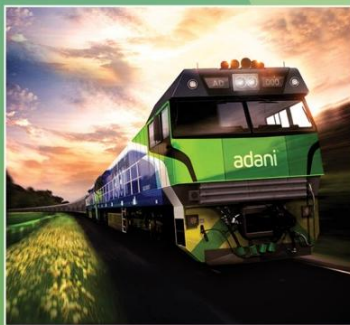




Adani Mining Pty Ltd

NORTH GALILEE BASIN RAIL PROJECT

Environmental Impact Statement

Appendix H1 Water Resources

November 2013

This North Galilee Basin Rail Project Water resources report (“the Report”) has been prepared by GHD Pty Ltd (“GHD”) on behalf of and for Adani Mining Pty Ltd (“Adani”) in accordance with an agreement between GHD and Adani.

The Report may only be used and relied on by Adani for the purpose of informing environmental assessments and planning approvals for the North Galilee Basin Rail Project (“the Purpose”) and may not be used by, or relied on by any person other than Adani.

The services undertaken by GHD in connection with preparing the Report were limited to those specifically detailed in 1.2 of the Report.

The Report is based on conditions encountered and information reviewed, including assumptions made by GHD, at the time of preparing the Report. Assumptions made by GHD are contained through the Report, including (but not limited to) concept design and operations information provided by Adani.

To the maximum extent permitted by law GHD expressly disclaims responsibility for or liability arising from:

- *any error in, or omission in connection with assumptions, or*
- *reliance on the Report by a third party, or use of the Report other than for the Purpose.*

Executive summary

This water resources report describes the existing surface water and groundwater resource environment relevant to the North Galilee Basin Rail Project (NGBR Project). The study area is defined by the major drainage areas associated with the preliminary investigation corridor (nominally 1,000 m wide). These drainage areas are the Suttor River, Bowen River and Lower Burdekin River catchments (all within the Burdekin Basin), and the Don River Basin. Within the Don River Basin the study area includes minor coastal drainage areas such as Splitters Creek, Saltwater Creek and Elliot River as they are traversed by the preliminary investigation corridor. A 15 km section of the preliminary investigation corridor intersects the Belyando River catchment (within the Burdekin Basin), however, no major watercourses are crossed in this catchment.

The drainage areas traversed by the preliminary investigation corridor include gentle undulating slopes with slight rises and shallow depressions. More dramatic topography associated with the Clarke Range and the Leichhardt Range is observed in the northern and southern extents of the preliminary investigation corridor. Approximately 16 major waterways are traversed, with most located within the Burdekin Basin. The waterways are predominantly characterised by moderate to poor geomorphic condition, with many exhibiting evidence of excessive sand sedimentation as a result of past upstream disturbances.

The climate of the study area is typically tropical, with temperatures ranging between 20°C and 40°C, and heavy rains during the wet season (November to May). The maximum summer rainfall volumes arise from prolonged eastward travelling monsoon depressions and intense short-term contributions from predominantly westward travelling tropical cyclones.

Rainfall and stream gauging records were used to determine precipitation and flow patterns within the study area. High flow patterns in waterways were observed to generally coincide with high rainfall events. However, while there are more flow events in the wet season, periods of zero flow can occur during any month of the year.

The frequency and extent of flooding within the study area was determined based on available historical flood data. The Burdekin Basin has experienced a number of major flooding events dating back to 1911, with more recent events occurring in 1991 and 2010/2011. Major flooding in the Don River Basin has been observed since 1861 with the highest recorded flooding occurring in 1946.

Groundwater characteristics within the study area were determined using readily available geological information, geomorphological field surveys (undertaken in May 2013) and available borehole data. A search of the Department of Natural Resources and Mines (DNRM) ground water database identified 81 bores within two kilometres of the preliminary investigation corridor (43 provided groundwater data). Groundwater levels ranged substantially between the bores with the shallowest depths occurring in the coastal dune, alluvial and deltaic deposits (1.2 to 9 m below ground surface). Bores within alluvial deposits further inland exhibited the deepest groundwater levels (4.2 to 45.7 m below ground surface). There is currently insufficient data to establish regional flow directions, however; it is expected that shallow groundwater systems would generally follow the topography and surface drainage systems.

Water usage within the study area is dominated by urban, industrial, stock watering and domestic uses. Water resource infrastructure includes channels, pipelines, pumps, pumping stations, weirs such as the Bowen Weir and major dams like Burdekin Falls Dam. Stock water is

supplied directly from the rivers in the wet season and for the rest of the year by residual natural waterholes or constructed impoundments of wet season runoff.

The NGBR Project is situated within the Galilee (groundwater) Basin and is outside the eastern boundary of the Great Artesian Basin. The preliminary investigation corridor is primarily situated within the Bowen Unincorporated Area. However, the northern and north-eastern portions traverse the Yarraman Unincorporated Area and Don River Unincorporated Area respectively. Unincorporated Areas include all groundwater resources that are not part of Groundwater Management Units and which have no requirements for allocations of groundwater abstraction for livestock or domestic use.

Potential groundwater dependant ecosystems identified along the preliminary investigation corridor included several surface features with “high potential for groundwater interaction” and many features with “low or moderate potential for groundwater interaction”.

Groundwater quality data extracted from previous investigations and publicly available information provided a reasonable understanding of water quality within the coastal aquifer systems and within the igneous intrusive deposits associated with Mt Roundback and the Clarke Range (up to chainage 68 km). The water quality of these areas has potential for use as water supply for domestic and stock purposes. However, water quality data for the majority of the preliminary investigation corridor (chainages greater than 68 km) is limited and cannot be relied upon to provide a reasonable understanding of aquifer water quality in these areas.

The environmental values considered relevant to the preliminary investigation corridor, include:

- Aquatic ecosystems – slightly to moderately disturbed
- Primary industries – irrigation
- Primary industries – stock watering
- Cultural and spiritual values.

An additional three values were identified as applicable only to the Suttor River catchment as they are associated with the Burdekin Falls dam (approximately 168 km downstream of the preliminary investigation corridor). These values are:

- Primary industries - human consumers of aquatic foods
- Recreation and aesthetics - secondary recreation
- Recreation and aesthetics - visual recreation.

Existing surface water quality conditions were determined based on water quality sampling undertaken in May 2013, pre-existing water quality data from previous studies, and the Department of Environment and Heritage Protection gauging stations. The water quality parameters analysed displayed both spatial and temporal variations. Temporal patterns were related to seasonal variability associated with the influx of overland flows and subsequent drying of water resources during the dry season. Water quality data was compared against regional, State and national water quality objectives adopted for the NGBR Project. Due to existing land use practices, water quality conditions in the Suttor, Bowen and Lower Burdekin catchments as well as the Don River Basin were outside the adopted water quality objectives on a number of occasions. As such, the regional, State and national water quality objectives are not considered appropriate for management of surface water quality during construction and operation of the NGBR Project and site specific objectives would be developed.

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Appendices

Appendix A – Assessment of rainfall data

Appendix B – Assessment of stream gauging data

Appendix C – Borehole locations and localised geology

Terms and abbreviations

Terms and abbreviations	Definition
1D	One-dimensional
2D	Two-dimensional
Adani	Adani Mining Pty Ltd
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
ASRIS	Australian Soil Resource Information System
BOM	Bureau of Meteorology
DEHP	Department of Environment and Heritage Protection
DERM	Former Department of Environment and Resource Management
DNRM	Department of Natural Resources and Mines
DO	Dissolved oxygen
EC	Electrical conductivity
EIS	Environmental Impact Statement
ENSO	El Niño-Southern Oscillation
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
EPP (Water)	<i>Environmental Planning (Water) Policy 2009</i>
EV	Environmental Value
Final NGBR Project footprint	The final NGBR Project footprint will accommodate all rail infrastructure required for construction and operation, scalable to accommodate 100 mtpa product coal transport, including passing loops, a maintenance road, rolling stock maintenance (provisioning, fuel storage and refuelling, maintenance, etc.), water supply and pipeline, track and signalling maintenance facilities, staff crib, accommodation and training facilities and other necessary infrastructure associated with the operational functions of the NGBR Project. Temporary construction facilities are expected to include laydown areas, construction depots (warehousing, fuel storage, vehicle storage, administration facilities, etc.), sleeper manufacturing yards, construction accommodation camps, quarries and borrow pits, access tracks into the corridor and other necessary infrastructure associated with the construction functions of the NGBR Project.
Final rail corridor	The final rail corridor is a nominal 100 m wide corridor
GBR	Great Barrier Reef
GDE	Groundwater dependent ecosystem

Terms and abbreviations	Definition
GMA	Groundwater management area
GMU	Groundwater management units
GPS	Global positioning system
GWDB	Groundwater database
HD	Highly disturbed
HEV	High ecological/conservation value
km	Kilometre
L/s	Litre per second
LIDAR	Light detection and ranging – laser terrain mapping
m AHD	Metres above the Australian Height Datum
m/day	Metre per day
mbgl	Metre below ground level
mg/L	Milligram per litre
mm	Millimetres
MNES	Matters of national environmental significance
mtpa	Million tonnes per annum
NGBR	North Galilee Basin Rail
NGBR Project	North Galilee Basin Rail Project
NRM	Natural Resource Management
NWQMS	The National Water Quality Management Strategy
PPD	Patch point dataset
Preliminary investigation corridor	The preliminary investigation corridor is a 1,000 m wide corridor
QRA	Queensland Reconstruction Authority
QWQG	Queensland Water Quality Guidelines
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SMD	Slightly-moderately disturbed
SPP	State Planning Policy
TDS	Total dissolved solids
TOR	Terms of Reference
UA	Unincorporated area
WQO	Water Quality Objectives

1. Introduction

1.1 Project overview

Adani Mining Pty Ltd (Adani) proposes the construction and operation of the North Galilee Basin Rail Project (NGBR Project), a multiuser, standard gauge, greenfield rail line that will transport coal from mines in the northern Galilee Basin to the Port of Abbot Point. The NGBR Project is approximately 300 km in length and connects the proposed Carmichael Coal Mine and Rail Project's east-west rail corridor, approximately 70 km east of the Carmichael Mine in the vicinity of Mistake Creek, with supporting infrastructure at the Port of Abbot Point (refer Figure 1-1). The NGBR Project will have an operational capacity of up to 100 million tonnes per annum (mtpa) of coal product expected to be sourced from both Adani and third-party mines in the northern Galilee Basin. Key features of the NGBR Project include:

- Approximately 300 km of standard gauge, bi-directional rail track located within a nominal 100 m wide rail corridor (the final rail corridor)
- A rail maintenance access road running parallel to the rail track for approximately 300 km and wholly within the final rail corridor
- Seven passing loops, each 4.3 km in length
- Signalling infrastructure
- Approximately 4.5 km of fill greater than 15 m in depth (11 locations) and approximately 3.4 km of cut greater than 15 m in depth (nine locations)
- At-grade and grade separated road, rail, stock and occupational crossings
- Bridge and culvert structures at major waterways and drainage lines, and various other longitudinal and cross drainage structures
- A rolling stock maintenance facility near the Port of Abbot Point including provisioning line, train maintenance line, wagon and locomotive service sheds, wash bay and queuing line
- Five temporary accommodation camps for construction workers
- A temporary construction depot at the southern end of NGBR Project
- Temporary construction yards, concrete batching plants, bridge and tack laydown areas and heavy vehicle turning circles.

During construction, quarries and borrow pits within acceptable haulage distances will be required to provide a cost effective source of fill, gravel, aggregate and ballast. The number and location of borrow pits and quarries will be investigated further during detailed design and each may require screening and crushing plants to process material.

1.2 Scope of report

This water resources report was prepared in accordance with the Terms of Reference (TOR) for the NGBR Project. A table that cross-references the contents of this report and the TOR is included as Volume 2 Appendix A Terms of Reference cross-reference.

The frequency and extent of flooding in the study area has been considered based on available historical data however a detailed hydrological and hydraulic investigation for the NGBR Project is provided in Volume 2 Appendix H2 Hydrology and hydraulics.

1.2.1 Report overview

This report consists of the following sections:

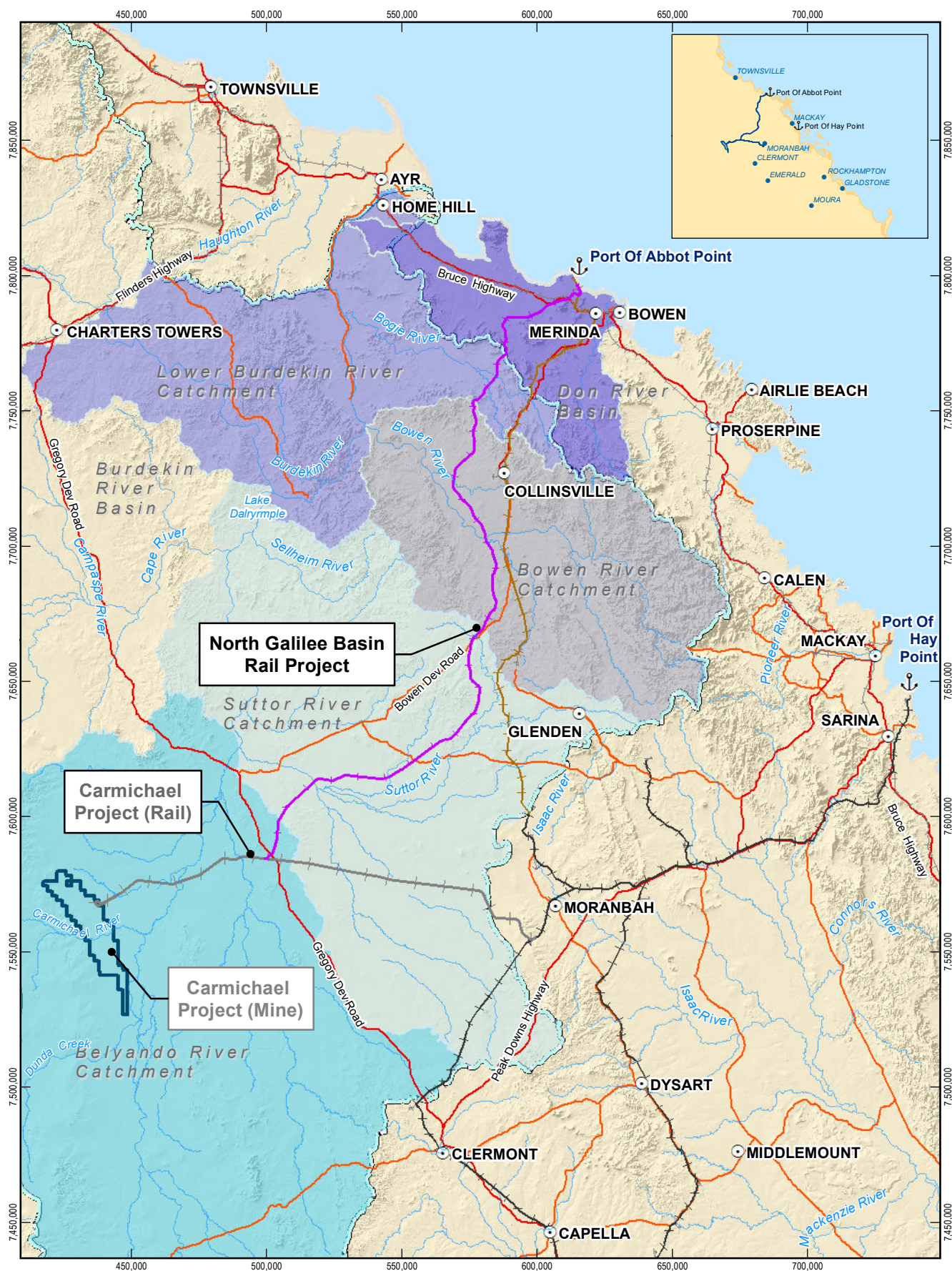
- Section 2 - Overview of the assessment methodology employed, data sources utilised and discusses relevant legislation and policy applicable to this study.
- Section 3 - Describes the baseline groundwater and surface water values in terms of hydrology, water quality, ecology and geomorphology.
- Section 4 - Summarises the key findings of this assessment.

A number of associated NGBR Project Environmental Impact Statement (EIS) studies are referenced within the following sections, but in particular this report should be read in conjunction with Volume 1 Chapter 9 Water resources.

1.3 Objectives

The overall objective of this report is to describe existing surface water (including hydrology and water quality) and groundwater values relevant to the NGBR Project. Specifically, the water resources report aims to identify and assess the existing conditions for each of the following elements:

- Catchments and waterways including any impoundments (dams)
- Floodplains, with reference to extent of flooding and flood frequency
- Environmental values
- Water quality
- Geomorphology
- Groundwater.



LEGEND

- | | | | | |
|--------------------|--------------------------|--------------------------------|---------------------------|---------------------------|
| Major Port | Watercourse (Major) | Suttor River Catchment | Burdekin River Basin | Carmichael Project (Mine) |
| Other Rail Network | Road | Bowen River Catchment | Carmichael Project (Rail) | North Galilee Basin Rail |
| Goonyella System | Major Drainage Areas | Don River Basin | | |
| Newlands System | Belyando River Catchment | Lower Burdekin River Catchment | | |

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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
North Galilee Basin Rail Project

Study area

Job Number 41-26457
Revision A
Date 29 Aug 2013

Figure 1-1

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Data Source: © Commonwealth of Australia (Geoscience Australia); Town, Railways, Watercourses, Burdekin River Basin (2007); DNRM: Hillshade, River Basins (2009); DMR: State Roads (2008); DME: EPC1690 (2010), EPC1080 (2011); Adani: Carmichael Rail (2012), NGBR: Corridor Opt6 Rev 2 (2013). Created by: MS

2. Methodology

2.1 Study area

For the purpose of this report, the study area is defined by the NGBR Project preliminary investigation corridor (nominally 1,000 m wide) and four associated major catchment areas, namely the Suttor River, Bowen River and Lower Burdekin River catchments (all within the Burdekin Basin), and the Don River Basin (refer Figure 1-1). Within the Don River Basin the study area includes minor coastal catchment areas such as Splitters Creek, Saltwater Creek and Elliot River as they are traversed by the preliminary investigation corridor. However, within the Don River Basin, the Don River catchment is not traversed and is therefore not included in the study area. A 15 km section at the southern extent of the preliminary investigation corridor intersects the Belyando River catchment (within the Burdekin Basin); however, no major watercourses are crossed in this catchment.

2.2 Data sources

This water resources report relies on the following data sources:

- Aerial imagery extracted from Google Maps
- Light detection and ranging (LIDAR) digital elevation data of the preliminary investigation corridor
- Historic rainfall data from Bureau of Meteorology (BOM) station data
- Patched-point datasets (PPD) purchased from the Queensland Government Department of Natural Resources and Mines (DNRM) SILO data store
- Historic flow and gauge height data extracted from relevant flow gauging stations in the Don River, Lower Burdekin River, Bowen River and Suttor River sub-catchments. Data for these were sourced from the DNRM
- Interim floodplain assessment overlay from Queensland Reconstruction Authority (QRA) for the Don River, Lower Burdekin River, Bowen River and Suttor River sub-catchments
- Water quality data collected from readily available information sourced from existing studies, data available within the public domain and field inspections undertaken by GHD in May 2013
- Groundwater and geomorphology data sourced from readily available information within the public domain and field inspections of the preliminary investigation corridor undertaken by GHD in May 2013.

2.3 Legislation and guidelines

Legislation and guidelines relevant to this water resources report are as follows:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cth)
- *Environmental Protection Act 1994*
- *Environmental Protection (Water) Policy 2009*
- *Coastal Protection and Management Act 1995*

- *Fisheries Act 1994*
- *Marine Parks Act 2004 (Cth)*
- *Sustainable Planning Act 2009*
- *Water Act 2000*
- *Water Regulation 2002*
- Water Resources (Burdekin Basin) Plan 2007
- Burdekin Resource Operation Plan 2009
- Policy for the Maintenance and Enhancement of Water Quality in Central Queensland 2003
- State Planning Policy 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide
- State Planning Policy 4/11: Protecting wetlands of high ecological significance in Great Barrier Reef catchments
- Social, Economic, Cultural and Environmental Values of Streams and Wetlands in the Burdekin Dry Tropics Region (Greiner, R. and Hall, N., 2006)
- Burdekin Water Quality Improvement Plan (Dight 2009)
- Australia and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (the ANZECC guidelines) (ANZECC and ARMCANZ 2000)
- Queensland Water Quality Guidelines 2009 (DERM 2009a).

A description of the legislation described above (not including guidelines) is provided in the Volume 1 Chapter 20 Legislation and approvals.

2.4 Desktop assessment

A desktop assessment was conducted to describe the existing environment of the NGBR Project. Steps in the methodology are described as follows:

- Review of existing studies and available data relevant to surface water and groundwater within the study area
- Document the current legislative framework and assessment criteria for surface water and groundwater management in the region
- Description of the baseline conditions within the study area, including physical, chemical and hydrological features.

