# 6. Water Resources

*This section provides a summary of the water resource assessment undertaken, and the potential impacts identified, in regards to the Project (Mine) during construction and operation. The water resource assessment was undertaken in accordance with the requirements of the Terms of Reference (ToR) and a table cross-referencing these requirements is provided in Volume 4 Appendix C ToR Cross Reference Table. The water resources assessment incorporates the results from the following studies:*

- *Volume 4 Appendix P1 Hydrology Report,*
- *Volume 4 Appendix R Hydrogeology Report*
- *Volume 4 Appendix Q Water Quality Report.*

## 6.1 Project Overview

Water resources include water in rivers, streams, wetlands, lakes, aquifers, estuaries and coastal areas. The water resources of the Project (Mine) are here described in terms of their physical characteristics, surface drainage patterns and history of flooding. These water resources have been described using pre-existing information and data collected from site specific investigations. Furthermore, the impacts of the Project (Mine) on these water resources were assessed.

For surface water, the assessment involved surface water monitoring and the design of preliminary flood protection infrastructure including minor and major levees, diversion drains, culverts and waterway crossings. It also involved flood modelling to assess the effectiveness of the conceptual drainage scheme and quantify the residual flooding impact as a result of the Project (Mine). For groundwater, the assessment included the installation of a groundwater monitoring bore network and subsequent monitoring and development of a numerical groundwater model.

An initial water supply assessment was undertaken to determine potential sources of water for the Project (Mine). This assessment concluded that adequate water could be sourced as follows.

- Flood harvesting from the Belyando River
- In-steam storages on North Creek and Obungeena Creek
- Groundwater bores in the vicinity of the off-site infrastructure area (refer to Figure 6-6).

A description of the Project (Mine) offsite water supply infrastructure is provided in Volume 2 Section 2 Description of the Project.

### 6.1.1 Methodology

The following methodology was employed to develop an accurate understanding of the existing environmental values, the potential impacts and associated management and mitigation measures for water resources that may be affected by the Project (Mine). The methodology has been designed to allow for outcomes of each step to inform the Project (Mine) design, and to inform other Project EIS specific specialist reports. The methodology involved the following:

- A definition of the Study Area, based on the extent of water resources that may be affected

- A review of the Commonwealth, State and local legislation, standards, codes and guidelines relating to water resources and associated approvals
- Confirmation of legislative interpretation (such as applicable Environmental Values) through review of existing literature
- Hydrologic and hydraulic modelling, discussed in Section 6.1.7
- Preliminary design of diversion, crossings, levees and storages, and operating rules for Project (Mine) offsite water supply infrastructure, discussed in Section 6.1.7
- Collection of data for the desktop review of the surface water resource, including:
  - A Digital Elevation Model
  - A Regional Elevation Model
  - Mine site layout for all Mine stages
  - Aerial photography
  - Intensity-Frequency-Duration rainfall data
  - Department of Environment and Heritage Protection (DEHP) stream gauge data
  - DEHP watercourse locations, as geospatial files
  - BoM historical rainfall and evapotranspiration data
  - Review of rainfall data reported by Bureau of Meteorology
  - DEHP licensing information for the Belyando River
  - Flooding extent in the Belyando region during Cyclone Helen (17 January 2008)
  - Queensland Government Data Drill evaporation data
- Collection of data for the desktop review of the groundwater resource, including:
  - Existing reports, maps and data
  - Queensland Groundwater Bore Database (DERM, December 2010) and
  - Communications with DERM (Rockhampton) and Isaac Regional Council
  - Geological Society of Queensland digital geology mapping
  - Australian Natural Resource Atlas (ANRA) interactive website
  - Hancock Prospecting Pty Ltd, Alpha Coal Project Environmental Impact Statement
  - Waratah Coal, Galilee Coal Project Environmental Impact Statement
- Hydrological field investigations to characterise the surface water resource
- Surface water monitoring at two monitoring stations
- Water quality field investigations including the establishment and assessment of twelve representative sites and in-stream sediment quality sampling
- Interpretation of water quality sampling results, comparing:
  - Median values for physical parameters and nutrient data (refer to QWQG; DERM 2009a)
  - $95^{th}$ percentile values for toxicant data (refer to the ANZECC guidelines; ANZECC and ARMCANZ, 2000)
  - Where appropriate calculation of hardness-modified trigger values for the comparison of metal data, as required by the ANZECC guidelines (ANZECC and ARMCANZ, 2000).

- Hydrogeological field investigations to appraise the hydrogeological conditions in the Study Area and to define the environmental values for groundwater resources including:
  - Inspection of accessible DERM registered bores (seven accessible of the 10 registered) located within EPC1690
  - Collection of information from inspected bores, including headworks, existing infrastructure, condition, and potential use
  - Installation of groundwater monitoring network (33 bores and 21 sites) to supplement publically available groundwater level and quality data for the site
- Assessment of potential impacts of the Project (Mine) on hydrology, water quality and groundwater
- Mitigation measures and monitoring strategies for potential impacts of the Project (Mine) on hydrology, water quality and groundwater
- Development of mitigation measures and monitoring strategies for potential impacts on groundwater resources
- Determination and confirmation of all relevant approvals relating to water resources required for the Project (Mine).

### 6.1.2 Regulatory Framework

Regulatory instruments relevant to water resources potentially affected by the Project (Mine) are outlined in Volume 4 Appendix D Project Approvals and Planning Assessment. In addition, there are a number of International, National and State standards, codes and guidelines used in defining and measuring environmental values for water resources.  These are also outlined below.

#### 6.1.2.1 Environment Protection Act 1994

The *Environment Protection Act* 1994 (EP Act) provides a regulatory framework for the protection and management of the Queensland environment.  The objective of the EP Act is to protect Queensland’s environment whilst allowing for development that is ecologically sustainable. This is achieve through various mechanisms including the management of environmentally relevant activities (ERAs) and the identification and protection of environmental values (EVs) under the *Environmental Protection (Water) Policy 2009*

#### 6.1.2.2 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy* 2009 (EPP (Water)) applies to all waters including tidal, non-tidal, lakes, wetlands and groundwater.  This purpose is achieved within a framework that includes identifying EVs such as aquatic ecosystems, water for drinking, water supply, water for agriculture, industry and recreational use for Queensland waters and stating corresponding water quality guidelines (WQGs) and water quality objectives (WQOs) to enhance or protect the environmental values.

The EVs considered applicable to the Project (Mine) to be particularly enhanced or protected under the EPP (Water) are the following:

- biological integrity of an aquatic ecosystem
- suitability for agricultural use

- the cultural and spiritual values of the water.

#### 6.1.2.3 Water Resource (Burdekin Basin) Plan 2007

It is a requirement of the *Water Act 2000* that Water Resource Plans are made to regulate the granting of water licences, permits and allocations. The Water Resource (Burdekin Basin) Plan 2007 (WRP (BB)), has been made accordingly under the *Water Act 2000*. The WRP (BB) also defines hydrological characteristics of the connected water system that makes up the Burdekin Basin, including flows, velocities and flood extents at low, medium and high levels.

#### 6.1.2.4 Policy for the Maintenance and Enhancement of Water Quality in Central Queensland 2003

The Policy for the *Maintenance and Enhancement of Water Quality in Central Queensland 2003* (PMEWQCQ) is administered by the Department of Local Government and Planning. The PMEWQCQ provides a non-regulatory Head of Agreement for collaborative planning and management of water quality by local government, industry and landholders. It provides guidance for implementing strategies for river health and water quality. The PMEWQCQ also recognises the importance of accurately assessing, valuing, monitoring and reporting on the condition of the region’s water resources for planning and management. The guiding principles of the PMEWQCQ will be considered during the development of water management plans for the Project (Mine).

### 6.1.3 National Land and Water Resource Audit 2000-2002

Groundwater management units (GMUs) have been identified for the whole of Australia as part of the Australian Water Resources Assessment 2000 (ANRA 2009). The assessment forms part of the *National Land and Water Resource Audit 2000 - 2002*.

GMUs used in the Audit are loosely based on surface water catchment areas or significant groundwater aquifers (e.g. Great Artesian Basin). The Audit determined broad scale groundwater resource conditions within each unit to give an overall estimate of quantity and sustainable yields.

The Audit determined that there are certain GMUs that rely extensively on groundwater for water supply and have comprehensive data from monitoring the resource. Other areas, referred to as Unincorporated Areas (UAs), had limited data to be able to inform groundwater conditions within that GMU. Groundwater resources and exploitation of the resource within UAs is typically not well developed (ARNA, 2009).

GMUs defined in the Audit are separate to groundwater management area (GMAs), which are defined by the Water Regulation. GMAs have specific legislative requirements in regards to interference with or take of groundwater.

### 6.1.4 Study Areas

The Study Area is located in the Burdekin Basin (see Figure 6-1), defined as part of the central coast region in the QWQG (DERM, 2009a). The water types include upland streams (greater than 150 m elevation above sea level), and freshwater lakes/reservoirs. Figure 6-2 shows the surface water resources within the Study Area including the Carmichael River, ephemeral creek drainage lines (dry during the monitoring period) and numerous farm dams. The Carmichael River, designated as a fifth order stream (DERM, 2009c), is the major surface water resource potentially affected by the Project (Mine). The flow regime of the Carmichael River is subject to seasonal variability as wet season overland flow drains from the catchment. Late in the dry season the Carmichael River is reduced to a low flow environment, interspersed with deeper pools. The Carmichael River was characterised by a well-established riparian zone that provided extensive shading of the water. Conversely, the farm dam sites and Cabbage Tree Creek all had limited riparian zones, resulting in increased exposure to direct radiance from the sun.

**Hydrology Study Area**

The Hydrology Study Area contains one major waterway, the Carmichael River, which flows through the southern section of the Hydrology Study Area (joining the Belyando River approximately 20 km to the east). The Hydrology Study Area is located within the Belyando River Basin (Burdekin). The Belyando Catchment is approximately 35,400 km$^2$ and is one of the main sub-catchments in the Burdekin Basin. The Study Area is located within the Carmichael River catchment. Tributaries within the Carmichael River catchment include:

- Cattle Creek
- Dylingo Creek
- Surprise Creek
- Carmichael Creek
- Dingo Creek
- Dooyne Creek.

Cattle Creek, Dylingo Creek and Surprise Creek converge into the Carmichael River just upstream of the Study Area boundary. The river also receives discharge from the Doongmabulla Spring complex. Topography across the Study Area typically slopes towards the east and north-east from a north-west to south-east trending ridge line, west of the lease boundary and running parallel to it (Figure 6-2). The topographic gradient flattens out in the vicinity of the Carmichael River and in eastern parts of the Study Area. The ridgeline is bisected by the Carmichael River, which flows west to east through the southern half of the Study Area.

Under existing conditions, most parts of the Study Area drain into a series of ephemeral creeks to the east of the Study Area including Pear Gully and Eight Mile Creek. There are also a number of ill-defined watercourses across the northern and southern parts of the Study Area that drain generally in an easterly direction towards the Belyando River. Within the Study Area the Carmichael River has a flow path to Cabbage Tree Creek in flood events. Cabbage Tree Creek is therefore a distributary creek of the Carmichael River. Approximately 10 km east of the Study Area, the Carmichael River catchment drains into the Belyando River, making the Carmichael River catchment a part of the Burdekin Basin.

**Water Quality Study Area**

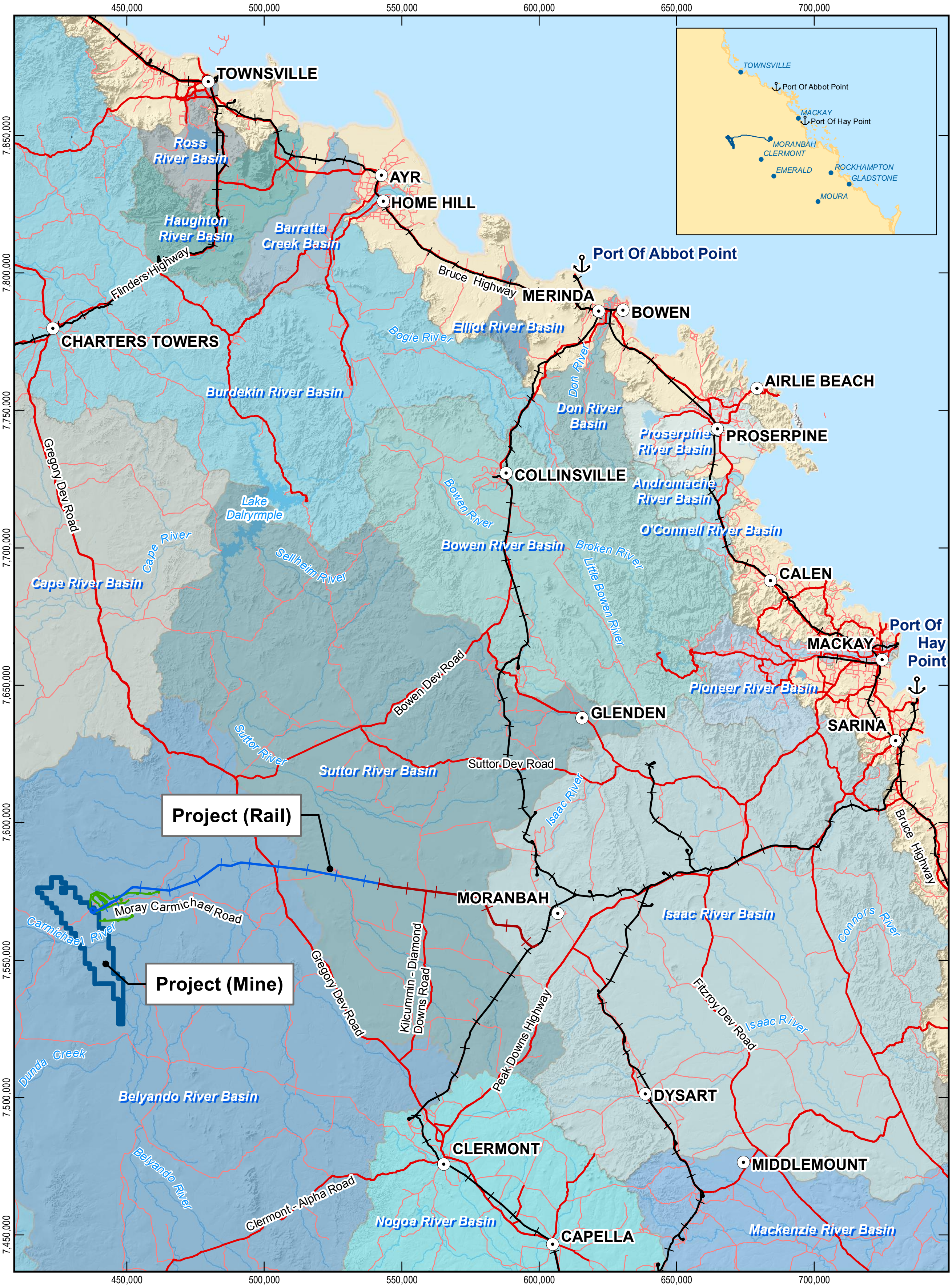
The Water Quality Study Area is defined by the boundaries of EPC 1690, and the area immediately upstream and downstream of the boundary where the Carmichael River crosses EPC 1690 (refer to Figure 6-4). The Water Quality Study Area incorporates sites located upstream and downstream of EPC1080. While field investigations to date have focused on EPC1690 (having been undertaken prior to the inclusion of EPC 1080 into the Mine design), impact assessment extrapolates downstream affects from data collected from the similar surrounding water bodies.

The Water Quality Study Area therefore includes the Carmichael River, Eight Mile Creek and Cabbage Tree Creek and an additional nine farm dams to those included in the Hydrology Study Area often associated with tanks or bores:

- Ten Mile Bore (Tank and Dam)
- Number Two Dam located along a drainage line associated with Eight Mile Creek
- Number One Dam located along a drainage line associated with Eight Mile Creek
- Four Mile Bore (Tank)
- Matheson's Dam located to the north of the Carmichael River
- Four Mile Dam located to the north of the Carmichael River
- Humes Bore (Dam) located to the north of the Carmichael River
- Swamp Tank located to the north of the Carmichael River
- Carmichael Bore (Tank) located to the south of the Carmichael River
- Unnamed Dam located to the south of the Carmichael River
- Michael's Tank located to the south of the Carmichael River
- Murphy's Bore (Dam) located to the south of the Carmichael River
- Grick's Corner Bore (Tank), located to the south of the Carmichael River.

**Hydrogeology Study Area**

The Hydrogeology Study Area was defined by a 10 km radius extending outwards from the boundary of EPC 1690 and the eastern portion of EPC 1080 (refer to Figure 6-5).




LEGEND
- Town
- Major Port
- Other Railway
- State Road
- Local Road
- Watercourse
- Project (Rail)
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

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Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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GHD adani

**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

Burdekin Basin

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|---|---|
| Job Number | 41-25215 |
| Revision | A |
| Date | 06-09-2012 |

Figure 6-1

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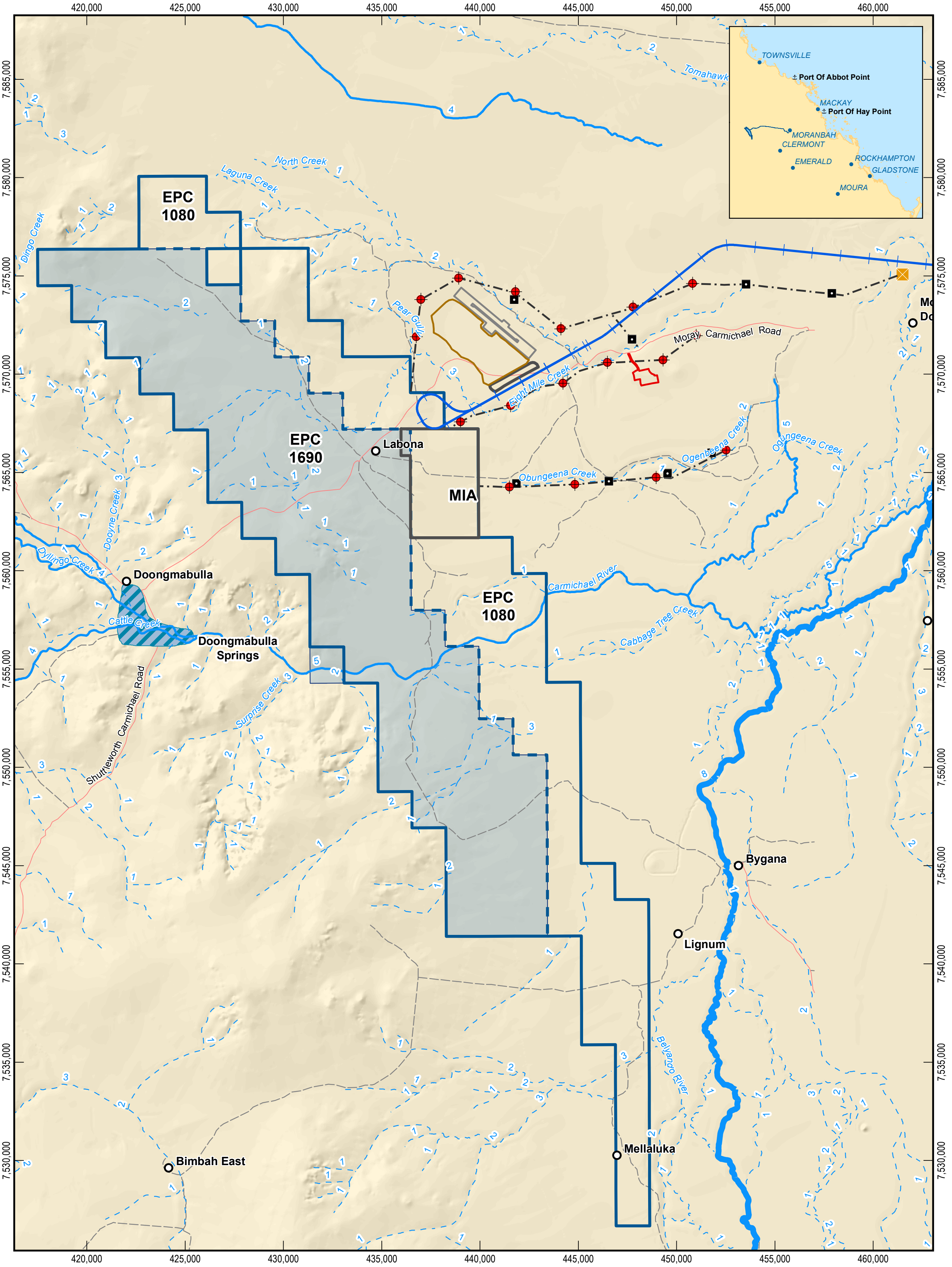
Data Source: © Commonwealth of Australia (Geoscience Australia): Town, Railways, Roads, Watercourses (2007); DERM: LGA, River Basins (2011); DMR: State Roads (2008); Gassman/Hyder: Mine (Offsite) (2012); DME: EPC1690 (2010), EPC1080 (2011); Adani: Alignment Opt9 Rev3 (2012). Created by: BW, JVC, CA




LEGEND

| | | | | |
|---|---|---|---|---|
| Homestead | Stream Order | Surface Water Quality Study Area | Mine (Offsite) | Airport Location |
| Local Road | 1; 2; 3 | Mine (Onsite) | Borehole | Rail Siding |
| Track | 4; 5; 6 | Directory of Important Wetlands | Storage Site (Instream) | Industrial Area |
| | 7; 8; 9 | | Storage Facility (Offstream) | Workers Accommodation Village |
| | | | Pipeline Network | |

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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**Adani Mining Pty Ltd**

Carmichael Coal Mine and Rail Project

Job Number 41-25215
Revision C
Date 04-09-2012

Watercourses Within the Study Area

Figure: 6-2

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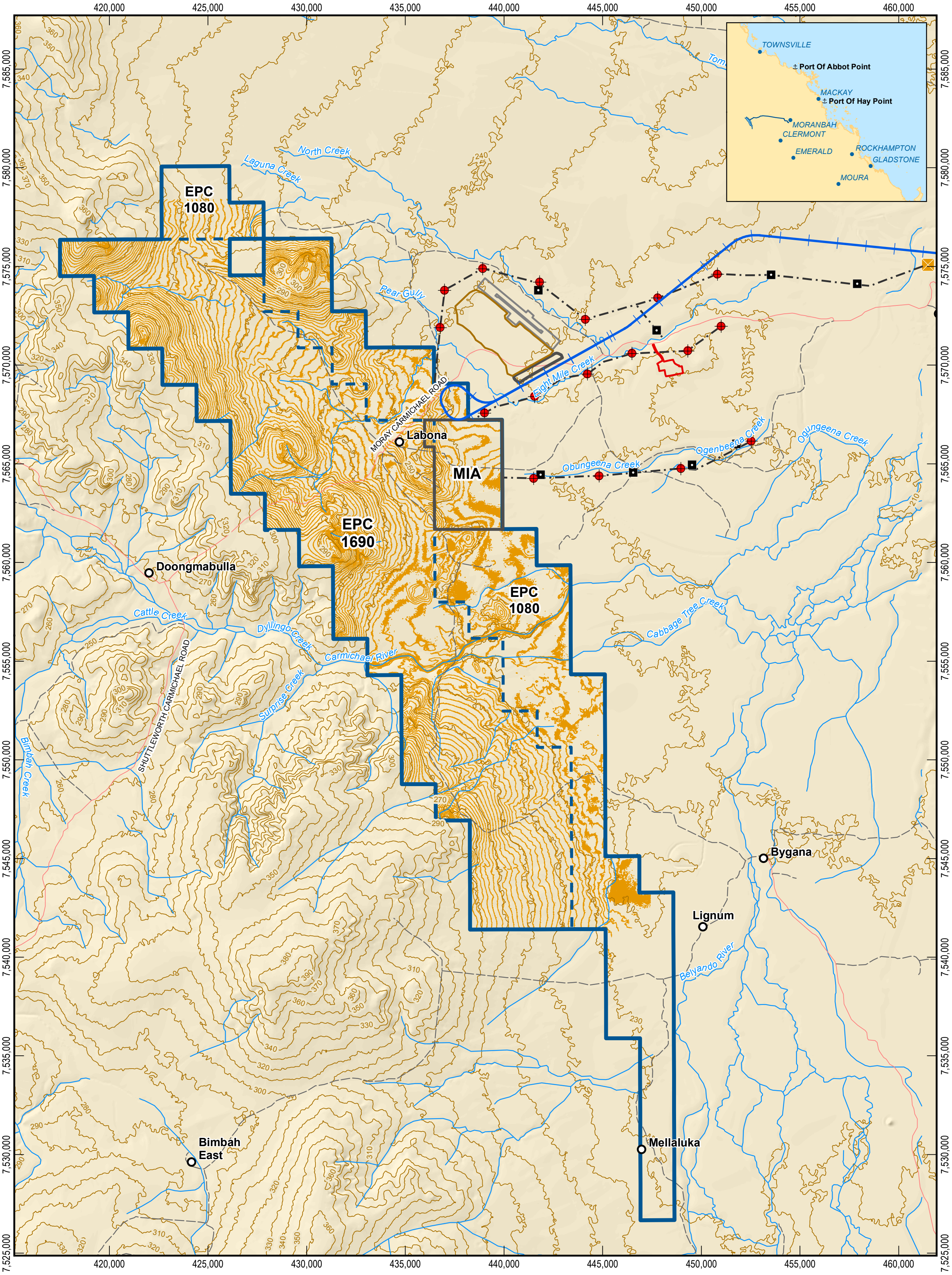
Data Source: DERM: DCDB, Stream Network (2010); DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road (2007); GHD: Surface Water Resources, Study Area (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman Hyder: Mine (Offsite) (2012); Created by: BW.




LEGEND

- Homestead
- Local Road
- Track
- Watercourse
- Contour - 10m
- Contour - 2m
- Rail (West)
- Mine (Onsite)
- Mine Infrastructure Area
- Mine (Offsite)
- Borehole
- Storage Site (Instream)
- Storage Facility (Offstream)
- Pipeline Network
- Airport Location
- Rail Siding
- Industrial Area
- Workers Accommodation Village

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Carmichael Coal Mine and Rail Project

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|---|---|
| Job Number | 41-25215 |
| Revision | B |
| Date | 04-09-2012 |

Topography of the Study Area

Figure 6-3

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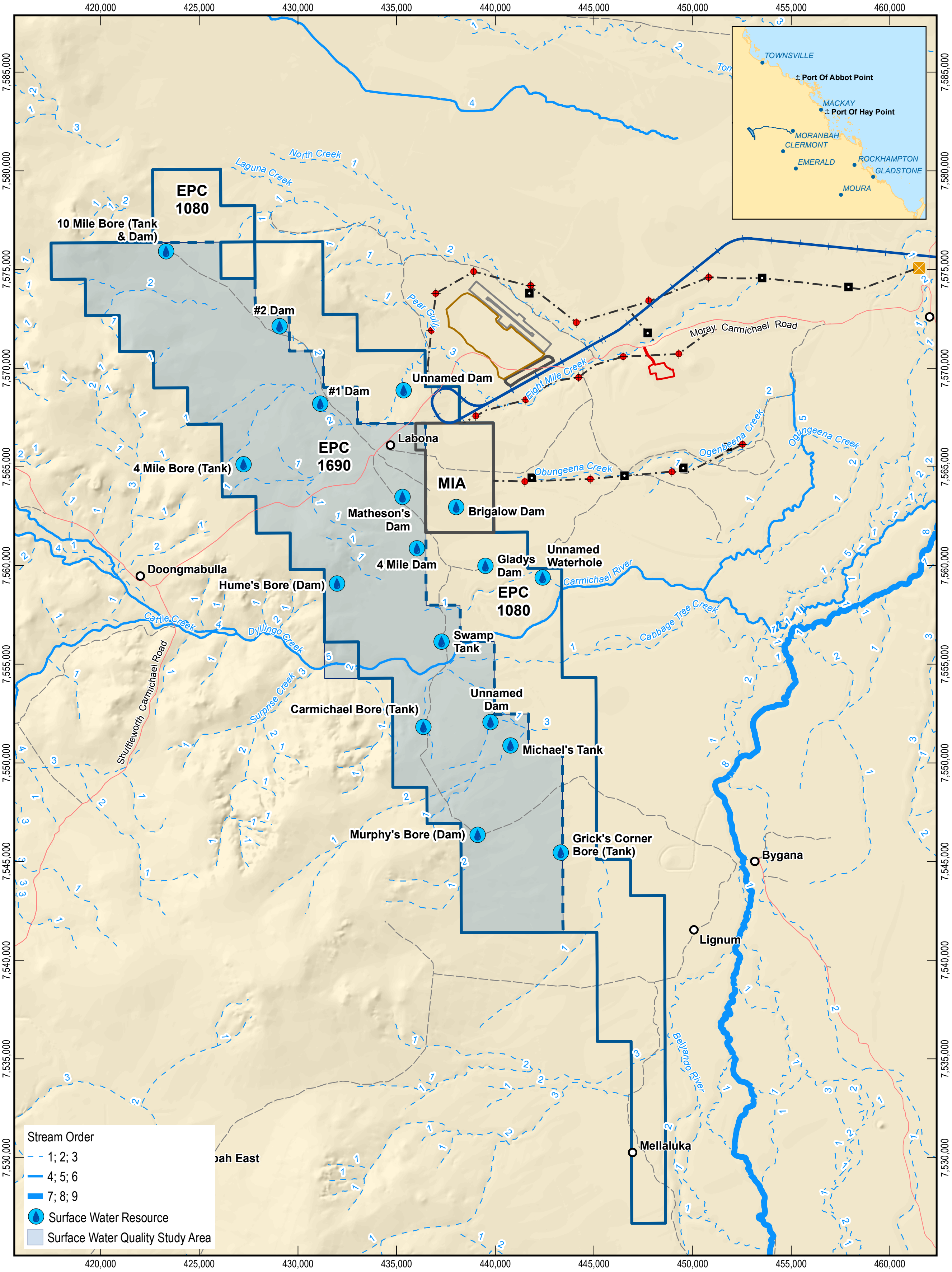
Data Source: DME: EPC 1690 (2010), EPC 1080 (2011); DERM: 10m Contours (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Watercourse (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012); GHD: 2m Contours (2012). Created by: BW, CA




LEGEND

| | | | |
|---|---|---|---|
| Homestead | Rail (West) | Mine (Offsite) | Airport Location |
| Local Road | Mine (Onsite) | Borehole | Rail Siding |
| Track | Mine Infrastructure Area | Storage Site (Instream) | Industrial Area |
| | | Storage Facility (Offstream) | Workers Accommodation Village |
| | | Pipeline Network | |



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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**Adani Mining Pty Ltd**

Carmichael Coal Mine and Rail Project

# Water Quality Study Area

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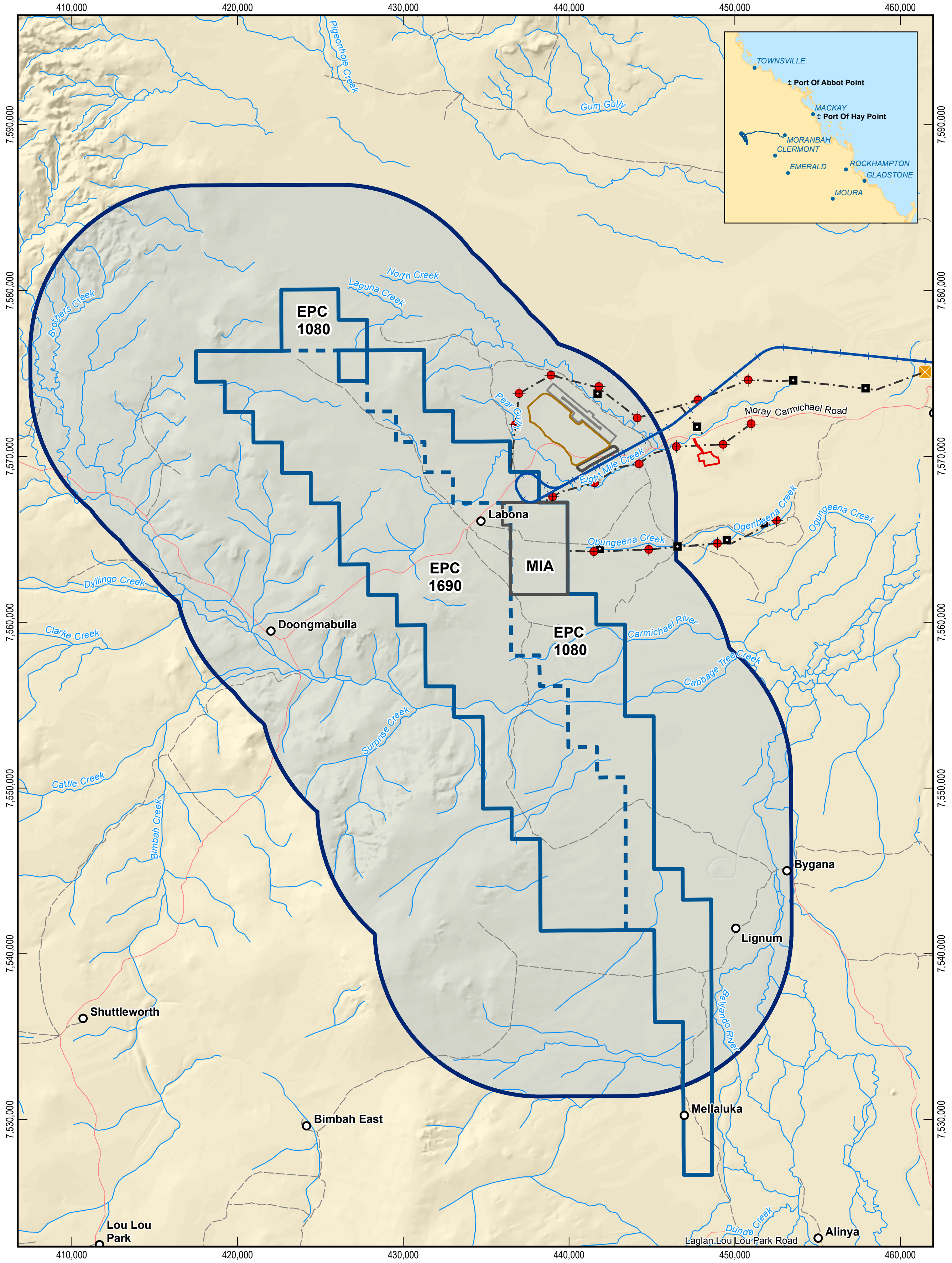
| Job Number | 41-25215 |
| Revision | A |
| Date | 06-09-2012 |

Figure: 6-4





Data Source: DERM: DCDB, Stream Network (2010); DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road (2007); GHD: Surface Water Resources, Study Area(2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012); Created by: BW.




LEGEND

| | | | |
|---|---|---|---|
| Homestead | Rail (West) | Mine (Offsite) | Airport Location |
| Local Road | Mine (Onsite) | Borehole | Rail Siding |
| Track | Mine Infrastructure Area | Storage Site (Instream) | Industrial Area |
| Watercourse | Hydrogeology Study Area | Storage Facility (Offstream) | Workers Accommodation Village |
| | | Pipeline Network | |

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

Job Number 41-25215
Revision B
Date 05-09-2012

Hydrogeology Study Area

Figure 6-5

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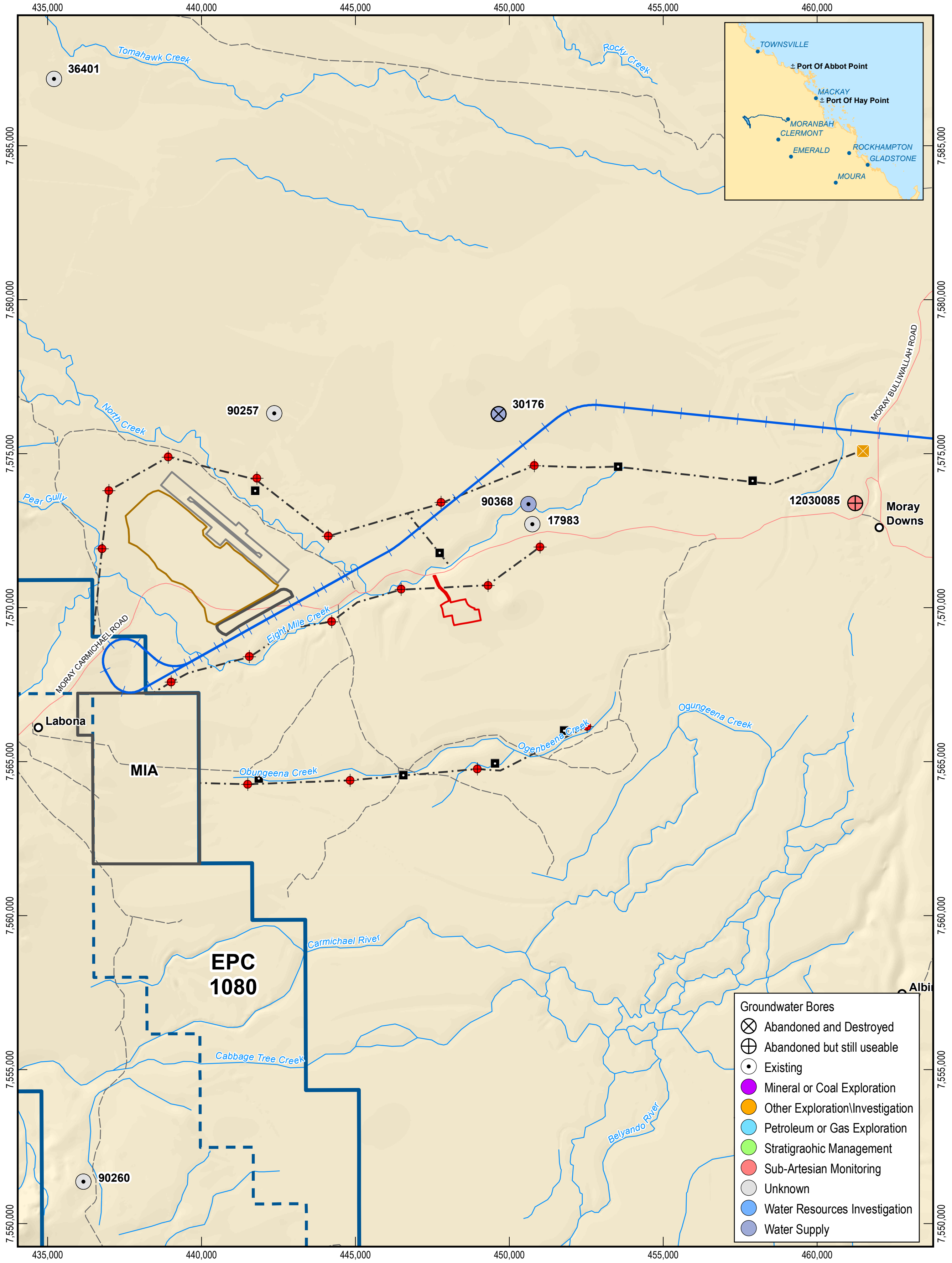
Data Source: DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Watercourse (2007);
GHD: Hydrogeology Study Area (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA




LEGEND

- Homestead
- Local Road
- Track
- Watercourse
- Rail (West)
- Mine (Onsite)
- Mine Infrastructure Area
- Mine (Offsite)
- Borehole
- Storage Site (Instream)
- Storage Facility (Offstream)
- Pipeline Network
- Airport Location
- Rail Siding
- Industrial Area
- Workers Accommodation Village



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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**Adani Mining Pty Ltd**

Carmichael Coal Mine and Rail Project

Offsite Infrastructure and Existing Registered Bores

| | |
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| Job Number | 41-25215 |
| Revision | A |
| Date | 05-09-2012 |

Figure 6-6

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Data Source: DME: EPC 1690 (2010), EPC 1080 (2011); DERM: Registered Bores (2010); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Watercourse (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

### 6.1.5 Surface Water Sampling

Field work was undertaken to support existing technical knowledge with some limitations due to land access restrictions. The concept design will continue to be refined as more field work and associated data becomes available and further community and agency feedback is obtained. The current concept design is, however, considered adequately robust to assess the environmental impacts of the construction and operational footprint of the Project (Mine), while allowing for the flexibility to review and validate the design once further data is available.

