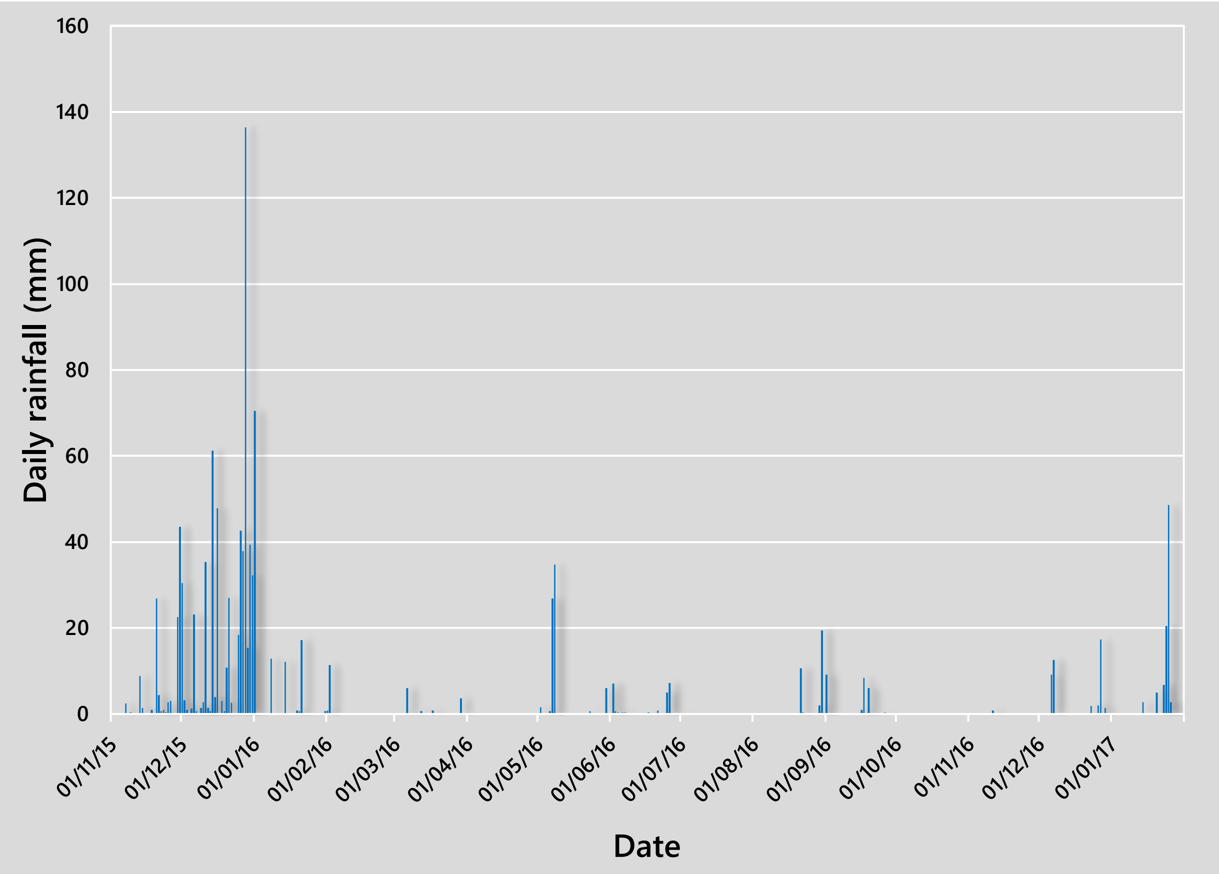


Figure 9-6 Daily average rainfall at Chandler - 5 November 2015 to 31 January 2017

Monthly average rainfall recorded at the Chandler AWS is shown in Table 9-8. As expected, the highest rainfall occurred in the wetter months (November to January). Minimal rainfall was recorded at the site in the drier months (April to July).

Table 9-8 Monthly average air temperature, rainfall and humidity at the Chandler AWS

Month	Air temperature (˚C)			Relative humidity (%)	Precipitation (mm)
	Average	Maximum	Minimum	Average	Total
November 2015	31.4	41.8	20.7	15.7	120.2
December 2015	29.5	41.5	17.5	37.2	581.2
January 2016	29.2	41.0	17.0	38.9	114.8
February 2016	31.1	43.1	18.5	24.4	12.2
March 2016	28.7	39.9	14.2	39.3	11.2
April 2016	24.4	36.4	9.5	28.7	0.2
May 2016	18.8	32.4	6.3	53.8	70.4
June 2016	14.5	25.5	2.1	69.5	22.4
July 2016	13.1	29.3	-2.0	54.4	0.4
August 2016	15.4	29.6	-0.3	44.3	32.6
September 2016	18.2	32.9	9.1	50.1	25.8
October*	-	-	-	-	-
November 2016	31.4	41.8	20.7	15.7	120.2
December 2016	29.5	41.5	17.5	37.2	181.2
January 2017	31.8	42.0	22.1	41.2	86.6
Average	**24.36**	**37.09**	**11.06**	**39.33**	**74.92**

**AWS instrumentation failed for the month of October*

Rainfall intensity

Average Recurrence Intervals (ARIs) have been determined by the BoM (Table 9-9). ARIs show predicted rainfall intensities for a range of storm durations and average recurrence intervals. For example, a 100- year ARI 24-hour rainfall intensity (7.4 mm/hr) is almost twice the 10-year ARI 24 - hour rainfall intensity (3.87 mm/hr) and one eighth of the 100-year ARI 1-hour rainfall intensity (55.7 mm/hr). In general, higher rainfall intensity occurs over short durations, also higher rainfall intensity events are a less frequent occurrence than lower intensity rainfall events.

Table 9-9 Rainfall intensity, frequency and duration data

Duration	1 year (mm)	2 year (mm)	5 year (mm)	10 year (mm)	20 year (mm)	50 year (mm)	100 year (mm)
5 mins	41.8	56.5	82.7	99.9	122	152	176
6 mins	39.0	52.7	77.2	93.2	114	142	164
10 mins	32.2	43.4	63.6	76.8	93.6	117	135
20 mins	24.1	32.5	47.4	57.2	69.4	86.5	100
30 mins	19.8	26.7	38.8	46.8	56.8	70.7	81.8
1 hour	13.3	18.0	46.3	31.7	38.6	48.1	55.7
2 hours	8.37	11.3	16.9	20.5	25.1	31.5	36.7
3 hours	6.25	8.51	12.8	15.7	19.3	24.4	28.5
6 hours	3.75	5.15	7.93	9.83	12.2	15.6	18.4
12 hours	2.28	3.15	4.93	6.17	7.72	9.94	11.8
24 hours	1.42	1.97	3.08	3.87	4.84	6.24	7.4
48 hours	0.885	1.22	1.89	2.36	2.94	3.78	4.47
72 hours	0.639	0.879	1.37	1.71	2.13	2.74	3.24

Source: Bureau of Meteorology

9.3.5 Rainfall recharge

Analysis of wet and dry periods is important to appropriately characterise seasons and climatic variability. This information can be used to analyse groundwater recharge responses and consider potential impacts.

Analysis of dry and wet periods can be completed using the statistical technique of cumulative deviation from the mean (CDFM). CDFM is commonly used to relate groundwater level fluctuations to trends in rainfall and can also be used to assess trends in long-term monthly and annual rainfall fluctuations. The CDFM method subtracts the actual rainfall over a defined period from the long-term mean rainfall of the same period (Ferdowsian and McCarron 2001; Yesertener 2007).

Figure 9-5 presents the cumulative departures from the mean for the Alice Springs Airport weather station. The upward or downward trend in the curve indicates a period of above or below average rainfall respectively; these are marked on the graph as wet or dry periods

Figure 9-7 shows defined wet and dry periods over the 65-year rainfall record. Four apparent dry periods with below average rainfall are observed over this period (1948-1973; 1983-1999; 2001-2009; 2011- current). Conversely, three defined wet periods are visible within the dataset (1973-1983; 1999-2001; 2009-2011).

The bulk of the monitoring period shows below average, or dry, conditions. This suggests that the above average, or wetter periods, comprise significant rainfall events such that the mean is skewed to portray average rainfall as 'dry'.

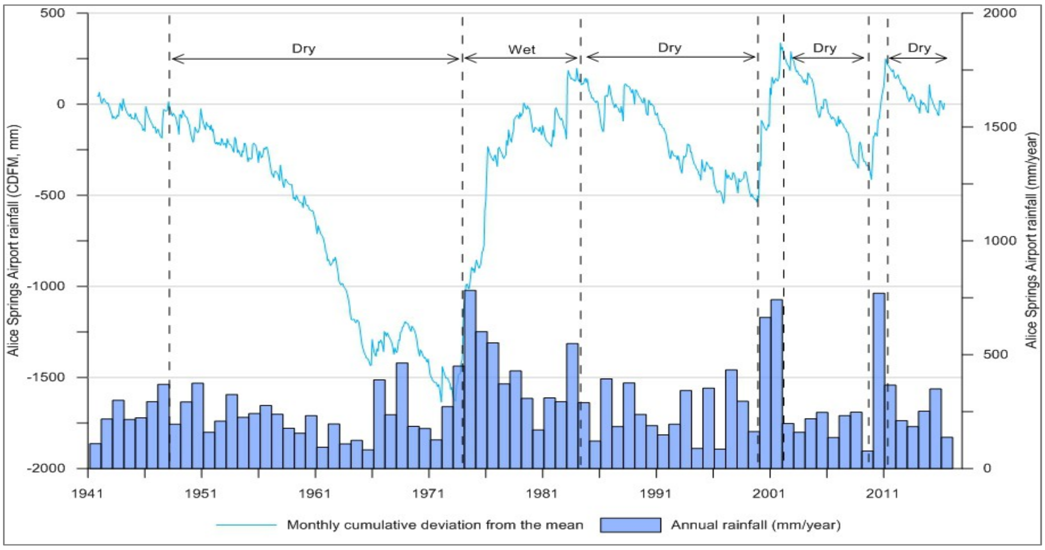


Figure 9-7 Rainfall - monthly cumulative deviation from the mean

9.3.6 Evaporation

Characterising evaporative losses is important to understanding the mechanisms for groundwater recharge and the regional climatic conditions. Daily mean pan evaporation data is available from the Alice Springs Airport weather station (BoM 015590). Pan evaporation is a measurement that integrates several climatic elements, including temperature, humidity, rainfall, solar radiation, and wind. The Alice Springs Airport weather station has a reliable pan evaporation dataset extending from 1959 to 2016 (approximately 57 years) for comparison with historic rainfall for the area.

The annual average pan evaporation measured at the station is approximately 3,147 mm, more than 42.5 times the monthly average rainfall and 23 times the annual average rainfall.

The greatest evaporation rates occur from October through to March, as evaporation is significantly influenced by temperature and solar radiation over the summer period. On average, evaporation exceeds rainfall by about 4.5 times in each month of the year.

9.3.7 Surface water

Regional setting

Three categories of surface water systems exist across the NT:

- Permanent or perennial surface water systems–these are ever-present and are typically observed as rivers, lakes, springs and swamps.
- Semi-permanent or ephemeral surface water systems–these systems hold water for part of the year and are typically observed as small creeks, lagoons, waterholes or low lying areas across arid zones.
- Engineered surface water systems–these systems are widespread across the NT and typically consist of dams, turkey nests or engineered swamps that provide a source of water for stock and domestic purposes.

The NT is represented by four major drainage divisions (Figure 9-8). Drainage divisions are topographically controlled and direct regional surface water flows to either a major sea or inland basin. There are 35 river basins represented across the NT. Each drainage division has numerous river basins, which form the catchment areas for major surface water systems. The Proposal lies within the Finke River Basin within the Lake Eyre Drainage Division.

The low average rainfall and extensive aridity in southern NT contributes to a lack of permanent watercourses in the vast majority of the land surface. Most watercourses are ephemeral with particularly infrequent flows, reflecting the rainfall distribution. Clay pans, salt pans, rivers and flood outs are dry for the majority of the year, flooding during irregular intense rainfall events. When flowing, rivers drain inland (athalassic) rather than to the sea. Watercourses originate where surface runoff discharges into defined channels, converging to form ephemeral rivers.

Despite their variable flow regimes, these ephemeral surface water systems provide a crucial source of water for arid landscapes. They support significant aquatic and terrestrial biodiversity, including many unique species

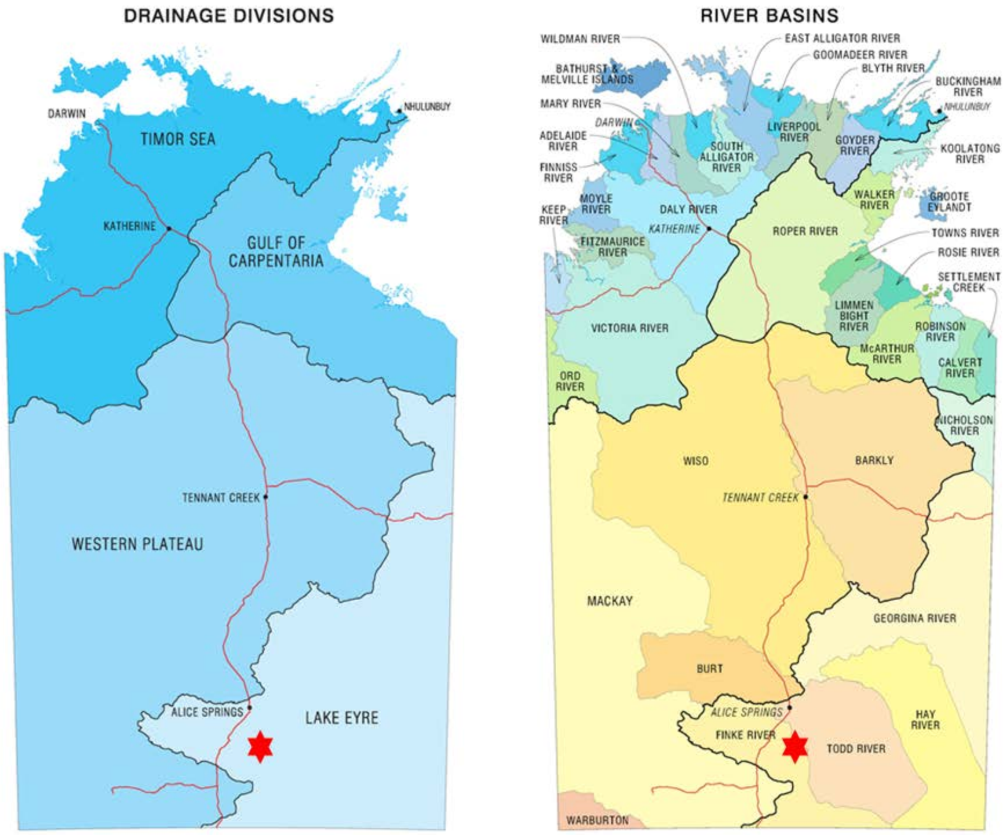


Figure 9-8 NT Drainage Divisions and River Basins

Approximate Study Area location; Source: NT Government, 2016

The Study Area also lies within the Lake Eyre Basin bioregion (Figure 9-9a). The Lake Eyre Basin bioregion covers an area of about 1.31 million square kilometres of central and north-eastern Australia, which is almost one-sixth of the country (Miles *et al*. 2015).

It extends across parts of Queensland, South Australia, New South Wales and the Northern Territory and incorporates the whole of the Lake Eyre drainage basin. The Lake Eyre Basin bioregion includes four subregions: the Galilee, Cooper, Pedirka and Arckaringa subregions. The Pedirka sub-region lies approximately 100 kilometres down-gradient from the Study Area (see Figure 9-9b).

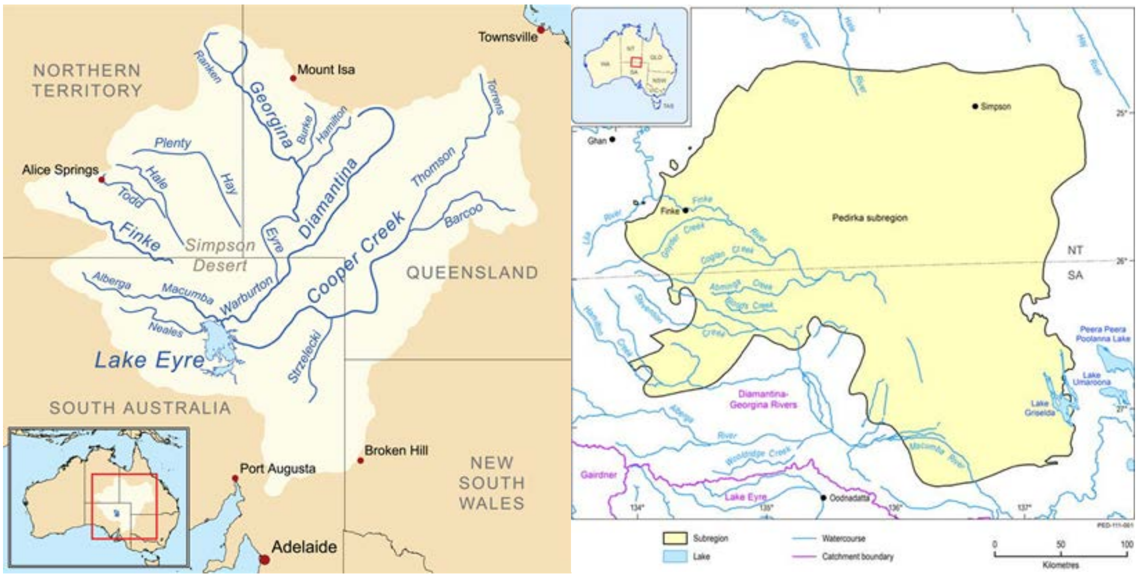


Figure 9-9 (a) Lake Eyre bioregion and (b) Pedirka subregion
Source: Miles et al., 2015

The Finke and Hugh Rivers are the major ephemeral surface water features in the Finke River Basin (Figure 9-10). The headwaters of the Finke and Hugh Rivers rise in the MacDonnell Ranges and basement rock hills to the west of Alice Springs. The Finke is the longest and largest of the Desert Rivers in Central Australia and passes the Proposal area 20 kilometres to the south and its catchment continues into northern South Australia. Major flows only occur along the Finke River about every decade. In some years flood flows in this river may occur along several stretches of the river but never meet. South of the Proposal area, the river flows on average less than once per year generally over summer but occasionally during winter.

In 2016, there have been four flows south of the Proposal area a minor flow in January and moderate flows in February, May and August. The Finke River recharges aquifers at specific localities along its length but it also picks up saline water from groundwater discharge zones. During major floods it carries and recharges good quality water to aquifers but during small flows in some catchments it carries salt water in many locations. A large volume of groundwater is stored and moves through its sandy and sandy clay river bed. These sediments fill an eroded river valley of more than 1 000 kilometres long, often several hundred metres wide and up to 30 metres deep.

The Hugh River is a major tributary of the Finke River, its junction is 30 kilometres to the south-east of the Proposal area and it also recharge aquifers along its length. Unlike the Finke River it is only around 500 kilometres long but unlike the Finke River is known for its excellent quality water. It provides the good quality water to the aquifer which provide the water supply to Titjikala and Maryvale Homestead. This aquifer has excellent quality groundwater in storage unlike the groundwater resources at the Proposal area which are saline (refer to Chapter 8 for more information).

Major flood flows in the Todd River dissipate into flood outs in the Simpson Desert 100 kilometres east of the Proposal area. Extensive data on streamflow in the Todd River though Alice Springs and from multiple stream gauging and climate stations in its upstream catchment plus the 144 year rainfall, temperature and evaporation record for Alice Springs provide very useful knowledge on the nature of the local arid zone stream flow hydrology, catchment yield and other surface water characteristics which are also relevant to the Proposal area.