2.4.1 Surface water quality

Four studies of major and minor watercourses that are intersected by the preliminary investigation corridor have been undertaken over the past five years within the region, primarily to inform EIS. These studies provide information regarding the spatial and temporal variability of the physical and chemical characteristics of surface water quality within the catchments. A review of the following existing studies was performed to inform the baseline water quality:

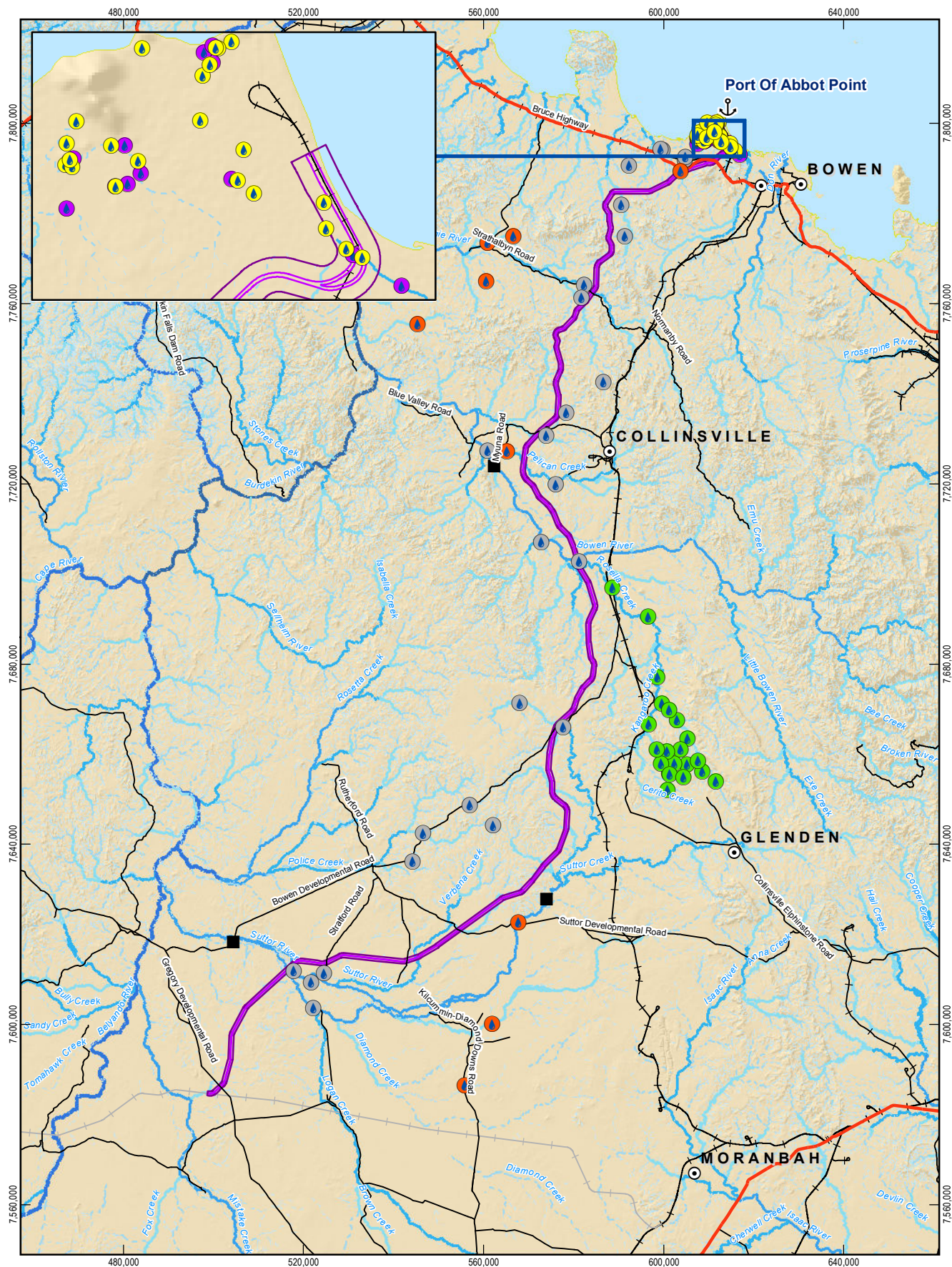
- Hancock Prospecting Pty Ltd Alpha Coal Project Environmental Impact Statement, Volume 6 Rail Corridor Appendices (Hancock Prospecting 2010). Desktop and water quality surveys were undertaken in April 2010 from nine sites selected to cover a geographic range of aquatic habitats, corresponding with the disturbance footprint of the proposed rail alignment

and representative of major aquatic habitats in the area. Results of this survey were compared to various water quality guidelines

- Waratah Coal Galilee Coal Project – Environmental Impact Statement (E3 Consulting 2011). The surface water chapter describing hydrology and water quality is relevant to this water resources report. Water quality, stream morphology and riparian vegetation field surveys were undertaken (October 2009 and March 2010) during the wet season and the dry season at 28 sites.
- Xstrata Coal Newlands Coal Extension Project – Environment Impact Statement (Kellogg Brown and Root 2012). Water quality was sampled between 2007 and 2011 within the Bowen River catchment at 26 sites.
- Abbot Point Cumulative Impact Assessment. (Eco Logical and Open Lines 2012). A comprehensive review was performed of previous water quality field-based investigations within the Caley Valley Wetland.

Figure 2-1 shows the location of the surface water quality sites sampled during the previous four studies.

In addition to the above studies, the Department of Natural Resource and Mines (DNRM) operates the Stream Gauging Station Network primarily to fulfil legislative requirements under part 3, section 35 of the *Water Act 2000* to regularly measure and keep publicly available records of volume and quality of water in Queensland. Data from three of the DNRM stream gauging stations was also used to determine the baseline water quality within the preliminary investigation corridor.



LEGEND

- | | | | | | | |
|-------------------------------------|---------------------|-------------------|-------------------------|---|---|---------------------|
| Population Centres Previous Surface | Hancock | GHD | Carmichael Stream Order | 3 | 6 | North Galilee Basin |
| Major Port | Water Quality Sites | Newlands Coal EIS | Project (Rail) | 1 | 4 | Rail 1000m Corridor |
| Gauging Station | Waratah | WBM | Railway | 2 | 5 | North Galilee Basin |
| | | | Main Road | | 8 | Rail 100m Corridor |
| | | | | | 9 | |

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Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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Adani Mining Pty Ltd
North Galilee Basin Rail Project

Job Number 41-26457
Revision A
Date 29 Aug 2013

Previous Surface
Water Quality Sites

Figure 2-1

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Data source: GA: Populated Places, Railway/2007; Adani: NGBR Corridor 13/05/2013, NGBR Corridor 06/06/2013, Carmichael Rail Project/2012; Hancock, Waratah, Newlands Coal EIS, WBM, GHD: Previous WQ Sites/ 2010-2013; DNRM: Roads/2010, Stream Order/2011. Created by:MS

2.4.2 Climate

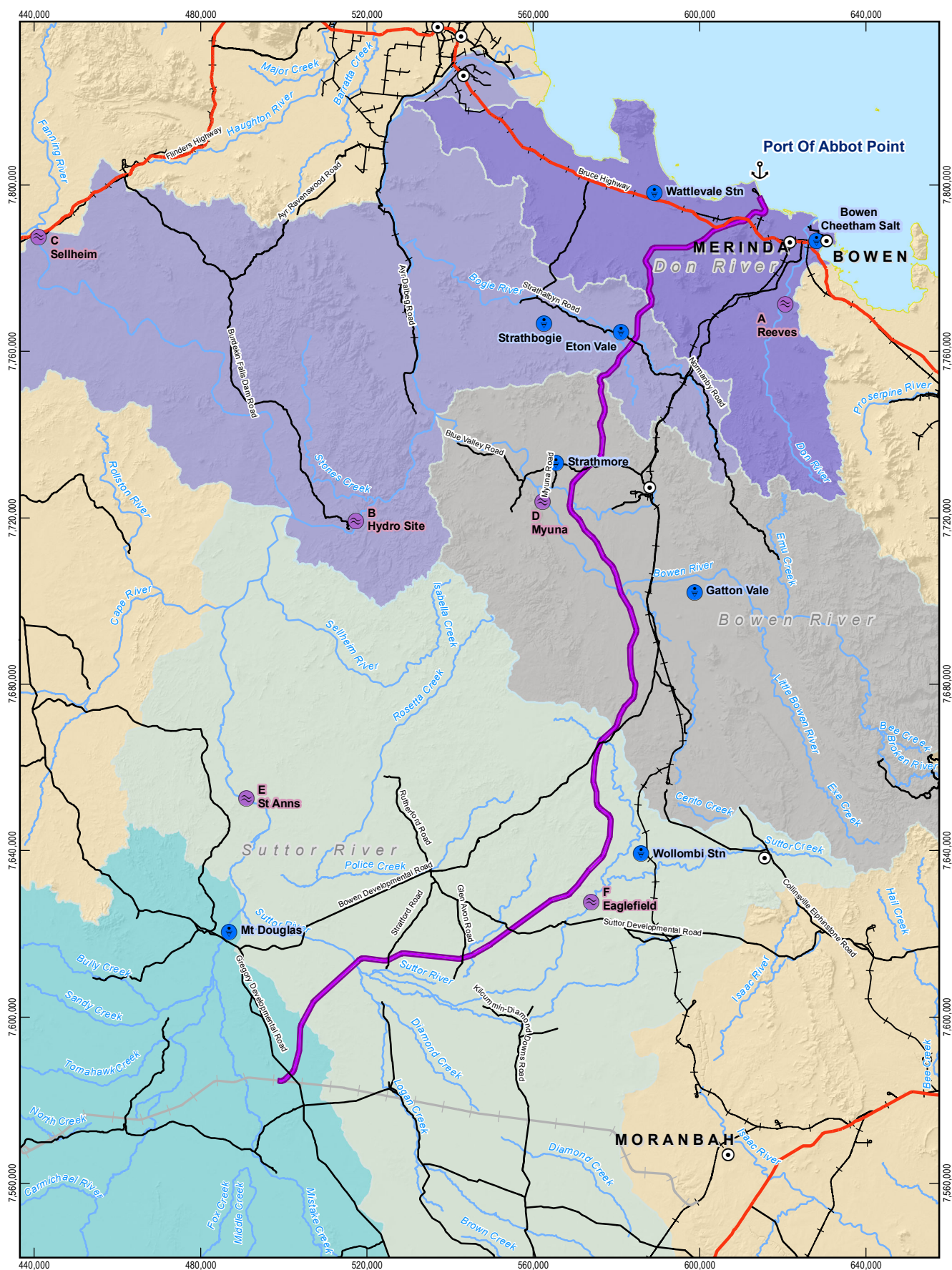
A desktop assessment was conducted to assess the rainfall and flow patterns for catchments bisected by the preliminary investigation corridor. Rainfall data and stream flow records were obtained from the BOM (BOM, 2013a) and the DNRM website (DNRM, 2013) respectively.

The distribution of rainfall stations as well as stream flow gauging stations in relation to the preliminary investigation corridor is shown in Figure 2-2 and discussed in Section 3.2.

2.4.3 Groundwater

Two major hydrogeological studies have previously been undertaken within the study area primarily to inform other projects. For the groundwater assessment, data was obtained and reviewed from these studies as well as other sources including:

- Hancock Prospecting Pty Ltd Alpha Coal Project Environmental Impact Statement, Volume 6 Rail Corridor Appendices (Hancock Prospecting 2010). An EIS for a proposed rail line between Port of Abbot Point to the Alpha Coal Mine. The proposed rail alignment follows a similar alignment to the preliminary investigation corridor.
- Adani Mining Pty Ltd. Report for Carmichael Coal Mine and Rail Project. Hydrogeology Report 25215-D-RP-002. Revision 1 (GHD 2012) and Adani Mining Pty Ltd. Report for Carmichael Coal Mine and Rail Project: Mine Technical Report. Hydrogeology Report 25215-D-RP-0026. Revision 2. 15 November 2012. EIS for a proposed rail line connecting the Carmichael mine to the existing line Goonyella and Newlands rail system. The preliminary investigation corridor joins this rail network in section 2.
- DNRM Groundwater database (GWDB)
- Published geological maps, within the vicinity of the preliminary investigation corridor, in particular the geological maps for:
 - Ayr, Sheet SF55-15, 1:250,000 scale
 - Mt Coolon, Sheet SF55-7, 1:250,000 scale
 - Bowen, Sheet SF55-3, 1:250,000 scale
 - Buchanan, Sheet SF55-6 1:250,000 scale.

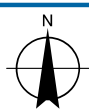


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|----------------------|------------------|---|-----------------------------|
| ○ Population Centres | ● BOM Rain Gauge | □ North Galilee Basin Rail 1000m Corridor | — Carmichael Project (Rail) |
| ⚓ Major Port | — Highway | □ North Galilee Basin Rail 100m Corridor | — Railway |
| ⦿ DNRM River Gauge | — Main Road | | — Watercourse (Major) |
-
- | | |
|---------------------|------------------------|
| River Basins | Bowen River |
| ■ Belyando River | ■ Don River |
| ■ Suttor River | ■ Lower Burdekin River |

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 Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
 North Galilee Basin Rail Project
 Location of Rainfall and
 Stream Flow Gauging
 Stations in the Study Area

Job Number 41-26457
 Revision B
 Date 09 Aug 2013

Figure 2-2

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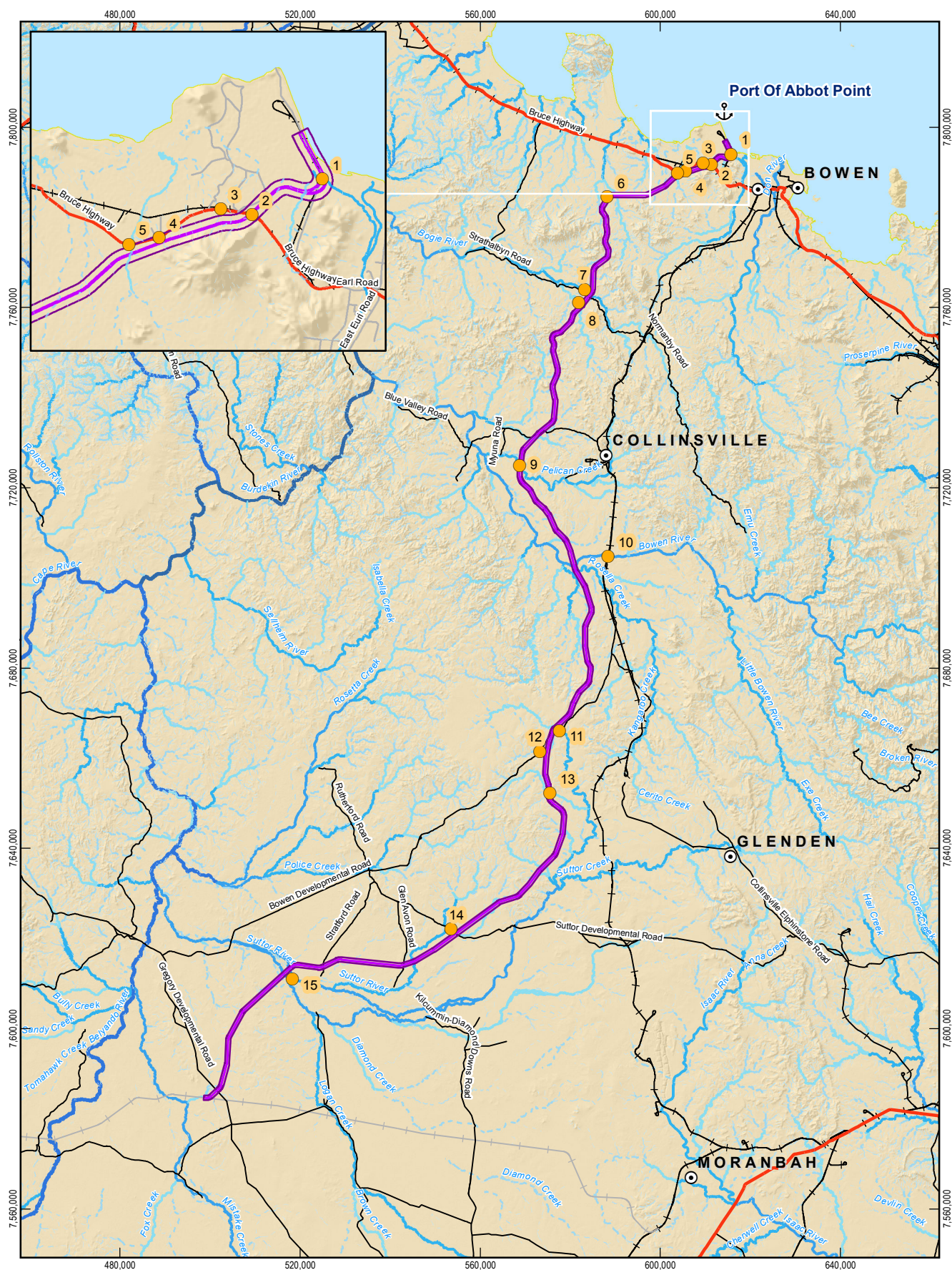
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 Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: NGBR Corridor 13/05/2013, NGBR Corridor 06/06/2013, Carmichael Rail Project/2012; DNRM: Roads/2010; BOM: River Gauge, Rain Gauge/2011. Created by:MS

2.5 Site assessment

The preliminary investigation corridor runs through the Burdekin Basin and Don River Basin. A site assessment of watercourses within these catchments took place on 7, 8 and 9 May 2013 including water quality sampling and assessment of geomorphic conditions, as outlined in Sections 2.5.1 and 2.5.2, respectively. The locations of the watercourse site assessments are shown in Figure 2-3 and listed in Table 2-1.

Table 2-1 Watercourses

Site number	Basin/ Catchment	Watercourse
1	Don River Basin	Saltwater Creek
2		Six mile Creek (dry)
3		Maria Creek (dry)
4		Tabletop Creek
5		Splitters Creek
6		Unnamed tributary off Finley Creek (dry)
7	Lower Burdekin River Catchment	Bogie River
8		Sandy Creek
9	Bowen River Catchment	Pelican Creek
10		Bowen River
11	Suttor River Catchment	Suttor River (upper crossing)
12		Lily Creek (dry)
13		Rockingham Creek
14		Gunn Creek
15		Suttor River (lower crossing)

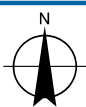


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|--------------------|-----------|---------------------------|--------------|---|---|---|
| Population Centres | Highway | Carmichael Project (Rail) | Stream Order | 3 | 6 | North Galilee Basin Rail 1000m Corridor |
| Major Port | Main Road | Railway | 1 | 4 | 7 | North Galilee Basin Rail 100m Corridor |
| Field Sites | | | 2 | 5 | 8 | |
| | | | | 9 | | |

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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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Adani Mining Pty Ltd
North Galilee Basin Rail Project

Job Number 41-26457
Revision B
Date 09 Aug 2013

Field Assessment Sites

Figure 2-3

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Data source: GA: Populated Places, Railway/2007; Adani: NGBR Corridor 13/05/2013, NGBR Corridor 06/06/2013, Carmichael Rail Project/2012; DNRM: Roads/2010, Stream Order/2011; GHD: Geomorphology Field Sites/2013. Created by:MS

2.5.1 Water quality sampling

All water quality sampling was undertaken in accordance with the requirements of the Monitoring and Sampling Manual 2009 (DERM 2009b) and ANZECC Guidelines (ANZECC and ARMCANZ 2000). Physio-chemical water quality parameters were sampled in-situ using a hand held multi-parameter water quality metre with logging capacity for:

- Temperature (°C)
- Electrical conductivity (EC) (µS/cm)
- Total dissolved solids (TDS) (mg/L)
- Dissolved oxygen (DO) (per cent saturation)
- pH
- Reduction-oxidation potential (Redox).

Ten samples from each site were stored on the logger and downloaded at the end of the sampling event.

2.5.2 Geomorphic investigation

The field investigation assessed the current physical characteristics of waterways at accessible locations within or close to the preliminary investigation corridor. These site assessments were undertaken at the same locations as water quality sampling, as shown in Figure 2-3. This involved recording key information at each site including:

- Channel form and in-stream features (i.e. bars, benches, pools and bedrock controls)
- Bed and bank stability
- Nature of bed and bank sediments.

The assessment of stream physical form and function was broadly based on the methods and principles of the River Styles® framework (Brierley and Fryirs, 2005). Determination of stream types is largely based on the following parameters:

- Degree of valley confinement and bedrock influences
- Presence and continuity of a channel
- Channel planform (number of channels, sinuosity)
- Channel and floodplain geomorphic features
- Nature of channel and floodplain sediments.

The assessment of geomorphic condition was based on Outhet and Cook (2004) who describe a rapid method of condition assessment that frames geomorphic condition in the context of natural and human induced variability. The characteristics of each condition category are described in Table 2-2. These categories provide an indication of the degree of alteration a reach has experienced from its expected natural form.

Table 2-2 Geomorphic condition category descriptions

Indicative condition	Characteristics
Good	Geomorphic structure is largely unchanged from the pre-disturbance state such that only minor cases of localised instability occur. Relatively intact and effective vegetation coverage dominated by native species, giving resistance to natural disturbance and accelerated erosion. There is minimal alteration to catchment controls such as sediment supply and the hydrological regime allowing fast recovery from natural disturbance. There is also a high potential for ecological diversity.
Moderate	Geomorphic structure is moderately altered such that a reduced diversity of river features exist and floodplain connectivity is somewhat limited. Localised degradation of river character and behaviour, typically marked by modified patterns of geomorphic units. Patchy effective vegetation coverage allowing some localised accelerated erosion. The river has not fully adjusted to prevailing conditions and is experiencing ongoing changes.
Poor	Considerable geomorphic alteration to the functioning and structure of the system when compared with the pre-disturbance condition. Type, extent and rate of processes are radically altered. Floodplain connectivity may be significantly altered. Abnormal or accelerated geomorphic instability (reaches are prone to accelerated and/or inappropriate patterns or rates of planform change and/or bank and bed erosion). Excessively high volumes of sediment inputs which blanket the bed, reducing flow diversity. Absent or geomorphologically ineffective coverage by vegetation (allowing most locations to have accelerated rates of erosion).