Two surface water monitoring stations were established for the Project (Mine) which recorded water levels and flows at approximately the upstream and downstream boundaries of the Hydrology Study Area. These were placed within EPC1690 on the Carmichael River at (refer Figure 6-7):

1. Station No. 333301: close to the upstream boundary of the lease
2. Station No. 333302: close to the downstream boundary.

These monitoring stations commenced monitoring in July 2011, however, during this period limited flows were experienced. Records from December 2011 at the upstream gauge are missing due to equipment failure. Field inspection of downstream gauge from August 2012 indicated that water level and flow were logged incorrectly.

The 2011 – 2012 wet season data was captured and will be incorporated into future modelling.

No historical stream gauge data exist within the Carmichael River. However, three Bureau of Meteorology flow depth and gauging sites were identified within the Belyando River. The water level gauging sites are:

- Gauge number 120301B: Belyando River at the Gregory Development Road Crossing, which is the closest water level recording to Study Area at approximately 70 km to the northeast of the Mine
- Gauge number 120309A: Mistake Creek at Twin Hills which is located 60 km to the east of the Mine. This gauge records water level and flow depths
- Gauge number 120305A: Native Companion Creek at Alpha located in the middle of the creek downstream of the Alpha Clermont Road at approximately 150 km to the southeast of the Mine.

Refer Section 6.2.3.1 for the results and interpretation of the above monitoring used to describe the existing conditions.

A field-based water and in-stream sediment quality assessment was undertaken from April to September 2011 to characterise the quality of the surface water resources within the Study Area. Survey design was undertaken having regard to the following factors:

- Seasonal constraints regarding sampling and site access, i.e. access to the Study Area is limited during the wet season when the Moray Carmichael Road becomes impassable
- Accessibility to the southern portion of the Study Area was restricted during periods of flood such that not all water bodies (e.g. to the south of the Carmichael River) have been sampled.

Areas sampled are considered to be representative, based on knowledge of land use and catchment inputs that would influence those water bodies. Interpretation of results to the nominated WQOs was undertaken by comparing:

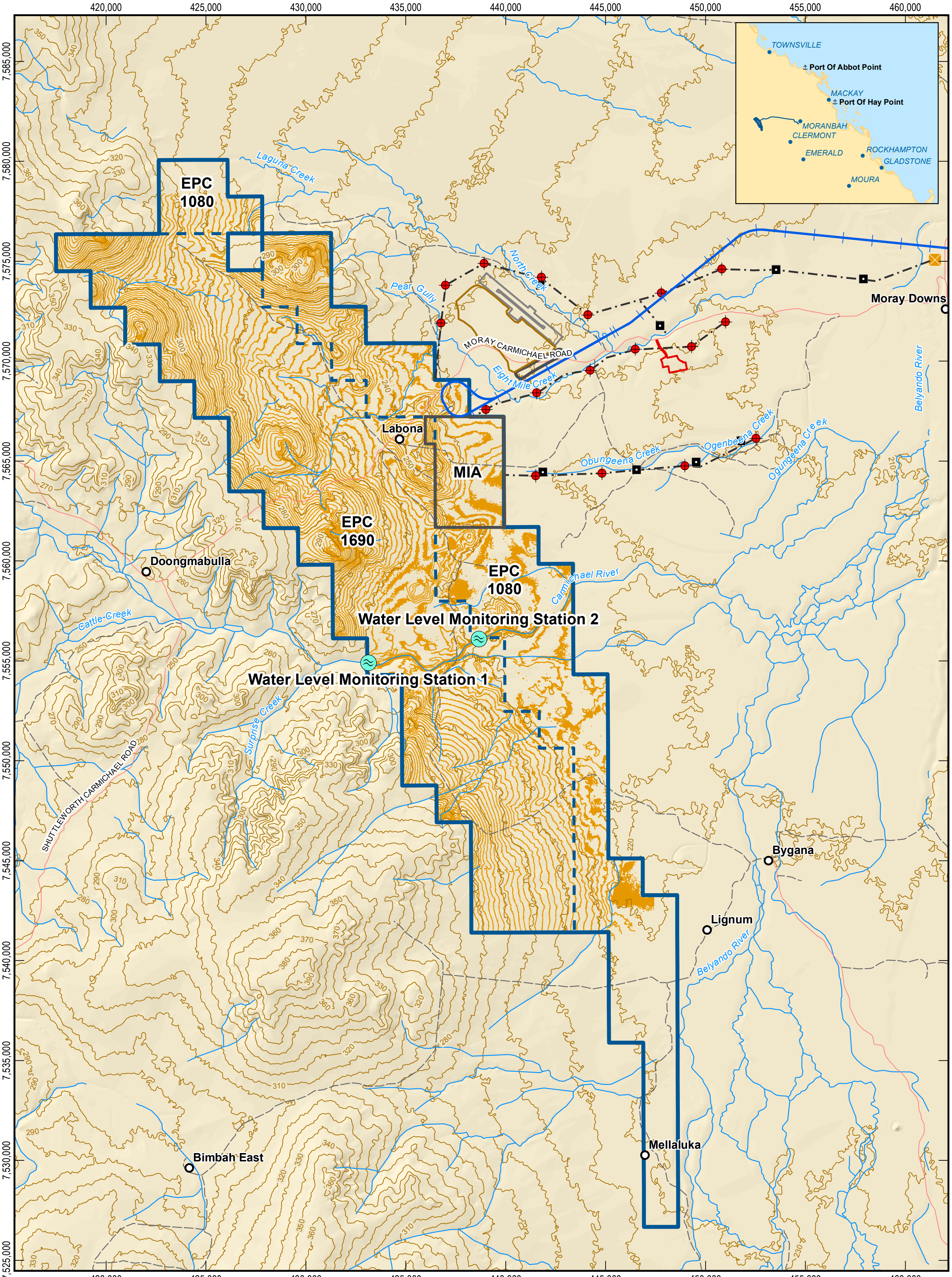
- Median values for physical parameters and nutrient data

- $95^{th}$ percentile values for toxicant data
- Where appropriate hardness-modified trigger values were calculated for the comparison of metal data, as required by the ANZECC guidelines (ANZECC and ARMCANZ, 2000).

As described in 6.1.4, the Study Area is comprised of four types of water resources:

- A major waterway with established riparian zone (the Carmichael River)
- A minor waterway with a standing pool (Cabbage Tree Creek)
- A minor waterway that contained water only during flash flow events (Eight Mile Creek)
- Farm dams.

Twelve sites representative of the four water resources within the Study Area were assessed. Of these, four were located on the Carmichael River, one on Cabbage Tree Creek, three on Eight Mile Creek (dry throughout the sampling program) and four at farm dams. With the exception of Cabbage Tree Creek, these sites were constrained to the north of the Carmichael River in order to avoid discontinuity in the data sets associated with lack of site access across the river. Sites sampled during the field assessment in Figure 6-8. Further detail on each site is outlined in Volume 4 Appendix Q Mine Water Quality Report.




LEGEND

| | | | | |
|---|---|---|---|---|
| Surface Water Quality Monitoring Station | Local Road | Rail (West) | Mine (Offsite) | Airport Location |
| Homestead | Track | Mine (Onsite) | Borehole | Rail Siding |
| Watercourse | Contour - 10m | Mine Infrastructure Area | Storage Site (Instream) | Industrial Area |
| | Contour - 2m | | Storage Facility (Offstream) | Workers Accommodation Village |
| | | | Pipeline Network | |

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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**Adani Mining Pty Ltd**

Carmichael Coal Mine and Rail Project

Flow Monitoring Stations

| | |
|---|---|
| Job Number | 41-25215 |
| Revision | C |
| Date | 05-09-2012 |

Figure 6-7

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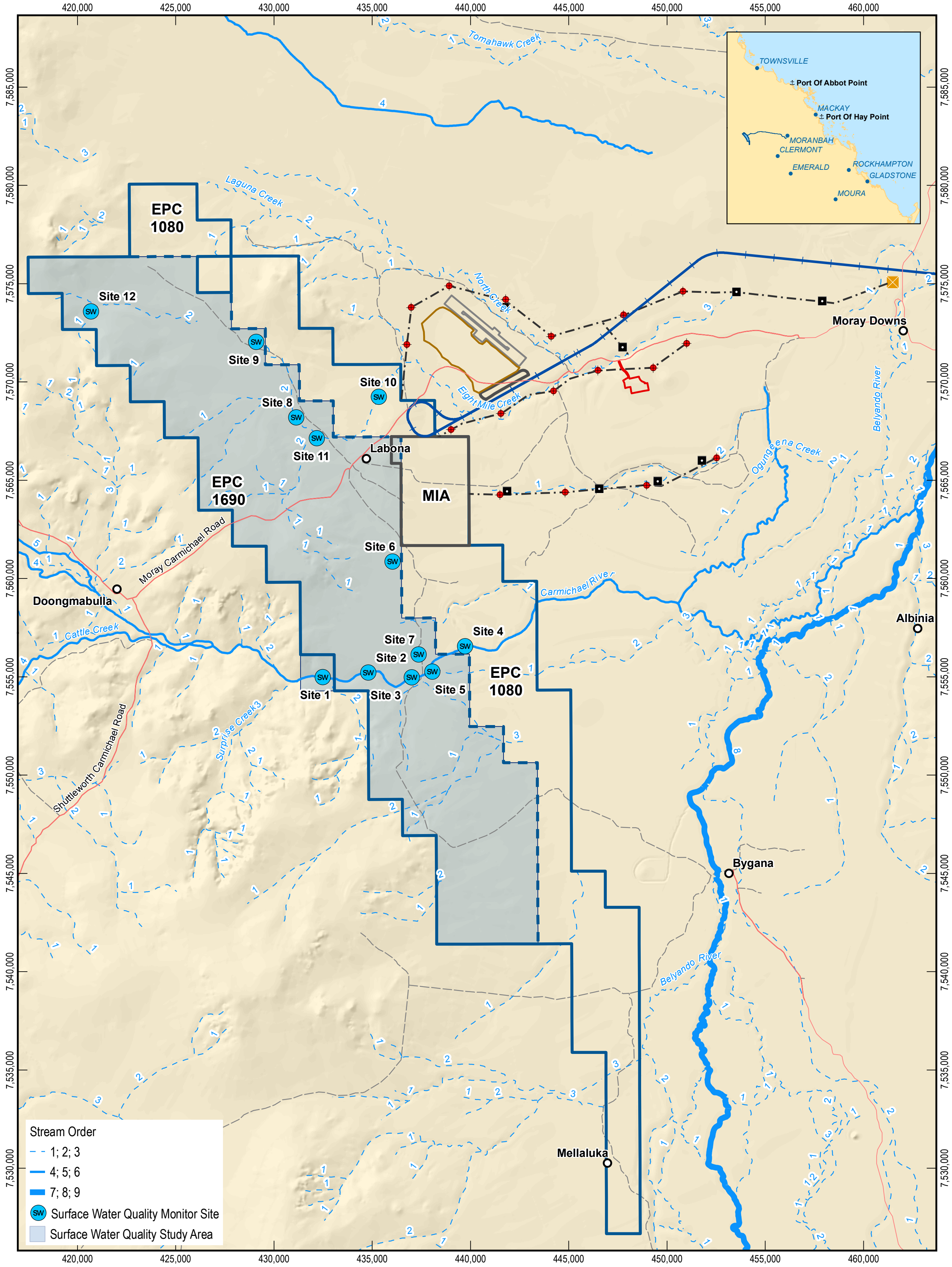
Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com



Data Source: DME: EPC 1690 (2010), EPC 1080 (2011); DERM: 10m Contours (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Watercourse (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012); GHD: Monitoring Stations (2011), 2m Contours (2012). Created by: BW, CA




LEGEND

| | | | |
|---|---|---|---|
| Homestead | Rail (West) | Mine (Offsite) | Airport Location |
| Local Road | Mine (Onsite) | Borehole | Rail Siding |
| Track | Mine Infrastructure Area | Storage Site (Instream) | Industrial Area |
| | | Storage Facility (Offstream) | Workers Accommodation Village |
| | | Pipeline Network | |



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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

Field Assessment
Sampling Sites

Job Number 41-25215
Revision C
Date 05-09-2012

Figure: 6-8

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Data Source: DERM: DCDB, Stream Network (2010); DME: EPC1690 (2010)/EPC1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road (2007); GHD: Surface Water Resources, Study Area (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW.

**Table 6-1 Project (Mine) Water Quality Sampling Program – Sampling Sites**

| Monitoring Site | Water Resource Represented | Location |
|---|---|---|
| Site 1 | Major Waterway: Carmichael River | Immediately upstream of EPC 1690 |
| Site 2 | Major Waterway: Carmichael River | Within EPC 1690 |
| Site 3 | Major Waterway: Carmichael River | Within EPC 1690 |
| Site 4 | Major Waterway: Carmichael River | Immediately downstream of EPC 1690 |
| Site 5 | A minor waterway with a standing pool | Cabbage Tree Creek |
| Site 6 | Farm Dam | Located at Four Mile Dam |
| Site 7 | Farm Dam | Located at Swamp Tank |
| Site 8 | Farm Dam | Located at Number One Dam |
| Site 9 | Farm Dam | Located at Number Two Dam |
| Site 10 | A minor waterway that contained water only during flash flow events / support flash flows only: Eight Mile Creek | Located downstream of EPC 1690 |
| Site 11 | A minor waterway that contained water only during flash flow events / support flash flows only: Eight Mile Creek | Located within EPC 1690 |
| Site 12 | A minor waterway that contained water only during flash flow events / support flash flows only: Eight Mile Creek | Located in the upstream portion of EPC 1690 |

The sampling program comprised of :

- **In-situ water suite:** In-situ sampling of physical water quality parameters using a hand held multi-parameter water quality meter with logging capacity. Ten replicate samples from each site were stored on the logger and downloaded at the end of each sampling event
- **Basic analytical suite (water):** Collection of water samples for laboratory analysis of basic and broad suites. Information was collected during each event using a standard pro-forma data sheet adapted from those provided in the Monitoring and Sampling Manual 2009 (DERM, 2009b) including weather conditions, localised disturbances, surface oils, foaming, colour and aquatic vegetation were noted to assist in interpretation of data.
- **Broad analytical suite (water):** Collection of In-stream sediments were collected for laboratory analysis
- **Sediment sampling suite:** Sediment samples were also collected at sites where water was not present
- **Deionised (DI) leach suite:** Additional sediment samples were collected from the stream bed at these sites during the July sampling event. These samples were subject to a DI water leach preparation. Testing of the DI leachate was undertaken in order to gain an understanding of the potential for the release of contaminants into surface waters during flow events. DI leachate

testing was only undertaken once during the monitoring program as sampled parameters were not expected to display large temporal variability. The DI water leachate was analysed for Ultra-trace nutrients, PAHs, TPHs (C6-C9, C10-C14, C15-C28 and C29-C36 fractions); Metals (aluminium, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, uranium, vanadium and zinc)

Table 6-2 provides details of the various parameters, indicators and methods of sampling employed.

Table 6-3 provides details of the sampling events and methods employed for each.

**Table 6-2 Water Quality Sampling Program**

| Parameter (Analytical Suite) | Indicator | Method |
|---|---|---|
| Physio-chemical | Turbidity (NTU) | A: In-Situ Sediment Quality Sampling |
| Physio-chemical | Dissolved oxygen (per cent saturation) | A: In-Situ Sediment Quality Sampling |
| Physio-chemical | Electrical conductivity (µS/cm) | A: In-Situ Sediment Quality Sampling |
| Physio-chemical | pH | A: In-Situ Sediment Quality Sampling |
| Physio-chemical | Temperature (°C) | A: In-Situ Sediment Quality Sampling |
| (Basic) | Nutrients | B: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Basic) | Chlorophyll a | B: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Basic) | Faecal (Thermotolerant) coliforms | B: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Basic) | Total dissolved solids (TDS) | B: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Basic) | Total suspended solids (TSS) | B: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Broad) | Major cations and anions | C: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Broad) | Total hardness as CaCO3 | C: Water Samples Collected for Laboratory Analysis with Observational Data |

| Parameter (Analytical Suite) | Indicator | Method |
|---|---|---|
| (Broad) | Total Petroleum Hydrocarbons (TPHs)<br>C6-C9 fraction<br>C10-C14 fraction<br>C15-C28 fraction<br>C29-C36 fraction | C: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Broad) | Polycyclic aromatic hydrocarbons (PAHs) | C: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Broad) | Dissolved silicon | C: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Broad) | Flouride | C: Water Samples Collected for Laboratory Analysis with Observational Data |
| (Broad) | Total and Dissolved Metals (aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, tin, uranium, vanadium, zinc) | C: Water Samples Collected for Laboratory Analysis with Observational Data Data |
| | Grain size | D: In-stream Sediment Quality Sampling |
| | Total organic carbon and moisture content | D: In-stream Sediment Quality Sampling |
| | Nutrients | D: In-stream Sediment Quality Sampling |
| | Faecal (thermotolerant) coliforms | D: In-stream Sediment Quality Sampling |
| | PAHs | D: In-stream Sediment Quality Sampling |
| | TPHs (C6-C9, C10-C14, C15-C28 and C29-C36 fractions) | D: In-stream Sediment Quality Sampling |
| | Total metals (aluminium, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, uranium, vanadium, mercury and zinc) | D: In-stream Sediment Quality Sampling |

**Table 6-3 Summary of Field Assessment Sampling Method Employed**

| Site No | Event 1 13-14 April 2011 | Event 2 4-5 May 2011 | Event 3 21-22 June 2011 | Event 4 26-27 July 2011 | Event 5 23-24 Aug 2011 | Event 6 20-21 Sept 2011 |
|---|---|---|---|---|---|---|
| 1 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 2 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 3 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 4 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 5 | A, B | Site not accessible | A, B | Site not accessible | A, B | A, B, C |
| 6 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 7 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 8 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 9 | A, B | A, B, C | A, B | A, B, C, D | A, B | A, B, C |
| 10 | No water | No water | No water | D, E | No water | No water |
| 11 | No water | No water | No water | D, E | No water | No water |
| 12 | No water | No water | No water | D, E | No water | No water |

Note: A: *In-situ* water suite B: Basic analytical suite (water) C: Broad analytical suite (water) D: Sediment sampling suite E: DI leach suite

All sampling was conducted in accordance with the following guidelines and standards:

- Monitoring and Sampling Manual 2009 (DERM, 2009b)
- The ANZECC guidelines (ANZECC and ARMCANZ, 2000)
- Australian Standard Number 5667.1.1998 – Water Quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples
- Australian Standard Number 5667.6.1998 – Water Quality – Sampling – Guidance on sampling rivers and streams
- Australian Standard Number 5667.12.1999 – Water Quality – Sampling – Guidance on sampling of bottom sediments.

All samples were collected, preserved and transported in accordance with the requirements of the Monitoring and Sampling Manual 2009 (DERM, 2009b) and the analytical laboratory, under chain of custody documentation. In addition to the internal laboratory quality assurance procedures, quality assurance replicates were collected at two separate sampling locations per event and tested as per the primary samples. Replicates were marked as QA01 or QA02 and noted on the corresponding field sheet. Upon receipt of laboratory results, Quality Assurance/Quality Control (QA/QC) results were checked and the results reviewed for anomalies. Validation of the laboratory data and quality assurance samples was undertaken according to the requirements of the Monitoring and Sampling Manual 2009 (DERM, 2009).

#### 6.1.6 Groundwater Sampling

Groundwater quality data relating to samples collected from the monitoring network bores are summarised in Table 6-4. The laboratory analysis results for dissolved metals have been corrected for hardness where appropriate. The major ion data are also shown on Piper diagrams (Figure 6-13 and Figure 6-14) in order to identify and make comment on differences in the major ion chemistry of the samples collected. As part of the review groundwater quality results have been compared to ANZECC (2000) fresh water quality guidelines (95 per cent level of protection) in order to identify any anomalous concentrations. Concentrations have also been compared to Australian Drinking Water Guidelines (ADWG, 2011) and ANZECC (2000) guidelines for livestock and for long-term irrigation in order to comment on potentially suitable uses for the groundwater.

The following data from Project (Mine) specific field investigations has been collated and reviewed:

- Geological data (borehole logs and geological model)
- Groundwater levels and quality (monitoring data)
- Hydrogeological testing results.

A total of 26 DERM registered groundwater bores have been identified within the Hydrogeology Study Area. The locations of the registered bores are illustrated in Figure 6-9. Selected information including facility type, facility role, yield, water level and selected water quality data for these bores is summarised in Volume 4 Appendix R Mine Hydrogeology Report. In summary:

- 23 of the registered bores were recorded as existing (facility status) of which 11 were recorded as being for water supply (facility role)
- Four of the water supply bores were indicated to be for stock use (RN 17981, RN 90256, RN 90258 and RN 90259) and three bores were recorded as abandoned and destroyed
- The use of the other four water supply bores was not recorded in the database
- Three of the registered bores have a licence to take water (RN 62623, RN 67627 and RN 90255) although no allocation quantity is recorded in the database
- The Isaac Regional Council does not hold information regarding privately owned unregistered bores and/or extraction rates.

Publically available groundwater monitoring data are therefore limited to information relating to registered bores within the Study Area. In summary these data indicate:

- Where geological and bore construction information are available, the registered bores typically intersect sandstone units (interpreted as being Tertiary, Triassic or Permian-age) with a smaller proportion intersecting alluvial deposits
- Groundwater in the alluvium in the south of the Study Area appear to be generally brackish (electrical conductivity (EC) in the range 3,700 to 8,100 µS/cm) and slightly alkaline (pH in the range 8 to 9.4 pH units)
- Groundwater in sandstone units ranges from fresh to brackish (recorded EC in the range 155 to 3,800 µS/cm) and typically neutral pH (7.1 to 8.1 pH units)
- Groundwater levels in alluvial areas towards the south of the Study Area may be relatively close to ground surface, based on data for RN 44489 (interpreted to intersect alluvium) where groundwater was recorded at five metres below ground level (mBGL)
- Conversely data for the single bore with groundwater data completed in Permian age sandstone units (RN 90258) towards the west of EPC 1690 indicates a static groundwater water level of around 40 mBGL.

To supplement the publically available groundwater level and quality data available, a groundwater monitoring network comprising 33 bores at 21 sites was established within EPC 1690 to collect hydrogeological data for the purposes of the EIS. The monitoring bore locations are shown in Figure 6-9 and the purpose of each monitoring site is summarised in Table 6-4.

**Table 6-4 Groundwater Monitoring Network Summary**

| Groundwater Monitoring Sites | Monitored Unit | Monitoring Purpose |
|---|---|---|
| C006P1<br>C006P3r | Interburden<br>D Seam | Levels and quality, vertical gradients between strata |
| C007P2<br>C007P3 | AB Seam<br>D Seam | Levels and quality, vertical gradients between strata |
| C008P1<br>C008P2 | Permian Overburden<br>AB Seam | Levels and quality, vertical gradients between strata |
| C011P1<br>C011P3 | Interburden<br>D Seam | Levels and quality, vertical gradients between strata |
| C012P1<br>C012P2 | Permian Overburden<br>Tertiary/Permian | Levels and quality, vertical gradients between strata |
| C014P2 | AB Seam | Levels and quality (no groundwater encountered in Tertiary-age strata) |
| C016P2 | AB Seam | Levels and quality |
| C018P1<br>C018P2 | Permian Overburden<br>AB Seam | Levels and quality, vertical gradients between strata |

| Groundwater Monitoring Sites | Monitored Unit | Monitoring Purpose |
|---|---|---|
| C018P3 | D Seam | |
| C020P2 | AB Seam | Levels and quality |
| C022P1 | Dunda Beds | Levels and quality, geological unit within the Great Artesian Basin |
| C024P3 | D Seam | Levels and quality |
| C025P1 | Tertiary | Levels and quality, potential connectivity between groundwater and the Carmichael River, vertical gradients |
| C025P2 | Tertiary | |
| C027P1 | Alluvium | Levels and quality, potential connectivity between groundwater and the Carmichael River, vertical gradients |
| C027P2 | Dunda Beds | |
| C029P1 | Alluvium | Levels and quality, potential connectivity between groundwater and the Carmichael River, vertical gradients |
| C029P2 | Tertiary | |
| C032P2 | AB Seam | Levels and quality |
| C034P1 | Interburden | Levels and quality, vertical gradients between strata |
| C034P3 | D Seam | |
| C035P1 | Rewan Group | Levels and quality, vertical gradients between strata |
| C035P2 | AB Seam | |
| C9553P1R | Dunda Beds | Levels, vertical gradients between strata |
| C553P_V01 | D1 Seam | |
| C553P_V02 | AB1 Seam | |
| C553P_V03 | Permian Overburden | |
| C555P1 | Rewan Group | Levels, vertical gradients between strata |
| C555P_V01 | D Seam | |
| C555P_V02 | AB1 Seam | |
| C555P_V03 | Rewan Group | |
| C556P1 | Rewan Group | Levels, vertical gradients between strata |
| C9556P_V01 | D2 Seam | |
| C9556P_V02 | AB1 Seam | |
| C9556P_V03 | Rewan Group | |
| C558P1 | Permian Overburden | Levels, vertical gradients between strata |
| C558P_V01 | D1 Seam | |
| C558P_V02 | Interburden | |
| C558P_V03 | AB1 Seam | |

| Groundwater Monitoring Sites | Monitored Unit | Monitoring Purpose |
|---|---|---|
| C056C_V01 | D1 Seam | Levels, vertical gradients between strata |
| C056C_V02 | AB1 Seam | |
| C056C_V03 | Rewan Group | |
| HD01 | Dunda Beds | Levels (west of EPC 1690) |
| HD02 | Clematis Sandstone | Levels (between EPC 1690 and Doongmabulla Springs) |
| HD03A | Dunda Beds | Levels, vertical gradients between strata (between EPC 1690 and Doongmabulla Springs) |
| HD03B | Alluvium | |

A Bourne Drill 1000 rig and a combination of Rotary Wash Bore and Percussion Air-hammer drilling techniques were used to advance the monitoring bores. Each bore was installed with 50 mm diameter uPVC casing (glued and/or screwed), machine slotted screen and fitted with a lockable monument cover. The bore annulus of the screened interval was filled with washed two millimetre silica sand, sealed with a bentonite plug and grouted to surface with a cement-bentonite grout mix. Each bore was developed by airlifting.

Three rounds of groundwater monitoring have been conducted (October and November 2011 and June 2012), to measure groundwater levels and to collect groundwater samples for water quality analysis (October and November 2011 only). In addition, automatic level loggers have been installed in all of the monitoring bores across EPC 1690 to provide a more continuous record of groundwater levels.

Groundwater samples were tested for a range of parameters in accordance with the ToR for the Project EIS and are summarised below. In addition, samples were collected from surface water sampling sites WQ1 and WQ3 on the Carmichael River at the same time as the groundwater monitoring samples to inform the assessment of interaction between surface water and groundwater.

The following groundwater quality parameters were measured at sampling bores prior to collection of samples for laboratory testing:

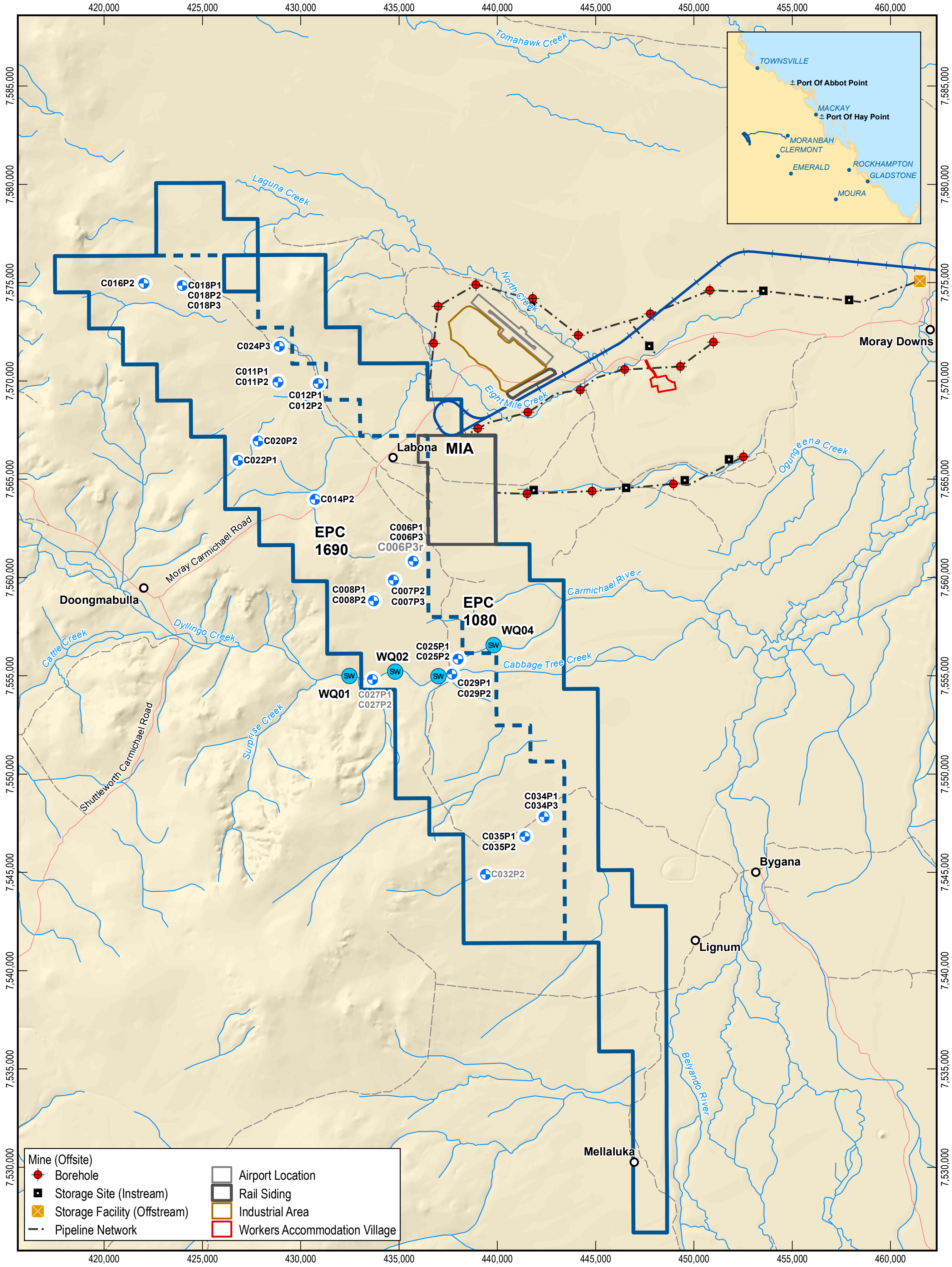
- Dissolved oxygen (DO)
- electrical conductivity (EC)
- pH
- temperature
- Total dissolved solids (TDS).

The following groundwater quality parameters were measured in laboratory conditions:

- EC, pH, total organic carbon (TOC)
- Dissolved metals: Aluminium, arsenic, boron, cadmium, cobalt, copper, chromium, iron, manganese, mercury, molybdenum, nickel, lead, selenium, silver, uranium, vanadium, zinc
- Nutrients: Ammonia as N, nitrate as N, nitrite as N, total phosphorous as P

- Major and minor ions: Calcium, magnesium, sodium, potassium, chloride, sulphate, alkalinity (carbonate and bi-carbonate)
- Fluoride, sulphide
- BTEX (benzene, toluene, xylene, ethylbenzene)
- TPH (total petroleum hydrocarbons C6 – C36).

A combination of rising and falling head tests (also known as slug tests) were conducted on 22 of the 33 groundwater monitoring bores and packer testing was conducted at five locations, to estimate the hydraulic conductivity of key hydrogeological units including the alluvium, Tertiary-age strata, AB seam, D seam, interburden, overburden, Rewan Group and Dunda Beds. Pumping tests were also conducted at three locations within EPC 1690, to estimate bulk aquifer properties of the AB seam and the D seam. A summary of slug , packer and pumping tests at each bore is provided in Volume 4 Appendix R Mine Hydrogeology Report.




LEGEND

- Homestead
- Surface Water Quality Monitoring
- Groundwater Monitoring Bore (Surveyed)
- Groundwater Monitoring Bore (GPS)
- Local Road
- Track
- Watercourse
- Rail (West)
- Mine (Onsite)
- Mine Infrastructure Area



1:275,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Carmichael Coal Mine and Rail Project

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| Job Number | 41-25215 |
| Revision | D |
| Date | 06-09-2012 |

Groundwater Monitoring Bores — Figure 6-9

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Data Source: DERM: Hillshade (2009); DME: Carmichael Mine Site (2010); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Watercourse (2007);
GHD: Monitoring Bores (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

### 6.1.7 Surface Water Modelling

Hydrologic (rainfall-runoff) and hydraulic modelling was undertaken to determine existing and developed conditions. The following models were developed:

- *A hydrologic model of the existing conditions in the Carmichael River catchment*

  This model estimated critical storm durations for the 10 year, 50 year, 100 year and 1000 year ARI events. These events were selected to match the design criteria set by the Proponent.

- *A hydrologic model of the developed condition in the Carmichael River catchment*

  This model was a modified version of the *hydrologic model of existing condition in the Carmichael River catchment* that included the proposed development. It demonstrated the hydrologic impact of the proposed development on contributing catchment areas and peak flows.

- *A two-dimensional hydraulic model of the existing condition in the Carmichael River and floodplain in the vicinity of the Mine*

  This model defines existing hydraulic conditions and peak flood levels and extents for 10 year, 50 year, 100 year and 1000 year ARI critical storm duration events.

- *A one-dimensional hydraulic model of the existing condition of minor watercourses within the MLA that do not drain to the Carmichael River*

  This model estimated critical storm durations for the 10 year, 50 year, 100 year and 1000 year ARI events at the northern and southern extents of the Carmichael River. The model also provided the volume of flow entering ephemeral creeks outside of the mining tenure during flood.

- *A two-dimensional hydraulic model of flooding under developed conditions*

  This model demonstrated the impact of the development and preliminary designs for flood protection infrastructure to mitigate flooding from the Carmichael River. It also demonstrates the flood immunity to the mine footprint provided by the proposed infrastructure and diversion drains.

- *An Integrated Quantity Quality Model (IQQM) of the developed condition of the Belyando Suttor sub catchment*

  The IQQM is used by Queensland Government for planning and evaluating water resource management policies and is a requirement of the WRP (BB) and BROP. The IQQM instance applicable to the BROP is comprised of nodes reflecting the location of gauging stations and owners of water allocations in the Belyando-Suttor sub-basin. Nodes representing water extractions by Project (Mine) offsite infrastructure were added to the IQQM (refer to Figure 6-10), to demonstrate the impact of water extractions by Project (Mine) offsite water supply infrastructure in the Belyando Suttor sub catchment. Recorded stream flow and height data and modelled rainfall runoff are included in the model for gauged catchments, as is the full entitlement of owners of water allocations. Stream flow and height data covering 1967 to present from the Gregory Development Road gauging station (120301B) were thus included. Stream flow and height data from 1889-1966 were in-filled a calibrated Sacramento model of the area based on recorded rainfall.

- *A Goldsim water balance model to model the supply of water from the Project (Mine) offsite water supply infrastructure and associated demand from the Project (Mine)*

The water balance for Project (Mine) offsite storage dams was modelled over a simulation period of 1890 - 2004. Parameters of the Goldsim model were rainfall, groundwater flow, Belyando River and North Creek flood harvesting stations, North Creek and Obungeena Creek in-stream storage extractions, Project (Mine) water demand and evaporation.

- *A preliminary water balance study to assess the water balances and deficits over the life of the Project (Mine)*

  This study calculated affected areas, inflows and outflows, net water quality, deficit and surplus for each stage of the Project (Mine).

#### 6.1.7.1 Preliminary Designs

The outputs of modelling were used to develop the following conceptual designs and operating rules:

- *A conceptual Project (Mine) flood protection and creek diversion plan that progresses throughout the Project (Mine) life*.

  This plan was based on operational requirements and provides a concept and alignment for preliminary sizing of flood protection infrastructure and diversion drains. This drainage scheme was based on the mine progress plots provided by Runge (2011).

- *A preliminary design of a haul road & conveyor crossing at the Carmichael River*

  Hydraulic analysis of the crossing and an associated bridge was undertaken to design a bridge that provided the required flood immunity to the bridge structure. Modelling was also used to determine the likely flooding of the bridge during storm events greater than the design event.

- *A preliminary design of a flood protection levee containing the Carmichael River*

  The levee bank alignments and heights were established based on providing 1 in 1000 year ARI flood immunity to the internal mine areas as required by the Proponent. The alignment was chosen to minimise hydraulic impact on the Carmichael River and the effluent Cabbage Tree Creek.

- *A case study design of a proposed creek diversion drain*

  One diversion drain proposed within the conceptual staged drainage plan was used as a preliminary design case study. Horizontal and vertical alignments of the drain were optimised to take flow through the mine site within allowable velocity constraints and to re-join existing natural channels. The preliminary design takes account for potential subsidence on the surface above the underground mining region.

- *A preliminary sizing of storage volumes for Project (Mine) offsite water supply infrastructure and Project (Mine) sediment basins*

  The outputs of the Goldsim model were used to determine the smallest storage volume to secure a 95 per cent reliable supply from the Project (Mine) offsite water supply infrastructure. A water quality model using the MUSIC package the outputs of this model were used to size sediment basins for Project (Mine).

- *Operating rules for Project (Mine) offsite water supply infrastructure*

  The IQQM was then run iteratively for a number of water extraction scenarios to determine the optimal operating rules for water extraction within the BROP and EFOs. These rules applied to flood harvesting stations and in-stream storage extractions, and included pumping thresholds, maximum pumping rates and minimum volume requirements in storages. For flood harvesting stations a start to pump stream flow of 430 ML/day, a pump capacity of 250ML/day was optimal. For in-stream storage extractions a pump capacity of 55 ML/day up to a total of 2 GL per year.

### 6.1.8 Groundwater Modelling

A conceptual groundwater model was developed to model the behaviour of the groundwater system and its interactions with surface water within the catchment. The conceptual groundwater model was developed based on the current understanding of the distribution of the various geological formations, aquifer testing (packer, slug and pumping tests) and groundwater monitoring.

The conceptual groundwater model, geological model surfaces (Xenith, 2012) and aquifer test data were used to develop a MODFLOW-SURFACT (HydroGeoLogic, 1996) groundwater flow model for the site. The groundwater flow model was used to predict:

- Groundwater inflows to the proposed open cut and underground mine workings for mine planning and water balance purposes;
- Groundwater level changes in the various hydrogeological units present within the area in response to dewatering of the proposed mine workings; and
- Potential baseflow impacts on local water courses.
- Impacts on local hydrological features of environmental or economic importance and which may be sensitive to groundwater level decline including:
  - The Carmichael River which bisects the site and other local watercourses;
  - A Great Artesian Basin spring system close to Doongmabulla around eight kilometres west of the lease area, which supports flow in the Carmichael River particularly during dry periods;
  - The two non-Great Artesian Basin (GAB) springs which are mapped to the north of Mellaluka around 10 km south of the Study Area ;
  - The Clematis Sandstone which occurs at outcrop to the west of the site and as one of the main aquifers of the GAB forms an important regional aquifer;
  - 21 licensed extraction bores within the modelled area; and
  - A further 25 other registered bores which are within 10 km of the Study Area.

Further information on the parameters and simulated Project (Mine) operations is provided in Volume 4 Appendix R Mine Hydrogeology Report.