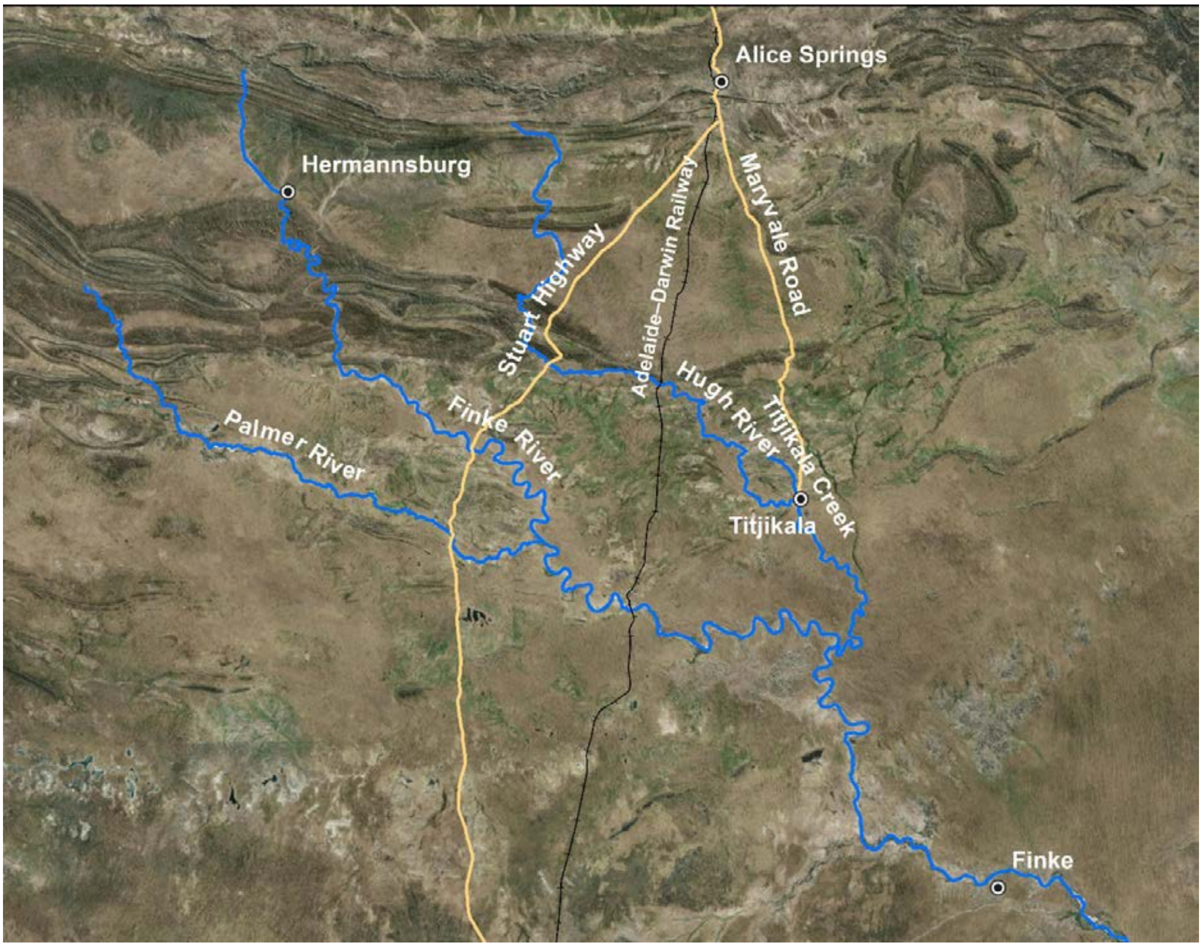
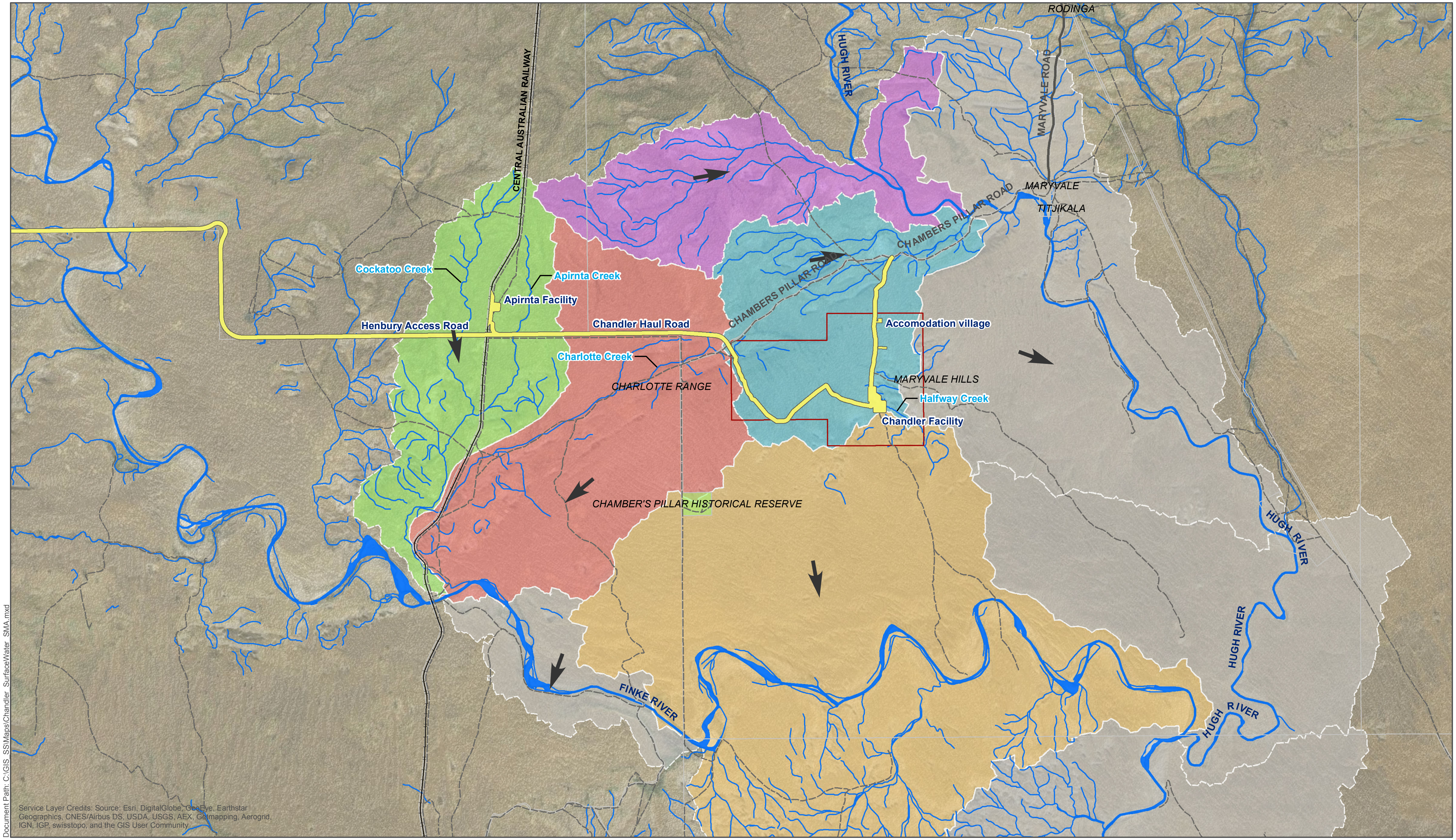


Figure 9-10 Major rivers surrounding the Proposal site. Aerial imagery sourced from ESRI partners

Both rivers originate at the foothills of the MacDonnell Ranges up to 200 kilometres north-west of the Proposal area. The Hugh River is located to the north of the Proposal and flows south-easterly where it joins for Finke River approximately 30 kilometres south-east of the Proposal.

The Finke River flows in a south-easterly direction to the south of the Proposal. Several ephemeral drainage lines discharge to the Finke River and Hugh River along the reaches adjacent to the Proposal area. These are predominantly topographical controlled by various sand dunes, ranges and outcropping basement rock visible across the Proposal area. For the purposes of this study, it was necessary to define the spatial extent of the assessment. A sub-catchment delineation map has been produced for the Study Area (see Figure 9-11). The Study Area has been defined as potential surface water receptors defined as those watercourses that drain the Proposal area and / or could be impacted by the proposed activities downstream. By definition, the Study Area is therefore larger than the Proposal area.



Legend

- Proposed development footprint
- Watercourse
- Pastoral boundaries
- Mining Lease Area
- Catchment A - 21,662 ha
- Catchment B - 18,986 ha
- Catchment C - 33,401 ha
- Catchment D - 81,707 ha
- Catchment E - 20,842 ha
- Flow direction

4 2 0 4 Kilometers

N

Coordinate System:
GDA 1994 MGA Zone 53

Figure 9-11
Catchment connectivity within the study area

TELLUS

Data source: Geoscience Australia, 250K Topo base data, 2006; USGS, SRTM elevation, 2000; AUSURV SURVEYORS, detailed elevation data, 2016.
Created by:adrian.miller

To define the spatial scale of this assessment the potential connectivity from this sub-catchment delineation was used to identify the following water features which would be considered:

- All dams within or down-gradient from the Proposal area.
- All drainage lines within the Proposal area.
- The Finke River from the Stuart Highway Crossing to the confluence.
- The Hugh River from the Rail Crossing to the confluence with the Finke River.

It should be noted that this sub-catchment delineation only refers to potential connectivity based on coarse-scale topography and has not been ground-truthed. In particular, anecdotal evidence suggests that the grey-shaded sub-catchment is not connected to the Hugh River.

Regional Flow characteristics

Surface water flow is ephemeral in all watercourses in and around the Proposal area, with the Finke, Hugh and Palmer Rivers running dry for long periods of time. Flow events are generally driven by large rainfall systems associated with monsoonal rain depressions from northern Australia or extreme weather caused from cyclonic lows. Small flow events occur with annual to bi-annual regularity, often only resulting in a section of each river flowing.

This is reflected in flow duration curves (see Figure 9-12), where a flow of 1 m^3/s is exceeded for only 10.4 % of the Finke River record and 8.1 % of the Hugh River record. No evidence of ongoing baseflow component can be seen in flow records, consistent with visual observations of dry river beds. Low or no-flow conditions dominate for approximately 80 % of the year on the Finke and Hugh Rivers, and 90 % of the year on the Palmer River[3].

Larger flow events (anecdotally known as those where a river flows simultaneously along its entire length (NT Government 2012)[4]) can result in rivers running for weeks as opposed to days. In February 2000, the Stuart Highway Bridge over the Finke River was submerged for approximately one week (DoIRD 2003). A decision was made to replace this bridge after it had been submerged under floodwaters 13 times between 1969 and 2003.

Occasionally multiple larger events occur in the same year (such as recorded on the Finke River in 2010 or on the Hugh River in 2000). Table 9-5 lists flow rates of selected floods measured in flow gauging records for the Finke, Hugh and Palmer Rivers[5].

---

[3] *Note that measurement uncertainty at the Palmer and Hugh Rivers prevent identification of flows less than 1.4 and 0.3 m^3/s respectively.*
[4] *In the case of the Finke River, this refers to the region between its Hermannsburg headwaters through to the flood-out area at Andado, downstream of the Finke township (approximately 100km straight line distance down-gradient from the CSMP Site Area).*
[5] *Note that as these rivers are ephemeral, opportunity to assess rating curves is restricted and therefore large flood flow rates may be of limited accuracy.*

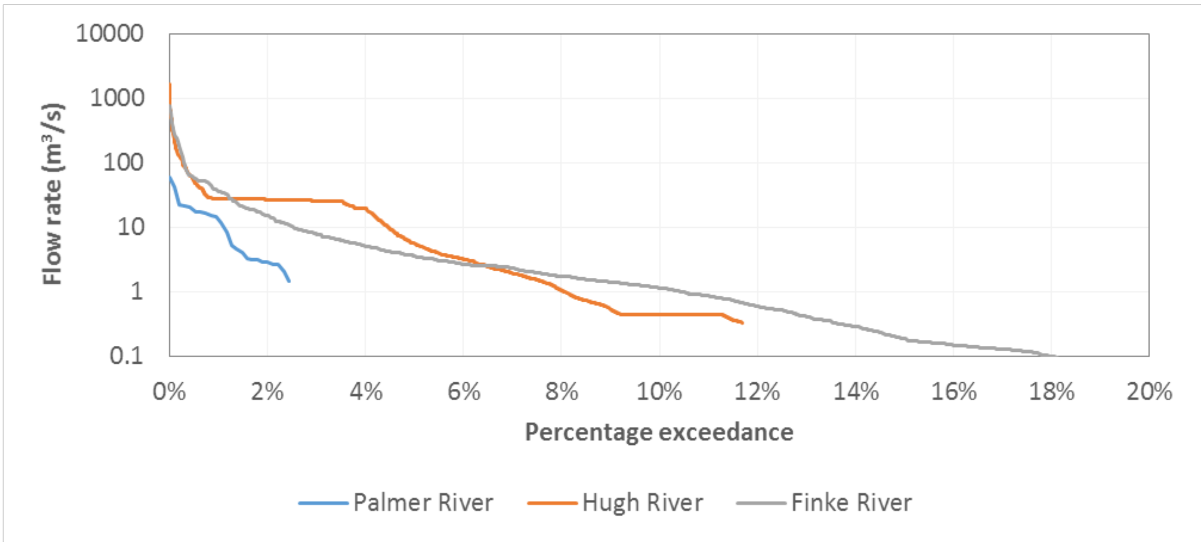


Figure 9-12 Percentage of flow record in which given average-daily flow rate is exceeded

The maximum water depth recorded on the Finke River at Stuart Highway was 9.7 metres, while on the Hugh River was 6.7 metres (NT Government 2016). Channel banks are approximately five metres and two metres high, respectively, at these locations. It follows that bank overtopping does occur but relevance to the sections of both rivers closest to the Proposal Area are unclear due to differences in bank heights, bed gradient and cross-sectional profile.

Table 9-10 Flow rate of significant floods, as measured at Stuart Highway gauging stations

River name	Date and daily mean flow
Finke River - (records commenced in 2004)	10 Jan 2010 – 755 m^3/s 1 Mar 2010 – 584 m^3/s
Hugh River - (records commenced in 1972)	18 Mar 1983 – 640 m^3/s 31 Mar 1988 – 1,039 m^3/s 17 Jan 1995 – 629 m^3/s 12 Feb 2000 – 1,667 m^3/s 22 April 2000 – 592 m^3/s
Palmer River - (records commenced in 2010)	22 Feb 2011 – 60 m^3/s 2 Mar 2012 – 42 m^3/s

The township of Titjikala is situated adjacent to Titjikala Creek, a tributary of Hugh River. While this creek is usually dry, it has been known to flood to a depth of one metre, effectively turning the town into an island (ABC 2014). In 2015 a new sewage system was built in Titjikala to address health issues generated when such flooding caused residential septic tanks to overflow (LGANT 2016).

Watercourse types within the study area

There are six types of surface water present in the Study Area, classified according to wetland types after Duid, 2011:

- Major wooded watercourses (type WL2001) most are sandy channels fringed by River Red Gum (*Eucalyptus camaldulensis*) and / or Coolabah (*Eucalyptus coolabah*). This includes the Finke and Hugh Rivers.
- Temporary generally dry waterholes (type WL1202) occur along the major Finke River. There is little survey or other data regarding how long individual waterholes last. Semi-permanent waterholes on the Finke River within the Study Area but outside of the Proposal area include the following:
    - Main Camp Waterhole.
    - Bankhole Waterhole.
    - Attalwaynimma Waterhole.
    - Oodratnamma Waterhole.
    - Arowie Waterhole.
    - Double Garden Waterhole.
    - Junction Hole Waterhole.
- It is understood that these are not supported by groundwater but rather are refuge pools which slowly evaporate following rainfall events and upstream catchment water delivery. The Hugh River does not contain any waterholes and there are no small creeks, lagoons, or low lying areas within the Proposal area that contain water outside of rainfall event periods.
- Generally dry upland channels (type WU2201) which are ephemeral first-order drainage lines.
- Small freshwater lakes and clay pans (type B1221). Notable examples include Mulga Claypan and Chambers Pillar Creek linear riverine lakes but it is expected that many more of these features exist in the Study Area. Clay pans are hard, bare, unproductive areas created from a loss of cover which exposes the soil surface to raindrop impact and erosion. This leads to surface sealing/crusting and water ponding following rainfall (Wouldiams and Biggs 2010).
- Shrubby / wooded flood prone flats (types F001 / F002) are flood outs receiving present in the Proposal area which are dry most of the time, but infrequent yet sometimes intense rainfall events cause up-gradient arid zone streams to flow for short periods and deliver sheet flow to these areas. They are not wet for sufficient periods to be regarded as a 'swamp' or 'wetland'.

- Dams across watercourses (type A1001) are man-made surface water held in artificial structures is present both within the Proposal area (Halfway Dam) and in the wider Study Area (Gypsum, Lookout, North-East and Robinson Dams).
- There are no lakes, artificial swamps or sewage treatment ponds within the Proposal area.
- There is no permanent or perennial surface water within the study area. There are no lakes, permanent waterholes, springs or swamps, supported by groundwater when there is little or no rain, present in the Proposal area.

A consequence of the short duration flow events and high evaporation of surface lay water in these headwater catchment is that it is difficult to monitor the events. In the absence of data, the following sub-sections detail anecdotal evidence on watercourse functioning for three specific watercourse features within the Study Area:

- Maryvale Hills drainage lines and flood out.
- In-line farm dams.
- Apirnta Creek at rail crossing.

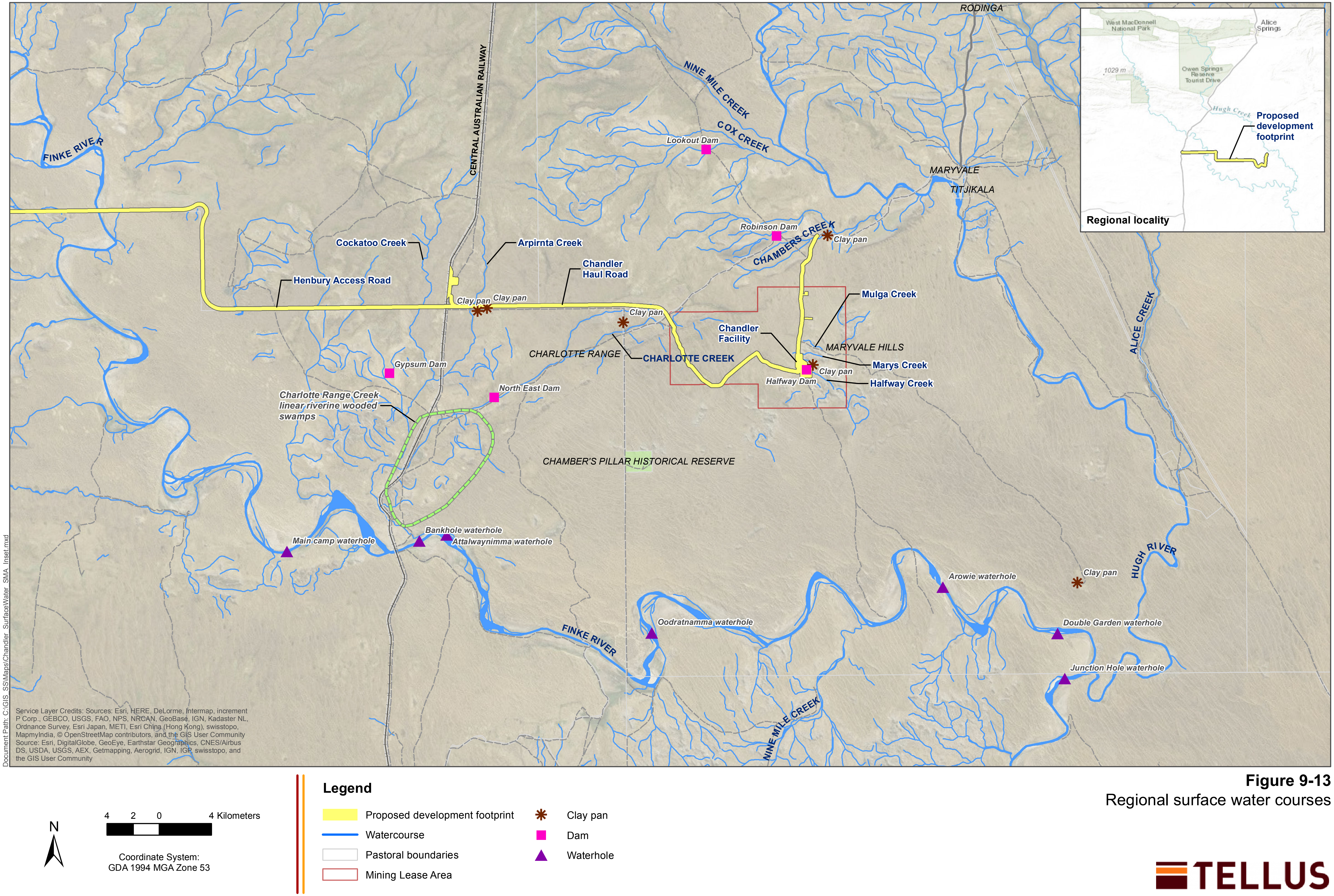


Figure 9-13
Regional surface water courses

Halfway dam

Halfway Creek's natural drainage course has been altered by the construction of Halfway Dam. This once flowed north and into a larger flood-out / sediment settlement zone as indicated in Figure 9- 14. The same zone supports indigenous groundcovers, shrubs and trees, some large tree species including Red Gums and Grey Box. However, these terrestrial plant communities have been adversely impacted by the location of Halfway Dam which cuts off the natural (north-westerly) flow of surface water. This is evident by the significant die back, or in some cases, mortality of large trees.