Source: Outhet and Cook, 2004

2.6 Limitations

The description of the existing surface water and groundwater values in this report is primarily a desktop study with most of the data sources being publically available. These data sources are supplemented by visual observations gained during the water quality sampling and geomorphic assessment field investigations.

Regional hydrometric data collection is limited to rainfall and flow gauging (water level) stations in the vicinity of settlements, station homesteads and major road crossings. Although some of the latter have reasonable lengths of record, coverage is geographically sparse and unevenly distributed across the catchments within the study area.

Published flow data used in this report are based upon recorded water levels and a relevant rating curve for conversion of the recorded level to a flow rate. The rating curves are not considered highly reliable due to the challenges associated with measuring the flows during flood events. Such measurements inform the rating curve. Challenges arise due to, in general, broad floodplains.

Collated water quality data was used to describe the spatial and temporal variability which occurs within the surface water of the preliminary investigation corridor. Although this data is not continuous temporally or spatially, the consistencies of the data records in time and space across the various catchments within the study area have been found sufficient to present an adequate picture of the hydrology of the NGBR Project in its immediate context.

3. Existing environment

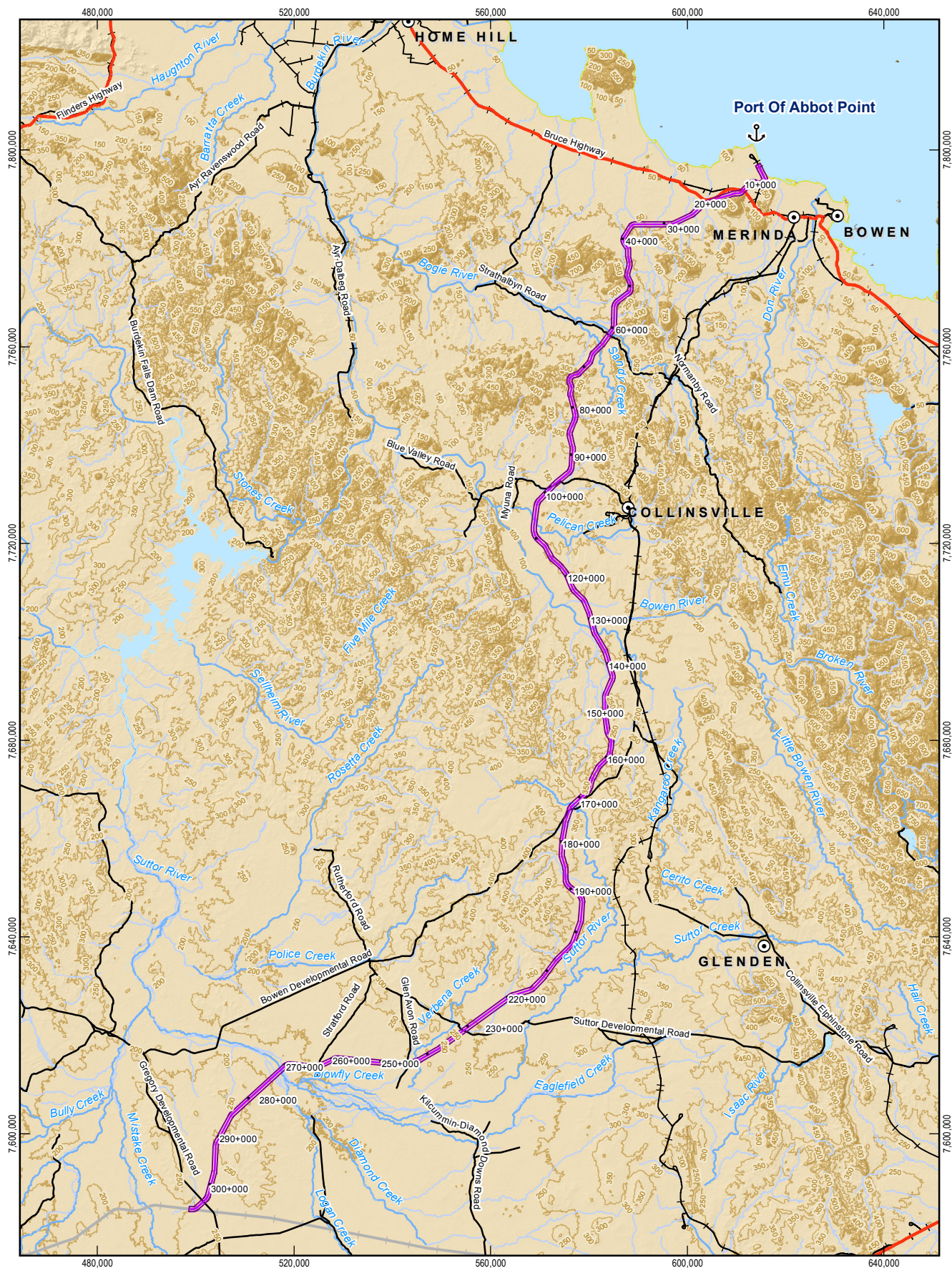
3.1 Catchment description

Given the NGBR Project's significant length, the preliminary investigative corridor traverses varied topography as shown in Figure 3-1. Dominant features throughout the preliminary investigation corridor include gentle undulating slopes with slight rises and shallow depressions. More dramatic topography associated with the Clarke Range and the Leichhardt Range is traversed by the preliminary investigation corridor in the northern and central sections of the corridor, respectively. The final rail corridor will intersect a number of regional surface water features and smaller ephemeral streams. The major waterway crossings along the preliminary investigation corridor are listed in Table 3-1. Land use along the preliminary investigation corridor, which is predominantly utilised for grazing purposes, is presented in Figure 3-2.

Table 3-1 Major waterway crossings and proposed structures

Watercourse name	Basin name
Splitters Creek	Don River
Elliot River	Don River
Bogie River	Burdekin River
Sandy Creek	Burdekin River
Strathmore Creek	Burdekin River
Pelican Creek	Burdekin River
Bowen River	Burdekin River
Suttor River (upper crossing)	Burdekin River
Lily Creek	Burdekin River
Rockingham Creek	Burdekin River
Murray Creek	Burdekin River
Upper Gunn Creek	Burdekin River
Gunn Creek	Burdekin River
Verbena Creek	Burdekin River
Serpentine Creek	Burdekin River
Suttor River (lower crossing)	Burdekin River

Source: Aarvee, 2013b

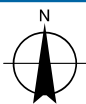


LEGEND

- ⊙ Population Centres
- ⚓ Major Port
- Highway
- Main Road
- Carmichael Project Rail
- Railway
- Watercourse (Major)
- Watercourse (Minor)
- Contour - 50m
- Lakes
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin Rail 100m Corridor

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Grid: GDA 1994 MGA Zone 55



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Study Area
Topography

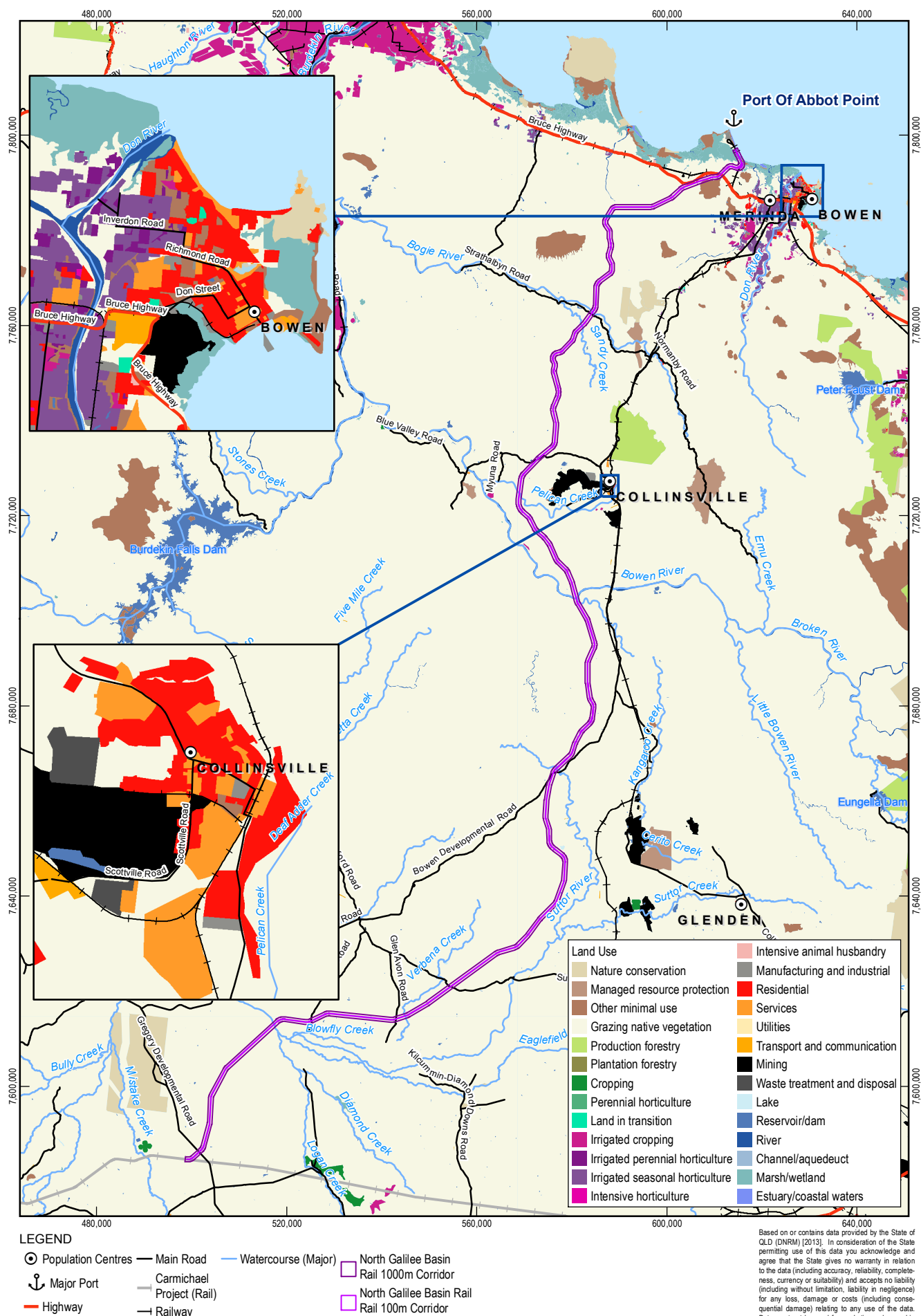
Job Number 41-26457
Revision A
Date 09 Aug 2013

Figure 3-1

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Data source: GA: Populated Places, Railway, Watercourse, Lakes/2007; Adani: NGBR 100m Corridor 06/06/2013, NGBR 1000m Corridor 03/05/2013, Carmichael Project Rail/2012; DNRM: Roads/2010, Contour - 50m/2011, Lakes/2008.
Created by:MS



3.1.2 Don River Basin

The Don River Basin spans from the Clarke Ranges up to Bowen and has a catchment area of approximately 3,695 km². Almost 87 per cent of the catchment land use is dominated by grazing with a small percentage being used for irrigated horticulture and cropping (Greiner, R. and Hall, N., 2006).

The preliminary investigation corridor traverses the catchment parallel to the alignment of the Don River, bisecting tributaries such as Splitters Creek and Elliot River. The preliminary investigation corridor is also observed to intersect many minor tributaries and flow paths within this catchment. The preliminary investigation corridor with respect to major watercourses in the Don River Basin is shown in Figure 1-1.

The Don River and its tributaries are mostly ephemeral streams flowing for short periods after significant rainfall. No major permanent waterholes are noted though some smaller holes are likely to be present and these may be vulnerable to disturbance (Maughan *et al.* 2006). Stream bank erosion, most likely the result of large scale clearing along the riparian areas, is known to be the greatest contribution to suspended sediment (Kinsey-Henderson *et al.* 2007).

The coastal freshwater wetlands are also mostly ephemeral or seasonal. The area is poorly known ecologically, especially the coastal freshwater wetlands (Kinsey-Henderson *et al.* 2007). There are approximately 227 lacustrine/palustrine wetlands in this region (DEHP 2013).

3.1.3 Burdekin Basin

Lower Burdekin River catchment

The Lower Burdekin River catchment drains an area of approximately 9,300 km² and is made up of seven coastal and non-coastal sub-catchments. The preliminary investigation corridor bisects Bogie River and its tributary, Sandy Creek at an almost perpendicular angle. The preliminary investigation corridor is also observed to intersect many minor tributaries and flow paths within this catchment. The preliminary investigation corridor with respect to the Lower Burdekin River catchment and major watercourses is shown in Figure 1-1.

Land use in the catchment is predominantly grazing on natural and modified pastures. Clearing along streams and floodplains over the last 30 years has seen a general decline in the condition of riparian habitat. The Lower Burdekin River catchment has 11 per cent of land in high cover category of riparian habitat, 21 per cent in the moderate cover category, 64 per cent in low cover and a four per cent in the bare cover category (Hasset *et al.* 2000).

Stream bank, hill slope and gully erosions are known to be the major causes of sediment and particulate nutrients affecting water quality in the Lower Burdekin Basin. However, loss of sediment and associated particulate nutrients from all sources is only moderate when compared to other larger basins (Kinsey-Henderson *et al.* 2007).

There are approximately 317 lacustrine/palustrine wetlands in this region (DEHP 2013). The two non-coastal sub-catchments consist of mostly dry, ephemeral creeks.

Bowen River catchment

The Bowen River catchment is approximately 8,200 km² and forms a major tributary of the Burdekin River. The preliminary investigation corridor bisects Pelican Creek and the Bowen River at its confluence with Rosella Creek. The preliminary investigation corridor is also observed to

intersect many minor tributaries and flow paths within this catchment. The preliminary investigation corridor in relation to the Bowen River catchment and major watercourses is shown in Figure 1-1.

Land use in this catchment is almost exclusively grazing on natural pastures. The condition of riparian habitat is predominantly poor due to floodplain clearing and gullying. The Bowen River catchment has two per cent of land in very high cover category of riparian habitat, 45 percent in high cover category, 43 per cent within the moderate cover category, eight per cent in low cover and a two per cent in the bare cover category (Hasset *et al.* 2000).

Stream bank, hill slope and gully erosions are known to be the major causes of sediment and particulate nutrients affecting water quality in the Bowen River catchment with the occurrences of erosion observed to be most significant in the middle reaches of the river (Kinsey-Henderson *et al.* 2007).

The Bowen River, being a major tributary of the Burdekin River basin, has many waterholes and clear flowing water for most of the year providing for significant aquatic habitat. The Bowen River Weir near Collinsville is a man-made storage that provides a large, non-flowing deep water habitat. There are approximately 163 lacustrine/palustrine wetlands in this region (DEHP 2013).

Suttor River catchment

The study area is characterised by wide floodplains of rivers and creeks with reasonably well defined channels. The wet season is typically November to May but the rivers and creeks of the study area may have zero flow in any month.

The preliminary investigation corridor within this catchment sits parallel to Suttor River for most of its length with two major crossings across the river and one across its tributary, Verbena Creek. The preliminary investigation corridor is also observed to intersect many minor tributaries and flow paths within this catchment. The NGBR Project with respect to the Suttor River catchment and major watercourses is shown in Figure 1-1.

The Suttor River catchment is approximately 18,000 km², and comprises almost 14 per cent of the area of the Burdekin Basin. The terrain in this basin differs markedly from others within the Burdekin Basin, lacking the high mountain backdrops and representing a drier, typically semi-arid western landscape. Cattle grazing is the dominant land use of the area and a small percentage of the land is used for dry land cropping of cereals.

The last 30 years of clearing along headwater streams and on the floodplains has resulted in altered hydrological regimes and deterioration of the riparian habitat of many of the waterways crossed by preliminary investigation corridor. The Upper Suttor River sub-catchment is estimated to have nine per cent in the very high cover category of riparian habitat, followed by 53 per cent of land within the high ground cover category, 29 per cent in the moderate cover category, and eight per cent in the low cover category (Hasset *et al.* 2000).

Greiner, R. and Hall, N., (2006) identified hill slope erosion as the major source of sediment and particulate nutrients affecting water quality within the Upper Suttor River sub-catchment. Gully and stream bank erosion are also identified as significant contributors. While the total volume of soil loss is high due to the size of the sub-catchment, the rate of soil loss is predicted to be quite low and below the Suttor Basin average.

The Suttor River and its tributaries are ephemeral streams with large waterholes fed from groundwater. This area shows some dry land salinity which is a potential to terrestrial and aquatic ecology. Macroinvertebrates have experienced moderate change along the whole river. Also, fish and water quality are moderately affected below the junction of Suttor River with Belyando River

(Greiner, R. and Hall, N., 2006). There are approximately 2,078 lacustrine/palustrine wetlands in this region (DEHP 2013).

Belyando River catchment

The Belyando River catchment is located within the Burdekin Basin and covers an area of approximately 35,000 km². The Belyando River is bound by the Great Dividing Range in the west and the Denham and Drummond Ranges to the east, and flows in a northerly direction before joining the lower reaches of Suttor River. The location of the Belyando River catchment is presented in Figure 1-1. Cattle grazing is the dominant land use of the area with a small percentage of the land used for dryland cropping of cereals. A 15 km section of the preliminary investigation corridor intersects the Belyando River catchment, however, no major watercourses are crossed.

3.2 Climate

The region is typically tropical, with temperatures ranging between 20°C and 40°C and heavy rains receive during the wet season (November to May). Temperature and rainfall distributions, described below, further illustrate the climatic characteristics of the study.

3.2.1 Rainfall

The main influence on the hydrology of the waterways crossed by the NGBR Project is rainfall patterns. Monthly rainfall data representing rainfall patterns for various catchments within the study area has been extracted, reviewed and plotted for the following rainfall stations:

- Don River Basin – Gatton Vale (refer Appendix A 1) and Wattlevale Station (refer Appendix A 2).
- Lower Burdekin River catchment – Strathbogie (refer Appendix A 3) and Eton Vale (refer Appendix A 4)
- Bowen River catchment – Bowen Cheetham Salt (refer Appendix A 5) and Strathmore (refer Appendix A 6).
- Suttor River catchment – Mt Douglas (refer Appendix A 7) and Wollombi Station (refer Appendix A 8)

These rainfall stations have been chosen based on their proximity to the preliminary investigation corridor and the length of data available. A minimum of two rainfall stations have been chosen for each catchment to show precipitation trends across the study area. The locations of these rainfall stations are shown in Figure 2-2 and details are provided in Table 3-2.

Table 3-2 BOM rainfall stations

Station Name and BOM Site Code	Elevation (m)	Date opened	Date closed	Catchment
Gatton Vale (33176)	130	1970	Still open	Don River
Wattlevale Station (33150)	15	1971	Still open	Don River
Strathbogrie (33070)	80	1915	Apr 2001	Lower Burdekin River
Eton Vale (33175)	144	1972	Still open	Lower Burdekin River
Bowen Cheethan Salt (33094)	0	1960	Still open	Bowen River
Strathmore (33082)	200	1886	Still open	Bowen River
Mt Douglas (34022)	170	1912	Still open	Suttor River
Wollombi Station (34020)	300	1965	Jan 2011	Suttor River

The plots for the rainfall stations listed in Table 3-2 show that:

- Rainfall patterns, in terms of maximum summer and winter volume, and annual totals are broadly similar across the study area particularly for inland areas. Rainfall totals for the coastal areas are comparatively higher (as seen in rainfall plots for Bowen Cheetham Salt (refer Appendix A 5))
- Although the typical wet season spans from November to May, this does denote that rainfall depths will be the highest during this period. In fact, in any month of the year, including in the typical wet season months, there can be zero rainfall.

The monthly rainfall trends described above are reflected in the gauged river flows seen in Appendix B 1 to B 6 Section 3.2.2. Similarly, the pronounced annual variations in rainfall, including the persistence of both dry years and wet years, affects the annual discharges at the stream gauging stations, i.e. the flow pattern is largely similar to the rainfall pattern. Annual rainfall totals for several relevant rain gauges are presented in Appendix A 9 to A 16.

The maximum summer rainfall volumes arise from prolonged eastward travelling monsoon depressions and also intense short-term contributions from predominantly westward travelling tropical cyclones. According to Sturman and Tapper (2006), Australian tropical cyclones commonly originate in the Gulf of Carpentaria and out into the Coral Sea between 9 and 19° south.

An average of ten tropical cyclones per year develop over Australian waters, of which six cross the coast, mostly over north-western Australia and northeast Queensland (Geoscience Australia, 2011). According to Watkins (2011), the frequency of cyclones in eastern Queensland is significantly correlated to the fluctuations in the El Niño-Southern Oscillation (ENSO), which is driven by variability on sea surface temperatures in the Pacific Ocean. A strong La Nina phase of the ENSO (cooler sea surface temperatures off eastern Australia) saw four tropical cyclones crossing Queensland over the 2010/2011 summer including Cyclone Yasi on 2 February 2011.