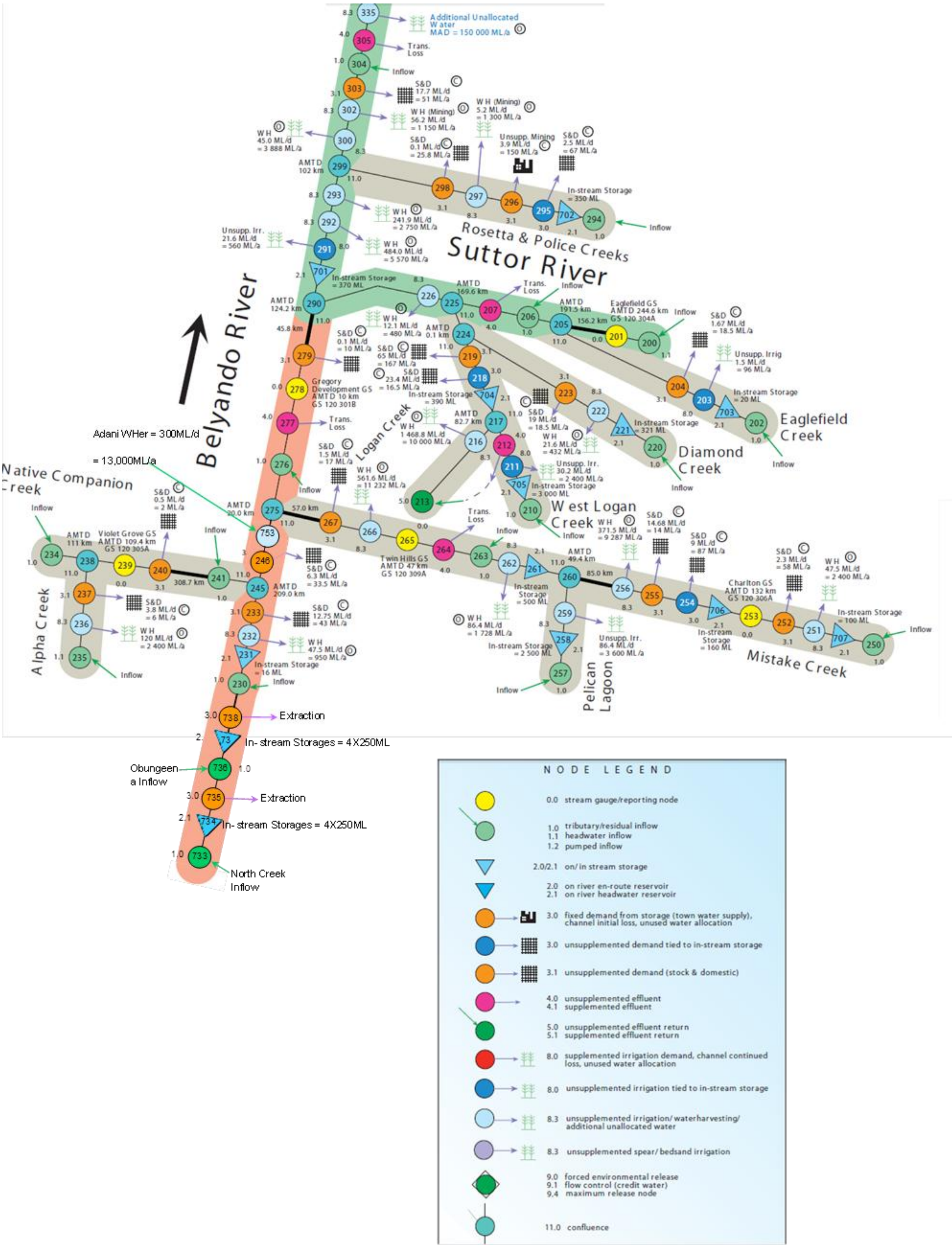



**Figure 6-10 Amended IQQM**

## 6.2 Description of Environment Values

### 6.2.1 Overview

The existing conditions of the water resources include a detailed description of the quality and quantity of surface and groundwater resources potentially affected by the Project (Mine). It includes consideration to seasonal variations in depth and flow, and all times of natural flow in ephemeral streams.

The following includes a description of:

- Physical, chemical and biological characteristics of both surface and groundwater
- Flows
- History of flooding, including the extent, levels and frequency.

The relationship between groundwater and surface water has been investigated to assess the nature of any interaction between the two resources and any implications of the Project (Mine) that would affect that interaction. A number of strands of evidence suggest that interaction between groundwater and surface water resources in the Carmichael River is likely to be occurring, as outlined below in the Sections 6.2.3.

An assessment of the water chemistry of the Carmichael River and nearby groundwater resources identified that it is likely that the surface water of the Carmichael River is influenced by the nearby groundwater aquifers. Temporal changes in the surface water chemistry also indicate that the influence of groundwater on the Carmichael River is greater in the dry season than in the wet season when rain water is entering the system.

Parameters analysed as part of the surface water monitoring program displayed both spatial and temporal variations. Spatial patterns were consistently related to the differences between the types of water resources (Carmichael River versus non-flowing environments). Sites sampled along the Carmichael River displayed little spatial variation, indicating that the results obtained from the monitoring program are fairly typical of that stretch of the river. Temporal patterns at the Carmichael River sites were related to seasonal variability associated with the influx of overland flows prior to the start of the monitoring program, and subsequent drying of the water resources as the dry season progressed. All monitoring was undertaken in low-flow conditions, and flow progressively decreased as monitoring progressed.

The Carmichael River displayed high turbidity at the start and end of the monitoring program. This has been attributed to the increase of overland flow input of fine sediments (associated with preceding rainfall events) at the start of the monitoring program, and re-suspension of sediments in shallower waters at the end of the monitoring program. Dissolved oxygen concentrations in the Carmichael River were relatively low throughout the monitoring program. These low values are likely associated with the low flow conditions experienced for the majority of the program. The waters of the Carmichael River displayed an alkaline pH throughout the monitoring program.

The soils investigation report associated with this Project (Mine) indicates this is likely linked to the alkalinity of the adjacent soils (refer Volume 4 Appendix L Soils Report). Temperature characteristics of the Carmichael River were closely linked to seasonality whereby higher temperatures were recorded in the warmer months. Effects of shading were also evident; the Carmichael River sites which were shaded had greater buffering capacity against changes in temperature than the exposed sites at the farm dams and Cabbage Tree Creek.

Concentrations of total nitrogen in the Carmichael River were consistently greater than expected ranges and were primarily derived from concentrations of organic nitrogen. Other nutrients including total and reactive phosphorus were within expected ranges. Despite the high concentrations of nitrogen no algal blooms were observed onsite, or detected using chlorophyll a testing. Faecal coliform testing identified faecal coliforms to be present at all the Carmichael River sites. This has been linked to the ongoing cattle grazing of the Study Area. Hydrocarbons were not present in the waters of the Carmichael River.

The in-stream sediments of the Carmichael River were characterised by sands. Nutrients were present in low concentrations and faecal coliforms were present in the sediments at one site only. As with the findings from the water quality assessment, hydrocarbons were not present in the in-stream sediments of the Carmichael River.

Metals detected in the waters of the Carmichael River include aluminium, antimony, arsenic, barium, boron, chromium, cobalt, copper, iron, lead, manganese, nickel, tin, vanadium and zinc. The majority of these metals were also present in the in-stream sediments of the river. Total copper and dissolved zinc $95^{th}$ percentile concentrations were above the HMTV for protection of aquatic ecosystems. Total and dissolved iron and manganese $95^{th}$ percentile concentrations exceeded the long-term trigger values (LTV) for metals in irrigation water.

The quality of the water in the still water bodies was different to the Carmichael River, which is primarily due to the non-flow conditions of those bodies, lack of riparian cover and use of the dam water resources by cattle. The electrical conductivity of the still water bodies was substantially lower than the Carmichael River indicating that input from the alluvial groundwater aquifer that interacts with the river is unlikely. Given that dams are designed to limit the potential for leaching of waters, the lack of link between these resources and groundwater aquifers is expected.

Turbidity values in the still water bodies were elevated, but still lower than those recorded in the Carmichael River. This has been associated with the non-flow conditions which allow for sediments to settle out of suspension. Dissolved oxygen concentrations were also low, one of the few parameters which was comparable to river concentrations. This is not unexpected given that the low DO concentrations in the river are likely associated with low-flow conditions. The pH values in the still water bodies were slightly elevated, although less alkaline than the waters of the Carmichael River. Temperature trends observed in the still water bodies were similar to the Carmichael River trends, although still water bodies experienced a greater range in temperature. This is associated with the lack of shading and thus reduced temperature buffering capacity of the still water bodies.

The concentrations of nutrients were generally higher in the still water bodies than in the Carmichael River. As with the Carmichael River results, concentrations of total nitrogen were attributable to concentrations of organic nitrogen. Some still water bodies also contained moderate concentrations of ammonia. Reactive phosphorus concentrations in the still water bodies were consistently higher than the concentrations found in the Carmichael River.

Chlorophyll a concentrations were also higher in the still water bodies than in the Carmichael River sites, however, no blooms were observed during monitoring. Faecal coliform testing identified that faecal coliforms were present at all the still water body sites. No distinct spatial patterns between the Carmichael River sites and the still water bodies were observed.

As with the Carmichael River sites, hydrocarbons were not present at the still water bodies. Similarly, a number of metals were present in the waters and sediments of the still water bodies. These include aluminium, arsenic, barium, boron, chromium, cobalt, copper, iron, lead, manganese, nickel, strontium, vanadium and zinc. The differences in metal concentrations between the Carmichael River and the still water bodies are likely attributable to local soil characteristics and previous farming activities. Total and dissolved aluminium, chromium, copper, lead and zinc $95^{th}$ percentile concentrations exceeded the WQOs for protection of aquatic ecosystems. Total aluminium $95^{th}$ percentile concentrations also exceeded the LTV for metals in irrigation water and the WQOs nominated for stock watering. The $95^{th}$ percentile concentrations of total and dissolved manganese exceeded the LTV for metals in irrigation water.

The sediments of the still water bodies were comprised of sands, silts and clays. Concentrations of nutrients in the sediments were generally much higher in the still water bodies than in the Carmichael River. These results are consistent with the findings of the water quality assessment, and have been attributed to the lack of flushing of the still water bodies. Faecal coliforms were detected in the sediments of all of the still water bodies, reflecting the findings of the water quality assessment. Hydrocarbons were not present in the sediments of the still water bodies.

Some of the nominated surface water sampling sites located in the north of the Study Area were dry throughout the monitoring program. In order to gain an understanding of the potential contaminants that may be released during flow events DI leach testing was undertaken. Results were generally consistent with the findings of the broader monitoring program, indicating that the sampling sites can be considered to be representative of the water resources present within the Study Area.

Limited site access during October 2011 to March 2012 prevented monitoring during the wet season when high flow conditions are expected to occur. The increase in flow and water depth that occurs during this period is expected to directly impact water quality within the Study Area. During the first flushing flows, water quality variance within the Carmichael River is expected to be high as mobilisation of nutrients, sediments and other parameters occurs. As flow and water depth increase with rainfall during the summer period, water quality within the Carmichael becomes less influenced by groundwater conditions. Overland flow input of fine sediments is expected to result in an increase in turbidity and nutrients. Water depth within the Carmichael River and the non-flowing environments increases resulting in an increase in the EVs of these water resources

### 6.2.2 Physical, Chemical and Biological Characteristics

The parameters to describe the existing physical, chemical and biological characteristics of surface water and groundwater quality include a broad range of physical, chemical and biological indicators including, but not limited to:

- Electrical conductivity
- Major cations and anions
- Dissolved metals
- Minor ions (such as ammonia, nitrite, nitrate, fluoride)
- Hydrocarbons
- Any other potential toxic or harmful substances
- Turbidity

- Suspended sediments
- pH.

These are assessed against identified WQOs were applicable.

#### 6.2.2.1 Electrical Conductivity

Average electrical conductivity (EC) values across the sample sites were close to or less than 1,000 µS/cm (Table 6-5). As such, the waters of the Study Area can be considered to be freshwater. EC levels at the Carmichael River sites, Sites 1  4 and were substantially higher than the still water bodies of Cabbage Tree Creek and dam sites, Sites 5 – 9, and the nominated WQOs. EC levels at the still water bodies were generally below the nominated WQOs (Sites 5 – 9; Figure 6-11; missing data at Site 5 related to site access issues). The Carmichael River sites all displayed a similar temporal pattern, with EC generally increasing through time (Figure 6-11). By June, 2011 the EC levels at the river sites had increased above 1,000 µS/cm, indicating an increased concentration of major ions present in the water. This water is still considered to be freshwater.

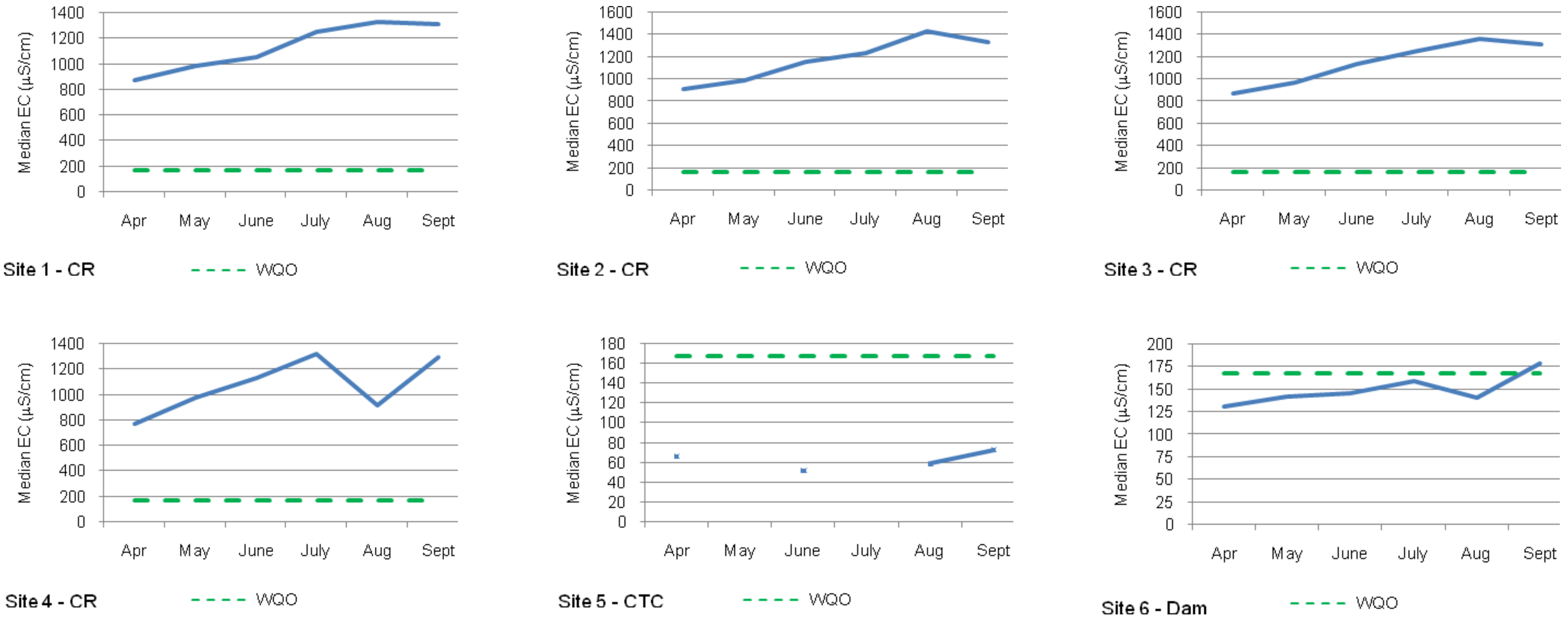
The temporal trends observed in the EC of river sites are likely linked to the local climate and flow regime. The lower EC levels were present at the end of the wet season during which time the heavy rainfall would have caused dilution of the salts present in the river. The observed increase in EC is as the dry season progressed is likely related to the cumulative effects of the evapo-concentration of the salts, and groundwater inputs.

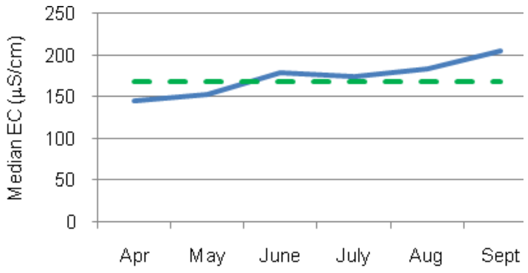
None of the sites displayed EC levels consistent with the nominated WQOs. As such, the nominated WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the Project (Mine). The development of site specific WQOs will need to take the large observed temporal variation into consideration.

**Table 6-5 Electrical Conductivity (µS/cm) Summary Statistics**

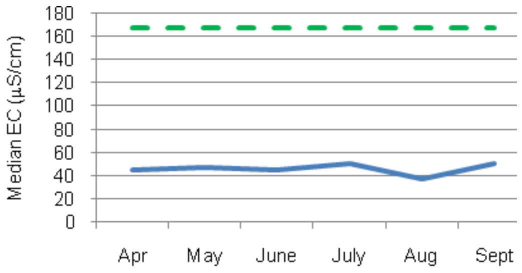
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Number of samples (n) | 60 | 60 | 60 | 60 | 40 | 60 | 60 | 60 | 60 |
| Minimum | 877 | 911 | 875 | 773 | 52 | 131 | 145 | 37 | 62 |
| $20^{th}$ percentile | 988 | 988 | 972 | 919 | 59 | 141 | 153 | 45 | 66 |
| Median | 1153 | 1193 | 1199 | 1054 | 67 | 144 | 177 | 47 | 74 |
| Average | 1135 | 1175 | 1154 | 1069 | 63 | 150 | 174 | 46 | 75 |
| $80^{th}$ percentile | 1309 | 1336 | 1315 | 1293 | 73 | 159 | 184 | 51 | 84 |
| $95^{th}$ percentile | 1328 | 1429 | 1360 | 1323 | 73 | 179 | 206 | 51 | 93 |
| Maximum | 1328 | 1430 | 1360 | 1327 | 73 | 180 | 206 | 51 | 93 |
| WQOs | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 168 |

## Figure 6-11 Median Electrical Conductivity (µS/cm) Values for each Site through Time

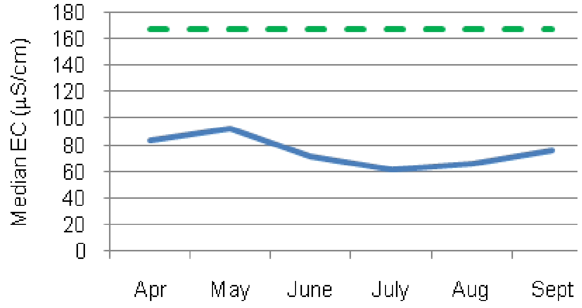





Site 7 - Dam - - - - WQO




Site 8 - Dam - - - - WQO




Site 9 - Dam - - - - WQO

#### 6.2.2.2 Major Ions Surface Water

An assessment of the following major ion concentrations of the surface water resources of the Study Area has been undertaken:

- sodium ($Na^{+}$)
- potassium ($K^{+}$)
- magnesium ($Mg^{2+}$)
- calcium ($Ca^{2+}$)
- chloride ($Cl^{-}$)
- sulphate ($SO_4^{2-}$)
- bicarbonate ($HCO_3^{-}$)
- carbonate ($CO_3^{2-}$).

Figure 6-12 presents a piper diagram categorising the water types based on major ion chemistry. This indicates that the water present in the still water bodies has a different major ion 'finger print' than the water present in the Carmichael River.

The still water bodies were characterised by a major ion water type comprising sodium/potassium bicarbonate. This characterisation was consistent throughout the monitoring program. At the end of the wet season (May, 2011) the Carmichael River was characterised by a major ion water type comprising sodium chloride bicarbonate. As the influence of the wet season decreased, the water type of the Carmichael River changed; concentrations of bicarbonate decreased and concentrations of sodium and chloride increased, resulting in a water type classified as sodium chloride. Towards the end of the dry season (September, October and November 2011) the concentrations of magnesium in the Carmichael River substantially increased, as reflected by the changes in EC (refer results presented Section 6.2.2.1).

Groundwater sampling bores in proximity to the Carmichael River were established towards the end of the surface water quality monitoring program (refer Volume 4 Appendix R Hydrogeology Report for details of the groundwater program). Sampling of the major ion chemistry of the groundwater in proximity to the Carmichael River was undertaken in October and November 2011 (Figure 6-12). The major ion chemistry of the groundwater at this time was characterised by a water type of sodium chloride. Magnesium was also present in the groundwater samples.

Additional surface water samples were obtained from Carmichael River sites during the groundwater sampling events in October and November 2011. These samples were tested for major ion concentrations. The additional samples provide temporal continuity between the surface water and groundwater major ion data sets, thus allowing for a comparison between these water resources to be undertaken.

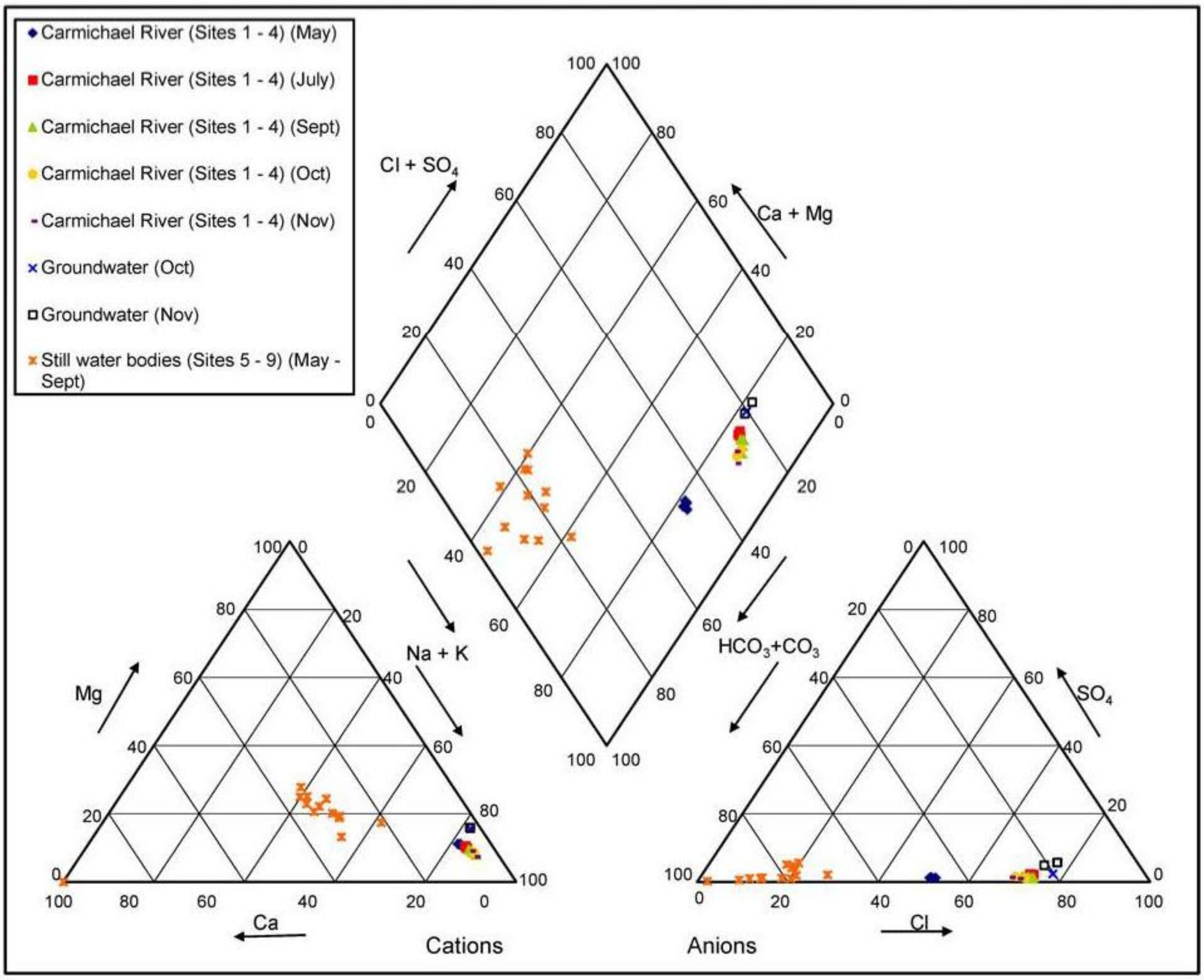
A comparison of the major ion chemistry of the groundwater and surface water (Figure 6-12) indicates that it is likely that the surface water of the Carmichael River is influenced by the nearby groundwater aquifers. From the temporal change observed in the surface water major ion chemistry it can also be surmised that the influence of groundwater on the Carmichael River is greater in the dry season than in the wet season when rain water is entering the system. Further sampling of the major ion chemistry of the groundwater and surface waters of the Carmichael River is planned so as to confirm this surface water / groundwater interaction.

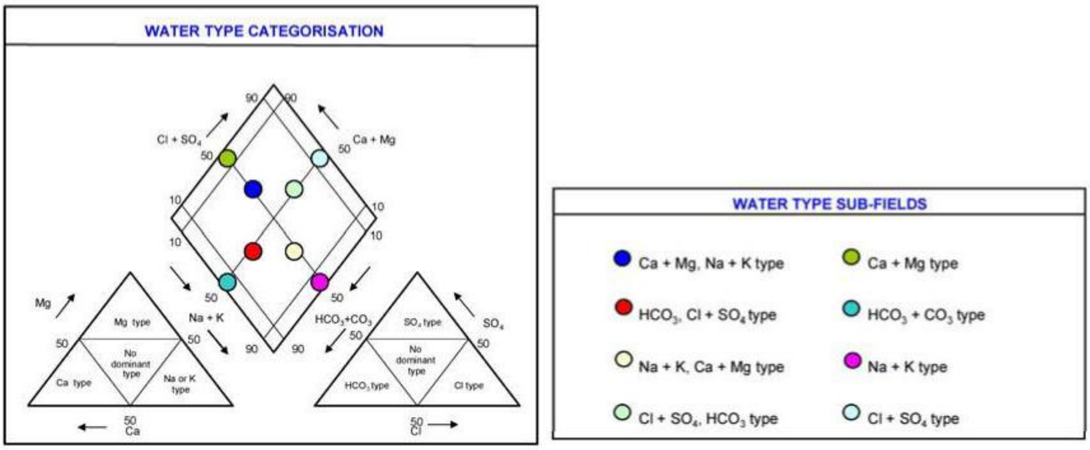
All surface water major ion concentrations were consistent with the nominated WQOs (Table 6-6). As a result, the nominated WQOs may be appropriate for the management of major ions during construction and operation of the Project (Mine). The applicability of the WQOs will be confirmed following the investigation into the surface water / groundwater interaction.

**Table 6-6 Maximum Values of Major Ion Concentrations (mg/L)**

| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Calcium | 14 | 14 | 14 | 15 | 5 | 14 | 13 | 4 | 6 |
| Calcium WQO | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Magnesium | 14 | 14 | 15 | 16 | 2 | 6 | 5 | 1 | 3 |
| Magnesium WQO | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
| Fluoride | 0.4 | 0.4 | 0.4 | 0.4 | 0 | 0.2 | 0 | 0 | 0 |
| Fluoride WQO | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Sulphate | 14 | 13 | 14 | 14 | 2 | 5 | 1 | 0.5 | 0.5 |
| Sulphate WQO | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| TDS | 932 | 960 | 894 | 954 | 234 | 378 | 240 | 129 | 136 |
| TDS WQO | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 | 2500 |

**Figure 6-12 Piper Diagram of Major Ion Chemistry**



#### 6.2.2.3 Major Ions and Inorganics Groundwater

A piper plot of the major ion chemistry for the sampled bores indicates that the groundwater is typically of sodium-chloride type in each of the strata monitored (Figure 6-13). For the most part there appears to be no clear difference between the major ion chemistry of the strata monitored, although the proportion of chloride and hence the final plotting position in most units is highly variable. A possible exception to this general rule is the D seam where some samples contain proportionally less chloride and more bicarbonate when compared to the overlying monitored units, i.e. some of the samples suggest a sodium-bicarbonate-chloride type rather than sodium-chloride type water.

Figure 6-14 shows a comparison of major ion chemistry for four surface water sampling sites along the Carmichael River (WQ1, WQ2, WQ3 and WQ4,) and two groundwater monitoring bores (C025P2 and C027P1) which are completed into the Quaternary / Tertiary alluvium close to the river (see Figure 6-9 for monitoring site locations).

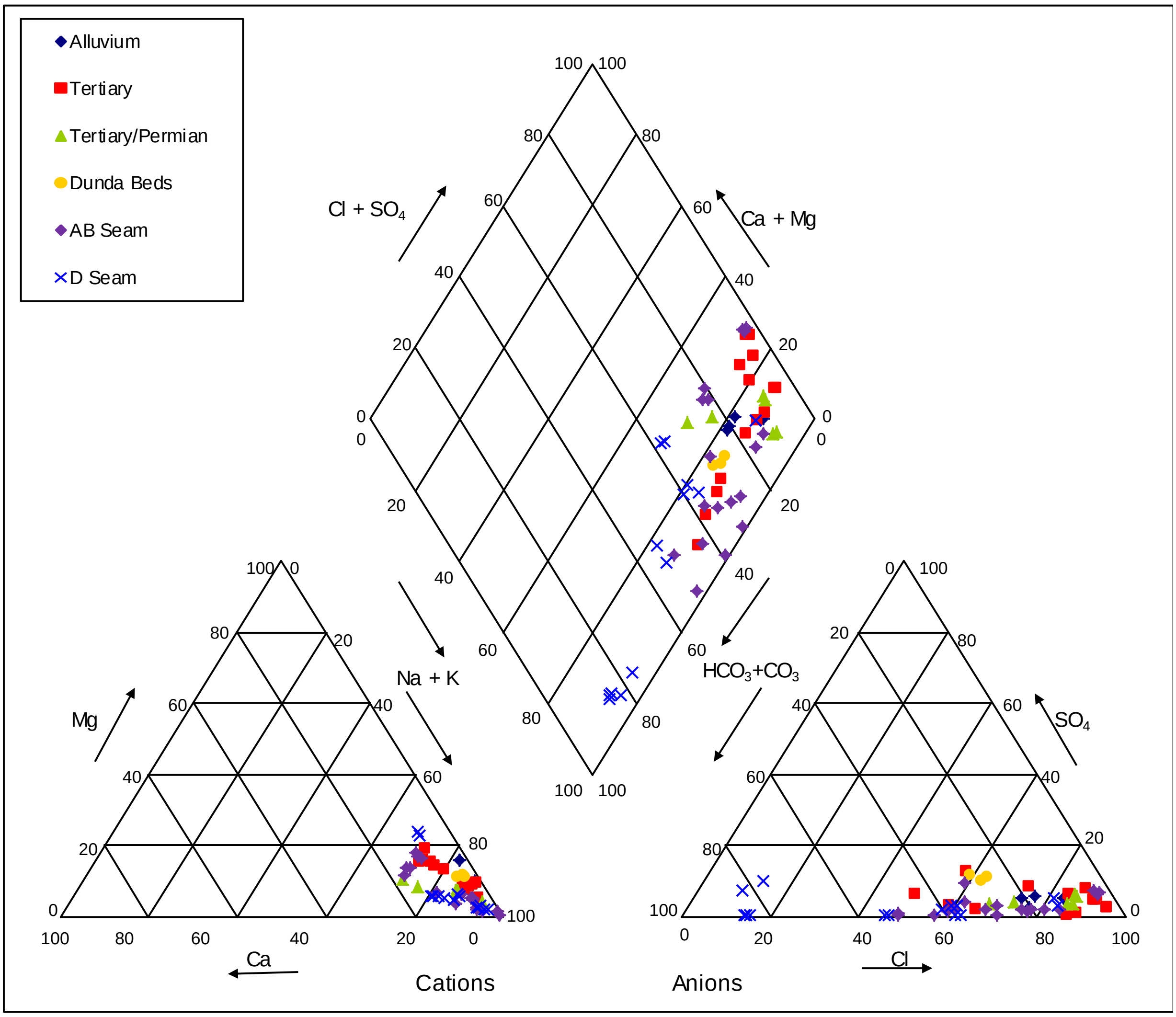
Information on surface water quality data for a number of still water bodies, predominantly local farm dams are also shown. Comparison of these data sets suggests that both the Carmichael River and groundwater samples can be classified as sodium-chloride type waters. The Carmichael River samples become progressively more similar to the groundwater samples as the dry season progresses. Hence, some difference can be observed between the major ion chemistry of the May 2011 surface water samples and the groundwater samples.

The main point of difference is the relatively low proportion of chloride present in the surface water samples which suggests a higher rainfall / runoff component. However, by July 2011 the proportion of chloride in the surface water samples had increased to 70 to 80 per cent such that there is little apparent difference between the major ion chemistry of the groundwater and surface water samples.

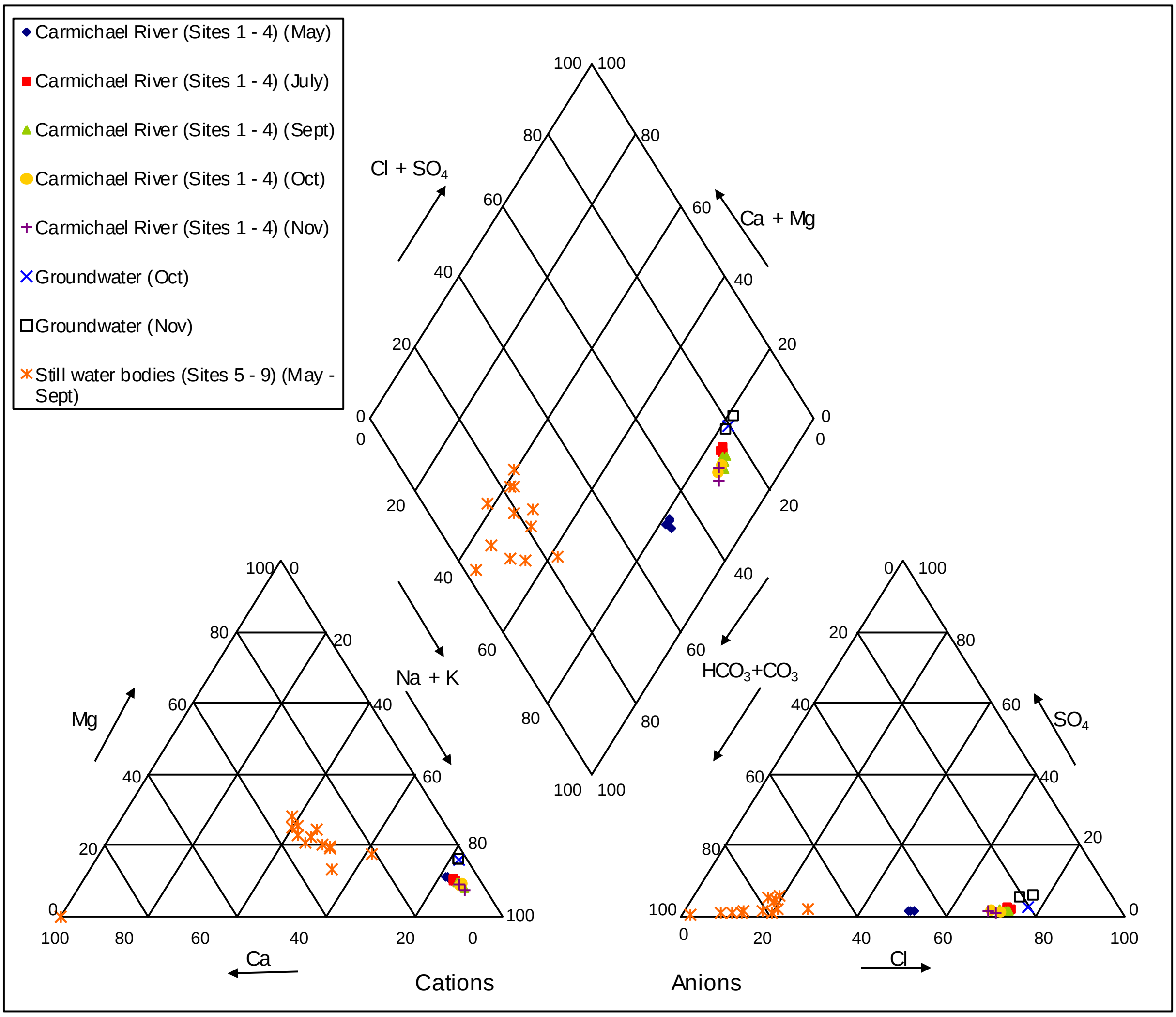
Concentrations of sodium in groundwater samples detected above the laboratory LoR ranged from 55 to 5,960 mg/L and exceeded the long-term irrigation guidelines (ANZECC 2000) in 24 samples, collected from the alluvium, Tertiary-age strata and the AB seam. Concentrations of chloride in groundwater ranged from 49 to 8,430 mg/L also exceeded the long-term irrigation guidelines in 23 samples tested (collected from the alluvium, Tertiary-age strata and the AB seam). Sulphate concentrations in groundwater only exceeded the drinking water guideline (500 mg/L) in one sample with a concentration of 686 mg/L.

Fluoride concentrations ranged from 0.1 to 2.6 mg/L and exceeded the drinking water guideline (1.5 mg/L) and livestock guideline (2 mg/L) in five samples collected from two bores monitoring the D seam.

**Figure 6-13 Piper Diagram – Groundwater**



### Figure 6-14 Piper Diagram – Groundwater and Carmichael River




#### 6.2.2.4 Total and Dissolved Metals and Metalloids

#### Surface Water

A number of metals were not detected above the laboratory limits of reporting, including boron, cadmium, mercury, selenium and silver. Where metals were detected, concentrations were generally lower in the Carmichael River sediments than at the other sites (refer Table 6-7). Where applicable, the concentrations of metals and metalloids in the sediment samples have been compared to the nominated SQOs. No exceedance of the lower interim sediment quality guidelines (ISQG Low) were recorded (refer to Table 6-8).

Total and dissolved metals measured as part of the monitoring program were aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, mercury, nickel, selenium, silver, tin, uranium, vanadium and zinc. A table of all the metal and metalloid analytical results is provided in Volume 4 Appendix Q Mine Water Quality. A number of the tested metals were not detected above laboratory limits of reporting throughout the monitoring program at any sites or times, these were:

- Beryllium (total and dissolved)
- Cadmium (total and dissolved)
- Mercury (total and dissolved)
- Molybdenum (total and dissolved)
- Selenium (total and dissolved)
- Silver (total and dissolved)
- Uranium (total and dissolved)
- Vanadium (dissolved).

Summary statistics of the dissolved metals that returned results for the Carmichael River sites (Sites 1 – 4) and the still water bodies (Cabbage Tree Creek and farm dams; Sites 5 – 9) are provided in Table 6-7 and Table 6-8 respectively. Sites 10 – 12 were dry throughout the monitoring program; as such no data for these sites is presented in this section. Where applicable, the 95$^{th}$ percentile value for each metal has been compared to the nominated WQOs. Shaded values denote those concentrations that exceeded the nominated WQOs.

The hardness of a water sample has the potential to affect the toxicity of metals and metalloids at particular concentrations (ANZECC and ARMCANZ, 2000). An assessment of water hardness across the Study Area has identified that the use of a hardness-modified trigger value (HMTV) is appropriate for the Carmichael River samples (moderate hardness; 60 – 119 mg/L).

Total copper and dissolved zinc 95th percentile concentrations were the only analytes that were above the HMTV for protection of aquatic ecosystems at the Carmichael River sites (Sites 1 – 4). Total and dissolved iron and manganese 95th percentile concentrations exceeded the long-term trigger values (LTV) for metals in irrigation water at the Carmichael River sites. All other 95th percentile metal concentrations recorded from the Carmichael River were below the nominated WQOs.

A number of exceedances of the nominated WQOs were recorded at the still water bodies (Sites 5 – 9). Total and dissolved aluminium, chromium, copper, lead and zinc 95$^{th}$ percentile concentrations exceeded the WQOs for protection of aquatic ecosystems. Total aluminium 95$^{th}$ percentile concentrations also exceeded the LTV for metals in irrigation water and the WQOs nominated for stock watering. The 95$^{th}$ percentile concentrations of total and dissolved manganese in the still water bodies also exceeded the LTV for metals in irrigation water. All other 95$^{th}$ percentile metal concentrations recorded from the still water bodies were below the nominated WQOs.