A large sediment trap / basin has been artificially formed on the upstream side of Halfway Dam. When full, it recharges Halfway Dam. It also has an outlet through a constructed embankment. When the basin is full, water flows (south) through an outlet which is approximately five metres above Halfway Creek. Halfway Creek at this point in the landscape is a relatively new surface water feature. The banks of Halfway Creek in this location are actively eroding, caused by livestock grazing.

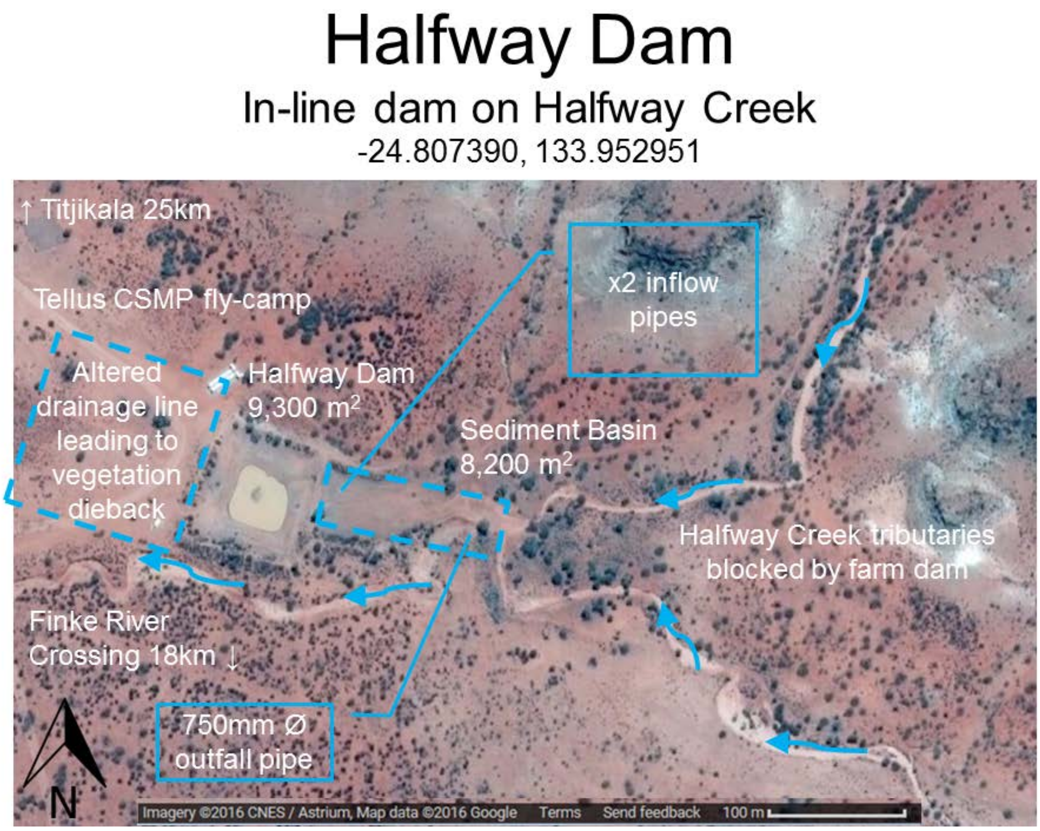


Figure 9-14 Hydraulic characteristics of Halfway Dam

Local hydrology

The Hugh and Finke rivers are large ephemeral surface water systems within the vicinity of the Proposal. These watercourses are considered to be drainage channels that convey surface water flows to discharge areas. Flow events in these rivers are characteristically infrequent. When in flow, they support permanent wetlands and waterholes that provide internationally significant habitats for water birds and aquatic flora and fauna (Miles *et al.* 2015).

Dryland rivers, such as the Fink River and Hugh River, also support consumptive and recreational water users and are widely used for agricultural and town supplies in inland Australia. These rivers are usually also important to Indigenous peoples with sacred sites and other culturally important requirements (Robson 2008).

Several ephemeral drainage lines discharge to the Finke River and Hugh River along the reaches adjacent to the Proposal area. These are predominantly topographical controlled by various sand dunes, ranges and outcropping basement rock visible across the Proposal area. The Charlotte Ranges to the west of the Proposal are a source of ephemeral drainage for the Finke River, while the ranges to the north of the Proposal (Oliffe Range and James Ranges) drain to the Hugh River.

The low average rainfall and high evaporation in southern NT contributes to a lack of permanent watercourses in the Proposal area and means most temporary watercourses are ephemeral with infrequent high flows during storm events. Watercourses originate where surface runoff discharges into defined channels, converging to form ephemeral rivers. Observations suggest runoff from the Maryvale Hills flows in drainage lines (gullies) westwards towards a flood-out zone (see Figure 9-14). In this area, water is ponded with negligible flow and, evaporation / infiltration into sub-soils gradually diminish the surface area.

Maryvale Hills

The drainage lines coming off the Maryvale Hills to the east of the Chandler Facility are gully like features. They are deeply incised, capable of carrying small to medium angular to sub-angular rocks through the mid slopes and towards the lower slopes where they enter the sediment settlement zone. Rocks in the mid to lower slopes are typically 10 cm x 7 cm with and some much larger than this (up to 20 cm x 20 cm) (see Plate 9-4). This indicates that water flows off the steeper slopes of Maryvale Hills are capable of transporting medium sized rocks.

Riparian vegetation in the form of juvenile to mature Mulga, Mature Desert Oak, Salt bush, Cassia and Paper Daisy dominate the banks of the gullies. Mary's Creek is the largest system of all the gullies followed by Oak Gully. Dingo, Ridey, Roo and Snake Gully are all small by comparison and do not consist of defined channels with banks like Mary's Creek and Oak Gully do (see Plate 9-4 and Plate 9-5).

Plate 9-4 Snake Gully colluvial zone and deeply incised gully

Plate 9-5 Mary's Creek – note the alluvial sands, defined embankment and riparian vegetation

Mary's Creek is the largest system of all the gullies followed by Oak Gully with Dingo, Ridey, Roo and Snake Gully all small by comparison and not consisting of a defined channel with banks. The drainage lines all flow westwards off the Maryvale Hills but the stock access road leading to Halfway Dam (and the Tellus camp site) acts as a barrier to westerly flows. Instead of flowing west towards the contiguous flood out zone as topography would have originally dictated, lower flows now tend to flow northeast along the road to an area of depression approximately 500 m northeast of Mary's Creek. A large clay pan lies between Halfway Creek and Roo Gully (refer to Figure 9-15).

Approximately 1 km beyond the flood out zone, in a north-westerly direction, lies a desert dune and swale system. The swales contain distinct plant community groups dominated by prostrate Daisy's and Millet Grass. The dunes probably act as a barrier to flows from the Maryvale Hill gullies and the plants instead rely heavily on locally sourced water from run-off out of the dunes. Conversely, the dune system also acts as a barrier to flows off the Charlotte Range (in the north-west). The Charlotte Range is located along the entire south section of Chambers Pillar Road. It too acts as a barrier to overland flows and acts as a barrier to flows between the Hugh River and the Chandler Facility

As stated above, the drainage lines all flow westwards off the Maryvale Hills but the stock access road leading to Halfway Dam (and the Tellus accommodation village) acts as a barrier to westerly flows. Instead of flowing west towards the contiguous flood out zone as topography would have originally dictated, lower flows now tend to flow north-east along the road to an area of depression approximately 500 m north-east of Mary's Creek. A large clay pan lies between Halfway Creek and Roo Gully (Figure 9-15).

Approximately one kilometre beyond the flood out zone, in a north-westerly direction, lies a desert dune and swale system. The swales contain distinct plant community groups dominated by prostrate Daisy's and Millet Grass. The dunes probably act as a barrier to flows from the Maryvale Hill gullies and the plants instead rely heavily on locally sourced water from run-off out of the dunes.

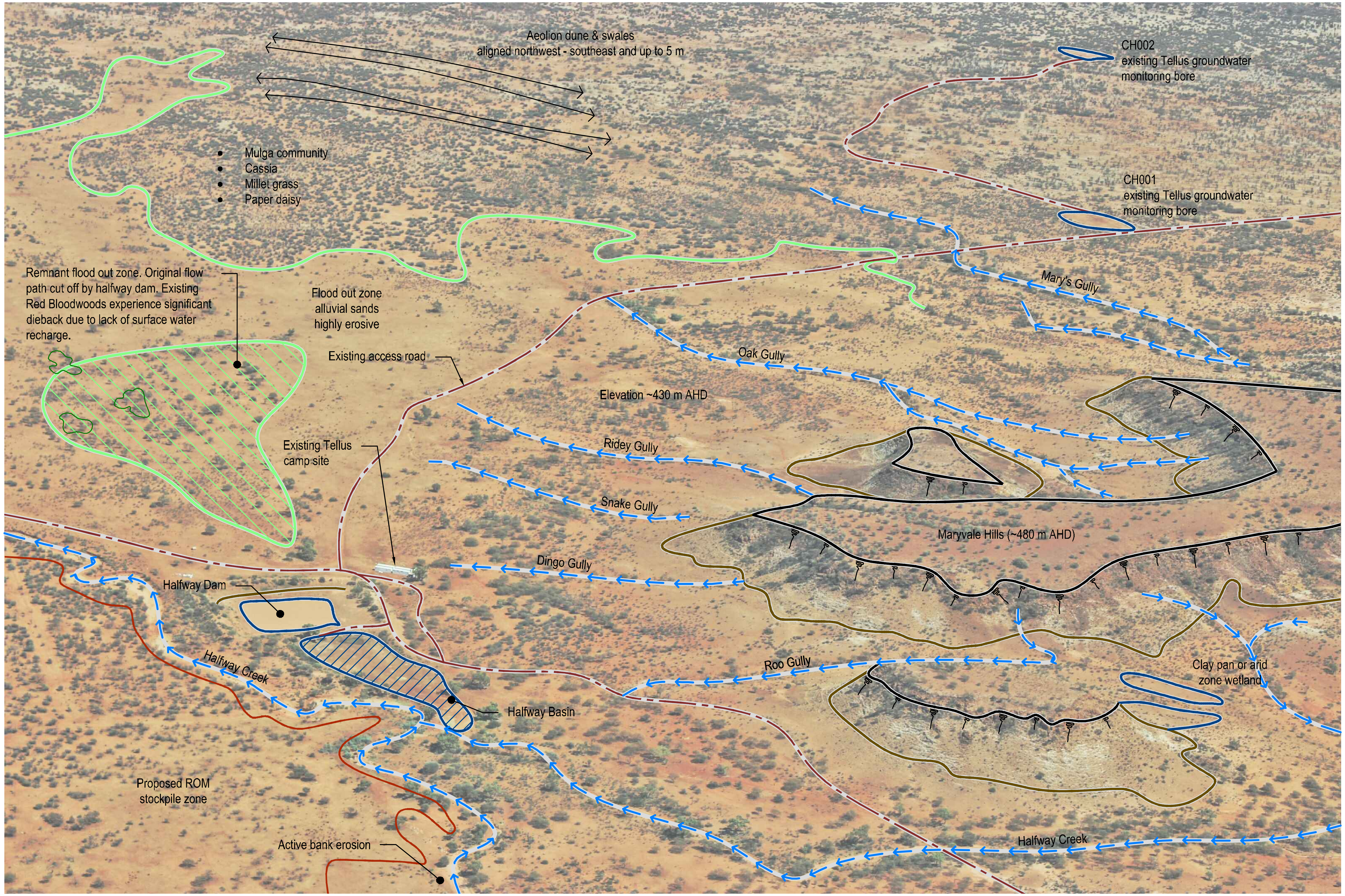
Conversely, the dune system also acts as a barrier to flows off the Charlotte Range (in the north-west). The Charlotte Range is located along the entire south section of Chambers Pillar Road. It also acts as a barrier to overland flows and acts as a barrier to flows between the Hugh River and the Chandler Facility. A more detailed fluvial geomorphology appraisal of Mary's Creek can be found in the BECA report in Appendix R.

No breakthrough to the dune area to the north of the sub-catchment is observed, with water in this area locally-derived from runoff from the adjacent dune system. Furthermore, no connectivity between the dune area and the Hugh River to the north is anticipated. No assessment downstream from the confluence between the Hugh and the Finke is deemed necessary because the flow contribution from the Proposal area to flows below this point is considered to be insignificant.

Whilst the flow of major rivers surrounding the Proposal is relatively well monitored, local drainage lines immediate to the Proposal area are poorly understood owing to its remote location and little variation in land use over the last century. Channels range from the poorly defined and transitory to well established stream beds, such as those within escarpment valleys.

Stream catchments surrounding the Proposal area are generally between 6 and 100 km^2, in contrast to catchment sizes between 3,100 and 7,500 km^2 for the Finke, Hugh and Palmer Rivers at Stuart Highway crossings. As a consequence, the storm duration for the critical flow rate events would be shorter, and flooding would be more heavily driven by localised rainfall events.

As with rivers such as the Finke and Hugh, rainfall and evaporation patterns would cause local channels to be dry throughout a large part of the year. In various regions, channels drain across flood plains, providing increased opportunity for evaporation of flow due to the higher surface area to volume ratio. In these downstream areas, connectivity is often unclear. Nevertheless, assuming flow patterns are analogous to those observed in river records, flood magnitudes in local channels are expected to be significant.



Legend

- Existing access road
- Watercourse
- Vegetation
- Indicative batter slope

Figure 9-15
Conceptual Site Hydrological Model

TELLUS

Apirnta Creek tributary rail crossing

Apirnta Creek provides a possible hydrological connection from the upstream catchment to the Finke River system. Apirnta Creek lies approximately two kilometres to the east of the Central Australian Railway and drains across the existing access road (soon to be named Chandler Haul Road) at 10 kilometres chainage from the upstream source. It flows towards a railway culvert at 16.5 km and continues in a westerly direction, joining another tributary at 17 kilometres until it flows south and eventually towards the Finke River, some 35 kilometres downstream at the Attalwaynimma Waterhole.

One of the tributaries of the Apirnta Creek flows along the east side of the rail line embankment and crosses the rail line under a 3.3 BRLEN deck culvert at rail chainage reference 1212.238 kilometres (*pers comm.* Peter Taylor, Genesee & Wyoming Australia 2016). It also receives inflow from the west side of the rail line via twin 700mm Ø circular culverts.

This site currently has significant erosion issues. The history of the site is not clear but it appears that the rail embankment concentrates the flow line and an embankment has been placed across the original drainage course, diverting the flow under the rail line.

In-line farm dams

Five in-line drainage dams have been identified, one within the Proposal area (Halfway Dam) and four others in the Study Area (Gypsum, Lookout, North-East and Robinson Dams). Schematics and a brief description of these dams are provided in Appendix R.

9.3.8 Water quality

Limited water quality data exists for Finke region in the scientific literature due to the unreliability of surface water flows and the remoteness of the area. Water quality criteria used for the Proposal is set out in Section 9.2.4.

Existing mine related water quality stations are outlined in Figure 9-1. The data collected from these stations were compared against the trigger values for 95 % freshwater aquatic ecosystem protection (Appendix R,) and primary industries livestock protection (Appendix R).

Due to the hardness of the water sample data, hardness modified trigger values (HMTVs) for cadmium, chromium, copper, lead, nickel and zinc were develop as outlined be the ANZECC guidelines. These HMTVs better represent the site-specific bioavailability of these metals in surface water on-site.

At the NT stations, the comparison of the surface water samples with physical and chemical guidelines showed the following:

- For aquatic ecosystem 95 % protection, electrical conductivity exceeded the guideline values. The surface water was found to be hard and the pH samples was either equal to or greater than the pH trigger limits. The dissolved oxygen was only sampled once at station G0050116 and was below the guideline. Total dissolved solids (TDS) was below the trigger values, except at stations G0050119 and G00140 where samples taken exceeded the guideline. Total suspended solids (TSS) was measured once at station G0050115 and exceeded the guideline value. Similarly, turbidity was measure once at station G50050116 and was greater than the trigger values.

- For livestock protection, both calcium and fluoride was below the trigger values required to cause adverse effects in livestock protection. However, nitrate results were above the guidelines. Sulphate was below trigger values, accept where it exceeded the trigger value once at station G005119. The TDS was below the guideline except at sites G0055119 and G0055140.

The Chandler Facility surface water sample comparison showed the following:

- For aquatic ecosystem 95 % protection, electrical conductivity was below the guidelines at CS005011, CS005013 and CS005021, but exceed the trigger values at CS005060 and CS005071. The water was found to be hard, with pH and turbidity results exceeding the guideline values at stations CS005060 and C005071. TDS and TSS were below the guideline values at station CS005060 and CS005071. Aluminium, chromium, copper, manganese and silver showed a split across the Chandler Facility water quality data, either exceeding or measuring below the guideline. Arsenic, boron, cadmium, mercury, nickel, nitrate, lead and selenium were lower than the guideline values. Zinc exceeded the guideline value, except at station CS005060 and CS005071. Ammonia was below the guideline value at sites CS005060 and CS005071. Phosphate was equal or greater than the trigger value at sites CS005071 and CS005060, respectively.

- For livestock protection, TDS was below the guideline values for livestock protection at station CS005060 and CS005071. Arsenic, boron, calcium, cadmium, cobalt mercury, nickel, nitrate, lead, selenium and uranium were lower than the guideline values. Aluminium, chromium, copper, manganese and silver showed a split across the Chandler Facility water quality data, either exceeding or measuring below the guideline. Molybdenum and zinc exceeded the guideline value, except at station CS005060 and CS005071. Ammonia was below the guideline value at sites CS005060 and CS005071. Fluoride was below the guideline value across each Chandler Facility site and sulphate was below the guideline value across all Chandler Facility sites, except CS005060. Phosphate was equal or greater than the trigger value at sites CS005071 and CS005060, respectively.

From the above results, NT monitoring site would be suitable for aquatic ecosystem protection, but may have adverse effects for livestock production due to the level of nitrate at these stations. At the Chandler Facility stations, the results showed split results for several chemical and physical stressors across the station and may be due to the irregularity of the rainfall events in the region. Overall the results, suggest CS005060 and CS005071 would be suitable for aquatic ecosystem protection, but all sites within the area may not be suitable for livestock production, due to the levels of metals within the surface water.

