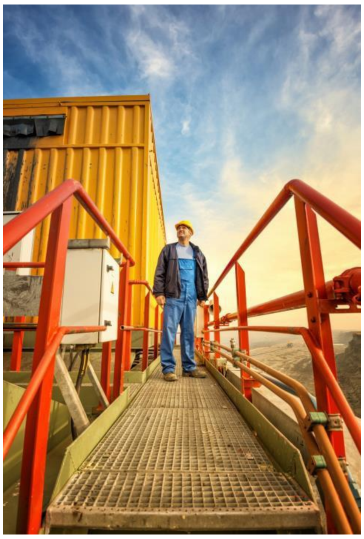


Taroborah Coal Project

Environmental Impact Statement

Section 4.5 – Environmental Values and Management of Impacts – Water

Prepared for:

Shenhuo International Group Pty Ltd

Table of Contents

LIST OF FIGURES

LIST OF PHOTO PLATES

LIST OF TABLES

4.5 WATER

The environmental values of both surface water and groundwater within and surrounding the Project site are described throughout this section. In addition, potential impacts are identified and described and appropriate mitigation measures are discussed.

4.5.1 Description of Environmental Values

4.5.1.1 Surface Waterways

An assessment of the surface water resources associated with the Project site was undertaken by ATC Williams Pty Ltd (ATC) during October and November 2013 and is provided in Appendix 13 as the *Surface Water Management Plan* (ATC 2013).

The following sections outline the findings of this assessment, including descriptions of the hydrological conditions associated with the Project site.

Regional Hydrological Characteristics

The Project site is located within the Fitzroy River Basin, whose catchment covers an area of 142,665 km^2 and includes the following rivers – Fitzroy, Comet, Connors, Dawson, Don, Nogoa and Mackenzie (refer to Figure 4.59 for the location of Queensland's River Basins and Figure 4.60 for regional catchment areas). This basin is the largest river catchment that flows to the eastern coast of Australia, commencing in the Carnarvon Ranges to the west and flowing to Keppel Bay in the east. The Burdekin River catchment area lies to the north of the Fitzroy River Basin, whilst the Burnett River catchment lies to the south.

A barrage has been developed on the Fitzroy River that provides fresh water for the city of Rockhampton. The Nogoa River's Fairbairn Dam and several weirs on the Mackenzie River provide water for irrigating a wide range of crops, coal mines and domestic use for the town of Emerald.

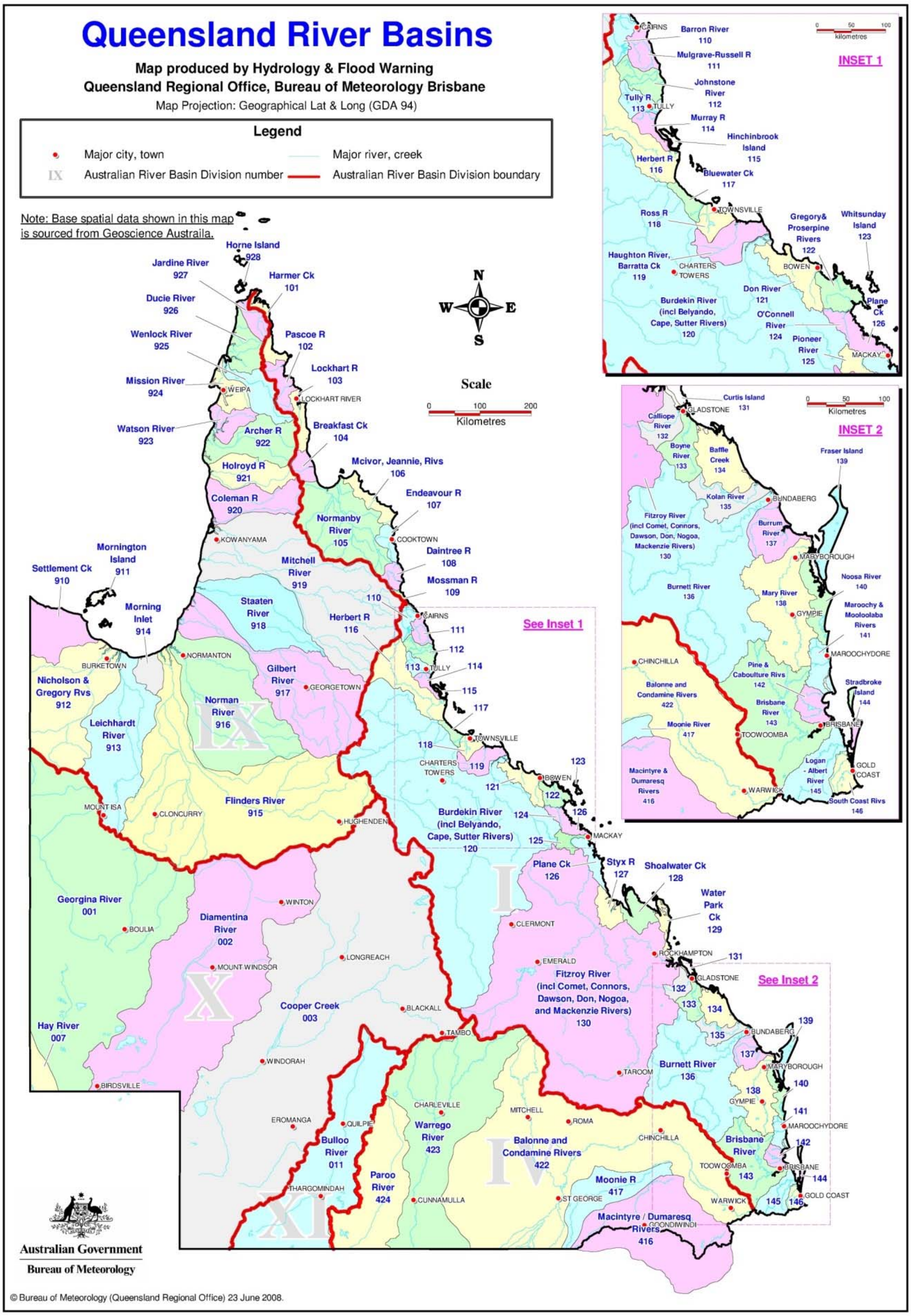


Figure 4.59 Queensland River Basins

Figure 4.60 Regional Catchment Areas and Telemetry Stations

Local Hydrological Characteristics

The following surface water resources exist within the Project site:

- Retreat Creek – runs west – east across the north of the Project site and flows into Theresa's Creek, before joining the Nogoa River;

- Centre Creek – originates to the west of MDL467 and discharges into Retreat Creek in the north-west corner of the Project site;

- Taroborah Creek – located in the south of the Project site, this creek flows in an east -- south easterly direction into St Helens Creek, which then flows into the Nogoa River; and

- Ephemeral drainage lines which drain into the above creeks.

Although ephemeral in nature, Retreat Creek, Centre Creek and Taroborah Creek are the drainage features within the Project site that are recognised as watercourses as defined under the *Water Act 2000*. The Project site is comprised of a gently undulating catchment area whose elevation ranges from 200m AHD to 280m AHD.

Lake Maraboon lies 5 km to the south of the Project site, discharges to the Nogoa River and represents Queensland's second largest lake. This lake was created in 1972 when the Fairbairn Dam was constructed and provides water to approximately 300 irrigators who farm in the Emerald area. The Project lies outside the catchment area for Lake Maraboon.

During the dry season, the drainage lines hold little to no water, but flow in response to significant rainfall events.

The surface watercourses and other drainage lines of the Project site are illustrated in Figure 4.61.

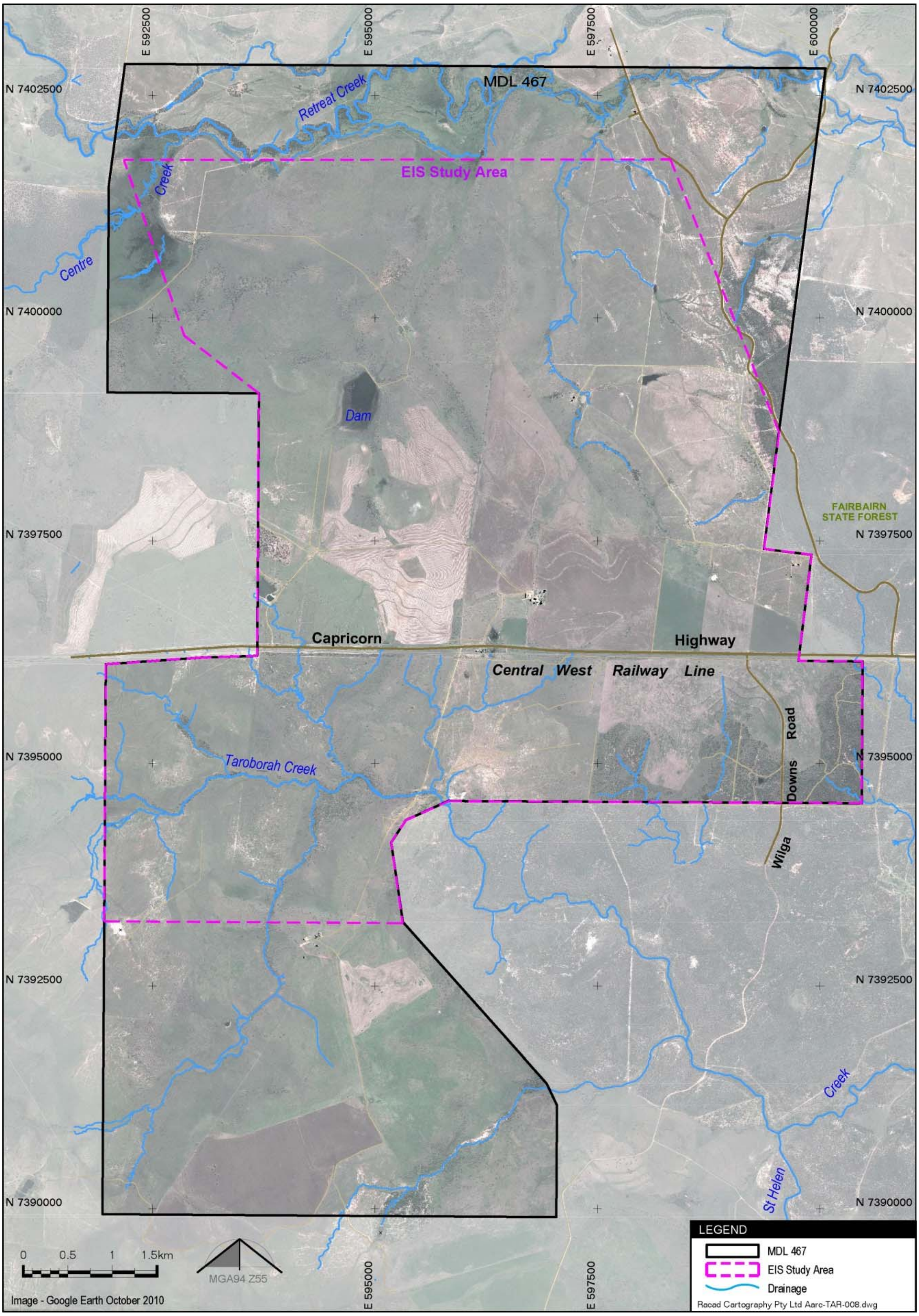


Figure 4.61 Surface Watercourses and Drainage Lines Located on the Project Site

Environmental Values

A rural landscape provides the setting for the Project site, where low-intensity cattle grazing and rain fed cropping are the main agricultural practices. Water for livestock watering is mainly obtained from local groundwater. Although most of the land within the Project site has been cleared, limited areas of remnant riparian vegetation persists. Fairbairn State Forest is located to the south-east and east of the Project site and is primarily used for forestry activities.

Schedule 1 of the EPP Water defines the Project site as a slightly to moderately disturbed ecosystem, with local surface water categorised as slightly disturbed.

Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water) outlines the Environmental Values (EV) and Water Quality Objectives (WQO) for the Lower Nogoa / Theresa Creek Sub-basin, in which the Project lies.

The EVs for the Nogoa River Sub-basin are presented in Table 4.35 while the physio-chemical WQOs are presented in Table 4.36 and Table 4.37 and are based upon *Queensland Water Quality Guidelines Central Coast Region*. The WQOs presented in Table 4.38 are based on the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council (ANZECC) 2000) default trigger values for physical and chemical stressors for tropical Australia for slightly disturbed ecosystems* in accordance with the *Environmental Protection (Water) Policy 2009 Nogoa River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Nogoa River Sub-basin* (EHP 2011).

In addition, toxicant WQOs presented in Table 4.39 have also been derived from ANZECC (2000) guidelines in accordance with the *Environmental Protection (Water) Policy 2009 Nogoa River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Nogoa River Sub-basin* (EHP 2011). The ANZECC (2000) guidelines provide a framework for gauging water quality. They set out general levels for a range of different elements found in waterways which are considered to be safe levels for environmental protection, essentially defining the water quality needed to protect the environmental values.

Table 4.35 Environmental Values for Nogoa River Sub-basin Waters

Water	Environmental Values											
	Aquatic ecosystems	Irrigation	Farm supply/use	Stock water	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual
Upper Nogoa main channel (upstream of Medway Creek junction)—developed areas	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Upper Nogoa southern tributaries—developed areas	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Upper Nogoa northern tributaries—developed areas	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Fairbairn Dam (storage)	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Fairbairn Dam catchment	✓		✓	✓		✓	✓	✓	✓	✓		✓
Upper Nogoa undeveloped areas	✓			✓		✓	✓	✓	✓	✓		✓
Upper Nogoa groundwaters	✓	✓	✓	✓			✓			✓	✓	✓
Lower Nogoa main channel (from Nogoa River junction with Comet River upstream to Fairbairn Dam)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Theresa Creek main channel (including dam)	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Lower Nogoa/Theresa Creek tributaries—developed areas	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Lower Nogoa/Theresa Creek—undeveloped areas	✓			✓		✓	✓	✓	✓	✓		✓
Lower Nogoa/Theresa Creek—groundwaters	✓	✓	✓	✓			✓			✓	✓	✓

Source: *Environmental Protection (Water) Policy 2009 Nogoa River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Nogoa River Sub-basin* (EHP 2011)

Table 4.36 Lower Nogoa / Theresa Creek Sub-basin Physio-chemical Water Quality Objectives to Protect Aquatic Ecosystems

Parameter	Water Quality Objective
Ammonia Nitrogen	< 10 µg/L [a]
Oxidised Nitrogen	< 60 µg/L [a]
Organic Nitrogen	< 420 µg/L [a]
Total Nitrogen	< 500 µg/L [a]
Filterable Reactive Phosphorus	< 20 µg/L [a]
Total Phosphorus	< 50 µg/L [a]
Chlorophyll a	< 5.0 µg/L [a]
Dissolved Oxygen	85%–110% saturation [a]
Turbidity	< 50 NTU [a]
Suspended Solids	< 10 mg/L[a]
pH	pH: 6.5–8.5 [b]
Conductivity - baseline	< 340 µS/cm [a]
Conductivity – high flow	< 250 µS/cm [b]
Sulphate	< 25 mg/L [b]

a) The values for these indicators are based on the QWQG Central Coast regional water quality guidelines.

b) The values for these indicators are based on sub-regional low flow water quality guidelines derived by the department as part of the process to establish EVs and WQOs in the Fitzroy Basin.

Table 4.37 Freshwater Lakes / Reservoirs Water Quality Objectives to Protect Aquatic Ecosystems

Parameter	Water Quality Objective
Ammonia Nitrogen	< 10 µg/L [a]
Oxidised Nitrogen	< 10 µg/L [a]
Organic Nitrogen	< 330 µg/L [a]
Total Nitrogen	< 350 µg/L [a]
Filterable Reactive Phosphorus	< 5 µg/L [a]
Total Phosphorus	< 10 µg/L [a]
Chlorophyll a	< 5 µg/L [a]
Dissolved Oxygen	90%–110% saturation [a]
Turbidity	1-20 NTU [a]
Suspended Solids	nd[a]
pH	pH: 6.5–8.0 [a]
Conductivity - baseflow	<250 µS/cm [b]

a) The values for these indicators are based on the QWQG Central Coast regional water quality guidelines.

b) The values for these indicators are based on sub-regional low flow water quality guidelines derived by the department as part of the process to establish EVs and WQOs in the Fitzroy Basin.

Table 4.38 Wetland Water Quality Objectives to Protect Aquatic Ecosystems

Parameter	Water Quality Objective
Ammonia Nitrogen	n/a
Oxidised Nitrogen	< 10 µg/L
Organic Nitrogen	n/a
Total Nitrogen	< 350-1200 µg/L
Filterable Reactive Phosphorus	< 5-25 µg/L
Total Phosphorus	< 10-50 µg/L
Chlorophyll a	< 10 µg/L
Dissolved Oxygen	90%–120% saturation
Turbidity	2-200 NTU
Suspended Solids	n/a
pH	pH: 6.0–8.0
Conductivity - baseflow	90-900 µS/cm

Toxicant water quality objectives use both, the 95% aquatic ecosystems protection level for slightly to moderately disturbed ecosystems and livestock drinking water guidelines from the ANZECC (2000) Guidelines outlined in Table 4.39.

Table 4.39 Toxicant Water Quality Objectives

Parameter	Unit	ANZECC (2000) Aquatic Ecosystems (95% species protection)	ANZECC (2000) Livestock Drinking Water
Aluminium (Al)	mg/L	0.055	5.0
Arsenic (As)	mg/L	0.013	0.5
Boron (B)	mg/L	0.37	5.0
Copper (Cu)	mg/L	0.0014	1.0
Cadmium (Cd)	mg/L	0.002	0.01
Chromium (Cr)	mg/L	0.001	1.0
Cobalt (Co)	mg/L	n/a	1.0
Iron (Fe)	mg/L	n/a	n/a
Lead (Pb)	mg/L	0.0034	1.0
Manganese (Mn)	mg/L	1.9	n/a
Nickel (Ni)	mg/L	0.011	1.0
Selenium (Se)	mg/L	0.011	0.02
Zinc (Zn)	mg/L	0.008	20

Wetland Values

Wetlands in Queensland are defined in *Wetland Mapping and Classification Methodology, Overall framework Version 1.2* (EPA 2005), where the riparian zone occurs below the level of saturation.

The EHP wetlands that have been mapped within the Project site are presented in Figure 4.62 (Queensland Wetland Mapping Version 2.0) and include the following wetland features:

- Remnant Regional Ecosystem (51 to 80 % wetland) along Retreat Creek;
- Lacustrine Dam located in the west central portion of the Project site; and
- Limited areas of Palustrine wetlands to the north and north-west of the Project site.

The ecological values of these wetlands were generally considered to be low due to grazing pressures and the fact that no flora or fauna of conservation significance were identified at these locations. Details of this assessment are provided in the following.

The *Environmental Protection Regulation 2008* (s81A) states that the environmental values of wetlands are the qualities that support and maintain:

(a) the health and biodiversity of the wetland's ecosystems;

(b) the wetland's natural state and biological integrity;

(c) the presence of distinct or unique features, plants or animals and their habitats, including threatened wildlife, near threatened wildlife and rare wildlife under the *Nature Conservation Act 1992*;

(d) the wetland's natural hydrological cycle;

(e) the natural interaction of the wetland with other ecosystems, including other wetlands.

The Project site is located in the Lower Nogoa / Theresa Creek Sub-basin of the Fitzroy River Basin. Wetland systems on the site have been noted by field ecologists for their Moderate to Good aquatic habitat quality and their importance as permanent and semi-permanent water sources in a region characterised by ephemeral watercourses.

Lacustrine Wetlands

Two lacustrine wetlands (created by dams) were mapped on the Project site. Neither is consistent with any vegetation community under Queensland's Regional Ecosystem framework. The larger dam in the central west of the Project site was found to support substantial and complex habitat for fauna, with little evidence of erosion due to an abundance of vegetation both in and surrounding the dam.

Permanent waterbodies on the Project site are likely to provide important habitat for a number of common amphibian species, particularly given the ephemeral nature of watercourses and floodplain wetlands. The larger lacustrine wetland in the central west area of the site provides the only source of permanent water. This dam has been scored as Medium under the Aquatic Conservation Assessment "ACA".

Palustrine Wetlands

One large, ephemeral palustrine wetland was identified in the north-west of the Project site, incorporating two smaller palustrine wetlands mapped by EHP on wetlands mapping. These smaller wetlands have been scored as Medium under the ACA.

During the dry season survey, only a small quantity of water was evident. The wetland is considered to support good aquatic habitat by field ecologists, with evidence of variation in substrate and cover elements. Vegetation is dominated by grass species, which vegetate the banks of the wetland.

Some vegetation communities on the Project site have been noted by field ecologists for their potential to utilise groundwater. However, vegetation associated with palustrine wetlands on the site is limited to shrub and groundcover species, reducing the likelihood for groundwater dependence.

Remnant Regional Ecosystems Associated with Wetlands

A close association was noted between palustrine wetlands and REs along Retreat Creek in the north of the Project site. These REs are considered to be 51-80% wetland and are typically River Red Gum Riparian Woodland (RE 11.3.25 – *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines) with a small segment (26.2 ha) of River Teatree Riparian Woodland (RE 11.3.3a – Riverine wetland or fringing riverine wetland/ *Melaleuca bracteata* woodland on alluvial plains).

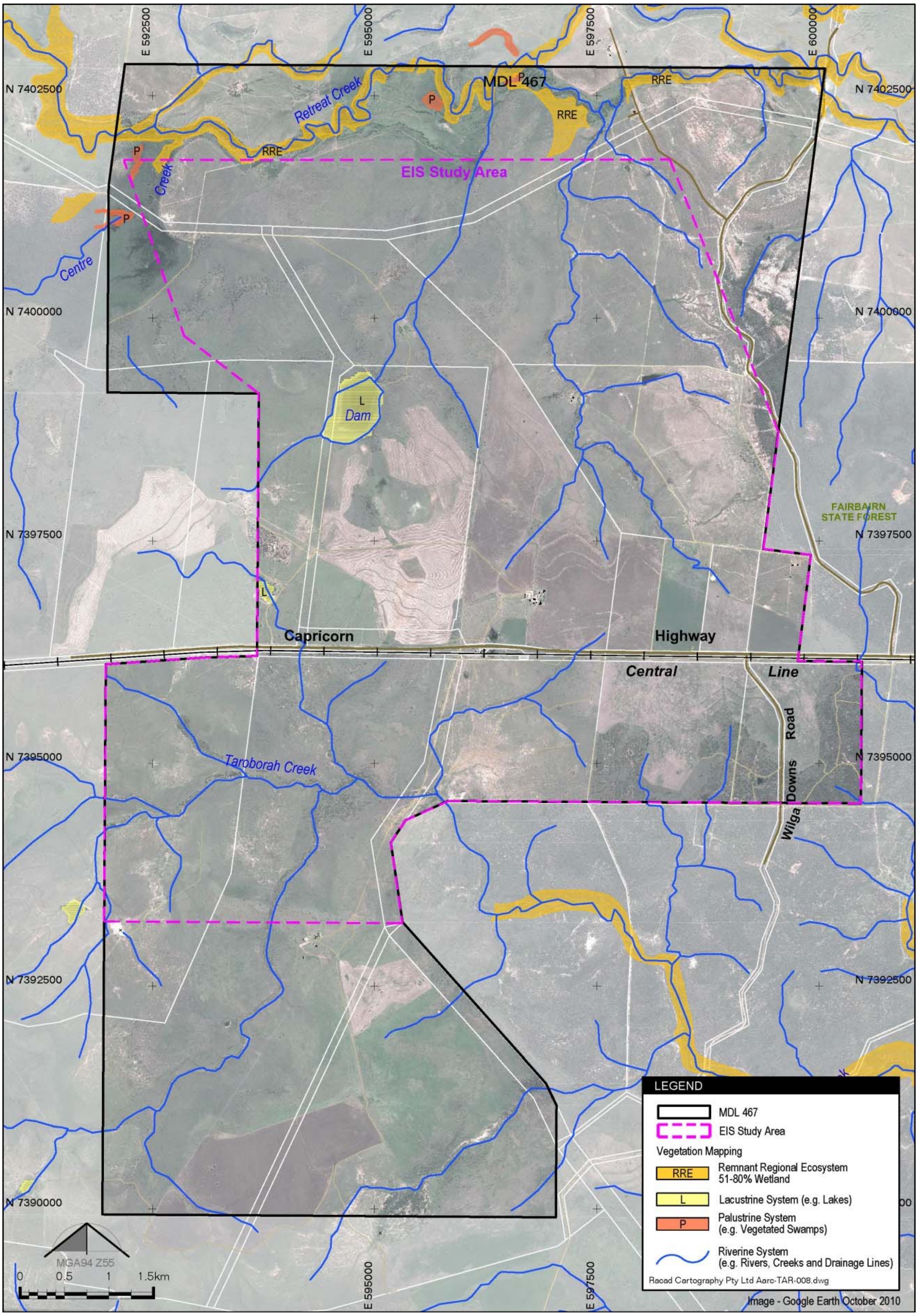
While Retreat Creek itself is not considered likely to receive surface expressions of groundwater, measured groundwater levels in the vicinity of Retreat Creek are approximately 6-10 mbgl. Deep-rooted vegetation species, such as Eucalypt species of RE 11.3.25, therefore have the potential to utilise sub-surface groundwater.

Waterholes

A few semi-permanent waterholes exist within the Project site, although some of these may become dry at certain times of the year. These areas should be monitored pre- and post-wet season, with the emphasis upon water quality and invertebrate fauna. This is in recognition of their importance and high conservation value to the ecology of the region. These waterholes are vital refuges to the aquatic biota, and in the dry season, may be the only available watering points for wildlife.

Habitat Quality

Water bodies on the Project site, including watercourses and dams, hold both permanent and temporary aquatic habitats for native fish species, and may provide habitat for breeding and dispersal during periods of high flow. The habitat assessment revealed that most wetlands were characterised as providing relatively good aquatic habitat. Some wetlands and dams received lower scores, falling into the Moderate category. These sites were found to be ephemeral / not flowing, lacking in aquatic habitat variability, and exhibited indications of bank instability.



Source: Queensland Wetland Mapping

Figure 4.62 EHP Mapped Wetlands on the Project Site

Creek Disturbance

No creek diversions are required for the Project, however, underground mining in the north of the Project site will result in limited land subsidence, and the water bodies and ephemeral drainage systems that run across these areas are expected to experience changes in topography.

The pre-mining physical characteristics of these water bodies and ephemeral drainage systems have been recorded, so that any changes in these systems that arise as a result of underground mining can be identified and suitable remedial actions conducted where required.

The water bodies / drainage systems associated with the Project were identified during aquatic surveys and have been categorised into one of six communities (refer to Figure 4.63). Two of these communities, recorded below and illustrated in Figure 4.63, are associated with underground land subsidence and exhibit the following geomorphic characteristics:

- Community 4 – Lacustrine system (pastoral dam): This dam possesses water all year round and includes deep water habitats. The gently sloping banks are in good condition and dominated by tree and shrub cover. Sediment samples collected from this location were found to comprise mainly of gravels and clays, with little sand present (refer to Photo Plate 4.13 and Photo Plate 4.14); and

- Community 6 – Silver-leaved Ironbark Open Woodland (RE 11.3.6): this creek is fed by a spring and flowing water was recorded during the dry season. A variety of in-stream habitats exist such as pools, runs and riffles which support a wide variety of habitats. Although a small amount of bank erosion was evident, channel scouring was found to be minimal. The banks of the creek were found to be in good condition and dominated by grass species. The creek sediment was mainly comprised of sand-sized particles, with equal amounts of clay and gravel present (refer to Photo Plate 4.15 and Photo Plate 4.16).

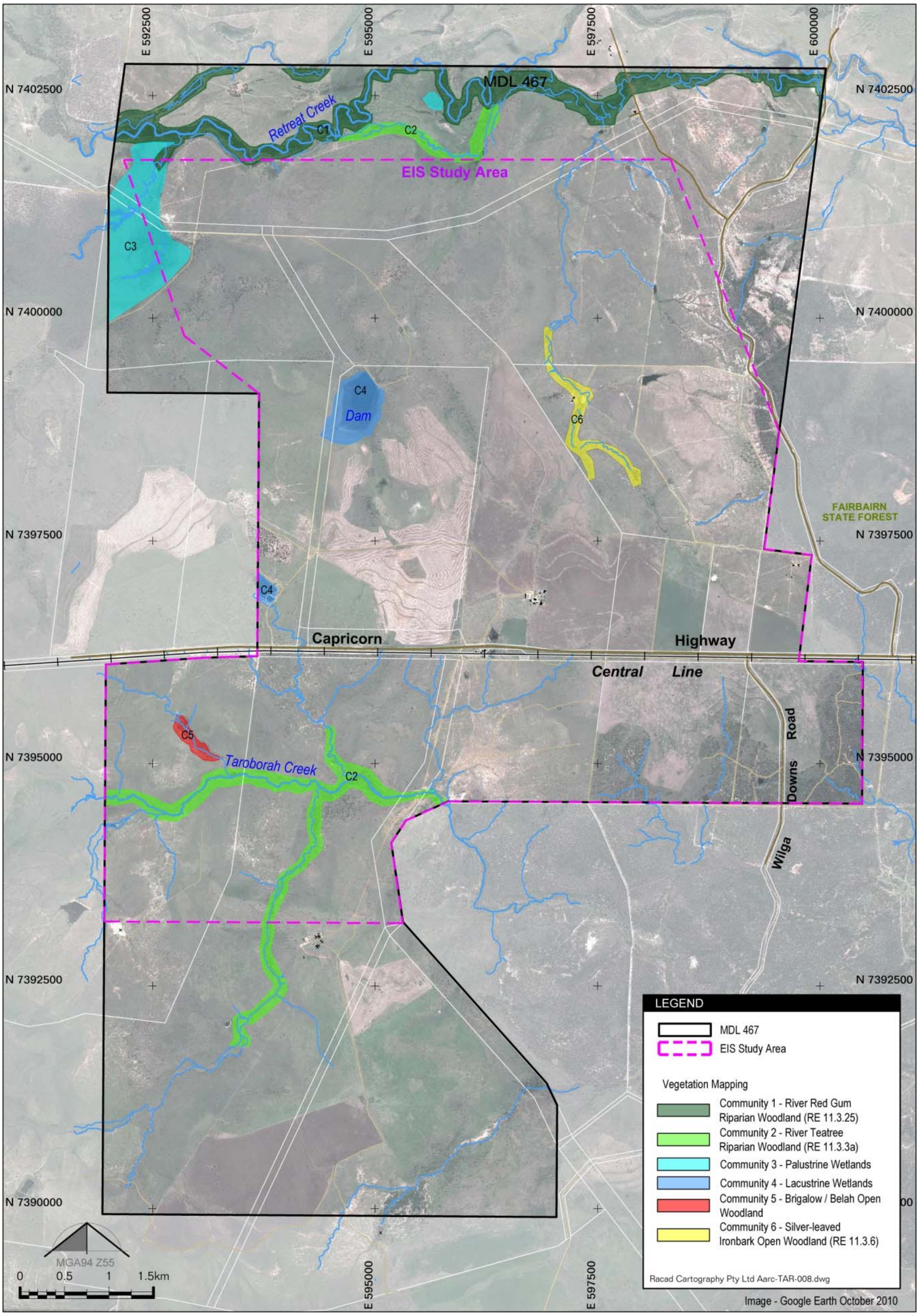


Figure 4.63 Water Bodies and Drainage Systems Associated with the Project

Photo Plate 4.13 **Community 4 – Lacustrine System (Pastoral Dam)**

Photo Plate 4.14 **Community 4 – Lacustrine System (Pastoral Dam)**

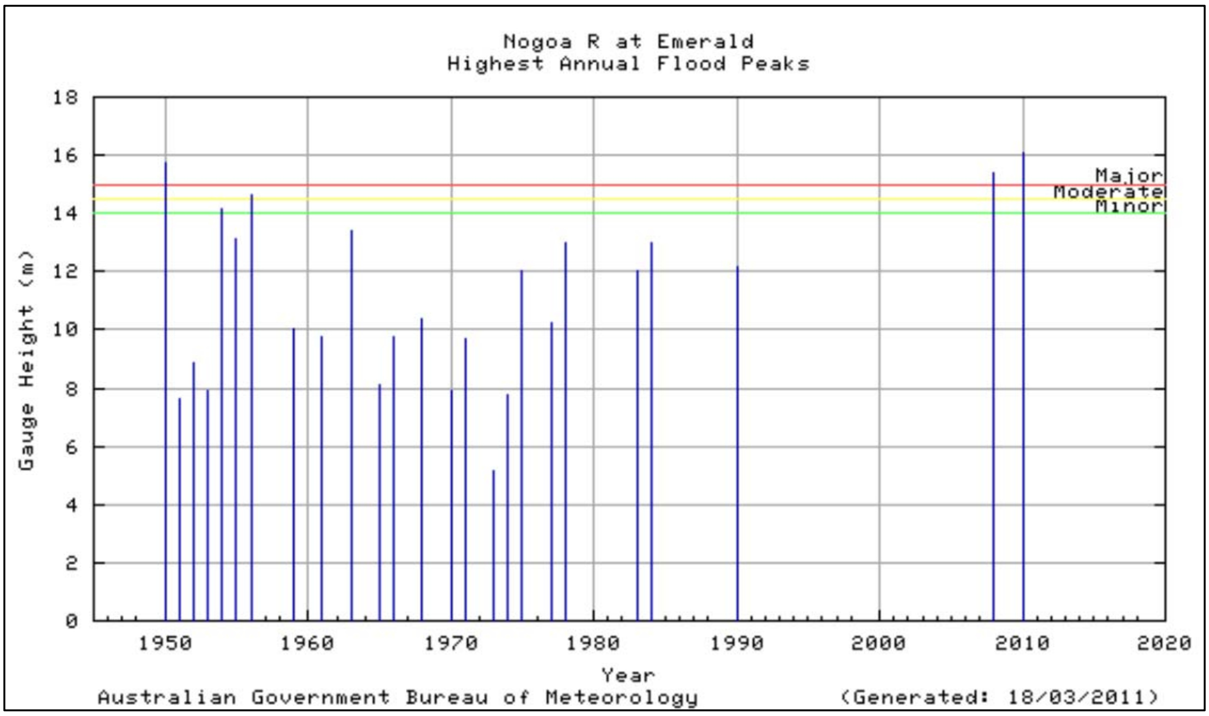
Photo Plate 4.15 Community 6 – Silver-leaved Ironbark Open Woodland (RE 11.3.6) Creek Bed

Photo Plate 4.16 Community 6 – Silver-leaved Ironbark Open Woodland (RE 11.3.6)

Flooding

History

The flooding of Taroborah Creek and its associated tributaries pose the main risk to mine infrastructure inundation. As there are no stream gauges in Taroborah Creek, no historical flooding data was identified for this surface water course. A review of previous floods of the Nogoa River at Emerald (22 km from the Project site) indicates that three major floods have been recorded in the region since 1950 (Figure 4.64). One in 1950 which peaked at 15.7 m, one in 2008 which peaked at 15.36 m and the last major flood recorded was in 2010 which peaked at just over 16 m.



Source: *Flood Summary for the Nogoa River at Emerald* (BOM 2011).

Figure 4.64 Highest Annual Flood Peaks for the Nogoa River at Emerald

Modelling

A hydrological model was developed to estimate peak flows and hydrographs for the streams in the Taroborah Creek catchment. Typically flow estimates require flood frequency analysis, regional regression analysis, or rainfall/runoff modelling. As there are no stream gauges located on Taroborah Creek and the catchment area is relatively large (i.e. approximately 160 km^2), rainfall/runoff modelling was undertaken to determine flows within the catchment. Rainfall/runoff modelling also permits the model to be modified to include mine infrastructure (dams, drains, increased impervious area, etc.) to demonstrate the impact of mine development on flood events within the catchment and assess the effectiveness of mitigation measures.

Modelling was based upon a 1,000 year ARI 90 minutes flood duration event and creek hydraulics together with the Probable Maximum Flood (PMF) event, which was selected for the flood protection design of the final void. The 1,000 year flood extent was used to design the Taroborah site layout by ensuring that the site infrastructure is not within the 1,000 year flood extent. As the site layout has been designed to suit the 1 in 1,000 year flood event, additional analysis of lesser design events were

not included as a part of the flood study.

The flood modelling indicated that flooding was largely uncontained and overflows were to the north-east towards the opencut pit. Figure 4.65 and Figure 4.66 indicates the modelled flood extents for the 1,000 year ARI and PMF event respectively. The flood modelling results have influenced the layout of the Project's mine infrastructure in order to minimise the risk of infrastructure flooding during the life of the Project.

Potential impacts and mitigation strategies in relation to the modelled flood extents are described in Section 4.5.2.1.

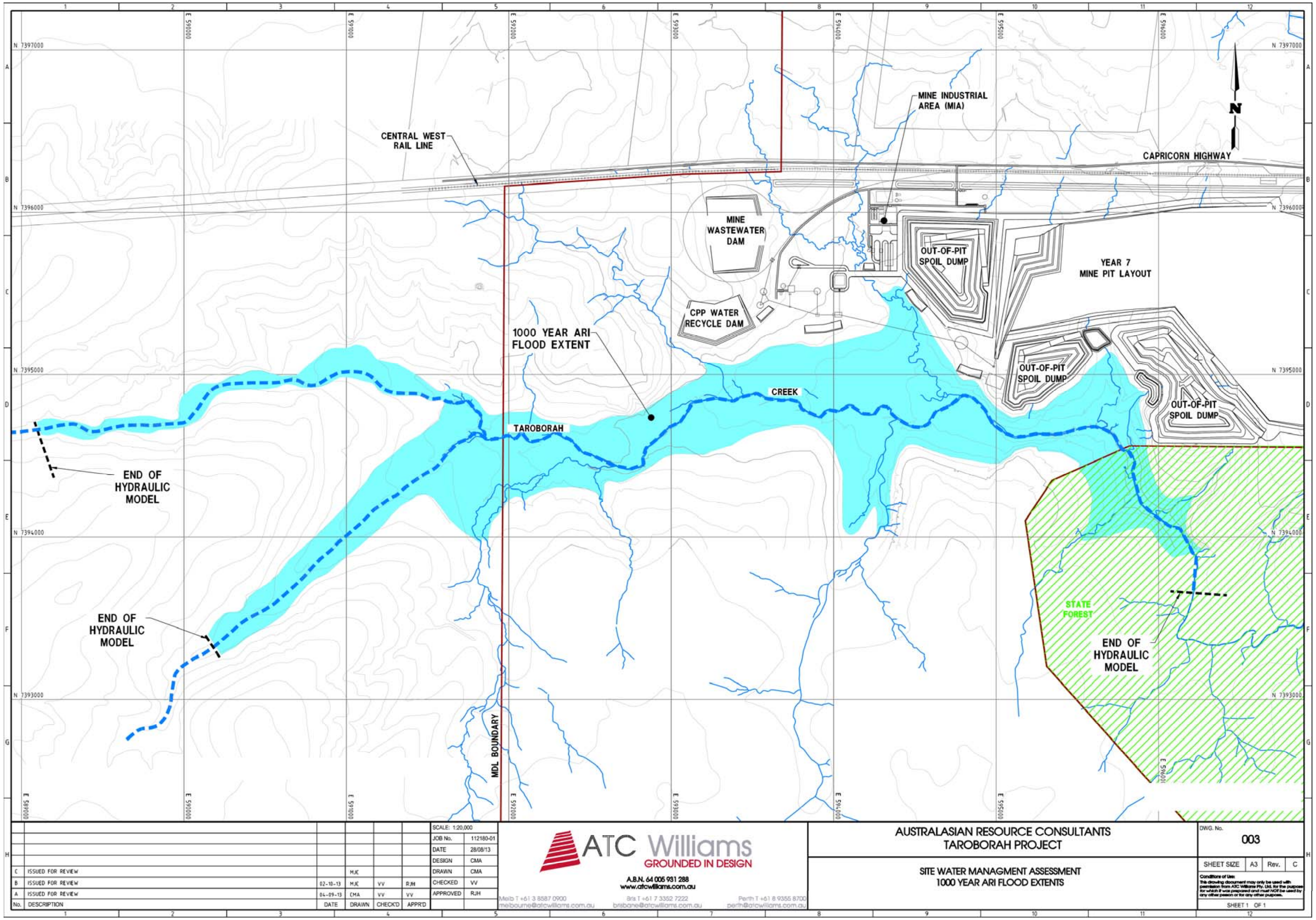


Figure 4.65 Taroborah Creek 1,000 Year ARI Flood Extent

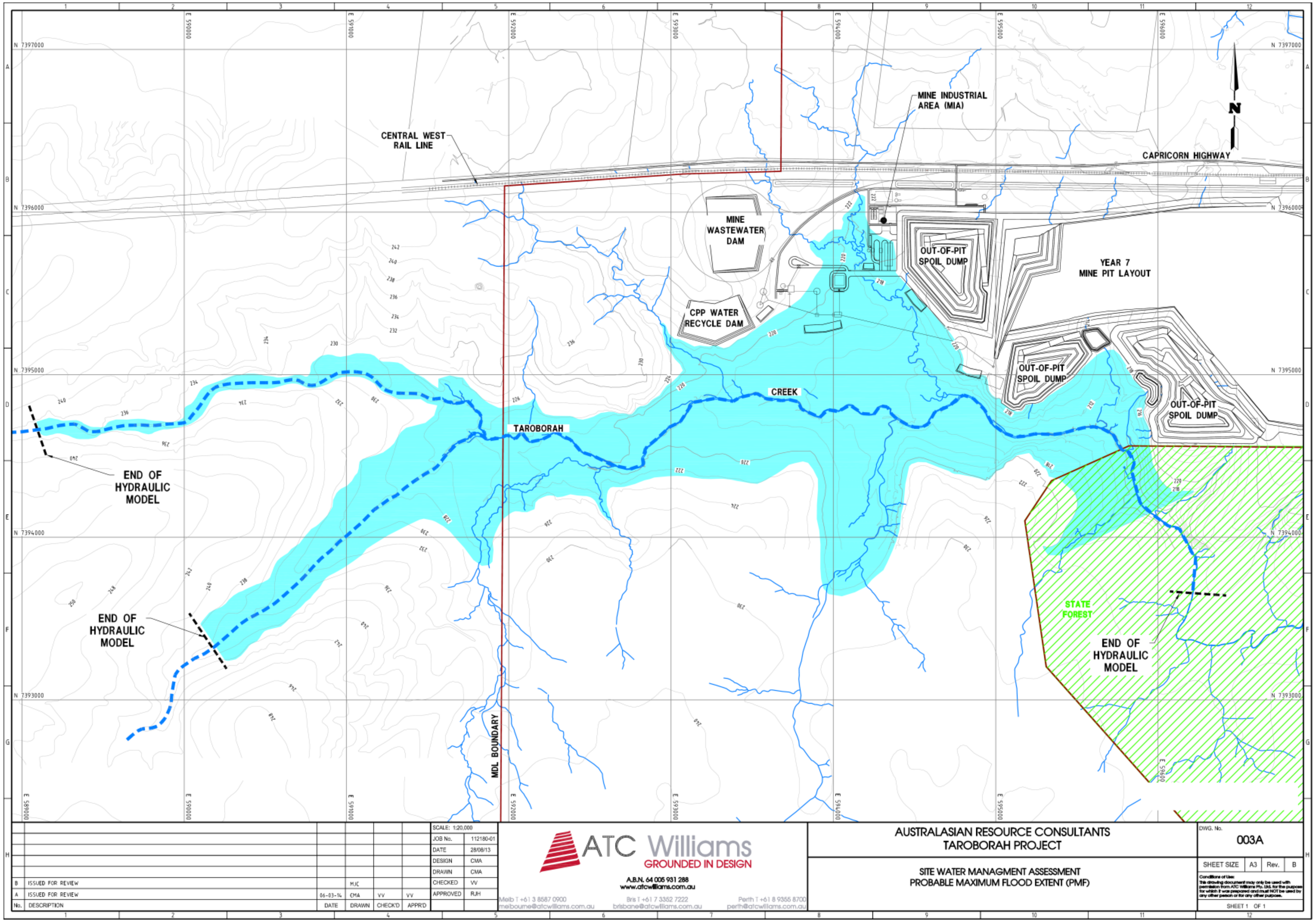


Figure 4.66 Taroborah Creek Probable Maximum Flood Extent

Present and Potential Water Users and Uses

The surface water stored in Lake Maraboon provides water to approximately 300 irrigators in the Emerald region for crop irrigation (cotton, citrus and other horticulture operations). The rate of flow from Lake Maraboon to the Nogoa River is regulated in order to supply a consistent water supply to downstream irrigators, as well as the township of Emerald.