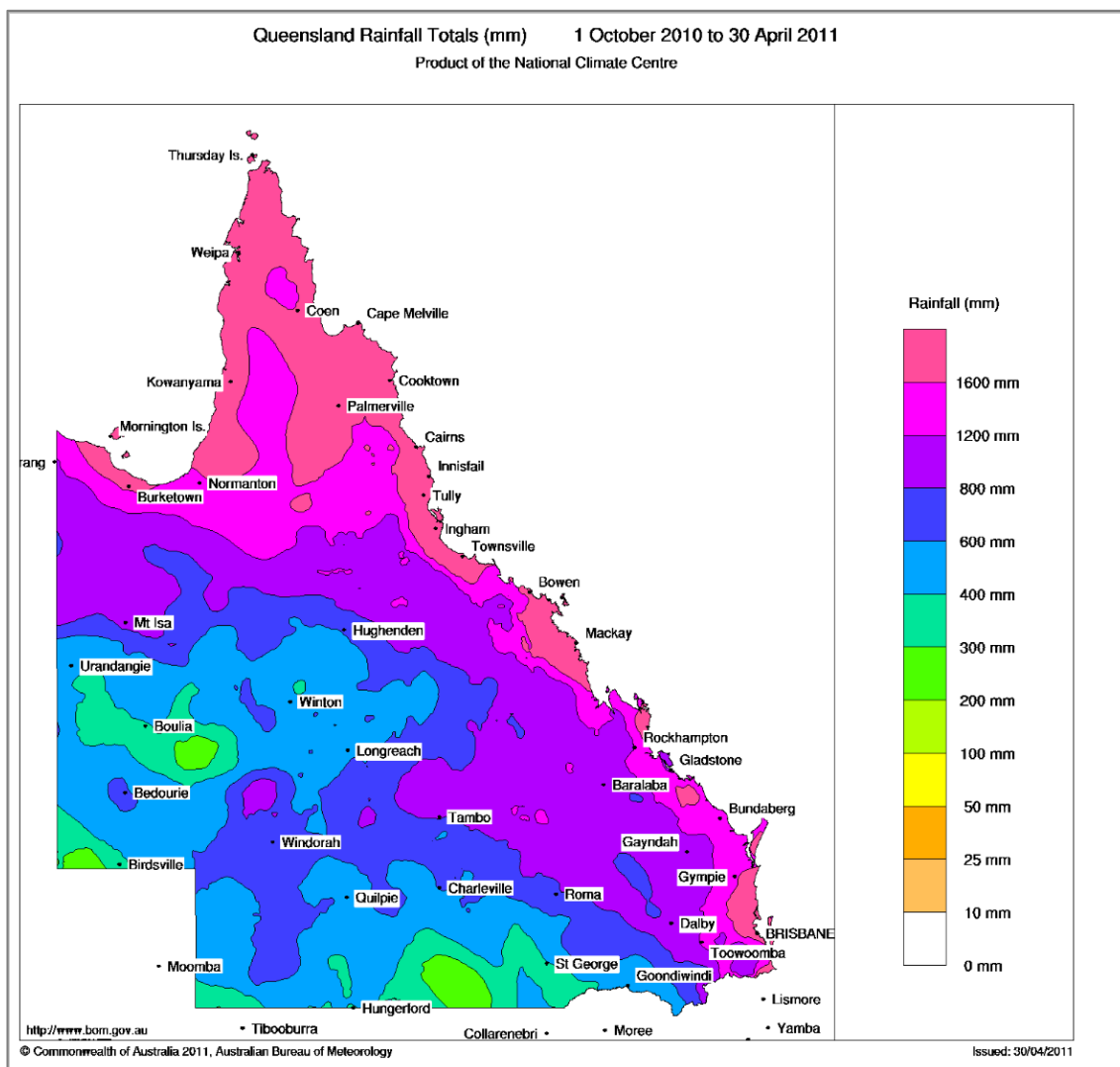
The lower winter rainfalls typically experienced in the region coincide with the stalling of large stable anticyclones over central Australia that cause cool dry, west to southwesterly airflow to

predominate over Queensland. Rainfall in this season is associated with short southerly fronts originating in the southern oceans that affect the southern and eastern coasts of Australia.

Rainfall associated with monsoons and tropical cyclones in North Queensland is often of extreme intensity and while as much as 1,000 millimetres (mm) can fall in a few days along the coast, depths of 200 to 300 mm are more common inland.

Relatively high rainfall totals were also observed in the catchments within the study area during the wet season of 2010/2011. Information sourced from the BOM website is presented in Figure 3-3 and indicates that the rainfall totals near the study area (east of Hughenden) were greater than 800 mm for this wet season.

Figure 3-3 Wet season rainfall totals for Queensland



Source: Bureau of Meteorology (2011a)

3.2.2 Stream flow

The description of existing flow conditions or hydrology is informed by data published by the Department of Natural Resources and Mines (2013). Data obtained from this source for the stream gauges is presented in Table 3-3.

Table 3-3 DNRM river gauging stations

Map label	Gauge and DNRM site code	Catchment	Catchment area served km ²	Record start date and record length
A	Don River at Reeves (121003A)	Don River	1,016	March 1984 29 years
B	Burdekin River at Hydro Site (120015A)	Burdekin River	114,700	Dec 1977 36 years
C	Burdekin River at Sellheim (120002C)	Burdekin River	36,260	Oct 1968 45 years
D	Bowen River at Myuna (120205A)	Bowen River	7,104	Oct 1960 53 years
E	Suttor River at St Anns (120303A)	Suttor River	50,290	Aug 1967 46 years
F	Suttor River at Eaglefield (120304A)	Suttor River	1,915	Dec 1967 46 years

These stream gauging stations have been chosen based on their proximity to the NGBR Project and the data available. The locations of these gauge locations with respect to the NGBR Project are shown on Figure 2-2. Data from the gauging stations have been assessed and presented in relevant figures:

- Don River Basin – Don River at Reeves (refer Appendix B 1).
- Lower Burdekin River catchment – Burdekin River at Hydro Site (refer Appendix B 2) and Burdekin River at Sellheim (refer Appendix B.3)
- Bowen River catchment – Bowen River at Myuna (refer Appendix B 4)
- Suttor River catchment – Suttor River at St Anns (refer Appendix B 5) and Suttor River at Eaglefield (refer Appendix B 6)

The flows were estimated by averaging monthly flow data available for the period of record length. They provide an overview of the flow regimes in the relevant catchments. It should be noted that it is not intended that these plots represent the flow at the intersection of the waterway with the preliminary investigation corridor. Rather, they indicate typical patterns of flow in the study area. Of particular note is that, even though the catchment areas at the gauges are large (up to 114,700 km²), recorded base flow is often zero or minimal. Flow patterns generally mimic rainfall, and while there are more flow events in the wet season, periods of zero flow occur in any month of the year.

In addition to the pronounced monthly fluctuation, significant variability can be observed from year to year. The variation in annual discharge volumes is presented in Appendix B 7 to B 12.

It is the large, short duration flood events, which can occur anytime from November to May, that dominate the discharge regime and long term averages. Intervening dry periods are frequent, although their length is unpredictable. The episodic, short-lived and unpredictable nature of these wet and dry events tends to mask the summer seasonality of flows.

3.2.3 Temperature

Monthly mean temperatures for BOM climate stations situated along the preliminary investigation corridor were investigated. Spatially, Bowen Airport (033257)/ Bowen Cheetham Salt (033094) represent the northern extent of the corridor, Collinsville Post Office (033013) represents the central portion of the corridor, and Twin Hills (036047) and Mt Douglas (034022) represent the southern portion of the corridor.

Monthly mean temperatures show daytime summer temperatures are between 24°C and 36°C with overnight temperatures from 8°C to 23°C. The greatest extremes in both minimum and maximum temperatures are shown at Mt Douglas, situated in the southern portion of the preliminary investigation corridor. Conversely, the Bowen climate station shows the least variation in temperature range.

The long term temperature records of over 100 years show temperature values ranging from -3.5°C to 46°C along the preliminary investigation corridor as shown in Table 3-4. Hot days, with temperatures exceeding 35°C, can be expected up to 21 days per year, with none of these occurring between May and August. Potential for frost days with temperatures below 2°C, can be expected up to 14 days per year (average of four days per year), between May and September. As mentioned previously, the majority of minimum temperature extremes identified occurred at the Mt Douglas climate station.

Table 3-4 Temperature records

Location	Minimum temperature record (°C)	Mean daily minimum temperature record (°C)	Mean daily maximum temperature record (°C)	Maximum temperature record (°C)
Bowen	2.5 (1908)	19.4	28.6	41 (1935)
Collinsville	15 (several years)	16.4	30.2	44 (1994)
Mt Douglas/Twin Hills	-3.5 (1946)	15.3	30.5	46.5 (1994)

3.2.4 Evaporation

Potential evaporation along the preliminary investigation corridor increases from north to, as relative humidity decreases. Potential evaporation ranges from 1,960 mm at Bowen to 2,155 mm at Mt Douglas. These evaporation rates are around 44 per cent and 28 per cent (respectively) greater than average precipitation at these locations.

3.3 Geomorphology

Waterways along the preliminary investigation corridor are predominately set within rural or semi-rural/bushland settings and have been modified over time by land clearance and other agricultural practices. Catchment responses to land clearance include increased runoff, increased drainage density, increased erosion and sediment yields within the catchment. In response to altered hydrological regimes channel morphology changes can occur as the result of bank erosion, channel incision and floodplain scour, which are generally associated with increasing stream power and sediment transport capacity. Such fluvial responses to catchment disturbances are well documented along rivers in eastern Australia (e.g. Prosser *et al.* 2001; Bartley *et al.* 2004; Bartley 2008; Hughes *et al.* 2009).

As a result, most waterways assessed along the preliminary investigation corridor are considered to be in moderate to poor geomorphic condition, with many exhibiting evidence of excessive sand sedimentation as result of past upstream disturbances.

3.3.1 Waterway types

Table 3-5 provides a summary of the geomorphology of waterways inspected during the field investigation. The location of sites that were field assessed is displayed in Figure 2-3.

Based on the field investigation and the interpretation of aerial imagery, six broad waterway geomorphic types are encountered along the preliminary investigation corridor.

Confined valley systems

Confined valley systems are characterised by a single, symmetrical channel often in bedrock controlled, irregular V or U shaped valleys. Channel geometry and sinuosity is valley controlled and the bed and banks are largely composed of bedrock. The system may transport sand and gravel, depending on local geology. The banks are composed of bedrock and floodplains are absent. These are geomorphically stable reaches that are subject to very slow rates of change due to the high degree of bedrock confinement.

While not encountered at any of the field investigation sites, aerial imagery indicates confined valley systems may potentially be encountered along the preliminary investigation corridor in upper catchment positions.

Valley fill systems

These systems are characterised by a relatively flat, un-incised valley floor surface such that there is no presence of a well-defined channel. Substrates are predominantly comprised of alluvial sands, fine silts and muds. Such features are typically formed by flows that lose their velocity and competence as they spread over an intact valley floor and deposit their sediment load. Material eroded from the catchment is not transported through the reach, which is often on a relatively flat longitudinal grade. When disturbed, these systems have the potential to develop a continuous channel through incisional processes, transforming the geomorphic nature of the system and releasing stored sediment to downstream reaches.

While not encountered at any of the field investigation sites, aerial imagery indicates valley fill systems may potentially be encountered along the preliminary investigation corridor in middle to upper catchment positions.

Channelised fill systems

Channelised fill systems exhibit a defined watercourse channel incised within a previous valley fill system. In most cases, the channel has evolved through headward retreat of a headcut have been channelised or formed as a constructed drainage line. The channel usually exhibits a gully like form with steep banks. The banks can often be subject to ongoing instability, often through undercutting during flow events leading to bank collapse.

While not encountered at any of the field investigation sites, aerial imagery indicates channelised fills may potentially be encountered along the preliminary investigation corridor in middle to upper catchment positions.

Bedrock controlled sand/gravel systems

These systems consist of a single, laterally stable channel with a bed composed of sand to gravel sized sediments. Valley width and alignment controls channel sinuosity and floodplain extents, creating discontinuous floodplains as the river migrates between valley margins. The channel is

prone to enlargement through erosion of the inside bank where alluvial floodplains are present. However, bedrock frequently outcrops within the channel bed and banks, controlling channel position and limiting any systemic adjustments to occur in response to disturbances.

Bedrock controlled systems were present at nine of the sites assessed during the field investigation. Of these, only the Bowen River and Tabletop Creek (not intercepted by the final rail corridor) exhibited a morphology dominated by gravel sized sediments. Bed sediments at all other sites were dominantly composed of sand-sized sediments. Aerial imagery indicates this system is also likely to be intersected by the preliminary corridor along other streamlines in middle to lower catchment positions.

Single channel alluvial sand systems

This waterway type exhibits a channel inset on both sides within wide, continuous floodplains composed of alluvial sediments. The bed consists of sand size sediments creating a planar bed with limited hydraulic diversity. As a result, there is no defined pool riffle sequence associated with these systems. Minor scour pools are associated with the presence of vegetation growing within the channel or accumulations of large woody debris.

Due to the lack of bedrock control, these systems have the capacity to adjust freely. In particular, channel migration occurs on meandering sections through bank erosion of the outside bend and deposition on the inside bends forming point bars. The banks are composed of sandy silt sediments and are prone to erosion by flows when riparian vegetation is disturbed or removed. Additionally, 'breakaways' (gulying of channel banks) can form within the banks where concentrated flood flows or local run-off drains over the banks into the channels. These systems can also incise if disturbed, causing significant alteration to stream form and releasing sediment to downstream reaches.

Alluvial sand systems were encountered within the preliminary investigation corridor crossings of Rockingham Creek and the Suttor River (northern crossing). Aerial imagery indicates this system is also likely to be present where the preliminary investigation corridor crosses other waterways including the Elliot River, Verbena Creek and Strathmore Creek.

Multi-channel alluvial systems

This system exhibits a network of anabranching channels inset within broader alluvial floodplains by up to three metres. The bed of the channels is dominated by fine-grained sediments (silt and mud) and localised scour pools are present within narrower channel sections.

The system is entirely alluvial and does not display bedrock controls. Due to the lack of bedrock control, the shape and position of the channel/s are able to adjust freely across the valley floor. The banks of both the low flow channels and the broader channel zone are composed of silt sediments and are prone to erosion by flows where riparian vegetation is disturbed or removed. Additionally, 'breakaways' (gulying of channel banks) can develop within the banks bounding the channel zone where concentrated flood flows or local run-off drains from floodplains over these banks. These systems can also incise if disturbed, causing significant alteration to stream form and releasing sediment to downstream reaches.

Of the sites investigated, the multi-channel alluvial system was only present along the southern crossing of the Lower Suttor River. Aerial imagery indicates this system is not likely to be present along any other waterways intersected by the preliminary investigation corridor.

Table 3-5 Summary of waterway geomorphology at investigation sites

Site	Photo	Waterway name	Waterway type	Comments
1	 Upstream view of Saltwater Creek.	Saltwater Creek	Single channel alluvial tidal	Inspected within the preliminary investigation corridor. Exhibits a wide, lagoon like channel up to 100 m wide with low banks set with a broad coastal floodplain environment. Banks are largely well vegetated with mangroves and the creek is considered to be in moderate to good geomorphic condition.
2	 View downstream at the Bruce Highway.	Six Mile Creek	Bedrock controlled sand	Inspected within the preliminary investigation corridor. Exhibits a single low sinuosity channel up to 10 m wide and 1.5 m deep bounded by floodplains. Channel is infilled with sand creating a planar bed with limited hydraulic diversity. Banks are well-vegetated and largely stable. Bedrock outcrops observed in bed and banks. The creek is considered to be in moderate to poor geomorphic condition due to excessive sedimentation.

Site	Photo	Waterway name	Waterway type	Comments
3	 Upstream view of Maria Creek.	Maria Creek	Bedrock controlled sand and gravel	Inspected approximately 700 m downstream of the preliminary investigation corridor. Exhibits a single low sinuosity channel up to 10 m wide and 1.5 m deep bounded by narrow floodplains. Channel is infilled with sand and gravel creating a planar bed with limited hydraulic diversity. Banks and benches are well-vegetated and largely stable. The creek is considered to be in moderate to poor geomorphic condition due to excessive sedimentation.
4	 Upstream view of riffle and bank attached bar.	Tabletop Creek	Bedrock controlled gravel	Inspected within the preliminary investigation corridor. Exhibits a single low sinuosity channel zone up to 20 m wide and less than 1.5 m deep. Bounded by a narrow floodplain on the right bank and the bedrock valley margin on the left. In-stream features include shallow pools separated by short runs/riffles, bedrock steps and bank attached bars dominated by gravel. Banks are near vertical and exhibit localised erosion indicative of past channel incision and widening. Hence, the creek is considered to be in moderate geomorphic.

Site	Photo	Waterway name	Waterway type	Comments
5	 Upstream view of Splitters Creek.	Splitters Creek	Single channel alluvial sand	Inspected within the preliminary investigation corridor. Exhibits a single low sinuosity channel up to 30 m wide and three to four m deep bounded by narrow floodplains. In-stream features limited to shallow pools separated by short runs/riffles. Channel is partially filled with sand reducing hydraulic diversity. Banks and benches are well-vegetated and largely stable. The creek is considered to be in moderate geomorphic condition due to sedimentation.
6	 Downstream view of waterway displaying bedrock outcrops.	Unnamed tributary of Elliot River	Bedrock controlled sand	Inspected within preliminary investigation corridor. Channel is up to 15 m wide and less than two m deep. Although banks are generally well-vegetated, evidence of localised bank erosion was prevalent. The channel bed exhibits a continuous, planar sheet of sand with limited in-stream hydraulic diversity apart from occasional bedrock outcrops. As a result, the creek is considered to be in moderate to poor geomorphic condition.

Site	Photo	Waterway name	Waterway type	Comments
7	 Upstream view of low flow 'channel zone' with vegetated remnant ridge on right of photo.	Bogie River	Bedrock controlled sand	Inspected approximately 1.5 km downstream of the preliminary investigation corridor. Exhibits a shallow, braided low flow channel inset within a planar sand sheet that occupies the entire bed of the 150 m wide main channel zone. A narrow, longitudinally discontinuous, well-vegetated ridge of remnant alluvial silt material bounds the left bank of the low flow channel at this location. Broader channel zone is bound by bedrock on the left (southern) bank and a small inset floodplain is located on the right bank. Banks are generally well-vegetated and stable. Creek is considered to be in moderate to poor geomorphic condition due to sedimentation.
8	 Downstream view of Sandy Creek within the rail corridor.	Sandy Creek	Bedrock controlled sand and gravel	Inspected approximately one kilometre downstream of the preliminary investigation corridor. Channel is bound by bedrock on the right (northern) bank and a small inset floodplain is located on the left bank. Channel bed exhibits a continuous, planar sheet of sand/gravel with in-stream hydraulic diversity limited to small pools formed at locations of local scour (e.g. woody debris and bedrock outcrops). Banks are generally well-vegetated with frequent bedrock outcrops observed, indicating high lateral stability. Creek is considered to be in moderate geomorphic condition due to sedimentation.

Site	Photo	Waterway name	Waterway type	Comments
9	 Upstream view of left bank floodplain in the upstream half of the preliminary investigation corridor.	Pelican Creek	Bedrock controlled sand	Inspected within the preliminary investigation corridor. Channel is bound by bedrock on the right (northern) bank and a narrow inset floodplain is located on the left bank. The floodplain is composed of loose mobile sand deposits indicating stripping of former floodplains composed of alluvial silts. The low flow channel exhibits a long, shallow pool at this location controlled by an extensive bedrock channel section at its downstream extent. Riparian vegetation is moderately disturbed and the creek is subject to an increased sediment load due to upstream disturbance. The system is therefore considered to be in moderate to poor geomorphic condition.
10	 View downstream across low flow channel at the crossing of the Bowen Development Road.	Bowen River	Bedrock controlled sand and gravel	Inspected approximately seven km upstream of the preliminary investigation corridor. View north across the Bowen River at the crossing of the Bowen Development Road. Channel is dominated by gravel-sized sediments and the low flow channel exhibits a defined pool riffle sequence with occasional bedrock outcrops. The main channel is approximately 200 m wide and displays large bars composed of gravel and sand. These features are considered to be eroded inset floodplains and as result the system is considered to be in moderate geomorphic condition.

Site	Photo	Waterway name	Waterway type	Comments
11	 Upstream view of Suttor River from Bowen Development Road.	Suttor River	Single channel alluvial sand	Inspected approximately 700 m downstream of the preliminary investigation corridor. Exhibits a single low capacity channel up to 50 m wide bounded by broad floodplains. Entrenched high capacity channel five to six m deep. Channel bed exhibits long shallow pools with small accumulations of sandy silt as bank attached bars. Banks are well-vegetated and largely stable. Creek is considered to be largely undisturbed being well vegetated and exhibiting limited infilling of pools with sand.
12	 Downstream view from Bowen Development Road.	Lily Creek	Single channel alluvial sand	Inspected approximately 1.5 km upstream of the preliminary investigation corridor. Exhibits a single low capacity channel up to 10 m wide bounded by narrow floodplains. Channel is infilled with sand creating a planar bed with limited hydraulic diversity. Banks and benches are well-vegetated and largely stable. The creek is considered to be in moderate to poor geomorphic condition due to excessive sedimentation.