Guideline sediment values were not exceeded for any of the metals tested at any site. Electrical conductivity (1:5 deionised water leach) were low at all sites, particularly CS005013 and CS0041, at 11 and 19 µS cm^{-1}, respectively. Total organic carbon in sediments were also low at CS005013, in addition to GEOM03, at 520 and 890 mg kg^{-1}, respectively. Presumably this was due to the high quartz content present in bed sediments at these two sites.

The Water Management Plan (see Appendix Q) defines sediment quality trigger values which would prompt a further investigation into source / activity and mitigation and contaminant limits which should not be breached at any time. It is recommended that sampling be continued at all sites on a bi-annual frequency (i.e. dry and wet season) during construction and operation phases

In general, cease-to-flow causes water to retract to a series of connected or disconnected waterholes where water quality is driven by processes such as evaporation, groundwater influence and the concentration or precipitation of compounds (Miles *et al*. 2015). Water quality conditions at a local scale include low dissolved oxygen levels, high temperatures, increasing salinities, hardness, alkalinity and cations (Sheldon and Fellows 2010).

Water quality during flooding flows is driven by the large volumes of catchment runoff. Flooding entrains organic carbon and nutrients from the productive floodplain areas into the river channels to support food webs (Miles *et al*. 2015). A unique feature of some Australian dryland rivers is their permanent high mineral turbidity, which is characteristic of the local geologies and land use (Sheldon and Fellows 2010). This leads to fine clays in suspension even under no-flow conditions (Bunn *et al.* 2006).

Analysis of long-term hydrological trends and storm and storm hydrographs on the Finke and Hugh Rivers has been undertaken (BECA 2016). Whilst not site specific, the data provides a reasonable estimate of local climatic and rainfall data as well as the behaviour of water within the sub-catchments referenced above. The results of this work, have been used to develop an estimate of flood inundation within the Proposal area.

9.3.9 Geomorphology

A detailed geomorphology baseline assessment is contained within the Beca (2016) report in Appendix R. The key objectives of this geomorphology assessment were identified as follows:

- Characterise geomorphological baseline conditions in existing channels.
- Sample and test sediments for physical characteristics.
- Identify key habitat within the existing channels.

Six sites were selected for the geomorphology study based on the following criteria:

- Major watercourses.
- Representative watercourses for the Proposal in terms of type, catchment area and geographical spread.
- Within the likely sphere of influence of the Proposal.

- Sites with existing data collection as part of the Proposal.

As a result, sites CS005013, CS005021, CS005041, GEOM1 (Finke River), GEOM2 (Railway Crossing Creek) and GEOM3 (Hugh River crossing near Titjikala) were nominated. The results from both the desktop and site work fluvial geomorphology baseline study are shown in Figure 9-2 and presented below.

Stream order

The Strahler stream classification system is a method of classifying waterways according to the number of tributaries associated with each waterway (Strahler 1957). Numbering begins at the top of a catchment where the headwaters of the system start. As the stream order increases the contributing catchment area and channel size also increase. Small tributaries at the top of the catchment are assigned as a first order streams. Where two first order streams join, the waterway downstream of the junction is referred to as a second order stream. Higher order streams are found in the lower parts of the catchment.

All drainage lines within the area surrounding the Chandler Facility are 1st order, with the exception of Halfway Creek (downstream from Halfway Dam), Chambers Pillar Road Creek downstream from Robinson Dam, Charlotte Range Creek downstream from bore # 14288 and Apirnta Creek downstream from the railway crossing which are all second order. The major of watercourses in the study area, Finke and Hugh Rivers are greater than stream 5 order.

Long profile analysis

Gradient have been assessed to assist in the characterisation of major courses. No long profile analysis was possible for CS005041, Finke River, Hugh River and Railway Crossing Creek sites because contours were too coarse (50 metres). The long profiles for sites CS005013, CS005021 and CS005031 (contour resolution 2 metres) have been plotted for comparison in Figure 9-16.

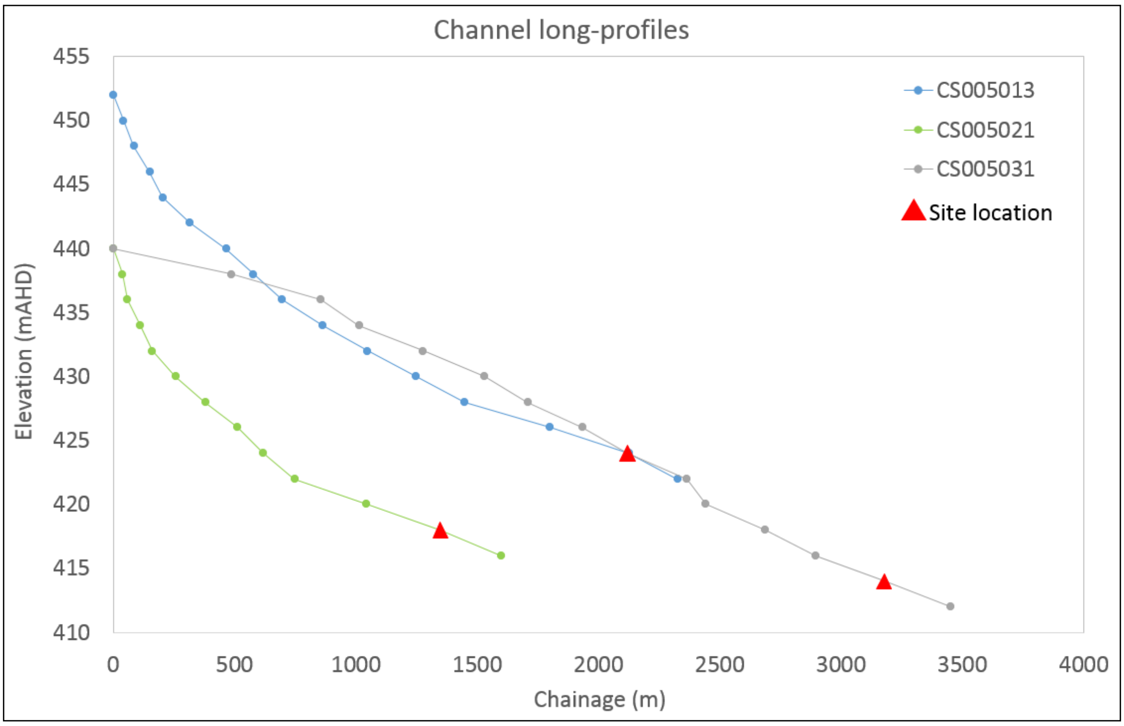


Figure 9-16 Long profiles of study channels

Typically, erosion zones are likely to occur on steep / vertical down gradient sections and deposition zones would occur on flat reaches with little to no downfall. As such, it is clear from these long profiles that all sites would be characterised as depositional environments, although sites CS005013 and CS005021 do have significant up-gradient erosion potential indicated by high gradients in the headwaters.

Channel planform

Sinuosity has been assessed to assist in the characterisation of major courses. The sinuosity derivations have been provided below in Table 9-11.

Table 9-11 Sinuosity estimates for study reaches

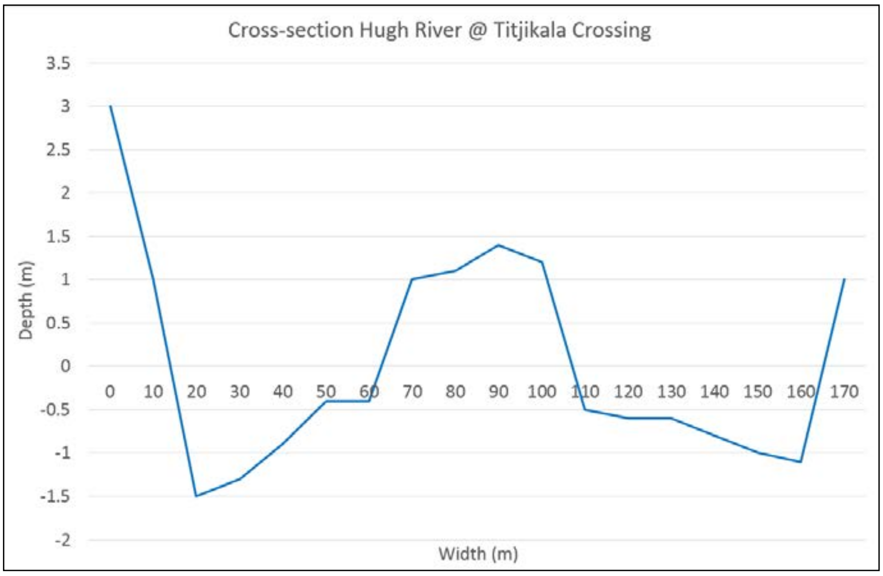
Study reach	Blue line network length (m)	Straight line length (m)	Sinuosity	Description
CS005013	2,125	1,987	1.1	Low
CS005021	1,349	1,266	1.1	Low
CS005041	1,800	1,800	1.1	Low
GEOM01	96,256	42,172	2.3	Meandering
GEOM02	9,860	8,630	1.1	Low
GEOM03	58,805	40,815	1.4	Meandering

Sinuosity is considered low if the degree of calculated sinuosity is between 1.06 and 1.30 and meandering between 1.31 and 3.0 (Brierly and Fryirs 2005). Open drainage lines within the alluvial floodplain show no defined or a discontinuous channel and low sinuosity. Finke River and Hugh River are considered meandering (high sinuosity).

As the majority of the study reaches are headwaters with low sinuosity, characterisation of meander bed characteristics (e.g. wavelength, amplitude, bend radius) was not relevant to the impact assessment.

Channel cross-sections

Typical cross-sections for the Hugh River and Railway Crossing Creek are provided in Figure 9-17. Environmental traverses for the existing Chandler Facility hydrographic stations have not been provided at the time of writing this report so cross-sections for these four sites (i.e. CS005013, CS005021, CS005031, CS005041) are not included. The Finke River was flowing at the time of the site visit so a cross-sectional survey was not possible due to health and safety reasons.



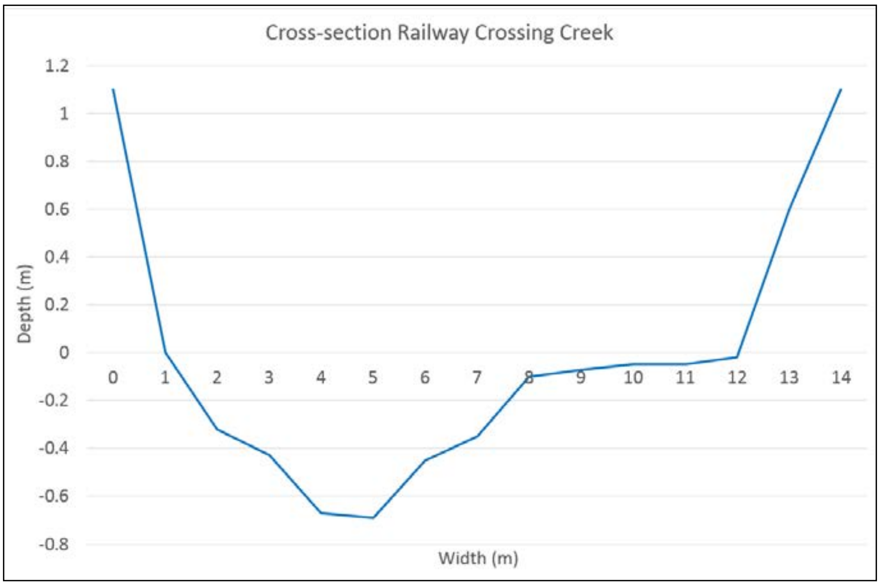


Figure 9-17: Typical cross sections for (a) Hugh River (b) Railway Crossing Creek

Sediment characteristics and transport

Variation in particle size for the five sampling sites are shown in Figure 9-18. Notable trends in particle size distribution were:

- GEOM02 and GEOM03 had largest particle size with a larger proportion of coarse sands and gravels than other sites. It is postulated that these two sites have higher flow velocities.
- CS005021 and CS005041 had the smallest particle size with the largest proportion of coarse silt and clay than other sites. It is postulated that these two sites have the lowest flow velocities as gradient in the flood out zones are lower and lack of channel form means flow is not constricted.
- No sites contained fine silts.
- Median particle size for CS005013, GEOM02 and GEOM03 was in the 0.15-0.3 mm fine sand range.
- Median particle size for CS005021 and CS005041 was in the 0.075 – 0.15 mm very fine sand range.

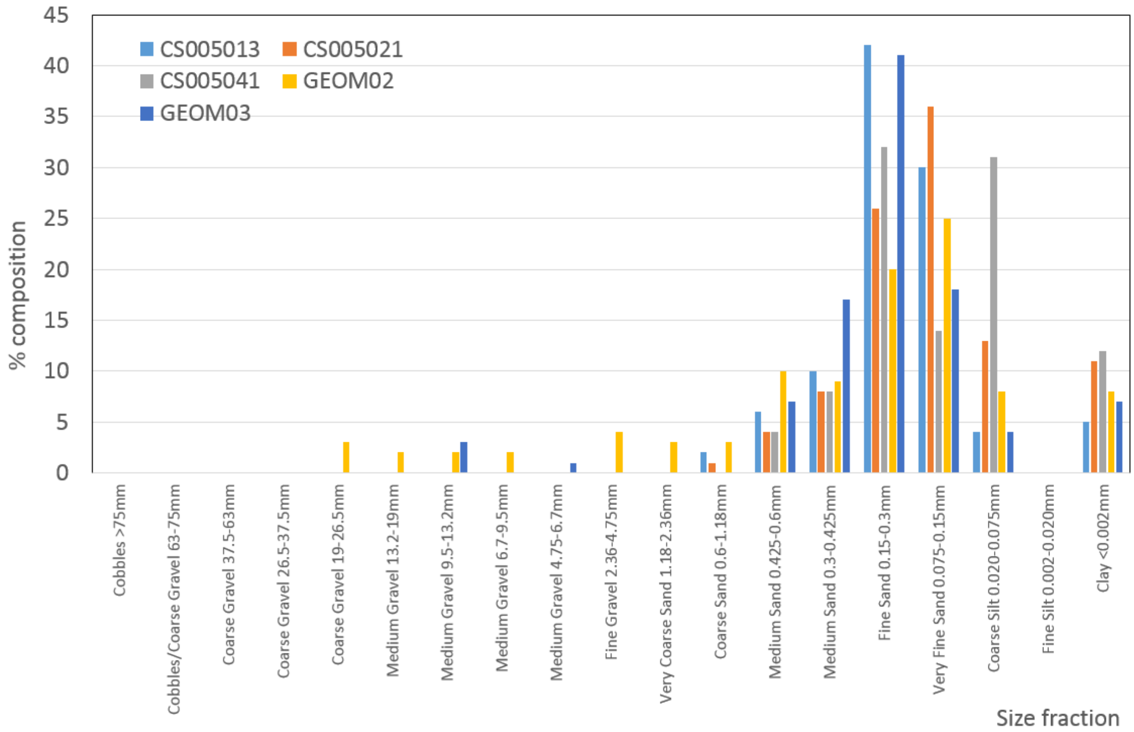


Figure 9-18: Particle size distributions

Sediment provenance and loads

At the time of writing this report, no flow nor suspended sediment concentration data has been provided for the nine storm samples collected from the surface water monitoring program. As such, it is not possible to estimate sediment loads transported down-gradient during storm events. Furthermore, it is not possible to establish the relationship between sediment size and the velocity regime causing erosion, transportation and deposition of channel material using a Hjulström curve as velocities have not been measured during storm events.

What can be concluded from particle size data are the theoretical thresholds for motion of sediments of known sizing. As such, median sediment particle size determined by geomorphology field investigations have been compared in Table 9-12 to the known velocities (cm/s) controlling movement or deposition of sediments in the study channels.

Table 9-12: Thresholds for movement of study channel sediments

Study reach	Median particle size (mm)	Motion threshold (cm/s)		
		Deposition	Transport	Erosion
CS005013	0.3	<2	2	10
CS005021	0.15	<1	1	12
CS005031	0.075	<0.8	0.8	15
CS005041	0.15	<1	1	12
GEOM01	0.3	<2	2	10
GEOM02	0.3	<2	2	10
GEOM03	0.15	<1	1	12

It is evident that it would be most difficult to deposit and transport sediments at CS005013 and GEOM03 due to the calibre of sediments found here. However, it is easiest to erode sediments at these two sites, conversely, because of a lack of silt and clay content which performs a cohesive function against flow shear stress.

It is hypothesised that sediment availability in the study channels is controlled by a combination of rainfall intensity, land cover and grazing pressure. Sediment transport is controlled by channel gradient and particle sizing.

Geomorphological classification of watercourses

A description of the River Styles™ types for each watercourse are listed below:

- CS0013 is a low-moderate sinuosity sand bed discontinuous channels. They feature chain of ponds with sand sheets and lateral bar features.
- CS005021 and CS005041 are both flood outs.
- GEOM01 is a fine-grained anabranching channel in an alluvial valley setting.
- GEOM03 is a coarse-grained anabranching channel in an alluvial valley setting.

The implications of these channel types for surface water geomorphological functioning are that the discontinuous channel are sediment supply systems in headwater catchments with rapid response to rainfall events.

The alluvial valley setting channel at GEOM01 and GEOM03 would act as a sink for sediments, with gradual deposition and channel accretion over time. However, large storm events would move this material further downstream in 'slugs'.

The Finke and Hugh Rivers are anabranching[6]. Characteristics of an anabranching river are flood dominated flows and erosion resistant banks (Nanson & Knighton 1996). Some systems characterised by mechanisms to block or constrict channels trigger avulsion (Nanson & Knighton 1996).

For the Finke and Hugh Rivers the flow can diverge for a large distance before re-joining the main channel. Anabranching river channels are active and are thought to be more efficient at moving water and sediment than a single channel at the same flow discharge (Monroe 2008). They are expected to have a lower velocity compared to single channels. Therefore, the Finke and Hugh Rivers have more periods of low flows and infrequent periods of high flows as a result of flood events.

Instream habitat

Part of the function of a geomorphological assessment is to identify sensitive habitat that might require special protection from impact.

No refuge pools were observed during the site walkover and it is clear that waterbodies within the mining lease area are ephemeral, rarely flowing except under extreme wet conditions. Instream habitat is not diverse, with a blanket of coarse sand observed at CS005013 thought to be due to high bedload transport during flow events.

Flood out sites have compact sand beds, thought to be a result of deposition of fine sands during sheet flow and gradual evaporation / percolation of waters forming a pan. However, vegetation assemblages associated with the channels / flood-outs are apparent. Low salt tolerant species were observed along the channels, indicating a source of fresh water other than groundwater springs.

The Finke River and Hugh River, however, have rich in-channel habitat diversity (see Plate 9-6). The low-moderate sinuosity sand bed stretches would act as conveyance stretches, storing sediments in-between events and supplying them to downstream reaches during high flow conditions. They would probably not provide material in-situ as the channels here are relatively stable. Conversely, the meander bends would provide new material to the channel during high flow events, due to erosion on the apex of the curve facing highest water velocities.

The secondary cut-off channels on both the Finke and Hugh Rivers perform an important function during high flow events and subsequent receding flows, providing additional storage capacity to reduce the likelihood of channel overtopping and acting as a fine sediment sink, respectively.

---

[6] *Sections of the river channel split from the main channel and re-join further downstream.*

Plate 9-6 Finke River in-stream habitat and pool areas laden with fine alluvial sediment deposition

The anabranching channels provide a complex geomorphological function, maximising bed sediment transport (work per unit area of the bed) under conditions where there is little opportunity to increase gradient. These features were located immediately downstream from the apex of meander bends, showing that the bends are a source of new material in the channel and that lower energy conditions downstream allowed subsequent deposition during flow recession forming the separating ridges. Major floods in the Finke and Hugh Rivers would form a laterally active short-lived anabranch.