Water from Fairbairn Dam is released down the Nogoa River to the Selma Weir for supply to the town of Emerald. Supplies are diverted by pipelines to the towns of Blackwater, Bluff, Tieri, Dysart and Middlemount. In addition to urban water supplies, water from Fairbairn Dam is also released to supply massive coal mining developments on the Bowen Basin.

The Nogoa Mackenzie Water Supply Scheme was established to meet agricultural and mining developments and the water requirements of associated urban communities in Central Queensland. Fairbairn Dam is the main storage for the scheme.

The central feature of the scheme is the conservation of water of the Nogoa River by Fairbairn Dam, near Emerald. The storage for the dam is known as Lake Maraboon, with the Selma, Bedford, Bingegang and Tartrus weirs below it on the Mackenzie River.

Under the *Fitzroy Basin Resource Operations Plan 2004* (amended July 2009) (Fitzroy ROP) the Nogoa Mackenzie Water Management Area is comprised of 14 zones; Mackenzie A through to Mackenzie N (refer to Table 4.40). 13 of these zones, specifically, Mackenzie A through to Mackenzie M are down stream of the Project site.

The supplemented water supply schemes including the Nogoa Mackenzie Water Management Area are illustrated in Figure 4.67.

Table 4.40 Zones that Apply to the Nogoa and Mackenzie Rivers

Zone	AMTD (km)	Description
Mackenzie A	310.3 – 339.3	Dawson River junction to Springton Creek junction
Mackenzie B	339.3 – 376.0	Springton Creek junction to Coolmaringa Gauging Station (GS130105)
Mackenzie C	376.0 – 429.5	Coolmaringa Gauging Station (GS130105) to Tartrus Weir
Mackenzie D	429.5 – 460.5	Tartrus Weir to effective upstream limit of Tartrus Weir
Mackenzie E	460.5 – 465.5	Effective upstream limit of Tartrus Weir to Isaac Mackenzie waterharvesting upstream limit
Mackenzie F	465.5 – 489.2	Isaac Mackenzie waterharvesting upstream limit to Bingegang Weir
Mackenzie G	489.2 – 513.0	Bingegang Weir to effective upstream limit of Bingegang Weir
Mackenzie H	513.0 – 548.8	Effective upstream limit of Bingegang Weir to Bedford Weir
Mackenzie I	548.8 – 585.8	Bedford Weir to effective upstream limit of Bedford Weir
Mackenzie J	585.8 – 611.5	Effective upstream limit of Bedford Weir to Comet River junction
Mackenzie K	611.5 – 615.1	Comet River junction to Comet Mackenzie waterharvesting upstream limit
Mackenzie L	615.1 – 649	Comet Mackenzie waterharvesting upstream limit to Theresa

Zone	AMTD (km)	Description
		Creek junction
Mackenzie M	649 – 685.6	Theresa Creek junction to Fairbairn Dam
Mackenzie N	685.6 – 737.5	Fairbairn Dam to upstream limit of Fairbairn Dam

a) AMTD - the Adopted Middle Thread Distance (AMTD) is the distance in kilometres along the middle of a stream from its mouth or junction with the main river;

b) Upstream limit – the upstream limit of an instream storage is the adopted upstream extent of the storage;

c) Effective upstream limit - the effective upstream limit of an instream storage is the upstream limit of where access to stored water is expected most of the time under typical operating conditions; and

d) Each zone includes those sections of tributaries where there is access to flow or pondage from the Nogoa or Mackenzie rivers.

Figure 4.67 Supplemented Water Supply Schemes

A total of 52 high priority water allocations are associated with the Nogoa Mackenzie Water Supply Scheme under the Fitzroy ROP. Table 4.41 identifies the quantity and purpose of the allocation within each zone.

Table 4.41 Details of High Priority Water Allocations Under the Nogoa Mackenzie Water Supply Scheme

Zone	Purpose		
	Any	Agricultural	Distribution Loss
Mackenzie G	4	-	-
Mackenzie H	2	-	-
Mackenzie I	12	-	-
Mackenzie L	1	-	-
Mackenzie M	4	9	1
Mackenzie N	-	19	-

a) 'Distributional Loss' is the nominated purpose for water allocations for distribution losses associated with the Selma and Weemah channel systems and Blackwater Pipeline;

b) 'Agriculture' is the nominated purpose for those existing authorisations that are primarily used for agricultural purposes;

c) 'Any' is the nominated purpose for all other uses of water

The high priority allocation for the nominated purpose of 'any' is mainly associated with the resource extraction industry in addition to Sunwater Pty Ltd and Emerald Shire Council. The majority of these high priority allocations span approximately 200 km between Mackenzie G (Bingegang Weir) and Mackenzie M (Fairbairn Dam).

The majority of allocations for agricultural purposes lie further upstream of the Nogoa River between Fairbairn Dam and the upper limit (Mackenzie N). The remaining agricultural allocations are within the Mackenzie M zone (between Theresa Creek Junction to Fairbairn Dam).

The total volume of supplemented water allocations in accordance with the Fitzroy ROP are outlined in Table 4.42 below.

Table 4.42 Total Volume of Supplemented Water Allocations under the Nogoa Mackenzie Water Supply Scheme

Zone	Medium Priority Water Allocation (ML)	High Priority Allocation (ML)
Mackenzie N	125,239	8,589
Mackenzie M	17,534	10,066
Mackenzie L	20,350	1,000
Mackenzie K	11,241	0
Mackenzie J	1,100	0
Mackenzie I	3,173	13,286

Zone	Medium Priority Water Allocation (ML)	High Priority Allocation (ML)
Mackenzie H	1,128	290
Mackenzie G	488	11,167
Mackenzie F	838	0
Mackenzie E	1,652	0
Mackenzie D	2,330	0
Mackenzie C	4,592	0
Mackenzie B	1,260	0
Total	190,925	44,398

Generally, landholder water usage in the region is likely to be supplemented by surface water capture and mains water supply (i.e. for farm supply use) and significant changes in surface water users or uses are not anticipated for the local area during the life of the mine.

However, no municipal, non-municipal, industrial or recreational uses of surface water are known within the Project site or the local area.

Surface Water Quality

The baseline quality of surface water across the Project site was assessed at both upstream reference sites and downstream sites that have the potential to be impacted by the Project once operations commence. Surface water sampling locations are illustrated in Figure 4.68. The surface water quality assessment was conducted from September 2011 to January 2013, with surface water samples collected at each sampling location in accordance with the EHP *Monitoring and Sampling Manual 2009 Version 2 September 2010*. A maximum of seven sampling events took place during the wet and dry season surveys, however, on average four samples were collected at each sampling location as insufficient water levels limited sample collection.

A total of six sites contained sufficient surface water during the dry season to allow for samples to be obtained and analysed. During the wet season, eleven sites contained sufficient surface water for samples to be obtained and analysed.

Surveys were conducted in September 2011, March 2012, June 2012, October 2012, November 2012, December 2012 and January 2013. Data sourced from the Bureau of Meteorology Emerald Airport Station (Station # 035264) shows September of 2011 was the driest month on record with no rainfall recorded. Several months leading up to the survey were also dry with June recording 12 mm and August recording 8 mm of rainfall in total.

The four weeks leading up to the surveys conducted in March and June of 2012 experienced the highest rainfall on record over the monitoring periods with 93.8 mm (February 2012) and 52.2 mm (May 2012) recorded respectively.

Similar to conditions found in September 2011, the conditions 8 weeks prior to the October 2012 sampling event were dry with only 5 mm of rainfall recorded during both August and September (2012).

Four weeks prior to the surveys conducted in November 2012, December 2012 and January 2013, a

total of 31 mm (October 2012), 25.6 mm (November 2012) and 40.6 mm (December 2012) of rainfall fell, respectively.

Water quality results were analysed for variations with flow (September 2011 and October 2012 were considered dry sampling periods) which indicated comparable concentrations for the majority of toxicants with no consistent trends detected.

Physio-chemical and biological water quality results at each sampling location including the Wetlands (refer to Table 4.43 and Table 4.44), the Pastoral Dams (refer to Table 4.47 and Table 4.48), Retreat Creek (refer to Table 4.51 and Table 4.52) and Taroborah Creek (refer to Table 4.55 and Table 4.56) have been compared to the Lower Nogoa / Theresa Creek WQOs, including the Freshwater Lakes / Reservoirs and Wetland components where applicable, in accordance with the *Environmental Protection (Water) Policy 2009 Nogoa River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Nogoa River Sub-basin* (EHP 2011), in addition to both the ANZECC (2000) Aquatic Ecosystem Guidelines for 95% species protection and the ANZECC (2000) Livestock Drinking Water Guidelines.

In addition, the results for dissolved and total heavy metal analysis for the Wetlands (refer to Table 4.45 and Table 4.46 respectively), the Pastoral Dams (refer to Table 4.49 and Table 4.50 respectively), Retreat Creek (refer to Table 4.53 and Table 4.54 respectively) and Taroborah Creek (refer to Table 4.57 and Table 4.58 respectively) have been compared to the ANZECC (2000) Aquatic Ecosystem Guidelines for 95% species protection and the ANZECC (2000) Livestock Drinking Water Guidelines.

Where these WQOs and guideline values have been exceeded is highlighted within each table as follows:

- Bold red numeral / white background cell – indicates an exceedance of the Lower Nogoa / Theresa Creek WQOs, the Freshwater Lakes/ Reservoirs WQOs or the Wetland WQOs, derived from ANZECC (2000) guidelines (where applicable);

- Bold red numeral / pink background cell – indicates a value exceeding the ANZECC (2000) Aquatic Ecosystem Guidelines for 95% species protection; and

- Bold red numeral / blue background cell – indicates a value exceeding the ANZECC (2000) Livestock Drinking Water Guidelines.

Please note that not all water quality parameters were tested for each sampling event. However, each summary table provided below outlines the number of analyses undertaken for each quality parameter at each site.

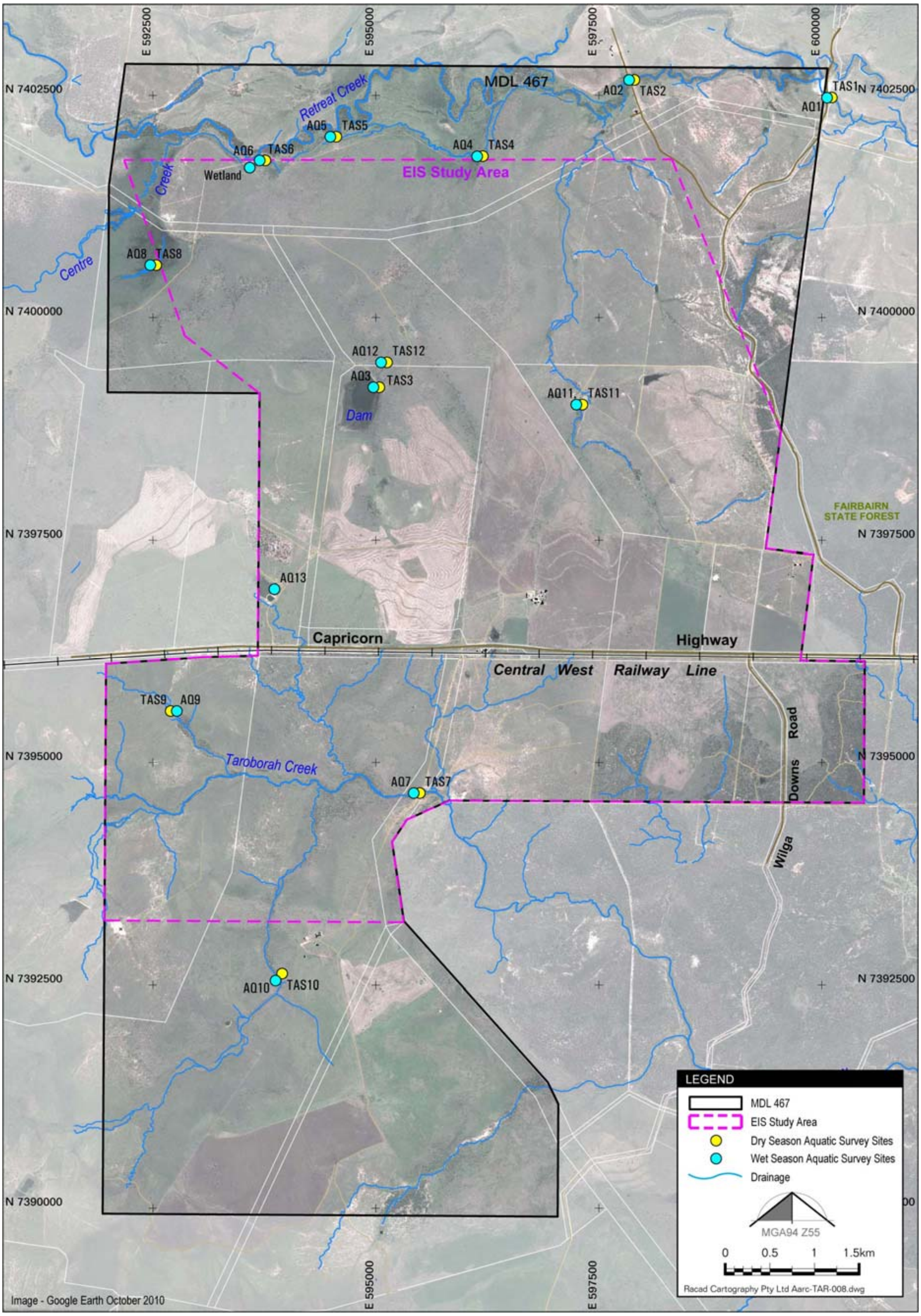


Figure 4.68 Surface Water Sampling Locations

Table 4.43 Wetlands – Summary of Surface Water Quality Chemical Analytical Results

Wetlands		Field pH	Field Temp (degrees Celsius)	Field Dissolved Oxygen (%)	Field Electrical Conductivity (µS/cm)	Field Turbidity (NTU)	Lab pH	Lab Turbidity (NTU)	Lab Electrical Conductivity (µS/cm)	Sulfate as SO4 (mg/L)	Total Recoverable Mercury (mg/L)
Wetland Water Quality Objectives[a]		6.0-8.0	n/a	90-120	90-900	2-200	6.0-8.0	2-200	90-900	n/a	n/a
ANZECC Aquatic Ecosystem Guideline		6.5-8.5	n/a	85-110	125-2200	n/a	6.5-8.5	n/a	125-2200	n/a	0.0006
ANZECC Livestock Drinking Water Guideline		n/a	n/a	n/a	n/a	1000	n/a	1000	n/a	1000	0.002
Site	Statistic										
AQ8 / TAS8	No. of Analyses	3	2	2	3	2	0	1	0	2	2
	Mean	7.46	24.45	90.00	581.67	529.17	-	165.00	-	1.00	0.0001
	Median	7.23	24.45	90.00	410.60	529.17	-	165.00	-	1.00	0.0001
	Min	6.94	17.10	51.00	224.40	150.35	-	165.00	-	1.00	0.0001
	Max	8.20	31.80	129.00	1110.00	908.00	-	165.00	-	1.00	0.0001
	80th Percentile	7.81	28.86	113.40	830.24	756.47	-	165.00	-	1.00	0.0001
	95th Percentile	8.10	31.07	125.10	1040.06	870.12	-	165.00	-	1.00	0.0001
AQ3 / TAS3	No. of Analyses	5	4	4	5	2	4	4	4	7	7
	Mean	9.14	24.40	80.15	249.82	146.03	9.22	178.50	266.25	1.57	0.0001
	Median	9.22	24.35	81.60	263.00	146.03	9.32	179.00	289.00	1.00	0.0001
	Min	8.47	17.10	67.90	175.40	115.05	8.69	167.00	158.00	1.00	0.0001
	Max	9.62	31.80	89.50	318.00	177.00	9.54	189.00	329.00	5.00	0.0001
	80th Percentile	9.35	27.48	85.12	284.40	164.61	9.50	186.00	313.40	1.00	0.0001
	95th Percentile	9.55	30.72	88.41	309.60	173.90	9.53	188.25	325.10	3.80	0.0001
AQ13 / TAS 13	No. of Analyses	2	2	2	2	1	0	1	0	2	2
	Mean	7.71	22.65	83.75	260.75	180.03	-	144.00	-	1.00	0.0001
	Median	7.71	22.65	83.75	260.75	180.03	-	144.00	-	1.00	0.0001
	Min	7.57	17.60	63.00	252.80	180.03	-	144.00	-	1.00	0.0001
	Max	7.84	27.70	104.50	268.70	180.03	-	144.00	-	1.00	0.0001
	80th Percentile	7.79	25.68	96.20	265.52	180.03	-	144.00	-	1.00	0.0001
	95th Percentile	7.83	27.20	102.43	267.91	180.03	-	144.00	-	1.00	0.0001
AQ12 / TAS12	No. of Analyses	1	0	0	1	1	1	1	1	2	2
	Mean	8.18	-	-	705.00	440.00	8.31	555.00	991.00	3.00	0.0001
	Median	8.18	-	-	705.00	440.00	8.31	555.00	991.00	1.00	0.0001
	Min	8.18	-	-	705.00	440.00	8.31	555.00	991.00	5.00	0.0001
	Max	8.18	-	-	705.00	440.00	8.31	555.00	991.00	4.20	0.0001
	80th Percentile	8.18	-	-	705.00	440.00	8.31	555.00	991.00	4.80	0.0001
	95th Percentile	8.18	-	-	705.00	440.00	8.31	555.00	991.00	3.00	0.0001

[a] derived from ANZECC (2000) default trigger values for physical and chemical stressors for tropical Australia for slightly disturbed ecosystems in accordance with the Environmental Protection (Water) Policy 2009 (EHP 2011).

Table 4.44 Wetlands – Summary of Surface Water Quality Chemical Analytical Results (continued)

Wetlands		Fluoride (mg/L)	Ammonia as N (µg/L)	Nitrite as N (mg/L)	Nitrate as N (mg/L)	Nitrite plus Nitrate as N (NOx) (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Nitrogen as N (TKN + NOx) (mg/L)	Total Phosphorus as P (mg/L)
Wetland Water Quality Objectives[a]		n/a	n/a	n/a	n/a	0.01	0.35-1.2	n/a	0.01-0.05
ANZECC Aquatic Ecosystem Values		n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.5
ANZECC Livestock Drinking Water Values		2	n/a	30	400	n/a	n/a	n/a	n/a
Site	**Statistic**								
AQ8 / TAS8	No. of Analyses	3	3	3	3	3	3	3	3
	Mean	0.20	0.13	0.01	0.02	0.02	4.43	4.43	0.58
	Median	0.20	0.13	0.01	0.02	0.02	1.40	1.40	0.29
	Min	0.10	0.09	0.01	0.02	0.02	1.30	1.30	0.24
	Max	0.30	0.16	0.01	0.02	0.02	10.60	10.60	1.22
	80th Percentile	0.26	0.15	0.01	0.02	0.02	6.92	6.92	0.85
	95th Percentile	0.29	0.16	0.01	0.02	0.02	9.68	9.68	1.13
AQ3 / TAS3	No. of Analyses	7	7	7	7	7	7	7	7
	Mean	0.19	0.07	0.01	0.03	0.03	1.06	1.07	0.04
	Median	0.20	0.06	0.01	0.03	0.03	1.10	1.10	0.04
	Min	0.10	0.04	0.01	0.01	0.01	0.60	0.70	0.01
	Max	0.30	0.15	0.01	0.08	0.08	1.60	1.60	0.08
	80th Percentile	0.20	0.08	0.01	0.04	0.04	1.20	1.20	0.04
	95th Percentile	0.28	0.13	0.01	0.07	0.07	1.48	1.48	0.07
AQ13 / TAS13	No. of Analyses	2	2	2	2	2	2	2	2
	Mean	0.15	0.07	0.01	0.01	0.01	1.15	1.15	0.56
	Median	0.15	0.07	0.01	0.01	0.01	1.15	1.15	0.56
	Min	0.10	0.04	0.01	0.01	0.01	1.10	1.10	0.06
	Max	0.20	0.10	0.01	0.01	0.01	1.20	1.20	1.05
	80th Percentile	0.18	0.09	0.01	0.01	0.01	1.18	1.18	0.85
	95th Percentile	0.20	0.10	0.01	0.01	0.01	1.20	1.20	1.00
AQ12 / TAS12	No. of Analyses	2	2	2	2	2	2	2	2
	Mean	0.35	0.08	0.01	0.03	0.03	1.55	1.55	0.05
	Median	0.35	0.08	0.01	0.03	0.03	1.55	1.55	0.05
	Min	0.30	0.06	0.01	0.02	0.02	1.40	1.40	0.03
	Max	0.40	0.09	0.01	0.03	0.03	1.70	1.70	0.07
	80th Percentile	0.38	0.08	0.01	0.03	0.03	1.64	1.64	0.06
	95th Percentile	0.40	0.09	0.01	0.03	0.03	1.69	1.69	0.07

[a]derived from ANZECC (2000) default trigger values for physical and chemical stressors for tropical Australia for slightly disturbed ecosystems in accordance with the Environmental Protection (Water) Policy 2009 (EHP 2011).

Table 4.45 Wetlands – Summary of Surface Water Quality Dissolved Metals Results

Wetlands		Dissolved Metals																	
		Al (mg/L)	As (mg/L)	Sb (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**0.013**	**n/a**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**0.5**	**n/a**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ8 / TAS8	No. of Analyses	2	2	2	1	2	1	2	2	1	2	1	2	3	3	3	2	1	3
	Mean	0.020	0.003	0.001	0.116	0.001	0.050	0.0001	0.001	0.002	0.001	0.210	0.001	0.015	0.001	0.003	0.005	**0.0001**	0.005
	Median	0.020	0.003	0.001	0.116	0.001	0.050	0.0001	0.001	0.002	0.001	0.210	0.001	0.016	0.001	0.004	0.005	**0.0001**	0.005
	Min	0.010	0.002	0.001	0.116	0.001	0.050	0.0001	0.000	0.002	0.001	0.210	0.001	0.006	0.001	0.002	0.000	**0.0001**	0.005
	Max	0.030	0.003	0.001	0.116	0.001	0.050	0.0001	0.001	0.002	0.001	0.210	0.001	0.022	0.002	0.004	0.010	**0.0001**	0.005
	80th Percentile	0.026	0.003	0.001	0.116	0.001	0.050	0.0001	0.001	0.002	0.001	0.210	0.001	0.020	0.002	0.004	0.008	**0.0001**	0.005
	95th Percentile	0.029	0.003	0.001	0.116	0.001	0.050	0.0001	0.001	0.002	0.001	0.210	0.001	0.021	0.002	0.004	0.010	**0.0001**	0.005
AQ3 / TAS3	No. of Analyses	5	5	6	5	6	4	6	6	4	6	5	5	6	6	6	6	3	6
	Mean	0.024	0.001	0.001	0.012	0.001	0.070	0.0001	0.001	0.001	0.001	0.054	0.001	0.009	0.001	0.003	0.002	**0.0004**	0.005
	Median	0.020	0.001	0.001	0.012	0.001	0.070	0.0001	0.000	0.001	0.001	0.050	0.001	0.007	0.001	0.003	0.000	**0.0001**	0.005
	Min	0.010	0.001	0.001	0.011	0.001	0.060	0.0001	0.000	0.001	0.001	0.050	0.001	0.004	0.001	0.002	0.000	**0.0001**	0.005
	Max	0.040	0.001	0.001	0.013	0.001	0.080	0.0001	0.001	0.001	**0.003**	0.070	0.001	0.021	0.003	0.003	0.010	**0.0010**	0.005
	80th Percentile	0.040	0.001	0.001	0.012	0.001	0.074	0.0001	0.001	0.001	**0.002**	0.054	0.001	0.010	0.001	0.003	0.000	**0.0006**	0.005
	95th Percentile	0.040	0.001	0.001	0.013	0.001	0.079	0.0001	0.001	0.001	**0.003**	0.066	0.001	0.018	0.003	0.003	0.008	**0.0009**	0.005
AQ13 / TAS 13	No. of Analyses	1	1	1	0	1	0	1	1	0	1	0	1	2	2	2	1	0	2
	Mean	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.001	-	0.001	0.024	0.001	0.009	0.010	-	0.005
	Median	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.001	-	0.001	0.024	0.001	0.009	0.010	-	0.005
	Min	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.001	-	0.001	0.006	0.001	0.006	0.010	-	0.005
	Max	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.001	-	0.001	0.042	0.001	0.012	0.010	-	0.005
	80th Percentile	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.001	-	0.001	0.035	0.001	0.011	0.010	-	0.005
	95th Percentile	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.001	-	0.001	0.040	0.001	0.012	0.010	-	0.005
AQ12 / TAS12	No. of Analyses	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
	Mean	0.025	0.001	0.001	0.021	0.001	0.060	0.000	0.000	0.001	0.001	0.190	0.001	0.075	0.001	0.003	0.000	**0.0001**	0.005
	Median	0.025	0.001	0.001	0.021	0.001	0.060	0.0001	0.000	0.001	0.001	0.190	0.001	0.075	0.001	0.003	0.000	**0.0001**	0.005
	Min	0.010	0.001	0.001	0.014	0.001	0.050	0.0001	0.000	0.001	0.001	0.060	0.001	0.013	0.001	0.003	0.000	**0.0001**	0.005
	Max	0.040	0.001	0.001	0.028	0.001	0.070	0.0001	0.000	0.001	0.001	0.320	0.001	0.136	0.001	0.003	0.000	**0.0001**	0.005
	80th Percentile	0.034	0.001	0.001	0.025	0.001	0.066	0.0001	0.000	0.001	0.001	0.268	0.001	0.111	0.001	0.003	0.000	**0.0001**	0.005
	95th Percentile	0.039	0.001	0.001	0.027	0.001	0.069	0.0001	0.000	0.001	0.001	0.307	0.001	0.130	0.001	0.003	0.000	**0.0001**	0.005

Table 4.46 Wetlands – Summary of Surface Water Quality Total Metals Results

Wetlands		Total Metals																	
		Al (mg/L)	As (mg/L)	Sb (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**0.013**	**n/a**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**0.5**	**n/a**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ8 / TAS8	No. of Analyses	3	3	3	2	3	2	3	3	2	3	2	3	3	3	3	3	2	3
	Mean	**1.887**	0.003	0.001	0.100	0.001	0.050	0.0002	**0.004**	0.004	**0.003**	4.125	0.001	0.256	0.001	0.007	0.007	**0.001**	0.007
	Median	**2.750**	0.002	0.001	0.100	0.001	0.050	0.0002	**0.003**	0.004	**0.003**	4.125	0.001	0.065	0.001	0.005	0.010	**0.001**	0.007
	Min	0.030	0.001	0.001	0.054	0.001	0.050	0.0001	0.001	0.002	0.001	2.770	0.001	0.020	0.001	0.005	0.001	**0.001**	0.005
	Max	**2.880**	0.005	0.001	0.145	0.001	0.050	0.0002	**0.008**	0.006	**0.006**	5.480	0.001	0.684	0.002	0.011	0.010	**0.001**	**0.009**
	80th Percentile	**2.828**	0.004	0.001	0.127	0.001	0.050	0.0002	**0.006**	0.005	**0.005**	4.938	0.001	0.436	0.002	0.009	0.010	**0.001**	**0.008**
	95th Percentile	**2.867**	0.005	0.001	0.140	0.001	0.050	0.0002	**0.008**	0.006	**0.006**	5.345	0.001	0.622	0.002	0.010	0.010	**0.001**	**0.009**
AQ3 / TAS3	No. of Analyses	6	6	7	6	7	5	7	7	5	7	6	6	6	6	6	7	6	6
	Mean	**0.943**	0.002	0.001	0.017	0.001	0.076	0.0001	**0.002**	0.001	**0.002**	0.487	0.001	0.050	0.001	0.005	0.003	**0.0004**	0.006
	Median	**0.335**	0.002	0.001	0.016	0.001	0.080	0.0001	0.001	0.001	**0.002**	0.405	0.001	0.046	0.001	0.004	0.000	**0.0001**	0.005
	Min	**0.130**	0.001	0.001	0.012	0.001	0.050	0.0001	0.000	0.001	0.001	0.100	0.001	0.020	0.001	0.002	0.000	**0.0001**	0.005
	Max	**3.670**	0.002	0.001	0.024	0.001	0.100	0.0001	**0.008**	0.002	**0.008**	1.220	0.001	0.104	0.001	0.009	0.010	**0.001**	0.008
	80th Percentile	**1.010**	0.002	0.001	0.019	0.001	0.092	0.0001	**0.003**	0.001	**0.002**	0.580	0.001	0.062	0.001	0.006	0.008	**0.001**	0.006
	95th Percentile	**3.005**	0.002	0.001	0.023	0.001	0.098	0.0001	**0.007**	0.002	**0.006**	1.060	0.001	0.094	0.001	0.008	0.010	**0.001**	0.008
AQ13 / TAS13	No. of Analyses																		
	Mean	**0.410**	0.001	0.001	0.086	0.001	0.080	0.0002	0.001	0.001	**0.003**	0.370	0.001	0.062	0.001	0.008	0.010	**0.001**	0.008
	Median	**0.410**	0.001	0.001	0.086	0.001	0.080	0.0002	0.001	0.001	**0.003**	0.370	0.001	0.062	0.001	0.008	0.010	**0.001**	0.008
	Min	**0.370**	0.001	0.001	0.086	0.001	0.080	0.0001	0.001	0.001	**0.002**	0.370	0.001	0.007	0.001	0.007	0.010	**0.001**	0.005
	Max	**0.450**	0.001	0.001	0.086	0.001	0.080	0.0003	0.001	0.001	**0.004**	0.370	0.001	0.116	0.001	0.009	0.010	**0.001**	**0.010**
	80th Percentile	**0.434**	0.001	0.001	0.086	0.001	0.080	0.0003	0.001	0.001	**0.004**	0.370	0.001	0.094	0.001	0.009	0.010	**0.001**	**0.009**
	95th Percentile	**0.446**	0.001	0.001	0.086	0.001	0.080	0.0003	0.001	0.001	**0.004**	0.370	0.001	0.111	0.001	0.009	0.010	**0.001**	**0.010**
AQ12 / TAS12	No. of Analyses	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Mean	**5.045**	0.001	0.001	0.094	0.001	0.095	0.0001	**0.006**	0.006	**0.004**	5.780	0.001	0.293	0.002	**0.019**	0.0002	**0.0001**	**0.009**
	Median	**5.045**	0.001	0.001	0.094	0.001	0.095	0.0001	**0.006**	0.006	**0.004**	5.780	0.001	0.293	0.002	**0.019**	0.0002	**0.0001**	**0.009**
	Min	**4.940**	0.001	0.001	0.050	0.001	0.060	0.0001	**0.004**	0.004	**0.002**	5.080	0.001	0.250	0.001	**0.013**	0.0002	**0.0001**	0.008
	Max	**5.150**	0.001	0.001	0.138	0.001	0.130	0.0001	**0.008**	0.008	**0.005**	6.480	0.001	0.336	0.002	**0.024**	0.0002	**0.0001**	**0.010**
	80th Percentile	**5.108**	0.001	0.001	0.120	0.001	0.116	0.0001	**0.007**	0.007	**0.005**	6.200	0.001	0.319	0.002	**0.022**	0.0002	**0.0001**	**0.010**
	95th Percentile	**5.140**	0.001	0.001	0.134	0.001	0.127	0.0001	**0.008**	0.008	**0.005**	6.410	0.001	0.332	0.002	**0.023**	0.0002	**0.0001**	**0.010**

Table 4.47 Pastoral Dams - Summary of Surface Water Quality Chemical Analytical Results

Pastoral Dams		Field pH	Field Temp (degrees Celsius)	Field Dissolved Oxygen (%)	Field Electrical Conductivity (µS/cm)	Field Turbidity (NTU)	Lab pH	Lab Turbidity (NTU)	Lab Electrical Conductivity (µS/cm)	Sulfate as SO4 (mg/L)	Total Recoverable Mercury (mg/L)
Nogoa River Water Quality Objectives – Freshwater Lakes/Reservoirs		6.5-8.0	n/a	90-110	<250	1-20	6.5-8.0	1-20	<250	n/a	n/a
ANZECC Aquatic Ecosystem Guideline		6.5-8.5	n/a	85-110	125-2200	n/a	6.5-8.5	n/a	125-2200	n/a	0.0006
ANZECC Livestock Drinking Water Guideline		n/a	n/a	n/a	n/a	1000	n/a	1000	n/a	1000	0.002
Site	**Statistic**										
AQ4 / TAS4	No. of Analyses	4	3	3	4	3	3	3	3	5	5
	Mean	8.25	26.87	78.57	856.75	548.79	7.83	480.67	1151.67	7.60	0.0001
	Median	8.30	24.90	66.00	917.50	543.00	8.11	603.00	1010.00	6.00	0.0001
	Min	8.05	21.60	65.80	211.00	141.37	7.26	170.00	995.00	1.00	0.0001
	Max	8.37	34.10	103.90	1381.00	962.00	8.13	669.00	1450.00	20.00	0.0001
	80th Percentile	8.33	30.42	88.74	1156.60	794.40	8.12	642.60	1274.00	9.60	0.0001
	95th Percentile	8.36	33.18	100.11	1324.90	920.10	8.13	662.40	1406.00	17.40	0.0001
AQ6 / TAS6	No. of Analyses	3	2	2	3	3	2	2	2	4	4
	Mean	8.07	24.10	64.55	1166.90	730.06	8.04	2349.50	3593.00	78.25	0.0001
	Median	8.15	24.10	64.55	290.80	194.84	8.04	2349.50	3593.00	55.50	0.0001
	Min	7.72	21.80	46.60	229.90	155.35	7.85	219.00	246.00	1.00	0.0001
	Max	8.34	26.40	82.50	2980.00	1840.00	8.23	4480.00	6940.00	201.00	0.0001
	80th Percentile	8.26	25.48	75.32	1904.32	1181.93	8.15	3627.80	5601.20	146.40	0.0001
	95th Percentile	8.32	26.17	80.71	2711.08	1675.48	8.21	4266.95	6605.30	187.35	0.0001

Table 4.48 Pastoral Dams - Summary of Surface Water Quality Chemical Analytical Results (continued)

Pastoral Dams		Fluoride (mg/L)	Ammonia as N (µg/L)	Nitrite as N (mg/L)	Nitrate as N (mg/L)	Nitrite plus Nitrate as N (NOx) (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Nitrogen as N (TKN + NOx) (mg/L)	Total Phosphorus as P (mg/L)
Nogoa River Water Quality Objectives – Freshwater Lakes/Reservoirs		**n/a**	**<10**	**n/a**	**n/a**	**<0.01**	**<0.35**	**n/a**	**<0.01**
ANZECC Aquatic Ecosystem Values		**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**0.5**
ANZECC Livestock Drinking Water Values		**2**	**n/a**	**30**	**400**	**n/a**	**n/a**	**n/a**	**n/a**
Site	**Statistic**								
AQ4 / TAS4	No. of Analyses	5	5	5	5	5	5	5	5
	Mean	0.14	0.13	0.01	0.03	**0.03**	**1.10**	1.12	**0.09**
	Median	0.10	0.09	0.01	0.02	**0.02**	**1.00**	1.00	**0.12**
	Min	0.10	0.05	0.01	0.01	0.01	**0.80**	0.80	0.01
	Max	0.20	0.33	0.01	0.07	**0.07**	**1.50**	1.60	**0.13**
	80th Percentile	0.20	0.14	0.01	0.04	**0.04**	**1.34**	1.36	**0.12**
	95th Percentile	0.20	0.28	0.01	0.06	**0.06**	**1.46**	1.54	**0.13**
AQ6 / TAS6	No. of Analyses	4	4	4	4	4	4	4	4
	Mean	0.20	0.18	0.01	0.06	**0.06**	**0.95**	0.98	**0.17**
	Median	0.20	0.06	0.01	0.04	**0.04**	**0.90**	0.95	**0.18**
	Min	0.20	0.05	0.01	0.01	0.01	**0.50**	0.50	**0.06**
	Max	0.20	0.55	0.01	0.15	**0.15**	**1.50**	1.50	**0.26**
	80th Percentile	0.20	0.26	0.01	0.08	**0.08**	**1.38**	1.38	**0.25**
	95th Percentile	0.20	0.48	0.01	0.13	**0.13**	**1.47**	1.47	**0.26**

Table 4.49 Pastoral Dams - Summary of Surface Water Quality Dissolved Metals Results

Pastoral Dams		Dissolved Metals																	
		Al (mg/L)	As (mg/L)	Sb (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**0.013**	**n/a**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**0.5**	**n/a**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ4 / TAS4	No. of Analyses	4	4	5	4	5	3	5	5	3	5	4	4	4	4	4	5	3	4
	Mean	0.038	0.002	0.001	0.101	0.001	0.053	0.0001	0.000	0.001	0.001	0.075	0.001	0.252	0.001	0.003	0.002	**0.00040**	0.005
	Median	0.030	0.002	0.001	0.105	0.001	0.050	0.0001	0.000	0.001	0.001	0.055	0.001	0.211	0.001	0.004	0.000	**0.00010**	0.005
	Min	0.010	0.001	0.001	0.073	0.001	0.050	0.0001	0.000	0.001	0.001	0.050	0.001	0.161	0.001	0.002	0.000	**0.00010**	0.005
	Max	**0.080**	0.002	0.001	0.120	0.001	0.060	0.0001	0.001	0.001	**0.002**	0.140	0.001	0.426	0.002	0.004	0.010	**0.00100**	0.005
	80th Percentile	**0.062**	0.002	0.001	0.118	0.001	0.056	0.0001	0.000	0.001	**0.002**	0.092	0.001	0.301	0.001	0.004	0.002	**0.00064**	0.005
	95th Percentile	**0.076**	0.002	0.001	0.120	0.001	0.059	0.0001	0.001	0.001	**0.002**	0.128	0.001	0.395	0.002	0.004	0.008	**0.00091**	0.005
AQ6 / TAS6	No. of Analyses	3	3	4	3	4	2	4	4	2	4	3	3	3	3	3	4	2	3
	Mean	0.027	0.006	0.001	0.236	0.001	0.050	0.0001	0.000	0.002	0.001	0.140	0.001	1.052	0.001	0.002	0.003	**0.001**	0.005
	Median	0.010	0.006	0.001	0.215	0.001	0.050	0.0001	0.000	0.002	0.001	0.130	0.001	1.080	0.001	0.002	0.000	**0.001**	0.005
	Min	0.010	0.002	0.001	0.084	0.001	0.050	0.0001	0.000	0.002	0.001	0.050	0.001	0.006	0.001	0.001	0.000	**0.001**	0.005
	Max	**0.060**	0.010	0.001	0.408	0.001	0.050	0.0001	0.001	0.002	**0.003**	0.240	0.001	**2.070**	0.002	0.004	0.010	**0.001**	0.005
	80th Percentile	0.040	0.008	0.001	0.331	0.001	0.050	0.0001	0.001	0.002	**0.002**	0.196	0.001	1.674	0.002	0.003	0.004	**0.001**	0.005
	95th Percentile	0.055	0.010	0.001	0.389	0.001	0.050	0.0001	0.001	0.002	**0.003**	0.229	0.001	**1.971**	0.002	0.004	0.009	**0.001**	0.005

Table 4.50 Pastoral Dams - Summary of Surface Water Quality Total Metal Results

Pastoral Dams		Total Metals																	
		Al (mg/L)	As (mg/L)	Sb (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**0.013**	**n/a**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**0.5**	**n/a**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ4 / TAS4	No. of Analyses	4	4	5	4	5	3	5	5	3	5	4	4	4	4	4	5	4	4
	Mean	**0.590**	0.003	0.001	0.111	0.001	0.053	**0.0141**	**0.101**	0.002	**0.362**	1.108	0.001	0.421	0.002	0.005	0.002	**0.0003**	0.005
	Median	**0.405**	0.002	0.001	0.110	0.001	0.050	0.0001	**0.001**	0.002	**0.002**	0.995	0.001	0.402	0.002	0.004	0.000	**0.0001**	0.005
	Min	**0.210**	0.002	0.001	0.084	0.001	0.050	0.0001	0.001	0.001	**0.001**	0.720	0.001	0.256	0.001	0.003	0.000	**0.0001**	0.005
	Max	**1.340**	0.004	0.001	0.141	0.001	0.060	**0.0700**	**0.500**	0.003	**1.800**	1.720	0.001	0.624	0.002	0.008	0.010	**0.0010**	0.006
	80th Percentile	**0.860**	0.003	0.001	0.133	0.001	0.056	**0.0141**	**0.102**	0.003	**0.363**	1.330	0.001	0.512	0.002	0.006	0.002	**0.0004**	0.005
	95th Percentile	**1.220**	0.004	0.001	0.139	0.001	0.059	**0.0560**	**0.400**	0.003	**1.441**	1.623	0.001	0.596	0.002	0.007	0.008	**0.00087**	0.006
AQ6 / TAS6	No. of Analyses	3	3	4	3	4	2	4	4	2	4	3	3	3	3	3	4	3	3
	Mean	**0.610**	0.006	0.001	0.250	0.001	0.050	0.0001	0.0007	0.002	**0.002**	0.673	0.001	1.100	0.001	0.001	0.003	**0.0004**	0.007
	Median	**0.060**	0.006	0.001	0.207	0.001	0.050	0.0001	0.0003	0.002	0.001	0.050	0.001	1.180	0.001	0.001	0.000	**0.0001**	0.006
	Min	0.030	0.002	0.001	0.116	0.001	0.050	0.0001	0.0002	0.001	0.001	0.050	0.001	0.051	0.001	0.001	0.000	**0.0001**	0.005
	Max	**1.740**	0.010	0.001	0.427	0.001	0.050	0.0001	**0.002**	0.002	**0.004**	1.920	0.001	**2.070**	0.002	0.002	0.010	**0.0010**	**0.009**
	80th Percentile	**1.068**	0.008	0.001	0.339	0.001	0.050	0.0001	0.001	0.002	**0.003**	1.172	0.001	1.714	0.002	0.002	0.004	**0.0006**	0.008
	95th Percentile	**1.572**	0.010	0.001	0.405	0.001	0.050	0.0001	**0.002**	0.002	**0.004**	1.733	0.001	**1.981**	0.002	0.002	0.009	**0.0009**	**0.009**

Table 4.51 Retreat Creek and Tributaries - Summary of Surface Water Quality Chemical Analytical Results