**Table 6-7 Metal Summary Statistics (mg/L) for Carmichael River Sites (Sites 1 – 4)**

| Metal | | Number of Detects (n = 12) | Minimum | 20th percentile | Median | Average | 80th percentile | 95th percentile | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| Aluminium | Total | 12 | 0.080 | 0.118 | 0.180 | 0.416 | 0.298 | 1.444 | 2.200 |
| | Dissolved | 12 | 0.010 | 0.020 | 0.050 | 0.040 | 0.054 | 0.060 | 0.060 |
| Arsenic | Total | 1 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| | Dissolved | 0 | - | - | - | - | - | - | - |
| Barium | Total | 8 | 0.285 | 0.287 | 0.295 | 0.305 | 0.330 | 0.337 | 0.339 |
| | Dissolved | 12 | 0.241 | 0.251 | 0.263 | 0.269 | 0.266 | 0.322 | 0.358 |
| Boron | Total | 12 | 0.120 | 0.126 | 0.150 | 0.143 | 0.160 | 0.160 | 0.160 |
| | Dissolved | 12 | 0.110 | 0.130 | 0.160 | 0.148 | 0.160 | 0.166 | 0.170 |
| Chromium (III+VI) | Total | 1 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| | Dissolved | 4 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Cobalt | Total | 4 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.004 | 0.004 |
| | Dissolved | 1 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Copper | Total | 7 | 0.0010 | 0.0010 | 0.0050 | 0.0098 | 0.0144 | 0.0276 | 0.0320 |
| | Dissolved | 7 | 0.0010 | 0.0010 | 0.0050 | 0.0044 | 0.0066 | 0.0084 | 0.0090 |
| Iron | Total | 12 | 0.630 | 0.680 | 1.590 | 2.212 | 2.664 | 5.946 | 7.950 |
| | Dissolved | 12 | 0.140 | 0.156 | 0.230 | 0.267 | 0.392 | 0.440 | 0.440 |
| Lead | Total | 2 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 |

| Metal | | Number of Detects (n = 12) | Minimum | 20th percentile | Median | Average | 80th percentile | 95th percentile | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | Dissolved | 0 | - | - | - | - | - | - | - |
| Manganese | Total | 8 | 0.136 | 0.158 | 0.167 | 0.173 | 0.186 | 0.216 | 0.226 |
| | Dissolved | 12 | 0.034 | 0.048 | 0.078 | 0.082 | 0.103 | 0.138 | 0.161 |
| Nickel | Total | 8 | 0.001 | 0.001 | 0.002 | 0.002 | 0.003 | 0.004 | 0.004 |
| | Dissolved | 4 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Strontium | Total | 12 | 0.205 | 0.206 | 0.210 | 0.213 | 0.218 | 0.226 | 0.231 |
| | Dissolved | 12 | 0.181 | 0.190 | 0.197 | 0.195 | 0.199 | 0.203 | 0.203 |
| Zinc | Total | 5 | 0.005 | 0.005 | 0.007 | 0.007 | 0.008 | 0.008 | 0.008 |
| | Dissolved | 2 | 0.043 | 0.043 | 0.043 | 0.043 | 0.043 | 0.043 | 0.043 |

Note: Shaded values denote those concentrations that exceeded the nominated WQOs.

**Table 6-8 Metal Summary Statistics (mg/L) for Still Water Body Sites (Cabbage Tree Creek (Sites 5) and Farm Dams (Sites 6 – 9))**

| Metal | | Number of Detects | Minimum | 20th percentile | Median | Average | 80th percentile | 95th percentile | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| Aluminium | Total | 11 (n=11) | 0.050 | 0.134 | 0.425 | 1.594 | 3.578 | 5.705 | 6.160 |
| | Dissolved | 11 (n=11) | 0.020 | 0.030 | 0.050 | 0.274 | 0.180 | 1.322 | 2.030 |
| Arsenic | Total | 11 (n=13) | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 |
| | Dissolved | 4 (n=13) | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Barium | Total | 11 (n=11) | 0.034 | 0.057 | 0.107 | 0.146 | 0.247 | 0.279 | 0.286 |
| | Dissolved | 13 (n=13) | 0.023 | 0.039 | 0.176 | 0.165 | 0.242 | 0.317 | 0.354 |
| Boron | Total | 7 (n=11) | 0.050 | 0.050 | 0.055 | 0.079 | 0.114 | 0.147 | 0.160 |
| | Dissolved | 11 (n=11) | 0.050 | 0.060 | 0.080 | 0.091 | 0.104 | 0.174 | 0.180 |
| Chromium (III+VI) | Total | 5 (n=13) | 0.002 | 0.004 | 0.006 | 0.005 | 0.007 | 0.008 | 0.008 |
| | Dissolved | 2 (n=13) | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Cobalt | Total | 9 (n=11) | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.004 |
| | Dissolved | 1 (n=13) | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Copper | Total | 11 (n=13) | 0.0010 | 0.0020 | 0.0030 | 0.0041 | 0.0060 | 0.0082 | 0.0100 |
| | Dissolved | 9 (n=13) | 0.0010 | 0.0020 | 0.0020 | 0.0026 | 0.0030 | 0.0045 | 0.0050 |
| Iron | Total | 11 (n=11) | 0.730 | 0.894 | 1.545 | 3.246 | 6.590 | 8.383 | 8.760 |
| | Dissolved | 10 (n=11) | 0.060 | 0.074 | 0.160 | 0.353 | 0.470 | 1.218 | 1.680 |
| Lead | Total | 8 (n=13) | 0.0010 | 0.0010 | 0.0010 | 0.0019 | 0.0030 | 0.0036 | 0.0040 |

| Metal | | Number of Detects | Minimum | 20th percentile | Median | Average | 80th percentile | 95th percentile | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | Dissolved | 1 (n=13) | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 | 0.0010 |
| Manganese | Total | 11 (n=11) | 0.048 | 0.124 | 0.228 | 0.250 | 0.356 | 0.508 | 0.528 |
| | Dissolved | 10 (n=13) | 0.002 | 0.003 | 0.007 | 0.034 | 0.038 | 0.155 | 0.182 |
| Nickel | Total | 10 (n=13) | 0.001 | 0.002 | 0.002 | 0.003 | 0.006 | 0.006 | 0.007 |
| | Dissolved | 9 (n=13) | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Strontium | Total | 11 (n=11) | 0.021 | 0.070 | 0.161 | 0.139 | 0.203 | 0.220 | 0.224 |
| | Dissolved | 11 (n=11) | 0.017 | 0.065 | 0.142 | 0.124 | 0.181 | 0.202 | 0.207 |
| Vanadium | Total | 4 (n=11) | 0.010 | 0.010 | 0.015 | 0.015 | 0.020 | 0.020 | 0.020 |
| | Dissolved | 0 (n=13) | - | - | - | - | - | - | - |
| Zinc | Total | 6 (n=13) | 0.008 | 0.009 | 0.011 | 0.012 | 0.012 | 0.019 | 0.022 |
| | Dissolved | 5 (n=13) | 0.012 | 0.015 | 0.020 | 0.023 | 0.031 | 0.038 | 0.040 |

Note: Shaded values denote those concentrations that exceeded the nominated WQOs.

## Ground Water

Concentrations of dissolved metals in all units tested were generally below the guideline concentrations for livestock, with the exception of manganese. Manganese concentrations in 48 out of 52 samples tested exceeded the guideline value (0.1 mg/L) with concentrations in groundwater detected up to 4.81 mg/L.

Guidelines for long-term irrigation were exceeded for aluminium (1 sample), boron (22 samples), iron (52 samples), manganese (32 samples), molybdenum (6 samples), selenium (1 sample) and uranium (6 samples). Exceedences of one or more of these metals species were detected in all of the units monitored (i.e. the alluvium, Tertiary-age strata, Dunda Beds, AB seam and D seam).

Drinking water guidelines were exceeded for arsenic (11 samples), manganese (14 samples), selenium (2 samples) and uranium (3 samples). Exceedences of one or more of these metals species were detected in all units monitored with the exception of the D seam.

### 6.2.2.5 Minor Ions Surface Water

## Surface Water Nutrients

Nutrient pollution has the potential to impact upon a system via the stimulation of growth of nuisance plants and cyanobacteria (ANZECC and ARMCANZ, 2000). Growth of these plants can lead to changes in the biological community composition as well as flow on affects to aspects of water quality such as dissolved oxygen concentration. Nutrients that were assessed as part of the monitoring program were total nitrogen, ammonia, oxides of nitrogen, total phosphorus and reactive phosphorus.

Observations of macrophyte presence and prevalence were undertaken during each monitoring event. No macrophytes of high prevalence (blooms) were noted during monitoring. A table of all the nutrient analytical results is provided in Volume 4 Appendix Q Mine Water Quality. Nitrogen concentrations displayed distinct spatial patterns whereby the concentrations found in the still water bodies were consistently higher than those found in the Carmichael River. The total nitrogen concentrations of the still water bodies were also consistently much higher than the nominated WQOs. Summary statistics of the total nitrogen values recorded throughout the monitoring program are provided in Table 6-9. There was little spatial separation of the total nitrogen concentrations at the Carmichael River sites. These sites all followed a similar pattern of high concentrations (above WQOs) at the end of the wet season (April 2011), followed by a decrease to below WQOs in June 2011 and then a gradual increase back to values above WQOs in September.

Total nitrogen is comprised of organic nitrogen, and inorganic nitrogen, including ammonia ($NH_3$ or $NH_4^+$), nitrate ($NO_3^-$) and nitrite ($NO_2^-$). The composition of the total nitrogen samples collected throughout the monitoring program is presented in Figure 6-15. This shows that the total nitrogen concentration was mainly comprised of organic nitrogen. Levels of organic nitrogen were generally above the nominated WQOs (225 μg/L and 330 μg/L for Carmichael River and the still water bodies (including Cabbage Tree Creek), respectively. The QWQG (DERM, 2009a) state that during periods of low flow increased organic nitrogen levels can result from a build-up of organic matter derived from natural sources. These higher organic nitrogen levels should not be considered to be exceedences of the guidelines if levels of inorganic nitrogen remain low (DERM, 2009). The Study Area was subject to low (Carmichael River sites) or no flow (Cabbage Tree Creek and dam sites) throughout the monitoring program (April – September). A build-up of organic matter, such as plant detritus and cow manure, was observed at all sites during the monitoring program.  As such, higher organic nitrogen levels, including those above the nominated WQOs, are not unexpected.

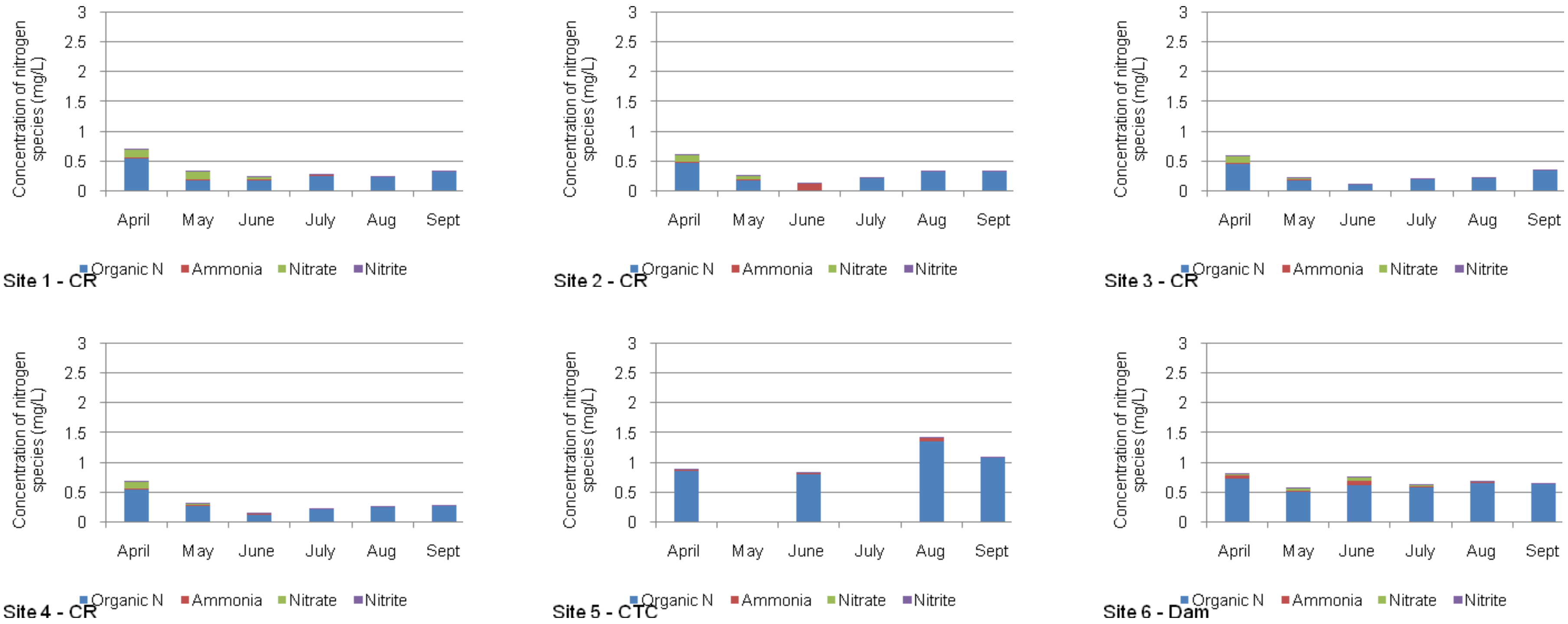
**Table 6-9 Total Nitrogen (µg/L) Summary Statistics**

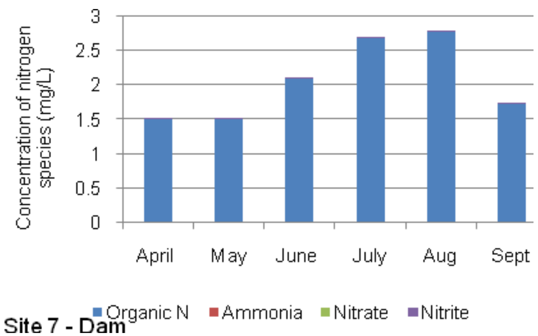
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Minimum | 250 | 140 | 120 | 150 | 830 | 590 | 1530 | 1360 | 1140 |
| 20th percentile | 250 | 230 | 220 | 240 | 866 | 640 | 1530 | 1930 | 2150 |
| Median | 310 | 300 | 235 | 280 | 995 | 670 | 1925 | 2030 | 2175 |
| Average | 362 | 325 | 297 | 328 | 1063 | 697 | 2068 | 2028 | 2070 |
| 80th percentile | 350 | 350 | 370 | 320 | 1232 | 780 | 2700 | 2210 | 2270 |
| 95th percentile | 613 | 560 | 543 | 605 | 1381 | 818 | 2775 | 2510 | 2450 |
| Maximum | 700 | 630 | 600 | 700 | 1430 | 830 | 2800 | 2610 | 2510 |
| WQOs | 250 upland streams | 250 upland streams | 250 upland streams | 250 upland streams | 350 lakes & reservoirs | 350 lakes & reservoirs | 350 lakes & reservoirs | 350 lakes & reservoirs | 350 lakes & reservoirs |

As seen in Figure 6-15, some nitrate, ammonia and nitrite was present at the Carmichael River sites early in the monitoring program.  With the exception of one sample (Site 2, June); concentrations of these inorganic nitrogen species at the Carmichael River sites were below the nominated WQOs.  As such, the organic nitrogen levels above the WQOs are not considered to be breaches of the QWQG.

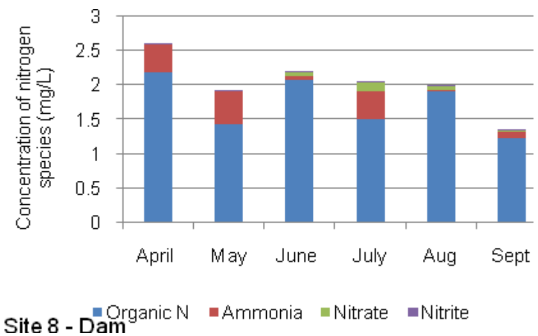
Concentrations of organic nitrogen in the still water bodies were consistently greater than the nominated WQOs.  Similarly, when present, the concentrations of ammonia were above the nominated WQOs.

## Figure 6-15 Composition of Nitrogen Species (mg/L) for each Site through Time

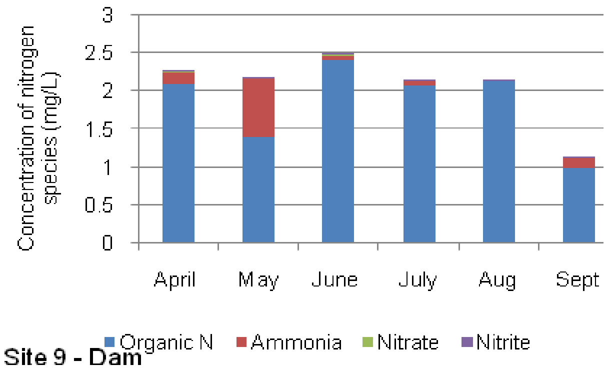




Site 7 - Dam



Site 8 - Dam



Site 9 - Dam

Note: Sites 10 – 12 were dry during sampling

Total phosphorus concentrations exhibited similar spatial and temporal patterns to total nitrogen concentrations. The still water bodies displayed substantially higher total phosphorus concentrations than the sites located in the Carmichael River. The Carmichael River sites displayed a small temporal variation (maximum variation of 0.029 mg/L at Site 4) when compared to the Cabbage Tree Creek and dam sites (maximum variation of 0.257 mg/L at Site 7; Table 6-10). The Carmichael River sites also displayed little spatial variation. With the exception of Site 1 and Site 2 in April, and Site 4 in May and August, all total phosphorus values recorded from the Carmichael River were below the nominated WQOs of 0.03 mg/L. All concentrations of total phosphorus in the still water bodies were above the nominated WQOs of 0.01 mg/L (Table 6-10).

**Table 6-10 Total Phosphorus (mg/L) Summary Statistics**

| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Minimum | 0.011 | 0.009 | 0.007 | 0.009 | 0.077 | 0.064 | 0.091 | 0.087 | 0.068 |
| 20th percentile | 0.018 | 0.014 | 0.013 | 0.013 | 0.132 | 0.070 | 0.159 | 0.096 | 0.087 |
| Median | 0.021 | 0.019 | 0.019 | 0.025 | 0.170 | 0.076 | 0.202 | 0.101 | 0.113 |
| Average | 0.021 | 0.020 | 0.016 | 0.024 | 0.172 | 0.079 | 0.219 | 0.108 | 0.115 |
| 80th percentile | 0.025 | 0.024 | 0.019 | 0.033 | 0.212 | 0.088 | 0.310 | 0.120 | 0.140 |
| 95th percentile | 0.029 | 0.032 | 0.021 | 0.037 | 0.257 | 0.098 | 0.339 | 0.137 | 0.160 |
| Maximum | 0.030 | 0.034 | 0.021 | 0.038 | 0.272 | 0.101 | 0.348 | 0.142 | 0.167 |
| WQOs | 0.030 upland streams | 0.030 upland streams | 0.030 upland streams | 0.030 upland streams | 0.010 lakes & reservoirs | 0.010 lakes & reservoirs | 0.010 lakes & reservoirs | 0.010 lakes & reservoirs | 0.010 lakes & reservoirs |

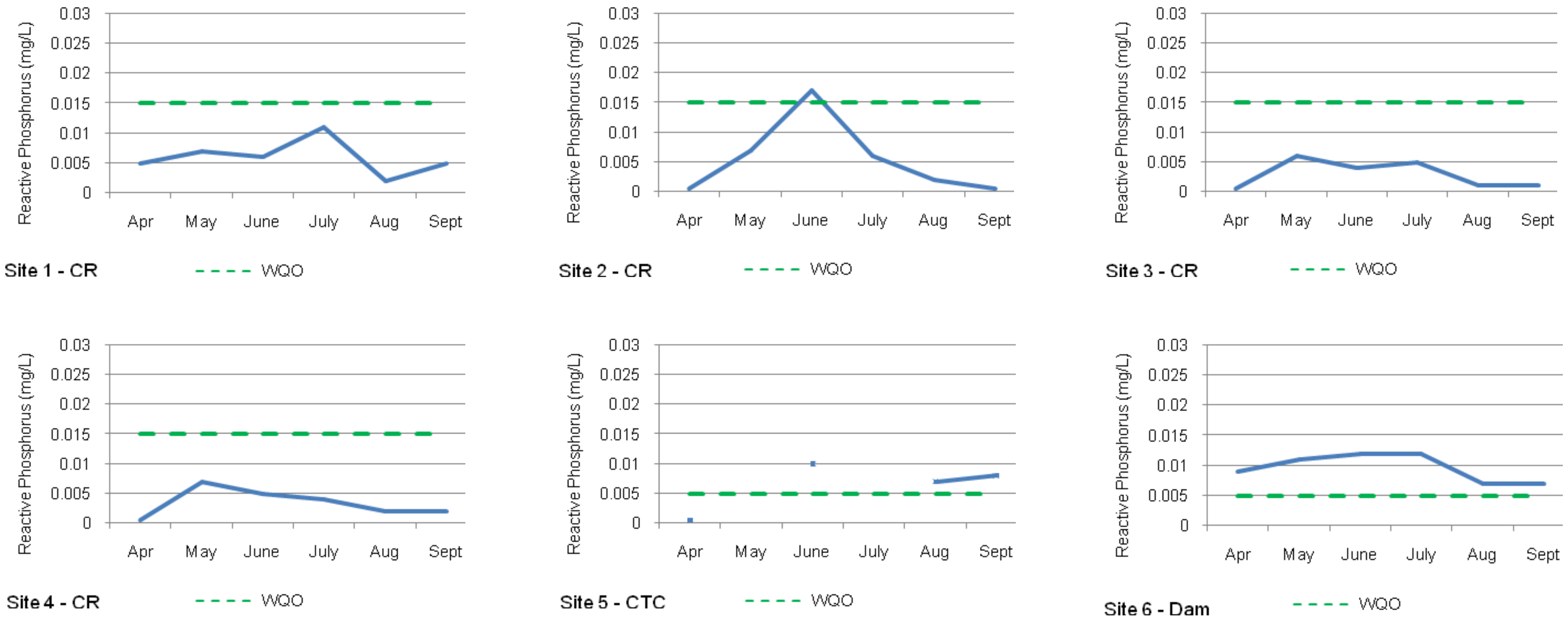
Measures of reactive phosphorus provide an indication of the potentially bioavailable forms of phosphorus in the system. The majority of reactive phosphorus samples from the Carmichael River were below the nominated WQOs (Figure 6-16). Conversely, the majority of the reactive phosphorus samples from the still water bodies were above the nominated WQOs (Figure 6-16).

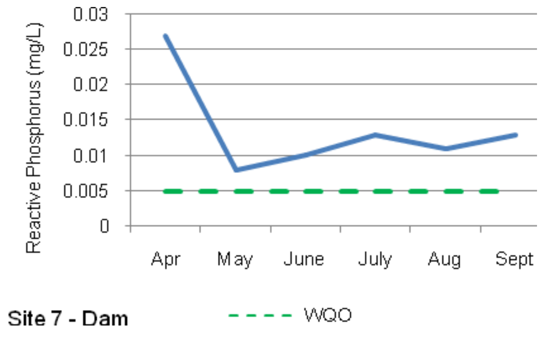
Reactive phosphorus concentrations ranged from 0.001 mg/L (Site 3) to 0.017 mg/L (Site 2) at the Carmichael River sites (Sites 1 – 4; Table 6-11). The still water body site (Sites 5 – 9), which generally contained higher levels of reactive phosphorus, ranged from 0.004 mg/L (Site 9) to 0.027 mg/L (Site 7). Overall nutrient levels were not consistent with the nominated WQOs. As such, the nominated WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the Project (Mine). The development of site specific WQOs will need to take the large observed temporal variation into consideration.

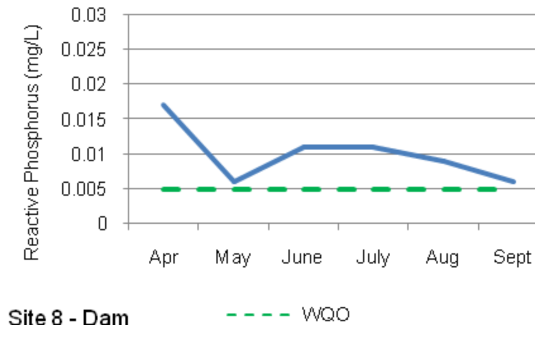
**Table 6-11 Reactive Phosphorus (mg/L) Summary Statistics**

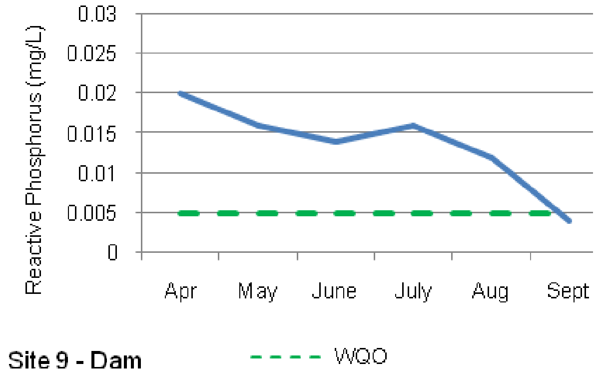
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Minimum | 0.002 | 0.002 | 0.001 | 0.002 | 0.007 | 0.007 | 0.008 | 0.006 | 0.004 |
| $20^{th}$ percentile | 0.005 | 0.004 | 0.001 | 0.002 | 0.007 | 0.007 | 0.010 | 0.006 | 0.012 |
| Median | 0.006 | 0.007 | 0.004 | 0.004 | 0.008 | 0.010 | 0.012 | 0.010 | 0.015 |
| Average | 0.006 | 0.008 | 0.003 | 0.004 | 0.008 | 0.010 | 0.014 | 0.010 | 0.014 |
| $80^{th}$ percentile | 0.007 | 0.011 | 0.005 | 0.005 | 0.009 | 0.012 | 0.013 | 0.011 | 0.016 |
| $95^{th}$ percentile | 0.010 | 0.016 | 0.006 | 0.007 | 0.010 | 0.012 | 0.024 | 0.016 | 0.019 |
| Maximum | 0.011 | 0.017 | 0.006 | 0.007 | 0.010 | 0.012 | 0.027 | 0.017 | 0.020 |
| WQOs | 0.015 upland streams | 0.015 upland streams | 0.015 upland streams | 0.015 upland streams | 0.005 lakes & reservoirs | 0.005 lakes & reservoirs | 0.005 lakes & reservoirs | 0.005 lakes & reservoirs | 0.005 lakes & reservoirs |

**Figure 6-16 Reactive Phosphorus (mg/L) Values for each Site through Time**





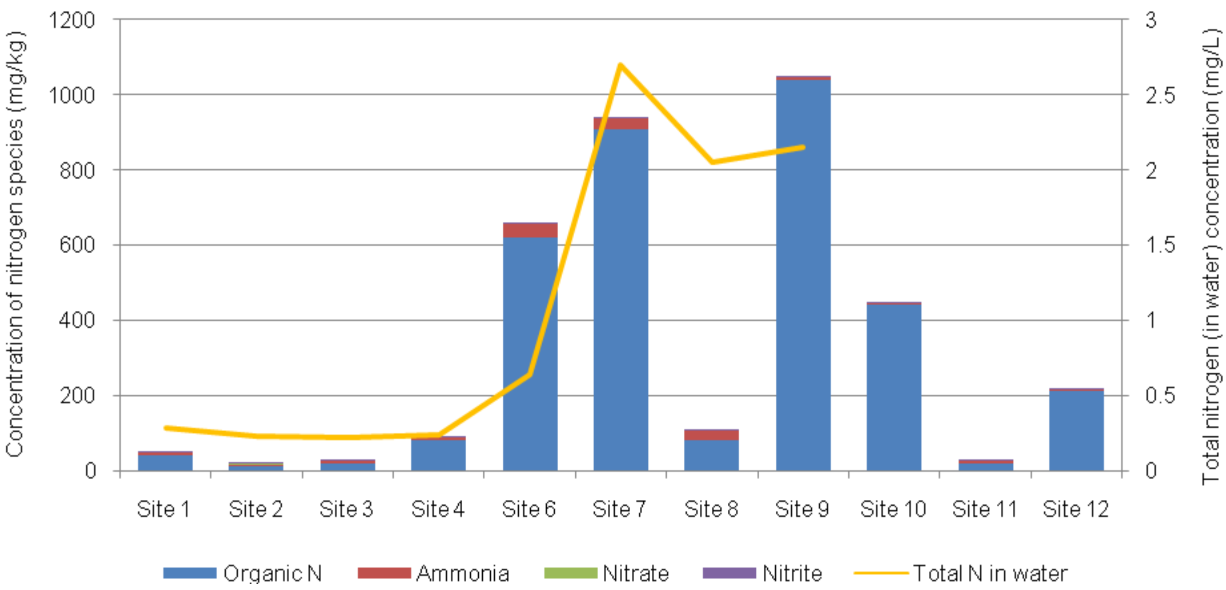

Note: Sites 10 – 12 were dry during sampling

The concentration of total nitrogen in the sediment samples displayed a similar spatial pattern to that observed in the water quality analysis. Peaks in total nitrogen in the sediment correspond to peaks in total nitrogen concentrations in the water from the same monitoring event (July; Figure 6-17). The Carmichael River sites (Sites 1 – 4) contained substantially less total nitrogen than the majority of the still water bodies (Sites 6 – 9), and three of the sites with no water (Site 10 - 12; Figure 6-17).

The composition of nitrogen species within the sediment was dominated by organic nitrogen (Figure 6-17), which is consistent with the findings of the water quality assessment. Concentrations of total phosphorus in the sediment samples displayed a similar pattern to total nitrogen (Figure 6-18). The Carmichael River sites (Sites 1 – 4) contained substantially lower total phosphorus concentrations than the still water bodies and dry creek beds (Figure 6-18). This observed spatial pattern is consistent with the results of the water quality assessment, however trends in sediment and water concentrations are not as closely aligned as those observed for total nitrogen (Figure 6-18). Reactive phosphorus was not found above laboratory limits of detection at the Carmichael River sites. Where detected at the still water bodies and dry creek beds, concentrations were low (maximum of 0.2 mg/kg).

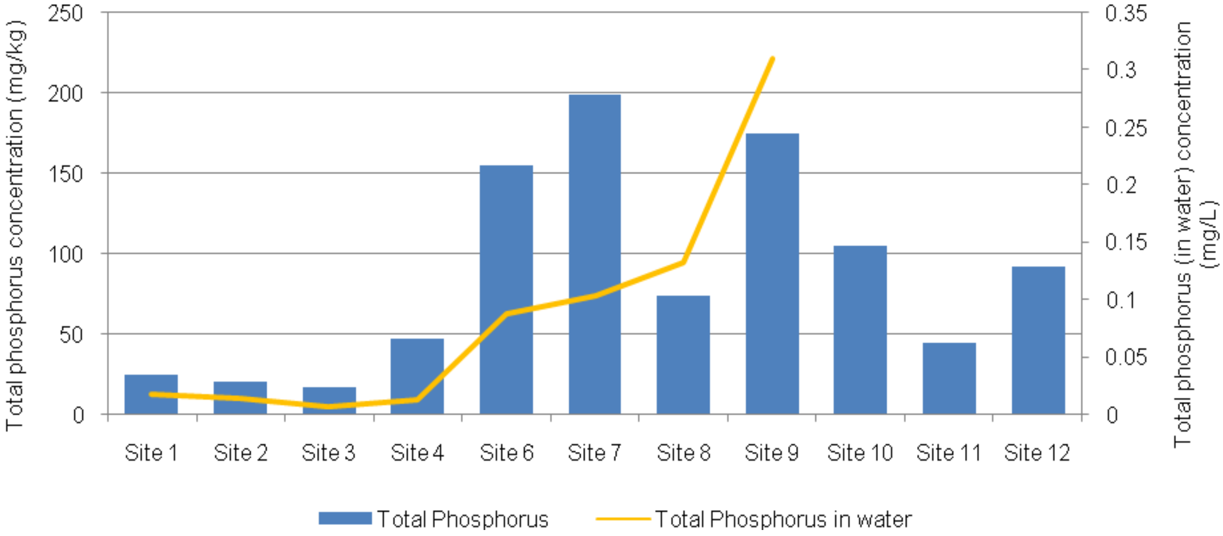
There are no available sediment quality objectives (SQOs) for nutrients. As such, no comparison of data to SQOs has been undertaken.

**Figure 6-17 Composition of Nitrogen Species (mg/L) for each Site**




Note: Sites 10, 11 and 12 did not have water at the time of sampling therefore no dissolved Nitrogen results are available.

**Figure 6-18 Total Phosphorus Concentrations for each Site**




Note: Sites 10, 11 and 12 did not have water at the time of sampling therefore no dissolved Phosphorus results are available.

#### 6.2.2.6 Minor Ions Groundwater

Concentrations of ammonia in groundwater exceeded the ANZECC (2000) fresh water (95 per cent level of protection) guideline value of 0.9 mg/L in 10 samples and exceeded the drinking water guidelines of 0.5 mg/L in 18 samples.  These exceedences of ammonia were identified in samples taken from monitoring bores installed in the alluvium, Tertiary-age strata and the AB seam.  Samples collected from bores completed in the Dunda Beds and the D seam did not exceed these guideline values.  Concentrations of total nitrogen, total dissolved nitrogen and phosphorous were also identified above the laboratory limit of reporting (LoR) in all of the monitored strata (i.e. the alluvium, Tertiary-age strata, Dunda Beds, AB seam and D seam).

Nitrate concentrations of up to 0.2 mg/L and nitrite concentrations of up to 0.06 mg/L were detected, which are below the guideline values for drinking water and livestock.  Concentrations of total nitrogen (up to 12 mg/L) and phosphorous (up to 1.99 mg/L) were detected in the samples tested and exceeded the long-term irrigation guideline value.

#### 6.2.2.7 Hydrocarbons

**Surface Water**

All PAHs and total petroleum hydrocarbons (TPH) tested were below the laboratory limit of reporting across all sites and all sampling events.  Hence hydrocarbons did not exceed any guidelines.  All PAHs and TPHs tested were below the laboratory limit of reporting; data is provided in Volume 4 Appendix Q Mine Water Quality.  For some PAHs (acenaphthene, anthracene, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, pyrene), the laboratory limit of reporting was not able to achieve the required level of detection for comparison against the nominated ISQG Low SQOs.  All PAHs were below the nominated ISQG High SQOs.

### Ground Water

Low concentrations of BTEX (benzene, toluene, ethylbenzene and xylene), comprising toluene (nine samples with the range 3 to 17 µg/L) and benzene (one sample at 2 µg/L), were detected just above the laboratory LoR (2 µg/L toluene and 1 µg/L benzene) at six locations. Exceedences of the LoR were detected in Tertiary-age strata, the AB seam and the D seam.

Low concentrations of TPH in the fraction range C6 to C14 were detected above the laboratory LoR (i.e. the lighter more volatile fractions of TPH) in each of the monitored units (i.e. the alluvium, Tertiary-age strata, Dunda Beds, AB seam and D seam).

The guidelines for drinking water, livestock and long-term irrigation for benzene (1 µg/L) were exceeded in one sample (with a concentration of 2 µg/L) collected from monitoring in the AB seam. The guideline values for ethylbenzene (300 µg/L), toluene (800 µg/L) and total xylene (600 µg/L) were not exceeded.

#### 6.2.2.8 Potential Toxic or Harmful Substances

### Surface Water

Testing for the presence and prevalence of faecal coliforms in the sediment was undertaken as part of the monitoring program. Faecal coliforms were only detected above laboratory limits of reporting at one of the Carmichael River sites (Site 4). Faecal coliforms were detected at all of the still water bodies and one of the dry creek bed sites. The highest concentrations of faecal coliforms were associated with the farm dams (still water bodies). These results are not unexpected given the presence of cattle in these areas, and the infrequent flushing of the farm dams.

The spatial patterns of faecal coliforms observed in the sediments is different to that identified in the water samples. It is likely that the results obtained from the water samples provide an indication of recent faecal coliform additions to the resources, whereas concentrations in the sediment are indicative of long term accumulation. There are no SQOs for faecal coliforms; as such no comparison of the data to SQOs has been undertaken.

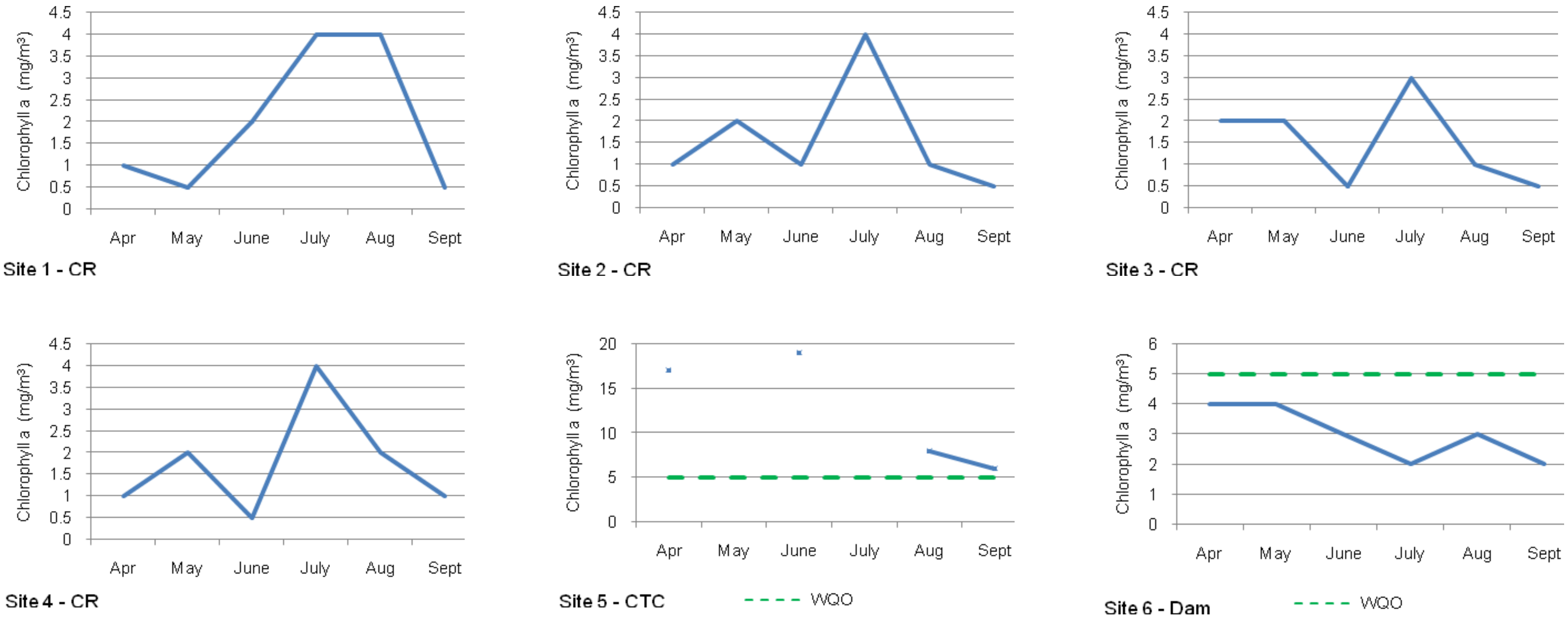
Biological parameters tested as part of the monitoring program were chlorophyll a and faecal coliforms. As noted in the QWQG (DERM, 2009a) measures of chlorophyll a provide an indication of the algal biomass in a water sample. Temporal trends in chlorophyll a at the Carmichael River sites (Sites 1 – 4) were consistent, with the majority of sites comparable during each sampling event (Table 6-12 and Figure 6-19). Temporal variation at these sites was between 2 $mg/m^3$ and 3 $mg/m^3$. Maximum concentrations at the Carmichael River sites of 4 $mg/m^3$ were recorded in July (Table 6-12 and Figure 6-19). There are currently no nominated WQOs for chlorophyll a for upland streams for comparison of the results from the Carmichael River sites.

With the exception of Site 6, all still water bodies (Sites 5 – 9) contained much greater concentrations of chlorophyll a, and thus higher algal biomass, than the Carmichael River sites (Table 6-12 and Figure 6-19; missing data from Site 5 due to site access issues). Temporal variation at these sites was between 2 $mg/m^3$ and 52 $mg/m^3$ (Table 6-12). With the exceptions of Site 6, the chlorophyll a concentrations at all the still water bodies were consistently greater than the nominated WQOs (5 $mg/m^3$). Site 6 displayed higher minimum turbidity values than the other still water bodies. It is likely that the turbidity values at this site limited the growth of algae in this water body.