Large woody debris was observed in the Finke and Hugh River channels, partly sourced from overhanging vegetation but also from further upstream. Bed or bank stabilisation by woody debris has been postulated in previous studies (Erskine *et al*. 2001).

In the Finke and Hugh Rivers, formation of semi-permanent log steps did dissipate energy, store bed load. However, due to the non-cohesive nature of the bed sediment and the large velocities predicted during high flow events, the presence of large woody debris only stabilised bed profiles on a temporary basis. In fact, scour and increased velocities (as reflected in increased particle size) was noted in the lee of logs and branches deposited within the channel due to creation of roughness.

Large woody debris was also observed in Halfway Creek and Mary's Creek predominantly sourced from in-stream debris (see Plate 9-7). The presence of large woody debris in this location appears to have stabilised bed profiles, at least on temporary basis. Evidence of historic high velocity flow events within Halfway Creek were seen upstream of Halfway Dam (see Plate 9-8).

Plate 9-7 Evidence of large woody debris within Halfway Creek

9.3.10 Flooding

A method has been developed to estimate areas of standing water from data recorded by the Moderate Resolution Imaging Spectroradiometer, an optical instrument on board the Terra and Aqua orbiting satellites (Guerschman *et al*. 2011).

Figure 9-16 plots an average of annual maximum inundation plots from between 2000 and 2015, developed using this method. Brighter colours indicate a greater frequency of water observations. Whilst being of coarse resolution (cells of approximately 475 metres by 475 metres), this data identifies a number of endorheic basins where water has ponded for a period of time. Within the Proposal area few distinct patterns can be seen, indicating both limited and spatially-varied ponding.

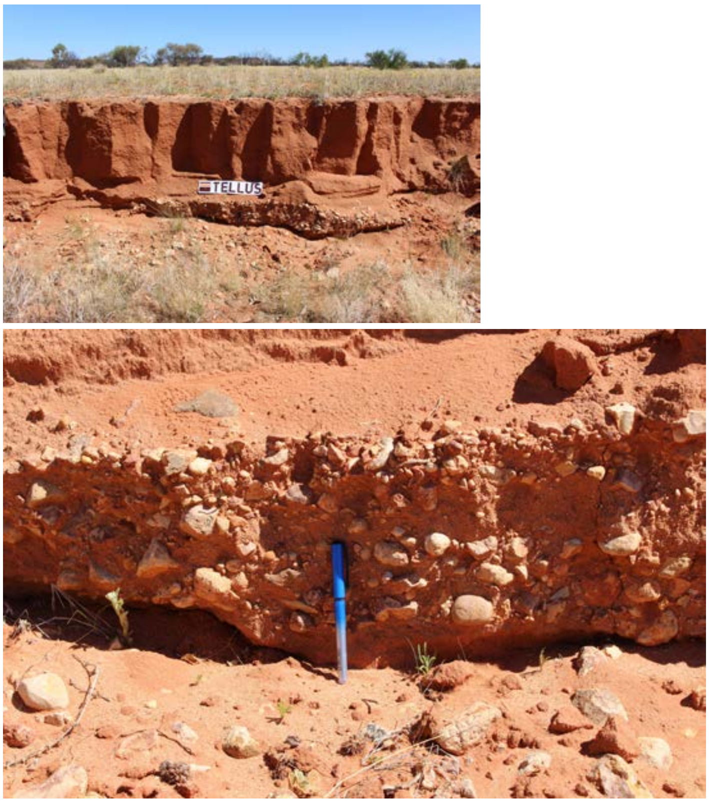


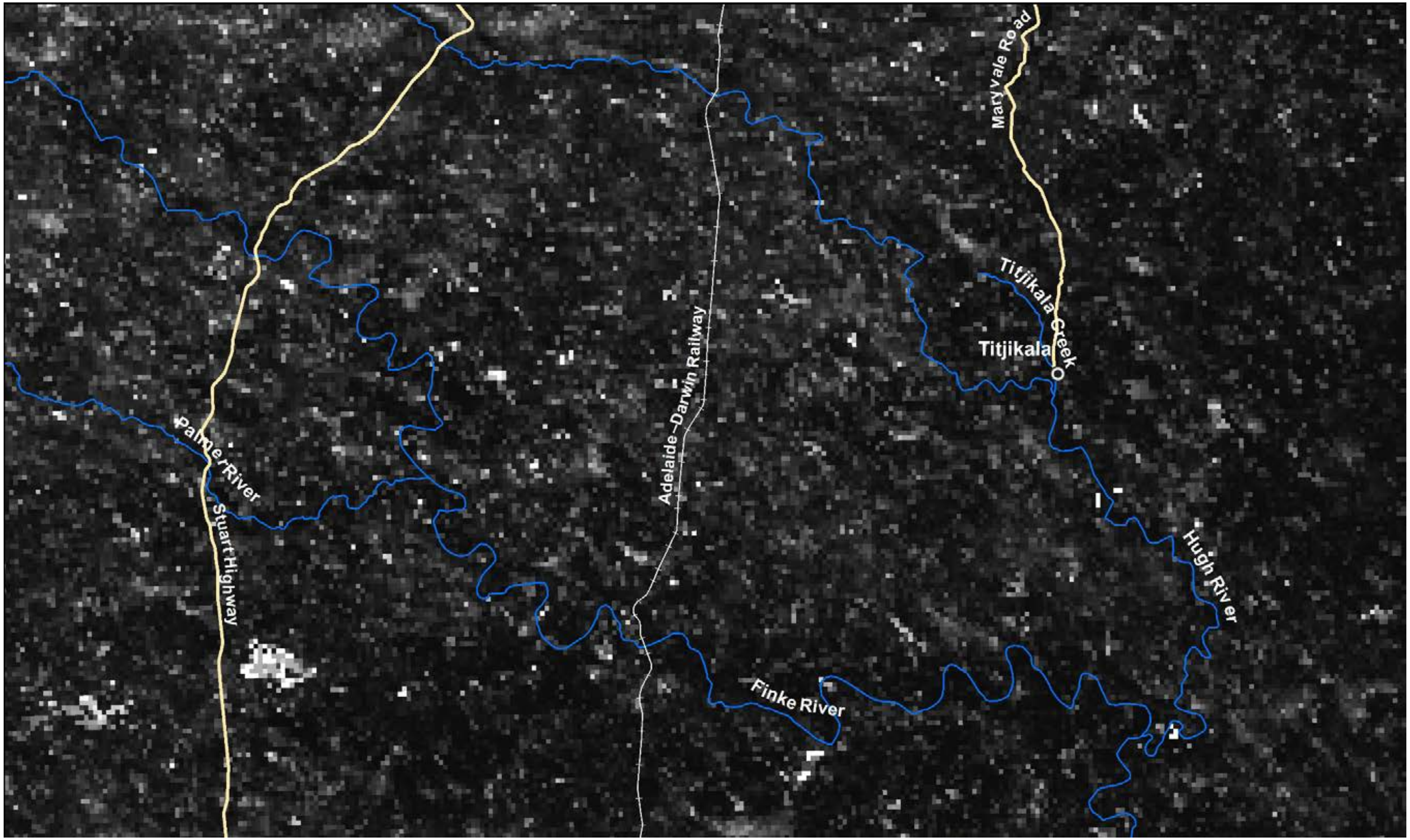
Plate 9-8 Evidence of historic high velocity flow events in Halfway Creek

Geoscience Australia (2016) developed a similar dataset, at a higher resolution (25 metres), a lower frequency but over a longer period. This data, derived from the Landsat 5 and Landsat 7 satellite imagery archive and known as *Water Observations from Space* (WOfS), presents the percentage of (good-quality) observations on which water was detected between 1987 and 2016. It is aimed to better understand where water is usually present and where it is seldom observed. plots the WOfS dataset for the CSMP area.

The Finke River is clearly distinguished, with water detected between 2 % and 50 % of observations along its length. Higher-observation areas correspond roughly to refuge pools and waterholes. The Hugh River is narrower in width, and so harder to identify in the WOfS data. Water is detected between 1 and 5 % in most sections, with occasional segments registering water in 20 % of observations. This confirms both flow record interrogation and anecdotal observations that the Hugh River is dry for longer periods of time than the Finke. Water flowing in the Palmer River is generally below the spatial and / or temporal resolution of this dataset.

Scattered ponds in the order of 100 metres to 500 metres in diameter can be seen across Figure 9- 19, particularly within the sand dune to the west of the Proposal area and the headwaters of Chambers Pillar Road Creek. The only ponding detected within the proposed Chandler Facility Mine Infrastructure Area is that of Halfway Dam (see Figure 9-20).

Figure 9-19 Average of annual maximum inundation from between 2000 and 2015



Source : ANU, 2016 - Brighter colours indicate a greater frequency of water observations.

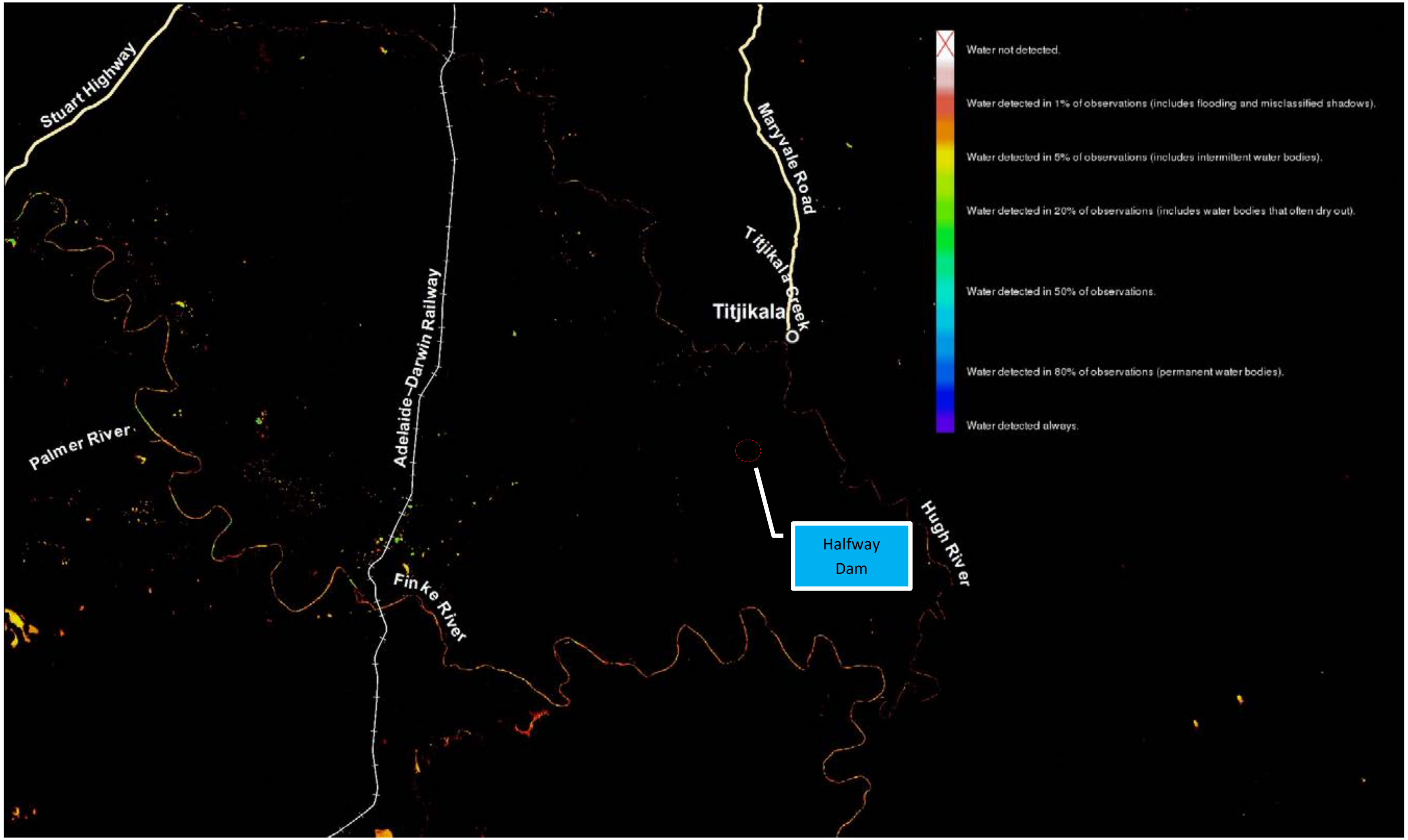


Figure 9-20 Water detected between 1987 and 2016 - image taken from GA (2016) Water Observations from Space dataset

Flood hydrographs have been defined for the catchments draining to the Proposal infrastructure (mine site, haul road and railhead) using the Australian Rainfall and Runoff (ARR87) guide to flood estimation and HEC-HMS hydrological modelling software. The resulting flood estimates have been verified with reference to the flood frequency of the major rivers.

The ARR87 approach requires:

- Catchment areas, lengths and slopes to be defined.
- Design rainfall.
- Storm depth.
- Aerial reduction.
- Profile.
- Losses.
- Method of the transforming effective rainfall into a flow hydrograph. This includes calculating the Time of Concentration (Tc)

Estimated peak flood flow rates from a generalised extreme value distribution fit of this data are given in Table 9-13 for the Hugh and Finke Rivers.

Table 9-13 Estimated flood flow rates at the Hugh and Finke Rivers

Return period (years)	Hugh River (m^3/s)	Finke River (m^3/s)
500	8,140	-
100	2,964	2,039
50	1,894	1,430
10	616	565
5	346	340

9.4 Assessment of risk during construction

Potential impacts on surface water environments within the Proposal area were identified in Section 9.3.7. This section presents the potential impacts (both direct and indirect) on surface water during construction of the Proposal. Mitigation measures to avoid or reduce these impacts are discussed in Section 9.7.

9.4.1 Direct impacts

Direct impacts on surface water during construction of the Proposal include erosion, flooding and changes to existing site surface water flows. These impacts are discussed below.

Soil erosion in disturbed areas resulting in increased sedimentation

In a disturbed environment, even a small amount of water can cause erosion. Whenever a raindrop hits bare soil it disturbs the soil aggregates and splashes soil particles into the air. Once the soil is disrupted it is easily eroded. More intense rainfall causes an increase in disruption to bare soil (DLRM, 2013b).

Soil erosion is one form of soil degradation. The erosion of soil is a naturally occurring process on all land. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur very quickly causing serious loss of topsoil. Accelerated erosion causes both "on-site" and "off-site" problems. The erodibility of a soil also depends on inherent soil characteristics, such as structural stability and infiltration rate (Dilshad 2007). The greater the structural stability of a soil, the greater is its resistance to being broken down by raindrop splash and overland flow. In addition, if it has a high infiltration rate, more water can percolate in the soil per unit time, which minimises shallow surface flow.

The Proposal includes three sites (Apirnta Facility, Chandler Facility and Road Infrastructure) with their site characteristics summarised in Table 9-14. For the purposes of this Erosion and Sediment Control Assessment, the Chandler Facility refers to overground features only. A more detailed description of the three sites can be found in Chapter 1 (Introduction).

Most runoff on the Apirnta Facility and Haulage Road sites are expected to occur as sheet flow. A film of water spreads across the soil surface, having low volume, velocity and energy. In undisturbed areas, this has low potential for erosion. However, if runoff is diverted or concentrated in sheet flow areas (e.g. along the eastern side of the railway track on the Apirnta Facility site or in channels crossing the Haulage road route), flow velocity and volume is increased. This leads to a higher risk of erosion.

At the Chandler Facility, degree of slope up-gradient would determine the amount of runoff energy on the site itself. The Maryvale Hills situated directly to the east are sufficiently sloping to create very rapid water flow. Rapid water flow can be very erosive and the length of slope would determine the speed and energy available to cause erosion. As such, the two drainage lines of most concern within the Chandler Facility footprint are the Mary’s Creek and Halfway Creek.

Both gullies are > 2 kilometres in length, falling from 480 to 424 m AHD. Dingo, Oak, Ridey and Snake Gully’s’ by comparison are 0.5 kilometres long, falling from 450 AHD to 424 m AHD. Sheet flow and concentrated flow at the Chandler Facility site eventually accumulates in low lying drainage lines or depression areas, flowing towards the flood out area downstream. This runoff would therefore impact down- slope habitat.

Table 9-14 Summary of site characteristics

Site name	Location	Site size	Average site slope	Upslope runoff	Soil type	Watercourse name
Apirnta Facility	Maryvale pastoral lease	0.40 km^2	0.3%	4 km^2 with a 100 year ARI flow of 13 m^3/s	Aeolian sand (soil type Q_s)	Apirnta Creek
Chandler Facility	Maryvale pastoral lease	0.86 km^2	1.25%	4.1 km^2	Aeolian sand (soil type Q_s)	• Dingo Gully • Halfway Creek • Mary's Creek • Mulga Creek • Oak Gully • Ridey Gully • Roo Gully • Snake Gully
Road infrastructure	Maryvale pastoral lease	0.27 km^2	Not applicable	1.6 to 1,800 km^2 with a 100 year ARI flow of 5.8 to 2,704 m^3/s	Aeolian sand (soil type Q_s) 57% alluvial gravel, sand and silt (soil type Q_a) 42% conglomerate (soil type Q_c) 1%	Multiple drainage channels including: • Apirnta Creek • Chambers Creek • Charlotte Creek • Finke River • Hugh River

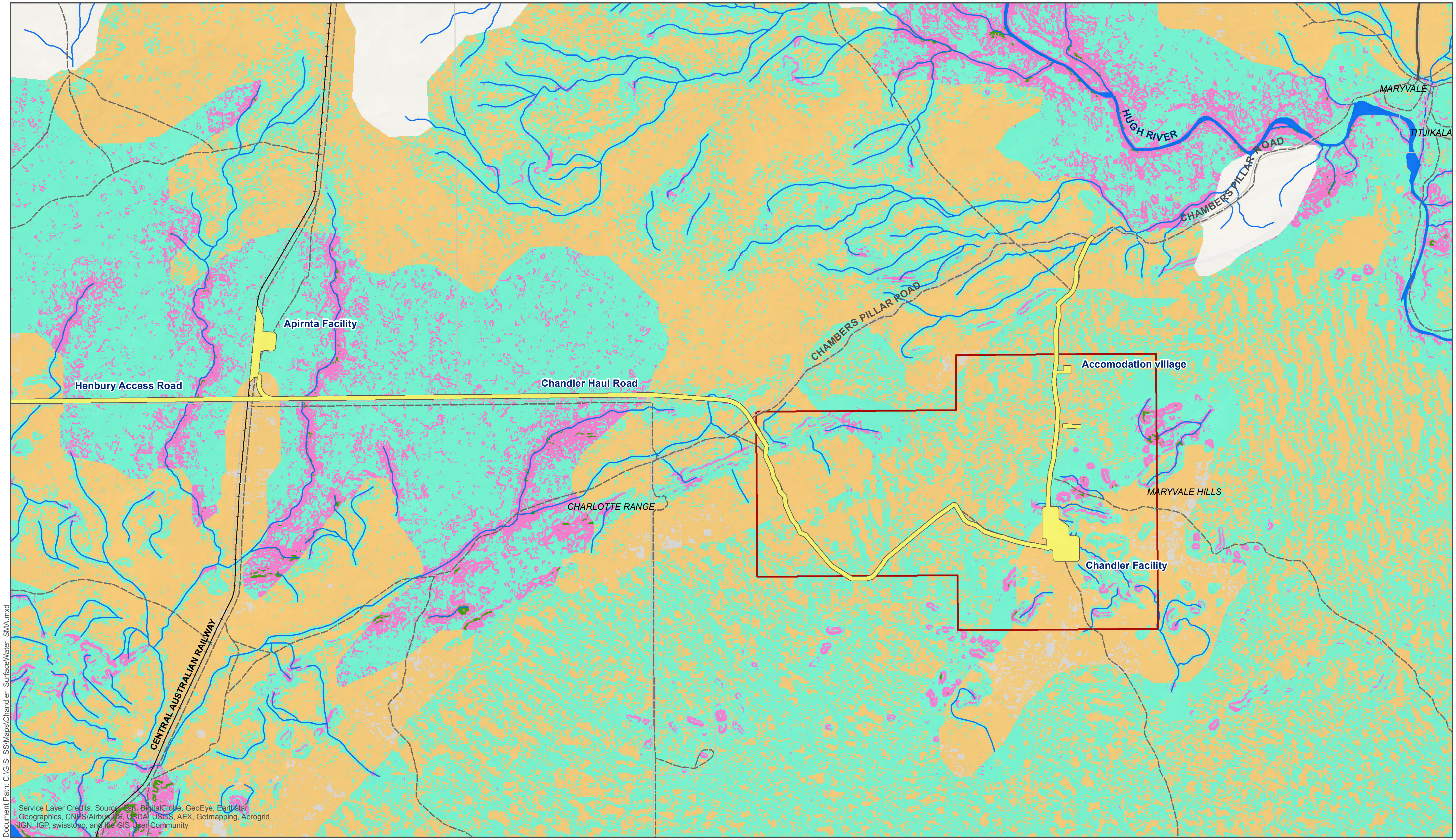
To assess erosion potential for the entire Study Area, a bespoke Erosion Hotspot Model of the Study Area was created (adapted from Evans *et al*. 2006). More details on how this model were generated can be found in Appendix R (Erosion and Sedimentation Assessment). A raster layer map was produced in GIS platform to display these erosion risk classifications visually with different colours representing different erosion potentials within the Study Area (see Figure 9-21).