Retreat Creek		Field pH	Field Temp (degrees Celsius)	Field Dissolved Oxygen (%)	Field Electrical Conductivity (µS/cm)	Field Turbidity (NTU)	Lab pH	Lab Turbidity (NTU)	Lab Electrical Conductivity (µS/cm)	Sulfate as SO4 (mg/L)	Total Recoverable Mercury (mg/L)
Nogoa River Water Quality Objectives		6.5-8.5	n/a	85-110	250-340	50	6.5-8.5	50	250-340	25	n/a
ANZECC Aquatic Ecosystem Guideline		6.5-8.5	n/a	85-110	125-2200	n/a	6.5-8.5	n/a	125-2200	n/a	0.0006
ANZECC Livestock Drinking Water Guideline		n/a	n/a	n/a	n/a	1000	n/a	1000	n/a	1000	0.002
Site	Statistic										
AQ1 / TAS1	No. of Analyses	4	3	3	4	2	1	2	1	4	4
	Mean	8.01	21.33	74.73	880.15	475.13	8.14	476.00	1150.00	54.00	0.0001
	Median	7.94	21.20	68.30	951.00	475.13	8.14	476.00	1150.00	64.00	0.0001
	Min	7.78	15.50	48.90	358.60	240.26	8.14	242.00	1150.00	1.00	0.0001
	Max	8.39	27.30	107.00	1260.00	710.00	8.14	710.00	1150.00	87.00	0.0001
	80th Percentile	8.16	24.86	91.52	1207.80	616.05	8.14	616.40	1150.00	73.80	0.0001
	95th Percentile	8.33	26.69	103.13	1246.95	686.51	8.14	686.60	1150.00	83.70	0.0001
AQ2 / TAS2	No. of Analyses	5	4	4	5	2	3	4	3	6	6
	Mean	7.73	23.48	57.15	1196.58	658.06	7.91	907.25	1448.00	5.00	0.0001
	Median	7.60	23.65	51.80	1670.00	658.06	7.92	900.00	1690.00	2.50	0.0001
	Min	7.39	16.60	9.70	233.30	156.11	7.80	159.00	814.00	1.00	0.0001
	Max	8.23	30.00	115.30	1875.00	1160.00	8.00	1670.00	1840.00	17.00	0.0001
	80th Percentile	8.01	28.08	91.18	1758.20	959.22	7.97	1376.00	1780.00	6.00	0.0001
	95th Percentile	8.18	29.52	109.27	1845.80	1109.81	7.99	1596.50	1825.00	14.25	0.0001
AQ5 / TAS5	No. of Analyses	4	3	3	4	3	2	2	2	4	4
	Mean	8.17	27.00	93.57	768.08	430.95	8.08	418.50	902.50	16.00	0.0001
	Median	8.12	26.60	78.70	857.00	468.00	8.08	418.50	902.50	17.50	0.0001
	Min	7.83	20.30	56.70	298.30	199.86	7.95	220.00	735.00	1.00	0.0001
	Max	8.61	34.10	145.30	1060.00	625.00	8.20	617.00	1070.00	28.00	0.0001
	80th Percentile	8.38	31.10	118.66	1057.00	562.20	8.15	537.60	1003.00	25.00	0.0001
	95th Percentile	8.55	33.35	138.64	1059.25	609.30	8.19	597.15	1053.25	27.25	0.0001
AQ11 / TAS11	No. of Analyses	5	4	4	5	3	4	4	4	6	6
	Mean	8.89	25.95	72.20	2302.20	1666.10	9.04	1430.00	2022.50	20.50	0.0001
	Median	8.95	27.10	56.30	2008.00	1417.00	8.98	1190.00	2050.00	20.50	0.0001
	Min	8.64	20.80	51.20	1797.00	1040.00	8.90	1040.00	1760.00	16.00	0.0001
	Max	9.08	28.80	125.00	3793.00	2541.31	9.31	2300.00	2230.00	24.00	0.0001
	80th Percentile	8.98	28.38	86.30	2385.00	2091.59	9.12	1652.00	2164.00	24.00	0.0001
	95th Percentile	9.06	28.70	115.33	3441.00	2428.88	9.26	2138.00	2213.50	24.00	0.0001

Table 4.52 Retreat Creek and Tributaries - Summary of Surface Water Quality Chemical Analytical Results (continued)

Retreat Creek		Fluoride (mg/L)	Ammonia as N (µg/L)	Nitrite as N (mg/L)	Nitrate as N (mg/L)	Nitrite plus Nitrate as N (NOx) (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Nitrogen as N (TKN + NOx) (mg/L)	Total Phosphorus as P (mg/L)
Nogoa River Water Quality Objectives		n/a	10	0.06	0.06	n/a	0.5	n/a	0.05
ANZECC Aquatic Ecosystem Values		n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.5
ANZECC Livestock Drinking Water Values		2	n/a	30	400	n/a	n/a	n/a	n/a
Site	Statistic								
AQ1 / TAS1	No. of Analyses	4	4	4	4	4	4	4	4
	Mean	0.23	0.06	0.01	0.03	0.03	0.68	0.68	0.17
	Median	0.20	0.06	0.01	0.02	0.02	0.50	0.50	0.17
	Min	0.20	0.04	0.01	0.01	0.01	0.30	0.30	0.09
	Max	0.30	0.09	0.01	0.05	0.05	1.40	1.40	0.24
	80th Percentile	0.24	0.07	0.01	0.03	0.03	0.92	0.92	0.22
	95th Percentile	0.29	0.09	0.01	0.05	0.05	1.28	1.28	0.24
AQ2 / TAS2	No. of Analyses	6	6	6	6	6	6	6	6
	Mean	0.12	0.06	0.01	0.02	0.02	1.20	1.20	0.31
	Median	0.10	0.06	0.01	0.01	0.01	0.95	0.95	0.19
	Min	0.10	0.05	0.01	0.01	0.01	0.70	0.70	0.07
	Max	0.20	0.07	0.01	0.03	0.03	2.60	2.60	0.90
	80th Percentile	0.10	0.06	0.01	0.02	0.02	1.20	1.20	0.37
	95th Percentile	0.18	0.07	0.01	0.03	0.03	2.25	2.25	0.77
AQ5 / TAS5	No. of Analyses	4	4	4	4	4	4	4	4
	Mean	0.25	0.08	0.01	0.04	0.04	1.50	1.53	0.19
	Median	0.20	0.08	0.01	0.03	0.03	0.75	0.75	0.12
	Min	0.20	0.05	0.01	0.01	0.01	0.50	0.50	0.08
	Max	0.40	0.09	0.01	0.07	0.07	4.00	4.10	0.43
	80th Percentile	0.28	0.08	0.01	0.05	0.05	2.08	2.12	0.24
	95th Percentile	0.37	0.09	0.01	0.07	0.07	3.52	3.61	0.38
AQ11 / TAS11	No. of Analyses	6	6	6	6	6	6	6	6
	Mean	0.25	0.09	0.02	0.12	0.13	1.27	1.37	0.11
	Median	0.25	0.08	0.01	0.04	0.04	1.15	1.30	0.12
	Min	0.20	0.06	0.01	0.02	0.02	0.80	1.00	0.01
	Max	0.30	0.12	0.08	0.56	0.64	1.80	1.80	0.22
	80th Percentile	0.30	0.11	0.01	0.04	0.04	1.70	1.70	0.19
	95th Percentile	0.30	0.12	0.06	0.43	0.49	1.78	1.78	0.21

Table 4.53 Retreat Creek and Tributaries - Summary of Surface Water Quality Dissolved Metals Results

Retreat Creek		Dissolved Metals																	
		Al (mg/L)	As (mg/L)	Sb (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**0.013**	**n/a**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**0.5**	**n/a**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ1 / TAS1	No. of Analyses	3	3	3	2	3	2	3	3	2	3	2	3	4	4	4	3	0	4
	Mean	0.017	0.002	0.001	0.080	0.001	0.050	0.0001	0.000	0.001	0.001	0.050	0.001	0.034	0.001	0.001	0.003	-	**0.009**
	Median	0.010	0.001	0.001	0.080	0.001	0.050	0.0001	0.000	0.001	0.001	0.050	0.001	0.015	0.001	0.001	0.000	-	0.007
	Min	0.010	0.001	0.001	0.061	0.001	0.050	0.0001	0.000	0.001	0.001	0.050	0.001	0.009	0.001	0.001	0.000	-	0.005
	Max	0.030	0.004	0.001	0.099	0.001	0.050	0.0001	0.001	0.001	0.001	0.050	0.001	0.098	0.001	0.001	0.010	-	**0.018**
	80th Percentile	0.022	0.003	0.001	0.091	0.001	0.050	0.0001	0.001	0.001	0.001	0.050	0.001	0.050	0.001	0.001	0.006	-	**0.012**
	95th Percentile	0.028	0.004	0.001	0.097	0.001	0.050	0.0001	0.001	0.001	0.001	0.050	0.001	0.086	0.001	0.001	0.009	-	**0.017**
AQ2 / TAS2	No. of Analyses	5	5	5	4	5	4	5	5	4	5	4	5	6	6	6	5	2	6
	Mean	0.028	0.003	0.001	0.141	0.001	0.053	0.0001	0.0005	0.001	0.001	0.123	0.001	0.443	0.001	0.002	0.002	**0.00010**	0.006
	Median	0.010	0.004	0.001	0.147	0.001	0.050	0.0001	0.0002	0.001	0.001	0.075	0.001	0.358	0.001	0.002	0.000	**0.00010**	0.005
	Min	0.010	0.001	0.001	0.102	0.001	0.050	0.0001	0.0002	0.001	0.001	0.060	0.001	0.014	0.001	0.001	0.000	**0.00010**	0.005
	Max	**0.100**	0.005	0.001	0.167	0.001	0.060	0.0001	0.0010	0.002	0.001	0.280	0.001	0.953	0.001	0.004	0.010	**0.00010**	**0.010**
	80th Percentile	0.028	0.004	0.001	0.160	0.001	0.054	0.0001	0.0008	0.001	0.001	0.166	0.001	0.919	0.001	0.002	0.002	**0.00010**	0.007
	95th Percentile	**0.082**	0.005	0.001	0.165	0.001	0.059	0.0001	0.0009	0.002	0.001	0.252	0.001	0.945	0.001	0.004	0.008	**0.00010**	**0.009**
AQ5 / TAS5	No. of Analyses	3	3	4	3	4	2	4	4	2	4	3	3	3	3	3	3	3	3
	Mean	0.033	0.004	0.001	0.117	0.001	0.060	0.0001	0.000	0.002	**0.002**	0.090	0.001	1.256	0.003	0.003	0.003	**0.0004**	0.005
	Median	0.020	0.004	0.001	0.125	0.001	0.060	0.0001	0.000	0.002	**0.002**	0.050	0.001	1.310	0.001	0.002	0.000	**0.0001**	0.005
	Min	0.010	0.001	0.001	0.055	0.001	0.050	0.0001	0.000	0.002	0.001	0.050	0.001	0.007	0.001	0.001	0.000	**0.0001**	0.005
	Max	**0.070**	0.008	0.001	0.170	0.001	0.070	0.0001	0.001	0.002	**0.003**	0.170	0.001	**2.450**	0.006	0.005	0.010	**0.0010**	0.005
	80th Percentile	0.050	0.006	0.001	0.152	0.001	0.066	0.0001	0.001	0.002	**0.002**	0.122	0.001	**1.994**	0.004	0.004	0.004	**0.0006**	0.005
	95th Percentile	**0.065**	0.008	0.001	0.166	0.001	0.069	0.0001	0.001	0.002	**0.002**	0.158	0.001	**2.336**	0.006	0.005	0.009	**0.0009**	0.005
AQ11 / TAS11	No. of Analyses	5	5	6	5	6	4	6	6	4	6	5	5	5	5	5	6	3	5
	Mean	0.012	0.002	0.001	0.081	0.001	0.340	0.0001	0.001	0.001	**0.003**	0.050	0.001	0.010	0.001	0.004	0.002	0.0004	0.007
	Median	0.010	0.002	0.001	0.076	0.001	0.340	0.0001	0.001	0.001	**0.002**	0.050	0.001	0.004	0.001	0.004	0.000	0.0001	0.005
	Min	0.010	0.001	0.001	0.046	0.001	0.320	0.0001	0.000	0.001	0.001	0.050	0.001	0.002	0.001	0.003	0.000	0.0001	0.005
	Max	0.020	0.003	0.002	0.114	0.001	0.360	0.0001	0.001	0.001	**0.007**	0.050	0.001	0.025	0.002	0.005	0.010	0.0010	**0.013**
	80th Percentile	0.012	0.002	0.001	0.101	0.001	0.354	0.0001	0.001	0.001	**0.003**	0.050	0.001	0.019	0.001	0.005	0.001	0.0006	0.007
	95th Percentile	0.018	0.003	0.002	0.111	0.001	0.359	0.0001	0.001	0.001	**0.006**	0.050	0.001	0.023	0.002	0.005	0.008	0.0009	**0.012**

Table 4.54 Retreat Creek - Summary of Surface Water Quality Total Metals Results

Retreat Creek		Total Metals																	
		Al (mg/L)	As (mg/L)	Sb (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**0.013**	**n/a**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**0.5**	**n/a**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ1 / TAS1	No. of Analyses	4	4	4	3	4	3	4	4	3	4	3	4	4	4	4	4	3	4
	Mean	**0.570**	0.003	0.001	0.093	0.001	0.050	0.0001	0.001	0.001	**0.002**	0.667	0.001	0.120	0.001	0.002	0.005	**0.0004**	0.005
	Median	**0.540**	0.002	0.001	0.096	0.001	0.050	0.0001	0.001	0.001	**0.002**	0.620	0.001	0.075	0.001	0.002	0.005	**0.0001**	0.005
	Min	**0.480**	0.002	0.001	0.078	0.001	0.050	0.0001	0.001	0.001	0.001	0.610	0.001	0.044	0.001	0.001	0.000	**0.0001**	0.005
	Max	**0.720**	0.004	0.001	0.105	0.001	0.050	0.0001	0.001	0.001	**0.002**	0.770	0.001	0.285	0.002	0.002	0.010	**0.0010**	0.005
	80th Percentile	**0.636**	0.003	0.001	0.101	0.001	0.050	0.0001	0.001	0.001	**0.002**	0.710	0.001	0.174	0.001	0.002	0.010	**0.0006**	0.005
	95th Percentile	**0.699**	0.004	0.001	0.104	0.001	0.050	0.0001	0.001	0.001	**0.002**	0.755	0.001	0.257	0.002	0.002	0.010	**0.0009**	0.005
AQ2 / TAS2	No. of Analyses	5	6	6	5	6	5	6	6	5	6	5	6	6	6	6	6	5	6
	Mean	**0.347**	0.004	0.001	0.141	0.001	0.054	0.0001	**0.002**	0.001	0.001	1.412	0.001	0.832	0.001	0.003	0.003	**0.0003**	0.007
	Median	**0.200**	0.004	0.001	0.131	0.001	0.050	0.0001	0.001	0.001	0.001	0.880	0.001	0.856	0.001	0.003	0.000	**0.0001**	0.006
	Min	0.040	0.001	0.001	0.092	0.001	0.050	0.0001	0.000	0.001	0.001	0.210	0.001	0.105	0.001	0.002	0.000	**0.0001**	0.005
	Max	**1.210**	0.006	0.001	0.204	0.001	0.070	0.0002	**0.006**	0.002	**0.004**	3.990	0.003	1.380	0.001	0.006	0.010	**0.0010**	**0.014**
	80th Percentile	**0.340**	0.006	0.001	0.183	0.001	0.054	0.0001	**0.002**	0.002	**0.002**	1.902	0.001	1.150	0.001	0.004	0.010	**0.0003**	**0.009**
	95th Percentile	**0.993**	0.006	0.001	0.199	0.001	0.066	0.0002	**0.005**	0.002	**0.004**	3.468	0.003	1.323	0.001	0.006	0.010	**0.0008**	**0.013**
AQ5 / TAS5	No. of Analyses	3	3	4	3	4	2	4	4	2	4	3	3	3	3	3	4	3	3
	Mean	**1.460**	0.007	0.001	0.155	0.001	0.060	0.0001	0.001	0.004	**0.002**	1.803	0.002	**2.039**	0.003	0.004	0.003	**0.0004**	**0.009**
	Median	**1.700**	0.004	0.001	0.119	0.001	0.060	0.0001	0.001	0.004	0.002	0.720	0.001	**2.190**	0.001	0.002	0.000	**0.0001**	**0.011**
	Min	**0.100**	0.002	0.001	0.088	0.001	0.050	0.0001	0.000	0.001	0.001	0.380	0.001	0.066	0.001	0.001	0.000	**0.0001**	0.005
	Max	**2.580**	**0.014**	0.001	0.258	0.001	0.070	0.0001	**0.003**	0.006	**0.005**	4.310	**0.004**	**3.860**	0.006	0.009	0.010	**0.0010**	**0.012**
	80th Percentile	**2.228**	0.010	0.001	0.202	0.001	0.066	0.0001	**0.002**	0.005	**0.003**	2.874	0.003	**3.192**	0.004	0.006	0.004	**0.0006**	**0.012**
	95th Percentile	**2.492**	0.013	0.001	0.244	0.001	0.069	0.0001	**0.003**	0.006	**0.004**	3.951	**0.004**	**3.693**	0.006	0.008	0.009	**0.0009**	**0.012**
AQ11 / TAS11	No. of Analyses	5	5	6	5	6	4	6	6	4	6	5	5	5	5	5	6	5	5
	Mean	**1.710**	0.002	0.001	0.088	0.001	0.340	0.0001	**0.003**	0.003	**0.004**	1.918	0.001	0.054	0.001	0.008	0.002	**0.0003**	**0.009**
	Median	**1.650**	0.002	0.001	0.098	0.001	0.345	0.0001	**0.002**	0.002	**0.004**	1.340	0.001	0.042	0.001	0.007	0.000	**0.0001**	0.007
	Min	**0.120**	0.001	0.001	0.048	0.001	0.270	0.0001	0.001	0.002	**0.002**	0.760	0.001	0.024	0.001	0.004	0.000	**0.0001**	0.005
	Max	**4.310**	0.003	0.001	0.113	0.001	**0.400**	0.0001	**0.008**	0.004	**0.007**	4.580	0.001	0.106	0.002	**0.013**	0.010	**0.0010**	**0.019**
	80th Percentile	**2.214**	0.002	0.001	0.111	0.001	**0.382**	0.0001	**0.004**	0.003	**0.005**	2.292	0.001	0.068	0.002	0.010	0.001	**0.0003**	**0.010**
	95th Percentile	**3.786**	0.003	0.001	0.113	0.001	**0.396**	0.0001	**0.007**	0.004	**0.007**	4.008	0.001	0.097	0.002	**0.012**	0.008	**0.0008**	**0.017**

Table 4.55 Taroborah Creek and Tributaries - Summary of Surface Water Quality Chemical Analytical Results

Taroborah Creek		Field pH	Field Temp (degrees Celsius)	Field Dissolved Oxygen (%)	Field Electrical Conductivity (µS/cm)	Field Turbidity (NTU)	Lab pH	Lab Turbidity (NTU)	Lab Electrical Conductivity (µS/cm)	Sulfate as SO_4 (mg/L)	Total Recoverable Mercury (mg/L)
Nogoa River Water Quality Objectives		**6.5-8.5**	**n/a**	**85-110**	**250-340**	**50**	**6.5-8.5**	**50**	**250-340**	**25**	**n/a**
ANZECC Aquatic Ecosystem Values		**6.5-8.5**	**n/a**	**85-110**	**125-2200**	**n/a**	**6.5-8.5**	**n/a**	**125-2200**	**n/a**	**0.0006**
ANZECC Livestock Drinking Water Values		**n/a**	**n/a**	**n/a**	**n/a**	**1000**	**n/a**	**1000**	**n/a**	**1000**	**0.002**
Site	**Statistic**										
AQ7 / TAS7	No. of Analyses	2	2	2	2	1	0	1	0	2	2
	Mean	**8.66**	22.05	**67.40**	**988.50**	**491.11**	-	**432.00**	-	1.00	0.0001
	Median	**8.66**	22.05	**67.40**	**988.50**	**491.11**	-	**432.00**	-	1.00	0.0001
	Min	8.19	13.20	**9.60**	**733.00**	**491.11**	-	**432.00**	-	1.00	0.0001
	Max	**9.13**	30.90	**125.20**	**1244.00**	**491.11**	-	**432.00**	-	1.00	0.0001
	80th Percentile	**8.94**	27.36	102.08	**1141.80**	**491.11**	-	**432.00**	-	1.00	0.0001
	95th Percentile	**9.08**	30.02	**119.42**	**1218.45**	**491.11**	-	**432.00**	-	1.00	0.0001
AQ10 / TAS10	No. of Analyses	6	5	5	6	3	4	4	4	7	7
	Mean	**8.89**	24.56	**140.16**	**2285.00**	**1787.53**	**8.85**	**918.50**	**2168.50**	**30.14**	0.0001
	Median	**8.97**	23.90	**111.30**	**1982.50**	**1980.00**	**8.99**	**895.50**	**1870.00**	23.00	0.0001
	Min	8.23	16.80	**70.00**	**877.00**	**587.59**	8.21	**513.00**	**664.00**	1.00	0.0001
	Max	**9.29**	32.10	**221.60**	**4206.00**	**2795.00**	**9.20**	**1370.00**	**4270.00**	**82.00**	0.0001
	80th Percentile	**9.17**	27.70	**210.08**	**3090.00**	**2469.00**	**9.12**	**1274.00**	**2884.00**	**48.20**	0.0001
	95th Percentile	**9.26**	31.00	**218.72**	**3927.00**	**2713.50**	**9.18**	**1346.00**	**3923.50**	**73.30**	0.0001

Table 4.56 Taroborah Creek - Summary of Surface Water Quality Chemical Analytical Results (continued)

Taroborah Creek		Fluoride (mg/L)	Ammonia as N (µg/L)	Nitrite as N (mg/L)	Nitrate as N (mg/L)	Nitrite plus Nitrate as N (NOx) (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Nitrogen as N (TKN + NOx) (mg/L)	Total Phosphorus as P (mg/L)
Nogoa River Water Quality Objectives		**n/a**	**10**	**0.06**	**0.06**	**n/a**	**0.5**	**n/a**	**0.05**
ANZECC Aquatic Ecosystem Values		**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**0.5**
ANZECC Livestock Drinking Water Values		**2**	**n/a**	**30**	**400**	**n/a**	**n/a**	**n/a**	**n/a**
Site	**Statistic**								
AQ7 / TAS7	No. of Analyses	2	2	2	2	2	2	2	2
	Mean	0.30	0.06	**0.18**	**1.71**	1.88	**0.70**	2.55	**0.10**
	Median	0.30	0.06	**0.18**	**1.71**	1.88	**0.70**	2.55	**0.10**
	Min	0.30	0.05	0.01	0.01	0.01	**0.60**	0.60	**0.09**
	Max	0.30	0.07	**0.34**	**3.40**	3.74	**0.80**	4.50	**0.11**
	80th Percentile	0.30	0.07	**0.27**	**2.72**	2.99	**0.76**	3.72	**0.11**
	95th Percentile	0.30	0.07	**0.32**	**3.23**	3.55	**0.79**	4.31	**0.11**
AQ10 / TAS10	No. of Analyses	7	7	7	7	7	7	7	7
	Mean	0.49	0.07	**0.07**	**0.35**	0.41	**4.07**	4.47	**0.75**
	Median	0.50	0.08	0.01	0.02	0.02	**2.00**	3.00	**0.10**
	Min	0.30	0.02	0.01	0.01	0.01	**0.60**	0.60	0.02
	Max	0.60	0.13	**0.44**	**2.33**	2.77	**13.80**	13.80	**3.28**
	80th Percentile	0.58	0.10	0.01	0.03	0.03	**6.04**	6.22	**0.93**
	95th Percentile	0.60	0.12	**0.31**	**1.64**	1.95	**11.70**	11.70	**2.59**

Table 4.57 Taroborah Creek and Tributaries - Summary of Surface Water Quality Dissolved Metals Results

Taroborah Creek		Dissolved Metals																	
		Al (mg/L)	Sb (mg/L)	As (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		0.055	n/a	0.013	n/a	n/a	0.37	0.002	0.001	n/a	0.0014	n/a	0.0034	1.9	n/a	0.011	0.011	0.00005	0.008
ANZECC Livestock Drinking Water Values		5	n/a	0.5	n/a	n/a	5	0.01	1	1	1	n/a	1	n/a	0.15	1	0.02	n/a	20
Site	Statistic																		
AQ7 / TAS7	No. of Analyses	1	1	1	0	1	0	1	1	0	1	0	1	2	2	2	1	0	2
	Mean	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.002	-	0.001	0.003	0.001	0.002	0.010	-	0.005
	Median	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.002	-	0.001	0.003	0.001	0.002	0.010	-	0.005
	Min	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.002	-	0.001	0.002	0.001	0.001	0.010	-	0.005
	Max	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.002	-	0.001	0.004	0.001	0.002	0.010	-	0.005
	80th Percentile	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.002	-	0.001	0.004	0.001	0.002	0.010	-	0.005
	95th Percentile	0.010	0.001	0.001	-	0.001	-	0.0001	0.001	-	0.002	-	0.001	0.004	0.001	0.002	0.010	-	0.005
AQ10 / TAS10	No. of Analyses	5	6	5	5	6	4	6	6	4	6	5	5	6	6	6	5	3	6
	Mean	0.022	0.001	0.003	0.092	0.001	0.288	0.0001	0.001	0.006	0.005	0.132	0.001	0.018	0.004	0.011	0.002	0.0004	0.005
	Median	0.010	0.001	0.002	0.086	0.001	0.310	0.0001	0.000	0.005	0.005	0.060	0.001	0.008	0.002	0.008	0.000	0.0001	0.005
	Min	0.010	0.001	0.001	0.041	0.001	0.150	0.0001	0.000	0.002	0.002	0.050	0.001	0.005	0.001	0.002	0.000	0.0001	0.005
	Max	0.050	0.001	0.006	0.162	0.001	0.380	0.0001	0.001	0.010	0.007	0.300	0.001	0.047	0.008	0.030	0.010	0.0010	0.005
	80th Percentile	0.034	0.001	0.004	0.104	0.001	0.350	0.0001	0.001	0.008	0.007	0.220	0.001	0.032	0.007	0.017	0.001	0.0006	0.005
	95th Percentile	0.046	0.001	0.006	0.147	0.001	0.373	0.0001	0.001	0.010	0.007	0.280	0.001	0.043	0.008	0.027	0.008	0.0009	0.005

Table 4.58 Taroborah Creek and Tributaries - Summary of Surface Water Quality Total Metals Results

Taroborah Creek		Total Metals																
		Al (mg/L)	Sb (mg/L)	As (mg/L)	Ba (mg/L)	Be (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Zn (mg/L)
ANZECC Aquatic Ecosystem Values		**0.055**	**n/a**	**0.013**	**n/a**	**n/a**	**0.37**	**0.002**	**0.001**	**n/a**	**0.0014**	**n/a**	**0.0034**	**1.9**	**n/a**	**0.011**	**0.011**	**0.00005**	**0.008**
ANZECC Livestock Drinking Water Values		**5**	**n/a**	**0.5**	**n/a**	**n/a**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**1**	**n/a**	**0.15**	**1**	**0.02**	**n/a**	**20**
Site	**Statistic**																		
AQ7 / TAS7	No. of Analyses	2	2	2	1	2	1	2	2	1	2	1	2	2	2	2	2	1	2
	Mean	**1.090**	0.001	0.001	0.177	0.001	0.090	0.002	0.0004	0.003	**0.004**	2.070	0.002	0.035	0.001	0.003	0.010	**0.001**	0.007
	Median	**1.090**	0.001	0.001	0.177	0.001	0.090	0.000	0.0001	0.003	**0.004**	2.070	0.002	0.035	0.001	0.003	0.010	**0.001**	0.007
	Min	**0.180**	0.001	0.001	0.177	0.001	0.090	0.000	0.0001	0.003	**0.002**	2.070	0.001	0.006	0.001	0.001	0.010	**0.001**	0.005
	Max	**2.000**	0.001	0.001	0.177	0.001	0.090	**0.010**	0.0010	0.003	**0.005**	2.070	0.002	0.064	0.001	0.004	0.010	**0.001**	**0.009**
	80th Percentile	**1.636**	0.001	0.001	0.177	0.001	0.090	0.001	0.0006	0.003	**0.004**	2.070	0.002	0.052	0.001	0.003	0.010	**0.001**	0.008
	95th Percentile	**1.909**	0.001	0.001	0.177	0.001	0.090	**0.008**	0.0009	0.003	**0.005**	2.070	0.002	0.061	0.001	0.004	0.010	**0.001**	**0.009**
AQ10 / TAS10	No. of Analyses	6	7	6	6	7	5	7	7	5	7	6	6	6	6	6	7	6	6
	Mean	**1.953**	0.001	0.003	0.108	0.001	0.254	0.0001	**0.003**	0.007	**0.006**	1.967	0.001	0.084	0.004	**0.016**	0.003	**0.0004**	**0.014**
	Median	**0.445**	0.001	0.002	0.110	0.001	0.280	0.0001	0.001	0.009	**0.003**	0.760	0.001	0.051	0.002	**0.012**	0.001	**0.0001**	0.007
	Min	**0.070**	0.001	0.001	0.079	0.001	0.160	0.0001	0.001	0.001	**0.003**	0.250	0.001	0.021	0.001	0.002	0.000	**0.0001**	0.005
	Max	**9.120**	0.001	0.006	0.144	0.001	0.350	0.0002	**0.014**	0.015	**0.012**	8.090	0.001	0.186	0.010	**0.042**	0.010	**0.0010**	**0.039**
	80th Percentile	**1.300**	0.001	0.004	0.120	0.001	0.326	0.0001	**0.002**	0.011	**0.008**	1.560	0.001	0.172	0.008	**0.025**	0.008	**0.0010**	**0.018**
	95th Percentile	**7.165**	0.001	0.006	0.138	0.001	0.344	0.0002	**0.010**	0.014	**0.011**	6.458	0.001	0.183	0.010	**0.038**	0.010	**0.0010**	**0.034**

Wetlands – Physio- chemical Analysis Results

The physio-chemical and biological monitoring results for several wetlands represented by sites AQ/TAS3, AQ/TAS8, AQ/TAS12 and AQ/TAS13, indicate that water exceeds the trigger values for physical and chemical stressors for tropical Australia provided in ANZECC (2000), in accordance with the Wetland WQOs (EHP 2011), and the specified guidelines for Aquatic Ecosystems (ANZECC 2000) for pH, DO, EC, TDS, oxides of Nitrogen, total Nitrogen and total Phosphorus (refer to Table 4.43 and Table 4.44).

Livestock Drinking Water Guidelines were not exceeded at any wetland sites.

The pH of water determines the solubility and biological availability of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). The pH also determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

Results indicate water bodies associated with sampling sites AQ/TAS3, AQ/TAS8, AQ/TAS12 and AQ/TAS13 are basic in nature with an average pH between these sites of 8.1, only marginally above the Wetland WQO (6.00-8.0) with a maximum pH 9.62 recorded at site AQ/TAS3.

DO levels were generally recorded outside both the ANZECC (2000) Aquatic Ecosystems Guideline (85-110%) and the Wetland WQO (90-120%). Among sites, AQ/TAS8 recorded a maximum DO gas pressure of 129%. AQ/TAS3 and AQ/TAS13 averaged 80% and 84% respectively.

Total dissolved gas pressures exceeding 115% over a period of a few hours can cause the death of any fish exposed to these conditions (Boulton and Brock 1999). This condition is termed ‘gas bubble disease’ and is caused by the formation of bubbles in the tissues, which eventually accumulate in the gill capillaries, killing the fish (Boulton and Brock 1999). However, DO can change considerably over a daily or diurnal period (ANZECC 2000).

Electrical Conductivity is one way to measure the inorganic materials including calcium, bicarbonate, nitrogen, phosphorus, iron, sulphur and other ions dissolved in a water body. Salinity is the component of conductivity that is critical to the survival of some aquatic plants and animals. Many species can survive only within certain salinity ranges so changes in salinity levels can result in changes to the variety and types of species found. The Wetland WQO for EC is between 90-900 µS/cm. All sites were within the Wetland WQO for EC with the exception of site AQ/TAS8, which recorded a maximum of 1110 µS/cm, but had a mean value of 582 µS/cm. All sites were within the ANZECC (2000) Aquatic Ecosystem Guideline for EC.

Nitrogen and phosphorus are two essential nutrients that are found in fresh and marine waters and are considered essential to support biological life. Eutrophication of a water body may occur during an increase of nutrient supply which can in turn lead to an abundance of algae (including toxic algal blooms) and aquatic plants. Total Nitrogen at wetland sites AQ/TAS8 and AQ/TAS12 exceeded the Wetlands WQO for total Nitrogen (0.35-1.2 mg/L). Site AQ/TAS8 recorded the highest maximum concentration of total Nitrogen of 10.6 mg/L and an average of 4.43 mg/L. The average concentration of total Nitrogen at site AQ/TAS12 was 1.55 mg/L. In addition, results indicate that total Phosphorus exceeds the Wetland WQO (0.01-0.05 mg/L) and the ANZECC (2000) Aquatic Ecosystem Guideline value of 0.5 mg/L at site AQ/TAS8 and AQ/TAS 13, maximums of 1.22 mg/L and 1.05 mg/L recorded respectively. Site AQ/TAS12 also exceeds the Wetland WQO for total Phosphorus with a maximum of

0.07 mg/L recorded.

Wetlands – Dissolved Heavy Metals

According to ANZECC (2000), the major toxic effect of metals comes from the dissolved fraction and comparison of total heavy metal concentrations are likely to overestimate the fraction that is bioavailable in the environment. Therefore, throughout this section we discuss the filtered (dissolved) results of heavy metal concentrations and the comparisons made against the applicable trigger values.

Heavy metal analysis results for the wetlands indicate that water exceeds the ANZECC (2000) Aquatic Ecosystem Guidelines for Cu and Ag (refer to Table 4.45).

Copper

Copper (Cu) was found to exceed the ANZECC (2000) Aquatic Ecosystem Guidelines at site AQ/TAS 3. The recorded maximum of Cu was 0.003 mg/L, over twice the Aquatic Ecosystem trigger value of 0.0014 mg/L.

The observed Cu concentrations in surface waters are considered to be naturally elevated and may be due to windblown dust, decaying vegetation and forest fires, processes which are known to naturally release Cu to the environment.

Silver

The concentration of Ag was exceeded at sites AQ/TAS 3, AQ/TAS 8 and AQ/TAS 12 when compared against the ANZECC (2000) Aquatic Ecosystem Guideline of 0.00005 mg/L. No Livestock Drinking Water Guideline value has been specified for Ag.

The highest average concentration of Ag was approximately 0.0004 mg/L with a maximum concentration of 0.001 mg/L at site AQ/TAS 3 approximately 20 times higher than the ANZECC (2000) Aquatic Ecosystem Guideline.

The levels of Ag are likely to be naturally occurring or may emanate from the upstream gemstone mining operations.

Pastoral Dams – Physio- chemical Analysis Results

The Pastoral Dams are located at sampling sites AQ/TAS 4 and AQ/TAS 6. Results indicate the average pH of these sites to be 8.16 with a maximum pH of 8.37 at site AQ/TAS 4. These results indicate site AQ/TAS 4 is basic in nature and these values exceed the Nogoa River Water Quality Objectives for Freshwater Lakes / Reservoirs (pH 6.5-8.0). However, pH did not exceeded either the ANZECC (2000) aquatic ecosystem guideline values or the ANZECC (2000) Livestock Drinking Water guideline values.

DO levels were generally below the Freshwater Lakes / Reservoirs trigger value (90-110%) with an average DO concentration of 71.56% and a minimum of 46.6% at site AQ/TAS 6. The highest recorded maximum for DO was 103.9% which is within the acceptable trigger value range. The average concentration of DO was also below the ANZECC (2000) aquatic ecosystem guideline value (85-110%); however livestock drinking water guideline values have not been specified for DO.

The Freshwater Lakes / Reservoirs WQO for EC is <250 µS/cm. Results indicate that the majority of sampling rounds exceeded this value with an averaged EC of 856.75 µS/cm at site AQ/TAS 4 and

1166.90 µS/cm at site AQ/TAS 6. EC was, however, within the acceptable range specified by the ANZECC (2000) Aquatic Ecosystem Guideline (125-2200 µS/cm).

Total Nitrogen at site AQ/TAS 4 and AQ/TAS 6 exceeds the Freshwater Lakes / Reservoirs WQO for total Nitrogen (<0.35 mg/L) with an average concentration of 1.10 mg/L and 0.95 mg/L respectively. A minimum concentration of 0.5 mg/L was recorded at site AQ/TAS 6. Aquatic ecosystem guideline values and livestock drinking water guideline values have not been specified for total Nitrogen. In addition, results indicate that total Phosphorus exceeds the Freshwater Lakes / Reservoirs WQO (<0.01) with an average concentration of 0.09 mg/L at site AQ/TAS 4 and 0.17 mg/L at site AQ/TAS 6. This WQO is considerably more stringent than the ANZECC (2000) Aquatic Ecosystem Guideline value of 0.5 mg/L which was not exceeded during any sampling event.

Pastoral Dam – Dissolved Heavy Metals

Dissolved metal analysis results for the Pastoral Dam (refer to Table 4.49) indicate that water exceeds either the ANZECC (2000) Aquatic Ecosystem Guidelines for Al, Cu, Mn and Ag.

Aluminium

Results indicate the average level of aluminium (Al) concentration at each site to be within the ANZECC (2000) Aquatic Ecosystem guideline value which is 0.055 mg/L. The maximum concentration of Al at site AQ/TAS 4 was 0.08 mg/L and 0.06 mg/L at site AQ/TAS 6, only marginally above the ANZECC (2000) trigger value for Aquatic Ecosystems. This value does not exceed the ANZECC (2000) Livestock Drinking Water trigger value of 5 mg/L.

Observed levels of Al are likely to be naturally occurring.

Copper

Copper (Cu) was found to exceed the ANZECC (2000) Aquatic Ecosystem Guidelines of 0.0014 mg/L at site AQ/TAS 4 and AQ/TAS 6.

The maximum recorded concentration of Cu was 0.002 mg/L at AQ/TAS 4 and 0.003 at AQ/TAS 6, twice the Aquatic Ecosystem Guideline. However, the average concentration of Cu at each site was below the ANZECC (2000) Aquatic Ecosystem Guideline.

The observed Cu concentrations in surface waters are considered to be naturally elevated and may be due to windblown dust, decaying vegetation and forest fires, processes which are known to naturally release Cu to the environment.

Manganese

Mn exceeded the ANZECC (2000) Aquatic Ecosystem Guideline value of 1.9 mg/L only marginally at site AQ/TAS 6. The maximum concentration of Mn recorded at this site was 2.07 mg/L. No Livestock Drinking Water Guideline value has been specified for Mn.

Observed levels of Mn are likely to be naturally occurring.

Silver

The concentration of Ag was exceeded at site AQ/TAS 4 and site AQ/TAS 6 when compared against the ANZECC (2000) Aquatic Ecosystem Guideline of 0.00005 mg/L. No Livestock Drinking Water

Guideline value has been specified for Ag.

The average concentration of Ag was approximately 0.0004 mg/L at site AQ/TAS 4 with a maximum concentration of 0.001 mg/L, approximately 20 times higher than the ANZECC (2000) Aquatic Ecosystem Guideline. The average and maximum concentration of Ag at site AQ/TAS 6 was 0.001 mg/L.

Although Ag occurs naturally in its pure free form, as an alloy with other metals and in minerals. However, most silver is produced as a by-product of copper, lead, gold and zinc refining. The levels of Ag are likely to be naturally occurring or may emanate from the upstream gemstone mining operations.

Retreat Creek – Physio- chemical Analysis Results

The physio-chemical and biological monitoring results for Retreat Creek, traversing the northern portion of the Project site, indicate that water exceeds the trigger values provided in the Lower Nogoa / Theresa Creek WQOs (EHP 2011) at several sites for pH, DO, EC, TDS, Sulfate, Nitrite, Nitrate, total Nitrogen and total Phosphorus. The ANZECC (2000) Aquatic Ecosystem Guidelines were exceeded at several sites for pH, DO, EC and total Phosphorus and the ANZECC (2000) Livestock Drinking Water Guidelines were exceeded at several sites for TDS (refer to Table 4.51 and Table 4.52).

Results indicate water bodies associated with sampling sites AQ/TAS 5 and AQ/TAS 11 are basic in nature with an average pH between these sites of 8.53 with a maximum pH 9.08 recorded at site AQ/TAS 11.

Alkalinity is also important for fish and aquatic life because it protects or buffers against rapid pH changes. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life (U.S. Geological Survey 2011). In addition, aquatic life reportedly function best in a pH range of 6.0 to 9.0, consistent with the majority of samples (Water Research Centre for Environmental Quality 2004).

DO is one of the primary determinants of fish presence in waterways located in arid regions (Glover 1982). DO levels were generally recorded within the ANZECC (2000) Aquatic Ecosystems Guideline and Lower Nogoa / Theresa Creek trigger values (85 – 110%), with the exception of several sites (AQ/TAS 1, AQ/TAS 2, and AQ/TAS 11) which exhibited low DO concentrations with an average concentration between these sites of approximately 68 %. The highest recorded maximum for DO was 145 % at site AQ/TAS 5. Total dissolved gas pressures exceeding 115% over a period of a few hours can cause the death of any fish exposed to these conditions (Boulton and Brock 1999). This condition is termed ‘gas bubble disease’ and is caused by the formation of bubbles in the tissues, which eventually accumulate in the gill capillaries, killing the fish (Boulton and Brock 1999). However, DO can change considerably, over a daily or diurnal period (ANZECC 2000).

Electrical Conductivity is one way to measure the inorganic materials including calcium, bicarbonate, nitrogen, phosphorus, iron, sulphur and other ions dissolved in a water body. Salinity is the component of conductivity that is critical to the survival of some aquatic plants and animals. Many species can survive only within certain salinity ranges so changes in salinity levels can result in changes to the variety and types of species found. The Lower Nogoa / Theresa Creek WQOs for EC are 250-340 µS/cm which are considerably more stringent than the ANZECC (2000) Aquatic Ecosystem Guidelines of 125-2,200 µS/cm. All sites were outside the Lower Nogoa / Theresa Creek WQO for EC with the average EC ranging between 768 µS/cm (AQ/TAS 5) and 2,302 µS/cm (AQ/TAS 11). One site, AQ/TAS 11 also exceeded the ANZECC (2000) Aquatic Ecosystem Guideline with a maximum of

3,793 µS/cm.

<u>*Retreat Creek – Heavy Metals*</u>

Heavy metal analysis results for Retreat Creek indicate that water exceeds either the ANZECC (2000) Aquatic Ecosystem Guidelines, the ANZECC (2000) Livestock Drinking Water Guidelines or both for Al, Cu, Mn, Ag and Zn (refer to Table 4.53).

Aluminium

Results from the metal analysis indicate locations AQ/TAS 2 and AQ/TAS 5 to be experiencing elevated levels of dissolved Al, exceeding the trigger values outlined in the ANZECC (2000) Guidelines for Aquatic Ecosystems Values.

Results indicate levels of Al to be up to 1.8 times higher than Aquatic Ecosystems guideline value of 0.055 mg/L, with site AQ/TAS 2 experiencing the highest level of Al returning a result of 0.1 mg/L.

These sampling sites occur within Retreat Creek, which flows in an easterly direction and has the potential to affect Theresa Creek and Nogoa River.

In the absence of industrial or mining disturbance, with no known history of or reason for contamination, the levels of Al are likely to be naturally occurring or may emanate from the upstream gemstone mining operations.

Copper

Copper (Cu) was found to exceed the ANZECC (2000) Aquatic Ecosystem Guidelines of 0.0014 mg/L at site AQ/TAS 11 and site AQ/TAS 5.

The average concentration of Cu at site AQ/TAS 5 was 0.002 mg/L (1.4 times higher than ANZECC (2000) Aquatic Ecosystem Guideline). Between sites AQ/TAS 5 and AQ/TAS 11 the average concentration of Cu was 0.0025 mg/L with a recorded maximum of 0.007 mg/L at site AQ/TAS 5, five times the ANZECC (2000) Aquatic Ecosystem Guideline for Cu.

The observed Cu concentrations in surface waters are considered to be naturally elevated and may be due to windblown dust, decaying vegetation and forest fires, processes which are known to naturally release Cu to the environment.

Manganese

Manganese (Mn) was elevated at site AQ/TAS 5, in comparison to the ANZECC (2000) Aquatic Ecosystem Guideline trigger value of 1.9 mg/L. The maximum concentration of Mn at AQ/TAS 5 was 2.45 mg/L.

A total of three samples were collected between 2011 and 2013 at this site and average concentrations were found to be lower than the ANZECC (2000) Aquatic Ecosystem Guideline trigger value with the highest average concentration of only 1.25 mg/L recorded.

Mn is considered to be naturally elevated.

Silver

Silver (Ag) exceeded the ANZECC (2000) Aquatic Ecosystem Guidelines of 0.00005 mg/L at sites

AQ/TAS2 and AQ/TAS 5. Each of these sites recorded a maximum concentration of 0.0001 mg/L, 20 times higher than the guideline value.