Site	Photo	Waterway name	Waterway type	Comments
13	 Downstream view of macro-channel with inset low flow channel.	Rockingham Creek	Single channel alluvial sand	Inspected within the central section of the preliminary investigation corridor. Exhibits a 'channel zone' up to 30 m wide and 2 m deep with one or two inset low flow channels. Low flow channels are less than one metre deep and up to five metres wide. These are infilled with sand creating a planar bed with limited hydraulic diversity. Banks and benches are well-vegetated and largely stable. Low flow channels display evidence of past incision and is subject to sedimentation. As a result, the creek is considered to be in moderate to poor geomorphic condition.
14	 Downstream view displaying bedrock outcropping in bed and banks.	Gunn Creek	Bedrock controlled, sand and gravel	Inspected approximately one km downstream of the preliminary investigation corridor. Channel generally less than two metres deep and 5 to 10 m wide. Bedrock largely dominates the bed and banks and banks, imparting high vertical and lateral stability. Where bedrock does not dominate, banks are composed of sandy silt and are well-vegetated. Sand and gravel accumulations indicate excessive sediment load and the creek is considered to be in moderate geomorphic condition.

Site	Photo	Waterway name	Waterway type	Comments
15	 Downstream view at the convergence of anabranch channels.	Suttor River	Multi-channel alluvial	Inspected approximately two kilometres upstream of the preliminary investigation corridor. Symmetrical channels generally less than two metres deep and 5 to 10 m wide. In-stream features limited to shallow pools separated by short runs/riffles with isolated woody debris elements. Bed and banks largely composed of mud/silt and exhibit erosion although riparian vegetation is largely undisturbed. As a result, the river is considered to be in moderate geomorphic condition.

3.3.2 Waterway stability

Most of the larger catchment waterways along the preliminary investigation corridor are considered to be relatively geomorphologically stable. This is a reflection of the landscapes and the type of waterway systems that the preliminary investigation corridor traverses. For the most part, the waterways along the preliminary investigation corridor are set within partly confined valleys which provide a high degree of bedrock control on the channel, limiting the potential for waterways to adjust and erode.

Nevertheless, some waterways displayed evidence of recent past or existing instabilities in the form of either headward erosion or bank erosion. These instabilities are described as follows:

Bed instability – headward erosion

Headward erosion ('headcut') is erosion which occurs along a channel in the opposite direction to water flows. This causes down cutting or incision of the bed of a stream and can alter the longitudinal profile of the waterway. Erosion can result in increased rates of sediment to be transported downstream.

Rockingham Creek exhibited channel forms indicative of past channel incision via headward erosion. This is considered to be associated with the dominantly alluvial nature of this waterway, such that bedrock controls on waterway geomorphology is limited, allowing the channel to freely adjust to disturbances. While the waterways assessed in the field investigation show no or limited signs of headward erosion, headward erosion may still be present along sections of any channelised fill systems that may be encountered along the preliminary investigation corridor.

Bank instability

Bank erosion was observed along some of the waterways investigated during the field investigations (Tabletop Creek, Elliot River and Suttor River). In particular, the alluvial single and multi-channel systems can exhibit active outside bank erosion on bends (see Figure 3-4). While this is a natural process of channel migration through meandering, disturbances such as land clearance can exacerbate the rate and extent of bank erosion. 'Breakaways' (gulying of channel banks) can also develop within the banks of these alluvial systems at locations where concentrated flood flows or local run-off drains form floodplains over these banks.



Figure 3-4 Upstream view of erosion of an outside bank along Suttor River

Additionally, some of the bedrock controlled gravel or sand bed systems displayed evidence of channel expansion through erosion of inset floodplains on the inside bank of bends. It should be noted that the outside bank of these systems are generally composed of bedrock and resistant to erosion, hence these systems adjust through erosion of the inside bank.

3.4 Flooding

The frequency and extents of flooding in the catchments within the study area have been assessed based on available historical flood data. The record mirrors the frequency of summer monsoonal and cyclonic rain events as described in Sections 3.2.1 and 3.2.2.

Major flooding in the Don River Basin has been observed since 1861 with the highest recorded flooding occurring in 1946 where significantly high flood levels were recorded such as 9.7 metres at the flood gauge in Warden Bend (BOM, 2013c). Recent major events include the January 1970, February 1979, January 1980, February 1991, February 2008 and the 2010/2011 events. The flooding extent for the 2010/2011 flood event is presented Figure 3-5. Flood levels recorded for recent major events at significant locations are presented in Table 3-6.

Table 3-6 Recorded gauge heights (m) within the Don River Basin

Stream gauge location	Jan 1970	Jan 1980	Mar 1988	Feb 1991	Feb 1999	Jan 2005	Feb 2007	Feb 2008	Mar 2011
Ida Creek	7.06	8.27	5.29	5.80	-	3.60	5.95	7.90	3.11
Mt Dangar	-	-	-	7.50	5.75	5.50	6.90	9.40	3.45
Reeves	-	10.38	7.62	7.43	5.08	5.11	-	9.16	4.66
Bowen Pump Station	7.25	7.20	5.35	5.55	4.80	4.79	5.29	6.50	4.15

Source: BOM, 2013c. Note: All heights are in metres on flood gauges

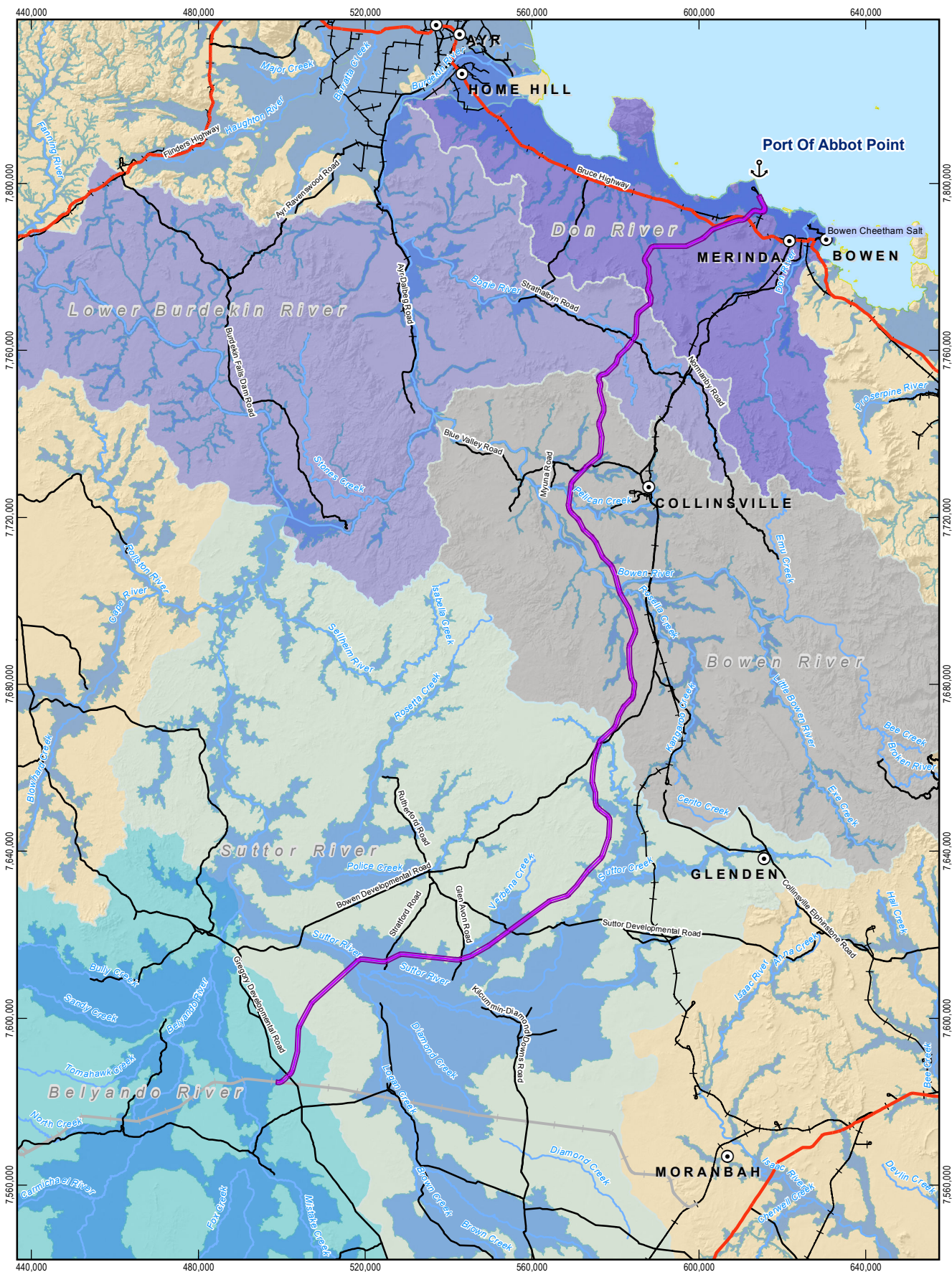
The Burdekin Basin has seen a number of major flooding events dating back to 1911. Recent major events include the February 1991 event and the 2010/2011 event. The flooding extent for the 2010/2011 flood event is presented Figure 3-5 as the Interim Floodplain Assessment Overlay for the Burdekin Basin as extracted from QRA's website. Flood levels recorded for other major events at significant locations within the catchment are presented in Table 3-7 below.

Table 3-7 Recorded gauge heights within the Burdekin Basin

Stream gauge location	Apr 1958	Feb 1968	Jan 1972	Jan 1974	Jan 1991	Early Feb 1991	Late Feb 1991	Jan 1998	Feb 2009
Mt Douglas (Belyando River)	11.61	8.66	-	8.71	7.58	7.98	7.85	-	-
St Anns (Suttor River)	-	8.17	-	8.69	7.71	8.16	-	-	5.03
Jacks Creek (Bowen River)	-	9.88	10.01	8.93	16.05	16.28	7.00	4.08	10.12
Birrilee (Bowen River)	22.00	8.76	8.46	7.93	15.90	16.80	-	-	-
Myuna (Bowen River)	15.64	5.97	5.61	5.62	11.09	12.34	-	-	6.93
Dalbeg (Burdekin River)	23.09	17.15	17.90	18.90	14.45	19.88	17.65	14.25	19.15
Strathbogie (Bogie River)	13.87	7.16	8.69	7.16	10.00	10.70	-	-	6.71

Source: BOM, 2013b

Note: All heights are in metres on flood gauges



LEGEND

- | | | | | |
|--------------------|---------------------|---------------------|----------------------|--------------------------|
| Population Centres | Carmichael | Flooding Assessment | Bowen River | North Galilee Basin |
| Major Port | Project (Rail) | River Basins | Don River | Rail 1000m Corridor |
| Highway | Railway | Belyando River | Lower Burdekin River | North Galilee Basin Rail |
| Main Road | Watercourse (Major) | Suttor River | | Rail 100m Corridor |

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1:1,300,000 Paper Size A4
0 10 20 40
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Interim Floodplain Assessment
Overlay (Based on 2010/2011
Flood Event) for Study Area

Job Number 41-26457
Revision A
Date 09 Aug 2013

Figure 3-5

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Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: NGBR Corridor 13/05/2013, NGBR Corridor 06/06/2013, Carmichael Rail Project/2012; DNRM: QRA-FloodPlain Assessment/2012; Roads/2010; BOM: River Gauge, Rain Gauge/2011. Created by:MS

3.5 Groundwater

3.5.1 Geological conditions

This section outlines the geology of the preliminary investigation corridor, including depositional history, stratigraphy. Much of the following section has been adapted from previous studies of the region.

The surface geology along the route is summarised in Bureau of Mineral Resources, Geology and Geophysics 1968/1971, 1:250 000 Geological Series for Ayr (Sheet SF/55-15) and Bowen (Sheet SF/55-3) and Mt Coolon (Sheet SF/55-7) and the accompanying Explanatory Notes compiled by C. M. Gregory, A. Paine & R Cameron and Hutton et al respectively. This is summarised in Figure 3-6 and presents the primary regional geological units along the route.

The main geological features are summarised relative to the preliminary investigation corridor chainages for the purpose of characterising the hydrogeology are presented in Table 3-8. The localised geology units are provided in Appendix C.

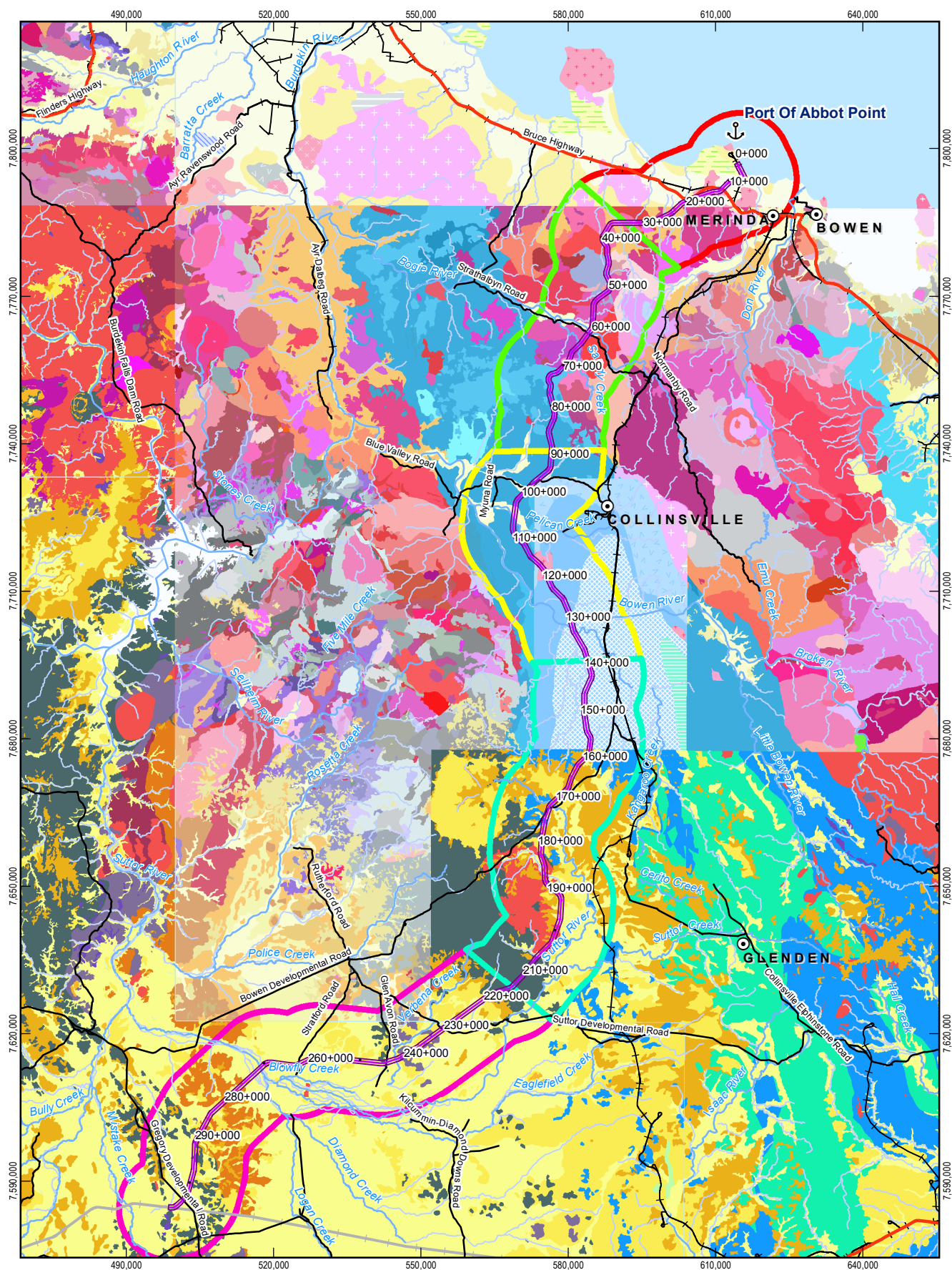
Table 3-8 Summary of geology along the preliminary investigation corridor

Geological zone	Approximate chainage (km)	Geological description	Map symbol
Zone 1: Coastal Zone - primarily associated with dune and alluvial systems.	3.46 - 6	Predominantly Quaternary aged coastal mud flats and sand dunes intersecting Quaternary aged alluvial deltaic deposits further inland.	TQr, Qe
	6 - 7	Isolated exposures of Upper Carboniferous aged intrusive igneous deposits including diorite and granodiorite associated with Mt Little.	kgc
	6 - 13	Predominantly Quaternary aged deltaic alluvial deposits.	Qa, Qr
Zone 2: Clarke Ranges - primarily intrusive igneous deposits with overlying colluvium/residual soils and alluvium associated with surface water features.	13 - 19	Upper Carboniferous aged intrusive igneous deposits associated with Mt Roundback	Kgc
	19 - 28	Predominantly Quaternary aged residual soils and colluvium comprising clays, silts, sands and gravels. . Inclusions of early Cretaceous Summer Hill Gabbro.	TQr Kgsh
	28 - 34	Late Cretaceous to Early Permian aged igneous intrusive deposits (Glenore Road Quartz Diorite and Fence Creek Granodiorite)	CPggr CPgmm Pgfc
	34 - 38	Late Tertiary aged colluvium and residual soil deposits (around the Elliot River) comprising clays, silts, sands and gravels.	TQr
	38 - 43	Late Cretaceous to Early Permian aged igneous intrusive deposits.	Pgfc Pg/D
	43 - 48	Early Permian aged volcanic andesite and rhyolitic flows, breccia and tuffs of the Karungule Volcanics and Early Permian and Cretaceous aged intrusive igneous deposits (including Euri Creek granodiorite).	Cpgec Pvk (karungule) kg/b2
	48 - 59	Late Carboniferous to Early Permian aged intrusive igneous deposits (predominately granodiorite).	CPg/b5
	61 - 62	Quaternary aged Bogie River alluvial flood plain deposits (clays, sands, silts and gravels).	Qa
	59 - 71	Late Carboniferous to Early Permian igneous intrusion deposits (including the Glen Alpine Granite).	CPg/b5, Cpgga, CPg/B7, CPgsu
Zone 3: Lizzie Creek Volcanics with overlying alluvium associated with surface water features. Associated with the Clarke	71 - 116	Early Permian Lizzie Creek Volcanic Group deposits that comprise of rhyolitic, basalt, andesite and breccia sediments. Some intrusive rocks and sedimentary siltstones, shales and coal layers are also present within this area. Within the this area the preliminary investigation corridor intersects narrow zones of alluvial flood plain deposits associated with Strathmore Creek (near to the town of Collinsville) between	Pvz/r

Geological zone	Approximate chainage (km)	Geological description	Map symbol
Ranges at the northern end.		chainage 93 km and 95 km and Pelican Creek between chainage 99 km and 102 km. The route crosses the Bowen River at an approximate chainage of 128 km.	
	93 - 94	Quaternary aged river alluvial flood plain deposits (clays, sands, silts and gravels).	Qa
	99 - 100	Quaternary aged river alluvial flood plain deposits (clays, sands, silts and gravels).	Qa
	104 - 106	Quaternary aged Pelican Creek alluvial flood plain deposits (clays, sands, silts and gravels).	Qa, Qha
Zone 4: Bowen River Valley - predominantly Permian and Tertiary sedimentary sandstones, siltstones, sandstone conglomerates and coal measures. Associated with the Leichhardt Range at the southern end.	116 - 158	Permian aged sandstones, siltstone, shales and coal measures of the Back Creek Group and Blackwater Group with upper Carboniferous aged intrusive igneous deposits	Pb, Pw Kgc
	158 - 171	Tertiary aged Suttor Formation comprising fluvial lacustrine sediments (sandy) with some Quaternary residual inclusions. Intersperse with Late Tertiary – Early Quaternary Suttor Formation colluvium and residual soils comprised of clays, silts, sands and gravels.	Ts/c, Qr/s TQr>Ts
	171 - 172	Tertiary aged Suttor Formation comprising sandstones, mudstones, conglomerate and lacustrine sediments.	Ts
	172 - 173	Quaternary aged flood plain alluvial deposits associated with the Suttor River.	Qa
	173 - 179	Tertiary aged Suttor Formation comprising sandstones, mudstones, conglomerate and lacustrine sediments with minor zones of Later Permian aged Blenheim Formation sandstones, siltstones and shales.	Ts, TQr, Td/f Pb
	179 - 181	Late Carboniferous aged Bulgonunna Volcanic group comprising intrusive rhyolite, feldspars and microgranite.	Cub/po
Zone 5: Leichhardt Ranges – predominantly volcanic extrusive sediments with overlying colluvium/residual soils and alluvium associated with surface water features.	180 - 182	Late Tertiary to Quaternary aged Bulgonunna Volcanic Group colluvial and residuals soils comprising of clays, silts, sands and gravels.	TQr>Cub
	182 - 189	Predominantly Carboniferous – Permian aged Bluegrass Creek Granite intrusive deposits comprising granodiorite and granite with Tertiary inclusions. Overlain in isolated areas by Rockingham Creek Quaternary flood plain alluvial deposits comprising clay, silt, sand and gravels.	CPgb, Td, Td Qa
	189 - 191	Tertiary aged Suttor Formation comprising mudstones, sandstones, conglomerate and fluvial, lacustrine sediments.	Ts
	191 - 196	Later Tertiary to Early Quaternary Suttor Formation colluvial and residual soils	TQr>Ts

Geological zone	Approximate chainage (km)	Geological description	Map symbol
		comprising clays, silts, sands and gravels.	
	196 - 199	Quaternary aged Suttor River alluvial flood plain deposits on high terraces comprising clay, silts, sands and gravels.	Qpa
	199 - 205	Predominantly Carboniferous Bulgonunna Volcanic Group – Blue Grass Creek intrusive deposits. Overlain in places by Tertiary – Quaternary aged flood plain alluvium, colluvium and residual soils comprising clays, silts, sands and gravels.	Cpbg Ts
	205 - 206	Quaternary aged alluvial flood plain deposits associated with Murray Creek.	Qpa, Qr>CPgb
	206 - 220	Carboniferous aged Locharwood Rhyolite – ignimbrite.	Cubl/d, Cub/po, Cubl/b, Cubl/c
	220 - 230	Predominantly Quaternary/Pleistocene aged flood plain alluvium on high terraces flanking Gunn Creek.	Qa, Qpa
Zone 6: Suttor River and Mistake Creek flood plains – extensive alluvium deposits and colluvium/residual soils overlying Anakie Metamorphic Group sediments and Carboniferous volcanic sedimentary deposits.	230 - 247	Predominantly late Tertiary colluvium and residual soils comprising clays, silts, sand and gravels. Localised zones of Devonian – Carboniferous aged Silver Hill Volcanics comprising rhyolites, ignimbrite and volcanoclastic sediments. Localised Zones of Quaternary aged flood plain alluvium associated with Serpentine Creek.	TQr, Dcd Qa
	247 – 275	Predominantly Quaternary/Pleistocene flood plain alluvium comprising clays, silts, sands and gravels. Crosses Suttor River between chainages of 268 km and 272 km.	Qpa, TQe\>Tu
	275 - 290	Predominantly Cambrian aged Anakie Metamorphic Group comprised of siltstone, fine sandstones, phyllite and schist. Large areas of overlying Quaternary/Pleistocene aged flood plain alluvium, colluvium and residual soils comprised of clays, silts, sands and gravels.	PLEa
	290 - 307	Predominantly Quaternary/Pleistocene flood plain alluvium associated with a tributary of Mistake Creek and comprising clay, silts, sands and gravels Isolated zones of Early Carboniferous Mt Hall Formation and Star Hope Formation comprising sandstones, conglomerate, mudstones, siltstones and ignimbrite flows.	Ch, Cs, TQr, Ts, Qpa

Notes: Chainage is approximate only.