The mapping shows that in general the east of the Study Area incorporating the Chandler Facility to the west of Maryvale Hills, Halfway Creek catchment, Chambers Pillar Road Creek have negligible, slight or low erosion potential.

The west segment of the study area incorporating Apirnta Creek, Charlotte Creek and the rail line have low or intermediate erosion potential. Areas of high erosion potential are generally grouped along creek / river lines reflecting hydrological connectivity and increased risk of sedimentation issues.

Very high erosion potential cells were in the upper catchments of these drainage lines, demonstrating the influence of lower ground cover and steeper slopes as well as hydrological connectivity.

Document Path: C:\GIS SS\Maps\Chandler SurfaceWater SMA.mxd



N

1.5 0.75 0 1.5 Kilometers

Coordinate System:
GDA 1994 MGA Zone 53

Legend

- Proposed development footprint
- Watercourse
- Mining Lease Area

Erosion risk value

- Negligible
- Slight
- Low
- Intermediate
- High
- Very high

Figure 9-21

Erosion potential hotspot map

TELLUS

This document incorporates Data which is © Commonwealth of Australia (Geoscience Australia) 2006.
Data source: Geoscience Australia, 250K Topo base data, 2006; USGS, SRTM elevation, 2000; AUSURV SURVEYORS, detailed elevation data, 2016.
Created by:adrian.miller

Vegetation clearance

Clearing and grubbing of the Chandler Facility, Apirnta Facility and Haulage Roads would be necessary to carry out further site preparation activities as described in the Proposal Description of the EIS (Chapter 3).

Under the Northern Territory Planning Scheme, native vegetation is defined as *'terrestrial and inter-tidal flora indigenous to the Northern Territory, including grasses, shrubs and mangroves'* (DLRM, 2013a). This means that clearing of any native vegetation for the Proposal requires consent, including vegetation cleared prior to the introduction of the native vegetation clearing controls. There are some general exceptions, which might apply to specific areas of the Proposal including clearing for:

- Fire breaks 5 metres wide for properties <8 hectares, or 10 metres wide for properties > 8 ha.
- Internal fence lines (up to 10 metres wide) only on properties > 8 hectares.
- Other exceptions as listed in the Northern Territory Planning Scheme.

These activities give rise to the following potential adverse impacts:

- Removal of filtering function for sediment and other pollutants from surface runoff by vegetation systems leading to a deterioration in water quality and associated loss of aquatic habitat.
- Decrease in shade and protection from wind and water erosion afforded by plants.
- Reduced infiltration and rise in salt water level.
- Decreased habitat quality surrounding the site, drainage lines and other sensitive areas.
- Increase in the speed of water runoff discharging creeks, exacerbating downstream flooding.
- Increase in chemical spray drift, noise and dust.

The potential impacts of vegetation clearance thus include the unnecessary removal of valuable native vegetation with associated habitat loss and fragmentation. Removal of the filtering function of vegetation surrounding watercourses leading to increased sediment input into creeks during rainfall events is another potential impact. Exposure of topsoil to rainfall leading to exacerbated erosion impacts would require pre and post construction mitigation. The site-specific impacts related to vegetation clearance are covered in Chapter 7 (Biodiversity) and in the Sediment and Erosion Plan (Appendix L).

Altered hydrology

The direct potential impacts of the Proposal on the hydrological regime of the receiving environment surrounding the mine infrastructure area is discussed below.

Chandler Facility

The Chandler Facility (mine infrastructure area) is about 3.5 km^2, with an upstream catchment area of 4.1 km^2. The village area is 3 kilometres north of the mine site, which is an area of about 0.35 km^2.

Under current proposals the remainder of the 100 km^2 mine lease site would not be developed. The majority of the lease area (including the mine site and accommodation village) lies within an 84 km^2 catchment with topographic gradient orientated north-east through the Charlotte Ranges towards the Hugh River and Titjikala, as shown in Figure 9-22.

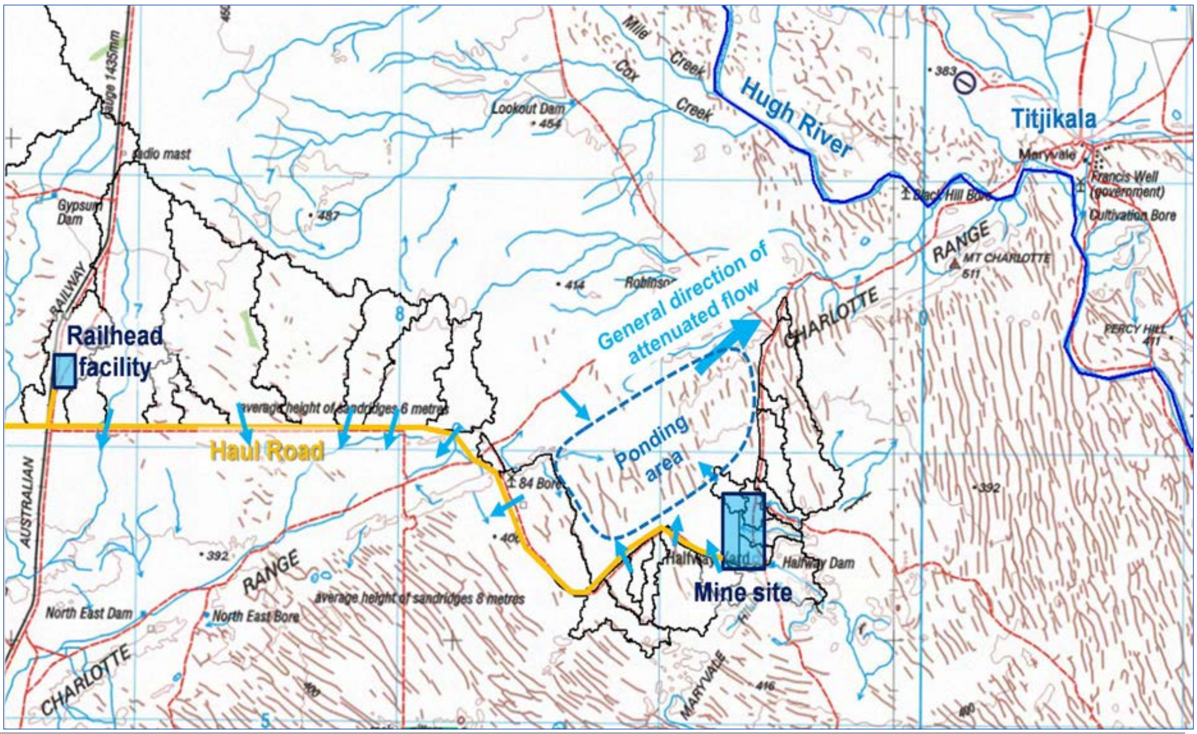


Figure 9-22 Topography and drainage lines

There are no signs that the drainage pathway from the MIA to the Hugh River is a permanent watercourse, and the Hugh River runs for less than 10% of the time. Water flowing through or from the mine site drains towards a flat washout area prior to passing towards the Charlotte Ranges. The detailed DEM only covers part of this washout area, but it is anticipated that the majority of the runoff would pond in this area, with significant to losses to evaporation and infiltration resulting in limited runoff reaching the Hugh River in all but the largest flood events. A conceptual drainage model for this area is detailed in the Surface Water Baseline Report (Beca 2016).

The 84 km^2 catchment draining the mine lease area towards the Charlotte Range would generate about 5.5 million m^3 of runoff in the 100-year ARI 9-hour storm. This represents a runoff coefficient of about 54 %. If 3.5 km^2 of the mine site were to be 100 % impervious, then this would contribute an additional 190,000 cubic metres of runoff to the catchment, which represents an increase of 3.5 %. The catchment topographical gradient lies towards the washout area before heading north-east towards the Hugh River and Titjikala. The washout area is about 12 km^2 (though difficult to define without detailed DEM) and would attenuate the flood.

The additional runoff from the mine site would represent an increase in water depth on the washout area of about 15 mm, if the area were totally ponded. However, while ponding in the washout area, floodwater would infiltrate into the ground and be subject to very high evaporation rates over a large area such that the effect of any additional runoff would be reduced further.

On this basis and as the mine site, accommodation village, and catchments upstream of the mine only represent about 10 % of the catchment draining through the Charlotte Ranges, it is not anticipated that the change in hydrological regime due to the Chandler Facility would have a noticeable effect on the Hugh River near Titjikala.

At the south-eastern boundary of the mine site lies Halfway Dam, which captures runoff from a 3.5 km^2 catchment. The current plan is to relocate Halfway Dam further down the creek line and utilise its current site as the salt stockpile (Tellus 2016). Therefore, further investigation during detailed is required to:

- Find a suitable location for a new dam;
- Assess the effect of any mine activity in the catchment upstream on flow yield / reliability; and
- Inform the dam location, intake structure (visible on Google Earth), and dam capacity.

Chandler Haul Road and Apirnta Facility

Upslope stormwater would flow through the Apirnta Facility, Chandler Facility and Haulage Road sites. Free passage of upslope stormwater would lead to additional water volume to manage. Water might become ponded on the site or flood infrastructure causing access issues or damage to critical equipment. It would also mix with dirty / contaminated water and thus necessitate additional treatment treatments. The additional water could cause structural damage to soils, leading to increased erosion.

The drainage lines crossing the haul road and intercepted by the Apirnta railhead facility generally flow in a southerly direction towards a drainage line running south-westerly along the northern flank of the Charlotte Range, and hence to the Finke River. Between the Chandler Facility and the railhead, the river is about 19 km from south of the Chandler Haul Road.

The only infrastructure of note downstream of the Chandler Haul Road are the rail crossing of the Charlotte Creek drainage line along the northern flank of the Charlotte Range and North-East Dam shown on the surface water bodies map in the Baseline report (Beca 2016).

Though the upgraded Chandler Haul Road would be less pervious than the existing track, the area would be insignificant when compared to areas of contributing catchments. As such, it is not anticipated that the proposed Chandler Haul Road would increase the peak flood flow or volume at the rail crossing or dam. If the Chandler Haul Road is raised, there is the potential for storm runoff to be intercepted and ponded upstream of the road. If the effect of the road is to be neutral, then measures should be taken to minimise upstream ponding.

The Apirnta Facility occupies a site of about 0.4 km^2, in a catchment of about 8 km^2 draining south towards the proposed Chandler Haul Road. The flood modelling of this catchment shows a runoff coefficient of 72 % in the 100-year ARI 9-hour storm, generating 700,000 m^3 of runoff. Were the 0.4 km^2 of the Apirnta Facility to be 100% impervious, then runoff would increase by 13,000 m^3 or 1.9 %. It is assumed that site runoff would be collected for treatment, and so it is not anticipated that there would be an increase in peak flow 4 kilometres downstream at the haul road.

9.4.2 Indirect impacts

Chandler Facility

Storm profiles

The critical storm durations for the identified catchments were assessed to determine the potential impacts associated with flood durations at the Chandler Facility, Apirnta Facility, Chandler Haul Road and Henbury Access Road.

Depending on the catchment size and shape, they were defined by the calculation of the catchment Time of Concentration as being from 1.5 to 24 hours. The storm rainfall depths for these critical storm durations were distributed using the storm profiles for Zone 5 in ARR87 Table 3.2. Examples of the 1.5, 6, and 24 hour rainfall profiles for the 100-year ARI storm events are provided in Figure 9-23, Figure 9-24 and Figure 9-25.

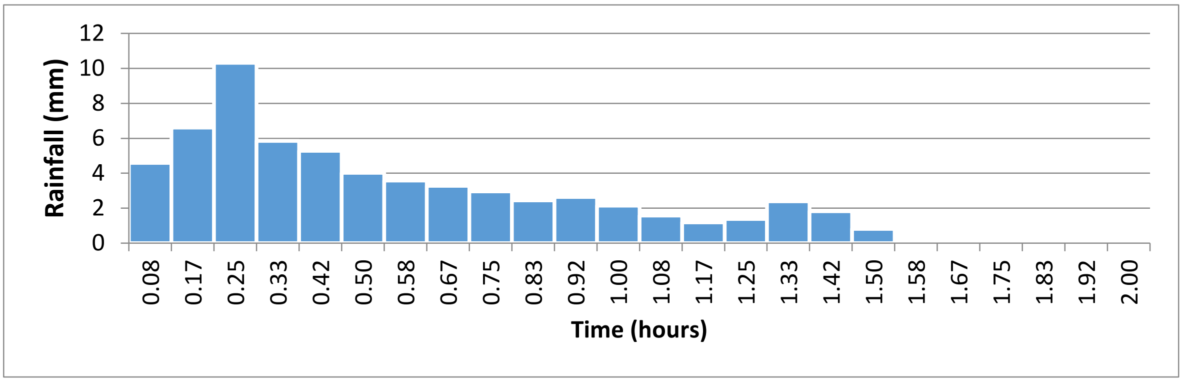


Figure 9-23 1.5 hour storm profile for 100-year ARI rainfall depth of 62.9 mm

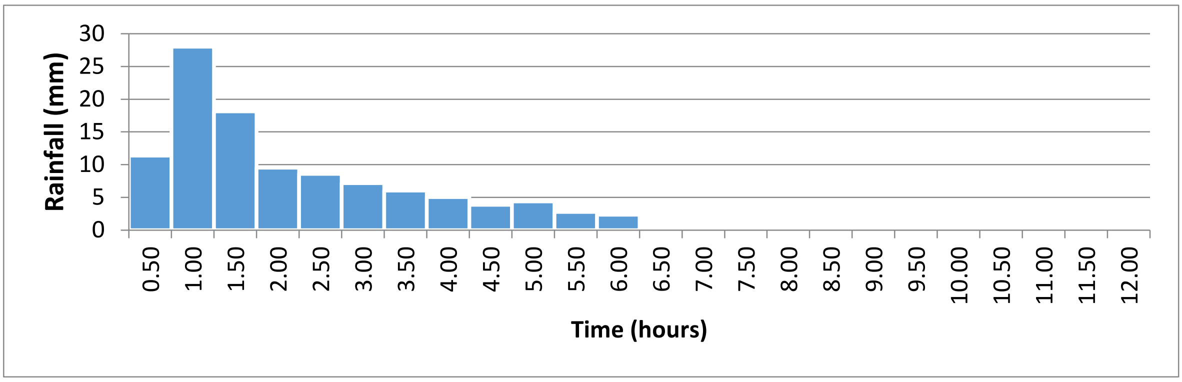


Figure 9-24 6 hour storm profile for 100-year ARI rainfall depth of 107.4 mm

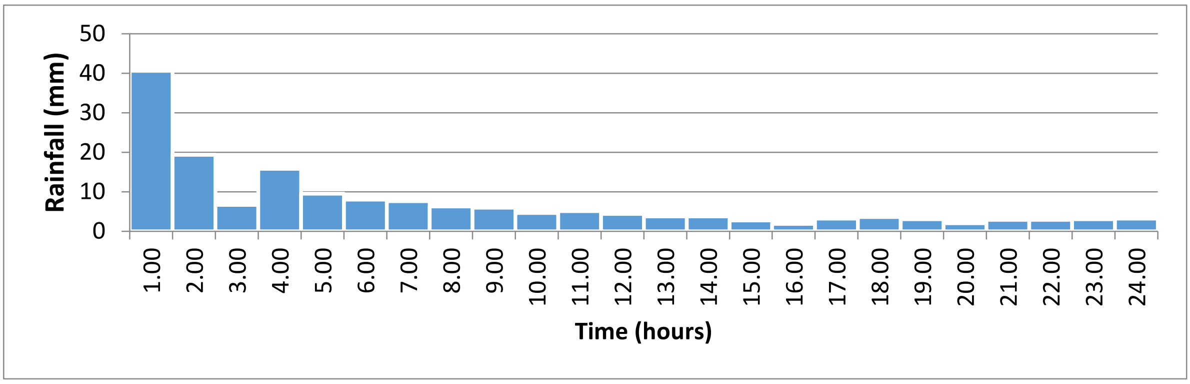


Figure 9-25 24 hour storm profile for 100-year ARI rainfall depth of 170.2 mm

However, subsequent modelling indicated that the losses applied to the rainfall resulted in little, or no, effective rainfall during short duration (< 3 hours) rainfall events, and that the maximum peak flows for the majority of catchments affecting the mine infrastructure were generated by storms of 6 to 12 hours duration.

For the 2-year ARI event, the 12 hour storm generated the highest peak flows. For the 10-year ARI event, there was little difference in peak flows generated by the 6, 9 or 12 hour storms. However, for the 100-year ARI event, the 6 and 9 hour storms generated the highest peak flows. The general relationship of the critical storm duration moving toward the catchment Time of Concentration as the magnitude of the event increases is expected, as the ratio of rainfall losses to total rainfall reduces.

The chance of that size of storm falling across the whole catchment reduces with catchment size. Therefore, a factor was applied to the rainfall depth. The factor varies according to catchment size and the storm duration, as shown in Figure 9-26 which was used for determining the factors for the Proposal's infrastructure catchments.

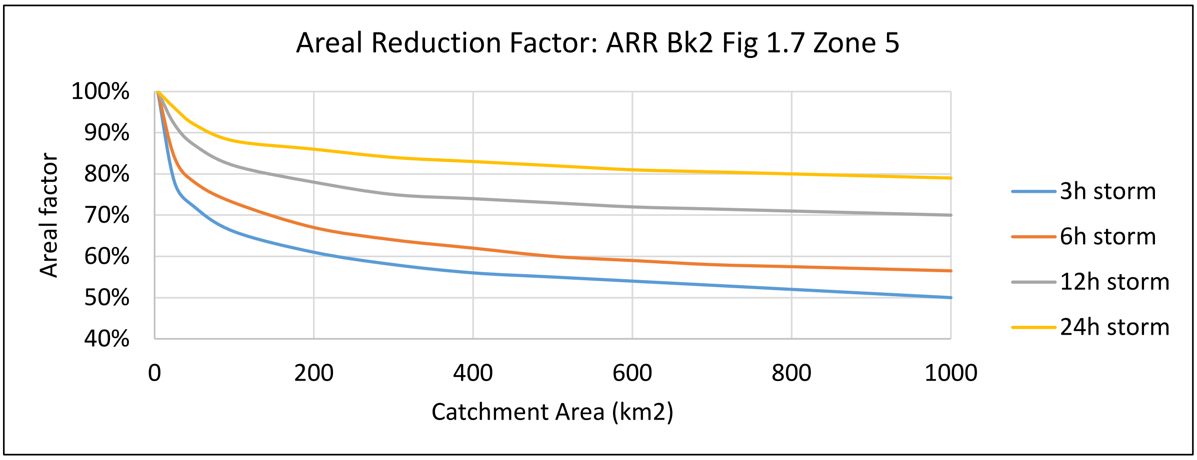


Figure 9-26 Rainfall areal reduction factor

Not all of the rainfall that falls on the catchment would contribute to storm runoff. Depending on antecedent conditions, vegetation and other factors, some of the rain is intercepted by vegetation, some lost to infiltration into the ground, while more may be held in shallow depressions / clay plans.