Zinc

Zinc (Zn) concentrations were found to be elevated at three sites AQ/TAS 1, AQ/TAS 2 and AQ/TAS 11 in comparison to the ANZECC (2000) Aquatic Ecosystem Guideline of 0.008 mg/L. The average concentration of Zn across the three sites was 0.007 mg/L which is lower than the trigger value. The maximum concentration of Zn was recorded at site AQ/TAS 1 (0.018 mg/L), approximately twice the guideline value.

Taroborah Creek – Physio- chemical Analysis Results

The physio-chemical and biological monitoring results for Taroborah Creek, traversing the southern proportion of the Project site, are similar to the results observed for Retreat Creek and indicate that water exceeds the trigger values provided in either the Lower Nogoa / Theresa Creek WQOs (EHP 2011), the ANZECC (2000) Aquatic Ecosystem 95% species protection Guidelines, or both at sites AQ/TAS 7 and AQ/TAS 10 for one or more of the following parameters: pH, DO, EC, TDS, Sulfate, Nitrite, Nitrate, total Nitrogen and total Phosphorus (refer to Table 4.55and Table 4.56). The ANZECC (2000) Livestock Drinking Water Guidelines were exceeded at AQ/TAS 10 for TDS (refer to Table 4.55)

Results indicate water bodies associated with sampling sites AQ/TAS 7 and AQ/TAS 10 are basic in nature with an average pH between these sites of 8.78 with a maximum pH of 9.29 recorded at site AQ/TAS 10.

DO levels varied across each site with average concentrations of 67% at site AQ/TAS 7 and 140% at AQ/TAS 10 both outside the WQOs for both the ANZECC (2000) Aquatic Ecosystems Guideline and Lower Nogoa / Theresa Creek trigger values (85 – 110%).

EC values for sites AQ/TAS 7 and AQ/TAS 10 were also outside the Lower Nogoa / Theresa Creek WQO for EC (250-340 µS/cm) with average measurements of 988 µS/c and 2,285 µS/cm recorded respectively. It can be seen from these results that the average measured EC value recorded at site AQ/TAS 10 exceeded the ANZECC (2000) Aquatic Ecosystem Guideline of 125-2,200 µS/cm by 85 µS/cm.

TDS was exceeded at both sites on Taroborah Creek however; one site AQ/TAS 10 also exceeded the ANZECC (2000) Livestock Drinking Water Guideline of 1,000 NTU with a maximum NTU of 2,795 recorded and an average of 1,787 NTU.

Taroborah Creek – Dissolved Heavy Metals

Results from the heavy metal analysis indicated elevated levels of B, Cu, Ni, and Ag at site AQ/TAS 10 with exceedances of Cu only experienced at site AQ/TAS 7 in comparison to the ANZECC (2000) Aquatic Ecosystem 95% species protection Guidelines (refer to Table 4.57).

Boron

Results indicate site AQ/TAS 10 had marginally elevated levels of Boron (B) when compared to the ANZECC (2000) Aquatic Ecosystem Guideline of 0.37 mg/L with a maximum recording of 0.38 mg/L. However, the average concentration of B was found to be only 0.28 mg/L which is within guideline trigger values.

Copper

The ANZECC (2000) Aquatic Ecosystem Guideline for Cu is 0.0014 mg/L and was exceeded at site AQ/TAS 7 which recorded a concentration of 0.002 mg/L during the single sampling event which took place. In addition, site AQ/TAS 10 also exceeded the ANZECC (2000) Aquatic Ecosystem Guideline for Cu with an average concentration of 0.005 mg/L and a maximum of 0.007 mg/L recorded, five times the guideline value.

Nickel

Although the average concentration of dissolved Nickel at site AQ/TAS10 was within the ANZECC (2000) Aquatic Ecosystem Guideline of 0.011 mg/L, the maximum concentration recorded at this site was 0.03 mg/L, almost three times the guideline limit.

Nickel occurs naturally in soils and is released to the atmosphere by windblown dust, combustion of fuel, municipal incineration and industries involved in steel production. In consideration to the rural setting of the Project and the absence of smelting and other nickel refining processes it is determined elevated levels of Nickel may be naturally occurring.

Silver

Elevated levels of Ag were also recorded at site AQ/TAS 10 consistent with the majority of results at various sampling sites. The maximum concentration of Ag recorded was 0.0006 mg/L, 12 times the guideline limit of 0.00005 mg/L.

Statistical Significance

The range of samples collected from the Pastoral Dam, the Wetlands, Retreat Creek and Taroborah Creek spans from one to seven samples per site.

It is currently understood that sample sizes less than about five tend to give rise to very inaccurate results and in practice, percentiles based on small numbers of samples would give rise to more stringent guidelines (QWQG 2009).

As error values tend to level off at around 15–20 data values, it is suggested this number of samples is sufficient to provide a reasonable estimate of the true percentile value (QWQG 2009). Research suggests 15–20 data values are applicable to most water quality indicators in accordance with the QWQG (2009).

The interpretation of data provided from wet and dry season surveys indicates a likely baseline condition for the Project site, however, in accordance with the QWQG this database is not absolute and may not be indicative of the reference condition of water ways associated with the Project site.

Although four sites (AQ/TAS 2, AQ/TAS 3, AQ/TAS 4 and AQ/TAS 11) have been sampled in excess of five times each, and thus these results should be considered statistically significant, further sampling will be required before a complete statistically significant database can be considered representative of the Project site.

Establishing Local Water Quality Objectives

Monitoring provides a mechanism for establishing a reference condition that provides both a target for management actions and a meaningful comparison used for impact assessment.

As described in the Queensland Water Quality Guidelines 2009 (QWQG), in order to define site-specific guideline values for *slightly to moderately disturbed* waters such as those defined on the Project site, the 20th and 80th percentiles of reference site values are to be used.

Data collected from reference sites is used to estimate percentile values, which in turn are used to derive guidelines. In accordance with the QWQG (2009), in order to derive guideline values at a reference site, a minimum of 18 samples need to be collected over a minimum time period of 12 months, preferably 24 months (as described in Table 4.4.2 of the QWQG 2009).

In addition, the QWQG (2009) prefers a minimum of two reference sites to be sampled, to establish a reliable dataset to derive reference site guideline values.

In order to derive guideline values for the Project site, water quality sampling should be undertaken in accordance with the *Monitoring and Sampling Manual 2009 Environmental Protection (Water) Policy 2009* (2010) at the sites situated on Retreat Creek and Taroborah Creek previously identified.

Six months of water quality sampling has been completed and will continue for a period of 12 to 24 months in order to collect a total of 18 sets of data. The water quality data will be analysed for at least those parameters outlined in Table 4.39. When streams are not flowing, water will continue to be collected from pools of standing water where water is available. When obtaining samples during and after flow events, sampling will allow for potentially high contaminant-load water (i.e. first flush), and more dilute water to be analysed to determine the range of background water for the area.

Water quality analysis results will be compiled into an Environmental Monitoring database. Reference data using indicators such as water quality parameters outlined in the ANZECC (2000) Guidelines will allow the environmental values outlined in the Environmental Protection (Water) Policy 2009 to be identified and protected. Once sufficient data is available, the data will be reassessed, and trigger levels for the Environmental Authority set as per the QWQGs (2009), where site-specific contaminant limits are necessary.

Stream Sediment Quality

Metal Concentrations

Stream sediment sampling was undertaken in watercourses associated with the Project site. Sediment samples were obtained from survey sites sampled during the dry season and wet season surveys (refer to Figure 4.68), between September 2011 to February 2013. At least 10 sub-samples of the stream–bed substrate were taken at different locations along a 50m stretch of each creek or river bed. The sub-samples were then mixed to obtain a composite sample, sealed in sterilised glass jars and sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis of the parameters outlined in Table 4.59.

Table 4.59 ANZECC 2000 Sediment Quality Guideline Values

Parameter	Units	ANZECC (2000) Stream Sediment (low) Triggers	ANZECC (2000) Stream Sediment (high) Triggers
Arsenic (As)	mg/kg	20	70
Silver (Ag)	mg/kg	1.0	3.7

Parameter	Units	ANZECC (2000) Stream Sediment (low) Triggers	ANZECC (2000) Stream Sediment (high) Triggers
Barium (Ba)	mg/kg	n/a	n/a
Beryllium (Be)	mg/kg	n/a	n/a
Cadmium (Cd)	mg/kg	1.5	10
Cobalt (Co)	mg/kg	n/a	n/a
Chromium (Cr)	mg/kg	80	370
Copper (Cu)	mg/kg	65	270
Iron (Fe)	mg/kg	n/a	n/a
Mercury (Hg)	mg/kg	0.15	1.0
Manganese (Mn)	mg/kg	n/a	n/a
Molybdenum (Mo)	mg/kg	n/a	n/a
Nickel (Ni)	mg/kg	21	52
Lead (Pb)	mg/kg	50	220
Selenium (Se)	mg/kg	n/a	n/a
Zinc (Zn)	mg/kg	200	410

Results associated with Retreat Creek and Taroborah Creek were compared to the low and high Interim Sediment Quality Guidelines (ISQG) within the ANZECC (2000) Guidelines for Fresh and Marine Water Quality Trigger Values as detailed in Table 4.60 and Table 4.61 respectively.

Silver levels recorded at all of the wet season sampling sites were less than the limit of reporting (2 mg/kg), which is above the low ISQG values for this metal, and therefore an assessment of silver in sediments against the low ISQG value cannot be conducted. However, during the dry season a lower limit or reporting was used (above the low ISQG values) and therefore the probability of silver exceeding the low ISQG value is considered to be low.

The guidelines state that in some areas natural mineralisation of stream sediments will mean that levels of some metals will be higher than the default low trigger values, or even the high trigger values, without any human interference. In these cases, site specific stream sediment low and high trigger levels should be determined from background data. Given that these results represent a baseline study conducted prior to proposed mining related disturbances within the Project site, the following stream sediment metal concentrations outlined should be used to determine site specific low and high trigger values where ANZECC 2000 stream sediment default values are exceeded during future monitoring events.

Table 4.60 Retreat Creek - Summary of Sediment Quality Chemical Analytical Results

Retreat Creek		Total Metals															
		Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Manganese	Molybdenum	Nickel	Selenium	Silver	Zinc	Mercury
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
ANZECC 2000 ISQG-Low trigger Value		**2**	**20**	-	**-**	**1.5**	**80**	-	**65**	**50**	-	**-**	**21**	-	**1**	**200**	**0.15**
ANZECC 2000 ISQG-High trigger Value		25	70	-	-	10	370	-	270	220	-	-	52	-	200	410	1
Site	Statistic																
AQ1 / TAS1	Mean	0.6	4.1	116.6	1.0	0.1	25.7	12.2	17.5	11.9	493.8	153.9	18.8	1	0.1	43.4	0.10
	Median	0.2	3.8	120.1	1.1	0.1	23.5	11.5	17.9	12.3	512.5	0.3	18.0	1	0.1	45.9	0.10
	Min	0.1	3.4	71.1	0.4	0.1	17.7	8.9	6.6	8.3	335	0.2	9.2	1	0.1	16.6	0.10
	Max	2	5.3	155	1.4	0.1	38.1	17.1	27.5	14.5	615	615.0	**30.2**	1	0.1	65.0	0.10
	80th Percentile	0.9	4.6	149.6	1.3	0.1	31.6	14.6	24.6	14.4	589.2	246.2	**25.5**	1	0.1	60.4	0.10
	95th Percentile	1.7	5.1	153.7	1.4	0.1	36.5	16.5	26.8	14.5	608.6	522.8	**29**	1	0.1	63.9	0.10
AQ2 / TAS2	Mean	0.1	3.1	127.425	1	0.1	30.5	12.6	19.2	10.7	439.0	89.5	**25.6**	1	0.1	45.6	0.10
	Median	0.1	2.95	136.5	1	0.1	31.1	13.5	21.0	11.5	402.5	0.3	**27.0**	1	0.1	48.7	0.10
	Min	0.1	2.8	92.7	0.7	0.1	21.7	9	12.5	8.2	357.0	0.2	16.1	1	0.1	34.4	0.10
	Max	0.2	3.7	144	1.1	0.1	37.9	14.3	22.2	11.8	594.0	357.0	**32.4**	1	0.1	50.6	0.10
	80th Percentile	0.14	3.34	143.4	1.1	0.1	37.4	14.1	22.0	11.6	502.8	143.0	**31.5**	1	0.1	49.8	0.10
	95th Percentile	0.2	3.6	143.9	1.1	0.1	37.8	14.3	22.1	11.8	571.2	303.5	**32.2**	1	0.1	50.4	0.10
AQ3 / TAS3	Mean	0.1	0.7	131.0	0.4	0.1	75.8	35.0	27.8	1.5	524.5	110.6	**124.3**	1	0.1	62.0	0.10
	Median	0.1	0.7	121	0.4	0.1	75	34.9	27.3	1.6	511.5	0.5	**130.0**	1	0.1	62.4	0.10
	Min	0.1	0.5	99.1	0.3	0.1	65.4	31.2	24	1.4	441.0	0.3	**102.0**	1	0.1	55.0	0.10
	Max	0.1	0.8	183	0.5	0.1	**87.6**	39.1	32.4	1.6	634.0	441.0	**135.0**	1	0.1	68.2	0.10
	80th Percentile	0.1	0.7	148.2	0.4	0.1	**82.1**	37.8	29.9	1.6	597.4	176.7	**134.4**	1	0.1	65.3	0.10
	95th Percentile	0.1	0.8	174.3	0.5	0.1	**86.2**	38.8	31.8	1.6	624.9	374.9	**134.9**	1	0.1	67.5	0.10
AQ4 / TAS4	Mean	0.1	2.6	157.7	1.0	0.1	64.2	26.5	34.6	9.2	1048.3	533.6	**60.6**	1	0.1	56.8	0.10
	Median	0.1	2.4	157	1	0.1	60.8	29.7	33.4	8.9	1090.0	0.4	**56.1**	1	0.1	55.6	0.10
	Min	0.1	1.9	156	0.7	0.1	31.9	14.4	24	4.9	455.0	0.3	**27.1**	1	0.1	53.3	0.10
	Max	0.2	3.4	160	1.4	0.1	**100**	35.3	46.5	13.9	1600.0	1600.0	**98.7**	1	0.1	61.4	0.10
	80th Percentile	0.2	3	158.8	1.24	0.1	**84.3**	33.1	41.3	11.9	1396.0	960.2	**81.7**	1	0.1	59.1	0.10
	95th Percentile	0.2	3.3	159.7	1.36	0.1	**96.1**	34.7	45.2	13.4	1549.0	1440.0	**94.4**	1	0.1	60.8	0.10
AQ5 / TAS5	Mean	0.1	3.3	92.7	0.7	0.1	14.3	7.6	11.7	8.6	486.0	249.4	12.0	1	0.1	32.6	0.10
	Median	0.1	3	118	0.8	0.1	16.5	8.9	14.4	10.2	560.0	0.2	14.7	1	0.1	38.9	0.10
	Min	0.1	2.7	21.2	0.2	0.1	3.3	2.6	2	3.2	150.0	0.1	2.5	1	0.1	6.9	0.10
	Max	0.2	4.3	139	1.1	0.1	23	11.4	18.6	12.4	748.0	748.0	18.7	1	0.1	52.0	0.10
	80th Percentile	0.2	3.8	130.6	0.98	0.1	20.4	10.4	16.92	11.5	672.8	448.9	17.1	1	0.1	46.8	0.10
	95th Percentile	0.2	4.2	136.9	1.07	0.1	22.4	11.2	18.2	12.2	729.2	673.2	18.3	1	0.1	50.7	0.10

Retreat Creek		Total Metals															
		Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Manganese	Molybdenum	Nickel	Selenium	Silver	Zinc	Mercury
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
ANZECC 2000 ISQG-Low trigger Value		2	20	-	-	1.5	80	-	65	50	-	-	21	-	1	200	0.15
ANZECC 2000 ISQG-High trigger Value		25	70	-	-	10	370	-	270	220	-	-	52	-	200	410	1
Site	Statistic																
AQ6 / TAS6	Mean	0.1	4.9	64.5	0.5	0.1	7.5	5.9	6.7	6.4	231.7	89.1	6.7	1	0.1	21.5	0.10
	Median	0.1	3	57	0.4	0.1	4.7	5.3	4	5.4	267.0	0.2	4.4	1	0.1	13.9	0.10
	Min	0.1	2.8	19.6	0.3	0.1	3	4.2	3.1	4.5	108.0	0.1	2.9	1	0.1	11.7	0.10
	Max	0.1	8.9	117	0.8	0.1	14.9	8.3	12.9	9.4	320.0	267.0	12.8	1	0.1	39.0	0.10
	80th Percentile	0.1	6.5	93	0.64	0.1	10.8	7.1	9.3	7.8	298.8	160.3	9.4	1	0.1	29.0	0.10
	95th Percentile	0.1	8.3	111	0.76	0.1	13.9	8	12.0	9.0	314.7	240.3	12.0	1	0.1	36.5	0.10
AQ8 / TAS8	Mean	0.1	1.1	203.7	1.5	0.1	65.4	26.4	33.9	7.7	751.3	266.8	**53.7**	1	0.1	76.2	0.10
	Median	0.1	1	204	1.6	0.1	67.9	26.2	36.5	8.5	754.0	0.3	**58.1**	1	0.1	81.3	0.10
	Min	0.1	1	173	1.2	0.1	54.1	23.6	27.4	5.7	700.0	0.2	**42.6**	1	0.1	59.3	0.10
	Max	0.1	1.2	234	1.6	0.1	74.2	29.4	37.7	8.8	800.0	800.0	**60.5**	1	0.1	87.9	0.10
	80th Percentile	0.1	1.1	222	1.6	0.1	71.7	28.1	37.2	8.7	781.6	480.1	**59.5**	1	0.1	85.3	0.10
	95th Percentile	0.1	1.2	231	1.6	0.1	73.6	29.1	37.6	8.8	795.4	720.0	**60.3**	1	0.1	87.2	0.10
AQ11 / TAS11	Mean	0.1	0.8	68.6	0.2	0.1	27.9	9.3	9.5	1.9	181.0	47.1	**24.1**	1	0.1	11.6	0.10
	Median	0.1	0.8	80.4	0.2	0.1	30.6	10.4	10.5	1.9	207.5	0.2	**27.9**	1	0.1	13.3	0.10
	Min	0.1	0.5	32	0.2	0.1	14.7	4.8	4.8	1.6	72.8	0.1	9.7	1	0.1	4.4	0.10
	Max	0.1	1	81.6	0.3	0.1	35.9	11.7	12.2	2.1	236.0	188.0	**30.9**	1	0.1	15.3	0.10
	80th Percentile	0.1	0.9	81.1	0.2	0.1	33.9	11.4	11.7	2.0	230.6	75.3	**30.2**	1	0.1	14.1	0.10
	95th Percentile	0.1	1.0	81.5	0.3	0.1	35.4	11.6	12.1	2.1	234.7	159.8	**30.7**	1	0.1	15.0	0.10
AQ12 / TAS12	Mean	0.1	1.05	142	0.55	0.1	72.4	26.9	28.8	4.1	834.5	252.9	**65.9**	1	0.1	34.9	0.10
	Median	0.1	1.05	146	0.6	0.1	73.8	28.1	30.6	4.3	830.0	0.7	**65.4**	1	0.1	34.2	0.10
	Min	0.1	0.8	110	0.4	0.1	55.4	19.2	22.1	3.2	428.0	0.3	**48.2**	1	0.1	25.4	0.10
	Max	0.1	1.3	166	0.6	0.1	**86.8**	32.4	31.9	4.8	1250.0	1010.0	**84.8**	1	0.1	45.7	0.10
	80th Percentile	0.1	1.3	158.8	0.6	0.1	**80.7**	31.4	31.5	4.8	1106.0	404.5	**77.2**	1	0.1	41.7	0.10
	95th Percentile	0.1	1.3	164.2	0.6	0.1	**85.3**	32.1	31.8	4.8	1214.0	858.6	**82.9**	1	0.1	44.7	0.10

Table 4.61 Taroborah Creek - Summary of Sediment Quality Chemical Analytical Results

Taroborah Creek		Total Metals															
		Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Manganese	Molybdenum	Nickel	Selenium	Silver	Zinc	Mercury
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
ANZECC 2000 ISQG-Low		**2**	**20**	-	-	**1.5**	**80**	-	**65**	**50**	-	-	**21**	-	**1**	**200**	**0.15**
ANZECC 2000 ISQG-High		25	70	-	-	10	370	-	270	220	-	-	52	-	200	410	1
Site	**Statistic**																
AQ7 / TAS7	Mean	0.1	0.3	75.1	0.1	0.1	9.8	11.0	4.0	1.1	420.3	146.3	7.7	1	0.1	3.8	0.10
	Median	0.1	0.3	70.8	0.1	0.1	10.5	8.7	3.6	0.9	376.0	0.1	5.9	1	0.1	3.2	0.10
	Min	0.1	0.2	64	0.1	0.1	7.8	6	2.3	0.8	344.0	0.1	5.2	1	0.1	2.4	0.10
	Max	0.1	0.3	94.6	0.2	0.1	10.6	20.4	6.6	1.8	585.0	585.0	13.9	1	0.1	6.5	0.10
	80th Percentile	0.1	0.3	80.9	0.1	0.1	10.6	13.7	5.1	1.3	465.6	234.1	9.4	1	0.1	4.6	0.10
	95th Percentile	0.1	0.3	91.2	0.2	0.1	10.6	18.7	6.2	1.7	555.2	497.3	12.8	1	0.1	6.0	0.10
AQ9 / TAS9	Mean	0.1	0.7	153.8	0.5	0.1	35.8	18.7	10.13	4.6	749.8	160.9	19.2	1	0.1	9.1	0.10
	Median	0.1	0.7	168.5	0.6	0.1	41.1	18.4	11.05	5.3	724.5	0.3	**23.7**	1	0.1	9.6	0.10
	Min	0.1	0.5	56.2	0.1	0.1	13.7	10	6.5	1.2	420.0	0.1	5.4	1	0.1	4.1	0.10
	Max	0.1	1.1	222	0.6	0.1	47.1	28	11.9	6.5	1130.0	643.0	**24.2**	1	0.1	12.9	0.10
	80th Percentile	0.1	0.9	213.6	0.6	0.1	44.0	22.3	11.9	5.8	935.6	257.4	**24.1**	1	0.1	12.1	0.10
	95th Percentile	0.1	1.0	219.9	0.6	0.1	46.3	26.58	11.9	6.3	1081.4	546.6	**24.2**	1	0.1	12.7	0.10
AQ10 / TAS10	Mean	0.1	0.5	108.8	0.2	0.1	17.1	12.1	5.8	1.5	547.8	212.8	18.0	1	0.1	6.5	0.10
	Median	0.1	0.5	107.9	0.2	0.1	16.9	12.5	5.5	1.5	497.0	0.1	16.4	1	0.1	6.3	0.10
	Min	0.1	0.2	73.4	0.2	0.1	15.6	7.4	4.4	1.1	346.0	0.1	14.8	1	0.1	6.0	0.10
	Max	0.1	0.9	146	0.3	0.1	19	15.8	7.6	1.8	851.0	851.0	**24.3**	1	0.1	7.5	0.10
	80th Percentile	0.1	0.7	129.2	0.2	0.1	18.2	14.9	6.5	1.7	666.2	340.5	19.9	1	0.1	6.8	0.10
	95th Percentile	0.1	0.8	141.8	0.3	0.1	18.8	15.6	7.3	1.8	804.8	723.4	**23.2**	1	0.1	7.3	0.10
AQ13	Mean	-	5	50	1	1	19.5	5	6	5	185	2	13	5	-	9.5	0.10
	Median	-	5	50	1	1	19.5	5	6	5	185	2	13	5	-	9.5	0.10
	Min	-	5	30	1	1	13	3	5	5	106	2	9	5	-	8	0.10
	Max	-	5	70	1	1	26	7	7	5	264	2	17	5	-	11	0.10
	80th Percentile	-	5	62	1	1	23.4	6.2	6.6	5	232.4	2	15.4	5	-	10.4	0.10
	95th Percentile	-	5	68	1	1	25.4	6.8	6.9	5	256.1	2	16.6	5	-	10.9	0.10

Retreat Creek Sediments – Total Metal Concentration

Heavy metal analysis indicates Cr and Ni are in exceedance of the ANZECC (2000) stream sediment quality trigger values (refer to Table 4.59) at several sites as outlined in Table 4.60 and described below.

Chromium

The results of metal analysis indicated Cr was exceeded at three sites (AQ3, AQ4 and AQ12) when compared to the ANZECC (2000) stream sediment quality trigger values. Only the low ISQG trigger value of 80 mg/kg was exceeded with a maximum concentration of 100 mg/kg recorded at site AQ4. The average concentration at each site, however, was within the ANZECC (2000) stream sediment quality trigger values with a mean concentration of 70.8 mg/kg recorded between sites.

Cr is known to naturally exist in soils and rocks and the slightly elevated levels found in Retreat Creek may be due to the catchment runoff passing over these soils entering the waterway.

Nickel

Ni was found to exceed the ISQG Low trigger value of 21 mg/kg at seven sites including AQ1, AQ2, AQ3, AQ4, AQ8, AQ11 and AQ12 in addition to the ISQG High trigger value of 52 mg/kg at sites AQ3, AQ4 and AQ8.

The highest recorded maximum of 135 mg/kg was recorded at site AQ3 together with the highest recorded average of 124 mg/kg. The average concentration of Ni among those sites exceeding only the ISQG Low trigger value (AQ1, AQ2 and AQ11) was 22.8 mg/kg only marginally outside the guideline value. The average concentration among those sites exceeding only the ISQG High trigger value (AQ3, AQ4 and AQ8 and AQ12) was 76.0 mg/kg.

In consideration to the rural setting of the Project and the absence of smelting and other nickel refining processes it is determined elevated levels of Ni may be naturally occurring.

Taroborah Creek Sediments– Total Metal Concentration

Heavy metal analysis indicates Ni is in exceedance of the ANZECC (2000) stream sediment quality trigger values (refer to Table 4.59) at two sites as outlined in Table 4.61 and described below.

Nickel

Elevated levels of Ni were recorded at sites AQ9 and AQ10 in comparison to the ISQG Low trigger value of 21 mg/kg. Exceedances were only marginal however with site AQ9 recording a maximum concentration of 24.2 mg/kg and an average concentration of 19.2 mg/kg which is under the guideline value. Site AQ10 recorded a maximum concentration of 24.3 mg/kg and an average of 18 mg/kg, also under the guideline value. Similar to Retreat Creek, Ni may be naturally elevated in Taroborah Creek due to natural weathering processes.

Particle Size

Stream substrates within the Project site vary between sampling sites (refer to Table 4.62 and Figure 4.69). Sampling sites TAS1, TAS5, TAS8, TAS12, AQ1, AQ2, AQ4, AQ5, AQ6, AQ8 and AQ12 exhibited the highest percentage of fine sediment (clay particles <2 micrometre (μm) and silt of 2 - 60μm). The fine sediments (with a larger clay component) permit water to be retained for longer. The stream substrates of Taroborah Creek (AQ7, AQ9 and AQ10) are predominantly comprised of sands;

which is depicted below in Table 4.62 and Figure 4.69 The low proportion of cobbles in all samples is most likely attributable to sampling method, as the size of the jars and method of obtaining samples favours smaller particles. Cobbles were noted at several sampling sites, including TAS3, TAS7, TAS10, TAS11, AQ01 and AQ11.

Table 4.62 Particle Size Distributions for Sediment Samples

Site	Unit	Fines (<75 µm)	Sand (>75 µm)	Gravel (>2mm)	Cobbles (>6cm)
TAS1	%	83	16	1	< 1
TAS2	%	59	40	1	< 1
TAS3	%	47	2	50	< 1
TAS4	%	94	5	< 1	< 1
TAS5	%	3	83	14	< 1
TAS6	%	60	39	1	< 1
TAS7	%	2	89	9	< 1
TAS8	%	99	1	< 1	< 1
TAS9	%	29	54	16	< 1
TAS10	%	11	82	7	< 1
TAS11	%	20	55	25	< 1
TAS12	%	72	27	1	< 1
AQ1	%	84	16	< 1	< 1
AQ2	%	76	24	< 1	< 1
AQ4	%	84	15	1	< 1
AQ5	%	79	21	< 1	< 1
AQ6	%	76	24	< 1	< 1
AQ7	%	5	88	7	< 1
AQ8	%	90	10	< 1	< 1
AQ9	%	33	64	3	< 1
AQ10	%	23	70	7	< 1
AQ11	%	20	78	2	< 1
AQ12	%	88	12	< 1	< 1
AQ13	%	50	49	1	< 1

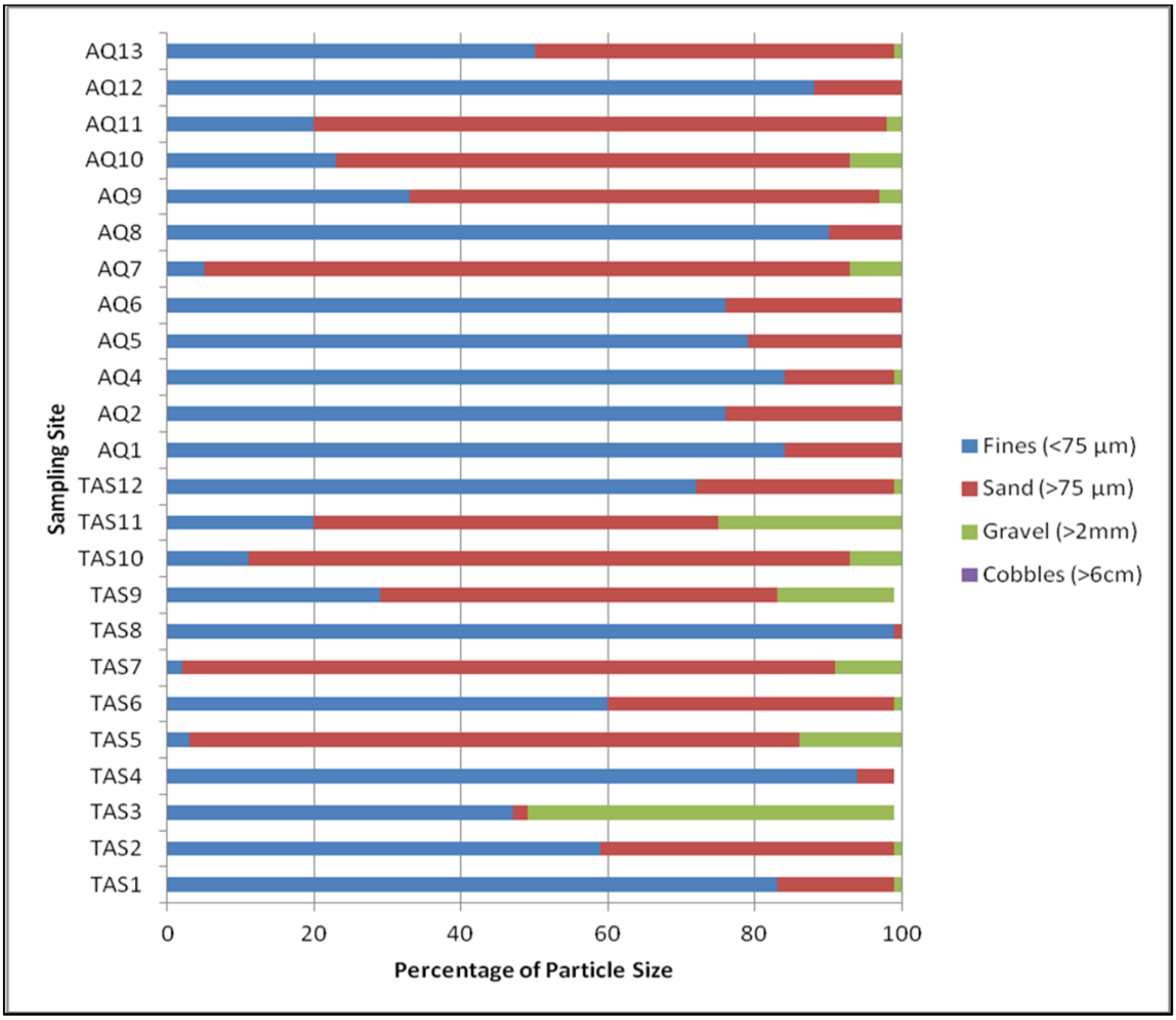


Figure 4.69 Stream Sediment Particle Size Distribution

Macroinvertebrates

During the wet and dry season aquatic surveys, 47 macro-invertebrate taxa were identified. An assessment of the quality of aquatic habitats at each sampling location was undertaken via SIGNAL scoring.

The Macroinvertebrate SIGNAL 2 assessment for the Project site during the wet and dry season surveys is presented in Figure 4.70. The four quadrants represent the following:

- Quadrant 1 – Indicates favourable habitat or chemically dilute water;
- Quadrant 2 – Often indicates high salinity or nutrient levels (may be natural);
- Quadrant 3 – Often indicates toxic pollution or harsh physical environments; and
- Quadrant 4 – Usually indicates urban, industrial, or agricultural pollution.

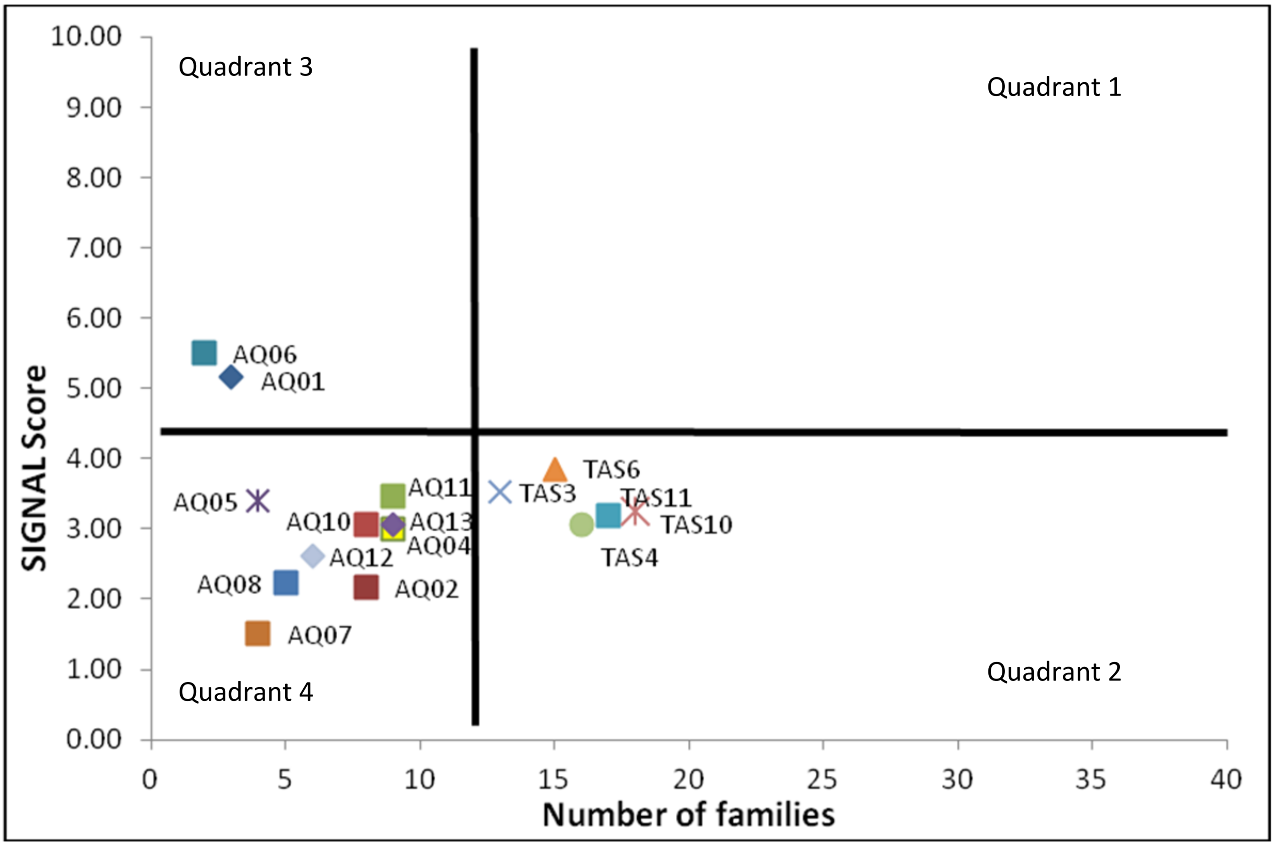


Figure 4.70 Macroinvertebrate SIGNAL 2 Scores

Results of the analysis indicate that none of the sites are pristine, as all dry season sampling sites fell within Quadrant 2 (often indicating high salinity or nutrient levels that may be natural), whilst during the wet season the majority of sites sampled are placed within Quadrant 4 (usually indicating urban, industrial, or agricultural pollution). These results are most likely associated with the ephemeral nature of the watercourses within the region. Retreat Creek, Taroborah Creek and their associated tributaries were placed within the 'relatively good' habitat category, whilst the pastoral dam and some wetlands generally fell within the 'moderate' habitat category.

These results indicate that most aquatic survey sites exhibited elevated nutrient levels and disturbance from cattle grazing.

4.5.1.2 Groundwater

A groundwater impact assessment was conducted by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to characterise the hydrogeological regime of the Project site and extrapolate the potential impacts as a result of the mining activities associated with the Project. The assessment included a review of all available data and historical reports, field investigations and the development of a numerical groundwater model to predict the scale and extent of mining impacts on groundwater levels, water quality and existing groundwater users.

The following sections provide a summary of the findings of the groundwater impact assessment. Complete findings, together with raw data, are provided in the *Groundwater Impact Assessment Taroborah Coal Project* (AGE 2014) in Appendix 14.

Stratigraphy

Three major geological units are present within the Project area at depths shallower than 250m. The stratigraphy typically comprises Permian coal measures overlain by Tertiary basalts and Quaternary alluvium. The stratigraphy of the Project area and surrounds is shown in Table 4.63.

Table 4.63 Stratigraphy of the Project Area

Age	Unit	Map Symbol	Lithology	Thickness
Quaternary - Tertiary	Alluvium	Qa	Sands and minor gravel related to present day streams, creeks and rivers; deposited during the Quaternary.	<30m
	Colluvium	Qr	Silt, mud, basalt derived colluvial and residual deposits; deposited during the Quaternary.	
	High-level alluvium	TQa	Poorly consolidated sand, silt, clay, minor gravel, generally related to present-day stream valleys; deposited during the Quaternary (and late Tertiary).	
Tertiary	Basalt/Clay	Tb	Olivine basalt where fresh. Clay where highly weathered	<90m
Permian	Aldebaran Sandstone	Pbl	Fine grained marine sandstone	<150m
			Fine to coarse fluvio-deltaic sandstone. Contains coal and coarse grained pebbly unit. Coal seams include the A and B seams, which are the target seams for the Project.	50m – 100m

Quaternary Alluvium

A review of the 1:100,000 surface geology mapping (refer to Appendix 14) shows a thin cover of alluvial (Qa and TQa) and colluvial (Qr) sediments deposited across much of the western and northern portions of the Project area. Recent exploration drilling shows that the alluvial cover, where encountered, generally comprises less than 25m of poorly consolidated clays, silts, sands and gravels. Thicker alluvial deposits are likely to exist within the present-day floodplains of Retreat Creek and Taroborah Creek.

The alluvial and colluvial deposits unconformably overlie Tertiary basalt (Tb) and sediments. Where the Tertiary geology is absent, the Quaternary alluvium and colluvium directly overlie the Permian Aldebaran Sandstone (Pbl).

Available exploration drill logs indicate that the extent of the alluvium is relatively consistent with the 1:100,000 geological mapping. However, exploration drilling has largely been conducted outside the alluvial floodplain, and therefore, some areas of mapped alluvium are expected to differ from local

ground conditions.

Tertiary Basalt and Sediments

The 1:100,000 surface geology mapping shows that Tertiary basalts outcrop throughout much of the middle and southern portions of the Project area (refer to Appendix 14). Where fresh, the basalt is described as being of a dark grey olivine type that is often highly vesicular (D'Arcy 1988).

Three main observations about the nature of the Tertiary deposits can be deduced from the recent exploration drilling across the Project area. Firstly, the occurrence of fresh basalt is sporadic, and where encountered, is generally less than 30m thick. Secondly, fresh basalt (where present) is generally underlain by highly weathered Tertiary clays and sands, and occasional silts and gravels that range in thickness from 30m to 90m. Lastly, the weathered clays and sands progressively grade into weathered Permian deposits beneath.

Permian Strata

Basement geology mapping (refer to Appendix 14) shows that the Aldebaran Sandstone sub-crops throughout the central and northern areas of the Project area. Exploration logs and historical data indicates the Aldebaran Sandstone is predominantly composed of quartzose sandstone deposited during cyclic marine to fluvial-deltaic environments and interbedded with conglomerate, shale, siltstone and coal. Below the base of weathering, strata is dominated by fine to very fine grained sandstones with occasional medium grained horizons deposited during a marine transgression. This fine grained sandstone has been removed by erosion in the south, where outcropping granite is present, but is up to 150 m thick in the northern portion of the Project area.

The fine grained sandstone is underlain by coarser grained fluvio-deltaic sandstones interspersed with several coal seams. The upper two coal seams in this sequence are locally referred to as the A and B seams, which are the target coal seams for the mining operation. Site exploration data indicates that:

- The A seam has an average thickness of 1.2m, and the underlying B seam 3.0m thickness;
- Interburden separating the A and B seams ranges in thickness from 5m to 14m, with an average thickness of 10m;
- Interburden material comprises fine to coarse grained sandstone with occasional thin siltstone, mudstone and pebble horizons; and
- Depth to the A seam ranges from about 40 metres below ground level (mbgl) where it occurs at sub-crop to the north of Taroborah Creek in the south of the Project area, deepening to about 200 mbgl at the northern Project boundary.

Structural Geology

The Project area is situated on the north-western edge of the Denison Trough, in the south-west of the Bowen Basin. The major period of deformation within the Dension Trough occurred prior to the Permian. Consequently, the pre-Permian basement is generally steeply dipping with major faults generally trending in a NNW-SSE, NW-SE and WSW-ENE direction.

Within the Emerald region, a potential fault trace along the Comet Platform, displaces the Reids Dome Beds to the south. This likely relates to the upthrown, subsurface expression of the Reids Dome Beds to the north of Kettle Creek and the Project area. This indicates a rapid change in the stratigraphic

bedding of the Aldebaran Sandstone, which have been mapped from exploration drilling and seismic surveys as dipping towards the north.

The structural geology to the east of the Project area has been variably mapped as being either:

- On the western limb of the north-north-west continuation of the Springsure Anticline; or
- Within a fault bound graben structure, which trends northward and is positioned to the west of the main Denison Trough.

Historic and recent exploration drilling indicates that the Project area contains a considerable thickness of Permian sediments that unconformably overlie a mixed basement of block faulted pre-Permian Retreat Granite and Drummond Basin sedimentary units. Seismic surveys and exploration drilling have identified several NW-SE trending faults to the east and west of the Project area. This, lower coal measures have been documented outside of the fault zones; however, no coal was intersected along the hinge zone of the inferred anticline (Veevers *et al.,* 1962). Overall, geological investigations and mapping show that the region has undergone extensive periods of deformation, resulting in disconnection of the coal seams from stratigraphy east of the inferred anticline.

Monitoring Network

The groundwater monitoring network across the Project area comprises 19 bores, which were constructed in two stages during 2008/2009 (identified as TAR series) and 2013 (identified as MB bore series).

The bore locations overlain on the surface geology map are shown in Figure 4.71, and construction details are summarised in Table 4.64. Further details concerning the construction and monitoring details of groundwater bores involved in the assessment are provided within Appendix 14.