### Table 6-12 Chlorophyll a (mg/m$^3$) Summary Statistics

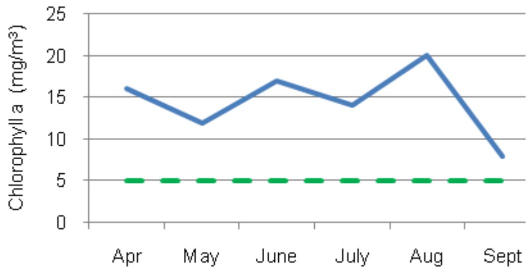
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Minimum | 1.0 | 1.0 | 1.0 | 1.0 | 6.0 | 2.0 | 8.0 | 10.0 | 12.0 |
| 20$^{th}$ percentile | 1.6 | 1.0 | 1.6 | 1.0 | 7.2 | 2.0 | 12.0 | 11.0 | 18.0 |
| Median | 3.0 | 1.0 | 2.0 | 2.0 | 12.5 | 3.0 | 15.0 | 15.0 | 23.5 |
| Average | 2.8 | 1.8 | 2.0 | 2.0 | 12.5 | 3.0 | 14.5 | 16.7 | 30.3 |
| 80$^{th}$ percentile | 4.0 | 2.4 | 2.4 | 2.4 | 17.8 | 4.0 | 17.0 | 17.0 | 41.0 |
| 95$^{th}$ percentile | 4.0 | 3.6 | 2.9 | 3.6 | 18.7 | 4.0 | 19.3 | 28.3 | 58.3 |
| Maximum | 4.0 | 4.0 | 3.0 | 4.0 | 19.0 | 4.0 | 20.0 | 32.0 | 64.0 |
| WQOs | n/a | n/a | n/a | n/a | 5.0 lakes & reservoirs | 5.0 lakes & reservoirs | 5.0 lakes & reservoirs | 5.0 lakes & reservoirs | 5.0 lakes & reservoirs |

## Figure 6-19 Chlorophyll a (mg/m$^3$) Values for each Site through Time

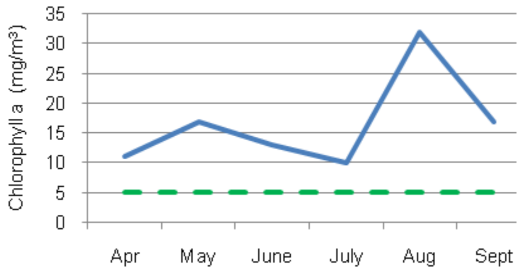




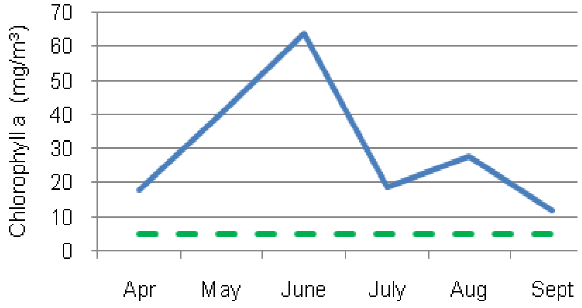
41/25215/437863




Site 7 - Dam ---- WQO




Site 8 - Dam ---- WQO




Site 9 - Dam ---- WQO

Note: Sites 10 – 12 were dry during sampling

Testing for the presence and prevalence of faecal coliforms provides an indication of faecal contamination, and thus the potential presence of microbial pathogens, in a water sample. Faecal coliform concentrations at all sites were consistently above the WQOs for irrigation (direct contact; 10 cfu/100 ml; Table 6-13). Site 2, Site 4, Site 6 and Site 8 all exceeded the WQOs for stock watering and irrigation (indirect contact; 1,000 cfu/100 ml) for at least one monitoring event (Table 6-13). Faecal contamination of a water body can be caused by a number of human and animal vectors.

As cattle grazing is the current land use of the Study Area and adjacent surrounds, it is likely that the faecal coliform concentrations identified during monitoring are associated with the presence of cattle onsite (Table 6-13).

**Table 6-13 Faecal Coliform (cfu/100 ml) Summary Statistics**

| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Minimum | 10 | 40 | 60 | 20 | 30 | 20 | 20 | 24 | 64 |
| 20th percentile | 50 | 140 | 74 | 30 | 42 | 36 | 26 | 30 | 69 |
| Median | 82 | 245 | 160 | 73 | 56 | 79 | 90 | 89 | 90 |
| Average | 71 | 2028 | 142 | 399 | 161 | 602 | 238 | 522 | 97 |
| 80th percentile | 100 | 500 | 200 | 200 | 237 | 1400 | 370 | 1100 | 124 |
| 95th percentile | 100 | 8375 | 200 | 1550 | 434 | 1850 | 715 | 1625 | 136 |
| Maximum | 100 | 11000 | 200 | 2000 | 500 | 2000 | 830 | 1800 | 140 |
| WQOs | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact | 10 direct contact 1000 indirect contact |

### 6.2.2.9 Turbidity

**Surface Water**

Turbidity is a measure of suspended particulate matter in water. Turbidity is known to fluctuate naturally with changes in flow regimes and rates of particle re-suspension. The bulk movement of suspended solids is often associated with high flow events (Dunlop *et al*., 2005). Levels of turbidity within a system are closely linked to environmental characteristics of the system including sediment grain size and the presence and prevalence of phytoplankton and organic matter. High levels of suspended sediment are noted by Dunlop *et al*. (2005) to be a major contributor to the turbidity of Queensland streams. Other contributors to turbidity measures include organic matter, biological matter and water colour (e.g. tannin stained waters) (Dunlop *et al*., 2005). Sources of suspended sediment can include point sources (e.g. stormwater drains – not present in the Study Area), diffuse land run off due to erosion of terrestrial soils (ANZECC and ARMCANZ, 2000) and alluvial processes within river channels (Dunlop *et al*., 2005) that result in sediment re-suspension.

Spatial and temporal variations in turbidity were observed throughout the program (Table 6-14 and Figure 6-20). Missing values at Site 4, Site 5 and Site 6 (Figure 6-20) are related to probe malfunction and site access issues. Sites 10 – 12 were dry throughout the assessment, and therefore do not have associated turbidity data. The highest turbidity values were recorded in April at the start of the monitoring program, which coincided with the end of the wet season. As monitoring progressed into the dry season and water flow decreased, the turbidity values decreased such that some sites were consistent with guideline values. In September 2011, towards the end of the dry season, turbidity generally increased to values substantially greater than the WQOs (Figure 6-20).

The sites located on the Carmichael River (Sites 1 – 4) were fairly comparable to each other; turbidity at these sites ranged from less than 5 NTU to greater than 220 NTU. The median turbidity (Figure 6-20) of the Carmichael River sites was typically greater than the sites located in the farm dams (Sites 6 – 9) and on Cabbage Tree Creek (Site 5), which was not flowing during sampling.

The range of turbidity experienced at the farm dam sites was less than the Carmichael River sites, with Site 7, located at Swamp Tank dam, displaying the smallest range of the program (56 NTU; Table 6-14). The minimum turbidity value at Site 6 was higher than all other sites. Similarly, Site 6 displayed the highest median and average turbidity values, indicating that occurrences of lower turbidity were not as common at this site compared to the other still water bodies.

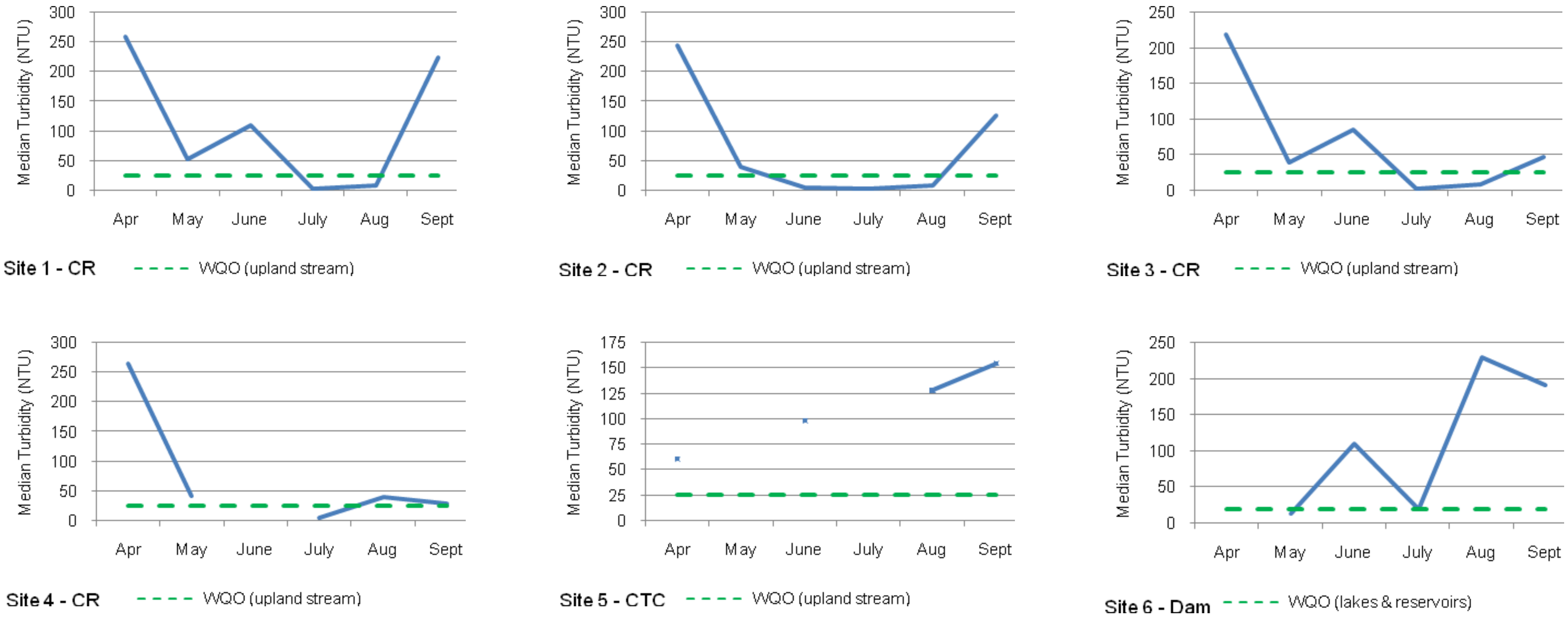
It is expected that sediment re-suspension in the flowing river is the cause of the spatial variation between the river and still water bodies. It is likely that the observed temporal variations in turbidity are linked to the changes in the onsite flow regime and associated process of evapo-concentration. All of the sites experienced a decrease in depth through time.

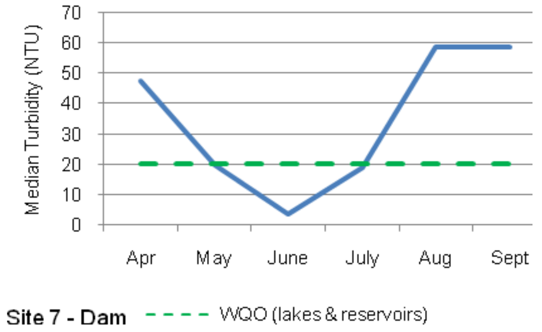
The change in depth at the Carmichael River sites is likely to have increased the potential for alluvial sediment re-suspension. None of the sites displayed turbidity values consistent with the nominated WQOs. As such, the nominated WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the Project (Mine). The development of site specific WQOs will need to take the large observed temporal variation into consideration.

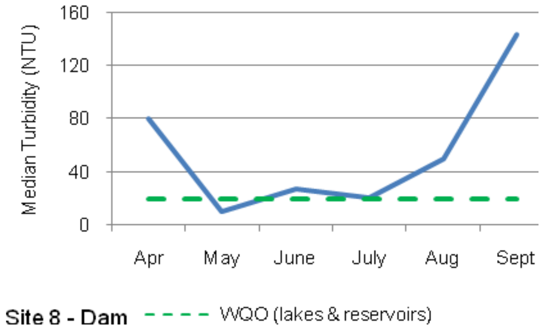
### Table 6-14 Turbidity (NTU) Summary Statistics

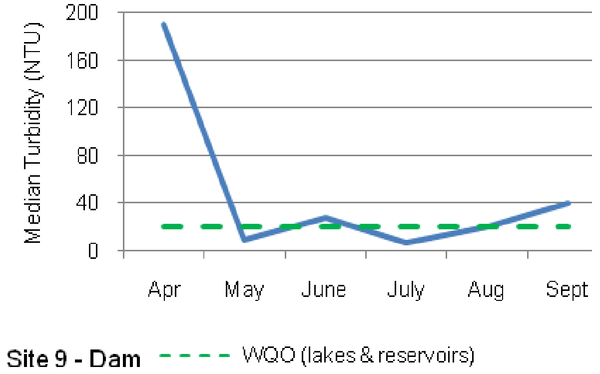
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Number of samples (n) | 60 | 60 | 60 | 50 | 40 | 50 | 60 | 60 | 60 |
| Minimum | 3.00 | 2.30 | 2.00 | 4.70 | 4.70 | 12.70 | 3.60 | 9.80 | 6.60 |
| 20th percentile | 8.38 | 3.98 | 7.70 | 23.54 | 59.30 | 17.10 | 18.34 | 18.76 | 10.20 |
| Median | 81.35 | 23.20 | 39.30 | 40.05 | 98.50 | 110.20 | 33.55 | 35.30 | 27.00 |
| Average | 110.02 | 70.00 | 64.20 | 76.18 | 107.28 | 113.01 | 34.56 | 56.20 | 49.60 |
| 80th percentile | 224.52 | 125.42 | 85.30 | 86.80 | 154.52 | 201.80 | 58.38 | 83.02 | 40.68 |
| 95th percentile | 264.15 | 247.05 | 219.10 | 266.00 | 264.74 | 232.00 | 59.51 | 159.16 | 190.11 |
| Maximum | 267.00 | 257.00 | 223.00 | 267.00 | 267.00 | 232.00 | 59.60 | 195.60 | 192.80 |
| WQOs | 25.00 upland streams | 25.00 upland streams | 25.00 upland streams s | 25.00 upland streams | 20.00 lakes & reservoirs | 20.00 lakes & reservoirs | 20.00 lakes & reservoirs | 20.00 lakes & reservoirs | 20.00 lakes & reservoirs |

## Figure 6-20 Median Turbidity (NTU) Values for each Site through Time






Note: Sites 10 – 12 were dry during sampling

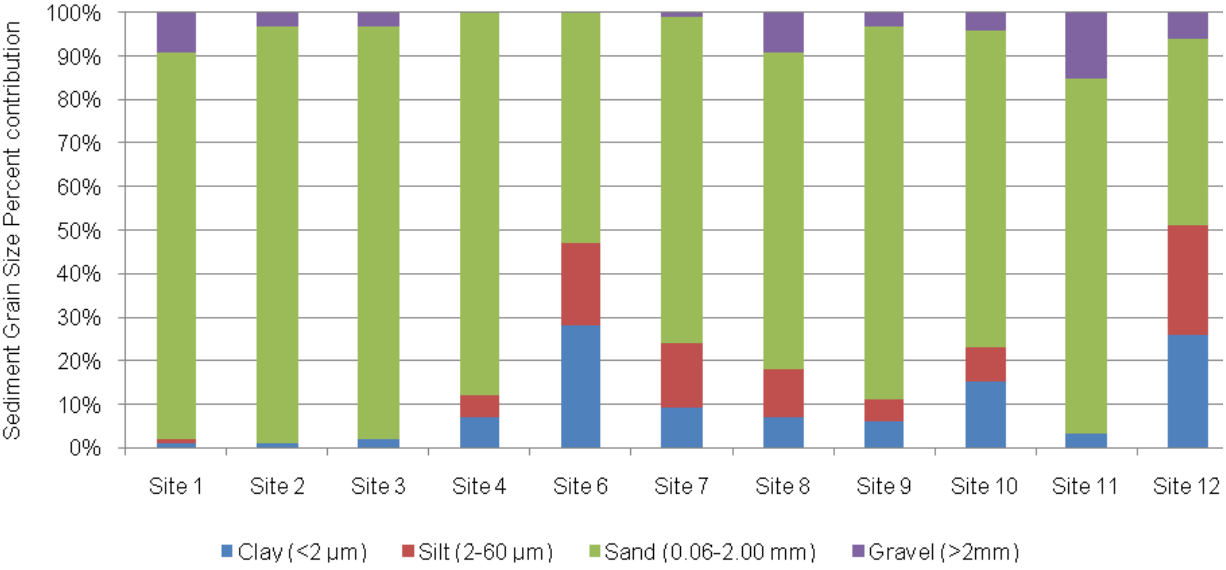
In-stream sediment quality testing undertaken as part of the monitoring program comprised testing for physical parameters, total metals, nutrients, biological parameters and hydrocarbons. A table of all in-stream sediment quality analytical results is provided in Volume 4 Appendix Q Mine Water Quality. Sampling of in-stream sediments at Cabbage Tree Creek was not achieved due to site access restrictions. References to still water body sites in relation to in-stream sediment quality are relate to the farm dam sites (Sites 6 – 9).

Physical parameters assessed as part of the monitoring program were sediment grain size, total organic carbon and moisture content. The latter two parameters were tested to assist in interpretation of analytical results and results are provided in Volume 4 Appendix Q Mine Water Quality. Sediment grain size results are below.

The sediment composition across the Study Area was dominated by sands (0.06 – 2 mm; Figure 6-21). The Carmichael River sites (Sites 1 – 4) were comprised of sand, gravel, clay and silt, at an average ratio of 92:4:3:1. Sampling of in-stream sediments at Cabbage Tree Creek was not achieved due to site access restrictions. The still water body sites (Sites 6 – 9) contained less sand than the Carmichael River sites, comprising sand, clay, silt and gravel (average ratio of 72:12.5:12.5:3). The sites with no water contained an average ratio of 66:15:11:8 of sand, clay, silt and gravel.

As shown in Figure 6-21, the Carmichael River sediments contained a greater proportion of coarse material, and conversely a smaller proportion of fine material on the river beds compared to the sites with no flow, or no water. This is likely associated with the flow characteristics of the Carmichael River, whereby fine materials are more easily mobilised and transported from the bed than coarser materials. This is supported by the turbidity findings, which identified high loads of fine sediments suspended in the water column.

**Figure 6-21 Sediment Grain Size Results for each Site**




Note: Cabbage Tree Creek (Site 5) not sampled

#### 6.2.2.10 pH

**Surface Water**

pH is a measure of the acidity or alkalinity of water. The pH of surface waters can be highly variable being driven by local and regional factors such as underlying geology, climate, land use, organic loading and flow regime. Most natural freshwaters range in pH from 6.5 (slightly acidic) to 8.0 (slightly alkaline; ANZECC and ARMCANZ, 2000). The QWQG (DERM, 2009a) considers extremes of pH to be less than 5 and greater than 9.

All sites located on the Carmichael River (Sites 1 – 4) were consistently outside the identified WQO range (6.5 – 7.5). pH at these sites ranged from 7.7 – 8.48, which, is marginally above the upper WQO. The Carmichael River sites all displayed a similar temporal pattern in pH, with little spatial variation between sites during each of the events. An investigation of the soil properties of the immediate surrounds identified that the soil types are alkaline (refer Volume 4 Appendix L Soils Report). It is expected that the soil alkalinity strongly influenced the alkaline pH levels of water quality of the Carmichael River.

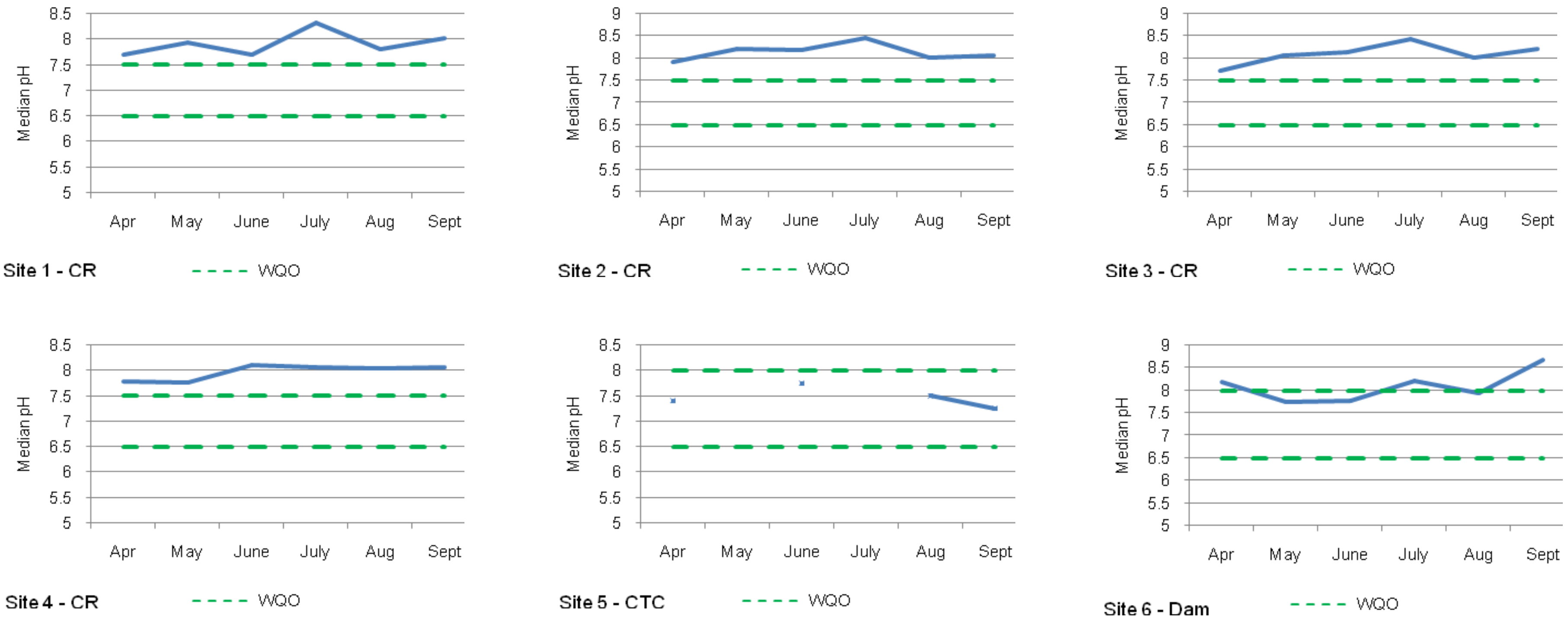
The pH of the still water bodies (Site 5, Cabbage Tree Creek and Sites 6 – 9, farm dams) were also regularly above identified WQOs (6.5 – 8.0). Missing data points at Site 5 are related to site access issues encountered during monitoring. pH at the still water sites showed a greater variation within each site, with ranges varying from 0.89 pH units at Site 5 to 2.64 pH units at Site 9. Extreme values of pH (> 9) were recorded at Site 7, Site 8 and Site 9. These values were recorded at the end of the monitoring program (September) at Site 7 and Site 8, and at the start of the monitoring program (April) at Site 9. Temporal patterns at the still water sites were not as distinct as those observed at the Carmichael River sites. Similarly, spatial variability between the still water sites was more pronounced during each monitoring event.

None of the sites displayed pH values consistent with the nominated WQOs. As such, the nominated WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the Project (Mine). The development of site specific WQOs will need to take the large observed temporal variation into consideration.

Table 6-15 pH Summary Statistics

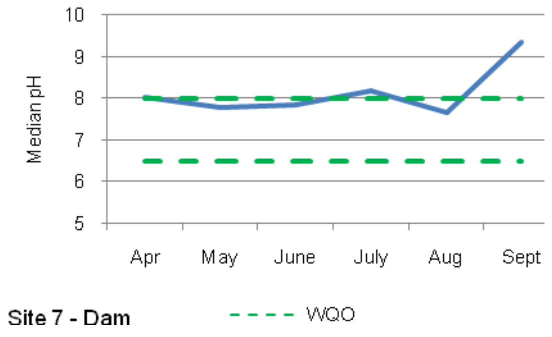
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Number of samples (n) | 60 | 60 | 60 | 60 | 40 | 60 | 60 | 60 | 60 |
| Minimum | 7.70 | 7.90 | 7.71 | 7.70 | 7.23 | 7.75 | 7.65 | 7.88 | 6.68 |
| 20$^{th}$ percentile | 7.71 | 7.95 | 8.01 | 7.78 | 7.40 | 7.77 | 7.77 | 7.99 | 7.59 |
| Median | 7.89 | 8.13 | 8.10 | 8.06 | 7.52 | 8.01 | 7.94 | 8.53 | 7.80 |
| Average | 7.92 | 8.14 | 8.09 | 7.97 | 7.64 | 8.08 | 8.14 | 8.58 | 7.95 |
| 80$^{th}$ percentile | 8.03 | 8.24 | 8.21 | 8.07 | 8.07 | 8.25 | 8.21 | 9.10 | 8.49 |
| 95$^{th}$ percentile | 8.34 | 8.47 | 8.43 | 8.12 | 8.11 | 8.69 | 9.35 | 9.41 | 9.32 |
| Maximum | 8.34 | 8.48 | 8.43 | 8.12 | 8.12 | 8.69 | 9.36 | 9.41 | 9.32 |
| WQOs | 6.5-7.5 upland streams | 6.5-7.5 upland streams | 6.5-7.5 upland streams | 6.5-7.5 upland streams | 6.5-8.0 lakes & reservoirs | 6.5-8.0 lakes & reservoirs | 6.5-8.0 lakes & reservoirs | 6.5-8.0 lakes & reservoirs | 6.5-8.0 lakes & reservoirs |

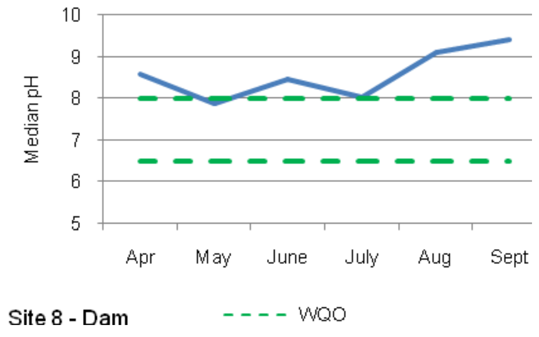
**Figure 6-22 Median pH Values for each Site through Time**

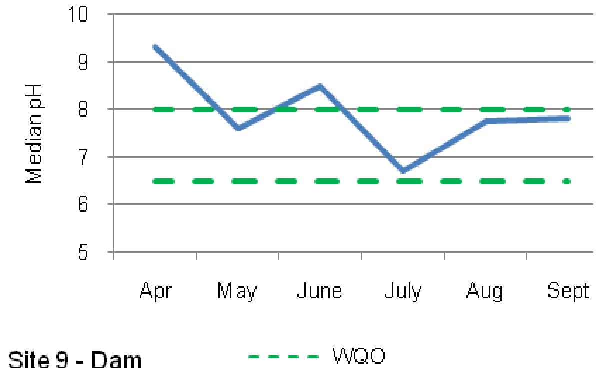




41/25215/437863




Note: Sites 10 – 12 were dry during sampling

#### 6.2.2.11 Dissolved Oxygen

**Surface Water**

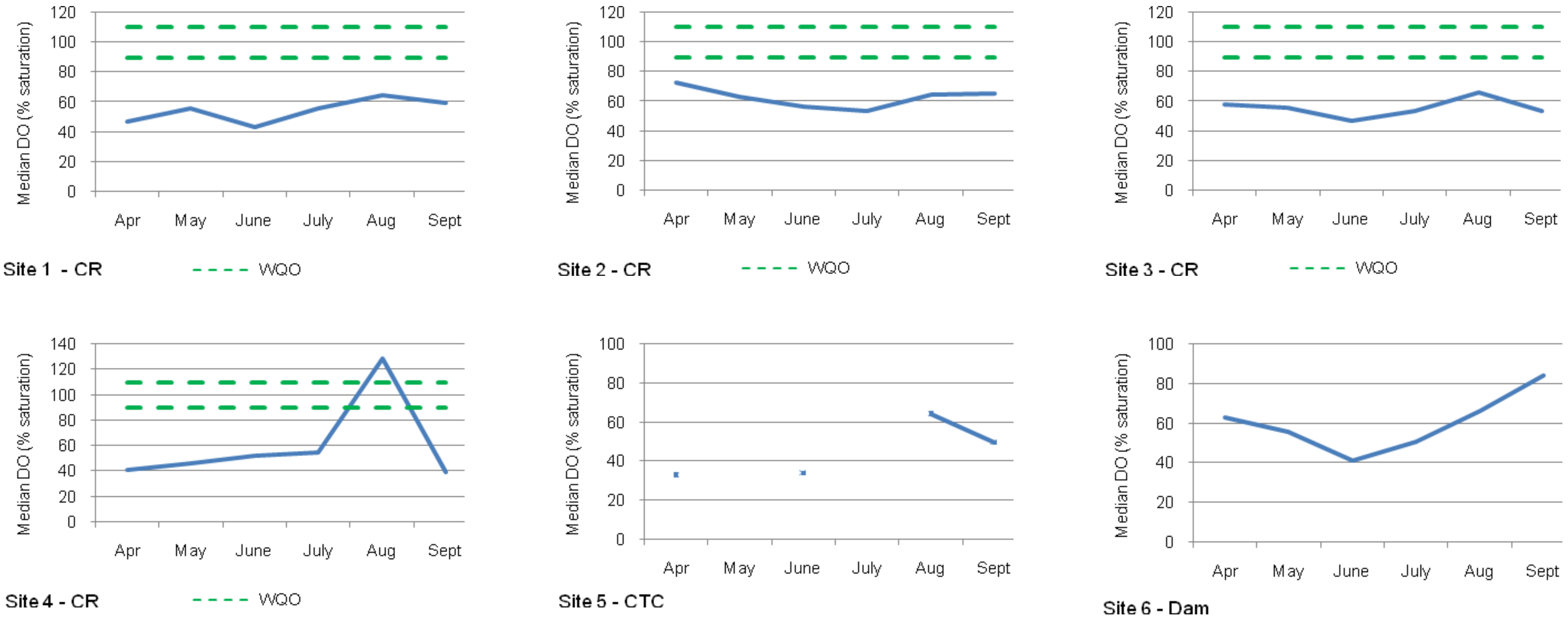
Values of DO displayed both temporal and spatial changes (Table 6-16 and Figure 6-23), which is not unexpected given the number of different factors that influence DO concentrations. Missing values at Site 5 are related to the inaccessibility of the site during some sampling events. All DO concentrations recorded at all sites throughout the monitoring program were outside the WQO range (Figure 6-23). The QWQG (DERM, 2009a) states that the DO guidelines for freshwater should only be applied to flowing waters. Stagnant pools in ephemeral waters can naturally experience DO levels below 50 per cent saturation (DERM, 2009a), which is consistent with the findings of the monitoring program.

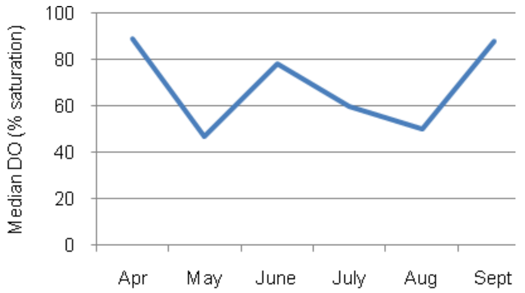
The distinct spatial patterns observed in the turbidity results were not present in the DO results. DO results at Sites 1 – 3 on the Carmichael River followed a similar temporal pattern (Figure 6-23), and displayed a range of less than 25 per cent saturation (Table 6-16). DO concentrations at Site 4, also located on the Carmichael River, were more comparable to those recorded at Site 5 (Cabbage Tree Creek) than the other Carmichael River sites. These two sites displayed a DO concentration range of greater than 90 per cent saturation (Table 6-16). The dam sites (Sites 6 – 9) generally followed a similar temporal pattern (Figure 6-23). These sites also displayed comparable ranges in DO concentration; approximately 45 per cent saturation (Table 6-16).

**Table 6-16 Dissolved Oxygen (per cent saturation) Summary Statistics**

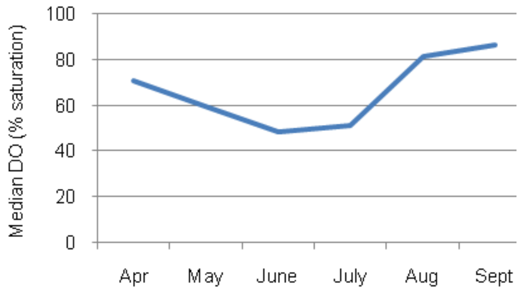
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Number of samples (n) | 60 | 60 | 60 | 60 | 40 | 60 | 60 | 60 | 60 |
| Minimum | 42.40 | 53.00 | 47.20 | 37.90 | 31.03 | 40.40 | 46.28 | 46.40 | 35.80 |
| 20th percentile | 45.61 | 56.28 | 53.14 | 40.33 | 34.20 | 50.40 | 48.56 | 50.80 | 49.48 |
| Median | 55.84 | 64.18 | 55.03 | 49.11 | 40.40 | 59.47 | 69.40 | 64.74 | 58.35 |
| Average | 54.16 | 62.97 | 55.95 | 60.11 | 51.11 | 60.40 | 68.79 | 66.48 | 59.77 |
| 80th percentile | 59.60 | 67.24 | 59.17 | 55.86 | 63.76 | 67.58 | 88.12 | 83.14 | 75.90 |
| 95th percentile | 64.82 | 73.48 | 66.41 | 129.72 | 127.71 | 84.88 | 90.31 | 87.91 | 81.61 |
| Maximum | 65.20 | 76.46 | 67.90 | 130.50 | 130.50 | 86.60 | 91.76 | 89.90 | 82.27 |
| WQOs | 90-110 upland streams | 90-110 upland streams | 90-110 upland streams | 90-110 upland streams | n/a | n/a | n/a | n/a | n/a |

**Figure 6-23 Median Dissolved Oxygen (per cent saturation) Values for each Site through Time**

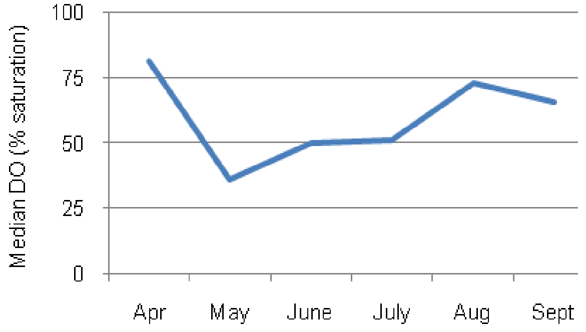




Site 7 - Dam



Site 8 - Dam



Site 9 - Dam

Note: Sites 10 – 12 were dry during sampling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#### 6.2.2.12 Temperature

**Surface Water**

No WQOs for temperature are available for data comparison. Recorded water temperature varied in accordance with seasonality (and air temperatures) throughout the monitoring period, with minimum temperatures recorded in June at all sites (Table 6-17 and Figure 6-24; missing data at Site 5 due to site access issues). Spatial variation in temperature was also observed (Figure 6-24), with the sites on the Carmichael River (Sites 1 – 4) generally recording lower temperatures to those in the still water bodies (Cabbage Tree Creek and dam sites).

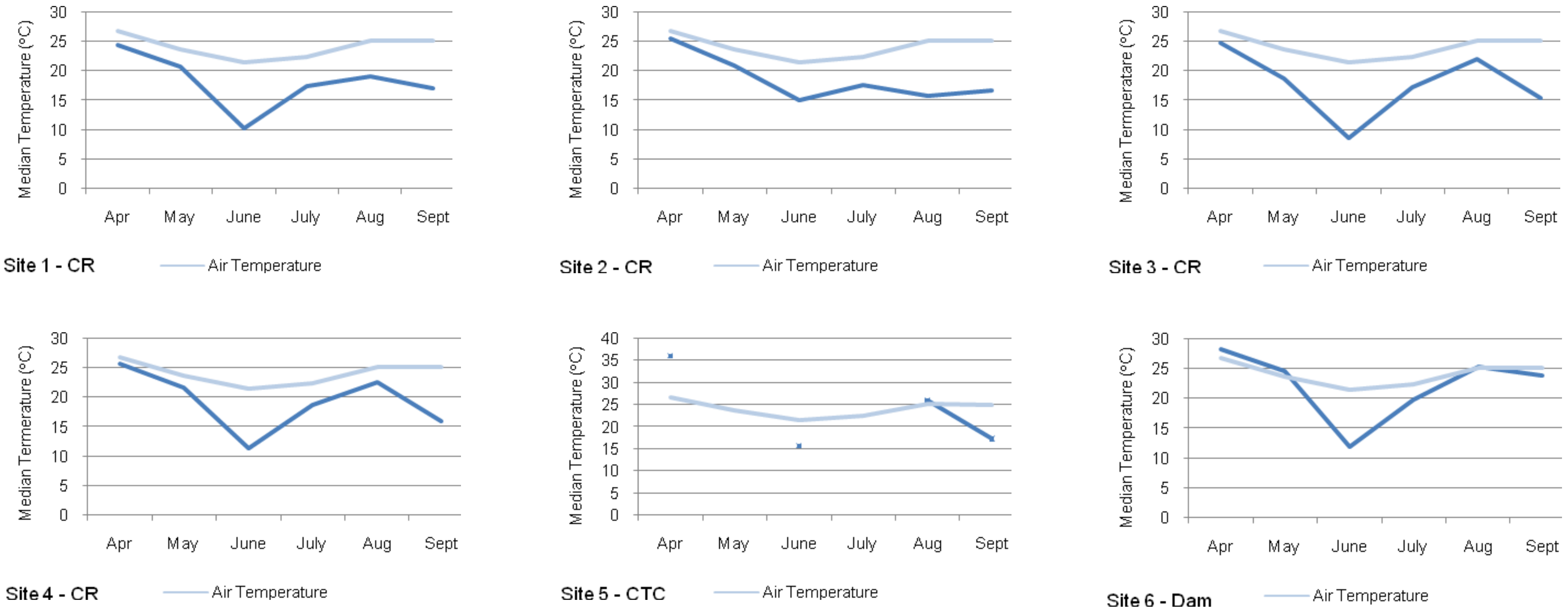
Temporal variation in temperature at the Carmichael River sites ranged from 10°C at Site 2 to 16°C at Site 3 (Table 6-17). In contrast, sites located in the still water bodies displayed a higher temporal variation with ranges from 16°C at Site 6 to 25°C at Site 5 (Table 6-17). The contrast in temporal variation trends is associated with the temperature maxima; there was less variation between river and still water body sites at the lower temperatures than at the higher temperatures.

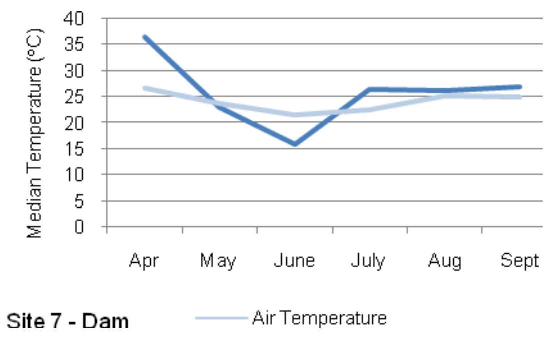
The differences in temperature between the Carmichael River sites and the still water bodies is likely associated with the high degree of shading by riparian vegetation at the river sites. The still water bodies had limited to no shading and would thus be more influenced by direct radiance from the sun, leading to heating of the water body. This indicates that shading of water bodies provides a buffering capacity against variations in temperature.