LEGEND

- | | | | | | |
|----------------------|--------------------------|-----------------------------|---------------------|----------------------------|-------------------------|
| ● Population Centres | North Galilee Basin | — Main Road | Watercourse (Major) | Regional Zone | Clark Range |
| ⚓ Major Port | Rail 1000m Corridor | — Carmichael Project (Rail) | Watercourse (Minor) | Abbot Point Coastal Plains | Leichhardt Range |
| • Chainage Points | North Galilee Basin Rail | — Railway | Lakes | Bowen River Valley | Sutor River Flood Plain |
| | Rail 100m Corridor | | | | |
| | Highway | | | | |

See Fig 3-6b for Legend

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1:1,100,000 Paper Size A4
0 7.5 15 30
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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North Galilee Basin Rail Project

Job Number 41-26457
Revision B
Date 09 Aug 2013

Regional Geology

Figure 3-6a

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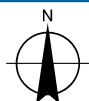
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Data source: GA: Populated Places, Railway, Watercourse, Lakes/2007; Adani: NGBR Corridor 06/06/2013, NGBR Corridor 03/05/2013, Carmichael Project Rail/2012; DNRM: Roads/2010, Lakes/2008, DME/DEEDI: Geology 100k, Geology 250k/2011, Geology - 500k/2012. Created by:MS

WATER BODIES	Dartmoor Granodiorite	Dozer Creek Granite	Earlscliffe Dacite/2?	QLD_GEOLOGY_2012_EDN_ROCK_UNIT
Water body (unspecified)	East Creek Tonalite	Dozer Creek Granite?	Earlscliffe Dacite/3	01 QUATERNARY (STRATIGRAPHIC UNITS)
HOLOCENE	Easter Granodiorite	Eight Mile Station Granite	Earlscliffe Dacite/3?	Qa, 3588
Qha-QLD	Ernest Creek Granodiorite	Euri Creek Granodiorite	Pyramid Rhyolite	Qe, 10704
Qhh-QLD	Expedition Pass Granite	Glen Alpine Granite	Pyramid Rhyolite?	02 NEOGENE
QUATERNARY	Fence Creek Granodiorite	Glen Easter Leucogranite	Smedley Dacite	Qr, 2559
Qa-QLD	First Pocket Igneous Complex/1	Glen Easter Leucogranite/1	Smedley Dacite?	04 PALEOGENE
Qcr-QLD	First Pocket Igneous Complex/2	Glendon Granodiorite	Whitestone Creek Dacite	TL, 3594
Qct-QLD	Goldbeetle Creek Granodiorite	Glenella Creek Granite	LATE CARBONIFEROUS (Intrusive)	09 TRIASSIC
Qr-QLD	Grant Creek Granite	Glenore Road Quartz Diorite	Amelia Creek Tonalite	Rr, 7764
Qrb-QLD	Highlanders Bonnet Granodiorite	Glenroy Creek Granodiorite	Birds Nest Granodiorite	11 PERMIAN
Qrs-QLD	Humburg Creek Granite	Greentop Granite	Cg-NCN	Pvk, 16004
LATE TERTIARY - QUATERNARY	Lady Norman Granodiorite	Isabella Creek Rhyolite?	Cgl1-NCN	Pw, 124
Qa-QLD	Marlborough Pocket Granodiorite	Joe-De-Little Granite	House and Kitchen Granite	Pb, 55
Qr-QLD	Massey Granite	Joe-De-Little Granite/m	McGains Gossan Granodiorite	Pvz, 16648
TERTIARY	Mount Cauley Granite	Joe-De-Little Granite/m?	McGains Gossan Granodiorite?	12 LATE CARBONIFEROUS - EARLY PERMIAN
Sutor Formation	Nostone Creek Granodiorite	Joe-De-Little Granite?	Milwarra Quartz Diorite	CPs, 16006
Sutor Formation?	Nostone Creek Granodiorite?	Lagoon Creek Granite	Milwarra Quartz Diorite?	14 CARBONIFEROUS
Tb-QLD	Pbr-8557	Leichhardt Range Granite	Mount Crompton Granodiorite	Cvk, 16000
To-8557	Perch Creek Granodiorite	Leichhardt Range Granite?	Mount Hector Granite	15 LATE DEVONIAN - CARBONIFEROUS
To-7-8557	Pg-8556	Lionel Diggings Granite	Mount Nutt Granite	DCI, 16514
Ts-QLD	Pgld-NCN	Molongie Creek Granite	Tommy Roundback Granodiorite	17 DEVONIAN
CRETACEOUS	Pgl7-NCN	Morer Granite	Tommy Roundback Granodiorite?	Dy, 324
Griman Creek Formation	Pgd-8556	Mount Mackenzie Granite	CARBONIFEROUS	23 NEOPROTEROZOIC - EARLY PALEOZOIC
CRETACEOUS (Intrusive)	Pickhandle Tonalite	Mount Mackenzie Granite?	Locharwood Rhyolite	PLE, 16108
Hecate Granite/1	Pla Creek Granodiorite	Mount Magnus Granite	Locharwood Rhyolite?	27 CRETACEOUS
Hecate Granite/2	Salitros Granite	Oaky Creek Monzogranite	Saint Anns Formation/b	Kgc, 15993
Hecate Granite/3	Scrubby Top Granite	Panhandle Granite	Scartwater Formation	29 TRIASSIC
Hecate Granite/4	Starvation Creek Complex	Peak John Well Granite/a	Scartwater Formation?	Pgoc, 15863
Hecate Granite/5	Turn Back Granite	Peak John Well Granite/b	CARBONIFEROUS (Intrusive)	31 PERMIAN
Hecate Granite/6	Viola Creek Granodiorite	Peak John Well Granite/c	Bootooloo Gabbro	Pgk, 16005
Hecate Granite/7	LATE CARBONIFEROUS? - EARLY PERMIAN? (Intrusive)	Peak John Well Granite/d	Bootooloo Gabbro?	Pgc, 16038
EARLY CRETACEOUS? (Intrusive)	Glenmore Creek Granodiorite	Peak John Well Granite/e	Cgd-8557	33 CARBONIFEROUS - EARLY PERMIAN
Summer Hill Gabbro	LATE CARBONIFEROUS - EARLY PERMIAN	Percy Douglas Tonalite	EARLY CARBONIFEROUS	CPgc, 15997
Summer Hill Gabbro?	Arundel Rhyolite/1	Pine Creek Granite	Cs-8556	CPgk, 16003
EARLY CRETACEOUS (Intrusive)	Arundel Rhyolite/2	Pine Creek Granite?	Edgecumbe beds	34 CARBONIFEROUS
Ben Lomond Granite	Collins Creek Rhyolite	Red Hill Creek Granodiorite	Edgecumbe beds?	Cgk, 16002
Blackwall Quartz Diorite	Collins Creek Rhyolite?	Roscow Granite/1	Key Creek Gneiss	37 SILURIAN - MIDDLE DEVONIAN
Devilins Pocket Quartz Diorite	McGregors Bonnet Volcanics	Roscow Granite/2	Mount Cavana beds	SDg, 16019
Elliot River Granodiorite	McGregors Bonnet Volcanics?	Roscow Granite/3	Star of Hope Formation	39 ORDOVICIAN
Flagstaff Hill Granite	The Tableland Volcanics	Shannon Vale Gabbro	Star of Hope Formation?	Ogm, 16010
Kg/1-8557	The Tableland Volcanics?	Smoko Creek Granite	LATE DEVONIAN - EARLY CARBONIFEROUS	
Kg/17-8557	LATE CARBONIFEROUS - EARLY PERMIAN (Intrusive)	Smoko Creek Granite?	Bimurra Volcanics	
Kg/2-8557	Billy-can Creek Granite	Springlands Gabbro	Bimurra Volcanics/d?	
Kg/3-8557	Binbee Quartz Monzogranite	Stony Creek Granite	Bimurra Volcanics/r	
Kg/4-8557	Black Pinnacle Igneous Complex/1	Stuart Pocket Granite	Bimurra Volcanics?	
Kg/5-8557	Black Pinnacle Igneous Complex/2	Sunbeam Granodiorite	Mount Wyatt Formation	
Kg/6-8557	Black Pinnacle Igneous Complex/3?	Sundown Creek Diorite	Rosetta Creek Formation	
Kg/7-8557	Black Pinnacle Igneous Complex/4?	Swans Lagoon Granite	Rosetta Creek Formation/m	
Kg/b1-NCN	Black Pinnacle Igneous Complex/4?	Teatree Creek Gabbro	Rosetta Creek Formation/mv	
Kg/b2-NCN	Bluestone Creek Granodiorite	Terry Creek Quartz Monzogranite	Rosetta Creek Formation?	
Kg/b3-NCN	Brawl Creek Granite	The Three Brothers Gabbro	Saint Anns Formation	
Kg/d7-NCN	Brown Creek Rhyolite	Upper Rosetta Creek Granite	Stones Creek Volcanics	
Kg/f-8557	CPd/b1-NCN	Upper Rosetta Creek Granite/a	Stones Creek Volcanics/1	
Kg/x-8557	CPg-QLD	Upper Rosetta Creek Granite?	Stones Creek Volcanics/2	
Kgdx-8557	CPg/1-8356	Wynne Creek Diorite	Stones Creek Volcanics/3	
Kgdy-8557	CPg/10-8356	CARBONIFEROUS - PERMIAN (Intrusive)	Stones Creek Volcanics/4	
Kgdz-8557	CPg/2-8356	CPd-NCN	Stones Creek Volcanics?	
Monte Christo Granite	CPg/27-8356	CPd?-NCN	DEVONIAN	
Mount Abbot Igneous Complex/1	CPg/8-8356	CPm?-NCN	Ukalunda Formation?	
Mount Abbot Igneous Complex/2	CPg/9-8356	CPp-NCN	Ukalunda Formation	
Mount Pring Granite	CPg/b-NCN	CPp?-NCN	Ukalunda Formation	
Mount Roundback Granodiorite	CPg/b1-NCN	Lulu Pocket Igneous Complex/2	EARLY DEVONIAN - MIDDLE DEVONIAN	
Pretty Bend Quartz Monzogranite	CPg/b2-NCN	Lulu Pocket Igneous Complex/3	LATE SILURIAN - EARLY DEVONIAN (Intrusive)	
Pretty Bend Quartz Monzogranite?	CPg/b2?-NCN	CARBONIFEROUS - EARLY PERMIAN (Intrusive)	Kedumba Granodiorite	
Selina Creek Granodiorite	CPg/b3-NCN	CPg-DRUMBULG	Mount Cuthbert Granodiorite	
Selina Creek Granodiorite?	CPg/b4-NCN	CPg?-QLD	Rangeview Station Tonalite	
Seventy Creek Granite	CPg/b5-NCN	LATE CARBONIFEROUS	Rangeview Station Tonalite?	
Seventy Creek Granite/f	CPg/b6-NCN	Bobby Dazzler Rhyolite	SDg/1-8357	
Ward Creek Granodiorite	CPg/b7-NCN	Bobby Dazzler Rhyolite?	SDg/2-8357	
MIDDLE TRIASSIC (Intrusive)	CPg/b8-NCN	Bulgonunna Volcanic Group/10	SILURIAN - EARLY DEVONIAN (Intrusive)	
Gloucester Granite	CPg/b9-NCN	Bulgonunna Volcanic Group/10?	Dalmore Granodiorite	
EARLY TRIASSIC? - MIDDLE TRIASSIC? (Intrusive)	CPg/h-NCN	Bulgonunna Volcanic Group/12	ORDOVICIAN (Intrusive)	
Passage Islet Granite	CPg/i-Leichhardt Range	Bulgonunna Volcanic Group/13	Carse Creek Complex	
PERMIAN	CPg/17-NCN	Bulgonunna Volcanic Group/14	Elbow Creek Granodiorite	
Mount Wickham Rhyolite	CPg/img-NCN	Bulgonunna Volcanic Group/14?	Og/a-8357	
Mount Wickham Rhyolite?	CPg/img?-NCN	Bulgonunna Volcanic Group/15	Og/a-8357	
PERMIAN (Intrusive)	CPg/w1-NCN	Bulgonunna Volcanic Group/15?	Og/a?-Ravenswood Batholith	
CPn-8555	CPg/w2-NCN	Bulgonunna Volcanic Group/17	Og/a?-8357	
Mamelon Quartz Monzogranite	CPg/w3-NCN	Bulgonunna Volcanic Group/17	Two Creek Granodiorite	
Thunderbolt Granite	CPg/w4-NCN	Bulgonunna Volcanic Group/18	CAMBRIAN - ORDOVICIAN	
EARLY PERMIAN	CPg/w5-NCN	Bulgonunna Volcanic Group/19	Les Jumelles beds	
Carmila beds	CPg/w5?-NCN	Bulgonunna Volcanic Group/20	Les Jumelles beds/q	
Carmila beds?	CPg/w6-NCN	Bulgonunna Volcanic Group/21	Mount Windsor Volcanics	
Collinsville Coal Measures	CPg/w7-NCN	Bulgonunna Volcanic Group/21?	CAMBRIAN	
Karungle Volcanics	CPg/y2-NCN	Bulgonunna Volcanic Group/22	Mount Windsor Volcanics?	
Lizzie Creek Volcanic Group	CPg/aa-NCN	Bulgonunna Volcanic Group/23	ORDOVICIAN - PERMIAN (Intrusive)	
Lizzie Creek Volcanic Group/f	CPg/-NCN	Bulgonunna Volcanic Group/27	Landers Igneous Complex/2	
Lizzie Creek Volcanic Group/f?	CPm-8356	Bulgonunna Volcanic Group/27?	ORDOVICIAN - DEVONIAN (Intrusive)	
Lizzie Creek Volcanic Group/s	CPri/1-8356	Bulgonunna Volcanic Group/28	ODg/d-8357	
Lizzie Creek Volcanic Group?	CPri/17-8356	Bulgonunna Volcanic Group/7	ODg/d-Ravenswood Batholith	
Lizzie Creek Volcanics/a	CPri/2-8356	Bulgonunna Volcanic Group/7?	ODg?-Ravenswood Batholith	
Lizzie Creek Volcanics/r	CPri/27-8356	Bulgonunna Volcanic Group/8	NEOPROTEROZOIC? - CAMBRIAN	
Lizzie Creek Volcanics/r?	CPri/3-8356	Bulgonunna Volcanic Group/8?	PLEm-8357	
Mount Aberdeen Volcanics	CPri/37-8356	Bulgonunna Volcanic Group/rh?	NEOPROTEROZOIC - CAMBRIAN	
EARLY PERMIAN (Intrusive)	CPri/47-DRUM	Bulgonunna Volcanic Groups?	Charters Towers Metamorphics?	
Adaluma Tonalite	CPx-8356	Conway Volcanics	NEOPROTEROZOIC? - EARLY CAMBRIAN?	
Alick Creek Tonalite	Charlie Creek Microgranite	Conway Volcanics?	Anakie Metamorphic Group/s	
Beckford Granodiorite		Earlscliffe Dacite/1		

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Adani Mining Pty Ltd
North Goonyella Basin Rail Project

Regional geology
legend

Job Number 41-26457
Revision A
Date 07 Aug 2013

Figure 3-6b

3.5.2 Hydrogeological data collation

Interpretations of the hydrogeological conditions were made from the geological information summarised in the previous section, geomorphological field surveys completed by GHD in May 2013 and available borehole information along the preliminary investigation corridor.

The DNRW GWDB stores Queensland's groundwater resource information including water level, water quality, construction, pump and flow test, elevation, location, strata, stratigraphy and aquifer details, bore condition, casing and wire line.

A search of the GWDB database was undertaken for the preliminary investigation corridor and the two kilometer buffer. This search identified 81 bores within the defined study area. These bores are dispersed throughout the preliminary investigation corridor, predominantly between Bowne and Collinsville. These bores were drilled to depths of up to 142 m, but average 24 metres below ground level (mbgl). There are currently only nine bores located beyond chainage 110 km (i.e. south of the Lizzie Creek Volcanic Group as described in Table 3-8).

Within the preliminary investigation corridor, there were no groundwater bores identified within the State observation bore network. Within 10 km of the northern portion of the corridor (around the Port of Abbot Point), several clusters of bores were identified within the vicinity of Bowen and Guthalungra townships. Available information pertaining to these observation bores was strictly locational; however, these bores are expected to monitor the alluvial aquifers which local townships and agricultural industries rely upon based on the information from the Queensland State observation bore network.

3.5.3 Hydrogeological units

The primary geological units along the preliminary investigation corridor can be categorised into the following primary units for assessment of hydrogeological properties:

- Unconsolidated coastal dunes, mud flats, alluvial and deltaic deposits comprising clays, silts, sands and gravels
- Unconsolidated flood plain alluvium comprising clays, silts, sands and gravels
- Colluvium and residual soils comprising clays, silts, sands and gravels
- Intrusive igneous deposits comprised predominantly of granite and granodiorite. These deposits may be extensively weathered in the near surface environment
- Sedimentary deposits comprised of siltstones, sandstones, mudstones, coal measures and conglomerates. These deposits may be extensively weathered in the near surface environment
- Volcanic sediments (extrusive igneous deposits) comprised of the rhyolites, basalts, breccia and tuffs. These deposits may be extensively weathered in near the surface environment.

The hydrogeological properties of these systems are discussed in more detail below and shown on Sheets one to 55 of Appendix C.

Unconsolidated flood plain alluvium

Flood plain alluvium sediments are expected to be present for a total distance of approximately 98 km (32 percent) beneath the preliminary investigation corridor. These deposits are primarily present along the edges of rivers and creeks between chainages:

- 61 to 63 km associated with the Bogie River
- 93 to 95 and 98 to 100 km associated with Strathmore Creek
- 105 to 107 km associated with Pelican Creek
- 171 to 179 km associated with the Suttor River
- 183 to 185 km associated with the Suttor River
- 190 to 191 km associated with the Suttor River
- 195 to 199 km associated with the Suttor River
- 201 to 203 km associated with the Suttor River
- 206 to 207 km associated with Murray Creek
- 220 to 231 km associated with Gunn Creek and other smaller river courses
- 242 to 278 km associated with the Suttor River
- 283 to 307 km associated with a tributary of Mistake Creek.

These sediments are anticipated to form localised aquifers of varying yields. These systems are anticipated to be recharged via rainfall and by river systems at times when river systems are flowing. They may also provide baseflow during times of low or no flows in river systems.

The geomorphological survey undertaken by GHD in May 2013 suggests that sands dominate the in-stream channel deposits along the preliminary investigation corridor, while embankments are generally silty, which suggests that the primary parent materials in the alluvial flood plains are sands and silts. It is noted however, that the Bowen River channel deposits are dominated by sand and gravel deposits.