Table 4.64 Groundwater Monitoring Network

Hole ID	Coordinates		Geological Unit	Drilled Depth (mbGL)	Screen (mbGL)
	Easting	Northing			
MB01_B	592504	7399983	Tertiary	43	27.9 – 33.9
MB02_C	593997	7397592	Aldebaran Sandstone	103	92.2 – 95.2
MB02_S	594017	7397580	Aldebaran Sandstone	154	89.35 – 95.35
MB03_S	599667	7399771	Aldebaran Sandstone	163	76 – 82
MB04_C	593513	7399534	Aldebaran Sandstone	173	118.5 – 120.5
MB04_S	593493	7399537	Aldebaran Sandstone	130	100 – 106
MB05_C	598860	7398819	Aldebaran Sandstone	151	141 – 144
MB06_B	592471	7394530	Tertiary	40	19.4 – 25.4
MB07_B	592065	7393041	Aldebaran Sandstone	31.2	27.5 – 30.6
MB08_B	594668	7390096	Tertiary	60	40 – 46
MB09_T	593575	7401714	Quaternary alluvium	43	24 – 30
MB10_T	600020	7402656	Quaternary alluvium	30	12.7 – 18.7
TAR016_CR	594956	7395372	Aldebaran Sandstone	85	58 – 64
TAR040_C	600263	7396108	Aldebaran Sandstone	84.1	55 – 58
TAR053	595642	7395113	Aldebaran Sandstone	97	52 – 58
TAR176_C	595549	7400349	Aldebaran Sandstone	168	97 – 103
TAR177_C	594586	7400197	Tertiary	202	18 – 21
TAR189_C	598843	7398818	Aldebaran Sandstone	164	137.5 – 140.5
TAR249_C	596635	7397000	Aldebaran Sandstone	110.4	84.5 – 87.5

* Coordinates in MGA 94 Zone 55

.

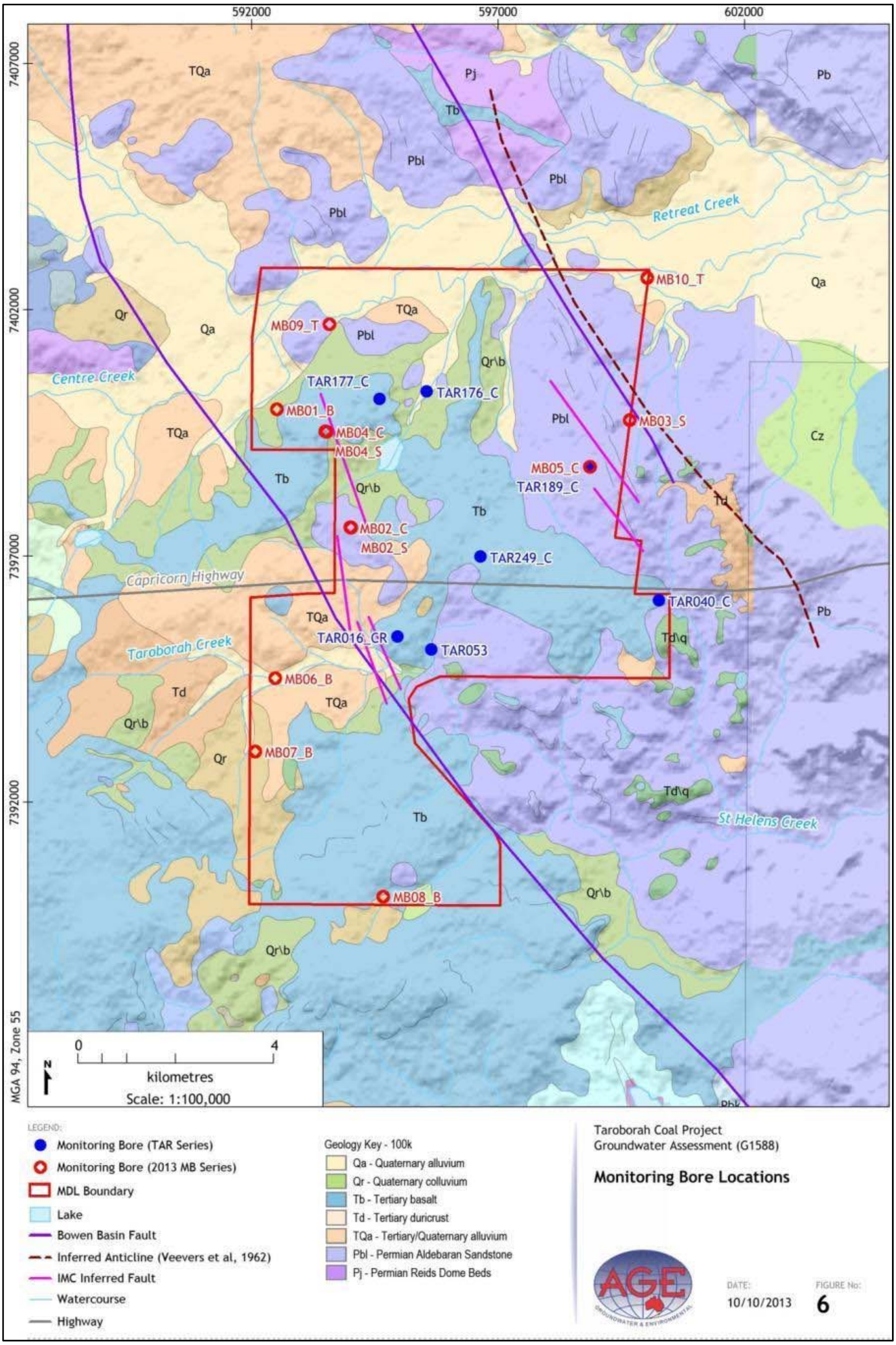


Figure 4.71 Groundwater Monitoring Bore Locations (AGE 2013)

Existing Groundwater Facilities

Twenty-two existing groundwater bores were identified within and surrounding the Project site that are currently in use, with the main use being for stock and domestic purposes. The identified bores have the following spatial distribution:

- Five within the Project boundary;
- Nine within 5 km of the Project boundary; and
- Eight between 5 km and 10 km from the Project boundary.

Table 4.65 summarises bore details for the 22 bores identified as being currently in use, and Figure 4.72 shows the location of these bores. As limited data was available from the landholder bores due to access and operational issues, hydraulic parameters, drawdown data and long-term monitoring data were not available from these bores for the assessment. However, the full bore survey results are provided in Appendix 14.

The main source of groundwater within the Project area is from the Aldebaran Sandstone. All six bores inferred to be screened across Aldebaran Sandstone are located either within the Project area, or immediately to the east of the Project boundary (Figure 4.72). In contrast, the main source of groundwater outside the Project area is from the Tertiary basalt. The majority of bores using the basalt are located to the west of the Project boundary. This coincides with observations from exploration drilling that the basalt within the Project area is thin (less than 30m) and poorly distributed.

Landholders utilising groundwater within the Quaternary alluvium are located north of the Project area, where three groundwater takes are associated with the alluvium of Retreat Creek and Kettle Creek. Two landholder bores are also located along Centre Creek, west (upstream) of the Project area. According to the Department of Natural Resources and Mines (DNRM) *Groundwater Database* (GWDB), one targets the Colinlea Sandstone (Registered bore number (RN) 89399), while the other (RN 90250) targets the Tertiary gravels.

Table 4.65 Landholder Bores Identified During Bore Census

Bore ID	DNRM Registered Bore No.	Easting (m)	Northing (m)	Bore Use	Data Recorded	Inferred Geological Unit
Within Project Area						
2	Not Registered	595087	7394403	Stock	-	Tertiary Basalt/Alderbaran Sandstone
3	Not Registered	599193	7396249	Stock and farm	Temp, Field pH, salinity and TDS	Alderbaran Sandstone – Pebbly coarse grained sandstone
7	90064	596819	7396888	Stock and farm	Field pH and salinity	Alderbaran Sandstone – Pebbly coarse grained sandstone
8	67349	592950	7400883	Stock	Water level, field pH and salinity	Tertiary Basalt
9	84184	593437	7396628	Stock	-	Alderbaran Sandstone
Within 5 km of Project Boundary						
11	37770	592914	7386412	Stock	Water level	Tertiary Basalt
13	103908	589653	7403718	Stock	Temp, Field pH, salinity and TDS	Quaternary Alluvium (Retreat Creek)
15	47238	605840	7400508	Stock and farm	Water level, Field pH and salinity	Tertiary Basalt
16	90250	588803	7398913	Stock	-	Tertiary Gravel
17	103728	602849	7400245	Stock	Temp, Field pH, salinity and TDS	Aldebaran Sandstone
18	103729	600681	7399512	Stock	Temp, Field pH, salinity and TDS	Aldebaran Sandstone
20	Not Registered	587049	7394528	Stock and farm	Water level, Temp, Field pH, salinity and TDS	Tertiary Basalt (vesicular)

Bore ID	DNRM Registered Bore No.	Easting (m)	Northing (m)	Bore Use	Data Recorded	Inferred Geological Unit
21	57603	600739	7393663	Stock	-	Aldebaran Sandstone
23	89399	586128*	7399707*	Stock and farm	-	Colinlea Sandstone
Between 5 km and 10 km of Project Boundary						
27	Not Registered	583773	7388873	Stock	Temp, Field pH, salinity and TDS	Tertiary Basalt
28	Not Registered	589127	7387106	Stock	-	Tertiary Basalt
31	Not Registered	584132	7390174	Domestic	Water level, Temp, Field pH, salinity and TDS	Tertiary Basalt
32	Not Registered	587605	7386451	Stock	-	Tertiary Basalt
37	89387	584831*	7405866*	Stock	-	Quaternary Alluvium (Retreat Creek)
44	47323	595100	7410014	Stock	Water level, Temp, Field pH, salinity	Quaternary Alluvium (Kettle Creek)
47	Not Registered	584393	7392258	Stock and spray rigs	Temp, Field pH, salinity and TDS	Tertiary Basalt (vesicular)
50	47217	581765	7395658	Stock	Water level, Temp, Field pH, salinity and TDS	Tertiary Basalt (vesicular)

* Bore location identified from DNRM GWDB

- Coordinate datum GDA94, Zone 55

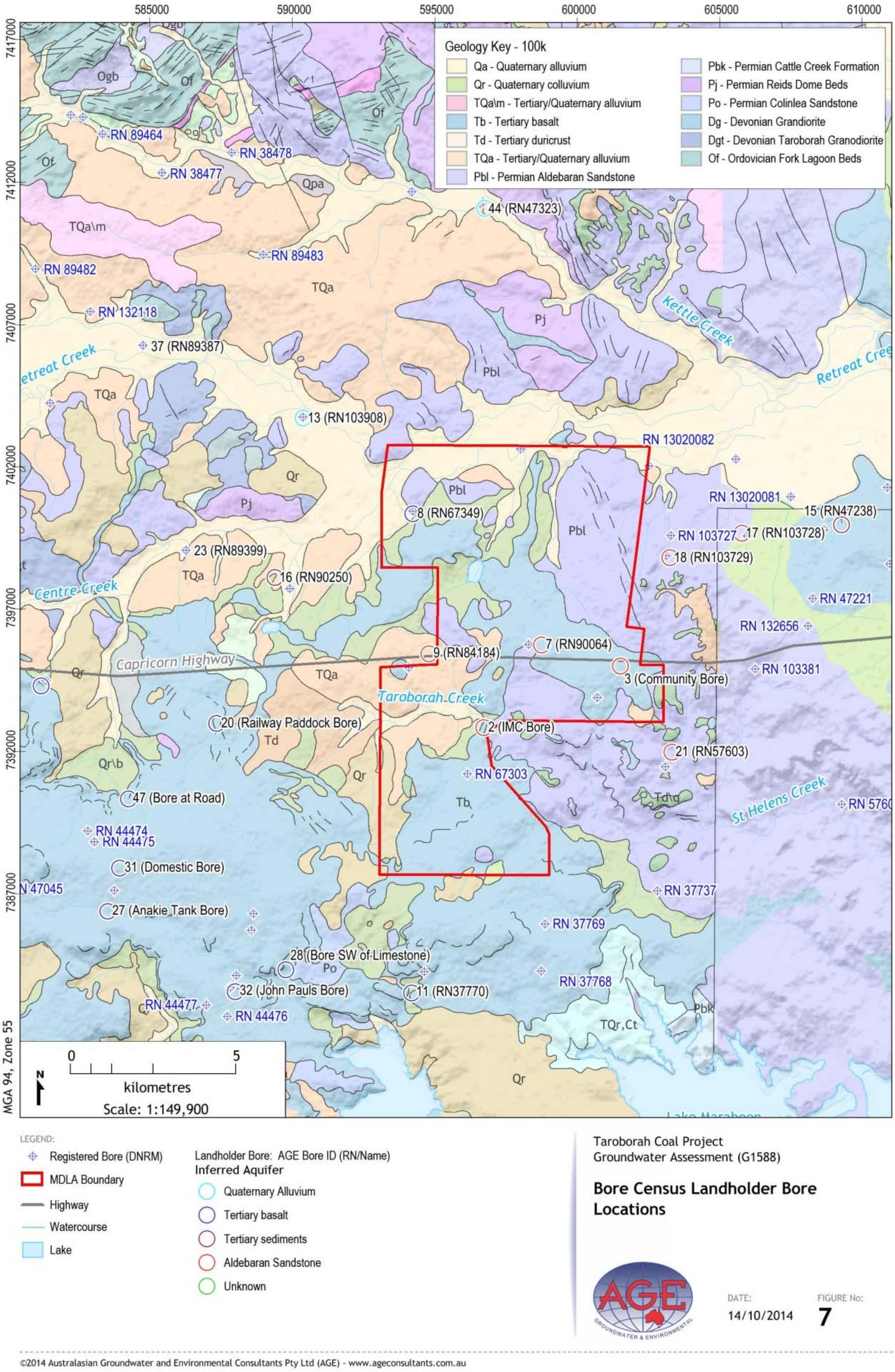


Figure 4.72 Landholder Bore Locations (AGE 2014)

Aquifers

The following geological units form groundwater systems within and surrounding the Project area:

- Quaternary alluvium, located primarily along Taroborah Creek, Retreat Creek and Kettle Creek;
- Tertiary basalt, and to a lesser extent Tertiary sands and gravels; and
- Permian Aldebaran Sandstone.

Descriptions of each groundwater system are presented in the following sections.

Aquifer Yield, Distribution and Use

Permian Alderbaran Sandstone

The Permian Aldebaran Sandstone appears on the 1:250,000 published basement geology map (refer to Appendix 14) as the predominant sub-surface geological unit within the Project area.

Geologically, the region has undergone extensive periods of deformation, resulting in disconnection of the coal seams from stratigraphy east of the Project area. This can therefore be considered as representing a regional boundary to groundwater flow.

Groundwater is present under confined conditions throughout a number of different horizons within the Aldebaran Sandstone including:

- A and B coal seams;
- Pebbly coarse-grained sandstone unit directly overlying A Seam; and
- Shallower, predominantly fine-grained, sandstones.

The Permian Aldebaran Sandstone is the most commonly used groundwater system within the Project area. However, regionally only six of the 22 landholder bores identified within 10 km of the Project area target the Aldebaran Sandstone. This indicates that landholder water usage is supplemented by surface water capture and mains water supply (i.e. for drinking water supply). Each of the Permian Aldebaran Sandstone horizons are discussed as follows.

<u>Fine Grained Sandstones</u>

Bore logs show that groundwater within the fine grained sandstones is not only present within the fine-grained portion of the unit, but is typically also present where coarser grained horizons, or palaeochannels, are intersected.

Air-lift yields measured during exploration drilling (51 groundwater intersections) varied between 0.17 L/s and 15 L/s, with an average of 1.9 L/s. Yields are generally higher in the north of the Project area. There is no correlation between air-lift yield and grain size. The exploration yields are likely to be biased towards higher values as water flows were only measured where significant flows were intercepted.

During installation of additional groundwater monitoring bores in 2013, the air-lift yield for a bore intersecting the fine grained Aldebaran Sandstone (MB03_S) was recorded at a rate of 0.07 L/s. Bore

MB07_B, which is also screened across the fine grained sandstone, was drilled as a dry hole, highlighting that the unit is not saturated over its full thickness.

Pebbly Coarse Grained Sandstone Layer

The main water bearing unit within the Project area is the pebbly coarse grained sandstone unit that lies directly on top of A seam. Drilling results show that this coarse layer is consistent and present throughout most of the Project area. Observations of geological cores and chip samples suggest this unit contains both primary porosity where groundwater is contained within pore spaces and secondary porosity where groundwater occurs within joints and/or fractures. The unit may act as either a confined or leaky unit, depending on the contact with the underlying coal seam. Where the contact with the underlying A seam is comprised of coarse sandstone, groundwater may leak from the unit into the coal seam. In contrast, where the contact with the underlying seam comprises siltstone or mudstone, hydraulic connection between the coarse sandstone and coal seam may be limited.

During exploration drilling, air-lift yields measured at 13 groundwater intersections were recorded at rates of between 0.5 L/s and 20 L/s, with an average of 3.1 L/s. Similar results were recorded during the 2013 monitoring bore installation program, where air-lift yields for five bores intersecting the pebbly course sandstone were measured at rates of between 0.3 L/s and 7 L/s. Similarly to the fine grained sandstone unit, yields for this coarse grained sandstone unit are generally higher in the north of the Project area.

Coal Seams

Observations during drilling have shown groundwater to be present within the A and B coal seams within the Project area. Air-lift yields within the coal seams were recorded for two bores during the exploration drilling program with measured flows of 0.5 L/s (TAR199_C) and 1 L/s (TAR187_C).

The potential for these flows to be influenced by the presence of the overlying sandstone is unknown. Air-lift yields measured during the 2013 monitoring bore installation program showed no significant increase in flows upon interception of the deeper coal seam.

As observed throughout the Bowen Basin, groundwater storage and movement within coal typically occurs within the coal cleats and fissures, and within open fractures that intersect the seams. The hydraulic connection between the A seam and the overlying pebbly coarse sandstone layer is likely to be dependent on the nature of the contact between these units, as described above. Likewise, the hydraulic connection between the A and B seams depends on the composition of the interburden material. Where the interburden is largely comprised of permeable coarse grained sandstones, the A and B seams are likely to be hydraulically connected. In contrast, hydraulic connection will be limited where the interburden contains low permeability siltstones or mudstones, and the A and B seams are likely to be hydraulically disconnected.

Tertiary Basalt and Sediments

Groundwater within basalt typically occurs within fractured and vesicular horizons. It is expected that the amount of flow within the basalts is dependent on the extent and intensity of the fractures.

Air-lift yields within Tertiary basalts were recorded for four bores during the exploration drilling program, with measured flows of between 0.6 L/s and 5 L/s. Drilling has shown groundwater to also be present within Tertiary clays, sands, and gravels, with measured yields generally lower than that of the basalts. The presence of thick, impermeable Tertiary clays throughout the Project area suggests the Tertiary units are likely to be confined and hydraulically disconnected from the underlying Aldebaran

Sandstone. Groundwater flows were too low to be measured by air lift tests for monitoring bores MB01_B (clay, silt) and MB08_B (clay, gravel). Bore MB06_B, screened across clay and silt; was drilled as a dry hole and indicates that Tertiary sediments are not fully saturated throughout the area.

Bore census results show that Tertiary basalts are predominantly used by landholders located to the west of the Project area, where the basalts are typically described as being fresh and vesicular. The basalt is not heavily used within the Project area, with only one landholder bore identified during the bore census.

Quaternary Alluvium

Alluvium within the Project area has limited groundwater potential, as drilling shows it is typically thin (<30m) and has limited lateral extent. Observations during drilling of MB06_B, located approximately 20m from Taroborah Creek, show that alluvial sands adjacent to the creek are dry in that location. No users of alluvium where identified within the Project area during the bore census. Where groundwater is present, the alluvium it is likely to be unconfined.

An air-lift yield of 1.0 L/s was recorded for the thick sequence of sands and gravels intersected at MB09_T. However, no flows were observed during drilling at MB10_T, which intersects sandy silt and a thin sequence of silty gravel. This highlights the variability in the depositional environment, and consequently the stratigraphy, of the alluvial sequences.

Bore census results show that the Quaternary alluvium is used by landholders located to the north of the Project area, within the present day floodplains of Retreat and Kettle Creeks.

Hydraulic Parameters

Permian Alderbaran Sandstone

The results of falling head tests conducted for 10 bores indicate that hydraulic conductivities are over one order of magnitude higher within the pebbly coarse-grained sandstone compared to the underlying coal seams and overlying fine grained sandstone (refer to Table 4.66). In general, the hydraulic conductivity results for the Permian strata are comparable to those measured in similar units for neighbouring projects.

Table 4.66 Hydraulic Conductivity of Aldebaran Sandstone

Lithology	Hydraulic Conductivity (m/day)			No. of Tests
	Minimum	Maximum	Average	
Pebbly coarse-grained sandstone	3.0×10^{-2}	3.00	1.10	5
Coal seams	2.3×10^{-2}	1.7×10^{-1}	8.1×10^{-2}	3
Fine grained sandstone	1.1×10^{-2}	5.4×10^{-2}	3.3×10^{-2}	2

Tertiary Basalt and Sediments

Results of permeability tests for three bores within Tertiary basalts and sediments show a range in hydraulic conductivity between 1.3×10^{-1} m/day and 5.5×10^{-4} m/day (refer to Appendix 14). The

highest hydraulic conductivity was measured in fresh basalt (TAR177_C) and the lowest measured across clay (MB01_B).

Quaternary Alluvium

Permeability results for the two alluvial bores (MB09_T and MB10_T) were recorded at rates of 2.0 m/day and 4.6 x 10^{-2} m/day, respectively (refer to Appendix 14). The significant difference in permeability between the two alluvial bores highlights the heterogeneity of the alluvial aquifer.

Aquifer Recharge and Flow

Permian Alderbaran Sandstone

Nested facilities, which are bores located within the same site but intersecting different strata, can be used to indicate the vertical gradients between different geological units. There are three nested facilities across the Project, located at the following locations:

- MB02_C (B seam) and MB02_S (pebbly coarse sandstone);
- MB04_C (B seam) and MB04_S (pebbly coarse sandstone); and
- MB05_C (A seam) and TAR189_C (pebbly coarse sandstone).

Recent groundwater levels at MB02 show a measured upward gradient from the pebbly coarse sandstone (188.92 mAHD at MB02_S) and the B coal seam (189.96 mAHD at MB02_C). The 1 m difference in groundwater levels suggest that the pebbly sandstone and underlying B seam are partially hydraulically disconnected at this location. A degree of hydraulic disconnection is also indicated by a difference in EC values between the two bores (2,153 µS/cm at MB02_C compared to 1,463 µS/cm at MB02_S).

In contrast, groundwater levels at the other nested facilities are very similar (193.6 mAHD at MB04_S versus 192.35 mAHD at MB04_C; and 191.98 mAHD at MB05_C versus 191.98 mAHD at TAR189_C). The similarity in groundwater levels suggest that the pebbly coarse sandstone and coal seams are hydraulically connected at these locations. Hydraulic connection at MB04 is also indicated by the similarity in EC values between MB04_C (2,377 µS/cm) and MB04_S (2,313 µS/cm).

The potentiometric surface of the pebbly coarse sandstone unit has been inferred from groundwater levels measured in monitoring bores during May 2014. As illustrated on Figure 4.73, the contours indicate that groundwater flow within the pebbly coarse sandstone reflects topography flows towards the south. Pumping from bore RN90064 appears to locally influence groundwater levels in the coarse sandstone creating a local zone of drawdown.

Recharge is expected to occur via rainfall percolation from mapped sub-crops of the Aldebaran Sandstone, shown on Figure 4.73. The southward flow direction in the northern Project area does not originate from any mapped sub-crop areas and could indicate recharge from either:

- Downward percolation from Quaternary alluvium associated with Retreat Creek; or
- Graben related fault leakage from the western fault zone.

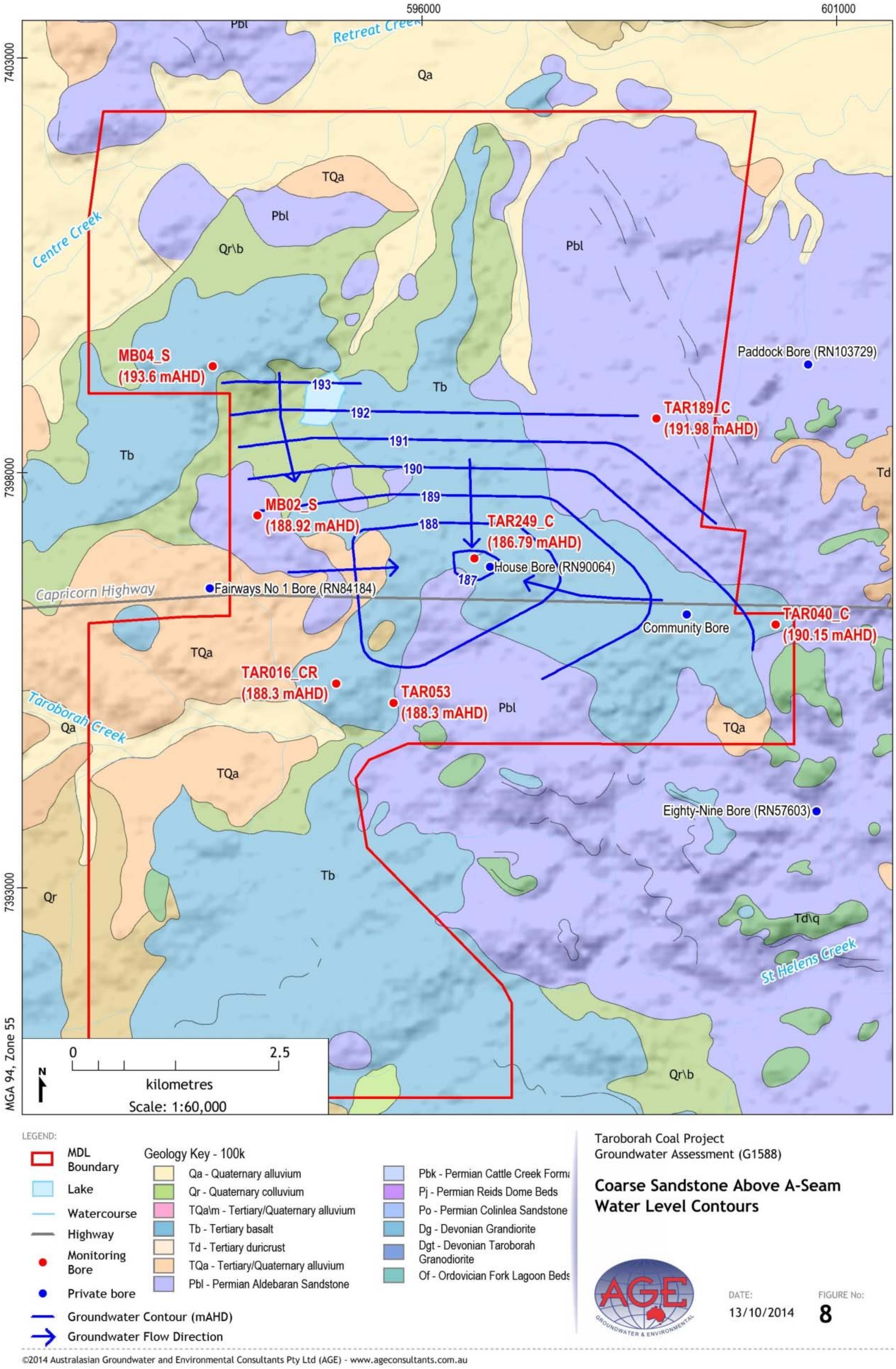


Figure 4.73 Pebbly Coarse Sandstone Water Contour Levels

There are not enough measured groundwater levels within the fine sandstone unit and coal seams to produce potentiometric contours for these units. Groundwater levels measured within the coal seams show little variation across the Project, with a range of 191.56 mAHD (MB02_C) to 192.34 mAHD (MB04_C).

Recharge to the fine grained sandstones and coal seams are likely to originate from the same sources as the pebbly coarse sandstone. Recharge to the Aldebaran Sandstone may also occur from leakage of overlying geological units. Discharge from the Aldebaran Sandstone will occur down-gradient from the groundwater flow direction.

Hydrographs of measured water levels in the Permian monitoring bores for the period April 2013 to May 2014 show a general flat trend for all bores. There are some bores that show variability in the data record, however, the variations are thought to be related to instrument error or the influence of pumping from a nearby landholder bore and not representative of the true water level in the bores.

Tertiary Basalt and Sediments

Potentiometric contours (refer to Figure 4.74) indicate that groundwater flow within the Tertiary is towards the east and northeast within the Project area and surrounds. This flow direction suggests that the main source of recharge to the Tertiary is from rainfall percolation in the sub-crop areas to the west and south-west of the Project area. The influence of Lake Maraboon on recharge is unknown. Contour elevations vary from about 255 mAHD in the west, to about 195 mAHD in the northeast corner of the Project area.

The potentiometric surface of the Tertiary basalt and sediments was inferred from groundwater levels measured in nine landholder bores during the bore census surveys, and monitoring bore TAR177_C. Elevations of landholder bores were estimated from 1 arc second DEM-S (smoothed digital elevation model – 1 second SRTM derived) data which is considered to have height errors of up to 3m in clear flat-lying areas such as the terrain present at Taroborah.

Discharge from Tertiary sediments is likely to occur as lateral flow down-gradient of the Project area. Leakage to underlying units may also occur where impermeable Tertiary clays are absent in the geological profile.

Hydrographs of measured water levels in the Tertiary Basalt monitoring bores for the period April 2013 to May 2014 show a general flat trend for all bores.

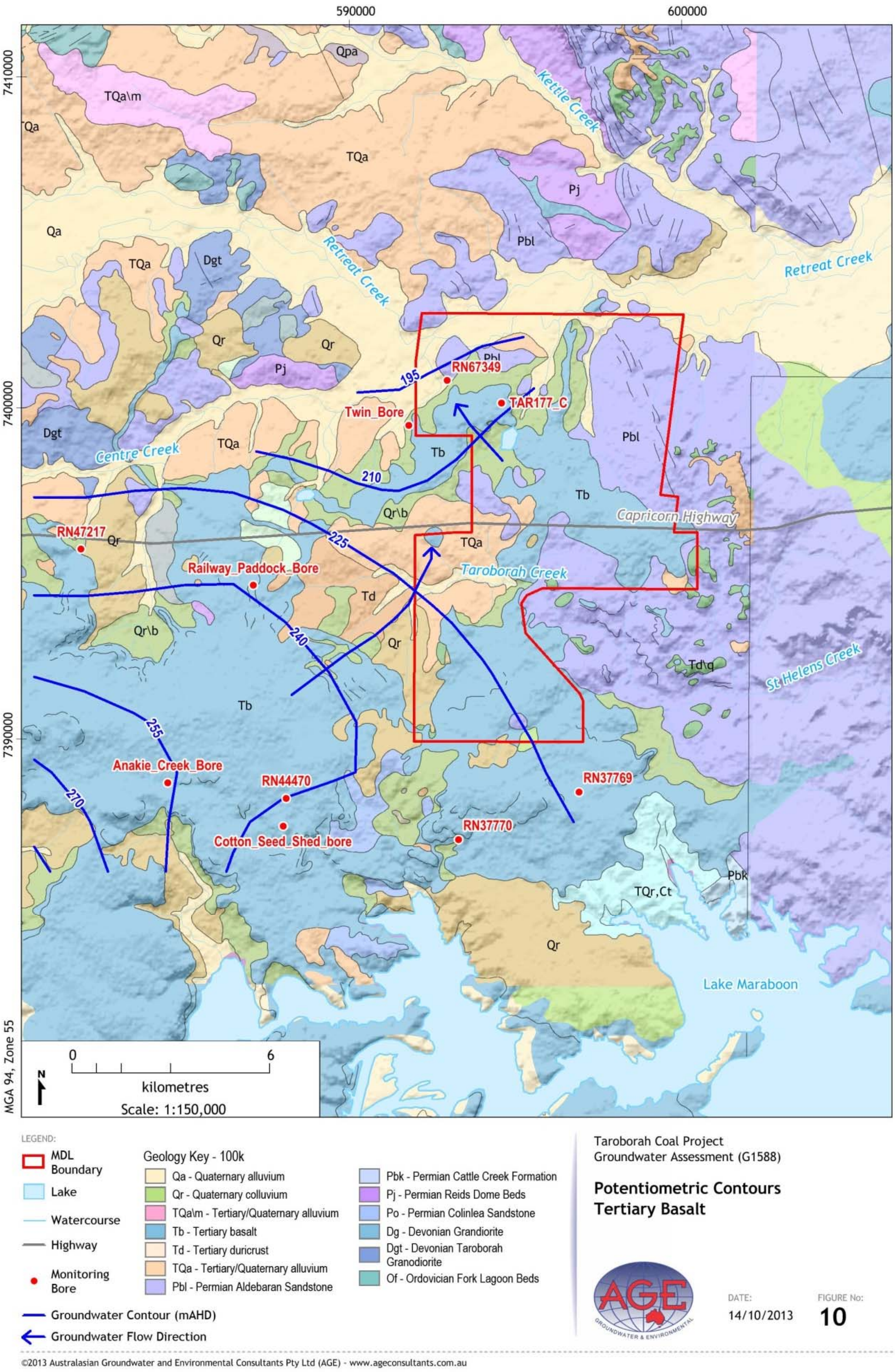


Figure 4.74 Tertiary Basalt Potentiometric Contour

Quaternary Alluvium

Groundwater levels measured in monitoring and landholder bores throughout the Project area show that the water table is shallow and generally less than 10 mbGL. Water table contours for the alluvium could not be inferred due to the scarcity of monitoring bores within it; however, the water table in the alluvium is expected to reflect topography, with groundwater flow being towards drainage features and watercourses.

The spatial distribution and depth of alluvial deposits suggests recharge occurs by a combination of:

- Direct rainfall percolation; and
- Seepage from adjacent creeks during periods of surface flow.

Comparison of groundwater levels within the alluvium (MB09_T and MB10_T) and Permian hard rock sequences indicates that the alluvium is generally a losing system (down-ward leakage to underlying sequences). Stored water within the alluvium is likely to largely discharge as base flow to adjacent creeks or as leakage to nearby sub-cropping Tertiary and Permian units. The ephemeral nature of the creeks suggests that discharge from the alluvium is unlikely to be significant or sustained.

The water level hydrograph for MB10_T shows a slight reduction (1.5 m) in water level over the April 2013 – May 2014 monitoring period. This trend is similar to that recorded for Tertiary basalt bore TAR177_C, and appears to correspond with a decline in rainfall over this period.

Groundwater Quality

Water quality sampling was undertaken in 2009, April 2013 and May 2014 to deliver an extract of the baseline groundwater quality associated with the Project site (refer to Table 4.67). The complete groundwater monitoring analysis including bore reference is provided in Appendix 14.

The results indicate that the groundwater within the alluvium and Tertiary basalt are generally fresher than the regolith and Aldebaran Sandstone units, with lower major ion concentrations.

Salinity is a key constraint to water management and groundwater use, and can be categorised by electrical conductivity (EC)..

The results for field salinity indicate that groundwater within the Quaternary alluvium is slightly brackish to brackish, with an average EC of 1,400 µS/cm. The coarse grained sandstone is generally less saline than the alluvium, with fresh water quality recorded at TAR249_C in 2014, and a larger number of samples classified as slightly brackish.

The A and B coal seams have brackish water quality, with an average EC of 2,300 µS/cm. EC of the coal seams is comparatively low for the Bowen Basin, which can typically vary from 5000 µS/cm to over 50,000 µS/cm. The lower EC of the A and B seams is likely related to leakage of 'fresher groundwater' from the immediately overlying pebbly coarse sandstone unit, and from rainfall infiltration where it occurs at sub-crop to the south.

The Aldebaran Sandstone dips towards the north, resulting in the Permian stratigraphy occurring at greater depth. The water quality results and geological setting indicates that the Permian groundwater in the northern end of the Project area has a higher residence time and salinity.

The shallower Aldebaran Sandstone bores (MB02_S, TAR016_CR and TAR053) record lower concentrations of chloride, and higher concentrations of bicarbonate (refer to Appendix 14). This likely

relates to increased recharge rates and potential interaction with faults.

Water quality results for fresh basalt bore TAR177_C indicates high concentrations of bicarbonate, calcium and magnesium, but low concentrations of chloride (refer to Appendix 14). This indicates the potential presence of fracturing within the basalt, which may enhance recharge by rainfall percolation. The heterogeneity of the basalt sequences is highlighted by the higher chloride and magnesium concentrations recorded within the weathered basalt at MB08_B.

Table 4.67 Summary of Water Quality Results – All Geological Units

Parameter	Statistic	Aldebaran Sandstone			Tertiary Regolith	Tertiary Basalt	Alluvium
		CG	FG	Coal			
Field EC @ 25 ^{0}C (µS/cm)	Avg.	1,435	1,765	2,301	2,059	1,354	1,431
	Min.	546	782	1,570	1,430	1,315	917
	Max.	2,572	3,130	3,180	2,533	1,380	1,775
Field Total Dissolved Solids (mg/L)	Avg.	848	1,060	1,415	1,186	793	853
	Min.	471	403	1,010	789	676	605
	Max.	1,590	1,990	2,000	1,410	910	1,010
Field pH (pH units)	Avg.	8	9	8	8	7	7
	Min.	7	7	7	7	7	6
	Max.	9	11	8	8	7	8
Calcium (mg/L)	Avg.	56	36	66	58	77	52
	Min.	17	2	37	30	71	34
	Max.	128	58	97	70	85	77
Magnesium (mg/L)	Avg.	55	25	81	116	107	52
	Min.	3	1	47	81	98	29
	Max.	89	47	129	163	116	78
Sodium (mg/L)	Avg.	167	253	273	213	72	186
	Min.	66	101	151	122	69	123
	Max.	494	482	354	257	74	262
Bicarbonate (mg/L)	Avg.	442	150	301	512	687	389
	Min.	21	1	245	398	629	225
	Max.	1,180	276	416	620	778	641
Chloride (mg/L)	Avg.	231	329	490	324	65	216
	Min.	48	124	291	129	52	134
	Max.	903	560	718	497	73	338
Sulfate (mg/L)	Avg.	41	131	125	81	22	64
	Min.	6	37	66	7	20	37
	Max.	156	293	198	131	25	84
Number of Samples		17	5	6	5	3	4

CG – coarse grained sandstone
FG – fine grained sandstone

Weathering also appears to influence water quality, with slightly brackish water quality recorded in the fresh Tertiary basalt (TAR177_C), compared to brackish water quality within the more weathered basalt sequence (MB01_B).

A significant portion of the EC dataset exceeds the 80th percentile limit that is specified for deep (> 30 m) groundwater quality objectives in the Nogoa River / Theresa Creek sub-basin. Major ion exceedances include Na, Ca, Mg, HCO3, Cl and SO4. A number of minor ions and metals also exceed the Nogoa River / Theresa Creek sub-basin water quality objectives. This assessment indicates that future monitoring of the groundwater quality should be undertaken based on baseline (pre-mining) data and not the specified water quality objectives.

4.5.2 Potential impacts and mitigation measures

The potential impacts of the Project upon water resource environmental values are described in this section. Practical impact mitigation measures are presented in order to address these impacts, together with descriptions of how impact mitigation will be monitored, audited and managed.

4.5.2.1 Surface Water

The Project site will be subjected to two different types of disturbance. In the north of the site, underground mining will cause subsidence of the land surface, whilst in the south of the site, vegetation clearance, pit excavation and infrastructure development associated mainly with the opencut pit operation will impact local surface water courses and overland flows.

Opencut Mining Hydrological Impacts and Mitigation

The catchment size south of the Project site will be modified by infrastructure development (modifications in catchment runoff characteristics) and pit development (removal of land surface).

In addition, the development of the opencut pit and out-of-pit spoil dumps in the south of the Project site will remove several surface water drainage lines associated with Taroborah Creek, although the flows currently entering these lines from the north will be redirected around the disturbance area and into the creek.

Water balance modelling for the Project indicates that water make from necessary removal of groundwater from the mining operations, together with rainfall collected from the mine surface area, will exceed the annual operational water requirements and water lost to evaporation by as much as 2.36 ML/day peak, and 0.87ML/day on average.

Two options for beneficial use are being considered. The first option would be to release the excess water directly into the irrigation channel downstream of the Fairbairn Dam that is located approximately 14 km east of the mine site. This would be accomplished via installation of a pumping station at the mine site and a pipeline run along the 66kV power line that will be constructed from Emerald to service the mine. A second option is to provide the water for supply to industrial users in the area who otherwise might take water from Fairbairn dam, which may include other mines to the north or west. This second option is currently being investigated with potential water suppliers to the Galilee Basin, who propose to run a pipeline in the near vicinity of the Project.

Monitoring

With the aim of identifying and describing the extent of any adverse impacts to the local riparian

environment it is proposed the receiving waters of Retreat Creek and Taroborah Creek will be monitored at the locations outlined in Table 4.68 and illustrated in Figure 4.75during each flow event.

Table 4.68 Receiving Water Upstream Background Sites and Downstream Monitoring Points

Monitoring Points	Receiving Waters Location Description	Latitude (GDA94)	Longitude (GDA94)
Upstream Background Monitoring Points			
MP 1	Taroborah Creek	592460	7394520
MP 2	Tributary south of Taroborah Creek	593875	7392625
MP3	Retreat Creek	594555	7402037
Downstream Monitoring Points			
MP4	Taroborah Creek	595695	7394650
MP5	Retreat Creek	597840	7402650
MP6	Retreat Creek	600070	7402480
MP7	Taroborah Creek	598685	7391555

Monitoring sites within the receiving waters downstream of the mining disturbance are classified as 'downstream sites' (refer to Table 4.68) and have been established to provide a direct comparison between unimpeached reference water quality (upstream of disturbance / release) and potentially contaminated downstream water quality. Comparison of water quality data between reference and impact sites will determine the severity and extent of the impact (if any) from the Project.

Field determinations for pH, EC and temperature will be measured and recorded for each sampling event in addition to a suite of predetermined dissolved metals. The collection, storage and transport of water quality samples for laboratory analysis will be undertaken in accordance with the *Monitoring and Sampling Manual 2009* (EHP 2013).

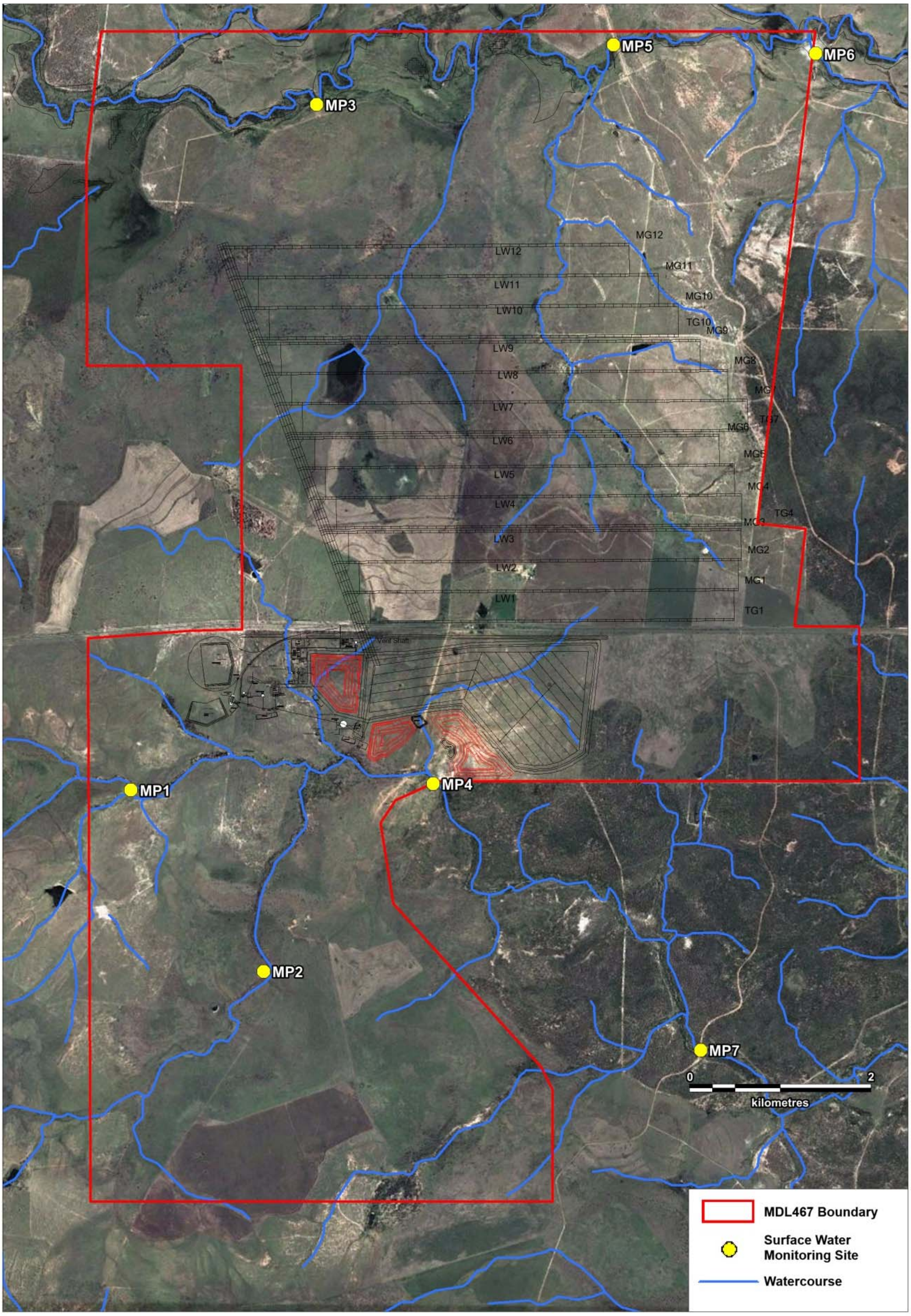


Figure 4.75 Receiving Water Upstream Background Sites and Downstream Monitoring Points

Underground Mining Subsidence Impacts and Mitigation

The following subsidence impacts are anticipated for surface water courses that flow across the area in the north of the Project site and will be subjected to underground mining:

- Scouring of the base of subsided creek beds;
- Ponding of water in sectors of subsided creeks;
- Tension cracks which develop as a result of land subsidence; and
- A potential reduction in surface water runoff for creek lines that have been subjected to subsidence.