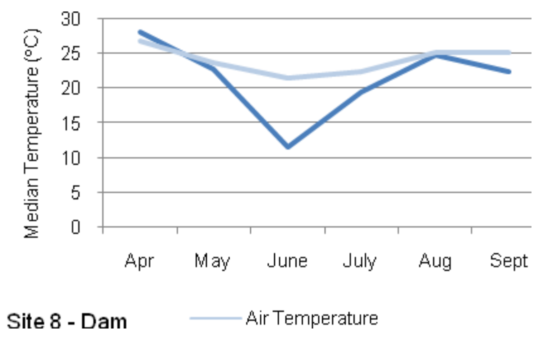
**Table 6-17 Temperature (°C) Summary Statistics**

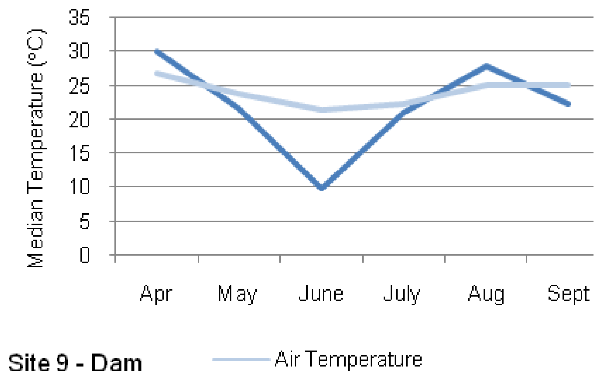
| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 | Site 9 |
|---|---|---|---|---|---|---|---|---|---|
| Number of samples (n) | 60 | 60 | 60 | 60 | 40 | 60 | 60 | 60 | 60 |
| Minimum | 10.30 | 15.00 | 8.60 | 11.30 | 11.30 | 12.00 | 15.80 | 11.50 | 9.90 |
| 20th percentile | 17.00 | 15.68 | 15.40 | 15.90 | 15.90 | 19.90 | 23.20 | 19.40 | 21.10 |
| Median | 18.30 | 17.15 | 18.00 | 20.15 | 17.30 | 24.50 | 26.45 | 22.65 | 22.00 |
| Average | 18.19 | 18.55 | 17.79 | 19.30 | 22.54 | 22.35 | 25.96 | 21.54 | 22.17 |
| 80th percentile | 20.90 | 20.92 | 22.00 | 22.60 | 26.20 | 25.50 | 27.10 | 24.82 | 27.90 |
| 95th percentile | 24.40 | 25.50 | 24.80 | 25.70 | 36.10 | 28.30 | 36.60 | 28.20 | 30.11 |
| Maximum | 24.40 | 25.50 | 24.80 | 25.70 | 36.20 | 28.30 | 36.60 | 28.20 | 30.20 |
| WQOs | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

## Figure 6-24 Median Temperature (°C) Values for each Site through Time






Note: Sites 10 – 12 were dry during sampling; air temperature data sourced from BoM, 2011

### 6.2.3 Flows

#### 6.2.3.1 Surface Water Flows

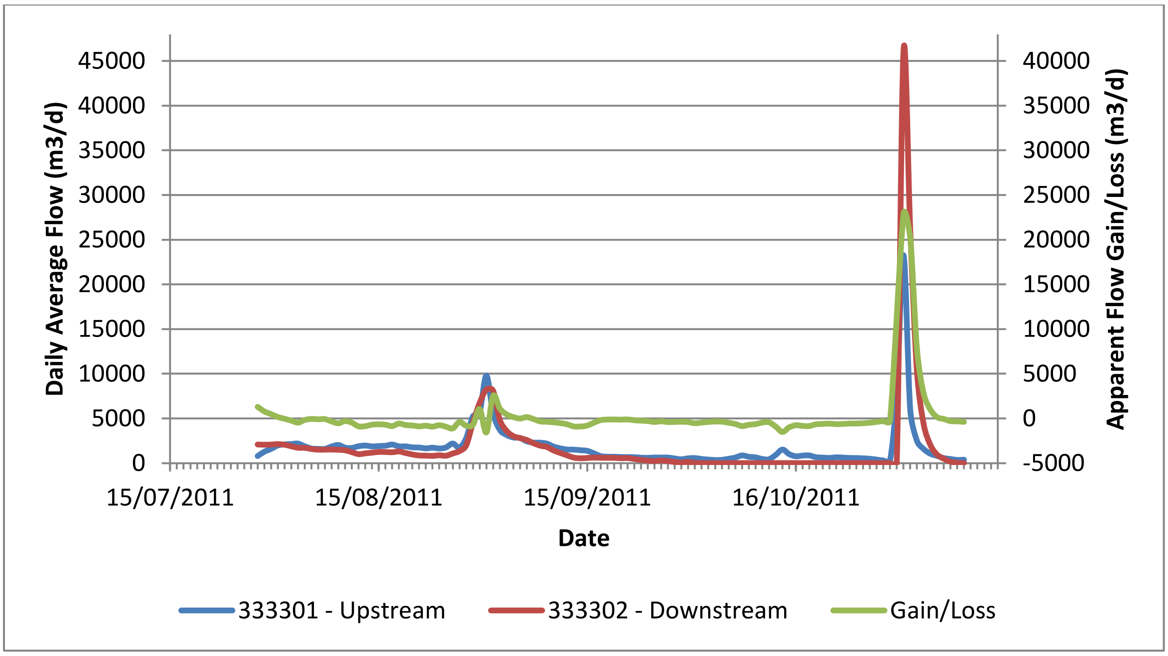
As discussed, two surface water monitoring stations have been established as part of the current study within Study Area on the Carmichael River, one close to the upstream boundary of the lease (Station No. 333301) and one close to the downstream boundary (Station No. 333302). These stations provide information on surface water levels and flows for various technical studies for the EIS. A hydrograph of the flow data collected to date, 28 July to 10 November 2011, is shown in Figure 6-25. It should be noted, however, that the estimates of flow are currently understood to be based on a stage-discharge relationship derived from a single flow gauging event. Gauging over a range of flow events is typically required for accurate flow estimation. As such, observed flow data for these gauges should be treated with some caution.

Nevertheless, the available flow data are considered to suggest the following:

- Continuous flow has been observed at the upstream gauge despite rainfall being limited to two events in late August and early November. This suggests that groundwater discharge to the Carmichael River upstream of the Study Area is occurring and is consistent with the upward gradient observed at site C027 close to the western margin of the lease.
- Apparent flow losses between the upstream and downstream gauges during dry periods. This is consistent with the downward gradient observed from river bed to groundwater at sites C025 to C029 close to the eastern margin of the lease.

One possible alternative explanation for the observations is that dry season flows in the Carmichael River are supported primarily by discharges from the Doongmabulla Springs and that direct groundwater discharge to the river itself is negligible.

**Figure 6-25 Surface Water Flows and Losses, Carmichael River**



#### 6.2.3.2 Groundwater Levels and Gradients

Data for the riverside monitoring location C027 that includes monitoring in the Quaternary alluvium (C027P1) and underlying Tertiary deposits (C027P2) indicates:

- An upward gradient from the Tertiary deposits to the overlying alluvium
- Groundwater levels in the alluvium are typically above the bed of the adjacent Carmichael River (based on a survey of the river bed elevation close to monitoring location C027).

This suggests the potential for groundwater discharge to the Carmichael River in this area, toward the west of EPC1690.

Data for two further nested riverside monitoring sites towards the east of the EPC1690 lease area (C025 and C029) show:

- Similar upward gradients from the Tertiary deposits to the overlying alluvium
- Groundwater levels in the alluvium, which appear to be below the bed of the adjacent river.

This suggests the potential for leakage from the river to groundwater in this area. Based on the groundwater level data alone it appears that the Carmichael River may switch from gaining flow from groundwater to losing flow to groundwater between the eastern and western boundaries of the site.

### 6.2.4 Environmental Values

EVs are defined by the EPP (Water) as the qualities of waterways that need to be protected to ensure that the ecological, social and economic values and uses of the waterway are maintained. WQOs are defined by the EPP (Water), as measurable indicators of the characteristics needed to protect the EVs of a waterway (refer to Section 6.1.2.1 and Section 6.1.2.2).

The Project (Mine) is located within the Burdekin Basin. Specific EVs and WQOs for the Burdekin Basin are expected to be scheduled in the EPP (Water) by December 2013. Draft WQOs are proposed in the Burdekin Water Quality Improvement Plan (Dight, 2009). These draft WQOs are consistent with the WQOs contained in the Queensland Water Quality Guidelines (QWQG) (DERM, 2009a) and the ANZECC guidelines (ANZECC and ARMCANZ, 2000).

The EVs considered applicable to the Project (Mine) are:

- Biological integrity of an aquatic ecosystem
- Suitability for minimal treatment before supply as drinking water
- Suitability for agricultural use
- The cultural and spiritual values of the water.

The WQOs considered applicable to the Project (Mine) are:

- Physical, including dissolved oxygen, pH, electrical conductivity and turbidity
- Biological, including Chlorophyll a and faecal coliforms
- Nutrients, including Ammonia as N, Nitrate (as N), Nitrite (as N), Nitrogen (Total), Organic Nitrogen, Phosphorus, Reactive Phosphorus as P
- Major Ions, including Calcium, Magnesium , Fluoride, Sulphate, TDS

- Metals and Metalloids including Aluminium, Arsenic, Beryllium, Boron, Cadmium, Chromium (III+VI), Cobalt, Copper, Iron, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium, Silver, Uranium, Vanadium and Zinc
- Polycyclic Aromatic Hydrocarbons including Naphthalene.

Analysis of the EVs identified in documents outlined in Section 6.1.2 against samples collected for the Project (Mine) have defined the environmental values applicable. The rationale for EVs assessed as not relevant to the Water Quality Study Area is outlined in Volume 4 Appendix Q. Those applicable to the Study Area are outlined in Table 6-18.

**Table 6-18 Environmental Values Applicable to the Study Area**

| Environmental Value | QWQG Definition (DERM, 2009a) | Relevant to the Study Area |
|---|---|---|
| Aquatic Ecosystems<br>Level 2: Slightly-moderately disturbed (SMD) ecosystem<br> | Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity.<br>The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation.<br>SMD systems could include rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism. | The catchment of the Study Area is considered to be SMD as the water resources receive runoff from land disturbed by grazing and are accessed by stock for watering |
| Primary Industries<br>Irrigation<br> | Suitability of water supply for irrigation | Some downstream crop irrigation occurs |
| Primary Industries<br>Stock Watering<br> | Suitability of water supply for production of healthy livestock. | Water resources within and downstream of Study Area used for stock watering |
| Cultural and Spiritual Values<br> | Indigenous and non-indigenous cultural heritage. | Traditional owners of the Study Area are the Wangan and Jagalingou people. Results of the assessment are of relevance to these groups |

As required by the QWQG (DERM, 2009a), WQOs for the protection of the EVs were identified.  Data obtained during the assessment has been compared to the nominated WQOs.  Table 6-19 outlines the EVs selected after analysis of existing conditions through desktop assessment and sampling and monitoring.

As outlined in Table 6-20, data collected did not consistently align with the WQOs. This was particularly evident at the end of the wet season (April), and at the end of the dry season (September).  As such, the nominated WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the Project (Mine).  The development of site specific WQOs will need to take the large observed temporal variation into consideration.

**Table 6-19 Project (Mine) Water Quality Objectives**

| Parameter | Units | Aquatic Ecosystems[#] | | Primary Industries* | |
|---|---|---|---|---|---|
| | | Upland streams | Lakes and reservoirs | Irrigation | Stock Watering |
| **Physical Parameters** | | | | | |
| Dissolved oxygen | % saturation | 90 - 110 | 90 - 110 | - | - |
| pH | | 6.5 - 7.5 | 6.5 - 8.0 | - | - |
| Electrical Conductivity | µS/cm | 168^ | 168^ | - | - |
| Turbidity | NTU | 25 | 1 - 20 | 2 - 15 | - |
| **Biological** | | | | | |
| Chlorophyll a | µg/L | - | 5 | - | - |
| Faecal coliforms | cfu/100 mL | | | 10 (direct contact)<br>1,000 (indirect contact) | 1,000 |
| **Nutrients** | | | | | |
| Ammonia as N | µg/L | 10 | 10 | - | - |
| Nitrate (as N) | mg/L | 0.158 | 0.158 | - | 400 |
| Nitrite (as N) | mg/L | - | - | - | 30 |
| Nitrogen (Total) | µg/L | 250 | 350 | 5,000 – 125,000 | - |
| Organic Nitrogen | µg/L | 225 | 330 | | |

| Parameter | Units | Aquatic Ecosystems# | | Primary Industries* | |
|---|---|---|---|---|---|
| | | Upland streams | Lakes and reservoirs | Irrigation | Stock Watering |
| Phosphorus | mg/L | 0.03 | 0.01 | 0.05 - 12 | - |
| Reactive Phosphorus as P | mg/L | 0.015 | 0.005 | - | - |
| Major Ions | | | | | |
| Calcium | mg/L | - | - | - | 1000 |
| Magnesium | mg/L | - | - | - | 2000 |
| Fluoride | mg/L | - | - | 1 - 2 | 2 |
| Sulphate | mg/L | - | - | - | 1000 |
| TDS | mg/L | - | - | - | 2500 |
| Metals and Metalloids* | | | | | |
| Aluminium | mg/L | 0.055 | 0.055 | 5 - 20 | 5 |
| Arsenic | mg/L | - | - | 0.1 - 2 | 0.5 |
| Beryllium | mg/L | - | - | 0.1 - 0.5 | - |
| Boron | mg/L | 0.37 | 0.37 | 0.5 | 5 |
| Cadmium | mg/L | 0.0002 | 0.0002 | 0.01 - 0.05 | 0.01 |
| Chromium (III+VI) | mg/L | 0.001 | 0.001 | 0.1 - 1 | 1 |
| Cobalt | mg/L | | | 0.05 - 0.1 | 1 |

| Parameter | Units | Aquatic Ecosystems# | | Primary Industries* | |
| --- | --- | --- | --- | --- | --- |
| | | Upland streams | Lakes and reservoirs | Irrigation | Stock Watering |
| Copper | mg/L | 0.0014 | 0.0014 | 0.2 - 5 | 1 |
| Iron | mg/L | | | 0.2 - 10 | - |
| Lead | mg/L | 0.0034 | 0.0034 | 2 - 5 | 0.1 |
| Manganese | mg/L | 1.9 | 1.9 | 0.2 - 10 | - |
| Mercury | mg/L | 0.00006 | 0.00006 | 0.002 | 0.002 |
| Molybdenum | mg/L | | | 0.01 - 0.05 | 0.15 |
| Nickel | mg/L | 0.011 | 0.011 | 0.2 - 2 | 1 |
| Selenium | mg/L | 0.005 | 0.005 | 0.02 - 0.05 | 0.02 |
| Silver | mg/L | 0.00005 | 0.00005 | - | - |
| Uranium | µg/L | - | - | 10 - 100 | 200 |
| Vanadium | mg/L | - | - | 0.1 - 0.5 | - |
| Zinc | mg/L | 0.008 | 0.008 | 2 - 5 | 20 |
| Polycyclic Aromatic Hydrocarbons | | | | | |
| Naphthalene | µg/L | 16 | 16 | - | - |

# from the QWQG (DERM, 2009a); * from the ANZECC guidelines (ANZECC and ARMCANZ, 2000), range values for irrigation WQOs represent long-term trigger values (LTV) and short term trigger values (STV); ^ 75th percentile for Belyando-Suttor salinity zone (DERM 2009a).

## Table 6-20 Assessment of Data Exceedances of Nominated Water Quality Objectives

| Parameter | Aquatic Ecosystems | | Primary Industries | |
|---|---|---|---|---|
| | Upland streams | Lakes and reservoirs | Irrigation | Stock Watering |
| **Physical parameters** | | | | |
| Dissolved oxygen | ✓ | ✓ | - | - |
| pH | ✓ | ✓ | - | - |
| Electrical Conductivity | ✓ | ✓ | - | - |
| Turbidity | ✓ | ✓ | ✓ | - |
| **Biological** | | | | |
| Chlorophyll a | - | ✓ | - | - |
| Faecal coliforms | | | ✓ | ✓ |
| **Nutrients** | | | | |
| Ammonia as N | ✓ | ✓ | - | - |
| Nitrate (as N) | × | × | - | × |
| Nitrite (as N) | - | - | - | × |
| Nitrogen (Total) | ✓ | ✓ | × | - |
| Organic Nitrogen | ✓ | ✓ | | |
| Phosphorus | ✓ | ✓ | ✓ | - |
| Reactive Phosphorus as P | ✓ | ✓ | - | - |
| **Major ions** | | | | |
| Calcium | - | - | - | × |
| Magnesium | - | - | - | × |
| Fluoride | - | - | × | × |
| Sulphate | - | - | - | × |
| TDS | - | - | - | × |
| **Metals and Metalloids** | | | | |
| Aluminium | × | ✓ | ✓ | ✓ |
| Arsenic | - | - | × | × |

| Parameter | Aquatic Ecosystems | | Primary Industries | |
|---|---|---|---|---|
| Beryllium | - | - | × | - |
| Boron | × | × | × | × |
| Cadmium | × | × | × | × |
| Chromium (III+VI) | × | ✓ | × | × |
| Cobalt | | | × | × |
| Copper | ✓ | ✓ | × | × |
| Iron | | | ✓ | - |
| Lead | × | ✓ | × | × |
| Manganese | × | × | ✓ | - |
| Mercury | × | × | × | × |
| Molybdenum | | | × | × |
| Nickel | × | × | × | × |
| Selenium | × | × | × | × |
| Silver | × | × | - | - |
| Uranium | - | - | × | × |
| Vanadium | - | - | × | - |
| Zinc | ✓ | ✓ | × | × |
| Polycyclic Aromatic Hydrocarbons | | | | |
| Naphthalene | × | × | - | - |

✓ indicates as least one exceedance of the nominated WQO; × indicates no exceedances; - no available WQOs.

The parameters for SQOs for the Project (Mine) assessment are based on the Interim Sediment Quality Guidelines (ISQG) from the ANZECC guidelines (ANZECC and ARMCANZ, 2000). Refer Table 6-21.

Groundwater resources within the Study Area are not listed in Schedule 1 of the EPP (Water) and EVs relevant to the study area are as described in Part 3 – 6 (2) of the EPP (Water). Site specific WQOs in order to enhance or protect the EVs have derived from relevant water quality guidelines, such as the *Queensland Water Quality Guidelines* 2009 (QWQG) and the *Australia and New Zealand Fresh and Marine Water Quality Guidelines* 2000 (ANZECC 2000).

**Table 6-21 Project (Mine) Sediment Quality Objectives**

| Parameter | Interim Sediment Quality Guidelines Low* (mg/kg) | Interim Sediment Quality Guidelines High* (mg/kg) |
|---|---|---|
| Arsenic | 20 | 70 |
| Cadmium | 1.5 | 10 |
| Chromium (III+VI) | 80 | 370 |
| Copper | 65 | 270 |
| Lead | 50 | 220 |
| Mercury | 0.15 | 1 |
| Nickel | 21 | 52 |
| Silver | 1 | 3.7 |
| Zinc | 200 | 410 |
| Acenaphthene | 0.016 | 0.5 |
| Anthracene | 0.085 | 1.1 |
| Benz(a)anthracene | 0.261 | 1.6 |
| Benzo(a) pyrene | 0.43 | 1.6 |
| Chrysene | 0.384 | 2.8 |
| Dibenz(a,h)anthracene | 0.063 | 0.26 |
| Fluoranthene | 0.6 | 5.1 |
| Fluorene | 0.019 | 0.54 |
| Naphthalene | 0.16 | 2.1 |
| Phenanthrene | 0.24 | 1.5 |
| Pyrene | 0.665 | 2.6 |

*ISQG (Interim Sediment Quality Guidelines); from the ANZECC guidelines (ANZECC and ARMCANZ, 2000)

### 6.2.5 Surface Water Vegetation

Much of the landscape surrounding the Study Area has experienced broad-scale vegetation clearing, and as such, remnant vegetation coverage is fragmented. Connectivity of remnant vegetation at a landscape level is maintained by tracts of remnant vegetation including mature river red gum (*Eucalyptus camaldulensis*) and Paper Bark (*Melaleuca leucadendra*) associated with major watercourses including the Carmichael and Belyando Rivers.

Flows in the major watercourses including the Carmichael and Belyando River are understood to be relatively persistent and this is supported by flow data for the site. Even during extended dry periods these systems are thought to maintain a series of semi-permanent to permanent waterholes. This suggests that the major watercourses and the associated remnant riparian vegetation are groundwater dependent to a degree in the regions upstream of the Project (Mine). Consequently the fauna which are attracted to these areas are also thought likely to be dependent on groundwater to a degree, but indirectly.

### 6.2.6 Groundwater Dependent Ecosystems

Flows in the major watercourses including the Carmichael and Belyando River are understood to be relatively persistent. Even during extended dry periods these systems are thought to maintain a series of semi-permanent to permanent waterholes. This suggests the major water courses and the associated remnant riparian vegetation are, to a degree, groundwater dependent. Groundwater dependent ecosystems (GDEs) are unlikely to be present elsewhere in the Study Area. Minor creeks and rivers within the Study Area are understood to be ephemeral and are not associated with areas of remnant vegetation. This lack of remnant vegetation around ephemeral water courses is likely to be due to the greater depths to the water table away from main river systems. However, River Red Gums have been identified next to an unnamed ephemeral creek at the Study Area's southern end.

#### 6.2.6.1 Doongmabulla Springs

Doongmabulla Springs are listed on the Directory of Important Wetlands. They are a group of permanent artesian, fresh water springs (based on information provided in the *Directory of Important Wetlands - Information Sheet* for Doongmabulla Springs, Australian Government Department of Sustainability, Environment, Water, Population and Communities), located approximately 8 km west of Study Area. Doongmabulla Springs are part of the Barcaldine spring supergroup (regional clusters of springs associated with the GAB), located on the eastern margin of the GAB within a recharge area to the GAB, the 'GAB Eastern Recharge A – Queensland' GMA. Reference to information held within the Queensland Spring Database which is understood to be largely based on the work of Fensham and Fairfax (2005) suggests that the Doongmabulla complex comprises 11 separate springs.

The Doongmabulla spring complex is comprised of three groups – Little Moses, Moses and Joshua. All three groups are included within the Doongmabulla Nature Refuge. Cumulatively, these spring groups are estimated to have a daily flow rate of 1.35 ML (Fensham, pers comm. 16 January, 2012). It forms part of the Barcaldine GAB supergroup, located within the Belyando catchment (a part of the greater Burdekin River catchment).

The spring complex is situated on a gently undulating to undulating plain of Quaternary alluvium, surrounded by mid to late Triassic sandstone of the Moolayember formation (Bureau of Mineral Resources, Geology and Geophysics, 1972). It is located near the junction of three third order streams, Cattle Creek (in the south), Dyllingo Creek (in the centre) and Carmichael Creek (in the north). These watercourses converge within a kilometre of each other to form the Carmichael River. Much of this flow proceeds directly to the Carmichael River, contributing to its baseline flow. Further details relating to the ecological significance of the Springs is provided in Volume 4 Appendix N2 Doongmabulla Springs.

The mapped geology in the vicinity of the Doongmabulla Springs complex suggests that all of the springs are likely fed by groundwater from the Clematis Sandstone aquifer which in the case of most of the springs discharges through the overlying Moolayember Formation and/or Quaternary alluvium. This is consistent with the Australian Wetlands Database which describe Doongmabulla Springs as "derived from faults allowing water to flow from thin confining beds of the Great Artesian Basin aquifer".

Water quality sampling was undertaken at fourteen springs and two nearby creeks of the Doongmabulla Spring complex to characterise potential water sources to the springs and identify any variations in water quality (refer to Volume 4 Appendix Q Mine Water Quality Report).

Despite the apparent single aquifer source some potentially significant differences can be observed in the hydrochemistry of samples taken from the springs. Based on the limited geological and major ion data currently available these observed differences could be related to:

- The proximity of the source aquifer to the surface and/or thickness of the overlying confining layer
- The discharge rate of the individual springs and hence potentially differences in flow pathways to the surface
- Differences in the degree of post discharge evaporation occurring between the various spring heads.

#### 6.2.6.2 Mellaluka Springs

Reference to Queensland Spring Database also suggests the presence of two further springs around 10 km south of the Study Area lease area to the north of Mellaluka. These springs are identified as non-GAB Eastern Desert Upland springs typically associated with outcropping Dunda Beds. In this case, however, it is considered unlikely that the Dunda Beds are present in the vicinity of the Mellaluka Springs. The springs are mapped around 10 km east of the nearest area of Dunda Beds outcrop and the geology typically dips from east to west making it more likely that the springs are associated with older Permian units and/or near surface Quaternary / Tertiary units.

### 6.2.7 Existing and Potential Users

#### 6.2.7.1 Surface Water

An understanding of present and potential users and uses of water resources is integral in understanding the potential effects of the Project (Mine). Within the Study Area:

- Water resources receive runoff from land disturbed by grazing and are accessed by stock for watering
- Some downstream crop irrigation occurs
- Farm dams are used for stock watering only
- No aquaculture occurs within or immediately downstream of the Study Area
- No recreational fisheries within or immediately downstream of the Study Area
- No water-based recreation activities occur within or immediately downstream of the Study Area
- Traditional owners of the Study Area are the Wangan and Jagalingou people.

More than 90 per cent of the Study Area is currently under grazing for beef cattle production. Surface water resources are utilised for drinking water, either directly from the channels of the Carmichael and Belyando Rivers during the wet season, or from impounded water in dams.

There is no existing major public water infrastructure in the Belyando River catchment. However, a number of unregulated private weirs, pumps and inline/off-stream storages (or farm dams) exist for water-harvesting and irrigation. Most of this infrastructure has been constructed by local farmers to take advantage of the wet season flows and any base flow.

Homestead Stations taking stock water from waterways in the vicinity of the Project (Mine) are:

- Bygana
- Moray Downs
- Mount Gregory
- Albina
- Mellaluka
- Lignum.

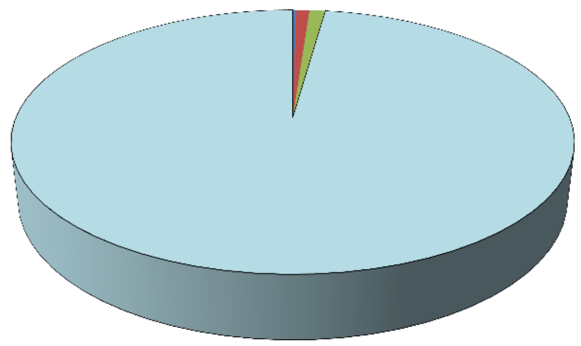
In the Belyando River catchment there are nine licences each for water harvest and impoundment, three for irrigation, two for stock and one each for channel diversion, construction (the Adani take from Dyllingo Creek) and domestic supply.

The licenced takes are in the reaches of the Belyando River that are potentially affected by the development and operation of the Project (Mine). The available licence information does not include references to daily, monthly or annual volumetric allowances or maximum diversion (or extraction) rates, or what water is used for. This limits the ability to assess the potential impact on local water users. The licence information shows only 650 ha under irrigation however it is estimated by Burdekin Dry Tropics Natural Resource Management Plan (BDTNRMP) (2005) that around 6,400 ha of cotton and grain crops are irrigated in the Belyando River Catchment with about half of this in Mistake Creek. Licences for Belyando River diversions (or water takes) obtained from DEHP is contained in Volume 4 Appendix P1 Mine Hydrology Report.

Figure 6-26 summarises water use in the wider Belyando/Suttor catchment. Urban and urban/industrial use is not specifically defined in BDTNRMP (2005), but is likely to cover potable supplies for small communities like Alpha at the head of the Belyando River and demand from mines in the Suttor River catchment for coal washing and dust suppression.

Figure 6-26 presents the distribution of four categories of water use the Belyando River catchment. The only water use category in the vicinity of the Project (Mine) is cattle grazing. Financial constraints within the farming industry may inhibit the more effective use of available water and land resources in the wider catchment. Further land suitability, agro-economic assessments and water resource assessments will be necessary to define the true agricultural potential of the region (BDTNRMP 2005). According to ANRA 2005, no sustainable yield studies have been conducted on the Belyando Suttor Surface Water Management Area.

**Figure 6-26 Water Allocation in the Belyando/Suttor Catchment**




Source: BDTNRMP 2005

#### 6.2.7.2 Groundwater

A review of the available data from the groundwater bore database (DERM, 2010) and site visits to registered bores within the EP1690 lease area indicated the following:

- Local groundwater is dominated by extraction for Stock and Domestic and Irrigation use
- To the west of Study Area, extraction is predominantly from the Triassic-age units of the GAB including the Moolayember Formation and the Clematis Sandstone
- Within and to the east of EPC extraction is thought to occur from Tertiary, Triassic and/or Permian-age sandstone units.

Based on comparison of the available groundwater chemistry data collected for the current study with relevant groundwater quality guidelines (for long term irrigation, livestock and drinking water (health)) potential uses for groundwater from each hydrogeological unit tested are as follows:

- **Alluvium. Potential for use for industrial purposes only**

  Monitoring results suggest that groundwater drawn from the Quaternary alluvium may not suitable be for drinking, based on the elevated observed concentrations of arsenic, manganese and uranium detected. It may also not be suitable for long term irrigation based elevated on concentrations of chloride, sodium, dissolved boron, iron and manganese. Lastly, it may also not suitable for livestock (on the basis of the observed elevated manganese concentrations).

- **Tertiary-age strata. Potentially only suitable for industrial purposes**

  TDS concentrations typically fall within the 'poor' (900 to 1,200 mg/L) and 'unacceptable' (>1,200 mg/L) palatability categories for drinking water making it generally not suitable for drinking. Groundwater in some areas does not appear to be suitable for long-term irrigation given significantly elevated concentrations of dissolved iron (0.29 to 24.9 mg/L), manganese (0.45 to 0.89 mg/L) and boron (0.9 to 1.29 mg/L) above the guideline values in some of the bores. TDS concentrations are also elevated above 8,100 mg/L (the guideline maximum TDS for irrigation) in some areas. The concentration of manganese is also generally above the guideline value for livestock (0.1 mg/L) and, in combination with elevated TDS in some areas, suggests that the water is generally unsuitable for livestock.

- **Dunda Beds. Potentially suitable for use as drinking water and/or industrial purposes**

  The measured TDS concentration for the single bore tested falls into the ‘good’ palatability category (0 to 600 mg/L TDS) for drinking water (ADWG, 2011) and all other parameters tested are below guideline level. However, the elevated iron concentrations present in the samples taken would make the groundwater unsuitable for long term irrigation and the results also indicate borderline suitability for livestock on the basis of dissolved manganese and pH.

- **AB seam. Potential for industrial use only**

  Generally not suitable for drinking water on the basis of palatability (aesthetic), given the measured TDS concentrations typically fall within the ‘poor’ (900 to 1,200 mg/L) and ‘unacceptable’ (>1,200 mg/L) palatability categories. The elevated observed concentrations of manganese (up to 0.9 mg/L) in some bores suggest that in some areas groundwater could also be unsuitable for livestock. Elevated concentrations of sodium (up to >2000 mg/L) and chloride (>5,000 mg/L) in some monitoring bores suggest that the groundwater from some areas would also be unsuitable for irrigation.

- **D seam. Potential for industrial use only**

  Generally potentially suitable for drinking water, however fluoride concentrations exceeded drinking water guideline values at two monitoring bores sampled indicating localised areas could be unsuitable for drinking. TDS concentrations typically fall into the ‘good’ and ‘fair’ (600 to 900 mg/L TDS) palatability categories for aesthetic quality. Concentrations of iron (up to 14.8 mg/L) indicate the groundwater would not be suitable for long term irrigation. The elevated observed concentrations of manganese and fluoride suggest that the water would also be generally unsuitable for livestock.

#### 6.2.8 Aquifer Properties

Hydraulic conductivity values estimated from slug tests and packer tests are summarised in Table 6-21. The majority of tests undertaken in the lease area (45 out of 58) were completed in Permian age strata since these units dominate the sub-surface geology and will largely control inflows to and the impacts of the proposed mine workings. The results of these tests suggest that the Permian strata are typically characterised by:

- Relatively low hydraulic conductivity and hence the median hydraulic conductivity for the different strata tested vary between 5.6x10-3 m/d for the D Seams to 5.0x10-4 m/d for the ‘interburden’ units between the AB and D seams
- A relatively high degree of variability. Test results vary across 5 orders of magnitude from 3.5 m/d to 5.8x10-5 m/d
- Generally higher hydraulic conductivity values are returned by tests undertaken in the coal seams, hence the highest median values are recorded in the AB and D Seams.

These observations are considered to be consistent with the findings of other similar analyses of similar Permian strata elsewhere in Queensland including summary statistics for Triassic and Permian age strata in the Surat and Bowen basin recently published by the Queensland Water Commission (QWC, 2012).

Only a small number of test results are available for the remaining strata present within the lease area and hence the results should be treated with some caution.

For instance tests undertaken on the Rewan Group within the site suggest a relatively high median hydraulic conductivity of $2.3x10^{-2}$ m/d.  However, whilst it is recognised that the Rewan Group is highly variable, it is typically considered to be an aquitard (QWC, 2012).  Regional data sets indicate a median hydraulic conductivity of $3.6x10^{-4}$ m/d and suggest that 95% of tests return values of less than $5.1x10^{-2}$ m/d (QWC, 2012).

Similarly based on the observed sandy lithology of the Quaternary alluvium the results of the two tests undertaken, which suggest hydraulic conductivity values of between $2.3x10^{-2}$ and $1.2x10^{-1}$ m/d and seem too low to be representative.

Conversely the hydraulic conductivity values returned by the three tests undertaken in Tertiary units, which suggest a median value of $5.3x10^{-2}$ m/d, seem relatively high given the clay dominated nature of this unit.

Results for the Dunda Beds suggest that the hydraulic conductivity of this unit is highly variable and vary from $2.2x10^{-3}$ to 3 m/d.  This is considered to be consistent with the variable lithological nature of strata attributed to the Dunda Beds in borehole logs.

**Table 6-22   Summary of Estimated Hydraulic Conductivity by Formation Tested**

| | | Estimated Hydraulic Conductivity (m/d) | | | |
|---|---|---|---|---|---|
| **Formation** | **Dominant Lithology** | **Minimum** | **Median** | **Maximum** | **Number of tests** |
| Quaternary Alluvium | Sand and Clayey Sand | $2.3x10^{-02}$ | $7.1x10^{-02}$ | $1.2x10^{-01}$ | 2 |
| Tertiary | Sandy Clay | $2.1x10^{-04}$ | $5.3x10^{-02}$ | $1.7x10^{-01}$ | 3 |
| Dunda Beds | Sandstone / Siltstone / Mudstone | $2.2x10^{-03}$ | $2.5x10^{-01}$ | $3.0x10^{+00}$ | 3 |
| Rewan Group | Mudstone / Siltstone | $1.7x10^{-04}$ | $2.3x10^{-02}$ | $2.9x10^{-01}$ | 5 |
| Permian overburden | Weathered Sandstone / Siltstone | $5.8x10^{-05}$ | $2.3x10^{-03}$ | $1.4x10^{+00}$ | 9 |
| AB Seam | Coal and Siltstone | $8.6x10^{-05}$ | $4.0x10^{-03}$ | $3.5x10^{+00}$ | 11 |
| Permian interburden | Sandstone / Siltstone | $8.6x10^{-05}$ | $5.0x10^{-04}$ | $1.3x10^{-03}$ | 6 |
| D Seam | Coal and Siltstone | $1.3x10^{-04}$ | $5.6x10^{-03}$ | $2.0x10^{-01}$ | 11 |
| Older Permian strata | Sandstone / Siltstone | $3.3x10^{-04}$ | $1.1x10^{-03}$ | $8.7x10^{-03}$ | 8 |

## 6.3 Description of Environmental Values – Offsite Infrastructure

### 6.3.1 Flows

#### 6.3.1.1 Surface Water Flows

The Project (Mine) offsite water supply infrastructure is proposed to be located within the Belyando River catchment, which takes up approximately 70 per cent of the Belyando Suttor sub catchment. The catchment suffers significant water losses due to natural breakouts and periods of no flow. North Creek and Obungeena Creek systems run for less than 20 kms and end in natural breakouts. These systems and associated drainage lines are ephemeral and, when in flow, suffer significant transmission losses before joining Belyando River.

#### 6.3.1.2 Groundwater Flows

Project (Mine) offsite water supply infrastructure is within the Bowen Unincorporated Area (UA), as per the *National Land and Water Resource Audit 2000 – 2002* (the Audit). The Bowen UA is bound to the west by the Great Artesian Basin Ground Management Unit (GMU) and to the north-west by the Isaac River GMU.

The extent of groundwater resources within the Bowen UA is not well studied and a sustainable yield has not been assessed. Preliminary estimates of the sustainable yield were calculated for the Bowen UA sub-catchments of Mackenzie, Nogoa, Comet and Isaac. The combined yield for sub-catchments is 260,000 ML/year, which characterised entire Bowen UA in the Audit (ANRA, 2009).

Predicted extraction rates within the Bowen UA for 2020 and 2050 of 15,000 ML/year and 20,000 ML/year respectively remain well below the sustainable yield of 260,000 ML/ year (ANRA, 2009). Groundwater abstraction for stock and domestic use are generally not recorded, however the amount of groundwater take is considered to be low overall. The Audit determined that major extractions are for agricultural and mining activities.

The Audit concluded that the Bowen UA resource is not under immediate threat requiring management plans for groundwater protection (ANRA, 2009). However, demand for groundwater is increasing with the expansion of the coal mining industry within the Bowen and Galilee Basins.

There is insufficient data to be able to definitively determine groundwater flow direction. However, groundwater will generally follow broad-scale topographical features. The low-lying topography of the Project (Mine) offsite infrastructure area is dominated by the Belyando River basin and the Suttor River basin. A ridge of outcropping bedrock in the middle of the Project (Rail) forms a natural ridge between the Belyando and the Suttor basins. Groundwater is thought to flow toward the low-lying rivers and the ridge forming a possible groundwater divide.

Further information on groundwater resources relevant to the proposed Project (Mine) offsite water supply infrastructure, including groundwater quality, flow direction and yields are identified as part of the Study Area for Section 1 of the Project (Rail) in Volume 4 Appendix AC Rail Hydrogeology Report.

### 6.3.2 Aquatic Ecosystems and Species

A one-day site inspection was undertaken in potential locations of water supply options, including existing bores and water storages and potential sites of water extraction. Assessment was undertaken at a number of sites to identify any existing environmental values, such as remnant or native regrowth vegetation and significant habitat values. An ecological assessment of existing storages and waterholes was undertaken, including identification of riparian or wetland habitat.

Five aquatic habitat types occur in EPC1690 and EPC1080, as follows:

- Lacustrine – Large, open, sparsely vegetation lakes and dams
- Palustrine – Large, non-flowing pools (e.g. swamps) with more than 30 per cent aquatic vegetation
- Riverine – Periodic or continuously flowing channels
- Drainage – Ephemeral drainage lines with little to no banks and loose, sandy substrate
- Gilgais – Small depressions holding ephemeral water.

As the Project (Mine) offsite infrastructure is adjacent to EPC1080 it is assumed that these habitat types are present. As such the:

- Belyando River and eastern North Creek are consistent with riverine habitat
- Obungeena Creek is consistent with lacustrine habitat, due to the presence of water storages; western portions of Obungeena Creek
- North Creek are expected to host drainage habitat types
- Gilgais are also expected to occur around the Project (Mine) area.

A number of Great Barrier Reef Wetland Protection Areas were identified in proximity to Belyando River and Obungeena Creek. No aquatic species listed under the *Environment Protection and Biodiversity Conservation Act 2009* or *Nature Conservation Act 1992* were identified or assessed as being likely to occur in the Project (Mine) offsite infrastructure area. Resident species were expected to be commonly occurring species of Least Concern status, along with some introduced species.

Refer to Volume 4 Appendix O1 Mine Aquatic Ecology Report for more information on the ecological assessment of the Project (Mine) offsite infrastructure.

#### 6.3.2.1 Groundwater Yield

No data is available on yields from the Tertiary aquifer. A yield of up to 11 L/sec was recorded from RN 30176 through possibly the Mt Hall Formation. Data for the alluvial aquifers suggests yields ranging from 0 L/s to 3.9 L/s (RN 90368). Anecdotal evidence and visual inspection of existing farm bores indicates that they will be unfit for commercial purposes because of their yields, size and age. Based on regional hydrogeology, areas with Tertiary, Triassic and Permian age beds are able to support industrial sized extractions. The estimated yield for each bore ranged from 0.1L/s to 4L/s.

#### 6.3.2.2 Groundwater Quality

Electrical conductivity (EC) of the groundwater is variable with values ranging from 373 µS/cm (RN 17980) in Tertiary sediments and up to 15,500 µS/cm (RN 12030175) in the Mt Hall Formation.

pH values range from slightly acidic to basic with pH levels of 6.7 (RN 17983) to 8.5 (RN 12030175), from Tertiary sediments and the Mt Hall Formation, respectively. No pH values are available for the alluvial sediments.

Very limited water quality data are available from the Groundwater Database (DERM, 2010). Of the data extracted, some pH, EC and/or total dissolved solids (TDS) data are available. Some bores have each recorded multiple readings though regular monitoring and other bores have a single reading (usually at the time the bore was installed). The table details the minimum, median (middle value) and maximum recorded value.