Flow data suggest that the majority of the river/creek systems along the preliminary investigation corridor are dominated by short term high flow events with subsequent dry/no flow periods. Extensive flooding would also occur during these events, which would result in the development of a range of the energy environments with more permeable sediments (sands and gravels) deposited within higher flow areas (in stream) and lower permeability silts primarily being deposited in over bank areas further afield from areas of concentrated flow. The geomorphological assessment suggests that at a number of the creeks the geomorphological conditions are such that stream alignment has the potential to change course, suggesting that higher permeability deposits and lower permeability deposits may be intermingled within the alluvial flood plains. Based on the depositional environments of the alluvial flood plains it is anticipated that over-bank lower permeability material would dominate. As a result, these deposits are expected to form shallow unconfined groundwater systems, although there may be partial confinement of buried channel deposits by lower permeability over-bank deposits in places.

Hydraulic conductivities of these aquifer systems may range between 0.7 metres per day up to 40 metres per day in higher permeability sediments (unburied and buried river channels) and between 0.0001 metres per day to 1.7 metres per day in over-bank deposits (Weight and Sonderegger, 2000). There is currently no yield information for bores intersecting these sediments within the study area.

Eleven bores were identified to intersect alluvium along the preliminary investigation corridor. The stratigraphic information from these wells suggests that the alluvium ranges in thickness from three to 74 m with an average thickness of 14 m. Given the low number of data points along the corridor characterising the alluvium, this data provides a guide only.

Unconsolidated coastal dune, mud flats, alluvial and deltaic deposits

Unconsolidated coastal dune, mud flats alluvial and deltaic deposits (Ayr Sheet SF55-15, 1:250,000 scale) are primarily expected to be present for a total distance of nearly 13 km (approximately four percent of the preliminary investigation corridor length) (zone 1 of Table 3-8). They are located in chainages of 3.46 to 13 km, in the coastal plains zone of the preliminary investigation corridor. These sediments are anticipated to form localised shallow unconfined aquifers of varying yields (DNRM GWDB). The deltaic and alluvial deposits located further inland are anticipated to have similar lithological properties to the alluvial deposits described in the previous section.

Coastal dune systems are anticipated to form a high permeability sand aquifer system and recharge is likely to occur via rainfall and the river systems in times of flow in inland areas with discharge to coastal water bodies such as Saltwater Creek, wetlands and the ocean. However, the lower energy environments associated with "The Lake" located near the Port of Abbot Point are expected to result in lower permeability estuarine and mud flat sediments.

Hydraulic conductivities of these aquifer systems may range between 0.7 metres per day up to 40 m per day in higher permeability sediments (higher energy – coastal fringe, river channel and deltaic deposits) and between 0.0001 metres per day to 1.7 metres per day in over bank flood and estuarine areas (The Lake) (Weight and Sonderegger, 2000). There is currently no yield information for these wells.

Approximately five bores are documented to intersect these deposits, however, there are approximately another 14 bores located in this area that do not have suitable information.

The available stratigraphic information suggests that the alluvials range in thickness from eight to 18 m with an average thickness of 12 m. Given the small number of data points along the preliminary investigation corridor characterising the sediments in this area this data provides a guide only.

Colluvium and residual soils

Colluvium and residual soil sediments are expected to be present for a total distance of approximately 67 km (22 percent) of the preliminary investigation corridor. These deposits are generally associated with weathering of underlying and outcropping bedrock and generally accumulate on slopes and in valleys floors (Hancock Prospecting Pty Ltd, 2010). These deposits are located in zone two, four, five and six from Table 3-8. These deposits are primarily present between:

- 19 to 29 km associated with greater topographic variability near Mt Roundback
- 35 to 38 km associated with greater topographic variability near Mt Abbot
- 164 to 165 km, 169 to 175 km, 180 to 181 km, 191 to 196 km (isolated zones only) associated with greater topographic variability through the Leichhardt Range
- 231 to 242 km, 247 to 252 km (unidentified source)
- 270 to 295 km (isolated areas) associated with greater topographic variability within the Anakie Metamorphic Group Deposits.

The colluvium and residual soil material are likely to comprise of clays, silts, sands and gravels (Mt Coolon, Sheet SF55-15, 1:250,000 scale). Because of their general locations on or at the base of hills slopes it is not anticipated that they would form extensive aquifer systems, however, at the

base of hills slopes where they are in contact with alluvium they could form part of larger alluvial aquifer systems. The hydraulic conductivities of these materials are anticipated to be lower than the alluvium expected to range between 0.0001 metres per day to 40 metres per day.

Borehole information along the preliminary investigation corridor suggests that there are currently no bores intersecting colluvium sediments, which indicates that these deposits are not a commonly used source of groundwater.

There are a number of bores located within zones of colluvium surface soils, particularly in and around the Mt Abbot area. These bores generally intersect the underlying weathered and/or fractured bedrock at depths ranging between seven and 16 m providing a general estimate of the thickness of colluvium and residual soils in this area. Colluvium thickness in other areas of the preliminary investigation corridor is poorly delineated by the available bore data.

Igneous intrusive deposits

Igneous based intrusive deposits are expected to be present for a total distance of approximately 53 km (17 per cent) of the preliminary investigation corridor. These sediments, comprised predominantly of Granite, Diorite and Granodiorite (Bowen Sheet SF55-3, 1:250,000), are located along the corridor between the following chainages:

- 15 to 19 km associated with Mt Roundback
- 28 to 35 km, 37 to 43 km, 49 to 59 km and 61 to 70 km associated with the Clarke Range
- 117 to 120 km
- 182 to 189 km and 199 to 206 km associated with the Leichhardt Range.

The upper profile of these deposits is anticipated to have varying degrees of weathering depending on the age and environmental conditions. Some fracturing may also be present in the profile but is anticipated to fall off with depth. Given these conditions, it is anticipated that the most permeable zones are located at shallow depths.

Aquifer systems within the upper weathered sediments are likely to form unconfined systems, whereas deeper fractured systems may represent unconfined to confined systems.

Hydraulic conductivities within the shallow weathered and fractured zones are likely to range between 0.001 metres per day and 25 metres per day. Bores 140634 and 140635 (located on Sheet 5 of Appendix C) have reported yields of two L/s and intersect fractures zones within these sediments at depths of between 20 and 23 mbgl. Bore 125722 (located on Sheet 11 of Appendix C) has a reported yield of one L/s and intersects the upper weathered zones of the deposits between depths of two and 11 mbgl. These yields would generally correspond with hydraulic conductivities within the range of one to 10 metres per day using the relationship between specific capacity and hydraulic conductivity presented in Driscoll (1986). Because of the intrusive nature of these deposits they are expected to be deep/thick.

Approximately ten bores are documented to intersect intrusive deposits along the preliminary investigation corridor suggesting that these deposits have suitable yields.

Sedimentary deposits

Sedimentary deposits are expected to be present for a total distance of approximately 77 km (25 percent) of the preliminary investigation corridor and are located between the following chainages:

- 71 to 116 km interbedded at isolated locations with volcanic sediments associated with the Lizzie Creek Volcanics
- 120 to 159 km – Permian aged Back Creek Group and Blackwater Group sediments
- 159 to 169 km – Tertiary aged Suttor Formation sediments
- 171 to 175 km – Tertiary aged Suttor Formation sediments
- 176 to 179 km – Tertiary aged Suttor Formation sediments and Permian aged Back Creek Group
- 180 to 182, 188 to 191 km – Tertiary aged Suttor Formation sediments
- 291 to 307 km – isolated zones of Carboniferous aged Mt Hall Formation and Star Hope Formation.

These sediments are comprised of interbedded mudstones, siltstones, shales, sandstones, conglomerates, lacustrine sediments and coal measures (Mt Coolon, Sheet SF55-15, 1:250,000 scale).

The upper profile of these deposits is anticipated to have varying degrees of weathering depending on the age and environmental conditions. Some fracturing may also be present in the profile but is anticipated to decrease with depth. Given these conditions, it is anticipated that the most permeable zones are located at shallow depths.

Shallow weathered zones are expected to form unconfined to partially confined aquifer systems, while deeper fractured zones are expected to form partially confined to confined systems.

Hydraulic properties of these types of sediments are likely to vary significantly with shales, siltstones and mudstones acting as aquitards/confining units and sandstones and coal layers forming the primary aquifer units.

The hydraulic conductivities of aquifer units generally range between the 0.001 metres per day to one metre per day with confining units generally ranging from 8×10^{-09} metres per day to 0.001 metres per day. There is currently no yield data available for these sediments along the preliminary investigation corridor.

There are currently six bores interpreted, from the available data, to intersect the consolidated sedimentary deposits this includes four bores intersecting the Back Creek and Blackwater Group Sediments at depths of up to 90.5 mbgl. There are no yield or use data for these bores. This suggests that there could be water supplies at depth in these sediments.

Bores 89009 and 89040 (Sheets 49 and 50 of Appendix C respectively) intersect the Mt Hall Formation at depths of approximately 105 to 142 m, which provides some indication of the potential depth and thickness of these sediments. There are no yield or use data for these bores; however, the data suggest that there may be water resources at depth in these sediments.

The depth of the Back Creek and Blackwater Group are interpreted to reach thicknesses of approximately 3,000 metres at chainage 155 km. It is currently unclear what the thickness of the Suttor Formation is beneath the preliminary investigation corridor.

Igneous extrusive deposits

Extrusive igneous deposits are expected to be present for a total distance of approximately 25 km (8 per cent) of the preliminary investigation corridor and are located between the following chainages:

- 38 to 45 km – Kurungle Volcanics
- 71 to 116 km – Lizzie Creek Volcanics
- 232 to 241 km (isolated outcrops only) – Silver Hill Volcanics.

The sediments are comprised of rhyolite, basalt, volcanic breccia, tuffs and other volcanoclastic sediments Mt Coolon, Sheet SF55-15, 1:250,000 scale).

Shallow weathered zones are expected to form unconfined to partially confined aquifer systems, while deeper fractured zones are expected to form partially confined to confined systems

Hydraulic conductivities within volcanic sediments can be highly variable. There is currently one bore (140127) (Sheet 15 of Appendix C) with yield data of four L/s, which is interpreted to intersect the upper weathered zone of the Lizzie Volcanics at depths of between 13 and 25 mbgl. These yields would generally correspond with hydraulic conductivities within the range of one to 10 metres per day using the relationship between specific capacity and hydraulic conductivity presented in Driscoll (1986). This is indicative of reasonable water bearing material.

Broad data from the geological maps suggests Lizzie Creek Volcanics may approximate thicknesses of up to 500 m (Bowen, Sheet SF55-3, 1:250,000 scale). Data is not available to characterise the thicknesses of the remaining volcanic groups.

The available bore log data also suggest that the Lizzie Creek Volcanics may also be intersected by bores 140119 and 38520 (Sheet 15 and Sheet 18 of Appendix C respectively) between depths of 16 to 44 metres below ground level (mbgl), which suggests the potential for slightly deeper groundwater systems.

3.5.4 Groundwater Management Areas

The *Water Act 2000* provides a framework under which catchment based Water Resource Plans (WRPs) are developed in Queensland. The WRPs are then activated through related Resource Operations Plans (ROPs) which provide detail on how the water resources will be managed to implement the strategies and objectives as set out in the WRP. A WRP provides a framework for sustainable management of water resources in the plan area including establishment of Groundwater Management Areas (GMAs) as well as Groundwater Management Units (GMUs) and unincorporated areas (UAs) which can be sub-divisions of a GMA. A GMU is a hydraulically connected groundwater system and the resource is actively managed. UAs incorporate all other groundwater resources that are not part of GMUs and which have no requirements for allocations of groundwater abstraction for livestock or domestic use.

In Queensland, regulated groundwater areas, which is a general term used to include declared sub-artesian areas, sub-artesian areas, sub-artesian management areas and groundwater management areas, have been established by the Queensland Government to protect groundwater resources. The water resources in these regulated groundwater areas are subject to management and are either established through a WRP, a Local Water Management Policy or as defined by Schedule 11 of the *Water Regulation 2002*.

The *Water Resource (Burdekin Basin) Plan 2007* applies to the NGBR Project as it is located within the Burdekin Basin. The *Burdekin Resource Operations Plan 2009* implements the *Water Resource (Burdekin Basin) Plan 2007* by specifying rules and operational requirements for managing surface water resources.

The NGBR Project is situated within the Galilee Basin and is outside the eastern boundary of the Great Artesian Basin. The preliminary investigation corridor is primarily situated within the Bowen UA. The northern portion of the preliminary investigation corridor also traverses the Yarraman UA, and at the north-eastern extent of the preliminary investigation corridor, the Don River UA is also straddled.

Table 3-9 provides a summary of the GMUs and UAs relative to the preliminary investigation corridor chainage.

Table 3-9 GMUs and UA intersected by the preliminary investigation corridor

Groundwater management units	Chainage start (km)	Chainage end (km)
Don River GMU	3.49	15
Yarraman Unincorporated Area	15	67
Bowen Unincorporated Area	67	306.9

Source: Adapted from Hancock Prospecting, 2010

Don River GMU

The Don River GMU is situated in the Don River Basin along the coastline. A small portion of the preliminary investigation corridor traverses the Don River GMU, in the vicinity of Abbot Point Road.

The Don River alluvial aquifers are used for town supply, irrigation and agriculture and show water qualities ranging from fresh to brackish. Bore yields range from 4 L/sec to 32 L/sec (URS, 2010).

Yarraman UA

The Yarraman UA is traversed by the NGBR Project east of the Bowen UA towards Bowen township. Groundwater occurrence in the Yarraman UA is within igneous and sedimentary rocks, with yields in the order of 0.5 L/sec to 10 L/sec in the igneous formations and generally less than 10 L/sec in the sedimentary aquifers (URS, 2010). Groundwater is primarily used for applications in the local sugar industry.

Bowen UA

The Bowen UA is bound to the west by the Great Artesian Basin GMU and the Isaac River GMU to the north-west and includes the Bowen Basin, Drummond Range, Galilee Basin and the Anakie Inlier.

Average groundwater resource usage in the Bowen UA is estimated to be 14,900 ML/yr (at the time of the NLWR 2001 Audit) compared to an estimated sustainable yield of 260,000 ML/yr (NLWR Audit 2001). Groundwater use within the Bowen UA includes irrigated agriculture, mining, livestock and domestic supply for individual dwellings and town water supply. Increased irrigation, development in the coal industry and increased mining activities in the Bowen Basin has resulted in escalating groundwater demands (ANRA website, last updated 2009).

The major aquifers within the Bowen UA are Quaternary age alluvium, the sand and gravel horizons of the Tertiary age sediments and the Tertiary age basalts. Bore yields are generally below 5 L/sec and consequently most groundwater development would be limited to stock and domestic supplies.

The quality of groundwater within the UA is generally described as marginal (that is, borderline fresh water to brackish water), with typically poorer quality groundwater encountered within coal bearing strata and higher quality groundwater typically found within alluvial and fractured basalt aquifers (DNRM, 2010).

The Bowen UA covers most of the NGBR Project, to the vicinity west of Bowen.

Water Regulation (2002)

The *Water Regulation 2002* is subordinate to the Water Act and defines sub artesian groundwater declared areas (i.e. regulated groundwater areas). It also details the purpose of use (such as stock and domestic use) that do not require authorisation to take water and, by omission, those purposes that do require authorisation. The NGBR Project preliminary investigation corridor can be defined by three such areas, Highlands Declared Subartesian Area, undeclared areas and Bowen Declared Subartesian Area (refer Figure 3-8).

Highlands Declared Subartesian Area

From its southern extent to the Suttor River crossing the NGBR Project preliminary investigation corridor lies within the Highlands Subartesian Area, as defined under Schedule 11 of the *Water Regulation 2002*. Within the Highlands Subartesian Area, water licenses and/or development permits are not required for stock or domestic bores and generally, development permits are not required for groundwater monitoring bores. Other groundwater-related activities, such as drilling of test pumping bores, and undertaking pumping tests, require permits from DNRM, as well as a development permit for drilling and construction of water bores.

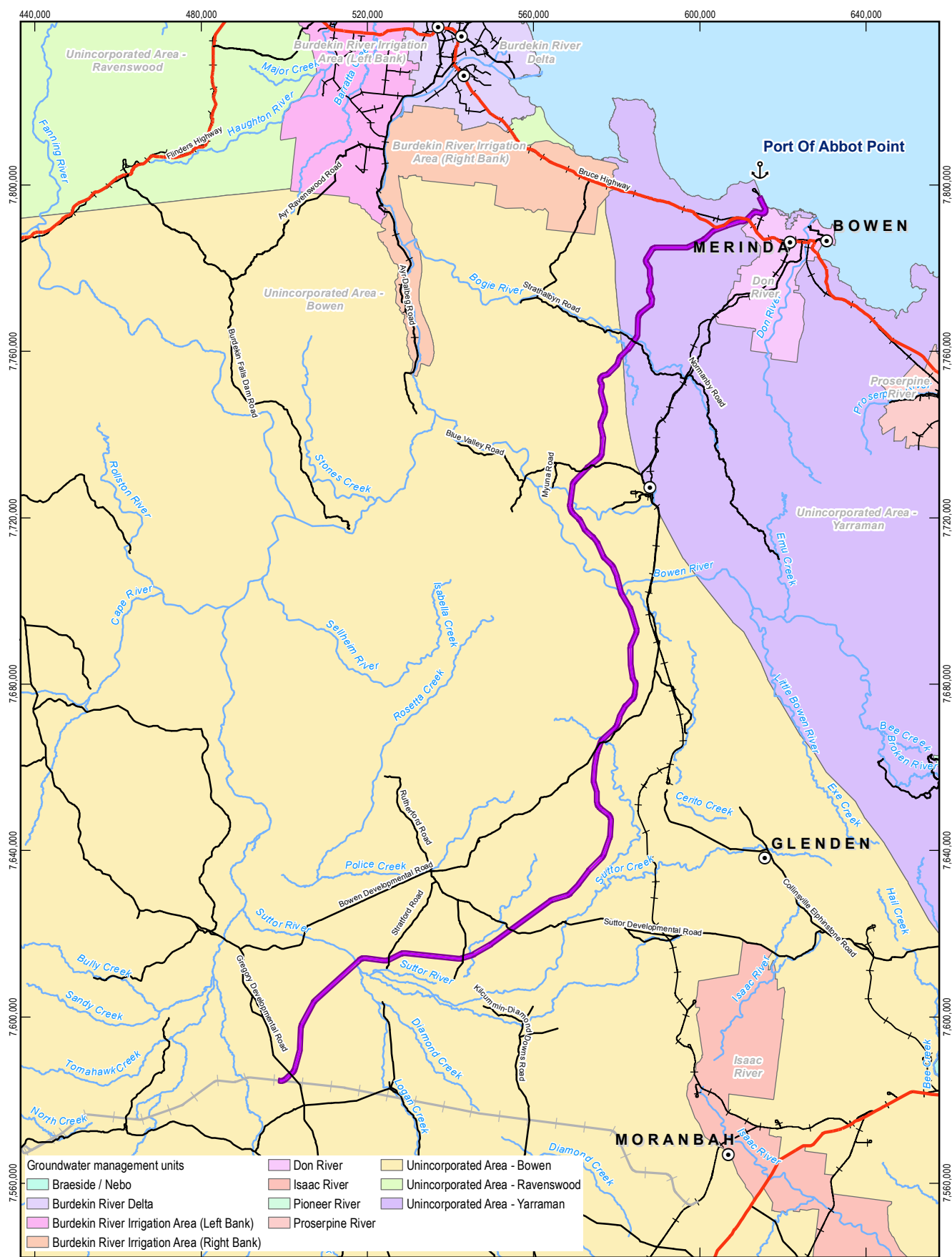
Long-term extraction of groundwater or interference (whether actively via bores or passively via drainage to mine workings) with surface water or other groundwater sources requires authorisation by way of a licence. The *Sustainable Planning Act 2009* provides the mechanism (via the Integrated Development Assessment System, or IDAS), via which assessment of a proposed development is undertaken, and under which a development permit is granted.

Undeclared Areas

From the Suttor River crossing to the Bruce Highway, approximately 13 km southwest of Abbot Point, there are no identified groundwater management areas.

Bowen Declared Subartesian Area

From the Bruce Highway, approximately 13 km southwest of Abbot Point, to the Abbot Point rail terminal, the NGBR Project preliminary investigation corridor lies within the Bowen Subartesian Area, as defined under Schedule 11 of the *Water Regulation 2002*. Water licenses and/or development permit requirements within the Bowen Subartesian Area are as per the Highlands Subartesian Area.