The riparian vegetation community most likely to be impacted by the Project (via land subsidence) is the Silver-leaved Ironbark Open Woodland (RE 11.3.6 – Community 6) located in the north of the Project site. The fauna groups considered to be most at risk include macro-invertebrates, amphibians and fish.

Pre and post mine surface elevations are provided in Figure 4.76. Average effects of subsidence cause a lowering in elevation of approximately 1 – 2m. Subsidence will generally be mitigated via remedial actions (sealing of tension cracks and removal of surface water flow barriers), therefore significant changes in flow and sediment transport and subsequent impacts upon downstream surface water users are not anticipated to occur.

Ongoing monitoring of land subsidence (visual assessment and photographic recording) within and around surface water drainage lines will be required to confirm that land subsidence does not appreciably increase with time, as is normally the case, and that the remedial works continue to be effective. Further remedial works may be required if land subsidence continues to impact surface water drainage lines, following initial remedial action.

If any downstream users become impacted by changes in creek flows and sediment transport, the following mitigation strategies will be considered in order to address such impacts:

- The installation of sedimentation ponds to reduce the sediment transported from site into the creeks; and
- The modification of drainage profiles into the creeks in order to control the flow of surface water along contributing drainage pathways.

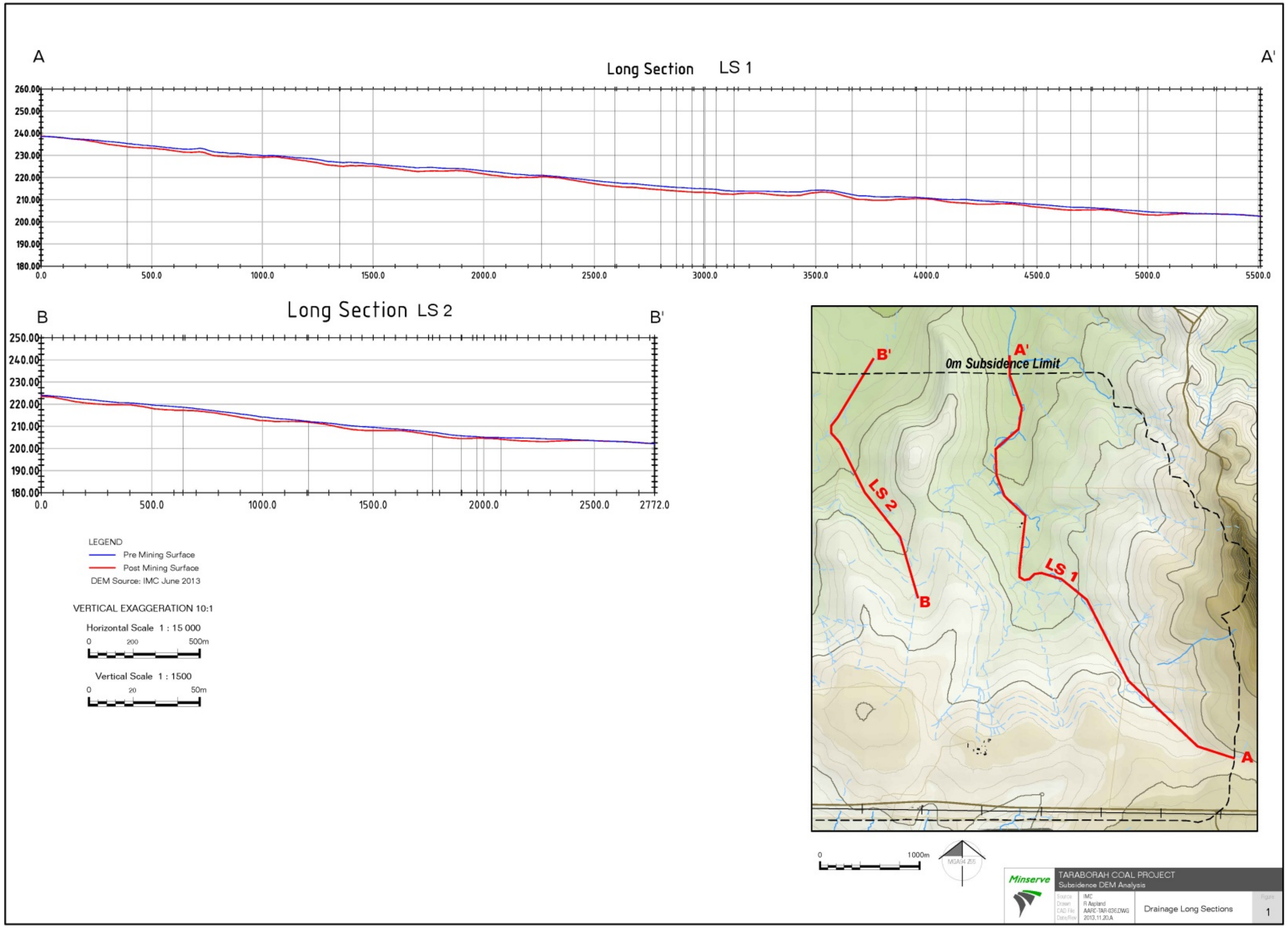


Figure 4.76 Pre and Post Mining Surface Elevation

Ponding of the surface area due to underground mining has been identified as potentially impacting the broader catchment hydrology and water resources availability in the Retreat Creek and subsequently into Theresa Creek and Nogoa River. Water that has previously drained freely from the Project site catchment and contributed to the downstream river flow may be lost now due to the subsidence of the panel. To this end, a subsidence impact assessment on surface hydrology was prepared by ATCW (2014) to assess the change in surface hydrology from existing conditions due to the predicted subsidence over the Project site underground mine area. The methodology and approach to assess the hydrological impacts and significance of potential ponding in subsidence involved the following steps:

I. Review of available surface water data and previous modelling studies based on the Fitzroy River Basin Water Resource Plan, 2011 to assess and quantify baseline hydrology at local and regional scale. The baseline water resources hydrology characterisation considered mean annual flow volumes and flow duration as a measure of flow variability;

II. The post subsidence topography was then used to identify possible drainage patterns and potential ponding areas due to subsidence, and the storage-elevation-area characteristics of the subsidence voids were determined; and

III. A hydrological simulation model for the Taroborah catchment was determined based on the subsidence voids using a Goldsim model taking into account a series of daily timestep water balance calculations for each void. The model was developed to simulate runoff, estimate losses due to subsidence voids, losses in the voids, and thereby calculate overflows and net stream flows reaching the Retreat Creek.

In general, the water balance model will account for the net sum for each daily time step being added to the previous day pond volume. Overflow volume will be calculated when the total inflows exceed the total loses and the remaining available storage capacity.

The process to identify subsidence voids that may pond water involved the subsided topography contours (supplied by IMC) which were reviewed to identify ponding locations, pond geometry, and estimate storage capacity of the ponds to the level at which the ponds would overflow.

The mapping of potential subsidence ponding extents and volumes within the Taroborah creek identified 10 ponding areas (P1 to P10) and are detailed below in Table 4.69 and illustrated in Figure 4.77. The subsidence ponds are estimated to range between 3 ML to 12.5 ML. The average capacity would be approximately 7.1 ML. The total area identified ponding areas would be some 28.2 hectares.

Table 4.69 Pond Geometry

Void ID	Level (Overflow – m AHD)	Maximum Depth when full (m)	Maximum Volume when full (m)	Maximum Area when full (ha)
P1	203.4	0.4	3.6	1.9
P2	205.6	1	10.2	3.6
P3	207.3	1	2.9	1.6
P4	210.1	1	6.9	2.8
P5	212.2	1	6.2	2.5
P6	213.3	1	9.6	2.1
P7	215.5	1	2.5	0.7
P8	203.4	0.5	12.5	6.7

Void ID	Level (Overflow – m AHD)	Maximum Depth when full (m)	Maximum Volume when full (m)	Maximum Area when full (ha)
P9	204.8	1	8.2	2.9
P10	206.4	1	8.3	3.3

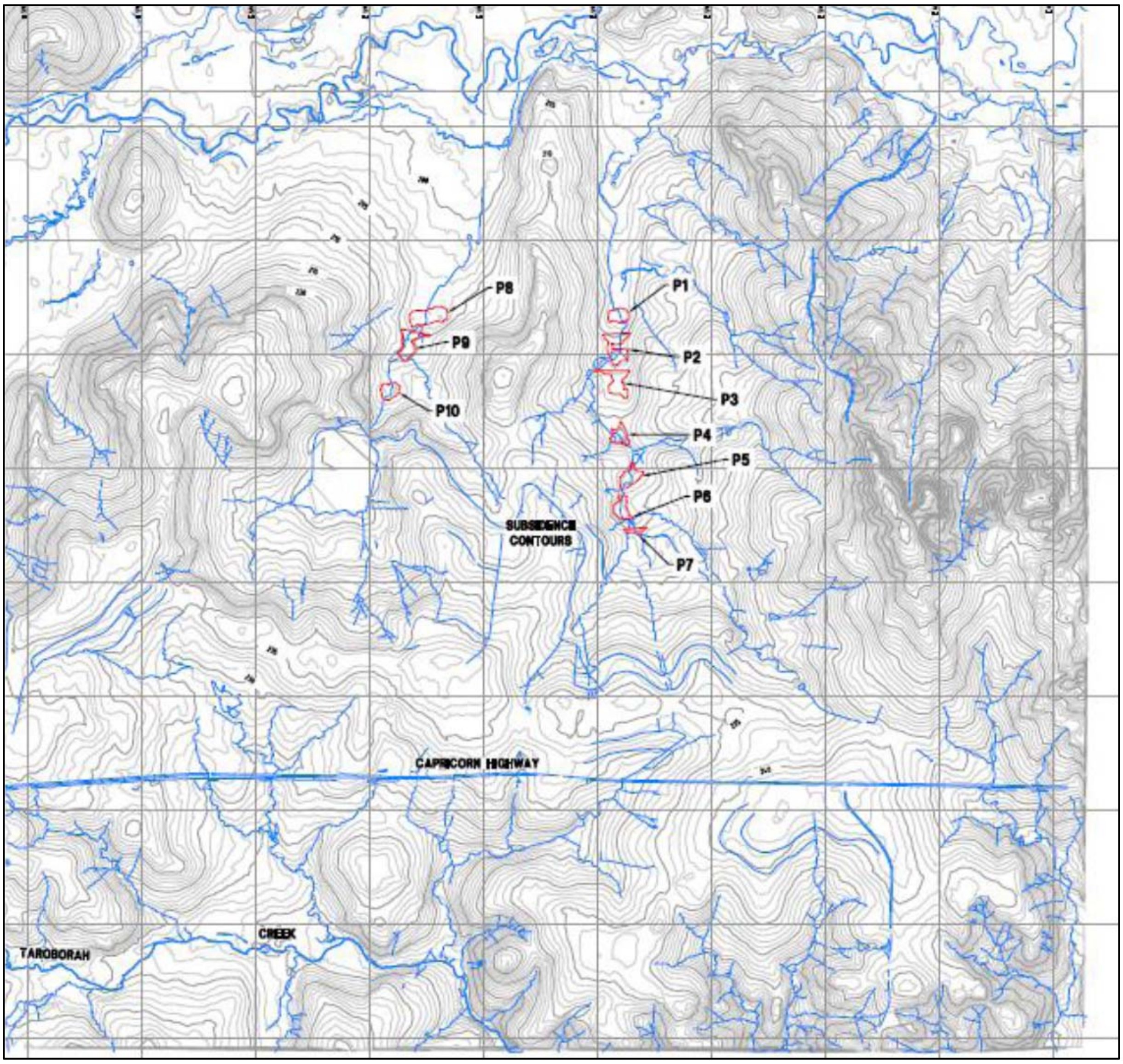


Figure 4.77 Potential Ponding Areas

Based on the model results and the catchment yield data from the Fitzroy River Basin Plan (2013), the following hydrological impacts may be experienced as a result of mine subsidence:

- Existing model conditions indicated a mean annual catchment yield on some 40 ML/km^2 and assessed against the Fitzroy River Basin Plan which is in the region of 40 ML/km^2 (after evaporation) and therefore considered that the model suitably represents catchment yield for the purpose of this comparative assessment;

- The post-development catchment yields of 38.0 ML/km^2 indicate that a loss of the order of 6 %

on average of runoff is possible;

- The flows within Retreat Creek would be potentially reduced by 0.1%; and
- Extrapolation of the site data and applied to Retreat Creek catchment indicates that mean annual yield would reduce from 41,233 ML to 41,180 ML pa which is some 0.1% less.

It is considered that the subsidence impact assessment represents the maximum impacts on hydrology. Based on this assessment, it is considered that the hydrological impacts on Retreat Creek from the Project site will not be significant i.e. less than 0.1% reduction in the runoff yield and less than 6 % at the Project site.

Although the subsidence impact is expected to be significantly less at a regional scale, there is potential to mitigate the loss of flow from the Project site due to ponding in subsidence voids by undertaking drainage works to drain some of the ponds created by subsidence. As the depth of the voids is considered shallow, the works required to completely or partially drain the subsidence voids would be achievable without unnecessary environmental disturbance.

Based on the Fitzroy River Water Resources Plan (s20(2)), the limit of overland flow taken from a surface runoff in any particular catchment due to works should be not more than 50 ML. For this Project site, the predicted yield that may be lost due to subsidence is approximately 53 ML, which has an excess of 3 ML of runoff withheld from overland flow. However, this would be expected to significantly reduce with the implementation strategies described above.

Flooding Impacts and Mitigation

Results from the flood assessment indicate that the majority of flooding associated with the Project site will be associated with Taroborah Creek, potentially affecting the opencut pit and are discussed below.

The estimated flood extent and depths for the 1,000 year ARI, 90 minutes critical and the PMP (determined to have an AEP of 10^{-7}) duration flood events, based on Australian Rainfall and Runoff data derived from BOM (2013), are shown in Figure 4.65 and Figure 4.66 respectively.

1,000 year Flood Extent

The 1,000 year flood extents of Taroborah Creek are largely uncontained, overflowing to the high flow creek channel running east to west through the MDL area. Taroborah Creek overflows to the north-east towards the proposed opencut mine pit, however, the modelled extents do not encroach on the opencut pits themselves.

In order to protect the operating pit from overland flow inundation, pit-protection bunds with a nominal height of 0.5m will be constructed around each void. These bunds will remain on site following mine closure in order to provide flood protection. The administration of pit-protection bunds is further discussed in context of the water management system throughout Section 4.5.2.3.

In addition, as no infrastructure will be developed within the modelled flood plain, development of the Project will not have a significant impact upon flooding in the south of the Project site.

Probable Maximum Flood (PMF) Extent

The PMF modelling indicates that the inundation level near the void entrance/ramp is at RL 220 m. Assessed against the void entrance level at approximately RL 224, modelling demonstrates that the

final void will not be inundated subject to the PMP flood event as modelled and therefore it is considered that no additional flood mitigation measures will be required around the void entrance.

Project Water Supply

Most of the water required for the Project will be supplied from necessary dewatering of the local aquifers to permit mining operations. The abstraction of groundwater for Project purposes will, over time, however, result in groundwater drawdown. The rates of groundwater abstraction and drawdown have been modelled by AGE in 2013 (refer to Appendix 14 for details). There is no requirement to take water from overland flow, since the volumes of groundwater abstracted are sufficient to supply the mine's water requirements. Groundwater impacts and mitigation is further described in Section 4.5.2.2.

Both construction and operational phases of the Project will use groundwater as their main supply of water. The large dam which is located to the north-west of the Project site also offers an additional water supply if required.

Process water will be recycled for the most part, with any make-up obtained from both the mine dewatering storage dam and site water drainage catchments.

The Water Resource (Fitzroy Basin) Plan 2011 applies to this Project and manages the taking of overland flow water and groundwater. Details of the proposed rates of groundwater abstraction are presented in the Groundwater Impact Assessment report (AGE 2013) presented in Appendix 14 and will be used by the Department of Natural Resources and Mines in order to develop and approve a licence or permit to take water under the *Water Act 2000*.

No Wild Rivers declarations exist on or near the Project site and therefore, no preservation, special floodplain management or sub-artesian management areas apply to this Project. In addition, no waterway barriers will be required under the *Fisheries Act 1994*, since in-stream barriers are not required.

4.5.2.2 Groundwater

A three-dimensional numerical groundwater flow model was developed for the Project using MODFLOW-SURFACT. The model consisted of a 10-layer representation (refer to Table 4.70) with a model extent of 41 km x 40 km.

Table 4.70 Model Layers

Model Layer	Hydrostratigraphy
1	Regolith / Alluvium
2	Tertiary regolith (clay)
3	Weathered Alderbaran Sandstone
4	Fine grained sandstone – Alderbaran Sandstone
5	Fine grained sandstone – Alderbaran Sandstone
6	Coarse grained sandstone – Alderbaran Sandstone
7	Seam A – Alderbaran Sandstone
8	Interburden – Alderbaran Sandstone
9	Seam B – Alderbaran Sandstone
10	Basal Sediments – Alderbaran Sandstone

The model was calibrated to a pre-mining condition, using water level observation data from the Project site, and from neighbouring bores, to achieve a suitable fit in accordance with modelling guidelines. Consideration was given to carrying out a transient calibration, however, the existing water level data shows little seasonal variation, and a transient calibration of the groundwater model was not considered beneficial. There are no reliable recharge or discharge processes evident in the water level hydrographs with which to calibrate the model against.

Once calibrated, the model was used to predict the groundwater level behaviour of the systems, in response to simulated mining over a 21-year period, consistent with the mine plan. The model also simulated groundwater level recovery post mining over a 1,000-year period.

The model allows groundwater levels, inflows and fluxes to be predicted within the model extent, and this model output is presented throughout this section. Details of the groundwater model setup and calibration are provided in Appendix 14 and the conceptual groundwater modelling cross sections, illustrating the conceptual understanding of the hydrogeological regime within the Project area, are shown in Figure 4.78 and Figure 4.79 and described by AGE (2014) below.

The unconsolidated Quaternary and Tertiary alluvium form localised aquifer systems along the watercourses of Retreat Creek, Centre Creek, Kettle Creek and Nogoa River. The bore census indicated private bores extract water from the alluvial groundwater systems associated with Retreat Creek up-gradient of the Project area, within the Anakie and Sapphire gemfields region, but the usage within the Project area is limited. The creeks form losing systems, recharging the underlying alluvium when flowing. The alluvium is lithologically heterogeneous with slightly brackish water quality.

Within the Project area, the Tertiary basalts are commonly weathered, with only localised, dissected areas of fresh basalt. The thickness of the basalt varies and in some areas becomes unsaturated. This means the basalt does not form a productive aquifer and there is a lack of landholder bores targeting the basalt within the Project area. The basalt is recharged by diffuse rainfall, as well as surface water features (i.e. Lake Maraboon). Due to the nature of deposition and weathering, hydrogeological connection across the mapped extent of the Tertiary basalt is considered unlikely.

The numerical model has used regional scale faults and structural domains to provide the basis for the model extent. These are based upon publically available reports and mapping. As these regional scale faults and structural domains are at the boundary extents of the model domain, these are discussed briefly in terms of model development.

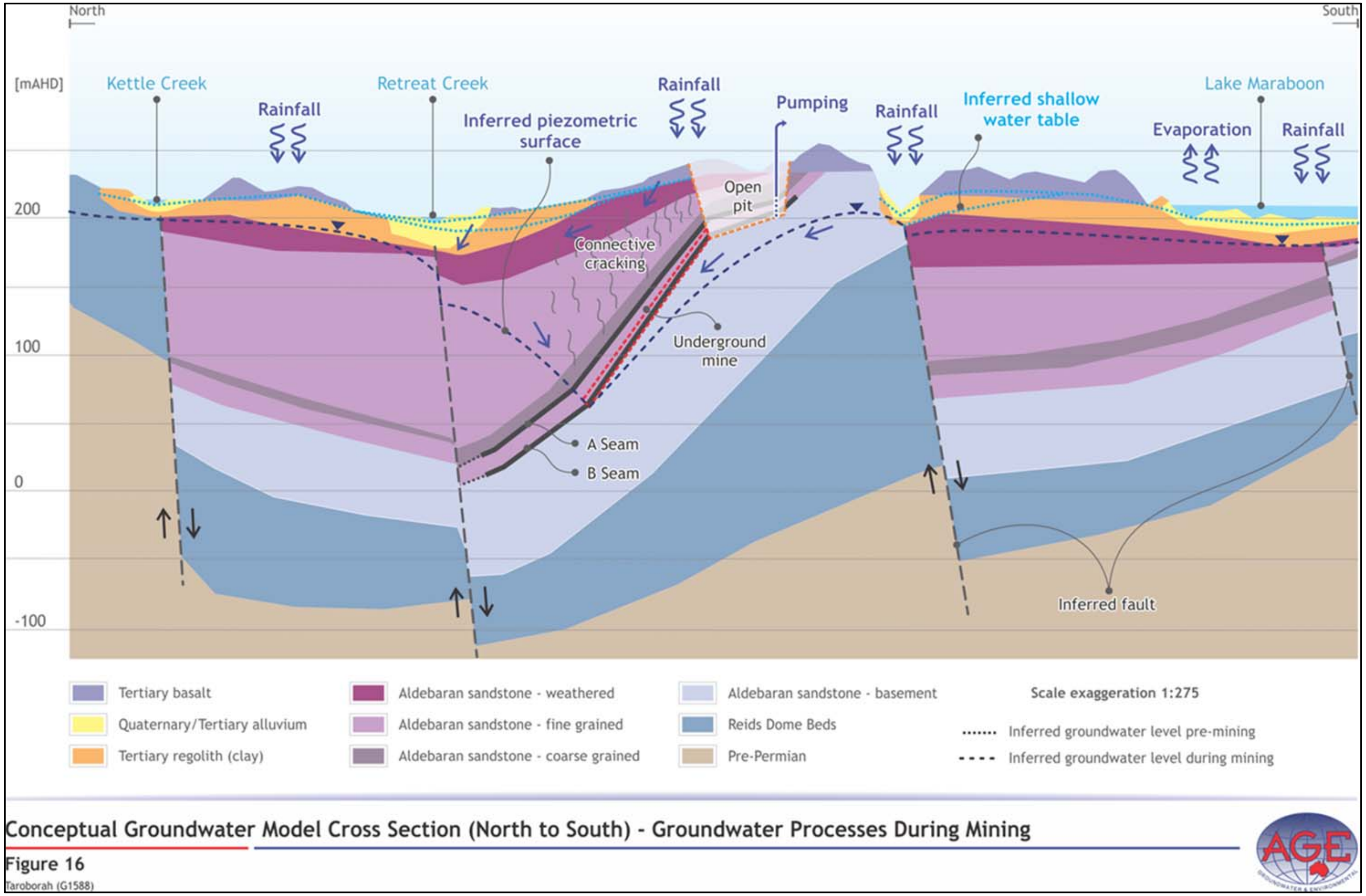


Figure 4.78 Conceptual Groundwater Model Cross Section (North to South)

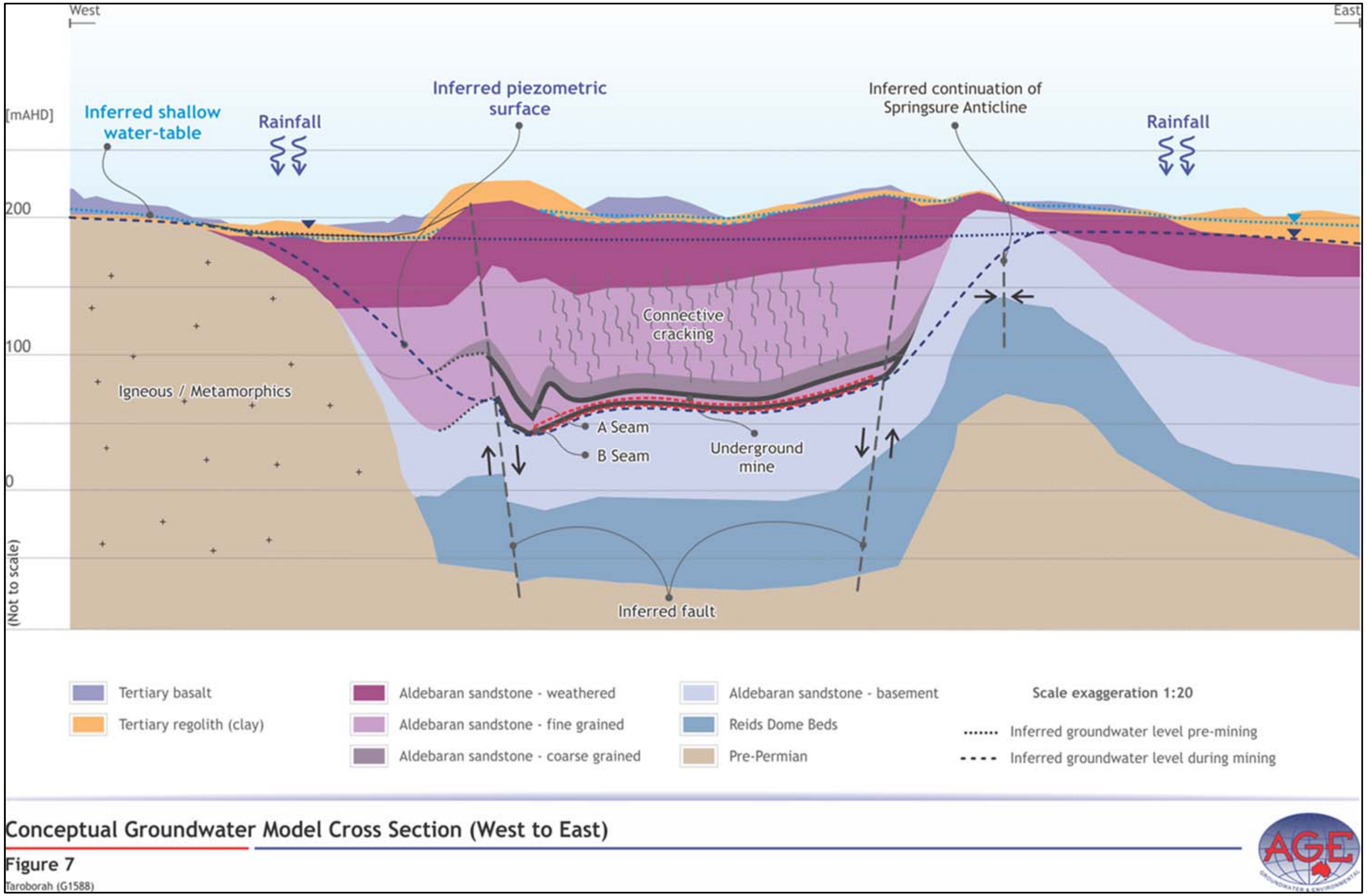


Figure 4.79 Conceptual Groundwater Model Cross Section (West to East)

The Permian aged stratigraphy occurs within a region that has undergone extensive periods of deformation which has resulted in groundwater flow boundaries within the Permian stratigraphy to the:

- West: where the extent of the Permian sequences is truncated by the presence of the Devonian aged Anakie metamorphics. A series of NW-SE trending faults have also been identified during exploration drilling, which show stratigraphic displacement;

- East: exploration drilling and lithological logging for monitoring bore MB03_S indicates that the coal seams do not occur east of the Project area. This corresponds with the presence of a potential anticline (Veevers *et al.*, 1962) and a series of NW-SE trending faults;

- South: geological maps and exploration drilling shows that the Permian sequences subcrop approximately 2 km south of the Capricorn Highway. The stratigraphy dips in a northerly direction, with minor parasitic folding identified during exploration drilling. Water quality results indicate that the Permian sequences are fresher further to the south (up-dip), indicating likely rainfall recharge of the groundwater system where it occurs at sub-crop;

- North: the presence of the older Reids Dome Beds stratigraphy to the north of Kettle Creek (within the Valeria exploration area) indicates extensive stratigraphic displacement, likely caused by an east-west trending fault.

Within the project area, the Proponent has defined a graben (fault bound) structure in which the coal measures are to be mined. These faults have been defined through project specific seismic data, detailed exploration drilling and State Government drilling and mapping. A conservative approach has been developed to simulate this graben structure. Rather than defining linear fault features in the model, drape features have been implemented with layer hydraulic continuity on either side of the mapped fault. Therefore, there is modelled hydraulic connectivity on either side of these faults rather than simulating them as impermeable barriers. The coal seams have then been simulated to pinch out to the east and west of the respective bounding faults, as they do not exist in this region. The basis for pinching out the coal strata (model layers) is based upon site specific and regional drilling data. This approach was adopted as it is expected to provide a conservative overestimate of the extent of depressurisation outside the fault bounded blocks, and therefore represents a likely worst case scenario.

The upper 250 m of Permian aged stratigraphy within the Project area comprises the Aldebaran Sandstone. The Aldebaran Sandstone contains relatively continuous stratigraphic layers of fine to coarse grained sandstones and coal seams, which dip in a northerly direction. The main water bearing unit within the Permian sequences is the pebbly to coarse grained sandstone, which directly overlies the A seam and records flow rates of between 0.5 L/s to 20 L/s.

The two main coal seams within the Project area, A seam and B seam, are approximately 1.2 m and 3.0 m thick, respectively. The coal seams are relatively permeable and show heterogeneous connection to the overlying pebbly to coarse grained sandstone sequence, and are also likely recharged where the seams occur at subcrop south of the Capricorn Highway.

Inflow to Mining Operations

It is predicted that a maximum of 5.7 ML/day of groundwater will be intercepted by the opencut and underground mine combined, with the peak inflows occurring around Year 19 of the Project. Inflows to the opencut mine peak at 3.3 ML/day around Year 5, while the underground inflows peak at 4.8 ML/day in Year 19. On average, the inflows associated with the mine operations are predicted at

approximately 2.6 ML/day. Figure 4.80 provides details of predicted mine inflows.

It is important to note that the predicted mine inflows do not represent the volume of water that will require pumping, rather the maximum loss from the groundwater systems. The estimates include ‘unseen water’, including moisture in coal and evaporation and extraction from the mine ventilation. Accounting for the ‘unseen water’, it is predicted that total groundwater inflows will be around 2.3 ML/day on average, with up to 3 ML/day entering the opencut pit, and up to 4.3 ML/day entering the underground mine.

In addition, predictive modelling has allowed for the simulation of porosity and permeability changes to the Permian strata as a result of mining induced subsidence.

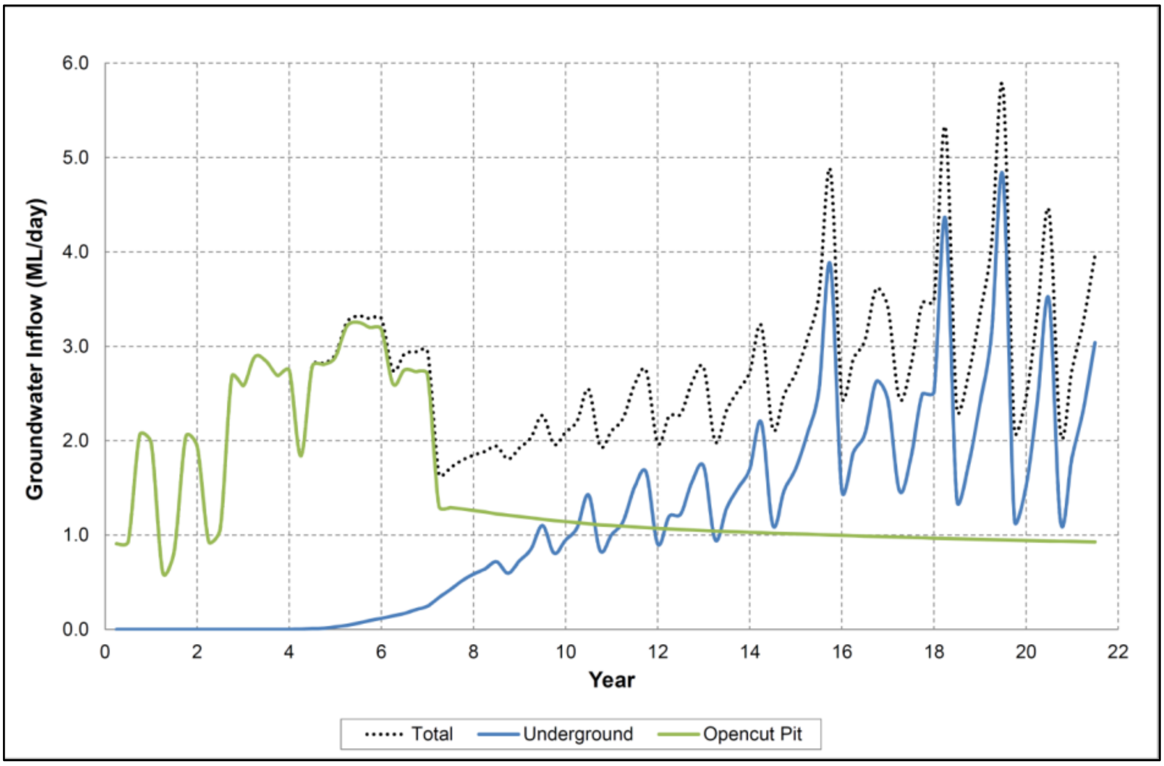


Figure 4.80 Predicted Mine Inflows

Groundwater Interactions

Figure 4.81 shows the key exchanges in the groundwater systems as a result of the Project, which includes:

- Mine dewatering (opencut and underground) extracts an average of 2.6 ML/day of groundwater;
- Evaporation removes approximately 0.4 ML/day of groundwater. This occurs after mining of the opencut and the development of a final void and pit lake;
- Recharge contributes an additional 0.3 ML/day to the groundwater system as a result of the proposed mine, on top of the 6.5 ML/day predicted for the baseline water budget. This additional recharge occurs after mining of the opencut and occurs as additional recharge to the void and spoil;

- A 0.9 ML/day increase in water entering the model through the SURFACT river package as leakage through the river bed. This occurs where there is a greater hydraulic gradient beneath the streams; and

- A 0.9 ML/day increase in water leaving the model through the SURFACT river package as baseflow or drains. This occurs in the lower lying areas where there is a smaller hydraulic gradient beneath the streams. The changes in the SURFACT river package effectively cancel each other out so that the net change in flow that mining has on the cells representing streams or rivers is close to 0 ML/day.

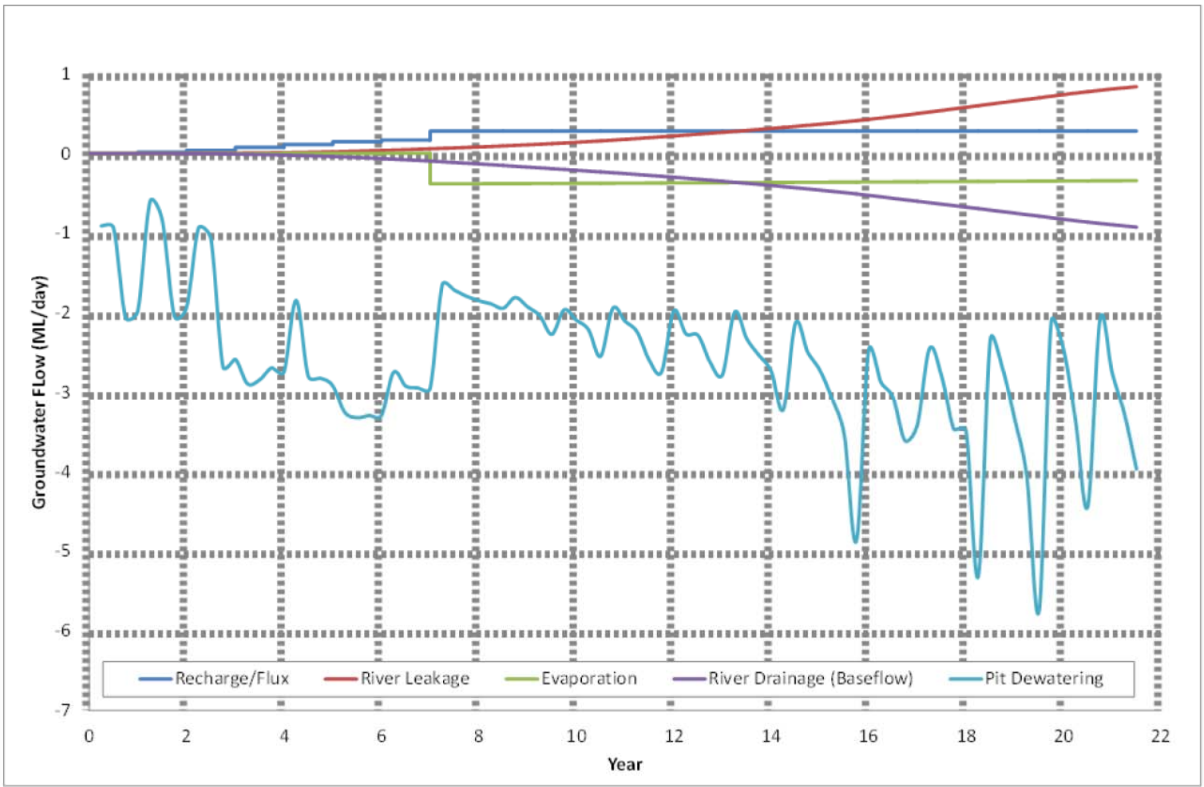


Figure 4.81 Predicted Groundwater Budget

The numerical model was calibrated to water levels considered representative of steady state conditions, with the assumption of constant surface recharge to the groundwater system. Constant recharge was applied in the predictive model and as a result, the model does not simulate seasonal variations in recharge. Recent groundwater level data has shown that the groundwater systems (in particular the Permian coal measures) are largely unaffected by seasonal rainfall, with immeasurable hydraulic response following rainfall events. Therefore, the model did not simulate seasonal recharge in the predictive model scenarios, but an annual average.

As groundwater inflow occurs from the Permian coal measures, any short-term fluctuations (increases or decreases) in recharge to the outcrop or subcrop of the Permian coal measures will not be observed in the groundwater discharge to the mine. The modelled recharge rate is low and groundwater travel times are long enough for the strata to buffer any additional water that may be accepted into the groundwater system as recharge.

The predicted groundwater inflow from the Permian coal measures will be unaffected by any seasonal changes in rainfall or recharge. Seasonal changes in rainfall will affect runoff into the opencut.

However, this water balance component is not represented in the groundwater model and it is understood that this is included in the surface water modelling.

Depressurisation and Drawdown

Figure 4.82 to Figure 4.85 show the predicted change in groundwater levels in Layer 1 (Quaternary and Tertiary alluvium and Tertiary basalt) and Layer 9 (Seam B) for Years 5, 10, 15 and 21 of the proposed mine schedule. The results show the extent and degree of groundwater level drawdown within areas modelled as having a saturated thickness prior to mining.

Figure 4.85 shows that the groundwater level drawdown within the alluvium could extend up to 3.5 km east (down-stream) of the MDL 467 boundary. The extent of drawdown north of the Project area is limited by the presence of Retreat Creek, which acts as a recharge source and buffers the effects of the predicted drawdown. Drawdown within the Tertiary basalts (Layer 1) are also mapped as extending up to 3 km south of the Project boundary.

The predicted drawdown within Seam B (Layer 9) is largely contained within the MDL 467 boundary. Due to the presence of underground mining, Seam B (Layer 9) is the model layer most affected by drawdown or depressurisation. The Layer 9 contours represent the worst case or maximum predicted drawdown within the model, and the drawdown or depressurisation predicted within other model layers will be less than that shown in Figure 4.82 to Figure 4.85.

The hydrostratigraphic units above the longwall panels do not completely depressurise, as groundwater drawdown is a function of the vertical hydraulic conductivity of the goaf and the fracture zone. As detailed Appendix 14, the model structure was based on the Taroborah Mine geological model, as well as government exploration drill logs and geological reports.

At the completion of each longwall panel, drain cells are removed from the simulation and water levels are allowed to recover. Unconfined storage properties of the mined longwall panel are increased to reflect additional void space in the rubble left behind following goafing due to the removal of the coal. The numerical model predicts groundwater levels recover to within 80% of their pre-mining levels after just 91 days. This is primarily due to the high storage within the Aldebaran Sandstone overlying the longwall mining area, which is not completely desaturated and allows rapid drainage of groundwater into the mined out areas. This high storage effectively buffers the groundwater systems adjacent to the Aldebaran Sandstone aquifer from impacts. Steep vertical hydraulic gradients form in the model and result in high groundwater flows towards the desaturated area within the coal seam, which causes groundwater levels to recover quickly. This occurs in the model because depressurisation is not extensive above the longwall mining area, and a high yielding aquifer exists adjacent to active mining.