Laboratory data is also available for major ions for some of the bores, indicating that groundwater is typically a sodium/potassium-chloride type water (with the exception of RN 17982, which can be classified as sodium/potassium-bicarbonate type water). The data suggests that the majority of the groundwater samples are end-product water meaning that the groundwater has long residence times and is not actively recharged from rainfall or infiltration from surface water bodies.

### 6.3.3 Groundwater Dependent Ecosystems

Flows in the major watercourses including the Belyando River and Mistake Creek are understood to be relatively persistent and even during extended dry periods these systems are thought to maintain a series of semi-permanent to permanent waterholes. This suggests that the major water courses and the associated remnant riparian vegetation are groundwater dependent to a degree. Consequently, the fauna which are attracted to these areas are also thought likely to be dependent on groundwater to a degree, indirectly.

Outside of the riparian areas associated with the main watercourses then groundwater dependant ecosystems (GDEs) are unlikely to be present. The other minor creeks and rivers are typically ephemeral and are not associated with areas of remnant vegetation. This is understood to be related to elevated depths to water table away from the main river systems and little or no groundwater contribution to vegetation demands and/or river flows.

### 6.3.4 Interaction of Surface Water and Groundwater

Other than the Belyando River, all the watercourses in the offsite groundwater search area are highly intermittent or ephemeral. The Belyando River typically sustains flow for several months after rainfall ceases. The remaining creeks, following heavy rainfall typically stop flowing and retract into a few small water holes within a few days to weeks. Peak surface water flow is likely to occur between November and May, with February producing the highest average flow.

The ephemeral nature of the watercourses within the offsite groundwater search area suggests little to no significant groundwater base-flow during dry periods. The Belyando River sustains permanent water holes in some sections of the river, indicating that there is some base-flow, although this would be highly reduced during the dry season.

Recharge of alluvium underlying the creeks and rivers likely occurs during the wet season when surface water levels are highest. Recharge of Tertiary-aged aquifers is via rainfall recharge at outcrop areas and from percolation through alluvial deposits during peak flow of surface water. The underlying Permian and Cambrian aquifers are recharged through leakage from alluvial and Tertiary sediments and via direct recharge at outcrop areas.

### 6.3.5 Existing and Potential Users

#### 6.3.5.1 Surface Water

Existing in-stream storages, located at North Creek and Obungeena Creek, receive approximately 1 per cent of the flow attributed to the upper Belyando River system. The location of the Project

(Mine) is such that relatively few downstream users stand to be affected by the extraction of water (refer to Table 6-23).

**Table 6-23 Existing users downstream of Project (Mine) water extraction**

| ROP IQQM Node | Licence Type | Mean Annual Demand ML/yr |
|---|---|---|
| 233 | Stock And Domestic | 15.4 |
| 246 | Stock And Domestic | 30.2 |
| 279 | Stock And Domestic | 5.7 |
| 232 | Water Harvester | 950 |
| 291 | Irrigator | 560 |
| 292 | Water Harvester | 5,570 |
| 293 | Water Harvester | 2,750 |
| 300 | Water Harvester | 3,888 |
| 302 | Water Harvester | 1,150 |

Refer to Section 6.2.7.1 for more detail on water use within the Belyando-Suttor sub catchment.

#### 6.3.5.2 Groundwater

The Bowen UA consists of several groundwater resources that are being underutilised (ANRA, 2009). The achievable bore yields are generally below 5 L/second and consequently most groundwater development would be limited to stock and domestic supplies.

There are 11 existing boreholes within the Project (Mine) offsite infrastructure area which are used to water stock and provide a small supply to the Moray Downs farmhouse. The existing bores are illustrated on Figure 6-6. Anecdotal evidence and a visual inspection of the bores indicated that the bores are unsuitable for commercial purposes due to their depth, yields, size and age. A larger borefield that covers the Project (Mine) offsite infrastructure area has been proposed to provide water to the Project (Mine).

Refer to Appendix AC Rail Technical Hydrogeology Report for further details on the registered bores.

## 6.4 Potential Impacts and Mitigation Measures – Onsite Activities

### 6.4.1 Overview

Potential impacts of the Project (Mine) on water resource environmental values differ between construction and operation. While general construction activities may be undertaken within the framework of an Environmental Management Plan (EMP) (refer Volume 2 Sections 13 and 14), river levees, external and internal diversion drains will be developed within the Mine area and the Carmichael River corridor with the specific aim of protecting the environmental values of the water resources. The construction and ongoing impact during the operation of the Mine of this infrastructure, however, has the potential to also impact on the local environment, and the upstream and downstream ecosystem, infrastructure and water users.

Through surface and ground water sampling, monitoring, and modelling, an understanding of these potential impacts has been attained, and in turn mitigated and managed through the considered design of the Mine infrastructure and footprint, and the construction and operational activities. These have been developed in response to a thorough understanding of the existing environment and in accordance with the regulatory framework as outlined in Section 6.2, further supplemented through the findings of other relevant EIS technical reports (refer Volume 4). From this, protection and enhancement of the water resource environmental values will be achieved and measured against quantitative standards and indicators through an agreed monitoring, auditing and management process throughout the life of the Project (Mine).

Key potential impacts of the Mine construction and operation include on Study Area:

- Environmental flows
- Water quality
- Alteration to groundwater regimes.

### 6.4.2 Surface Water Flows

#### 6.4.2.1 Potential Impacts – Project (Mine) Onsite Operations

The Project (Mine) requires the following project components for successful operation:

- The Mine, consisting of the on mine infrastructure
- offsite infrastructure, including offsite water supply infrastructure.

The offsite infrastructure is located between two key drainage lines, on a consistent level, flat and elevated area. The potential impact of the offsite infrastructure will be further assessed upon the further development of the design. The mine infrastructure includes the:

- Open cut mine (located within EPC1690 and part of EPC1080)
- Underground mine (located within EPC1690) – northern, central and southern underground mines
- Mine infrastructure area (MIA), excluding the rail balloon loop (located within EPC1080)
- Out-of-pit dumps (located within EPC1080)
- Associated raw water and waste water management infrastructure .

The geological characteristics of the mine define the location of open cut and underground mining operations. These then define the optimal location of mine infrastructure and their interdependencies, including site access, services and infrastructure connecting the mine with offsite infrastructure and third party service providers. If on mine infrastructure is developed over coal deposits, those deposits will be difficult or unfeasible to extract. The layout of the infrastructure is therefore designed to avoid this. This, in turn, places parameters on the placement of water infrastructure within the mine.

The management of the Carmichael River, which bisects the mine east west, has been integrated in to the mine design. The initial mine design identified a 500 m corridor to be retained either side of the centre line of the Carmichael River to protect it and the riparian zone from mining operations. Subsequent to this initial design, hydrologic modelling of the Carmichael River regional catchment was undertaken to generate design flood flows and has been utilised in the design of water management infrastructure for the mine (Volume 4 Appendix P).

The out-of-pit dumps were initially located over the underground mining areas within EPC1690. Subsequent to the development of the 2011 Mine Plan, Adani secured the eastern portion of EPC1080, adjacent to the eastern boundary of EPC1690. EPC1080 will now be used for the out-of-pit dumps. .

Mine production is scheduled to commence on the southern side of the Carmichael River around 2047, when the Carmichael River will be spanned to allow access to the south. The development of a causeway was investigated in the initial design. However, the causeway would have a low flood immunity standard and would be overtopped by large floods and a large number of culverts would be required to provide 50 year ARI flood immunity. A haul road and conveyor crossing, associated bridge and flood protection levee at Carmichael River was instead designed.

Given that the crossing of the Carmichael River has the potential to have an impact on the existing flood regime, particularly flood levels, a preliminary design of the crossing has been undertaking using the hydraulic models to inform the design and minimise such potential hydraulic impacts. A preliminary drawing of the proposed haul road and conveyor crossing of the Carmichael River is provided in Volume 4 Appendix P1 Mine Hydrology Report. Key features of the concept design of the crossing include:

- A 180 m bridge comprising 7 x 25 m bridge spans located over the river channel
- Six 1 m diameter cylindrical piers aligned in the direction of flow for each bridge support
- Bridge deck level of 230 m AHD
- The bridge soffit level of 228.8 m AHD (i.e. a 1.2 m deep bridge deck structure). At this stage the soffit level is 0.7 m above the 50 year ARI flood level to allow for debris passage
- Four 3.1 m diameter culverts located approximately at a low point in the floodplain approximately 250 m from the centreline of the Carmichael River
- Four 2.75 m diameter culverts located at approximately 175 m from the centreline of the Carmichael River
- Riprap placement at and just downstream of the bridge to minimise scour potential and protect the abutments and piers due to high velocities through the bridge
- The haul road with a maximum longitudinal gradient of 10 per cent and 600 mm freeboard above 50 year ARI flood level
- The culverts are included to provide additional flow capacity, and therefore limit afflux, and to provide waterway capacity at naturally occurring floodplain channels in order to minimise impact to the ecology of the area. Circular pipe culverts have been used in the hydraulic model, but box culverts of equivalent cross-sectional area could be used instead
- The one-dimensional (HEC-RAS) analysis of the proposed design shows that it meets the design immunity criteria, in scope to refine the design if required. The two-dimensional developed case model analysis shows that the velocity guidelines are also met.

Hydrologic modelling of the Carmichael River regional catchment was undertaken to generate design flood flows. The 10 year, 50 year, 100 year and 1,000 year ARI design floods were determined. Two models were created, one for existing conditions and one for post-development conditions, which were then compared to quantify the change in flood flows in the Carmichael River, i.e. the potential impact of the Project (Mine).

The model estimated the potential runoff hydrograph from an individual sub-catchment based on rainfall intensities, temporal patterns and the definition of parameters describing the sub-catchment characteristics, including area, slope, roughness and fraction of impervious area. The change in sub-catchment area takes into account the development of new terrain and diverted or collected runoff areas. In order to protect the Mine infrastructure from receiving the runoff from sub-catchments, streams intersecting the Mine area will be diverted from either the north or south.

Upstream of the Study Area, flows in the Carmichael River will be unaffected by the post-development changes. However, within the Study Area, the change will result in the Carmichael River receiving additional flood flows form the diversion of the local creeks along the western boundary. In additional the development will change or remove a number of sub-catchment areas that previously contributed to the Carmichael River.

Peak flow estimates through modelling were analysed to determine the critical storm duration and hence the peak flow for each ARI event. Results indicate that the contribution of the diversion drains only creates a minor increase in peak flow at the haul road crossing. This is due to the effect of the short critical duration; relatively small flow contribution hydrographs of the diversion drains being largely attenuated by the dominant Carmichael River hydrograph.

Based on the results of the hydraulic modelling carried out as part of the Project (Mine), the change in flows at the Carmichael River levee is less than 1 per cent of peak flows for 10, 50 and 100 year ARI events. The change in 1,000 year ARI event is predicted to be 1.4 per cent. This location is where any increase in flow should be greatest due to the reduction in floodplain size and addition of diverted water from surrounding watercourses through the Project (Mine) site. Based on the limited change predicted for this location, it can be assumed that any change in peak flows downstream of the Project (Mine) will be less than these values and therefore insignificant in terms of impacts on any existing land uses.

A series of diversion drains are planned over the course of the Project (Mine). These drains will direct flows away from mine activities and be rehabilitated as mining activities progress. A case study was undertaken for a single diversion drain. The drain was designed with a conveyance capacity equal to a 100 year ARI event and a 600 mm freeboard.

The proposed drainage scheme takes into account an intention to retain flows to the east of the mining tenure as close to existing hydrology as possible, however some alteration to the hydrology of the Mine site is expected. The proposed external and internal diversion drains effectively redirect surface water from existing pathways, and reduce the existing catchment areas of affected creeks. Whilst some of the redirected water will be returned to its natural flow path, water management will result in some losses. Alterations to the hydrology of the mine site also mean that peak flows on some local waterways will increase. This in turn could potentially result in a reductions and increases to flows available to users downstream of the Project (Mine).

The impact of diversion is most likely to be higher at the eastern boundary of the Project (Mine) as creeks flow through the site from west to east. It is therefore here that the alteration to flows will be experienced by users.

In addition, afflux could cause flooding on existing infrastructure routes, in particular any existing roads. However, as the Study Area is relatively remote and undeveloped there are a limited number of roads or other infrastructure routes nearby which could be impacted. No change in existing flood extent or duration is predicted at any existing infrastructure corridors. The extent of afflux is unlikely to affect existing land use activities within the Study Area, including cattle grazing.

According to the Queensland government Scientific Advisory Group (SAG) guidelines, rainfall is likely to increase or decrease approximately 20 per cent by the end of the design life of the Project (Mine) – this is estimated at a 20 per cent increase for flood estimation purposes. The estimated potential peak flow rates under climate change conditions of a 20 per cent increase in rainfall intensity produces an average of 35 per cent increase in run-off.

Hydraulic modelling of the proposed levees under climate change-affected hydrology showed that the southern levee will overtop upstream of the haul road and conveyor crossing but not downstream, thereby keeping the open cut pit areas dry. On the northern side, overtopping occurs along the first two-thirds (from the east) of the levee alignment. Overtopping ceases downstream of the natural hill in the topography at approximately eight kilometres chainage.

While the above estimated flows shown an average increase of 35 per cent by the end of the mine lifespan due to climate change impacts, it is an estimate only. Other climate change scenarios are possible which may differ from those presented in this report. The risk of climate change over the period of the mine infrastructure and operations should be considered during future mine planning and design. Potential increases in peak flow rates and the resultant impact they may have on the operation of the flood protection infrastructure present a particular risk.

#### 6.4.2.2 Mitigation and Management

The management and mitigation of the potential impact of the Project (Mine) to environmental flow is primarily through the design of the raw and waste water management system. The Project (Mine) water management system will involve the management of:

- Clean water: rainfall runoff from areas that are not disturbed by mining activities
- Raw water (or external) supply: supplied through a pipeline from an external source and can (with minimal treatment) be treated to potable water standards
- Mine Affected Water (MAW): water of lesser quality than raw water that has been affected by the mine workings. MAW is available for reuse.

MAW comprises:

- Groundwater inflow from the pits
- Process water (used raw water or reused MAW) removed from the pits
- Coal Handling and Processing Plant (CHPP) process water
- Surface drainage water from catchment areas containing hazardous materials (e.g. workshop area and coal stockpile areas classed as 'industrial' catchment areas).

The raw and waste water management system for the Mine is designed to protect both the environmental values of water resources (regarding flows and water quality), and the Mine infrastructure. The water management system has been designed using hydrologic modelling (refer 6.1.1) and includes the development of:

- Levees
- External diversion drains

- Internal diversion drains
- Sediment basins.

Levee banks are proposed to reduce the risk of flood waters entering pits and to assist with the separation of mine affected areas, therefore reducing the amount of mine affected water (MAW). The proposed levees include:

- Levees located either side of the Carmichael River and extending to wrap around active open cut pits and out-of-pit waste rock dump areas to reduce the risk of Carmichael River flood waters from entering the pits. These levees are referred to as the Carmichael River levees and are required from approximately Year 2047 for the southern levee and from Year 2067 for the northern levee.
- Bunds around pit areas to prevent flooding due to runoff from local mine runoff within the Study Area in all years
- Minor levees either side of Eight Mile Creek inflow at the eastern edge of the mining tenure so as to safely pass the existing waterway between out-of-pit waste rock dump areas
- Minor levees around active pit areas to protect from flooding of local minor waterways
- Other levees to protect underground mine access areas from either local or regional flooding (to be designed when the locations of these access areas are confirmed).

The design criteria adopted for the preliminary design of the flood protection levees along the Carmichael River corridor includes:

- The alignment of the flood protection levees along the northern and southern sides of the Carmichael River corridor is based upon the alignment developed as part of the Mine plan (Runge, 2011)
- The flood protection levees along the northern and southern sides of the Carmichael River corridor, and the levees along the northern and southern external diversion drains, have been designed with crest levels set at the 1,000 year ARI flood level, with 600 mm of freeboard.
- Batter slopes on the levees are set at 1 vertical to ~~3~~ 5 horizontal, and a ~~3~~ 6 m top width of levee. Further design refinement is required upon confirmation of geotechnical engineering.
- Levees must provide 1000 year ARI flood immunity to the open cut pits, and a minimum of 100 year ARI immunity to the waste dump areas.

Hydrological modelling of the existing conditions indicates that the 100 year ARI flood is generally contained within a 1.5 km corridor centred on the river channel.

Modelling results for local waterways supports this:

- For the 10 year ARI, flood does not reach along the length of the levee and causes only marginal increases in flood levels immediately upstream of the haul road. Afflux is negligible at the western boundary of the mining tenure, and nil at the eastern boundary. Through the corridor bounded by the levees, there are no significant increases in flood levels.
- For the 50 year ARI, increases of more than 0.5 m in flood levels are predicted immediately upstream of the haul road the impacts at the western mining tenure boundary are expected to be negligible. Through the levee corridor, moderate increases in flood level of 0.1 – 0.2 m are expected, dropping away to nil at the eastern boundary in the Carmichael River. Flood levels in Cabbage Tree Creek at the eastern mining tenure boundary are increased by approximately

0.07 m because the levee redirects some water that would have otherwise left the creek as overland flow to the south.

- For the 100 year ARI, the impacts predicted are marginally worsened in the 100-year ARI event. The haul road causes localised afflux of more than 0.7 m. A minor 0.03 m increase in flood level is predicted at the western mining tenure boundary, which drops to nil 2 kilometres further upstream. Increases in the range of 0.2 – 0.3 m are indicated through the levee corridor. Moving further downstream, there is no significant increase in flood level in the Carmichael River at the eastern mining tenure boundary, although Cabbage Tree Creek levels are increased by approximately 0.1 m.
- For the 1000 year ARI, more significant impacts are indicated as the haul road is overtopped. Afflux of 1.5 – 2.0 m is expected at this location, decreasing to 0.2 m at the western mining tenure boundary, and then to 0.03 m by 2 km upstream of the boundary. A negligible 0.01 m increase is predicted at the upstream model boundary, which is approximately 4 km upstream of the mining tenure. Through the levee corridor, flood levels are increased by 0.5 to 0.7 m on average. At the eastern mining tenure boundary, Carmichael River and Cabbage Tree creek levels are increased by 0.07 and 0.2 m respectively.

The alignment geometry was chosen to curve around the open cut pits and waste dump areas to provide protection from local overland flow as well as flooding from the Carmichael River. The alignment was also designed to allow for the effluent flow path from the Carmichael River into Cabbage Tree Creek.

The height of the levee above natural ground level averages at approximately 2 m with a maximum height of 6.1 m. The maximum height occurs in a localised area where the levee crosses a natural depression or gully.

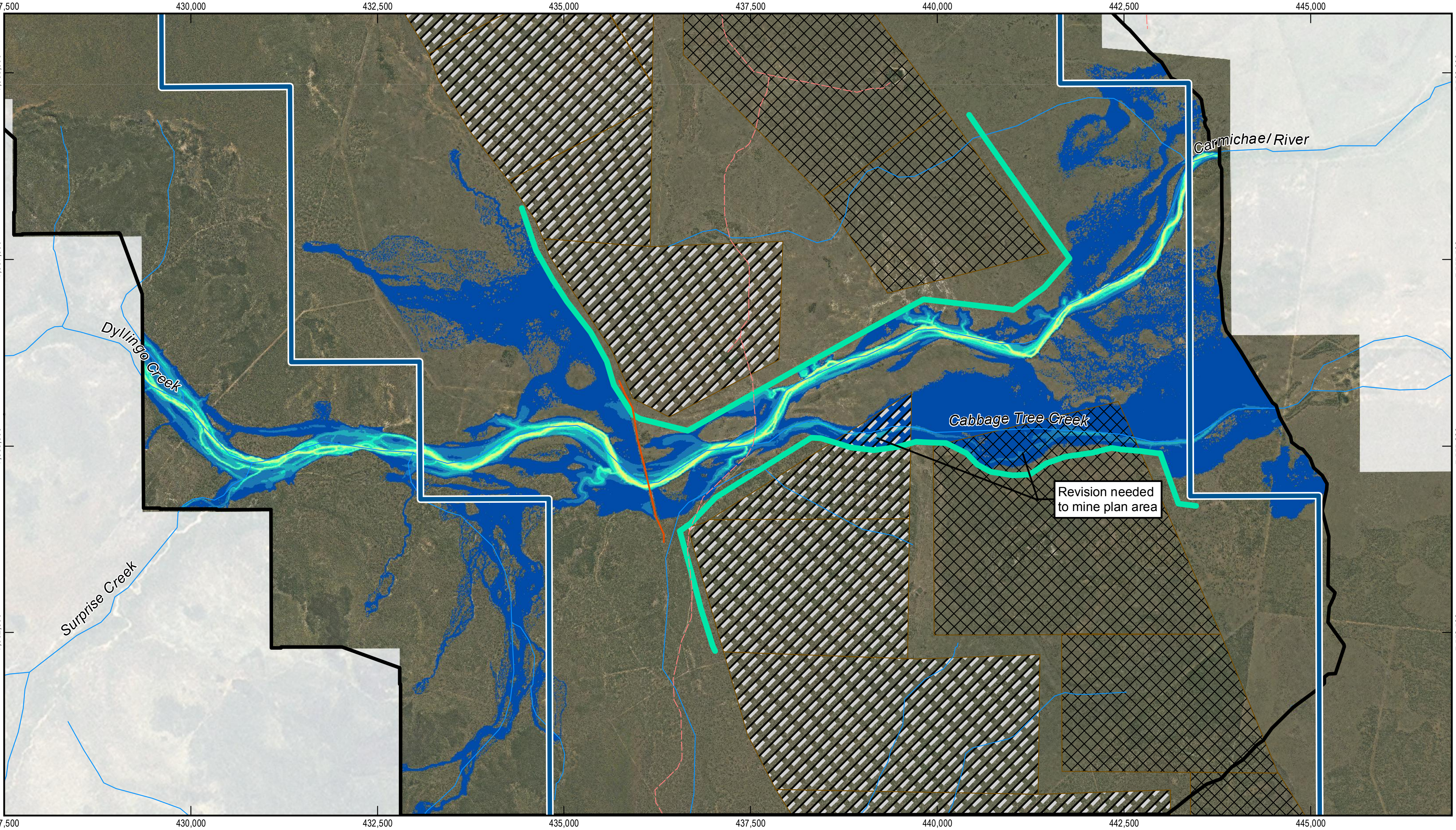
Levees to protect Eight Mile Creek from the out-of-pit waste rock dumps were assessed during the sizing of the case study diversion drain.

Preliminary hydraulic modelling indicated that a minimum waterway corridor width of 75 m is required through the waste dump at the downstream end of the drain to manage afflux. Levees to protect the waste dumps should be located outside of this 75 m corridor, and should be constructed to a height equal to or exceeding the 100-year ARI flood level plus 600 mm.

Afflux due to the proposed development at locations of interest is outlined in Volume 4 Appendix P1 Mine Hydrology Report.

The proposed levees successfully prevent flooding of either the underground mining area or the open cut pit areas. The haul road is immune to the 10 year or 50 year ARI events, but is overtopped by the 100 year and 1,000 year events.

The drain types are external diversion drains and internal diversion drains. External diversions drains are located outside of the mine affected area (but within Study Area), constructed in line with the Project (Mine) Stage Plan (refer Volume 2 Section 2).

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Watercourse
- Track
- Minor Road
- Proposed Carmichael River Levees
- 2D Model Extent
- Mine (Onsite)
- Waste Rock Dump Area
- Open Cut Mining Area

Depth (m)

- 0.08 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- 10.0 - 11.0

**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

10 Year ARI Flood Event
(Post Development)

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| Job Number | 41-25215 |
| Revision | B |
| Date | 06-09-2012 |

Figure 6-25

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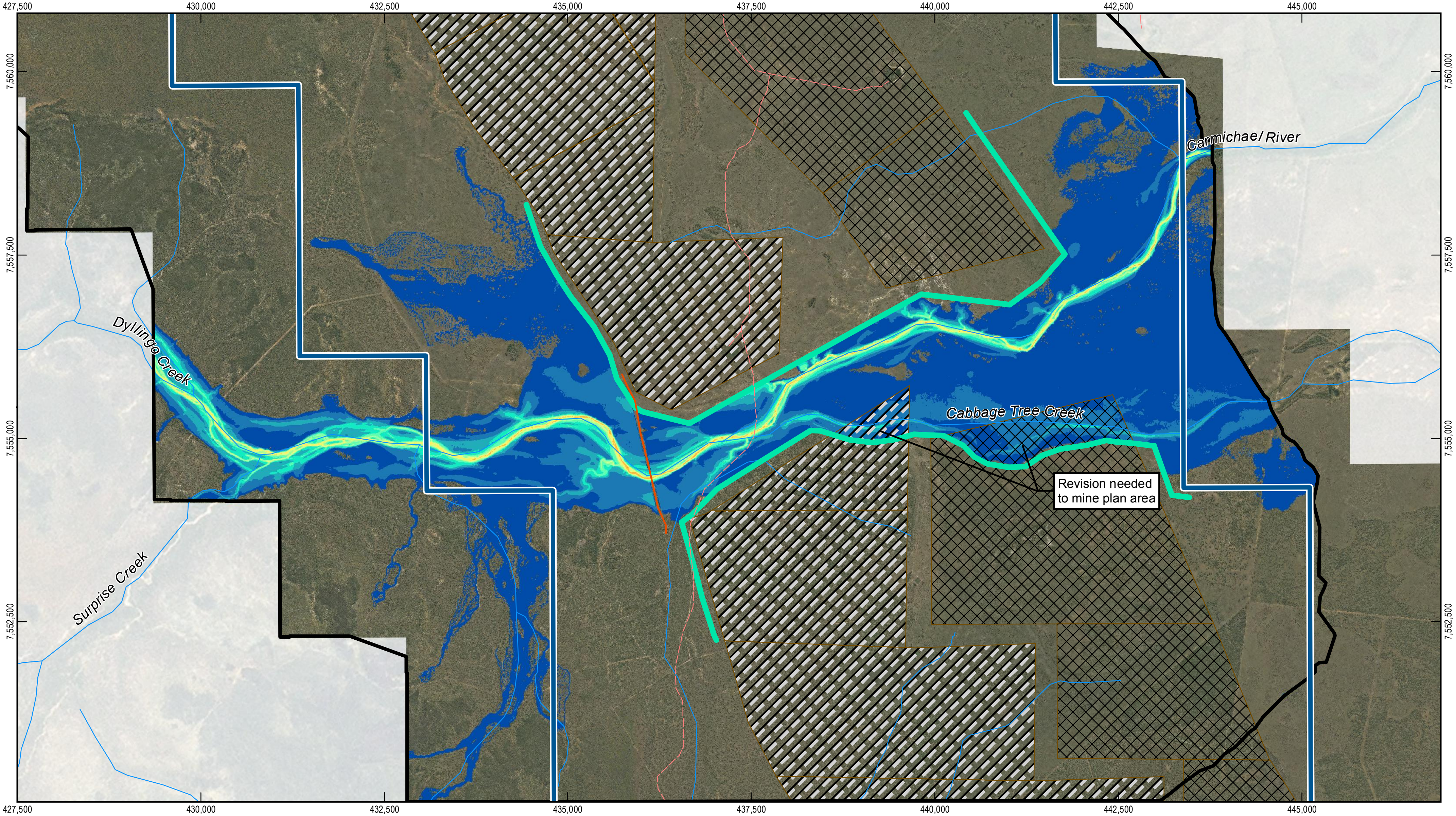
Data source: DME: EPC1690 (2010)/EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Tracks, Roads, Watercourse (2007); Adani Pty Ltd: Waste Dump Areas, Open Cut Areas (2012)
GHD: Flood Modelling, Levees (2012); Created by: BW, CA

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Watercourse
- Track
- Minor Road
- Proposed Carmichael River Levees
- 2D Model Extent
- Mine (Onsite)
- Waste Rock Dump Area
- Open Cut Mining Area

Depth (m)

| | | |
|---|---|---|
| 0.08 - 1.0 | 3.0 - 4.0 | 7.0 - 8.0 |
| 1.0 - 2.0 | 4.0 - 5.0 | 8.0 - 9.0 |
| 2.0 - 3.0 | 5.0 - 6.0 | 9.0 - 10.0 |
| | 6.0 - 7.0 | 10.0 - 11.0 |

**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

50 Year ARI Flood Event
(Post Development)

| | |
|---|---|
| Job Number | 41-25215 |
| Revision | B |
| Date | 06-09-2012 |

Figure 6-26

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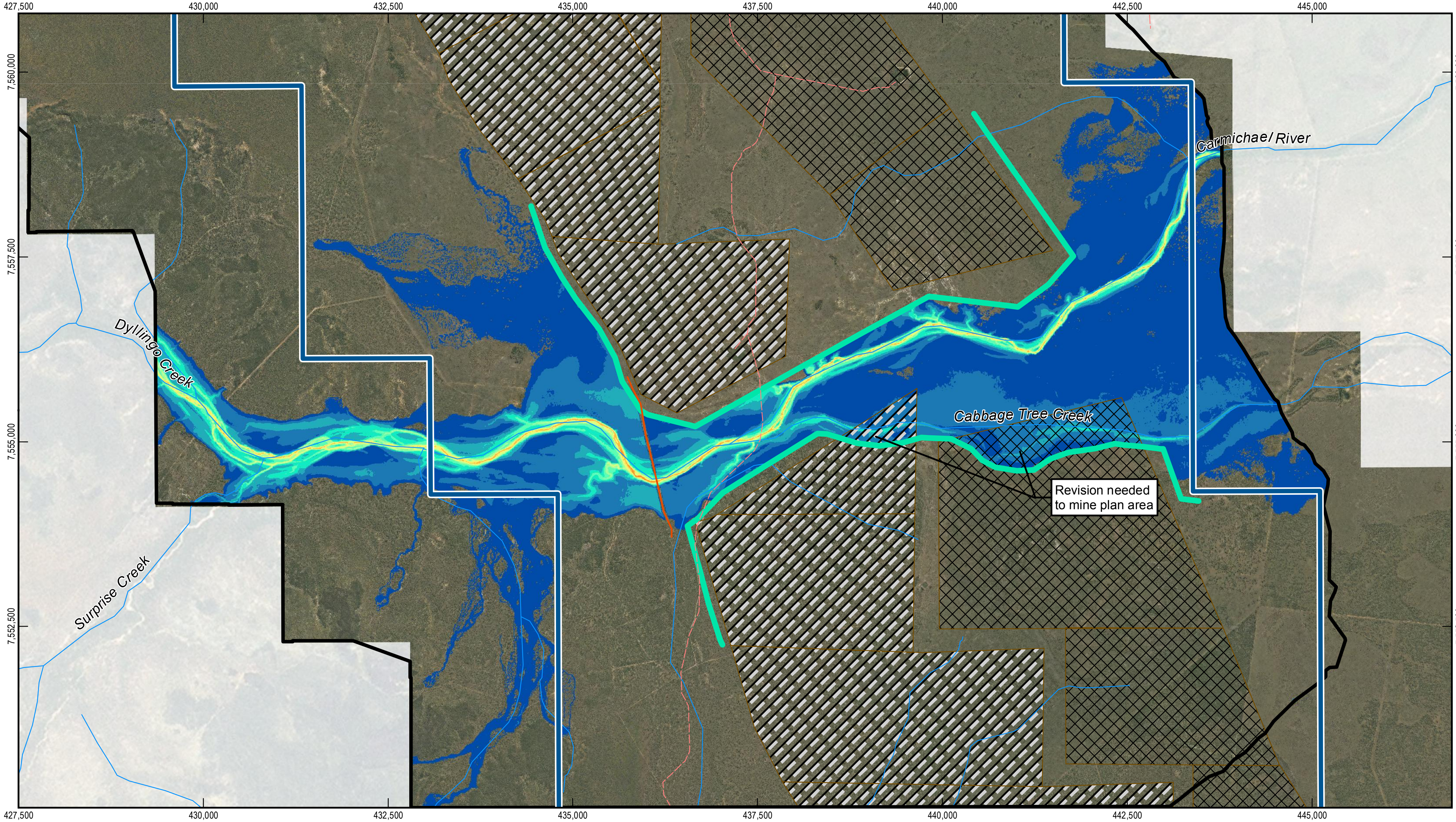
GHD: Flood Modelling, Levees (2012); Created by: BW, CA

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

**LEGEND**

- Watercourse
- Track
- Minor Road
- Proposed Carmichael River Levees
- 2D Model Extent
- Mine (Onsite)
- Waste Rock Dump Area
- Open Cut Mining Area

Depth (m)

| | | |
|---|---|---|
| 0.08 - 1.0 | 3.0 - 4.0 | 7.0 - 8.0 |
| 1.0 - 2.0 | 4.0 - 5.0 | 8.0 - 9.0 |
| 2.0 - 3.0 | 5.0 - 6.0 | 9.0 - 10.0 |
| | 6.0 - 7.0 | 10.0 - 11.0 |

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**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

100 Year ARI Flood Event
(Post Development)

| | |
|---|---|
| Job Number | 41-25215 |
| Revision | B |
| Date | 06-09-2012 |

Figure 6-27

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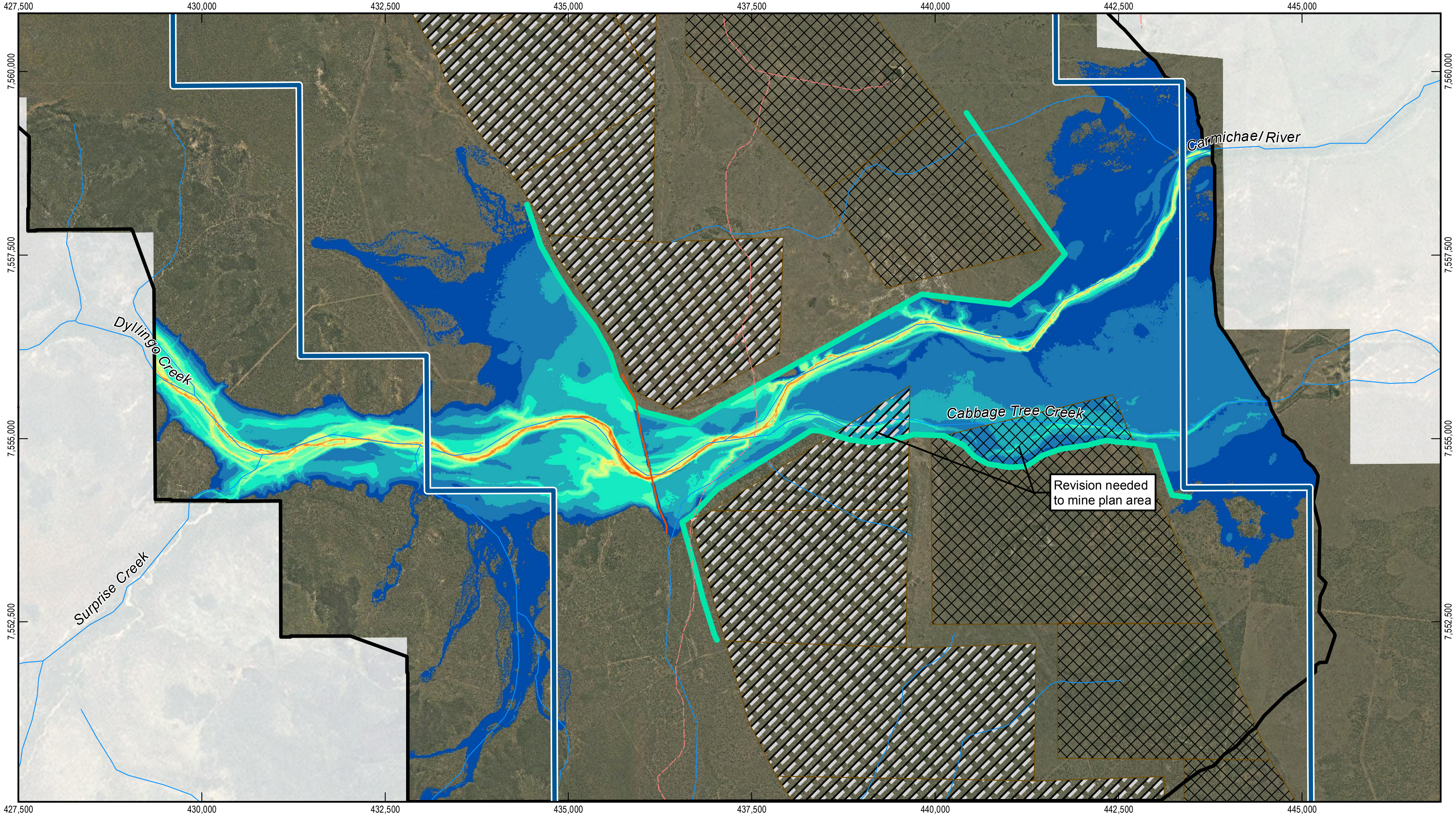
GHD: Flood Modelling, Levees (2012); Created by: BW, CA

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Watercourse
- Track
- Minor Road
- Proposed Carmichael River Levees
- 2D Model Extent
- Mine (Onsite)
- Waste Rock Dump Area
- Open Cut Mining Area

Depth (m)

- 0.08 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- 10.0 - 11.0

GHD adani

**Adani Mining Pty Ltd**
Carmichael Coal Mine and Rail Project

Job Number 41-25215
Revision B
Date 06-09-2012

## 1000 Year ARI Flood Event (Post Development)

## Figure 6-28

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GHD: Flood Modelling, Levees (2012); Created by: BW, CA

The external diversion drains have been designed in accordance with the following criteria:

- The drains are to be aligned within the Study Area
- Diversion drains will not be aligned above the underground mining area
- The design will accommodate the 100 year ARI flow, with no allowance for climate change (higher rainfall intensities), as derived using the hydrologic models described in Section 6.1.1.
- The maximum flow velocity in the diversion drains no greater than 2.5 m/s velocity for 50 year ARI event (DERM, 2011) "Watercourse Diversions – Central Queensland Mining Industry version 5.0", 2011)
- No greater than 80 N/m$^2$ shear stress for 50 year ARI event (DERM, 2011)
- No greater than 220 watt/ m$^2$ stream power for 50 year ARI event (DERM, 2011)
- Minimise the length of the diversion to reduce earthworks.

Assumptions adopted for the drain designs include:

- The cost of digging drains is less than the cost of building levees
- The minimum freeboard above the 100 year ARI flood must be 600 mm
- Where the mine pits are potentially at risk of inundation from the diversion drains, diversion bunds will be constructed along the eastern side of the drain to provide for 1,000 year ARI flood immunity for the pit from flood waters originating from the diversions drains. These are sized according to the 1,000 year ARI peak flood level, plus 600 mm freeboard.

As the diversion drains have been sized to accommodate the 100 year ARI runoff from the intersected existing waterways, in a 1000 year ARI event some regions of the drain cannot contain the flow. D.

Modelling indicates that the above management and mitigation measures are successful for the 10, 50 and 100 year ARI events.

Through the implementation of the water management system, there is no significant impact to the environmental flow.

### 6.4.3 Surface Water Quality

#### 6.4.3.1 Potential Impacts

Potential impacts on water quality include those from clearing land, water management during construction and alteration of the groundwater regime (refer 6.4.4).The construction and to a larger extent the operation of the Mine will require activities that have the potential to mobilise sediments and pollutants. This includes removal or vegetation, removal and stockpiling of topsoil, cut, fill and compaction earthworks and mining activities.

Uncontrolled release of water from the Project (Mine) poses a potential impact on water resource environmental values. The impacts to water quality may be through the release of sediment and the release of water with physical and chemical characteristics that impact on the receiving waters. The potential impacts on water levels or flows as a result of catastrophic failure i.e. dam break, are addressed in Volume 2 Section 12 Hazard and Risk.

#### 6.4.3.2 Management and Mitigation

The drain diversion system will manage the movement of clean water away from Mine workings, releasing this water back in to the environment without interaction with Mine workings.

MAW dams sediment basins will receive all raw water and MAW from operational pits, via the internal diversion drains. The design of these pits is underpinned by the requirement for discharge waters to meet relevant water quality objectives.