ARR87 suggests that rainfall losses should be accounted for by applying an Initial Loss (Ia) to the rainfall and then an Ongoing Loss (OL) for the duration of the storm. For 'Central Australia' parts of the Northern Territory, Table 3.8 of ARR87 Book 2 directs the user to the losses for 'Arid Zone' parts of South Australia, which are given in Table 3.4 of ARR87 Book 2. Two combinations of initial and ongoing losses are provided; Initial Loss of 15 mm or 40 mm, and Ongoing Loss of 4 mm/h or 1- 3 mm/h. Using an Initial Loss of 40 mm, rainfall depths would result in no runoff for the majority of design events of 5 years ARI or less. While selecting a higher ongoing loss is expected to result in no effective rainfall from much of the longer-duration storm profiles.

Flow results

Using the method for rainfall flow transformation in Section 9.2.6, a calculation was made to model and show the relationship between peak flows across the catchments affected by the Proposal which range from 6 km^2 to 246 km^2 (Figure 9-27). For the 10-year and 100-year ARI events there are good relationships that can be described by power equations. However, the relationship for the 2-year ARI event is less clear, with peak flows appearing to reduce once the catchment size is greater than about 100 km^2. This could reflect the longer times of concentration for these larger catchments, and hence, the greater relative effect of ongoing rainfall losses in reducing the effective rainfall.

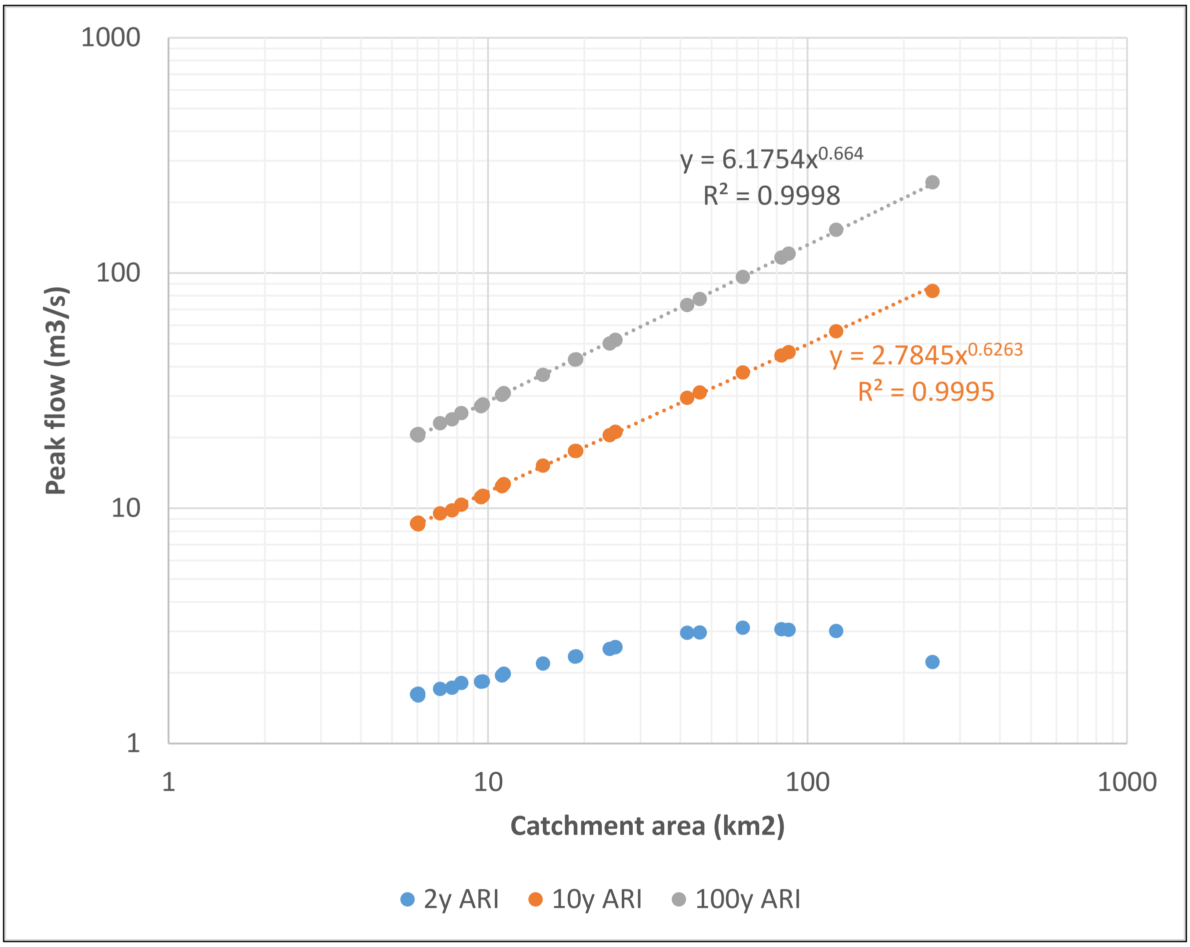


Figure 9-27 Catchment area – peak flow relationship

Figure 9-28 shows the peak flows per km^2 of catchment. As with Figure 9-27, the 10-year and 100- year ARI yields can be described by single power equations. The 2-year ARI relationship is more complex and has been split into two separate relationships; one representing catchments smaller than 60 km^2 and one for catchments greater than 60 km^2.

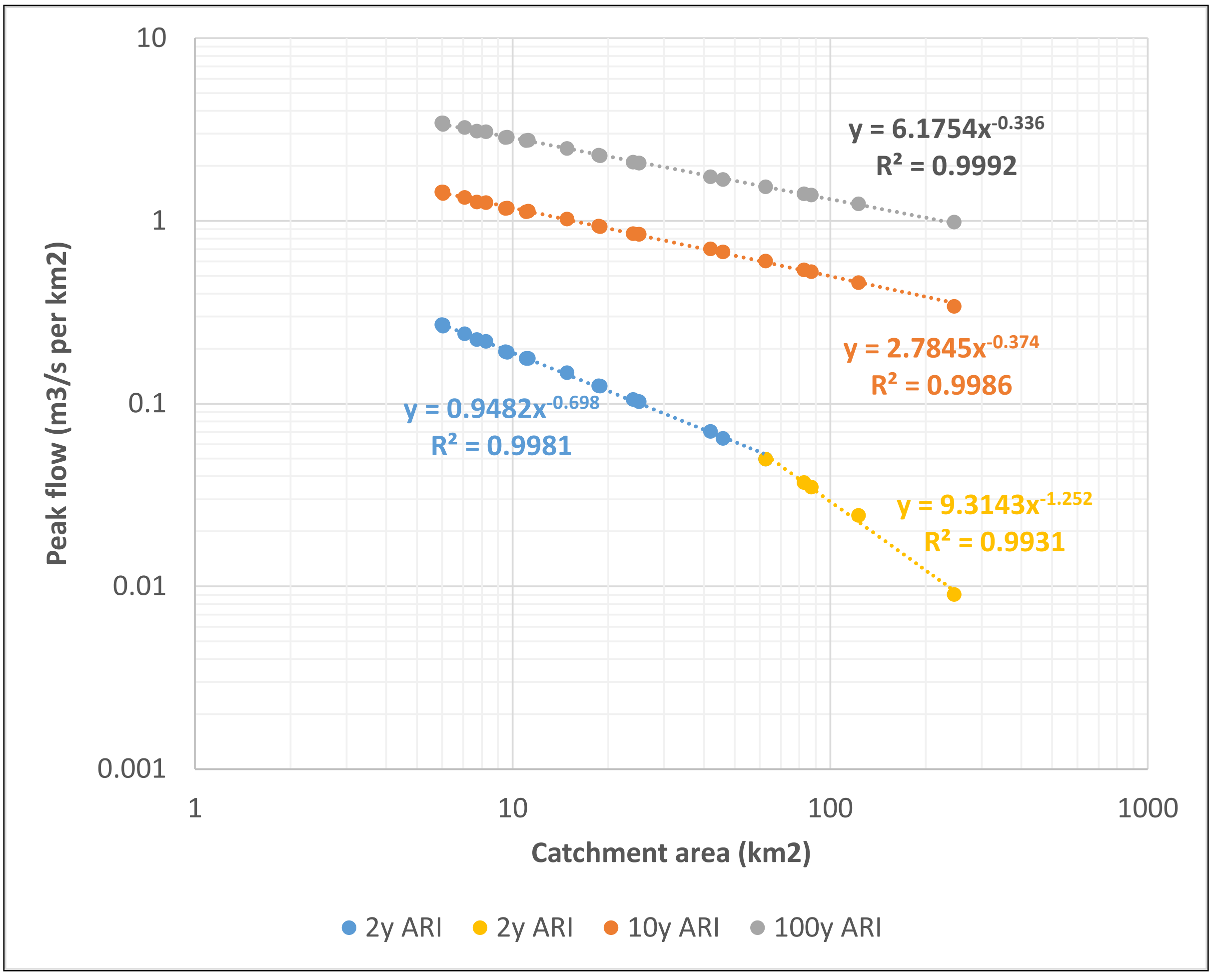


Figure 9-28 Peak flow per km²

The calculated peak flows for the Finke at the haul road crossing (22.8 kilometres) should be validated against recorded data for the Finke at the Stuart Highway (upstream of the haul road) and at the rail crossing (downstream of the haul road).

Catchment flooding

As outlined in Section 9.2.6, rrainfall depths for design storms up to the 100-year ARI event were taken from a BoM IFD. Results indicated that rainfall depths varied by less than 5% between the Stuart Highway and the mine site.

The mine site lies at the foot of an escarpment and a number of drainage lines and ephemeral creeks/gullies drain across the site and onto washout plains. At the mine site boundary, these range in size from about 0.03 to 3.5 km^2; the largest being the catchment that drains to Halfway Dam with a 100-year ARI peak flow of 11.7 m^3/s, and a 2-year ARI peak flow of 1.4 m^3/s. The total catchment area draining to the mine site is 4.1 km^2 (including the Halfway Dam catchment) which would generate the following peak flows:

- 2-year ARI 1.5 m^3/s.
- 10-year ARI 6.7 m^3/s.
- 100-year ARI 13.7 m^3/s.

Drainage through or around the mine site would need to accommodate these peak flows. Short duration (< 3 hours) rainfall does not generally result in significant runoff, as the majority of the rainfall is used to satisfy the initial rainfall loss. The peak flows are generally associated with longer duration rainfall that result in excess runoff. Under these conditions, it would be expected that the mine drainage network would have to manage flood flows for about eight hours.

Road flooding

Peak flows and time-series hydrographs have been derived for each of the catchments crossed by the access road and haul road between the mine site and the Stuart Highway. In total, the access and haul roads cross a significant watercourse or flow line 20 times over a total distance of 90 kilometres. At each of these locations, there is the potential for the haul road to be flooded or to pond water (if the road is carried on an embankment across the floodway).

A detailed DEM of the road alignment between the mine site and the railhead allowed an assessment of the depth and duration of flooding, and the length of road affected. Between the railhead and Stuart Highway (proposed Henbury Access Road), a detailed assessment is not practical due to the absence of a high-resolution DEM, though an estimate of the flood risk at the Finke River crossing (22.8 kilometres) has been made.

For the catchments between the Chandler Facility and railhead (Chandler Haul Road), the DEM was used to define the main channel and floodway cross-section, and the channel gradient. The Mannings flow formula (with a Mannings 'n' roughness of 0.04) was then used to calculate the:

- Depth of flooding over time.
- Velocity of water over time.
- Length of road flooded.
- Duration of flooding.

The results are presented in Table 9-15.

It is assumed that the road could be passable with shallow flooding (< 100 mm). Therefore, the length of time that the maximum flood depth along the road exceeds 100 mm is also noted, as is the length of road affected by flooding of more than 100 mm.

Table 9-15 Chandler Haul Road flood risk – 100-year ARI

Crossing (distance from Stuart Highway)	Peak flow	Max. depth	Maximum velocity	Flood hazard	Length of road flooded		Duration of flooding	
					Water on road	>100 mm flooding	Water on road	>100mm flooding
km	*m^3s^{-1}*	*m*	*ms^{-1}*		*m*	*m*	*hours*	*hours*
59.6	50.2	1.00	0.94	Medium	79	72	30	22
65.7	37.7	0.48	0.63	Low	159	154	26	14
67.9	30.6	0.29	0.60	Low	148	103	24	9
69.0	19.9	0.30	0.50	Low	154	143	18	8
71.0	27.0	0.60	0.77	Medium	69	43	19	16
72.8	19.3	0.60	0.44	Medium	205	107	15	12
78.3	26.6	0.50	0.65	Medium	107	103	24	18

Based on this assessment, peak water velocities are not high and are not the principal driver behind flood hazard at the crossings (Figure 9-29). Rather, the maximum depth of flooding puts some of the crossings into the medium hazard category, with the crossing at 59.6 kilometres verging on the high category. These categories represent the risk to life of entering the floodwaters.

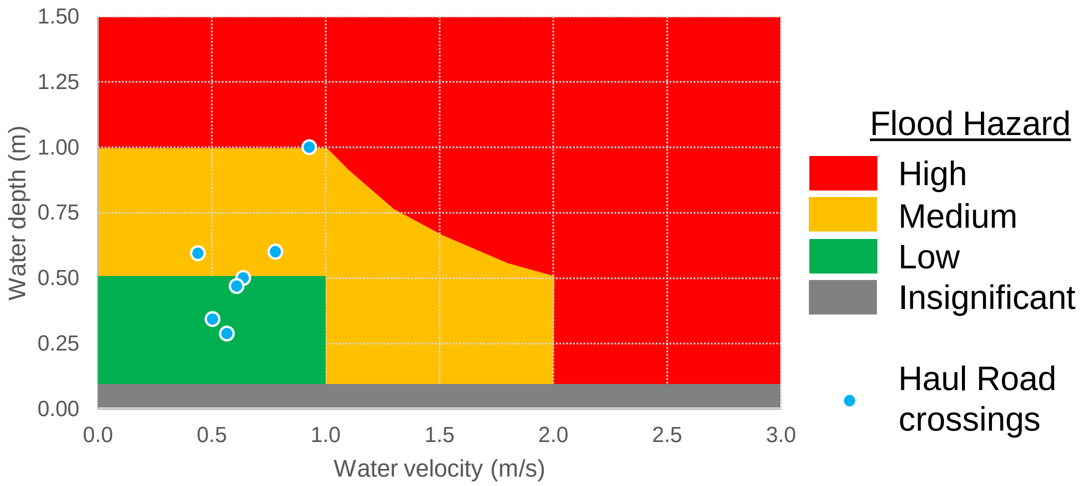


Figure 9-29 Flood hazard at Chandler Haul Road Crossing

While the assessment was limited to those crossings where high definition DEM data was available and a reasonably well-defined drainage line could be identified, it is assumed that the flow depths, velocities and lengths of road flooded are representative of all crossings along the haul road.

The modelling approach assumed that all of the flow passes over the road, and that the road is not raised above local ground level. As such, it is the worst case flooding scenario. The information would inform the road design, including options to mitigate flooding of the road, such as road raising and the use of culverts or bridges to pass flow. Such crossings would not be expected to interrupt natural streamflow and geomorphological processes. However, post-event maintenance may be required to ensure road usability

Apirnta Facility

The detailed DEM includes the proposed Apirnta Facility, which is about 2 kilometres north of the existing rail crossing. The Facility lies about halfway along an 8 km^2 catchment draining to the haul road. Figure 9-30 shows the location of the facility and contour lines that indicate that the facility intercepts the catchment drainage path, which has a slope of 0.4%. With an upstream catchment area of about 4 km^2, the peak 100-year flow would be about 13 m^3/s.

This would need to be diverted around, or through, the site. For example, a 5 metres wide channel with 4:1 side slopes and a roughness of n = 0.04, a flow of 13m^3/s would have a depth of 1.1 metres and a velocity of 1.3 m/s.

The area shown as the railhead facility in Figure 9-30 is about 0.4 km^2; which equates to 10 % of the catchment upstream of the railhead facility and 5 % of the catchment draining to the haul road.

Developing the Apirnta Facility and associated railhead would result in an increase in impervious area, and potentially a corresponding increase in runoff from the site, though it is understood that the Proposal intention is to capture stormwater runoff from this site for reuse, such as dust suppression.

It is anticipated that this runoff would be intercepted for water quality treatment, which would have the additional benefit of attenuating flows and mitigating any increase in peak flows of volumes down to acceptable levels. The storage capacity for capturing all storm water could be significant for larger design events. The design requirements for this storage system are beyond the remit of this assessment and would be addressed in detailed design and later updated within the Proposal's draft Water Management Plan attached in Appendix Q.

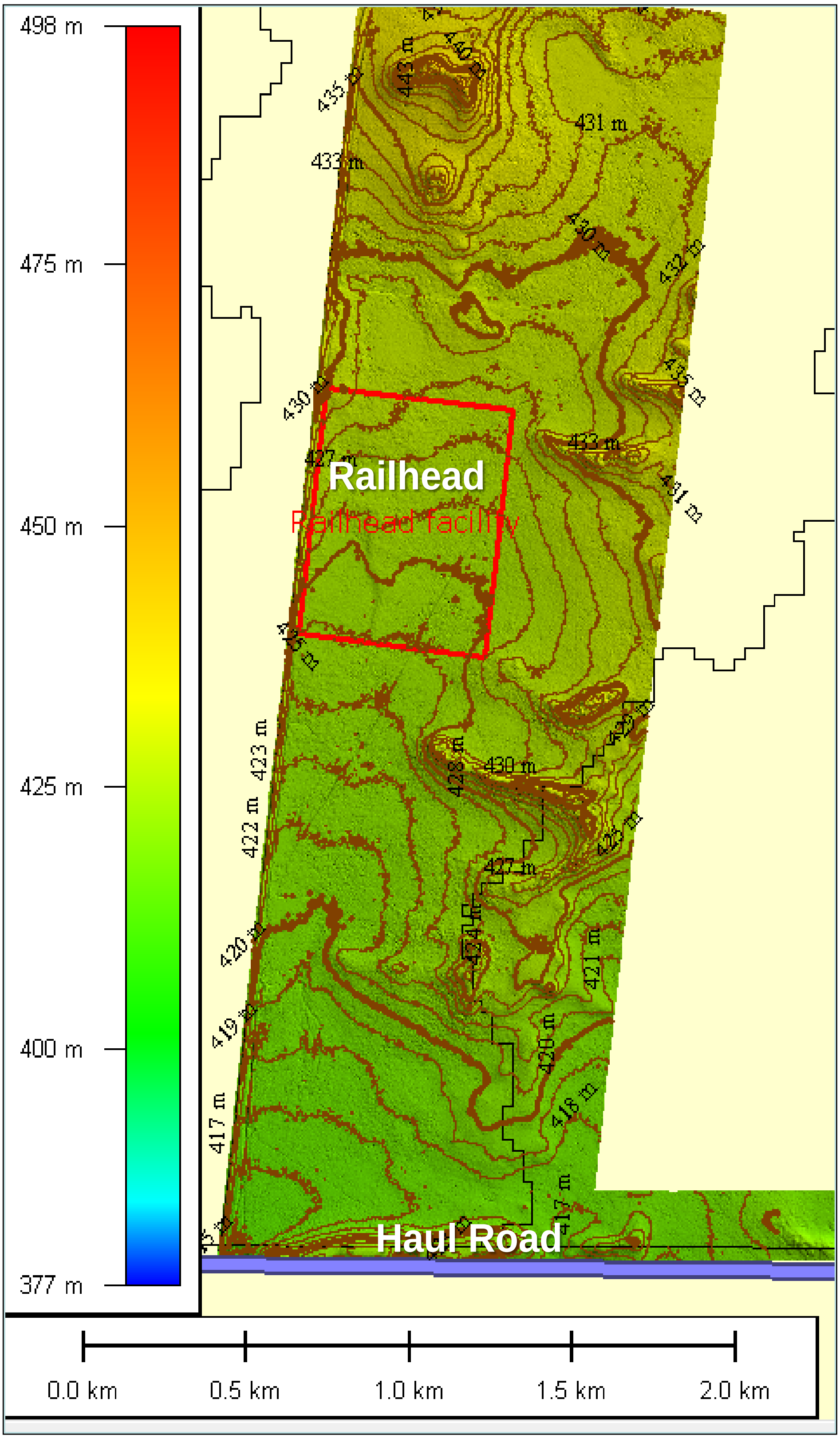


Figure 9-30 Topography at the proposed Apirnta Facility

Runoff from mine stockpiles

Uncontrolled sediment runoff from large stockpile can cause blockage of drainage systems, leading to increases in flood risk, maintenance costs for the stormwater infrastructure owner, road safety risks and mosquito issues. Sedimentation of waterways with coarse particulate matter could lead to increases in flood risk, channel instability, weed infestation and maintenance costs as well as loss of essential aquatic habitats.