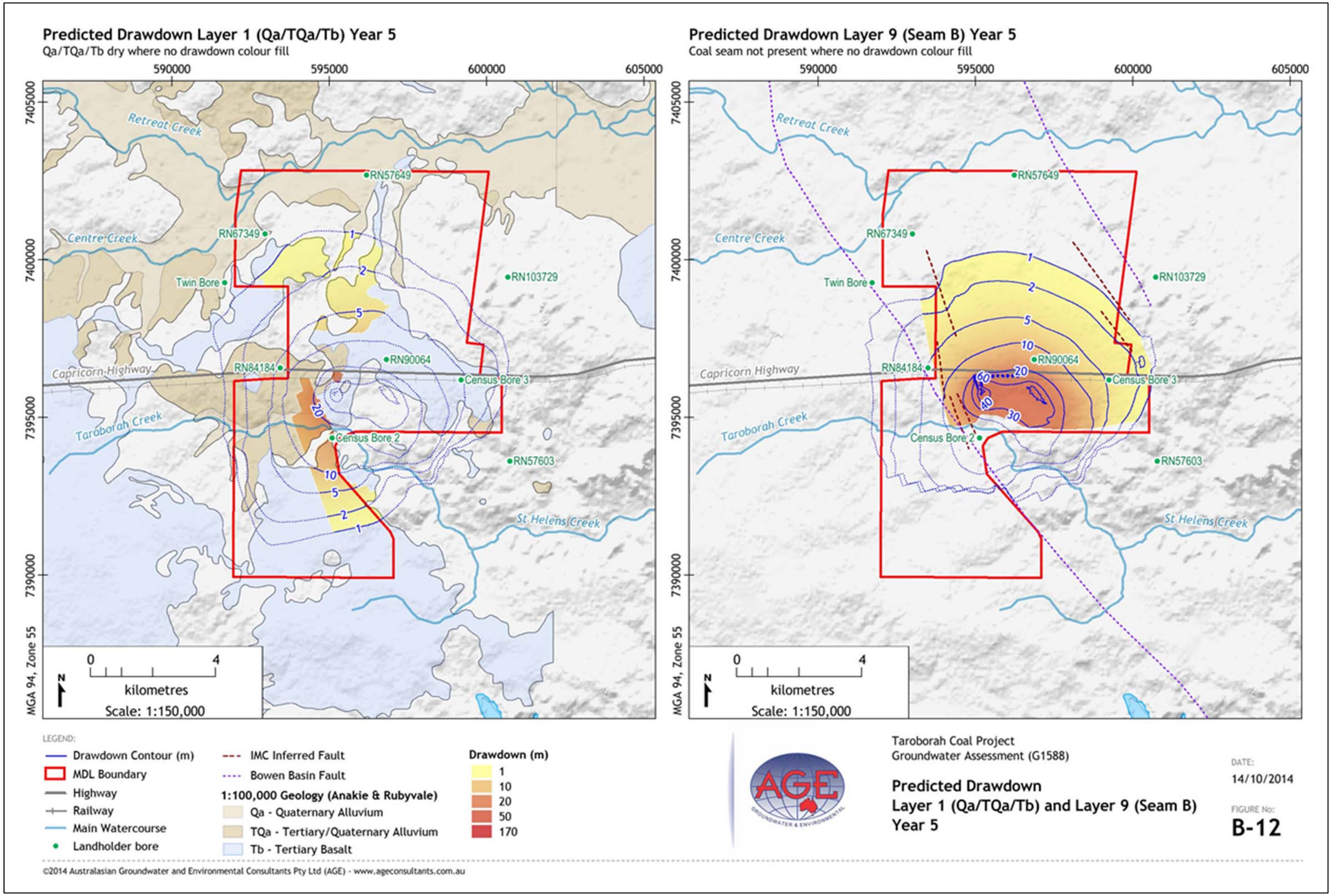


Figure 4.82 Predicted Drawdown Layers 1 and 9 – Year 5

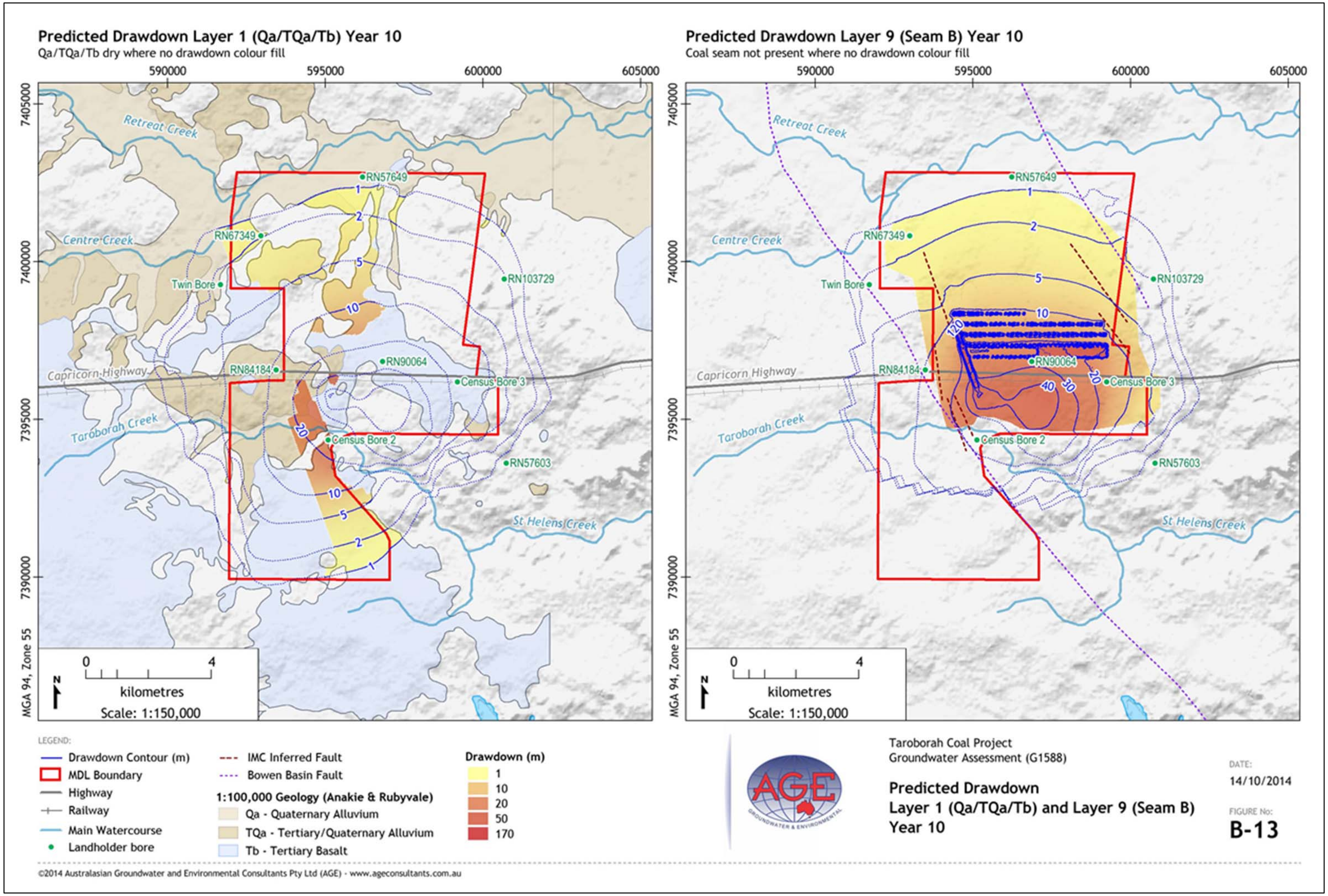


Figure 4.83 Predicted drawdown Layers 1 and 9 – Year 10

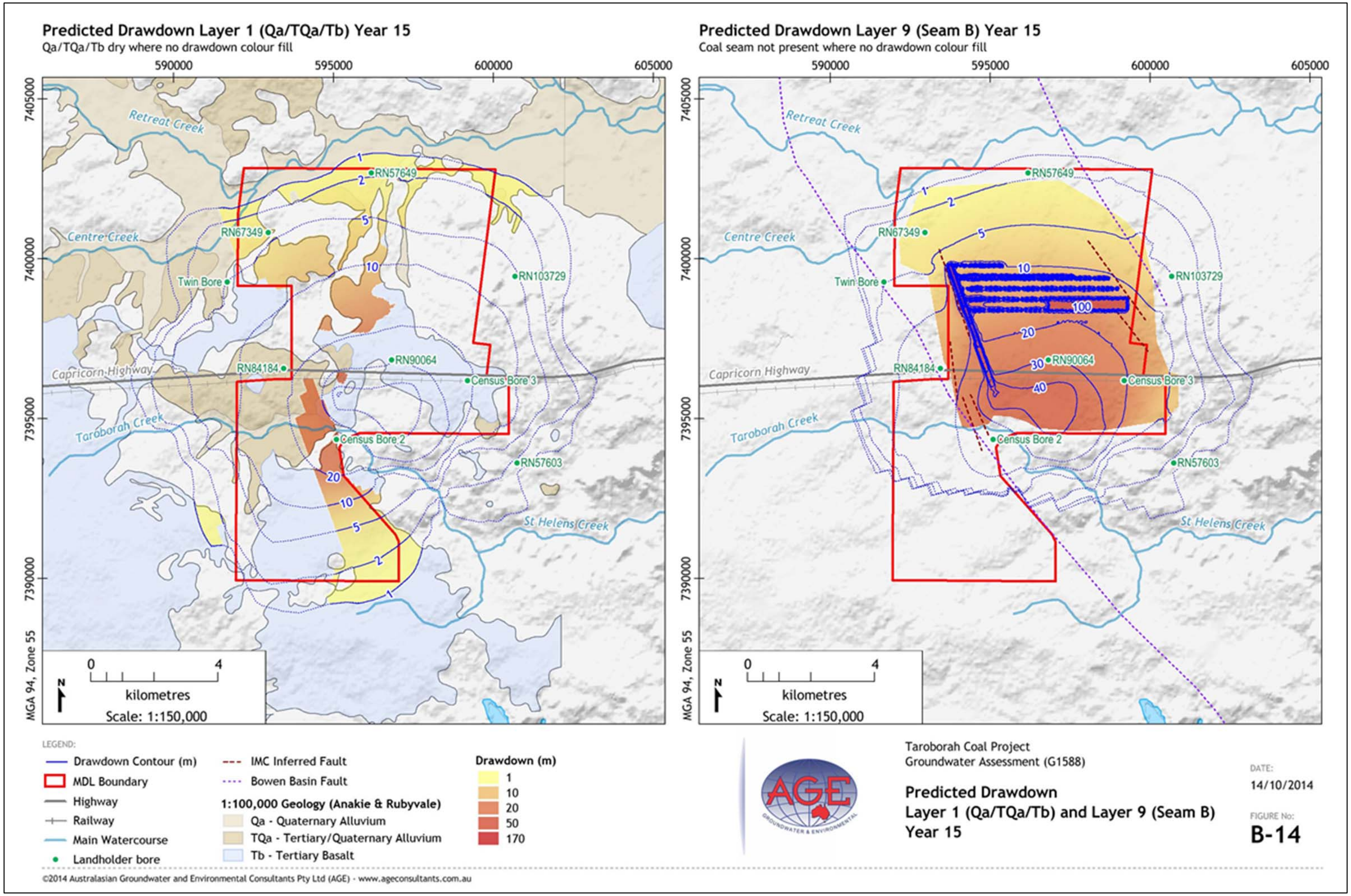


Figure 4.84 Predicted Drawdown Layer 1 and 9 – Year 15

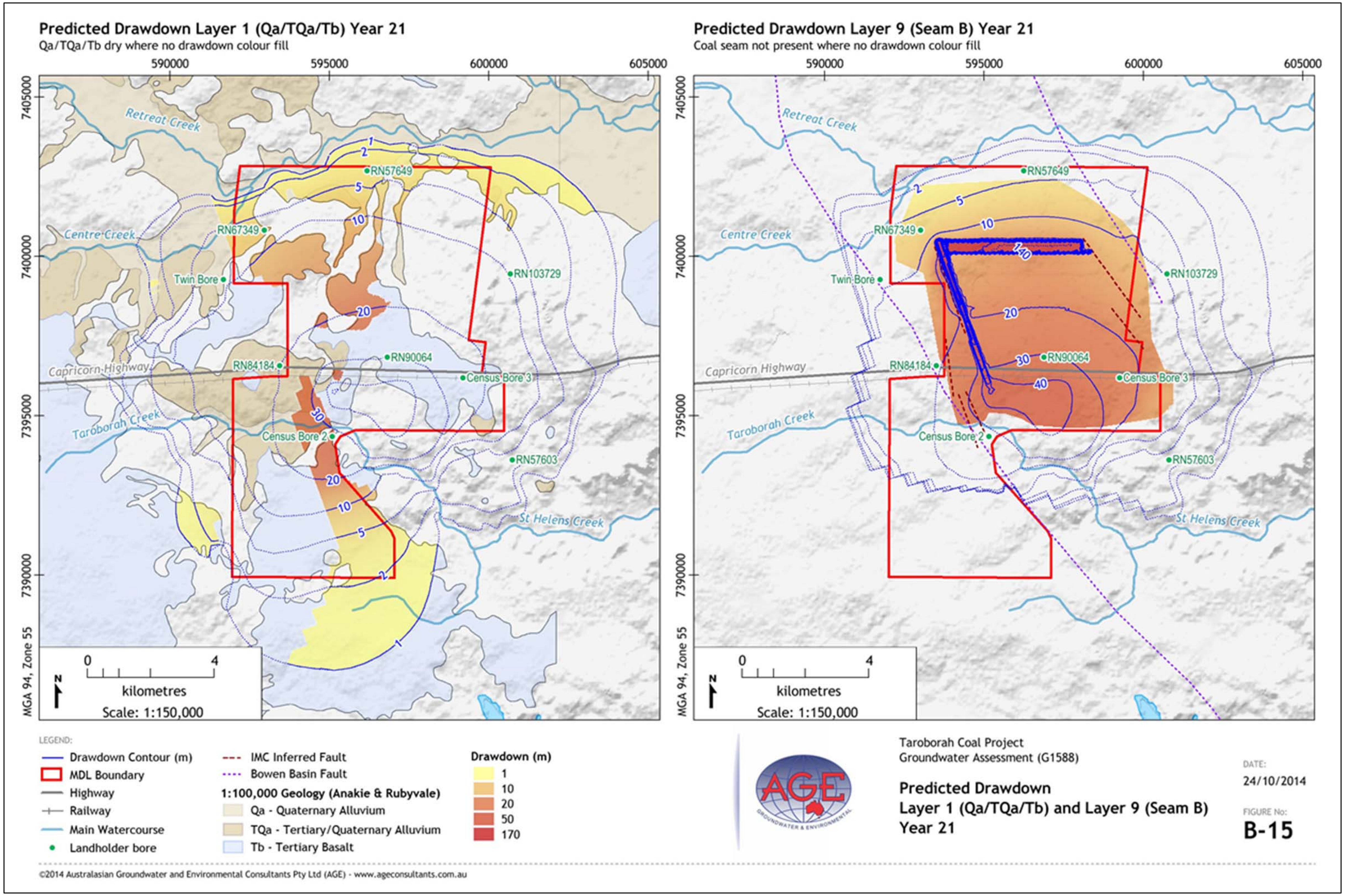


Figure 4.85 Predicted Drawdown Layer 1 and Layer 9 – Year 21

In summary, drawdown contours and results for the Quaternary and Tertiary alluvium, Tertiary basalt and Aldebaran Sandstone indicate:

- Drawdown within alluvium could extend up to 3.5 km east (downstream) of MDL 467;
- Drawdown within the Tertiary basalt could extend up to 3 km south of MDL 467; and
- The Aldebaran sandstone drawdown could extend up to 3.5 kilometres east.

It is important to note that the model only allows for porous media flow, and does not mimic natural heterogeneity within the alluvium and basalt, which was observed from field observations. Therefore, it is anticipated that the extent of drawdown, in real terms, will be lower than predicted.

Model Sensitivity Analysis

Basic Parameters

Parameter sensitivity on predictions was explored through additional model scenario runs and varying key parameters values such as pit inflow rates and drawdowns. It is important to note that the sensitivity results are presented in order to show the degree of variability inherent within numerical modelling and the model design. As the hydraulic parameters used in the model are largely based on field data, the sensitivity results relating to significant changes in hydraulic parameters are not considered realistic for the Project.

Sensitivity of the predicted groundwater inflow rates to the mine workings as a result of changes in the model parameters is summarised in Table 4.71 which shows that increasing the hydraulic conductivity by 50% and the storage by an order of magnitude raises the overall maximum predicted inflow by 128% (7.4 ML/day) and 125% (7.2 ML/day), respectively. The other parameters are less sensitive, with the change in inflow results, when compared to baseline values, ranging between 111% and 118%.

Table 4.71 Summary of Sensitivity Analysis

Parameter	Average Daily Groundwater Inflow		Maximum Daily Groundwater Inflow	
Unit	ML/day	%	ML/day	%
Baseline	2.6	100	5.7	100
HC_VHC + 50 %	3.1	120	7.4	128
HC_VHC - 50 %	2.3	87	4.3	75
RCH + 1 x OM	3.3	128	6.5	114
RCH - 1 x OM	2.5	96	6.6	115
SS + 1 x OM	3.9	148	7.2	125
SS – 1 x OM	2.1	81	4.6	80
SY + 1 x OM	2.7	104	6.4	111
SY – 1 x OM	2.7	103	6.8	118

Notes:
HC – Horizontal and Vertical Hydraulic Conductivity; SY – Specific Yield; SS – Specific Storage;
RCH – Recharge; OM – Order of Magnitude (x10); and % – percentage compared to baseline model scenario

Results from the sensitivity analysis indicate that the predicted mine inflow seepages to the opencut pits (initial 7 years) are most sensitive to changes in storage (SS) and recharge (RCH) whilst the underground mining inflows are most sensitive to changes in hydraulic conductivity (HC) and storage (SS).

Figure 4.86 shows the maximum extent of 1 m water table drawdown within the model for the baseline and sensitivity analysis. The 1 m drawdown contours encompass drawdown within all model layers, as it represents the maximum extent of drawdown within the uppermost saturated aquifer. Therefore the extent of drawdown is not representative of one aquifer (i.e. alluvium) and has only been used to identify the sensitivity of the model to different hydraulic parameters.

Figure 4.86 indicates that the extent of drawdown predicted by the model is most sensitive to changes in storage (SS). The parameters used within the model were based on field results (Appendix 14) and standard hydraulic parameters within the Bowen Basin. The drawdown extent as a result of a one order of magnitude reduction in storage is not considered likely, as conservative values for storage have already been applied to the baseline model.

Subsidence Induced Fracturing

Two further sensitivity analyses have been conducted in relation to the conceptual approach used to represent subsidence induced fracturing and the parameters used in the model to represent this.

Within the basecase model, the longwall mine was represented by applying a series of drains to each longwall panel. These drains remained active for the entire mining strip of the longwall panel. Once mining of the longwall panel is complete, the drains were then switched off and the material above the mined coal seam was simulated to be goafed or affected by subsidence induced fracturing.

An alternative method of representing the longwall panel was explored as a sensitivity analysis in that the drains are not active for the entire mining strip of the longwall panel but switched off progressively in conjunction with the active mining face. The overburden material above and behind the mined strip is also progressively goafed or fractured.

In addition to the alternative of how the model represents drainage, the height of fracturing was also increased. The baseline model used a 30 times multiplier (30 t) above the mined B seam (equivalent to 90 m) for the height of continuous fracturing, as postulated by the 1993 model of Kendorski (2006) and commonly used in the industry. However, there is anecdotal evidence in Australia and elsewhere that, in the right geological conditions, the height of fracturing can extend to 40t or more above the mining horizon.

Secondly, model sensitivity was also explored in terms of the vertical hydraulic conductivity values applied to the strata impacted by subsidence induced fracturing. The vertical hydraulic conductivity values applied to the fractured strata representing layers 4 to 9 were increased in comparison with the baseline model.

The predicted inflows from the subsidence induced fracturing sensitivity analyses are provided in Table 4.72. The analyses indicate that by modifying the representation of the longwall mine drainage and by increasing the height of subsidence induced fracturing (from 30 t to 40 t), the inflows increase around 1-2 ML/day to on the order of 4 ML/day to 5 ML/day with an average of 3.6 ML/day and two short duration peaks of 8 ML/day and 9.2ML/day toward the end of mining.

By also modifying the vertical hydraulic conductivity of layers 7, 8 and 9, the predicted inflows increase between 0.5 - 2 ML/day, with total inflows generally between 4 ML/day and 6 ML/day and averaging 4.6 ML/day. The two short duration inflow peaks toward the end of mining increase to up to 10.9 ML/day.

Table 4.72 Summary of Subsidence Induced Fracturing Sensitivity Analysis

Parameter	Average Daily Inflow		Maximum Daily Inflow	
	ML/day	% Increase	ML/day	% Increase
Baseline	2.6	100	5.7	100
Modified method and fracturing height	3.6	141	9.2	161
Increased vertical K	4.3	167	10.9	190

The sensitivity analysis shows that during the later stages of mining, groundwater inflows in the order of 8 ML/day to 10 ML/day are predicted. This inflow occurs when the longwall mine progression is in the northern portion of the mine, directly under a thick sequence of Tertiary material, which in the model is represented as having relatively high hydraulic conductivity and direct connection via the increased subsidence fracturing. This predicted high inflow is not considered realistic for the reasons outlined below.

The experience of subsurface fracturing with regard to weak sediments (i.e. mudstones, claystones and weathered siltstones) and clays is that these units do not generally form continuous open fractures due to their plasticity, and the fractures that do form tend to be self-healing over a relatively short period of time due to swelling from moisture.

The overburden in the underground mining area includes a significantly thick sequence of weak Tertiary strata and weathered Permian, ranging in thickness from 45 m to 90 m. Included are numerous, often times thick, layers of clay and weathered claystone, which lie beneath the scattered basalt occurrences and alluvial gravels in the north near Retreat Creek. Based on experience elsewhere, it is expected that these units will not be highly fractured from subsidence where they occur more than 60 m to 70 m above the mine workings and therefore, will continue to act as an aquiclude to the overlying groundwater and surface waters.

Therefore, whilst the sensitivity analysis predicts high inflows to the underground mine, it is unlikely that these flow rates would eventuate due to the nature of the overlying sediments.

Figure 4.87 shows the 1 m drawdown extent for the subsidence induced fracturing sensitivity analysis, and indicates that the extent of drawdown predicted by the sensitivity model is comparable to the other sensitivities presented in Figure 4.86.

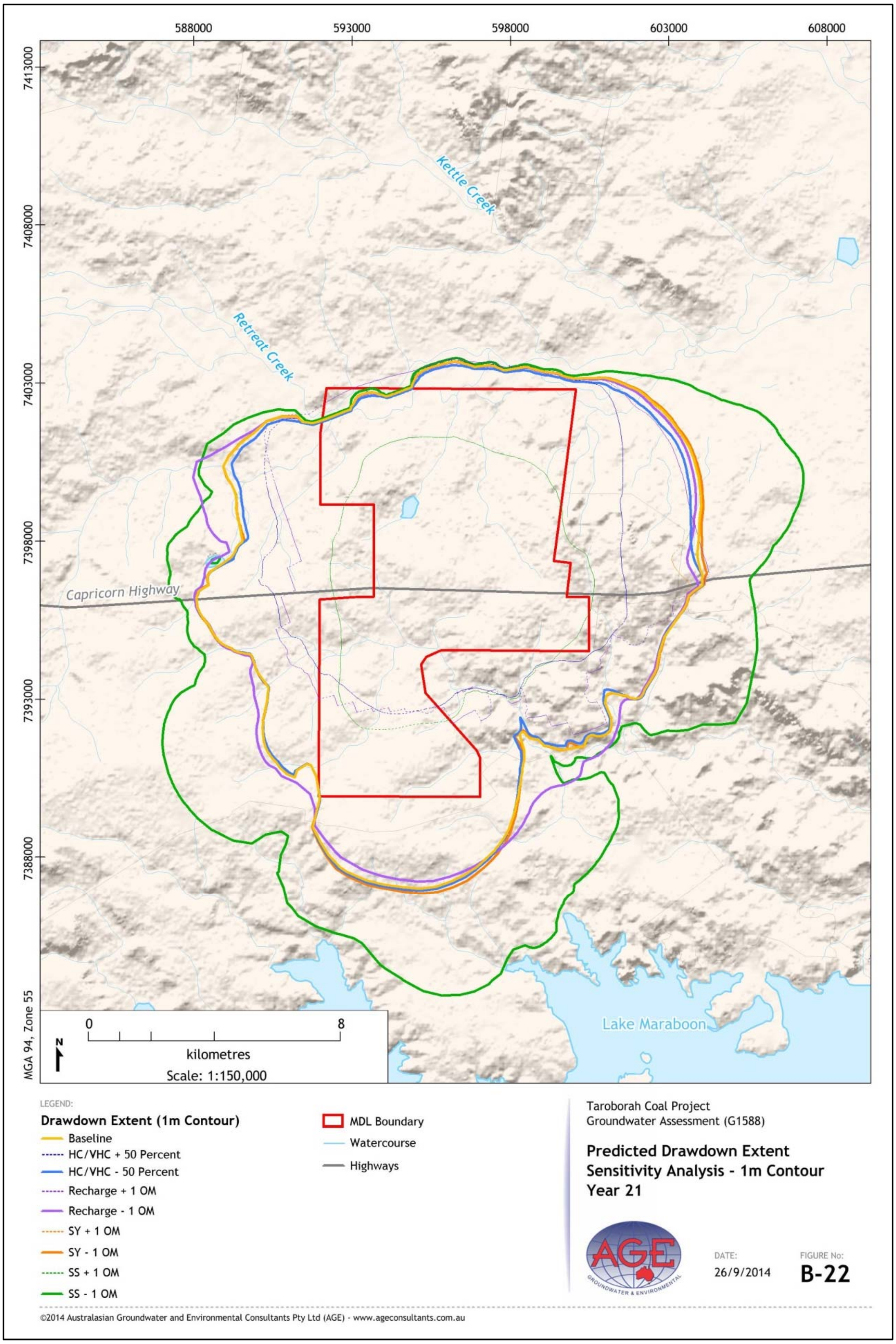


Figure 4.86 Maximum 1 m Predicted Drawdown Extent: Sensitivity Analysis – Year 21

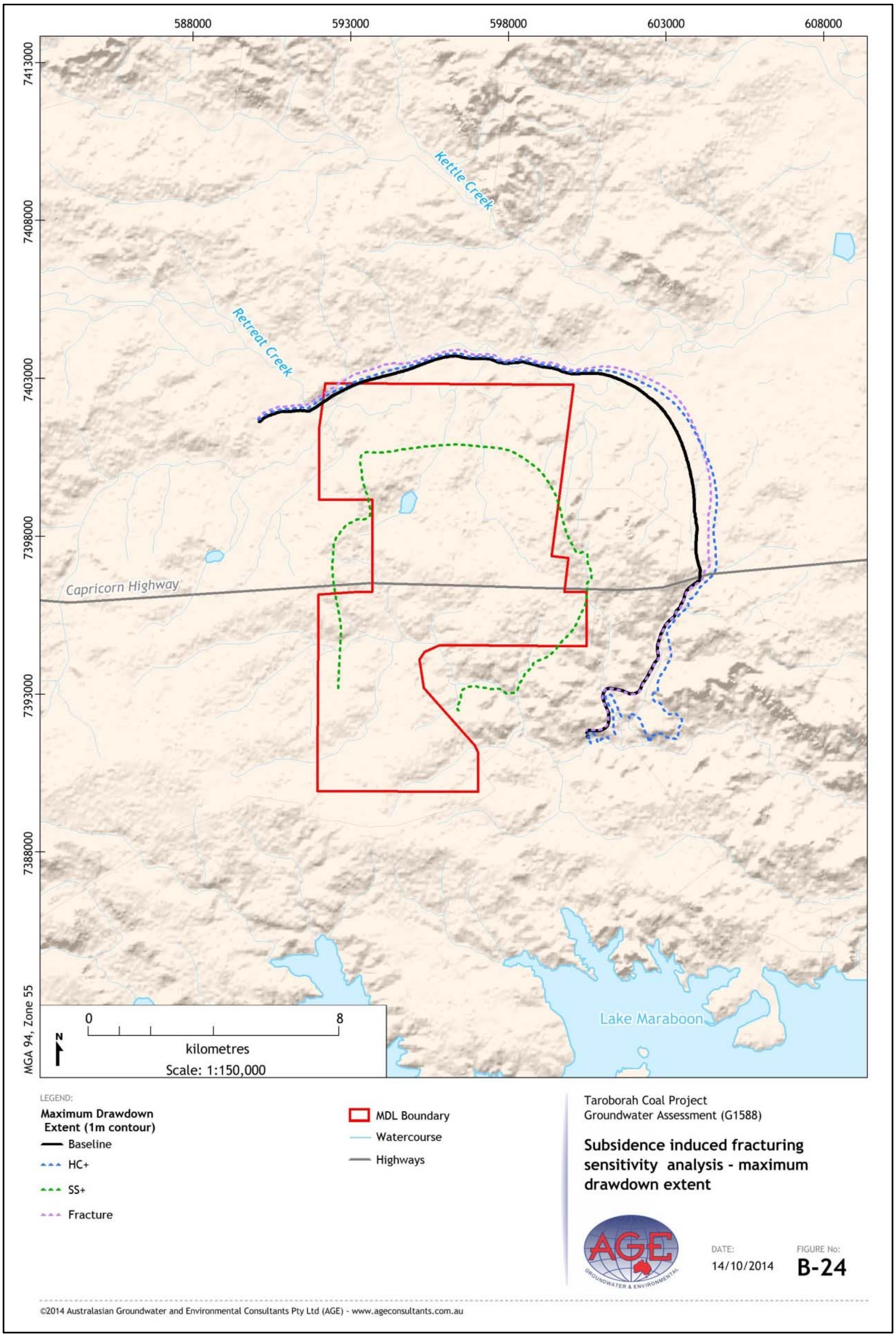


Figure 4.87 Subsidence induced fracturing sensitivity analysis – drawdown extent

Impact on Groundwater Users

Model groundwater drawdown results for indicate that eight active (existing) private landholder bores could report groundwater level declines of greater than 2 m as a result of the proposed mine. This includes:

- one bore used for stock water supply, with a predicted decline of less than five metres;
- two bores used for stock water supply, with a predicted decline of between five to ten metres;
- four bores used for stock and farm water supply, with a predicted decline of over ten metres; and
- one bore used for stock, farm and drinking water supply with a predicted drawdown of over ten metres.

Table 4.73 summarises these eight bores and provides an assessment of the reduction in available drawdown in the bore.

Table 4.73 Predicted Drawdown in Private Bores

Bore ID	Stratigraphy	Use	Bore Depth (mbgl)	SWL (mbgl)	Predicted Drawdown (m)	Head available (m)	Reduction in available drawdown*
RN57603	Aldebaran Sandstone	Stock	80.0	5.5*	2.5	77.5	3%
RN67349	Tertiary Basalt	Stock	32.0	7.83	7.2	24.8	29%
Twin Bore	Tertiary Basalt / Aldebaran Sandstone	Stock - Not currently in use	46	19	8.5	37.5	23%
Census Bore 2	Aldebaran Sandstone	Used for stock	137	10.6*	20.3	116.7	17%
RN84184	Aldebaran Sandstone	Stock	76.5	30.7*	17.3	59.2	29%
RN90064	Aldebaran Sandstone / Coal	Stock & farm water	92.0	42.0*	29.7	62.3	48%
RN103729	Aldebaran Sandstone	Stock	121.5	33.7*	10.1	111.4	9%
Census Bore 3	Aldebaran Sandstone	Stock, farm& drinking water	123	47.8*	23.6	99.4	24%

Note: **SWL estimated from groundwater model*

Table 4.73 shows that, as a result of the Project, one bore is predicted to have a nearly 50% reduction in available drawdown, two bores are between 25% and 50%, and five bores are reduced by <25%.

Those bores with a reduction of greater than 50% are likely to be significantly impacted and are likely to require an alternative source of water to replace this supply. This may be a replacement bore or supplementation of the supply. Bores with a reduction of between 25% and 50% are likely to be

impacted and may require to be deepened, replaced or supplemented with an alternative supply. Those bores with a reduction of available drawdown of less than 25% may be impacted by the project. These bores may require deepening or supplementation with an alternative supply.

Any significant loss of groundwater supply in affected bores will be replaced by the Proponent. Mitigation measures may entail deepening of the bore, deepening of the pump, constructing a replacement bore or supplementation of supply with alternative water. Details of the mitigation measures will be developed in agreement with the landholder at the appropriate time.

Groundwater Dependent Ecosystems

The maximum predicted drawdowns within the unconsolidated stratigraphy correspond to some areas of mapped ecosystems with low to moderate potential for groundwater dependence (Groundwater Dependent Ecosystems (GDE) Atlas 2012) (refer to Figure 4.88).

Ecological field investigations carried out by AustralAsian Resource Consultants (AARC) in 2013 discovered only one creek, which flows northward towards Retreat Creek, that is fed by a local spring and as groundwater levels in the vicinity of Retreat Creek have been recorded approximately six metres below ground level, it has been determined only deep-rooted vegetation (such as the Eucalypt trees which form the dominant canopy) may potentially be affected by groundwater drawdowns.

Groundwater Recovery

Groundwater recovery was modelled for 1,000 years post mining (Year 1021) using the predicted groundwater levels and hydraulic properties at the end of the mining period (refer to Figure 4.89). The results indicated that groundwater levels recover relatively quickly, reaching approximately 60% to 70% of the pre-mining levels within 100 years following cessation of mining..

Groundwater level recovery in the pit voids is likely to be slower, primarily due to evaporation rates exceeding rainfall. The rate of groundwater recovery will be governed by groundwater inflow overcoming evaporation in the pit void. The results indicate that groundwater levels within both pit voids will begin to stabilise approximately 500 years following active mining. Groundwater levels within the western pit void will be maintained at around 194 mAHD, while groundwater levels within the eastern pit void will be maintained at around 190 mAHD (consistent with pre-mining water levels). Both pit lake levels fall well below the pit crest, indicating that the voids will not over-top and will act as 'sinks'.

The private landholder bores are generally all predicted to recover within 5 m of pre-mining water levels with the majority predicted to recover within 3 m. This recovery typically occurs within 200 to 300 years post mining, with the rate of recovery dependent upon proximity to the pit voids. The water levels in the remaining opencut voids are projected to remain well ground level elevation.

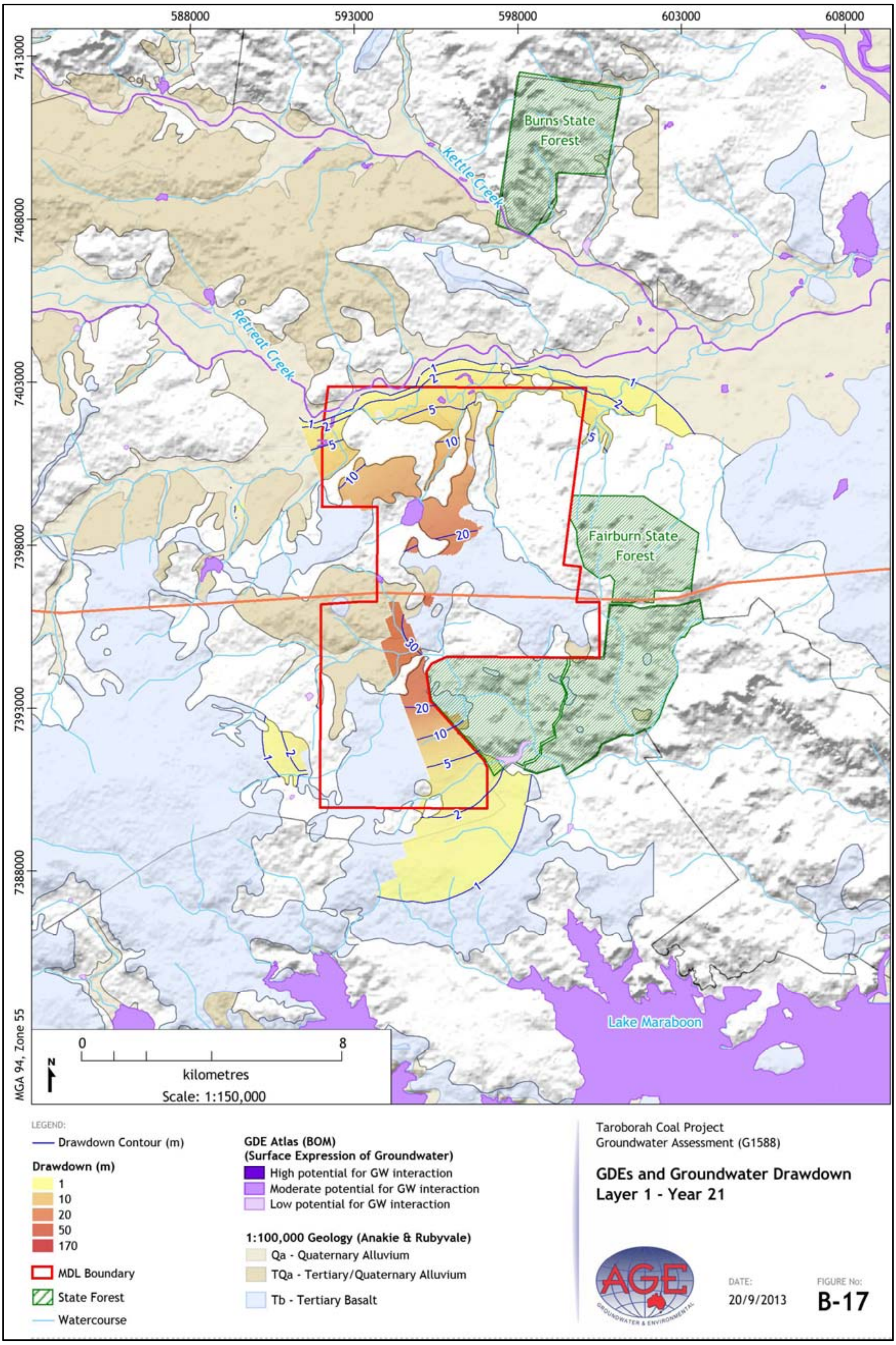


Figure 4.88 Groundwater Dependent Ecosystems and Groundwater Drawdown

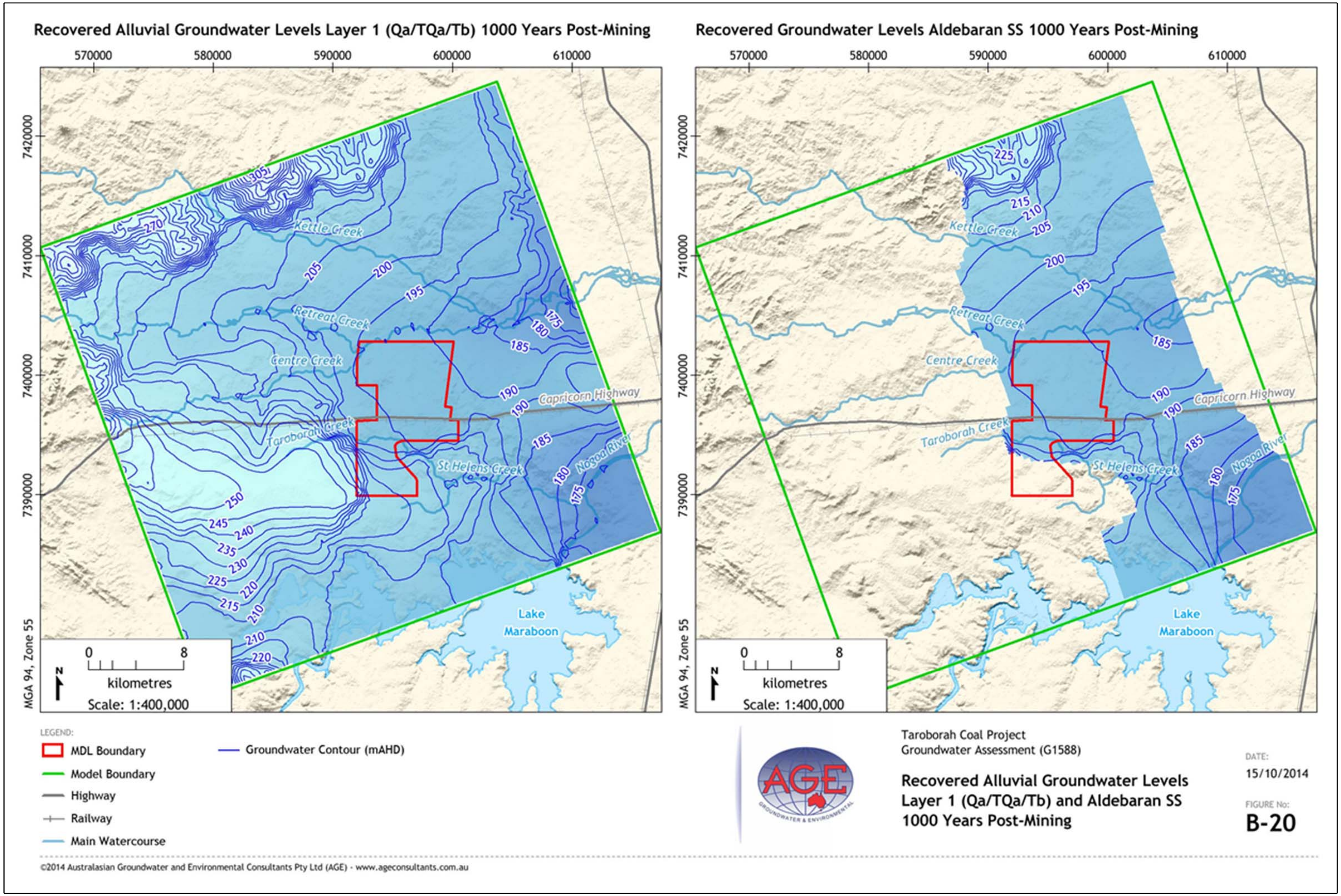


Figure 4.89 Modelled Groundwater Recovery Levels Layer 1 and Layer 9 – 1,000 Years

Groundwater Contamination

Although there is potential for shallow groundwater contamination to occur as a result of hydrocarbon and metals contamination from workshops, waste disposal, mining and non-mining fuel storage, effective operational procedures and adequate emergency response will be used to mitigate sources of contamination and avoid contamination of groundwater resources.

Monitoring

Initially, a 24-month sampling program will be undertaken for the collection of baseline data to improve the understanding of the groundwater interactions and quality characteristics associated with the Project area. Following completion of the initial 24-month baseline sampling, the frequency of this monitoring will be reviewed, but will continue at bi-annual intervals as a minimum.

Groundwater quality and levels are proposed to be monitored at the locations defined in Table 4.74 below and illustrated in Figure 4.90 by an appropriately qualified person.

Table 4.74 Groundwater Monitoring Locations

Monitoring Point	Location		Surface RL (m AHD)
	Easting (GDA94 – Zone 54)	Northing (GDA94 – Zone 54)	
Reference Bores			
MB01B	592504	7399983	213.7
MB02C	594017	7397580	236.8
MB02S	594017	7397580	236.8
MB03S	599667	7399771	230.5
MB04_C	593513	7399534	234.9
MB04S	593493	7399537	235.0
MB06_B	592471	7394530	221.1
MB07_B	592065	7393041	233.1
MB08B	594668	7390096	242.6
MB09T	593575	7401714	201.6
MB10T	600020	7402656	193.4
TAR040C	600263	7396108	230.5
Compliance Bores			
TAR016C	594956	7395372	228.2
TAR053	595642	7395113	213.6
TAR176C	595549	7400349	204.0
TAR177C	594586	7400197	221.1
TAR189C	598843	7398818	236.8
MB05_C	598860	7398819	237.3
TAR249C	596635	7397000	236.2

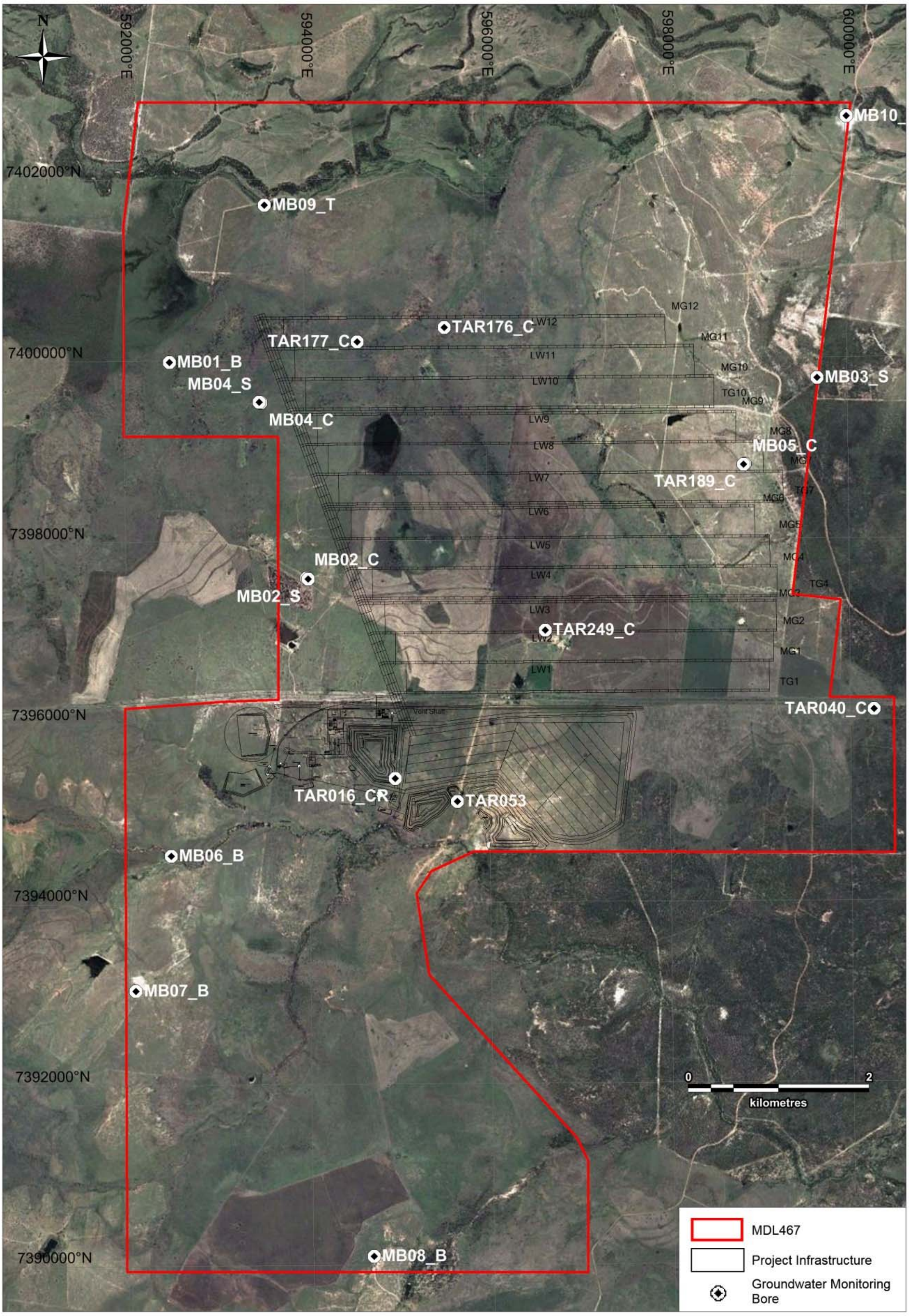


Figure 4.90 Proposed Groundwater Monitoring Locations

Water Level Monitoring Plan

The recording of groundwater levels from the groundwater monitoring network (refer to Table 4.74) within the Project area will be facilitated by using electronic loggers installed in all bores, as well as manual recordings. Monitoring of these bores will continue from pre- to post-mining in order to:

- Enable natural water level fluctuations (such as responses to rainfall, river/creek flows or landholder usage) to be distinguished from potential water level impacts due to depressurisation resulting from mining; and

- Assist with determination of groundwater trigger levels.