Discharge control measures include:

- Raw water will be delivered and temporarily stored in a raw water dam(s)
- Mine affected water (MAW) is to be retained on site and stored in facilities that are designed and managed in accordance with the draft guideline Regulated Dams in Environmentally Relevant Activities (Regulated Dams Guideline) (DERM), Managing Dams Containing Hazardous Wastes (DERM, 2010)
- All water entering in the pit or underground working areas is considered MAW
- Runoff from disturbed catchments areas has to be treated to a sufficient level before being released into the natural environment or is considered MAW
- Clean water runoff from undisturbed catchments areas is diverted around any mine workings or disturbed areas and released downstream
- If there is a water in sediment basins available with sufficient settlement time (5 days) then this water will be used for dust suppression
- In case of Acidic Mine Drainage (AMD), water needs to be treated through neutralization. The nature of exact treatment will depend upon the water quality
- Each spoil area needs sedimentation basins
- When spoil areas are rehabilitated in the later mine stages, the associated sediment basins are assumed to remain operational for a nominal minimum period of 10 years until vegetation cover is sufficient to mimic the pre-existing natural conditions.

Contaminants that have the potential to cause environmental harm will not be released back in to the environment except in line with permit conditions. These will in turn comply with release limits as identified in the Receiving Environment Monitoring Program. An assessment of existing water quality within the Study Area indicates that naturally variable conditions onsite are not consistent with the WQOs, it is proposed that site specific contaminant release limits are identified.

Operational activities have the potential to impact on water quality via discharge of contaminants to the environment. Potential impact upon the quality of water resources will be managed through the application of appropriate engineering solutions and water release management measures. No residual impacts to water quality of the site are expected from the release of water.

Modelling of water quality after treatment in each of the sediment basins showed TSS reductions meeting or exceeding the water quality objective.

### 6.4.4 Groundwater Regimes

### 6.4.4 Potential Impacts - Construction Phase

Potential impacts on groundwater resources during the construction phase of the Project (Mine) include:

- Potential for localised and temporary changes to groundwater levels and flows as a result of temporary dewatering during construction of foundations and/or the general waste landfill
- Potential to degrade the groundwater quality as a result of leaks and spills and/or uncontrolled discharges of site runoff occurring during construction works.

It is understood that all water required for construction will be sourced from offsite surface water resources; hence, groundwater extraction for use in construction use has not been considered in the impact assessment.

**Temporary Dewatering**

The depth to groundwater is anticipated to be generally greater than 20 m below ground surface in the vicinity of the Mine Infrastructure Area (MIA) where the majority of construction is proposed. The construction of foundations for infrastructure (including the village and airport) or for the construction of a general waste landfill is therefore unlikely to require temporary dewatering given this depth.

Temporary dewatering is also considered unlikely to be required for construction of crossings of minor ephemeral creeks and minor surface watercourses in the Project area where groundwater is also anticipated to be at least 20 m below ground surface.

Minimal excavation will be required for the proposed low-level crossing (consisting of a proposed causeway construction and culverts) and bridge across the Carmichael River since groundwater levels in this area are relatively close to ground surface (within five metres in places). Hence significant temporary dewatering is also unlikely to be required for this construction activity.

**Uncontrolled Discharges**

Potential leaks and spills of environmentally hazardous materials used during the construction might include diesel and oil stored for refuelling of machinery and vehicles, waste oils and sewage. The potential for acute discharges of these materials to reach the groundwater table is low due to the relatively high anticipated depths to groundwater (20 m below ground surface) and the clayey nature of much of the strata encountered across the site. Provided the storage facilities are designed in accordance with Australian standards and site controls followed are consistent with standard practices for the management and handling of these contaminants, large quantity, long term releases are not expected.

If treated sewage is to be disposed of by irrigation, this will be in accordance with an effluent disposal management plan that is informed by modelling to determine the application rates required to avoid leaching to groundwater.

The highest risks to groundwater quality relate to any construction activities in the vicinity of the Carmichael River. Groundwater levels in this area are relatively close to ground surface and the shallow sub-surface materials are likely to be relatively sandy, i.e. permeable. It is likely that any contaminant leaks or spills at the ground surface in this area could reach the water table relatively quickly and with little or no attenuation. Any impacts on groundwater quality in this area could also affect surface water quality as a component of flow in Carmichael River during dry periods is thought to be derived from local groundwater sources.

However, assuming that construction activities are managed and operated according to management and mitigation measures outlined in Section 6.4.4.1 then no significant impacts on groundwater quality are anticipated during the construction phase.

#### 6.4.4.1 Management, Mitigation and Monitoring Activities - Construction Phase

Laydown areas containing vehicles and machinery and storage facilities for chemicals, oils and fuels must be appropriately designed and allow for full containment of any leaks and spills. Containment may include: sealed/lined surfaces and hard stand areas; bunded areas; containerised storage.

Storage of chemicals, oils, fluids and other hazardous substances must be in accordance with the specifications of the material substance data sheet, as appropriate. Containment and correct storage will prevent spills, leaks, infiltration and surface runoff and hence prevent contaminants from entering aquifers, waterways and the general environment.

Laydown and storage areas must not be located in the vicinity of creeks or rivers or near to sensitive receptors (i.e. groundwater bores or GDEs).

Spill kits must be available to all personnel in the event of a spill or leak. Brooms and spill kits must be onsite at refuelling facilities. Refuelling must only occur at designated sites away from watercourses and other sensitive receptors. A spill kit must be present for any mobile refuelling and mobile refuelling must be supervised.

Sources of sand must, as far as is practicably possible, be obtained from borrow pits in areas where shallow aquifers are not present (e.g. older alluvial palaeochannels) and should not be obtained from present-day creek beds.

Where temporary dewatering of excavations for construction is required, the quality of groundwater should first be ascertained and an appropriate means for managing and disposing of the groundwater determined in accordance with procedures in the Construction Environmental Management Plan (CEMP). Dewatering should be kept to a minimum by forward planning of construction activities around seasonal fluctuations.

A surface water management system and associated management plan (SWMP) should be developed to ensure that all water leaving the construction site is captured, treated and recycled (where possible) to a suitable quality and quantity to prevent any significant impacts on groundwater quality.

#### 6.4.4.2 Potential Impacts – Operational Phase

Potential impacts on groundwater resources during the operational phase of the Project (Mine) include:

- Potential for changes to groundwater levels and reduction in surface water flows as a result of dewatering of open cut pits.
- Potential to degrade the groundwater quality as a result of leaks and uncontrolled discharges from spoil and tailing disposal to pits and or from tailings dams.
- Potential to degrade the groundwater quality as a result of leaks and uncontrolled discharges from the operation of processing and storage facilities, plants and machinery.

- Potential for changes to groundwater levels and reduction in surface water flows as a result of minor ephemeral creek diversions
- Potential to degrade the groundwater quality as a result of leaks and uncontrolled discharges from the operation of general waste landfill
- Potential for leakage of aquifers and surface watercourses from longwall mining of the underground workings.

It is understood that the water demand for the operational phase of the Project (Mine) will be met from a combination of water from dewatering, stored surface water and water imported from offsite. The impact of additional groundwater extraction from boreholes, specifically for the purposes of meeting the operational water demand, has not been considered in the impact assessment.

**Mine Dewatering**

Dewatering will be required to lower groundwater levels for the propose workings for safe and efficient operation of the open cut and underground mines. This will result in declining groundwater levels, drawn down by more than one metre up to around 10 km from the Project (Mine) site during the operational phase.

Groundwater discharge to the proposed mine workings will typically be re-cycled for use elsewhere within the mine, to meet processing and other water demands. Excess water will be managed as part of the mine water management system (refer to Volume 4 Appendix P2 Preliminary Water Balance).

Dewatering has the potential to reduce groundwater levels in existing groundwater bores that fall within the cone of influence of the proposed mine and hence has the potential to impact on existing groundwater users. It has been assumed that the ten registered bores located within the lease boundary will be decommissioned prior to commencement of mining and hence have been excluded from the impact assessment.

Potential impacts on 31 of the 36 licensed and other registered bores, outside of the lease area assessed by the model, are not anticipated to be significant, on the basis that the predicted drawdowns at these locations are less than one metre. In most cases it is likely that a 1 m drawdown will have little or no impact on the yield of an individual bore.

Predicted drawdowns of greater than one metre are anticipated at five registered bores which may significantly impact ground water levels (refer to Table 6-24). The significance of these predicted drawdowns will depend on a range of localised factors. A detailed assessment of individual bores will be carried out prior to development and in consultation with landholders with the aim to maintain the existing water production rates and quality with augmentation.

**Table 6-24 Summary of Significant Impacts at Registered Groundwater Bores**

| Site | Model Layer | Formation Targeted | Maximum Drawdown (m) | Notes |
|---|---|---|---|---|
| RN 90255 | 4 | Clematis Sandstone / Dunda Beds | 3.6 | North of lease area |
| RN 44486 | 5 | Dunda Beds | 6.4 | South-east of lease area |
| RN 90256 | 10 | Permian Sandstone | 2.2 | North of lease area |
| RN 90259 | 10 | Permian Sandstone | 19.8 | North of lease area |
| RN 103229 | 10 | Permian Sandstone | 1.6 | South of lease area |

No direct impacts on groundwater in the GAB are anticipated, however, some indirect impact may be possible primarily via inducing drawdown in the near surface Tertiary and Quaternary-age units present throughout the Project Area and extending west into the GAB.  .

The area to the west of Study Area is mapped as representing part of the Eastern Recharge area of the GAB.  Hence, any impacts on groundwater levels in outcropping relatively permeable sandstone units such as the Dunda Beds and Clematis Sandstone has the potential to reduce the volume of recharge to the GAB.  However, it should be noted that the topography, groundwater modelling results and the limited available groundwater level data all suggest that current groundwater flow in Triassic-age units to the west of the site may be towards the east i.e. away from the GAB rather than towards it.  Where this eastward groundwater flow direction is confirmed by further monitoring then no impacts on the GAB groundwater resources would occur as a result of dewatering.

Any potential impact to the recharge of the GAB through dewatering is not anticipated to be significant: the topography and available data indicate that current groundwater flow in Triassic-age units to the west of the site may be towards the east away from the GAB.

For the most part the predicted cone of influence of mine dewatering does not extend beneath the GAB Doongmabulla Spring complex to the west of the Project (Mine) site and hence less than 0.05 m of drawdown is predicted at 9 of the 11 mapped spring sites.  However, minor impacts of up to around 0.1 m drawdown are predicted at the two springs closest to the lease, Little Moses and Doongmabulla or Joshua Spring.  There is the potential, therefore, for some minor impact on groundwater levels at two springs which in turn has the potential to reduce the rate of flow from the springs and to reduce the amount of water available for the ecological communities dependent on and associated with the springs.  Any reduction in the flow from the springs will also impact flows in the Carmichael River downstream.

Based on recent assessments of the potential for impacts on GAB springs in response to Coal Seam Gas (CSG) extractions carried out by DNRM and the Queensland Water Commission, drawdowns of over 0.2 m at GAB spring locations are considered to be potentially significant.  Predicted drawdowns at all of the mapped Doongmabulla Springs are below this threshold and are therefore considered to be insignificant.

Drawdowns of up to 0.7 to 0.8 m are predicted at the location of the two non-GAB springs mapped just north of Mellaluka (approximately 10 km south of the Project (Mine) site) during the operational phase and hence it is possible that these springs could be impacted.  It should be noted, however, that limited data are currently available on the geology and hydrogeology of the area to the south of the Carmichael River and that little is known about the status or source of these springs. The Mellaluka springs are identified as non-GAB Eastern Desert Upland springs typically associated with outcropping Dunda Beds. In this case, however, it is considered unlikely that the Dunda Beds are present in the vicinity of the Mellaluka Springs. The springs are mapped around 10 km east of the nearest area of Dunda Beds outcrop and the geology typically dips from east to west. Further assessment of the ecology and hydrogeology of the springs themselves and of the area between the springs and the proposed mining area is required to better understand the potential for impact in this area. It should also be stressed that significant drawdowns are not expected in the Mellaluka Springs area until around 60 years into the proposed life time of the mine. There will therefore be ample opportunity to collect further data and develop management and mitigation measures before any impacts eventuate.

Given that the groundwater discharge to the Carmichael River is thought to help maintain the flow in the river during dry seasons, surface water flows in the river are likely to decline as a result of the predicted reduction in groundwater levels along the river. Groundwater modelling results suggest that groundwater discharges to local water courses, predominantly the Carmichael River, will be reduced by up to 1,000 $m^3$/d or 7 per cent of pre-development discharge during the operational phase. Where groundwater discharge is reduced by 7 per cent as predicted then this may have some impact on the duration of zero flow and/or low flow periods in the Carmichael River and also possibly the Belyando River downstream. Ongoing monitoring and measurement of flows in the Carmichael River and of discharges from the Doongmabulla Springs is required to quantify the magnitude of these impacts. The Carmichael River also receives a proportion of its water from Doongmabulla Springs; hence any reduction in the rate of flow from the springs as a result of the minor predicted impacts on groundwater levels at two of the springs may also contribute to a reduction of flow in the river.

No significant impacts on flows in the various ephemeral minor creeks which drain the Project area are anticipated as these are not thought to currently receive substantial recharges from groundwater.

Riparian vegetation, particularly the stands of mature River Red Gum and Paper Bark tree communities, may be potentially impacted by a reduction in the direct groundwater discharges underlying the river and discharge from the Doongmabulla Springs. Any significant reduction in groundwater levels and or surface water flows in the Carmichael River and/or Belyando Rivers during dry periods has the potential to impact on the health of these communities.

**Spoil and Tailings Disposal**

A combination of in pit and out-of-pit disposal will be employed for the Mine. Tailings will be initially disposed of to a tailings dam within the MIA until the in-pit disposal becomes operational. These facilities will be operated to minimise discharges, therefore no significant impacts on groundwater resources are anticipated.

Whilst significant impacts related to in-pit or above ground storage are not anticipated, it is understood that the proposed coal washing process involves the addition of magnetite. No tailings leachate trials have been undertaken to date and hence the potential impact of this part of the process on the quality of leachate is currently unknown.

Initial desktop (SRK 2012a) and geochemical assessments (SRK 2012b and c) of the potential for excavated material to produce acid and metalliferous drainage have been conducted. The initial geochemical assessment has identified the potential for a proportion of the coal, roof, floor, interburden and overburden materials to be potentially acid forming (refer to Volume 4 Appendix V Acid Mine Drainage Report).

**Leakages and Spills**

Leakages and spills from plant (such as for coal processing, vehicles and maintenance) during the course of day to day site operations and from any fuel and/or chemical storage facilities have the potential to degrade the quality of local groundwater resources.

The highest risks to groundwater quality relate to any operational activities carried out in the vicinity of the Carmichael River since groundwater levels in this area are relatively close to ground surface (within five metres in places) and shallow sub-surface materials are likely to be relatively sandy. Hence, any contaminants introduced at the ground surface (such as leaks and spills) in this area are likely to reach the water table relatively quickly, with little or no attenuation. However, operational activities in the immediate vicinity of the river are understood to be limited to mine vehicle traffic across the river via a specifically engineered structure. The risk of any significant leaks and spills in this area is therefore considered to be negligible.

**Creek Diversion**

The diversion of minor ephemeral creeks which currently flow during heavy rainfall events is unlikely to have a significant impact on groundwater given that the elevated depths of groundwater observed across most of the site and the diversion drainage system is unlikely to intersect the water table over the majority of the length. Consideration to the depth of groundwater will be considered during the detailed design of this system.

**General Waste Landfill**

The management of waste from the Project (Mine) will be in accordance with relevant legislation and the principles of the waste management hierarchy (refer to Volume 2 Section 10 Waste). The general waste landfill would be designed, constructed and operated in accordance with the appropriate waste management legislation and guidelines and as such would include appropriate measures to minimise any leachate leakage from the landfill to groundwater.

Upon decommissioning of the Mine, nine of the open cut pits will not be significantly backfilled and will therefore be substantially below pre-development ground surface and groundwater elevations. Potential evaporation exceeds the predicted inflow, aside from heavy rainfall events. In this case, these voids will essentially act a long term groundwater extractions from within the Project (Mine) area, with the potential to permanently reduce groundwater levels to the base of the proposed final voids. . Potentially significant post closure impacts of between one and 26 m are predicted at two out of 21 licenced registered bores and 14 out of 15 other registered bores outside the Study Area. .

**Subsidence**

Longwall mining creates a void, or goaf, into which unsupported material typically collapses and this, can result in fracturing of the overlying material remaining in-situ and cause subsidence of the ground surface. The extent of this fracture zone and the potential for surface subsidence has been assessed in separate study undertaken by MSEC (MSEC, 2012). The results of this study suggest that a free draining fracture zone with a maximum height of approximately 150 meters above each of the mined seams is likely to develop above the underground longwall mine workings. The impact of these changes in the hydraulic conductivity in areas above the mine has been assessed as part of the groundwater modelling work through the introduction of time varying hydraulic conductivity to the predictive model. The hydraulic conductivity of the Permian and Triassic age strata which fall within the predicted free draining fracture zone has been increased for the modelled post-mining period. The impacts of subsidence on groundwater are therefore incorporated into the potential mine dewatering impacts.

#### 6.4.4.3 Management, Mitigation and Monitoring Activities – Operation Phase

The following management and mitigation methods will be employed for the Project (Mine).

For discharge of excess groundwater flows:

- All inflows to the Mine will be directed into the mine water management system
- All discharge from this system will be subject to appropriate levels of control and monitoring
- Operational of the mine water management system will be documented in the mine water management plan, which will form a part of the overarching EMP.

For drawdown at existing groundwater extraction locations, further assessment will be undertaken to further refine an understanding of the status of each of the registered bores that may be significantly impacted by drawdown. After the refined assessment, any bores that are operational and that may be significantly impacted will be incorporated in to the Project (Mine) monitoring network in order to identify the development of the mine cone of depression in the direction of the bores. Any final loses and changes in the extracted groundwater will be addressed, for example, through supplementing the supply through imported water. Monitoring will be incorporated into the EMP for the Project (Mine) (refer to Volume 2 Section 15 Environmental Management Plan).

Groundwater model predictions suggest the potential for some minor indirect impacts on groundwater levels and recharge to Triassic-age units, which form part of the GAB system. Given the importance of the GAB from a national water resource perspective additional monitoring bores have been installed in the area to the west of the Study Area including the installation and monitoring of two multi-level facilities at sites close to the Carmichael River, upstream of Study Area but downstream of the Doongmabulla Spring complex. Initial results from these bores are incorporated in modelling of predicted impacts. These facilities will continue to monitor pre-development groundwater flows in Triassic units and track the progression of any impacts on GAB units to the west of the Project (Mine).

Further investigations and monitoring of Doongmabulla Springs will be undertaken prior to commencement of mining operations to establish a reliable baseline conditions and groundwater levels between the springs and the Project (Mine) site. The following investigations and monitoring are proposed at least 12 months prior to commencement of any dewatering operations:

- An ecological survey of the spring complex to establish its ‘health’ and to establish any seasonal variations. The survey would include measurement or estimation of discharge flows, assessment of the water quality and assessment of the ecology (for example extent, health and species present). An initial ecological survey of Doongmabulla Springs has been undertaken (refer to Volume 4 Appendix N2 Doongmabulla Springs Report).
- The monitoring of bores installed at the Little Moses and Doongmabulla Springs. Data from these bores will be used to confirm the relative levels and quality of groundwater in the near surface and underlying Triassic-age strata. These facilities will complement similar monitoring bores/stations

already installed along the Carmichael River to monitor GAB units to the west of the Project (Mine).

Drawdowns of up to 0.7 to 0.8 m are also predicted after around 60 years at the location of the two non-GAB springs mapped just north of Mellaluka during the operational phase and hence it is possible that these springs could also be affected. However, relatively little is currently known about these springs and is understood that they may be currently used for water supply purposes. Further assessment of the ecology and hydrogeology of the springs themselves is therefore proposed initially, in order to confirm their environmental values, current status and confirm likely source aquifers for the springs. Subsequent to these surveys, any necessary further steps will be identified to reduce any predicted impacts at these springs to acceptable levels. Potential mitigation measures which may reduce and/or mitigate predicted impacts during the operational phase include:

- Reviewing and revising the extent, location and/or timing of the proposed mine workings
- Offsetting or 'making good' any residual impacts.

Continued detailed monitoring of the surface water flows in the Carmichael and Belyando River will occur. In the event that groundwater level and/or surface water flow impacts are identified post development, Adani will work with relevant parties to compensate the water balance for identified loses. Potential alternative sources of water which could be used to mitigate observed flow impacts on the Carmichael include the diversion of minor creeks that currently flow across the mine footprint and the discharge of suitably treated inflows to the proposed mine workings.

The potential impacts on the health of the mature River Red Gum and Paper Bark communities will be monitored before during and after mine dewatering operations.

Mitigation and monitoring for spoils and tailings disposal siting and operation will include the establishment of a dedicated monitoring network, leach testing of tailings and other materials proposed for disposal in pit and above ground tailings facilities prior to operations to identify the likely contaminants. Post closure capping of in-pit and above ground facilities will occur. The placement of these facilities will be more than 5 km from the Carmichael River. All operations will be undertaken according to relevant standards.

Laydown areas for all plant and equipment will be designed in accordance with regulatory requirements. Containment may include sealed/lined surfaces and hard stand areas, bunded areas and contained storage. These facilities will not be placed in the vicinity of creeks or rivers or near to sensitive receptors. These facilities will also be integrated in to the water management system.

The drainage diversion system will be designed and located to minimise areas where the drain invert is below the current water table. Where this is not practical, further modelling will be undertaken to determine appropriate mitigation measures.

The design, construction and management of general land fill will act to mitigate potential impacts to groundwater resources. Furthermore, the groundwater monitoring network will provide a perimeter of at least four monitoring locations around landfill. As a final measure, post closure capping of the proposed landfill will occur.

Management and monitoring and mitigation post closure of the Mine will include the final ground level (after backfill) of the open cut pit voids are above the pre-development groundwater levels, to allow groundwater levels to rebound to pre-development elevations.

#### 6.4.4.4 Potential Impacts – Post-Closure Phase

**Mine Dewatering**

There is the potential for significant reductions in groundwater levels at selected registered groundwater bores if the voids are only partially backfilled. Potentially significant post closure impacts of between one and 46 m are predicted at one out of 21 licensed registered bores and all of the 15 other registered bores outside of the Study Area.

As during the operational phase, the predicted post closure cone of influence extends to the west and includes areas where the Triassic-age Dunda Beds, Clematis Sandstone and/or the Moolayember Formation are mapped at outcrop. Hence, there is the potential for groundwater levels to remain lower than pre-development levels after cessation of mining activities and for a permanent reduction in the availability of recharge to the GAB in this area. However, it should be noted that the topography, groundwater modelling results and the available groundwater level data all suggest that current groundwater flow in Triassic-age units to the west of the site may be towards the east i.e. away from the GAB rather than towards it. If this eastward groundwater flow direction is confirmed by further monitoring then no impacts on the GAB groundwater resources are expected to occur as a result of dewatering.

Minor impacts on groundwater levels at the two springs closest to the lease, Little Moses (1034) and Doongmabulla or Joshua Spring (1041), are predicted to continue to be impacted post-closure of the mining operations. No impact on the remaining nine springs in the Doongmabulla complex are predicted during the operational or post closure period.

At the Mellaluka Spring site, however, predictions suggest ongoing drawdown post closure result in drawdowns of around 5 m at these springs in the long term although it should be stressed that predictions also suggest that significant impacts will not occur until around 60 years into the proposed life time of the mine. Further assessment of the ecology and hydrogeology of the springs themselves is therefore proposed initially. Subsequent to these surveys, any necessary further steps will be identified to reduce any predicted impacts at these springs to acceptable levels. Potential mitigation measures which may reduce and/or mitigate predicted impacts during the post-closure phase include:

- Backfilling of final voids to above pre-development groundwater levels to prevent ongoing losses due to evaporation; and/or
- Offsetting any residual impacts.

There is potential for further reductions in base flow to local surface watercourses (including the Carmichael River and the Belyando River) during the post-closure phase, with long term impacts of around 1,00 $m^3$/d or 7 per cent of pre-development base flows predicted. Where groundwater discharge is reduced by 7 per cent as predicted then this may have some impact on the duration of zero flow and/or low flow periods in the Carmichael River and also possibly the Belyando River downstream. Further information on flows in the Carmichael River and on discharges from the Doongmabulla Springs is required to quantify the significance of these impacts.

#### 6.4.4.5 Management, Mitigation and Monitoring Activities – Post-Closure Phase

Significant potential impacts on groundwater levels, groundwater extractions and on the groundwater regime within and in the vicinity of Study Area are predicted as a result of partial backfilling of pits and in most cases are predicted to be greater than the operational phase of the Project (Mine).

The following mitigation measure is therefore proposed:

- Partial backfill all open cut pit voids such that the final ground surface within each of the pit areas is above the pre-development groundwater levels, to allow groundwater levels to rebound to pre-development elevations.

In order to confirm no impact on groundwater quality from waste storage and former operational areas of the site (such as in pit and above ground disposal of tailings and spoil, seepage from the general waste landfill and coal processing facilities), continuation of monitoring of groundwater quality beyond the end of the operational phase will be undertaken.  A staged approach to post-mining monitoring of tailings and spoil disposal areas is proposed in order to tie in with the various stages of mining as they are completed and rehabilitated.

The operational monitoring network for the Project (Mine) site would be reviewed and modified as appropriate in order to develop an appropriate post closure monitoring network.  A post closure GWMP would be developed as part of the post closure EMP and include key components such as monitoring duration and frequency, chemical analyses, definition of trigger values and appropriate action plans.

### 6.4.5 Stygofauna and Groundwater Dependent Ecosystems

#### 6.4.5.1 Potential Impacts

Stygofauna are species of subterranean, aquatic fauna that may be found in groundwater, primarily near the air/groundwater interface and appear most abundant in alluvial aquifers.  Stygofauna were detected at two groundwater bores within EPC1690 during surveys for Volume 4 Appendix O Mine Aquatic Ecology Report.

Mining activities have the potential to impact stygofauna communities with respect to the extent of the proposed groundwater drawdown zone and the likely impacts on groundwater quality.  Both these factors, over time, may cause prospective stygofauna habitat to be degraded or lost with the potential for significant impact on groundwater communities.

#### 6.4.5.2 Mitigation Measures

Management and mitigation approaches will align with those identified to manage impacts to groundwater quality, quantity and interactions (refer to Section 6.4.4).

Specific to understanding the significance of impacts to the stygofauna community, the following management approaches are recommended:

- Build on and extend the existing baseline survey by conducting additonal stygofauna surveys during mine construction, operation and closure phases in order to monitor and measure groundwater health and condition both within the Study Area and outside (i.e. the Doongmabulla and Mellaluka Springs)
- Extend the stygofauna sampling to the Mellaluka Springs to determine the presence to stygofauna and to identify if endemicity in the stygofauna community exists within the aquifer.

## 6.5 Potential Impacts and Mitigation Measures –Offsite Water Extraction

The following construction phase activities for the Project (Mine) offsite water supply infrastructure have the potential to impact on environmental flows, existing and potential uses and aquatic habitat.

- Construction of flood harvesting stations at the Belyando River and North Creek
- Construction of in-stream storage extractions at North Creek and Obungeena Creek
- Trenching and construction of pipelines, including waterway crossings
- Construction of seventeen borehole pumps to a depth of approximately 120 m in the Highland sub-artesian declared area

During operation, Project (Mine) offsite water supply infrastructure will extract up to 20 GL of flood water, 2 GL of in-stream storage water and up to 2.5 GL of ground water per annum. Boreholes will extract water at a rate of 6 L per second.

The following operation phase activities for the Project (Mine) offsite water supply infrastructure have the potential to impact on environmental flows, existing and potential uses and aquatic habitat.

- Extraction of water at Belyando River and North Creek flood harvesting stations
- Extraction of water at North Creek and Obungeena Creek in-stream storages
- Extraction of water at seventeen boreholes in the Highland sub-artesian declared area

Potential impacts of the construction and operation of the Project (Mine) offsite water supply infrastructure were assessed for their reduction in environmental flows against EFOs, inhibition of downstream uses and degradation of aquatic habitat.

The results of the preliminary analysis show the development boreholes has limited potential to impact on springs and surface flows, groundwater uses and groundwater dependent ecosystems.

### 6.5.1 Environmental Flows

#### 6.5.1.1 Potential Impacts

The IQQM modelled the impact of water extractions by the Project (Mine) offsite infrastructure on the EFOs set out in the *Water Resource (Burdekin Basin) Plan 2007*. The output of the IQQM indicated that the water extractions would have minimal impact against the EFOs (refer to Table 6-25). This is due to the following factors.

- In-stream storages see a low percentage of overall flows and are situated high in the catchment where large breakouts and water losses occur regardless of Project (Mine) water extraction
- The Belyando River and North Creek flood harvesting stations start to pump at a stream flow of 430 ML/d, meaning small flows are largely unaffected
- All water extractions by the Project (Mine) offsite water supply infrastructure will preserve the 150 GL reserve in the IQQM (node 335)

**Table 6-25 IQQM Environmental Flow Objectives and Developed case**

| | EFO (GL/year) | Developed case (GL/yr) |
|---|---|---|
| Mean Annual Flow | 2,663 | 2,660 |
| Median Annual Flow | 10,239 | 10,214 |
| **Percentage change of flows from Natural Conditions** | | |
| Mean Annual Flow | 92% | 92.7% |
| Median Annual Flow | 88% | 88.9% |
| Low Flow Objectives (compared against natural flow conditions) | Mandatory Objectives | ROP IQQM Case plus Project Extractions (GL/yr) |
| Total number of days 50% non-zero daily flow is equalled or exceeded | 32% | 32.2% |
| Total number of days 80% non-zero daily flow is equalled or exceeded | 52% | 53.1% |
| **Medium to High Flow Objectives** | | |
| 1.5 year daily flow volume in the simulation period, expressed as a percentage of the 1.5 year daily flow volume for the pre-development flow pattern | 94% | 94.5% |
| 5 year daily flow volume in the simulation period, expressed as a percentage of the 1.5 year daily flow volume for the pre-development flow pattern | 96% | 97.2% |
| 20 year daily flow volume in the simulation period, expressed as a percentage of the 1.5 year daily flow volume for the pre-development flow pattern | 98% | 98.3% |

Testing of Belyando River and North Creek flood harvesting stations and North Creek and Obungeena Creek in-stream storage pump stations will involve sourcing and discharge of a large volume of water. The precise quantity and source of water is unconfirmed.

The installation of temporary watercourse diversions during construction may alter the hydrology of watercourses. Trenching and construction of pipelines at waterway crossings at North Creek, Obungeena Creek and Eight Mile Creek may also impact local geomorphology.

Valenza (2012) found that the predicted cone of influence of the nearest bore does not extend beneath the GAB Doongmabulla Spring complex and the Mellaluka Springs. .Boreholes were positioned to maintain a distance equivalent to the maximum expected radius of influence to the Carmichael River at peak extraction. Consequently, the construction and operation of boreholes is not expected to impact the flow of the Carmichael River.

A number of boreholes have been positioned at distances ranging between 2 and 3 km from surficial drainage channels, creeks and tributaries of the Belyando and Carmichael Rivers. Based on the preliminary analysis, the impact on groundwater level is likely to range between 0.5 and 2.5 m.

#### 6.5.1.2 Mitigation Measures

The Belyando River and North Creek Flood harvesting stations will operate according to operating rules developed using the IQQM. The Belyando River and North Creek flood harvesting stations start to pump at a stream flow of 430 ML/d, meaning small flows are largely unaffected. This includes small flows that are seen as critical for protection of environmental values, such as those required for fish spawning. Pumps will activate once the flood level defined in the Water Licence is reached. All pipelines will include flow meters and all pumps will be controlled remotely to ensure that permitted extraction volumes are not exceeded.

Storage extension works will be undertaken offline from the existing storages to minimise the duration of lowered water levels. During initial fill of the storages, low flows will be released to ensure local flow conditions are maintained downstream. As the North Creek and Obungeena Creek in-stream storages form an end of a natural waterhole, complete emptying of storages will not occur.

The 5 GL storage dam will be situated between Belyando River and North Creek at a natural high point to reduce the likelihood of flood.

### 6.5.2 Existing and Potential Users

#### 6.5.2.1 Potential Impacts

The Project (Mine) offsite water supply infrastructure will extract water from a total of eight existing in-stream storages; four at North Creek, four at Obungeena Creek. Each existing in-stream storage may be expanded to accommodate annual water abstraction of 250 ML.

Clearing of riparian vegetation for river harvesting stations and in-stream storage extractions may result in erosion and sedimentation. This impact will primarily occur after clearing and before the natural recruitment of ground cover takes place in cleared areas. The reduction in water quality associated with clearing can impact downstream livestock, domestic and irrigation uses.

The output of the IQQM indicated that water extractions would have minimal to no impact on downstream water users (refer to Table 6-26). Users relatively close to extractions by Project (Mine) offsite water supply infrastructure receive minimal impacts. Minor increases in supply downstream were shown due to a reduction in the reserve from 150 GL to 135 GL and 15 GL being allocated to the Project (Mine).

A subset of groundwater bores are positioned at distances ranging between 2 and 3 km from registered users. Based on the preliminary analysis the impact on groundwater levels at those locations is likely to range between 0.5 and 2.5 m.

**Table 6-26 IQQM Downstream users and Developed case**

| Node | Licence | Downstream use (GL/year) | | | Developed case (GL/yr) | | |
|---|---|---|---|---|---|---|---|
| | | Mean Annual Demand<br>ML/yr | Monthly Reliability | Annual Reliability | Mean Annual Demand<br>ML/yr | Monthly Reliability | Annual Reliability |
| 233 | Stock And Domestic | 15.4 | 99.9 | 99.1 | 15.4 | 99.9 | 99.1 |
| 246 | Stock And Domestic | 30.2 | 100 | 100 | 30.2 | 100 | 100 |
| 279 | Stock And Domestic | 5.7 | 100 | 100 | 5.7 | 100 | 100 |
| 232 | Water Harvester | 828 | N/A | N/A | 828 | N/A | N/A |
| 291 | Water Harvester | 550 | N/A | N/A | 550 | N/A | N/A |
| 292 | Water Harvester | 4803 | N/A | N/A | 4799 | N/A | N/A |
| 293 | Water Harvester | 2675 | N/A | N/A | 2683 | N/A | N/A |
| 300 | Water Harvester | 3454 | N/A | N/A | 3506 | N/A | N/A |
| 302 | Water Harvester | 1113 | N/A | N/A | 1116 | N/A | N/A |

#### 6.5.2.2 Mitigation Measures

Belyando River and North Creek flood harvesting stations will be constructed during non-flood periods to minimise impact to water quality. Belyando River and North Creek Flood harvesting stations will operate according to operating rules developed using the IQQM to limit impacts to downstream users (refer to Table 6-26).

Registered borehole users have been considered in the positioning of boreholes at suitable distances from listed sites, to reduce the effect of drawdown on groundwater dependent ecosystems and downstream uses. A baseline groundwater level and water quality monitoring program will be undertaken in conjunction with nearby bore extraction yields and associated drawdown records. If a registered bore is found to be impacted as a result of the borehole, groundwater losses will be accounted for in a *made good* agreement with Adani. Potential alternative sources of water which could be used to mitigate losses would include suitably treated water from mine workings.

### 6.5.3 Aquatic Habitat and Riparian Vegetation

#### 6.5.3.1 Potential Impacts

Clearing of riparian vegetation for river harvesting stations, in-stream storage extractions and pipelines may result in erosion and sedimentation. This impact will primarily occur after clearing and before the natural recruitment of ground cover takes place in cleared areas. The reduction in water quality associated with clearing can degrade aquatic ecosystems (refer to Volume 4 Appendix O Mine Aquatic Ecology Report).

Draining and extension of existing in-stream storages at North Creek and Obungeena Creek will have local impacts to non-conservation significant fish, macrophytes, crustaceans and turtles that are likely to be present, and create barriers to the movement of aquatic fauna.

Accidental spills or release of construction waste in or near a watercourse can cause contamination of water, degradation of aquatic habitat and reduction in fauna usage.

Construction of pipelines to connect the Belyando River and North Creek flood harvesting stations and in-stream storage extractions at North Creek and Obungeena Creek to 5 GL and 20 GL storage dams may result in localised fragmentation of ephemeral watercourses.

It is unlikely that this fragmentation will be of significance to regional populations, breeding patterns, feeding patterns or normal movement of aquatic species. As ephemeral watercourses, North Creek and Obungeena Creek are likely to be utilised opportunistically by aquatic flora and fauna that are tolerant of significance disturbance events. Such species can rapidly recolonise and regenerate when conditions are suitable.

The installation of temporary watercourse diversions during construction may create barriers to the movement of aquatic fauna.

Testing of Belyando River and North Creek flood harvesting stations and North Creek and Obungeena Creek in-stream storage pump stations will involve sourcing and discharge of a large volume of water. The precise quantity and source of water is unconfirmed. Water used to test the pump stations will flush construction debris from pipes. Test water from leaks in the pump station structure will discharge directly to the ground.

The operation and maintenance of Belyando River and North Creek flood harvesting stations, in-stream storage extractions at North Creek and Obungeena Creek and pipelines connecting to 5 GL and 20 GL storage dams may present barriers to movement to aquatic species, particularly fish and crustaceans.

The operation of pumps at Belyando River and North Creek flood harvesting stations and in-stream storage extractions at North Creek and Obungeena Creek may result in the entrainment and subsequent injury or death of aquatic species, or transfer of aquatic fauna and flora between basins. Draw down at in-stream storages may also result in injury or death of aquatic species. Operational noise and vibration may degrade local aquatic habitat also.

A number of boreholes have been positioned at distances ranging between 2 and 3 km from surficial drainage channels, creeks and tributaries of the Belyando and Carmichael Rivers. Based on the preliminary analysis, the impact on groundwater level is likely to range between 0.5 and 2.5 m.

#### 6.5.3.2 Mitigation Measures

Belyando River and North Creek flood harvesting stations and in-stream storage extractions at North Creek and Obungeena Creek are designed to avoid significant environmental values in the floodplain and riparian zone, including riparian habitat, referrable wetlands and gilgais. Sensitive areas in the vicinity of all Project (Mine) offsite water supply infrastructure will be clearly demarcated before clearing or construction commence.

Belyando River and North Creek flood harvesting stations will be constructed during non-flood periods to minimise impact to water quality. As erosion and sedimentation impacts are likely to be most significant during peak flow periods, construction during non-flood periods may also contribute to reduced erosion and sedimentation.

Construction of pipelines within the riparian zone will be reduced. Pipeline watercourse crossings will be minimised during route selection. To the extent that crossings cannot be avoided, crossings will be selected to minimise disturbance to aquatic flora, watercourse junctions, waterholes and steep banks. Pipelines will also be collocated into one watercourse crossing wherever practicable. Controls will be implemented during construction to minimise erosion and prevent spills and leaks with the potential to impact aquatic ecosystems. The EMP will include monitoring programs for the effectiveness of these controls and associated water quality outcomes (refer to Volume 2 Section 13 Environmental Management Plan).

Storage extension works will be undertaken offline from the existing storages to minimise the duration of lowered water levels. Low water levels will, however, be triggered upon undertaking connection works between the existing storage and the offline extension. Temporary screens will be installed during testing at Belyando River and North Creek flood harvesting pump stations and North Creek and Obungeena Creek in-stream storage pump stations. The screens will capture debris flushed from pipes. The debris will then be disposed of appropriately. Further Management and mitigation for aquatic fauna mortality impacts and the introduction of pest species are addressed in Volume 4 Appendix N Mine Terrestrial Ecology Report and Volume 4 Appendix O Mine Aquatic Ecology Report.

Screens will be installed upstream of Belyando River and North Creek flood harvesting pumps to prevent transfer of aquatic flora and fauna between basins. Strainers will be installed in suction pipes at Belyando River and North Creek flood harvesting pumps and in suction pipes at North Creek and Obungeena Creek in-stream storages to prevent transfer of aquatic flora and fauna between basins.

Entrainment will be mitigated at the point of water extraction by screening pump intakes. As the North Creek and Obungeena Creek in-stream storages form an end of a natural waterhole, complete emptying of storages will not occur. Operational procedures will be developed to this effect. The expansion of existing in-stream storages will present the opportunity for the creation of additional habitat. Aquatic habitat structures will be established at in stream storages, with riparian structures established adjacent, wherever practicable.

## 6.6 Summary

The Project (Mine) has the potential to impact on the surrounding water resources. Many of these potential impacts are insignificant as a result of the water management system which involves the development of a drain diversion system and levees that protect water quality and environmental flows downstream. The potential impact of the groundwater regime may generally be mitigated through project design processes, however further monitoring is required.

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