The release of fine sediments, including salt laden sediments, into waterways adjacent to the Proposal have potential to increase the concentrations of particulate-bounds metals and nutrients, reduce light penetration and adversely affect the health of semi-aquatic life in temporary refuge pools.

Management measures to avoid and/or control unintentional release of sediments is detailed in Section 9.7.

9.5 Assessment of risk during operation

This section presents the potential impacts (both direct and indirect) on surface water during operation of the Proposal. Mitigation measures to avoid or reduce these impacts are discussed in Section 9.8

9.5.1 Direct impacts

The potential for direct impacts on surface waters during operation are considered to be the same issues raised as direct impacts during construction. Therefore, this section cross references to Section 9.4.1 for potential direct impacts during operation.

9.5.2 Indirect impacts

Section 9.4.2 provides a detailed assessment of flood risk during construction of the Proposal. The issues addressed in that section would also apply to indirect impacts during operation. In addition, the potential impacts of uncontrolled run-off from mine stock piles is also discussed in Section 9.4.2.

9.6 Assessment of risk during closure and rehabilitation

This section presents the potential impacts (both direct and indirect) on surface water during closure and rehabilitation of the Proposal. Mitigation measures to avoid or reduce these impacts are discussed in Section 9.7.

9.6.1 Direct impacts

The potential for direct impacts on surface waters during closure and rehabilitation of the Proposal are considered to be the same issues raised as direct impacts during construction. Therefore, this section cross references to Section 9.5.1 for potential direct impacts during closure and rehabilitation. Mitigation measures to avoid or reduce these impacts are discussed in Section 9.8 and in Appendix N7.9.

9.6.2 Indirect impacts

The potential for indirect impacts on surface waters during closure and rehabilitation of the Proposal are considered to be the same issues raised as direct impacts during construction. Therefore, this section cross references to Section 9.5.1 for potential direct impacts during closure and rehabilitation. Mitigation measures to avoid or reduce these impacts are discussed in Section 9.8 and in Appendix N7.9.

9.7 Mitigation and monitoring

Mitigation and management measures proposed to minimise the impacts on surface water during construction, operation, and closure and rehabilitation of the Proposal are listed in Table 9-16. These measures would be incorporated into the Sediment and Erosion Plan (Appendix L), Water Management Plan (Appendix Q) and the Rehabilitation Closure Plan (Appendix J) for the Proposal. These plans would be included into a Construction Environmental Management Plan and Operation Environmental Management Plan.

Table 9-16 Mitigation and management measures (surface water)

ID	Outcome	Mitigation/management measure	Timing
SW1	Management of floodwater draining towards the Chandler Facility from the Maryvale Hills upstream of the mine site.	Formalise drainage channels through or around the site so that upstream runoff does not cause flooding of the site, and so that it is not contaminated by site runoff or sedimentation (refer to Figure 9-31). Raise flood prone site infrastructure above surrounding ground level. Diversion channels should be designed according to best practice guidance including sizing and lining type (IECA, 2008). Estimates of water volumes generated during storm events at the three sites are given in the Flood and Hydrology Assessment for different return periods. These diversion channels would reduce the amount of "dirty water" requiring management, improve wet weather access to the sites and limit erosion and sediment mobilisation on the sites.	Detailed design and pre-construction
SW2	Improved water quality and attenuation of surface water flow.	Treat runoff to improve water quality resulting in an attenuation of flows, mitigating any increase in runoff peak flows or volumes.	Pre-construction
SW3	Movement or reconfiguration of Halfway Dam.	Investigate current and future use of the Halfway Dam. Develop proposals to move or reconfigure the dam and intake.	Pre-construction
SW4	Management of floodwater on Chandler Haul Road.	Manage floodwater by: • Raising the road above surrounding ground level to prevent flooding. • Installing culverts to pass flood flow and reduce/minimise upstream ponding. • Installing causeways over which floodwaters in excess of the design event	Pre-construction

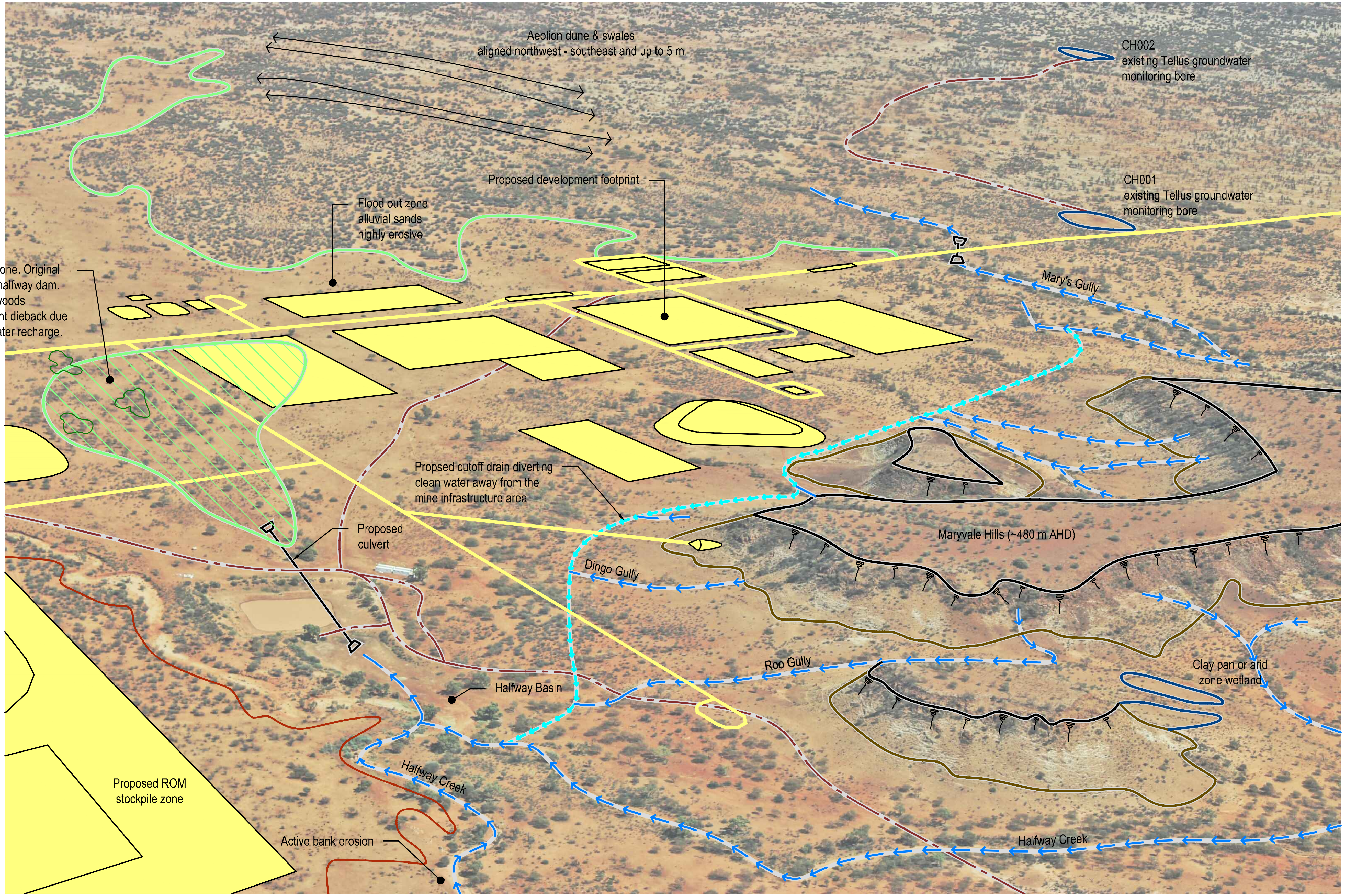
ID	Outcome	Mitigation/management measure	Timing
		can pass, but that raise the road above frequent flood levels. • Carrying out repairs, following flood events, as necessary.	
SW5	Minimisation of impacts from the Henbury Access Road at the Finke River crossing.	Limit the engineering required to cross the river.	Construction
SW6	No long term alterations to local hydrology.	Allow natural surface drainage to continue without interruption, where possible.	Construction
SW7	No long term alterations to local hydrology.	Avoid clearing or disturbance to watercourses or drainage depressions, where possible.	Construction
SW8	No long term alterations to local hydrology.	Avoid infrastructure developments in any watercourse or drainage depressions, where possible.	Construction
SW9	No long term alterations to local hydrology.	Ensure no impedance to natural creek flow, where possible.	Construction
SW10	No long term alterations to local hydrology.	Develop creek crossings to natural contours of creek bed.	Construction
SW10	No long term alterations to local hydrology.	Remove any concentrations points that would impede natural sheet flow.	Construction
SW12	No long term alterations to local hydrology.	Ensure minimal disturbance within watercourse buffer zones.	Construction
SW13	No long term alterations to local hydrology.	Leave large mature trees and shrubs, where possible.	Construction
SW14	No long term alterations to local hydrology.	Conduct routine inspection and maintenance of drains and watercourses.	Construction, operation, closure and rehabilitation
SW15	Avoidance of spills or accidental loss of hazardous materials.	Store hazardous waste within a bunded area sufficient to hold 110% of all material.	Construction, operation, closure and rehabilitation
SW16	Additional monitoring	Undertake level/flow measurements on Halfway Dam catchment and three to four catchments draining to the Chandler Haul Road or Chandler Facility, and including the catchment draining through the Apirnta Facility.	Pre-construction; construction, closure and rehabilitation.
SW17	Additional investigations during detailed design	Develop stormwater models of the Chandler Facility and Apirnta Facility, including the management of site runoff and the diversion /conveyance of floodwaters from upstream catchments around the sites.	Pre-construction
SW18	Additional investigations during detailed design	Develop two-dimensional modelling of flow paths and inundation in the mine lease area, including the 'washout area' to better understand the potential for floodwaters to reach the Hugh River near Titjikala. This investigation would include an assessment of infiltration and evaporation.	Pre-construction
SW19	Additional investigations during detailed design	Model flood risk and scour protection at the crossing of the Finke River.	Pre-construction

ID	Outcome	Mitigation/management measure	Timing
SW20	Additional investigations during detailed design	Model flood risk[7] of haul crossings (bridges, culverts, causeways) of drainage lines.	Pre-construction
SW21	Develop site specific water quality guidelines	Develop guidelines for both the no-flow and flowing phases. This could be done by collecting and interrogating monitoring data and developing conceptual, probabilistic and/or numerical models that incorporate flow, catchment and in-stream influences. This site-specific system would be developed during detailed design and as part of the Water Management Plan and relies on obtaining more site data.	Pre-construction
SW22	No offsite sedimentation	Improving water retention by slowing upstream surface flow and improving transmission properties, which provides more time for water to infiltrate	Pre-construction and Construction
SW23	Preventing erosion and sedimentation	Decreasing runoff rate and its velocity by providing appropriate surface drainage systems for safe conduct of water into pre-designed surface storage systems (Section 5	Pre-construction
SW24	No offsite pollution	Silty or oily water should not be used for dust suppression purposes, because this would transfer pollutants to the haul roads or generate more dust	Construction and operation
SW25	No offsite release of salt laden sediment	A clay lined drainage swale would be constructed around the perimeter of the run of mine salt stock pile to prevent offsite release of salt laden sediment	Operation
SW26	Prevent sediment from being tracked off site and onto the road	It is recommended that one entry / exit point to the Apirnta Facility and Chandler Facility sites should be established. If the site slopes towards this entry / exit, drainage and sediment control devices should be installed so that all sediment laden runoff can be fully contained and treated on-site	Pre-construction
SW27	Prevent sediment from being tracked off site and onto the road	Vehicles and construction equipment may require washing to prevent transfer and accumulation of mud on the haulage and access roads. Alternatively, manned jet washes or lance sprays could be used in a bunded area where the runoff can be contained and channelled to a treatment area, such as a settlement pond.	Construction and operation
SW28	Best practice in stockpile management	Soil and sand stockpiles need to be located within the compound and upslope of a sediment control. Impervious covers, filter fences, mulch berms or sediment fences.	Construction and operation
SW29	Prevent sediment runoff	Provision of a sediment trap, such as a mulch bank or a sediment fence, on the downslope boundaries of the Apirnta Facility, Chandler	Construction and operation and closure

[7] *The modelling would include an expanded suite of design events, including extreme events such as the Probable Maximum Flood*

ID	Outcome	Mitigation/management measure	Timing
		Facility and haulage roads is recommended. The mulch banks and sediment fencing should be positioned on the contour where possible	
SW30	Prevent sediment runoff	Onsite drop inlet pits and haulage road side entry pits should be protected prior to the commencement of works or as soon as constructed	Construction and operation and closure
SW31	Prevent sediment runoff	Buffer strips and vegetation filters should be employed, where practical, along the haulage road instead of sediment trapping structures (DLRM, 2013b)	Construction and operation and closure
SW32	Best possible location for the replacement of Halfway Dam	Make use of a similar gully or depression off-line from an adjacent to a creek with similar catchment area nearby on gently sloping terrain (<15%). A site investigation and selection should be undertaken to optimise the sustainable use of available water within a dam's catchment. The size of the catchment, soil and vegetation characteristics and path of surface run-off water determines what water is available within a catchment. Contour maps should be used to predict the path of rainfall and irrigation run-off within the dam's catchment.	Detailed design
SW33	Prevent the release of stormwater offsite	Stormwater from disturbed areas would not be discharged into down-gradient properties. To capture 'dirty' surface runoff, u-shaped earth banks would be constructed to pond water (DLRM, 2013b).	Detailed design and pre-construction
SW34	Provide habitat and prevent erosion	Retained vegetation can have the dual purpose of not only assisting in the settling of sediment from overland flows, but also provide a refuge for flora and fauna.	Construction and operation.
SW35	Prevent erosion and sedimentation	A disturbance plan would be prepared following the completion of detailed design. This would be done to retain or preserve as much of the existing vegetation as possible would be implemented, especially adjacent to drainage lines. Identification of any areas to be used as 'turn around' or laydown areas should be completed with an indication in the Construction Notes how cleared and NO-GO areas would be implemented e.g. GPS data provided to clearing contractors and areas flagged on the ground prior to any clearing activity.	Pre-construction
SW36	Retain riparian vegetation and prevent offsite release of sediments.	DLRM Land Clearing Guidelines provide information on required buffer zones for watercourses (DLRM, 2013a and DLRM, 2013b). To be effective as a sediment control, the area for retention should contain at least 80% ground cover. Buffer zones for the Apirnta Facility, Chandler Facility, and Haulage Roads have been developed based	Construction and operation

ID	Outcome	Mitigation/management measure	Timing
		on stream order. The bulk of buffer zones are 25 metres. The exception is Charlotte Creek, a second order stream, requiring a buffer of 50 metres.	



Legend

- Existing access road
- Watercourse
- Vegetation
- Indicative batter slope
- Proposed development footprint
- Proposed cutoff drain
- Proposed culvert

Figure 9-31
Proposed surface water diversions
within the mine infrastructure area

TELLUS

8.1 Summary of risk assessment

A summary of the risk assessment undertaken for surface water during construction, operation, closure and rehabilitation of the Proposal is provided in Table 9-17.

Table 9-17 Summary of surface water risk assessment

Hazard	Pre-mitigated risk			Post-mitigated risks			Risk outcome
	Likelihood	Consequence	Risk ranking	Likelihood	Consequence	Risk ranking	
Surface water ingress into decline area and general mining infrastructure	Likely	Moderate	High	Remote	Moderate	Low	Risk reduced
Contaminated surface water runoff off-site	Unlikely	Minor	Low	Remote	Minor	Low	Risk reduced
Salt dissolution and transport off-site	Likely	Major	High	Remote	Minor	Low	Risk reduced
Flash flooding into mine infrastructure area	Possible	Major	High	Remote	Moderate	Low	Risk reduced
Flooding of access/haul roads	Likely	Moderate	High	Possible	Minor	Medium	Risk reduced
Soil erosion leading to excess sedimentation in watercourses	Possible	Major	High	Remote	Minor	Low	Risk reduced
Contamination of regional surface waters (Hugh and Finke Rivers) through loss of containment	Remote	Major	Medium	Eliminated	Major	Eliminated	Risk reduced
Contamination of Hugh River through loss of containment	Remote	Major	Medium	Eliminated	Major	Eliminated	Risk reduced
Contamination of Finke River through loss of containment	Remote	Major	Medium	Eliminated	Major	Eliminated	Risk reduced
Altered hydrology surrounding Maryvale Hills	Almost certain	Moderate	High	Almost certain	Minor	High	Risk reduced
Altered hydrology surrounding the mine infrastructure area	Almost certain	Major	Extreme	Almost certain	Major	Extreme (Beneficial)	Risk same

9.8 Conclusion

The Proposal is located in a remote, dry and sparsely populated part of the NT. Watercourses in the region are generally dry for the majority of the year. Rainfall is seasonal, with the potential to generate large flood events. Due to generally dry antecedent conditions, the first rain to fall is needed to satisfy the moisture demand of the surface layer, with runoff generated from rain later in the storm.

Without suitable mitigation, flooding has the potential to affect the mine site, Apirnta railhead facility and haul road. Mitigation would be required to divert / convey flood flows from upstream catchments past the mine site and Apirnta railhead facility, and to manage stormwater falling on both sites. Stormwater management would include water quality treatment (not considered in this report).

Where the access and haul road crosses drainage lines, the road could be closed for up to 24 hours following the 100-year ARI 9-hour storm unless mitigation measures (, culverts or causeways) are incorporated into the road design. The crossing of the Finke River (between Apirnta and the Stuart Highway) could require a bridge, if that section of road is to be kept open.

If managed correctly, the remote location of the Proposal limits the potential for the associated infrastructure to adversely affect other communities or environment. The changes in hydrological regime due to the mine site development are unlikely to be observed at the Titjikala community near the Hugh River, as the affected area is a small percentage of the contributing catchment and hydrological connectivity from the proposed mine site area through the washout zone and dunes to the Hugh River is unlikely.

Due to the site's aridity and its isolated location, surface water data is not comprehensive. However, as outlined in Section 9.7, the proponent is committed to further field work, data collection and modelling to verify the results of research undertaken for this EIS.