The groundwater monitoring bores have been equipped with electronic loggers to record water levels at 6-hourly intervals to assist with the collection of background levels. In addition to the installation of loggers, groundwater levels will be manually measured at quarterly intervals. Data collected from the data-loggers will be downloaded manually at quarterly intervals.

Water Quality Monitoring Plan

The purpose of groundwater quality sampling is to establish baseline groundwater quality to assist the determination of trigger levels and assess the potential groundwater quality impacts during pre- and post-mining.

On-going sampling of existing monitoring bores (refer to Table 4.74) will be undertaken quarterly for a period of two years and collected samples may be analysed for:

- pH, EC and TDS;

- Major anions (CO3, HCO3, Cl, SO4);

- Major cations (Ca, Mg, Na, K);

- Dissolved Metals (Al, Ar, Be, Cd, Cr, Cu, Pb, Ni, Se, Ag, Zn, B, Fe, Hg); and

- Nutrients (ammonia, nitrite, nitrate, total nitrogen, total phosphorus).

Field determinations for pH, EC and temperature will be measured and recorded for each sampling event. The collection, storage and transport of water quality samples for laboratory analysis will be undertaken in accordance with the *Monitoring and Sampling Manual 2009* (EHP 2013).

In addition, monitoring of mine dewatering will be undertaken in order to enable groundwater inflow rates and water quality to be estimated.

4.5.2.3 Site Water Management

The water management system for the Project was designed by ATC Williams in accordance with their findings from associated flood modelling. *The Surface Water Management Plan* (ATC 2013) is provided in Appendix 13.

The water management system evolves and expands as the mine plan progresses and is modified as the opencut pit is developed from Mine Stage Plan Year 1 to Mine Stage Plan Year 7. The surface water management associated with the Project is illustrated in Figure 4.91 to Figure 4.94.

The management of both surface water and groundwater on the Project site has been developed in order to separate clean water (water which has not come into contact with mine disturbance areas) from site water (potentially contaminated by mine activities) using two separate water management circuits as follows:

Clean Water

- Clean water drains (CWD1 and CWD2 – refer to Figure 4.91 to Figure 4.94) are proposed for the east and north of the opencut mining area in order to drain clean water which runs onto the Project site into Taroborah Creek tributaries. These drains have been designed to contain a 1 in 1,000 year peak flow event; and

- Pit protection bunds (CWDS1A to CWDS1D – refer to Figure 4.91 to Figure 4.94) have been designed to a nominal height of 0.5 m high to intercept water before it enters the opencut pit, transfer it to sump pumps (east and west), which then discharge this clean water to the local drainage lines.

Rainfall intensity data was used to calculate the design storms to size the water diversion drains and Manning's equation was used to estimate channel roughness and calculate velocity and discharge. Areas which exhibit higher velocities due to topographical constraints will require placement of durable, benign overburden as rock armouring. Rock armouring will also be placed at drain discharge areas, extending over a sufficient drain length to dissipate flows such that potential scouring can be minimised.

The hydraulic designs for the clean water diversion drains associated with perimeter catchment flows are shown in Table 4.75 below.

Table 4.75 Clean Water Drain – Design for 1000 Year Event

Drain	Catchment Area (km^2)	Peak Flow (m^3 / s)	Drain Width (m)	Drain Slope Max (m/m)	Flow Depth Max (m)	Velocity Max (m/s)
CWD1	3.43	88.09	5.00	0.0036	2.77	3.05*
CWD2	0.007	0.57	5.00	0.0034	1.20	1.86*

* Drain with flow velocity higher than 1m/s will be armoured with in-situ material

Clean water drains designed to intercept upstream catchment water from entering the opencut pit are required at different stages during the opencut production phase of the Project. The hydraulic designs for these clean water drains are shown in Table 4.76.

Table 4.76 Opencut Pit Clean Water Drains

Mine Operational Year	Drain	Catchment Area (km^2)	Peak Flow (m^3 / s)	Drain Width (m)	Drain Slope Max (m/m)	Flow Depth Max (m)	Velocity Max (m/s)**
Year 1	CWDS1B	24.4	13.13	6	0.5%*	0.95	2.00
	CWDS1C	26.3	14.91	7	1.8%	1.00	3.20
	CWDS1D	31.9	12.64	10	1.0%	1.00	2.25
Year 3	CWDS1B	16.7	9.13	2	0.8%	1.00	2.33
	CWDS1C	3.1	1.79	1	1.6%	0.50	2.00
Year 5	CWDS1D	29.0	14.65	4	1.0%	1.00	2.75

* Pit excavation activities may necessitate a re-assessment of these bunds as diversion drainage devices should the grading of catchments near the pit be affected by on-going development of the site.

** Drain with flow velocity higher than 1m/s will be armoured with suitable material.

Site Water

- A Mine Wastewater Dam (MWD) will be constructed within the rail loop and represents the main water storage structure on site. This dam will be constructed by excavating a shallow void and then constructing three dam walls from local clean materials;
- A Coal Preparation Plant Waste Recycle Dam (CPPWRD) will also be constructed in the same manner as the mine wastewater dam and will be used to store water from and supply water to the CPP;
- Two pit sumps with storage capacities of 20 ML each will be constructed in the west and east areas of the opencut pit to collect groundwater and rain water runoff from the spoil that will accumulate in the base of the pit. This water is then transferred to the MWD;
- An underground dewatering system to collect groundwater from the underground mine workings will be constructed and intake will be pumped into the MWD;
- Three site water drains (SWD1 to SWD3 - Figure 4.91 to Figure 4.94) will surround the out-of-pit spoil dumps and collect runoff from these dumps for deposition into sediment dams;
- Bunding around coal stockpiles and the infrastructure areas, which direct water to four separate sediment dams; and
- All sediments dams have been designed based on their respective catchment areas to hold 0.1 AEP runoff. Sediment from overland flow from the out-of-pit spoil dumps, stockpiles, mine infrastructure area and surrounding areas will be retained in these dams, thereby allowing clarification of the water through settlement, before pumping into the CPPWRD.

Site water collection drains and bunds have been designed to accommodate a 100 year Annual Reoccurrence Interval (ARI) event of critical duration. Similar to the design of clean water drains, site

water drains displaying flow velocities greater than 1 m/s will require armouring to limit erosion.

The hydrological and hydraulic design of the main site water collection drains is outlined in Table 4.77 below.

Table 4.77 Site Water Collection Drain Design

Drain	Catchment Area km^2	Peak Flow m^3/s	Drain Width m	Drain Slope Max m/m	Flow Depth Max m	Velocity Max m/s*
SWD1A	0.14	3.73	5.00	0.01	0.43	1.48
SWD1B	0.17	4.24	5.00	0.01	0.45	1.82
SWD2A	0.13	3.49	5.00	0.01	0.33	1.52
SWD2B	0.23	4.81	5.00	0.01	0.48	1.91
SWD3A	0.04	1.77	5.00	0.01	0.07	2.84
SWD3B	0.081	2.37	5.00	0.01	0.32	1.20

* Drain with flow velocity higher than 1m/s will be armoured with in-situ material.

Dam Hazard Assessment and Design Storage Allowance

The dams that will be constructed on the Project site have been assessed in terms of the hazard that they pose to the local environment.

- CPPWRD – deemed to be a High Hazard dam, therefore, it is designed to accommodate a 1 in 100 AEP event (in the wet season) as a minimum requirement, which is equivalent to a 1% spill probability; and
- MWD – assessed as a High Hazard dam that, as a minimum requirement, is designed to accommodate a 1 in 100 AEP event (during the wet season), which is equivalent to a 1% spill probability.
- Sediment Dams – assessed as Low Hazard dams that are not considered as a regulated structure and therefore do not have a minimum design volume requirement. However, to allow for the storage of a heavy rainfall event that would runoff the mine affected areas, a minimum design volume to accommodate a 1 in 10, 72 hour AEP event has been used.

The key criteria relevant to regulated structures relates to the capacity of the structure to accommodate a wet season allowance, referred to as the Design Storage Allowance (DSA). The DSA for each of the regulated dams and the sediment dams based on the hazard assessment is provided in Table 4.78 .

Notwithstanding the minimum DSA requirements for the CPPWRD and MWD, the groundwater modelling suggests significantly more volume will be required for each of these structures in order to adequately handle the expected water make from dewatering the mining operations and limit the necessary discharge of significantly affected mine water. Therefore, within the space allowed for each structure, a designed storage volume of 1077ML for the MWD and 832 ML for the CPPWRD have been used in the site water balance model.

Table 4.78 Minimum Design Storage Requirements for Site Water Storage Structures

Structure	Containment Criteria	Equivalent Rainfall (mm)	Contributing Catchment (ha)	Minimum Design Storage Allowance (ML)
Regulated Structures				
MWD	1 in 100 AEP	1,200	22.1	577#
CPPWRD	1 in 100 AEP	1,200	32.7	392*
Non-regulated Structures				
SED 01	1 in 10 AEP, 72 Hour	142.9	3.9	6
SED 02	1 in 10 AEP, 72 Hour	142.9	16.9	24
SED 03	1 in 10 AEP, 72 Hour	142.9	18.9	27
SED 04	1 in 10 AEP, 72 Hour	142.9	40.3	58
SED 05	1 in 10 AEP, 72 Hour	142.9	7.6	11
SED 06	1 in 10 AEP, 72 Hour	142.9	38.6	55
SED 07	1 in 10 AEP, 72 Hour	142.9	16.9	24

This value includes 312 ML of groundwater inflow that will be concurrently transferred to this dam from mine workings.
* The direct contributing catchment for the CPPWRD is 11.9 ha. The current evaluation of DSA for CPPWRD includes the process plant catchment area of 20.8 ha which is proposed to be captured within SED01 and SED02 and subsequently pumped into the CPPWRD to ensure full containment of significantly contaminated water.

The accumulation of water stored in the MWD will be regulated to maintain capacity to handle a 100 year ARI event, which is approximately 577ML including mean groundwater inflows. Once the remaining capacity reaches this level, pumping of water will be undertaken and either sent to the CPPWRD (if capacity exists) or necessarily released outside the site water management system.

Water balance modelling indicates the maximum accumulation within the MWD based on the simulated 123 year rainfall record, has a spill risk of less than 1% using a full storage capacity of 1,077 ML and with the operational conditions above in place. Under mean conditions, an excess volume of 6377 ML (mean) of water designated to be stored in MWD is projected for the entire 21 year modelling period.

Similar to the MWD, the accumulation of water stored in CPPWRD will be regulated to maintain capacity to handle a 100 year ARI event, which is approximately 390 ML. Once remaining capacity reaches this level, water will be transferred to the MWD for use in dust suppression.

Water balance modelling indicates the maximum accumulation within the CPPWRD based on the simulated 123 year rainfall record exceeds the full supply capacity of 832ML only for the final year. The mean storage volume ranges from 50ML during the dry season to 400ML in the wet season with the higher storage levels occurring in the final 3 years of operation. The modelled spill risk for the CPPWRD is less than 0.5%, which is less than the spill risk criteria of less than 1% for a High consequence structure.

The water balance model indicates that water make from necessary removal of groundwater from the

mining operations, together with rainfall collected from the mine surface area, will exceed the annual operational water requirements and water lost to evaporation by as much as 2.36 ML/day peak and 0.87 ML/day on average, even with the proposed 1.9 Gigalitres (GL) of water storage. Therefore, release of water from site (after necessary treatment) may need to be an annual occurrence.

As it is possible and planned to separate the largely uncontaminated groundwater make (stored in the MWD) from the more contaminated rainfall run-off from the waste storage dumps, coal stockpiles and mine infrastructure areas (stored in the CPPWRD), it is proposed to release the excess water for beneficial use rather than into the local surface drainage system. The quality of the groundwater is suitable for both stock watering and crop irrigation purposes (when mixed in proportionately small quantities with normal irrigation water from Fairbairn Dam) as indicated in Appendix 14 and in general, this groundwater can be collected and pumped to storage in the MWD prior to significant interaction with potentially contaminating fuels, oils and solvents used in mining operations or acidic mine waste rock.

Two options for beneficial use are being considered. The first option would be to release the excess water directly into the irrigation channel downstream of the Fairbairn Dam that is located approximately 16 km east of the mine site. This would be accomplished via installation of a pumping station at the mine site and a pipeline run along the upgraded Central West Railway line to the point where it overpasses the Selma irrigation channel. Maximum discharge rates of approximately 2-4ML/day would not affect the quality of the typical 165-180ML/day of Fairbairn Dam water already flowing in the channel. A second option is to provide the water for supply to industrial users in the area who otherwise might take water from Fairbairn Dam, such as the proposed Teresa Mine or the Galilee Basin mines to the west. This second option is currently being investigated with potential water suppliers to the Galilee Basin, who propose to run a pipeline in the near vicinity of Taroborah. In either case, the water would be released at a controlled rate, lowering the storage dam levels in the dry months and allowing dam levels to rise in the wetter months. As modelled, release rates would need to average approximately 0.9 ML/day.

To control the excess water release and provide for maximum release water quality, lowering of the MWD prior to the wet season is proposed. In this manner, the storage capacity of the MWD can be increased to receive the increased runoff during this period, allowing the water accumulated more time to clarify before release. Further, this will reduce release rates during the wet season and increase release rates during the dry season, when it is most beneficial for the purpose of irrigation and providing a more consistent flow volume for treatment purposes prior to release.

Monitoring and testing of the water in the MWD will be conducted before any planned release.

Based on the water balance modelling, and using the Method of Operational Simulation in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Dams* (EHP 2013) the proposed storage volumes for the MWD and CPPWRD will be 1077 ML and 832 ML respectively, in order to accommodate all sediment dam inflow and other process inputs and reduce the spill risk to 1% and 0.5%, respectively.

At the end of mine life, the water contained within the MWD and CPPWRD will either be drained or allowed to evaporate. The remaining void will then be filled in with benign material in order to cover residual sediments in each dam.

These dam areas will then be re-contoured to shed surface water (maximum slope gradient of 1 in 10), compacted to minimise erosion, topsoiled (to a depth of approximately 100 mm) and re-seeded with native flora.

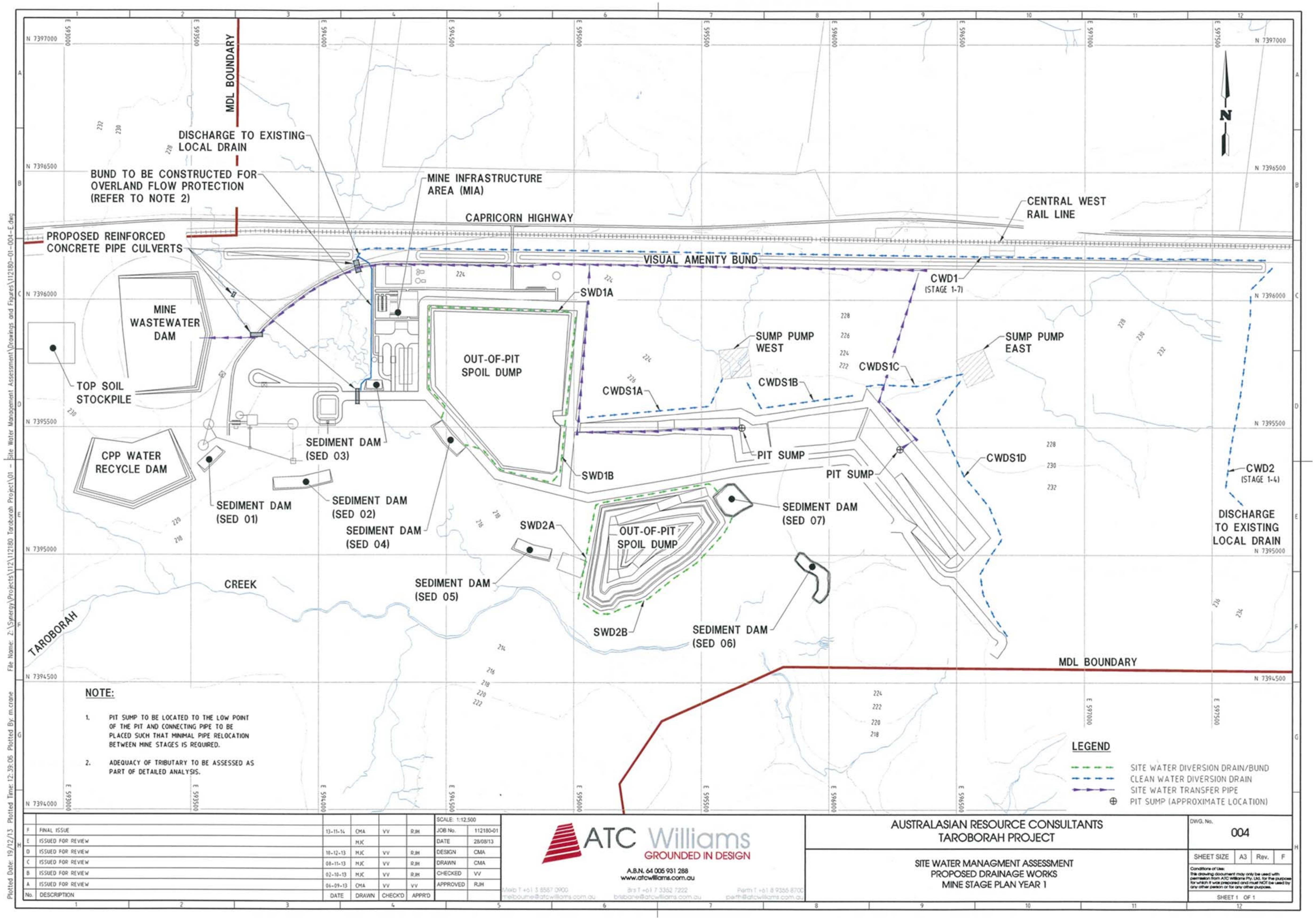


Figure 4.91 Surface Water Management System for Mine Stage Plan Year 1

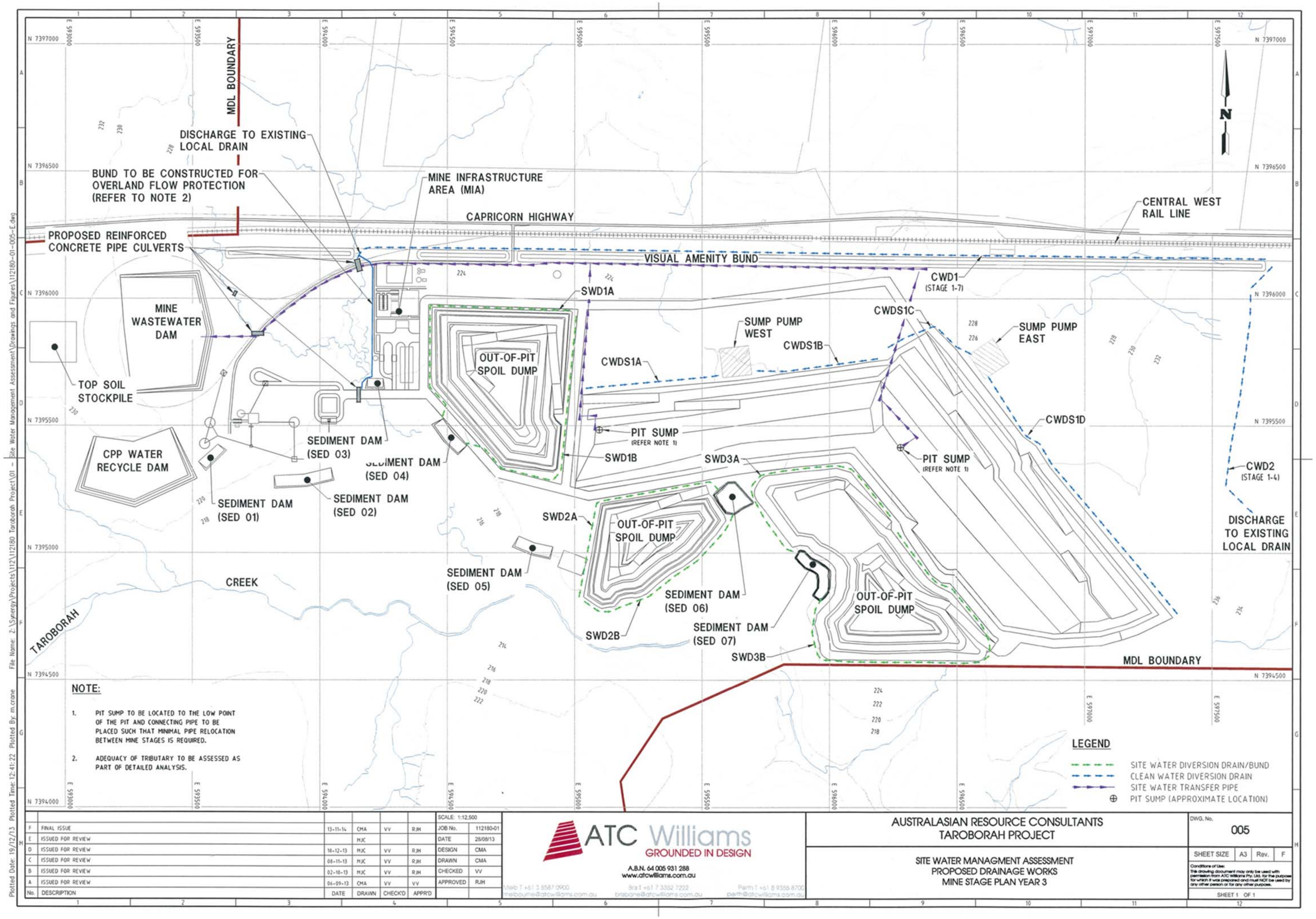


Figure 4.92 Surface Water Management System for Mine Stage Plan Year 3

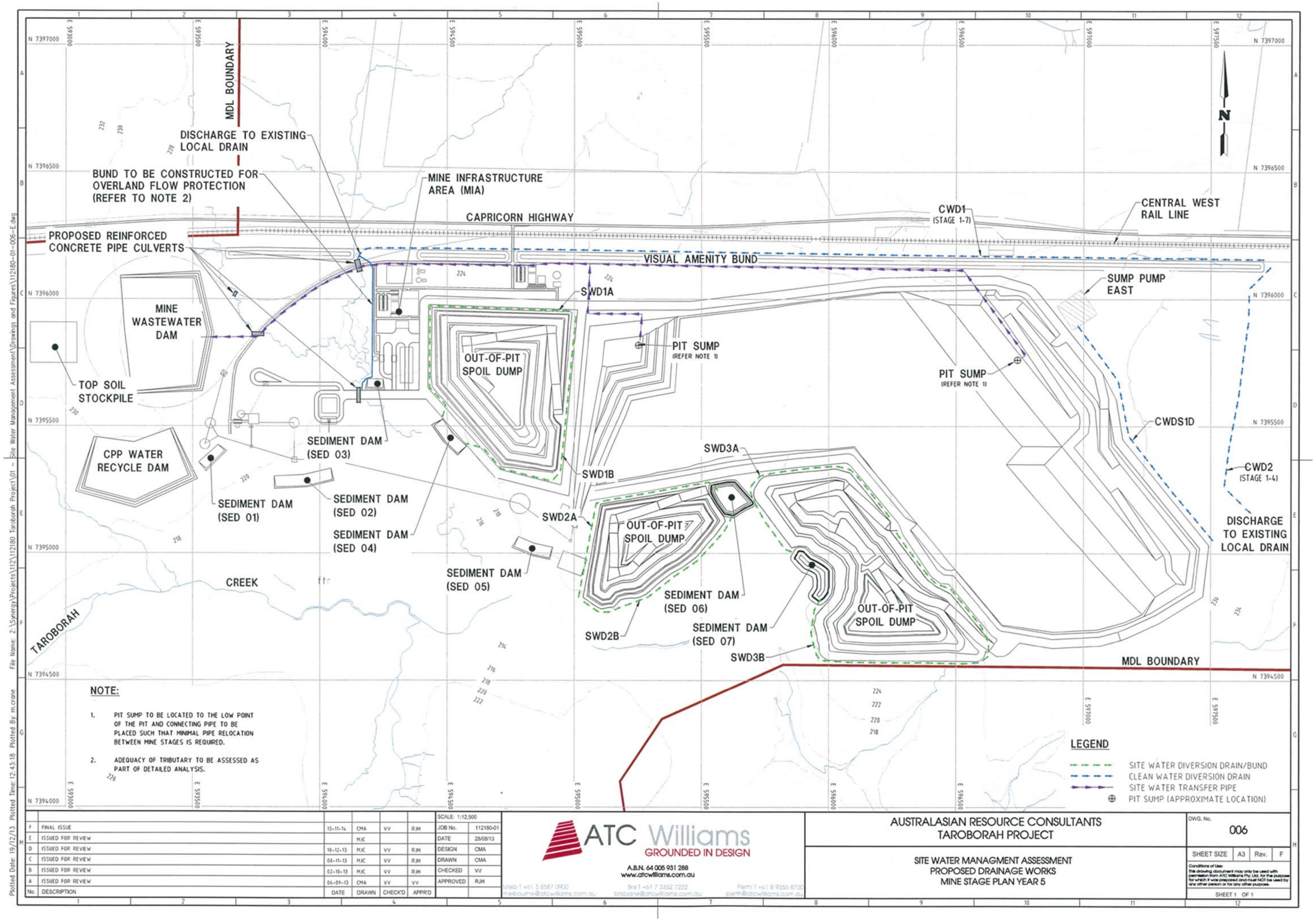


Figure 4.93 Surface Water Management System for Mine Year 5

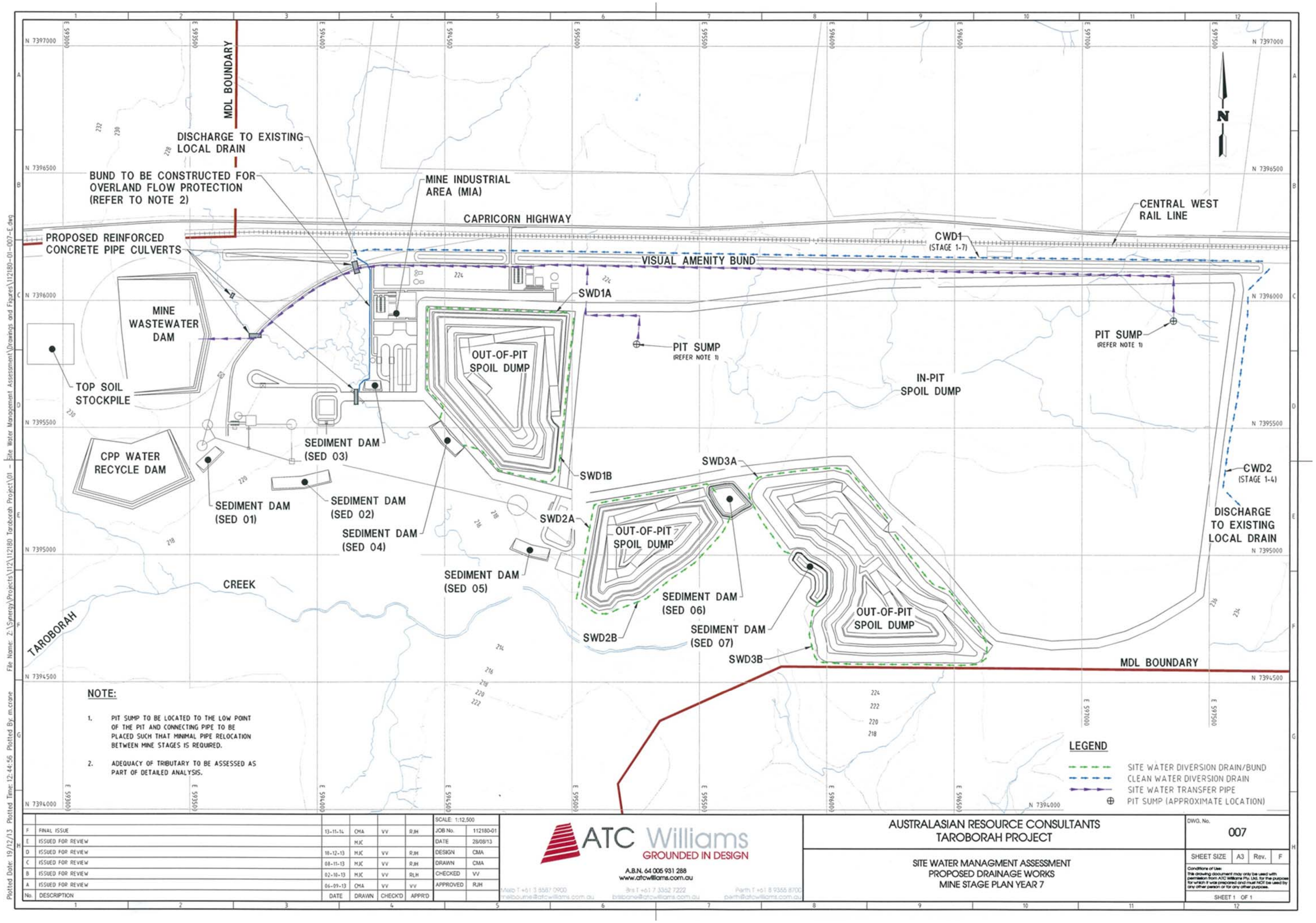


Figure 4.94 Surface Water Management System for Mine Year 7

Uncontrolled Discharges

The site water management system has been designed to minimise the risk of uncontrolled discharge to receiving waters, therefore, the potential impacts of site water discharge upon local and downstream water quality are considered to be minimal. The main water management design philosophy is to divert clean water away from the Project site (thereby minimising the volumes of clean water that have to be managed on site) and retain contaminated site water within the site's water management circuit (to the maximum extent possible) for recycle and re-use. Any necessary discharges resulting from excess groundwater will be conducted in a controlled manner, and after necessary water treatment, into existing irrigation systems, as discussed above.

Site water collection drains / bunds which intercept site water from disturbed surfaces and drain to containment structures have been designed to accommodate a 100 year ARI event of critical duration in order to minimise the risk of discharge to receiving water. Site water drains will also be positioned around the perimeter of out-of-pit spoil dumps, in order to contain and transport contaminated site water to proposed collection points.

The storage capacities of the MWD and CPPWRD have also been designed to minimise the risk of uncontrolled site water discharge to the environment. In terms of containment criteria for both CPPWRD and the MWD, these storage structures can and will be operated to accommodate a 1 in 100 AEP event (in the wet season) as a minimum requirement (equivalent to a 1% spill probability).

If an uncontrolled discharge from the water storage system on site does occur due to system or catastrophic failure in the event of heavy and continued rainfall, it is considered that the volumes of precipitation concerned would dilute the site water to such an extent that the quality of discharged water would not significantly impact the quality of the receiving water. Due to the limited number of homesteads, and the distance the water will travel before reaching the Emerald water supply intake, no impacts are anticipated upon human health.

As no other mining projects or industrial activities are located close to the Project site and the local catchment is not associated with any other mines / industry, the cumulative impacts of discharges from multiple sources is not considered to pose a risk to the local receiving environment.

While the Taroborah Project is not anticipated to cause impacts to the local receiving environment, the potential exists for the Project to contribute to catchment-wide downstream cumulative impacts resulting from uncontrolled discharges of mine affected water. The potential impacts associated with the release of mine affected waters include:

- Toxicity related to the release of sulphate, salinity, acid or alkaline solutions, metals or metalloids;
- Changes in the bioavailability of metals caused by changes to pH of receiving waters, impacting flora and fauna;
- Detrimental impacts to the structure and function of ecosystems; and
- Impacts to the suitability of water for drinking, stock water, or irrigation.

While it is inevitable that all developments will contribute to some extent to cumulative impacts, the degree and severity of this contribution is dependent on a number of factors, including:

- Quality and quantity of mine discharge water;
- Time of release;
- Weather conditions at the time of release;
- Existing quality and flow of the receiving catchments. For example, it has been noted that northern sub-catchments such as Isaac/Connors typically has naturally higher EC than the Nogoa sub-catchment (DERM 2009);
- The number and type of other developments in the area; and
- Whether the release coincides with releases from other mines.

In order to determine the potential for the Project to contribute to cumulative impacts, the following section provides an overview of the other resource and infrastructure developments located, or proposed to be located, in the Fitzroy River Basin.

A study conducted by the Department of Environment and Resource Management (DERM) in 2009 investigated the cumulative impacts of mining activities on water quality in the Fitzroy River Basin. The study concluded that the limits and conditions imposed on coal mines were inconsistent and not necessarily effective in protecting downstream environmental values, and insufficient data are available to provide a quantitative assessment of the cumulative impacts of mine water discharges (DERM 2009).

It is considered that salinity presents the most significant risk to water quality in the Fitzroy Basin due to discharges from coal mines. As part of the study, a risk assessment was conducted using electrical conductivity, discharge data (i.e. duration, frequency, volume, water quality and receiving waters) and geographic location within the basin. The matrix shown in Table 4.79 was used to determine the risk rating for each mine.

Table 4.79 Cumulative Risk Assessment Matrix for Mine Discharges in the Fitzroy Basin

Frequency/Volume (ML/year)			EC (µS/cm)			
			Very Low	Low	Medium	High
			<720	<1,250	<2,500	>2,500
Very Low	Zero/small	<100	Very Low	Low	Low	Medium
Low	Few releases, infrequent	<1,000	Low	Low	Medium	Medium
Medium	Frequent	<10,000	Low	Medium	Medium	High
High	Continuous, some dry weather	<100,000	Medium	Medium	High	Very High
Very High	Continuous, months	>100,000	Medium	High	Very High	Very High

Source: DERM 2009

The assessment found that the greatest contributors to potential downstream cumulative impacts on water quality were:

- Coppabella (Peabody Energy);
- North Goonyella (Peabody Energy);
- Goonyella Riverside (BHP Billiton Mitsubishi Alliance);
- Millennium (Peabody Energy);
- Peak Downs (BHP Coal Pty Ltd); and
- Ensham (Ensham Resources Pty Limited).

The results of the risk assessment are illustrated in Figure 4.95. With the exception of Ensham (located in the Nogoa sub-catchment), these mines are located in the Isaac-Connors sub-catchment. An additional six mines in the northern sub-catchments were found to present a medium cumulative risk. Most mines in the southern sub-catchments (i.e. Dawson, Nogoa and Mackenzie), however, presented only a low cumulative risk to water quality impacts based on EC. Coal mine development in the northern sub-catchments of the Fitzroy Basin is considered to pose a greater risk of downstream cumulative impacts than mines in the southern sub-catchments, in which the Taroborah Project is located.

Three main recommendations were proposed based on the conclusions of the study:

1. Development of appropriate standardised environmental authority conditions relating to mine water discharges;
2. Development of locally-relevant water quality guidelines; and
3. Development of a cumulative impact assessment model for the region.

These recommendations have culminated in the establishment of an Integrated Quantity and Quality Model (IQQM) for the Fitzroy Basin, the Model Water Conditions for Coal Mines in the Fitzroy Basin and Environmental Values and Water Quality Objectives at localised sub-basin scales across the Fitzroy River Basin. The IQQM simulates stream flows, releases, in-stream infrastructure and diversions, and was used to inform the Water Resource Plan development process.

It is anticipated that the Model Water Conditions will be applied to the Taroborah Project, located in the lower Fitzroy Basin (Zone 3). The Model Water Conditions were developed specifically for improving water management in relation to coal mines in the Fitzroy Basin, particularly in terms of improving the cumulative impact of multiple mine discharges, and achieving consistency in Environmental Authority conditions between mining developments. The model conditions consider the spatial location of a project within the catchment when determining appropriate trigger levels and contaminant limits applicable to its mine discharges.

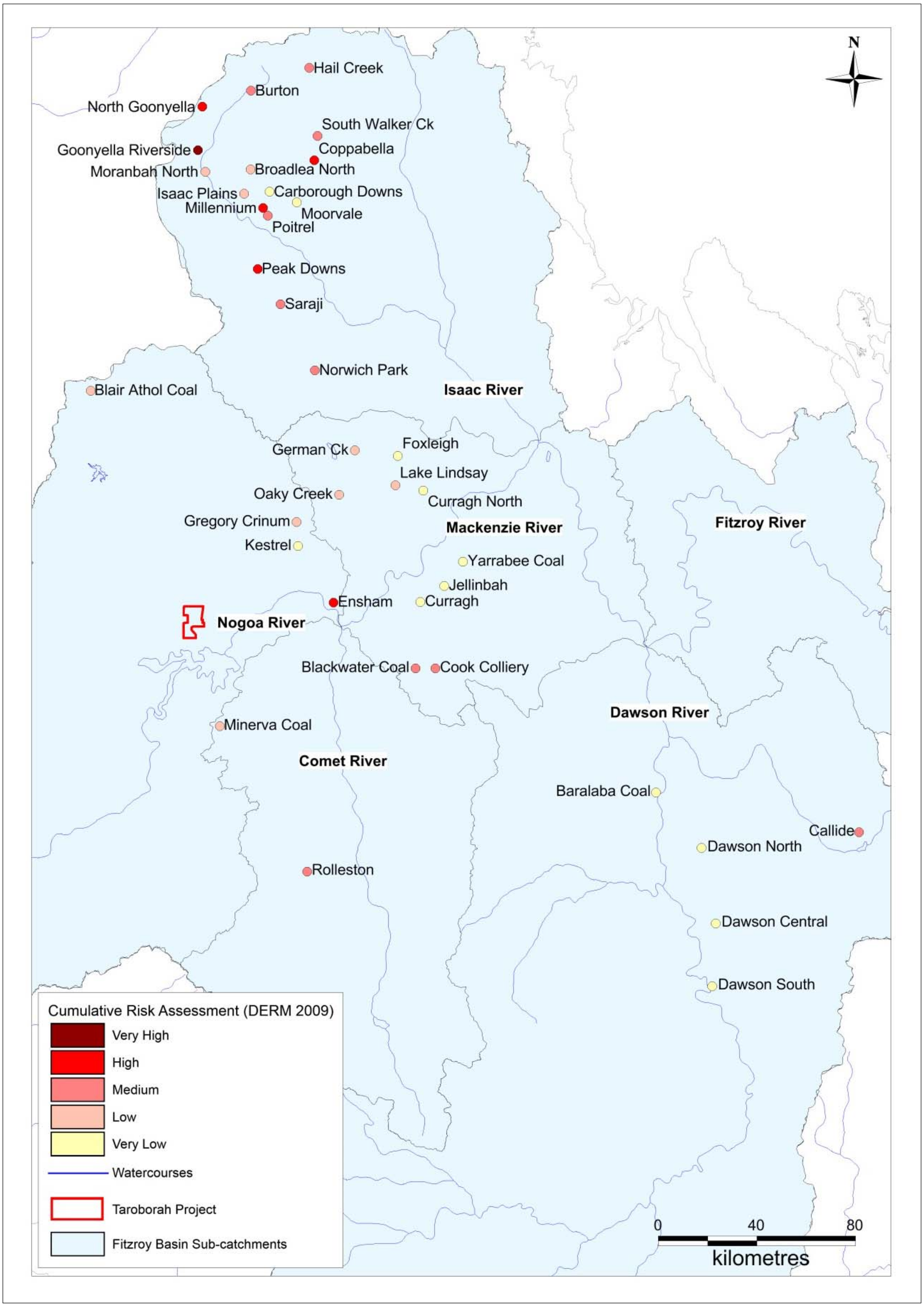


Figure 4.95 Cumulative Risk Assessment of Major Operational Mines in the Fitzroy Basin

Rejects Storage Leachate and Final Void Water Quality

The coarse and fine rejects produced by the CPP will be stored both in out-of-pit spoil dumps and in-pit, therefore, no separate rejects storage structure will be constructed. The rejects will be stored in clay-lined engineered cells in order to minimise the migration of leachate that may be produced from waste material. For the in-pit rejects, this waste material will also be inundated with groundwater once groundwater levels have recovered. Groundwater inundation will help to reduce the process of oxidation and therefore the production of acid mine drainage following mine closure.

To assess the effectiveness of the rejects storage system on final void water quality and potential groundwater contamination, a final void management plan will be developed prior to the completion of opencut mining. The Project's surface water and groundwater monitoring programmes will include assessment of surface and groundwater pH, salinity, sulphate and heavy metals, as indicators of potential rejects leachate. The post closure groundwater monitoring network is unlikely to maintain bores within the spoil or emplacement areas as there is no perceived level of environmental risk within the spoil or pit void. The pit void is assessed to be a sink post mining and the network is more likely to be installed to monitor groundwater within groundwater systems around the void, from which local groundwater supplies are extracted, hence, with the objective of monitoring and maintaining the environmental value of the resource.

Quarry Material Allocation Notice

No Quarry Material Allocation Notices (QMAN) holders were identified in or downstream of the Project site. Therefore, the potential increase in sediment loading on local watercourses as a result of land subsidence will not have an impact upon the resource or entitlement of local QMAN holders.

Watercourse Monitoring, Auditing and Management

The various surface waters which flow across the Project site will be monitored throughout the life of the mine as follows, to ensure that these surface water systems are not adversely affected by Project activities:

- Chemical analysis of surface water samples at reference, midstream and downstream sampling locations daily during any site water releases. The results of this chemical assessment will be compared with site-specific target values for surface waters and sediments that have been agreed with EHP, in order to identify any exceedances of these target values. An investigation of any water and sediment quality exceedances will be conducted, in order to identify the cause of these exceedances;

- The surface water and sediment quality data produced for local watercourses will be audited against the Project's Environmental Authority to ensure that the Project site is compliant with this authority;

- Photographic surveys of watercourse and vegetation condition will conducted before and during mining operations in order to generate a record of their environmental values that can be referred to, in the event of any Project induced significant changes to each watercourse; and

- Surface water banks and beds will be frequently inspected in order to identify any tension cracks which may have developed along these watercourses as a result of underground mining activities. Any tension cracks which may have developed will be sealed to prevent any loss of surface water or damage to local flora.