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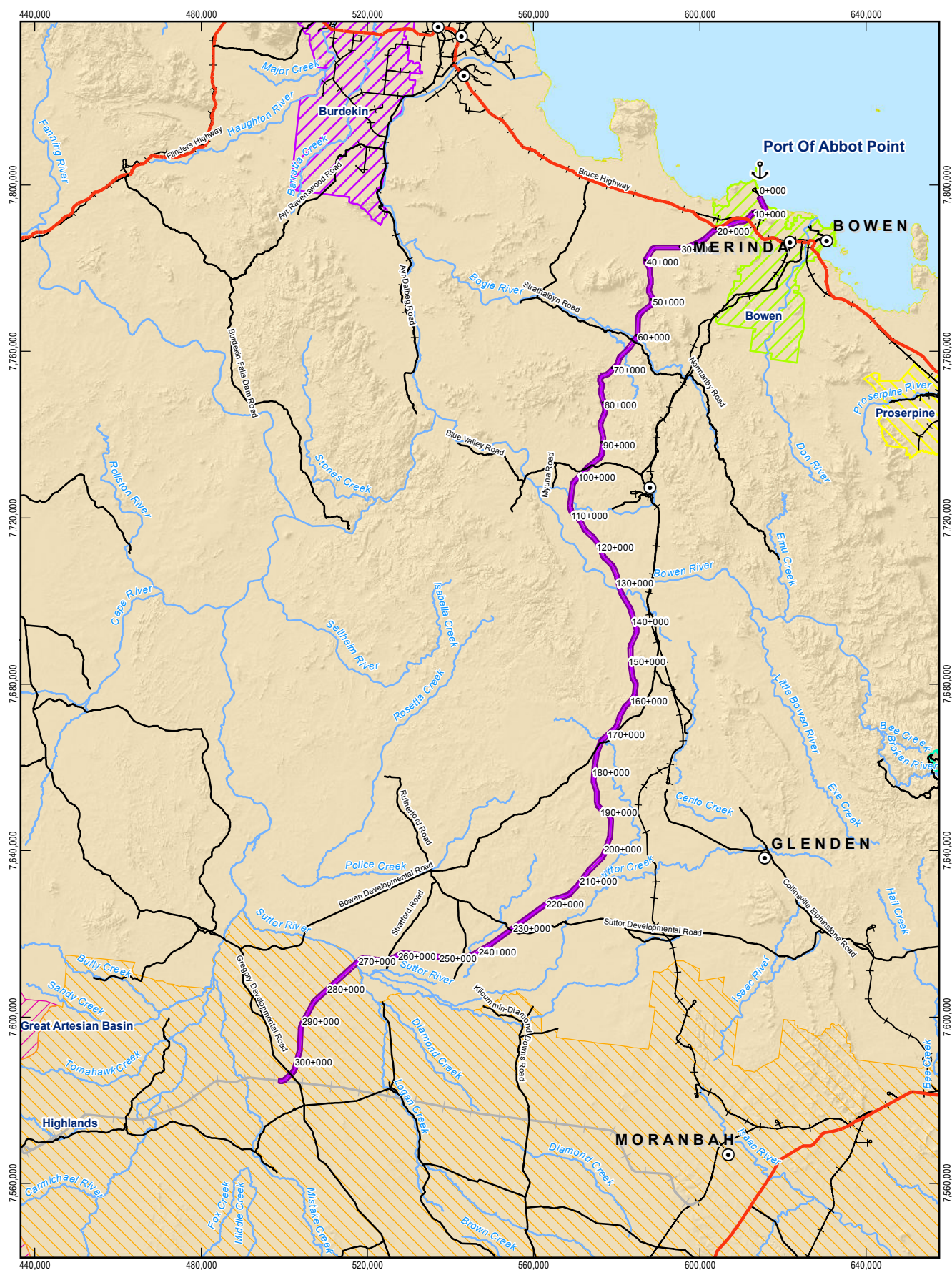
Groundwater Management Units Figure 3-7

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LEGEND

- Chainage Points
- ⊙ Population Centres
- ⚓ Major Port
- Highway
- Main Road
- Rail 1000m Corridor
- Rail 100m Corridor
- Carmichael Project (Rail)
- Railway
- Watercourse (Major)
- Declared Sub-Artesian Areas
- North Galilee Basin
- Burdekin
- Great Artesian Basin
- Highlands
- Pioneer
- Proserpine

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Horizontal Datum: GDA 1994
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Groundwater Management Areas Figure 3-8

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Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: NGBR Corridor 13/05/2013, NGBR Corridor 06/06/2013, Carmichael Rail Project/2012; DNRM: Roads/2010, Declared Sub-Artesian Areas (2012). Created by:MS

3.5.5 Groundwater use

The NGBR Project study area is dominated by livestock grazing on native vegetation. It is considered that the primary demand for groundwater would be for stock and domestic water supply purposes. At the Port of Abbot Point land use is primarily manufacturing and industrial, suggesting that there may be some demand for industrial related supplies of groundwater. Near Collinsville, approximately four kilometres east of the preliminary investigation corridor at chainage 100 km, an area of open cut mining exists. In this area groundwater is expected to be dewatered to expose coal seams for mining, which could result in extensive groundwater disturbance beneath the preliminary investigation corridor. To the west of the preliminary investigation corridor at chainage 105 km, an area indicated as intensive animal husbandry is present. Groundwater demand from these type of facilities are expected to be for stock and domestic uses only.

Within the vicinity of the preliminary investigation corridor (within two kilometres either side), 43 of the identified 81 bores had bore-use data available. This information showed that:

- Twenty eight bores are listed as used for water supply – from available data (seven bores), formations developed primarily comprise alluvium and granite. The information was not specific on the type of water supply use; however given the predominantly shallow bore depths (average of 20 m) groundwater is likely to be extracted largely for stock watering purposes. The water supply data is presented in Table 3-10 and Appendix C
- Seven bores are used for stratigraphic investigation. Only two of these bores contained target formation information (Don River Alluvium) or depth information
- Eight bores are used for water resource investigation purposes. Stratigraphic and bore use information was not available for these bores.

Of the bores used for water supply purposes nine are located within the coastal dune, alluvial and deltaic deposits at the Port of Abbot Point end of the NGBR Project (up to an approximate chainage of 6 km). Thirteen bores intersect intrusive deposits, mainly through the Clarke Range area (approximate chainage of 33 to 70 km), but also within Mt Little and Mt Roundback at chainages less than 20 km. These bores intersect both upper weathered zone systems and fractured rock systems. Three bores intersect the weathered zone of the Lizzie Creek Volcanic Group between approximate chainages of 68 to 110 km. Two bores intersect alluvium in these areas. There are no water supply bores present beyond this chainage apart from one well potentially intersecting alluvium or the Mt Hall Formation deposits near chainage 290 km, however, this bore has been abandoned and destroyed.

Overall the available groundwater data only provides a broad understanding of the groundwater use along the preliminary investigation corridor, however, the data suggests that there is little to no use of groundwater after chainage of 110 km. This may be due to water quality and yield issues but may also be due to an absence of demand in these areas.

It should be noted that there may also be water supplies along the route that are not registered with DNRM. This is particularly likely given that licenses are not required for domestic and stock supplies in these areas and that the primary land use in this area probably results in demand primarily being for domestic and stock purposes. A survey of all landowners and their water usage requirements during future NGBR Project stages would be useful to close this information gap.

Table 3-10 Water supply data

Well name	Easting	Northing	Bore use	Formation monitored	Aquifer condition	Aquifer top	Aquifer bottom	Facility status	Casing top	Casing bottom	Drill date	Interpreted geology intersected
125141	614325	7793439	WS	-	-	-	-	EX	-	-	13/09/2004	Alluvial and deltaic deposits
60587	612554	7793380	WS	-	-	-	-	EX	0	8.5	24/03/1983	Alluvial and deltaic deposits
125335	615238	7793270	WS	-	-	-	-	EX	-	-	17/08/2004	Alluvial and deltaic deposits
60588	609985	7792612	WS	-	-	-	-	EX	0	14.9	24/03/1983	Intrusive deposits
39565	614115	7792479	WS	Alluvium	UC	9	15	EX	0	15.2	1/01/1969	Alluvial and deltaic deposits
39671	616595	7792419	WS	-	-	-	-	EX	0	9.1	20/03/1973	Coastal dunes and/or alluvial deposits
25573	609165	7792129	WS	Upper Carb	WZ	0	20	EX	0	20.1	30/07/1965	Intrusive deposits
32590	613585	7791869	WS	Upper Carb	WZ	1	7	EX	0	0	15/11/1972	Intrusive deposits
60589	605831	7791783	WS	-	-	-	-	EX	0	11.3	24/03/1983	Alluvial and deltaic deposits
32589	611350	7791594	WS	Earth Lime	UC	11	18	EX	0	18.3	1/05/1969	Earth lime or alluvial and deltaic deposits
24708	615976	7791499	WS	-	-	-	-	EX	0	24.4	17/03/1965	Intrusive deposits
39670	612815	7790099	WS	-	-	-	-	EX	0	10.9	1/01/1934	Alluvial and deltaic deposits
140634	601277	7789431	WS	-	FR	20	23	EX	0	25	14/12/2007	Intrusive deposits - fractured rock
140635	600586	7789172	WS	-	FR	20	21.5	EX	0	22.3	14/12/2007	Intrusive deposits - fractured rock
54642	627496	7789089	WS	Don River Alluvium	UC	4.6	6.1	EX	0	8.8	6/03/1979	Alluvial and deltaic deposits (near Bowen)
36389	616595	7788079	WS	Splitters Ck	FR	9.5	15.9	EX	0	17	4/10/1970	Intrusive deposits -

Well name	Easting	Northing	Bore use	Formation monitored	Aquifer condition	Aquifer top	Aquifer bottom	Facility status	Casing top	Casing bottom	Drill date	Interpreted geology intersected
				Granite								fractured rock
125140	593950	7786313	WS	-	-	-	-	EX	-	-	12/09/2004	Intrusive deposits
125142	589608	7786045	WS	-	-	-	-	EX	-	-	12/09/2004	Intrusive deposits
125392	588497	7777709	WS	-	-	-	-	EX	-	-	6/09/2003	Intrusive deposits
125722	587387	7767273	WS	-	WZ	2	11	EX	0	18	26/09/2004	Intrusive deposits
125706	582916	7760830	WS	-	-	-	-	AD	5	36	16/12/2004	Intrusive deposits
125563	582531	7758605	WS	-	FR	29	34	EX	0	124	17/06/2006	Intrusive deposits - fractured rock
125674	579753	7755784	WS	-	-	-	-	AD	6	64	20/10/2005	Lizzie Creek Volcanic Group
25192	576273	7741465	WS	Alluv	UC	13	15	EX	0	8.8	8/09/1965	Alluvium
25191	576438	7741420	WS	-	-	-	-	EX	0	11.8	1/01/1965	Alluvium
140119	576644	7741286	WS	-	WZ	16	44	EX	0	49	23/05/2007	Lizzie Creek Volcanic Group
140127	577589	7740103	WS	-	WZ	13	25	EX	0	25	24/05/2007	Lizzie Creek Volcanic Group
132307	504842	7590828	WS	-	-	-	-	AD	-	-	12/07/2003	Sedimentary or alluvial

Notes:

Interpreted geology intersected represents a subjective assessment of potential zone intersected by the bore based all available information

mbgl = metres below ground level (approximate)

Bore use symbol – WS = Water Supply

Facility Status symbols – EX = Existing, AD = Abandoned and Destroyed

Aquifer Condition symbols – FR = Fractured Rock, UC = Unconsolidated, WZ = Weathered Zone

'-' = No data

Source: DNRW GWDB

3.5.6 Groundwater dependent ecosystems

Potential groundwater dependant ecosystems (GDEs) have been inferred along the preliminary investigation corridor using data published by the Bureau of Meteorology (BOM, 2013). Figure 3-9 presents this information. Much of the data is the result of high level probability assessment and has not been subject to ground-truthing.

Surface features which are indicated to be subject to a “high potential for groundwater interaction” include:

- Bogie River
- Sandy Creek
- Pelican Creek
- Bowen River
- Verbena Creek
- Suttor River.

These are generally described as wetlands or rivers. In these areas flows may be relatively persistent and during extended dry periods these systems may 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. Consequently the fauna which are attracted to these areas are also thought likely to be dependent on groundwater to a degree, albeit indirectly.

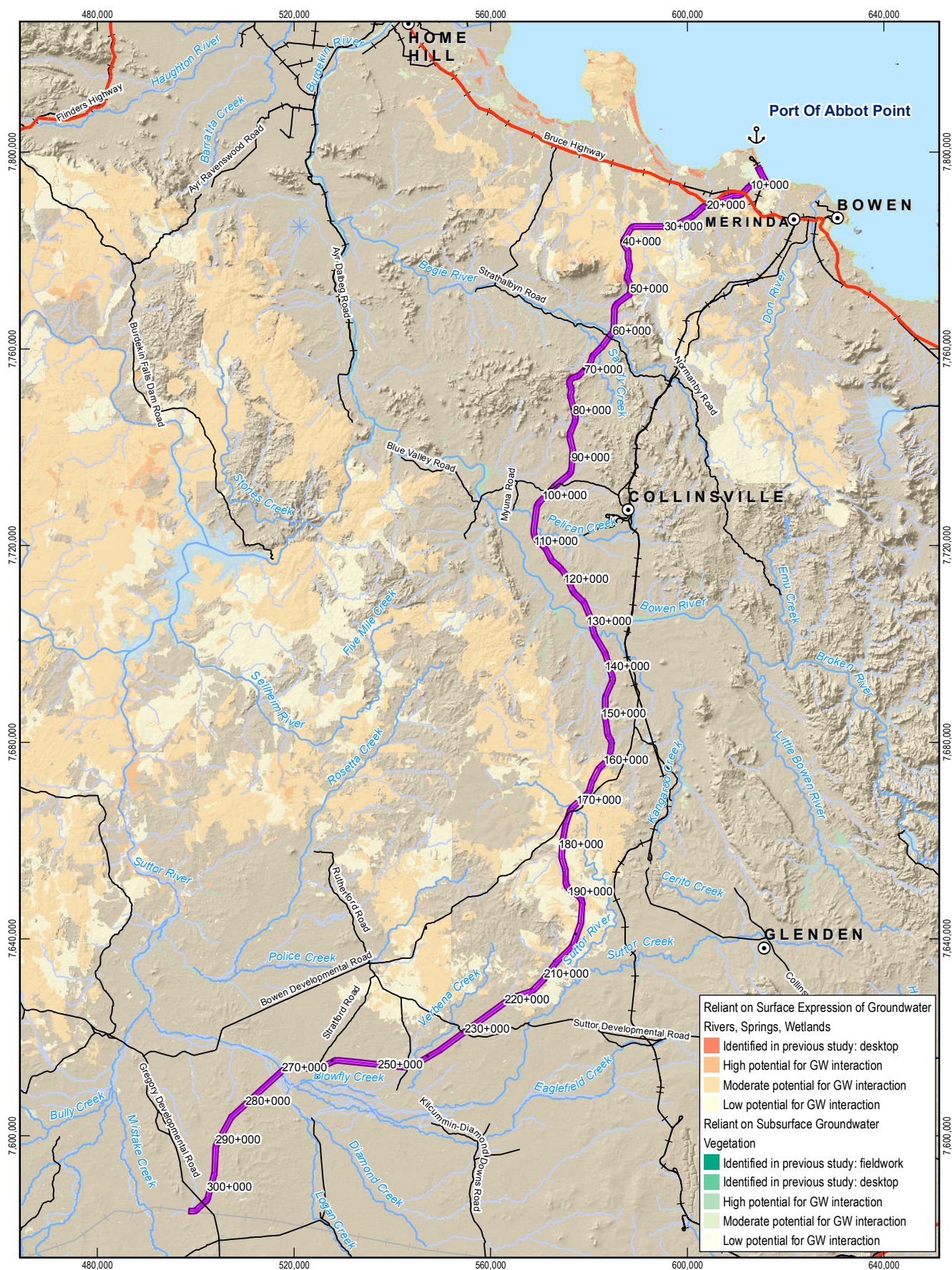
The preliminary investigation corridor passes many areas indicated as having either a “low or moderate potential for groundwater interaction”. The approximate chainages at which these areas are evident are listed below:

- Saline swamp area to the south west of the NGBR Project between chainage 0 to 8 km
- 30 to 120 km
- 130 to 210 km
- 220 to 230 km
- 270 to 290 km.

These areas are generally outside of the riparian areas associated with the main watercourses and are not expected to represent significant GDEs. Other minor creeks and rivers are typically ephemeral and are not anticipated to have significant reliance on groundwater.

Areas with “high potential for groundwater interaction” along the preliminary investigation corridor were indicated between chainages:

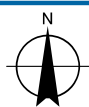
- 150 to 155 km
- 270 to 275 km.



LEGEND

- Population Centres
- Chainage Points
- Highway
- Watercourse (Major)
- Watercourse (Minor)
- Main Road
- Lakes
- Carmichael Project (Rail)
- Railway
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin Rail 100m Corridor

1:1,100,000
0 10 20 40
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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North Galilee Basin Rail Project
**Potential Groundwater
Dependant Ecosystems**

Job Number 41-26457
Revision A
Date 29 Aug 2013

Figure 3-9

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Data source: GA: Populated Places, Railway, Watercourse, Lakes, Springs/2007; Adani: NGBR Corridor 06/06/2013, NGBR Corridor 03/05/2013, Carmichael Project Rail/2012; DNRM: Roads, Groundwater Dependant Ecosystems/2010, Lakes/2008.
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3.5.7 Spring complexes

According to the Springs of Queensland dataset (EPA, 2005) and the Queensland Government Wetland information database which present the locations of spring dependent ecosystems shows that there are no reported spring complexes within the study area. The nearest are Doongmabulla Springs and are listed under the Directory of Important Wetlands. They are located approximately 11 km west of the Carmichael Coal Mine and Rail Project (Mine), some 70 km distance from the western extent of the NGBR Project. However, due their distance they are not considered relevant to the NGBR Project.

3.5.8 Groundwater levels and flow regime

There are approximately 40 bores along the preliminary investigation corridor with groundwater elevation data. This data is presented in Table 3-11 and is summarised below:

- There are seven bores with groundwater elevation data within the coastal dune, alluvial and deltaic deposits. The groundwater elevations in these bores generally range between 1.2 and 9 mbgl with an average of 4.5 mbgl
- There are fifteen bores with groundwater elevation data weathered intrusive deposits mainly within the Clarke Range area. The groundwater elevations in these bores generally range between 3 and 19.5 mbgl with an average of 9.7 mbgl
- There are four bores with groundwater elevation data within fractures intrusive deposits mainly within the Clarke Range area. The groundwater elevations in these bores generally range between 7.3 and 18 mbgl with an average of 13.8 mbgl
- There are three bores with groundwater elevation data within alluvial deposits in inland areas along the preliminary investigation corridor. The groundwater elevations in these bores generally range between 4.2 and 45.7 mbgl with an average of 20.2 mbgl
- There are three bores with groundwater elevation data within weathered zones of the Lizzie Creek Volcanics. The groundwater elevations in these bores generally range between 6.0 and 8.2 mbgl with an average of 7.4 mbgl
- There are eight bores with the geology is not specified.

The data suggests that the shallow groundwater system is the primary zone intersected for groundwater monitoring and supply along the preliminary investigation corridor. Figure 3-10 shows the depth to groundwater along the preliminary investigation corridor from data obtained from the DNRW GWDB.

There is currently insufficient data to establish regional flow directions, however, it is expected that shallow groundwater systems in alluvium and the shallow weathered zones of intrusive deposits and the Lizzie Volcanic Group will follow the topography and surface drainage system. It is unclear at this point what the overall flow directions are for deeper confined aquifer systems.

Table 3-11 Water levels

Well name	Easting	Northing	Formation monitored	Aquifer condition	Bore use	Reading date	Groundwater water level (mbgl)	Interpreted geology intersected
125269	612319	7799481	Don River Alluvium	UC	SI	Not specified	4	Coastal dunes and/or alluvial deposits
125268	612317	7798996	Don River Alluvium	UC	SI	Not specified	4	Coastal dunes and/or alluvial deposits
39671	616595	7792419	Not specified	Not specified	WS	20/03/1973	7.6	Coastal dunes and/or alluvial deposits
36390	612358	7792333	Upper Carb	WZ	Not specified	10/12/1970	4.5	Intrusive deposits
25573	609165	7792129	Upper Carb	WZ	WS	30/07/1965	8.2	Intrusive deposits
60150	604565	7791979	Alluv Spli	UC	Not specified	25/10/1982	4.16	Intrusive deposits
32590	613585	7791869	Upper Carb	WZ	WS	15/11/1972	3.6	Intrusive deposits
32589	611350	7791594	Earth Lime	UC	WS	15/05/1969	9.1	Earth lime or alluvial and deltaic deposits
24708	615976	7791499	Not specified	Not specified	WS	28/03/1973	13.1	Intrusive deposits
140634	601277	7789431	Not specified	FR	WS	Not specified	14	Intrusive deposits - fractured rock
140635	600586	7789172	Not specified	FR	WS	Not specified	16	Intrusive deposits - fractured rock
54642	627496	7789089	Don River Alluvium	UC	WS	6/03/1979	3.6	Alluvial and deltaic deposits (near Bowen)
25170	604932	7788375	Alluv Don	UC	Not specified	22/02/1965	1.2	Coastal dunes and/or alluvial deposits
36389	616595	7788079	Splitters Ck Granite	FR	WS	4/10/1970	7.3	Intrusive deposits - fractured rock
31121	605150	7787902	Alluv Don	UC	Not specified	1/06/1968	1.8	Coastal dunes and/or alluvial deposits

Well name	Easting	Northing	Formation monitored	Aquifer condition	Bore use	Reading date	Groundwater water level (mbgl)	Interpreted geology intersected
12100485	592782	7787299	Not specified	Not specified	IN	22/01/1998	4.03	not specified
32587	598975	7786709	Upper Carb	WZ	not specified	15/05/1969	10.6	Intrusive deposits
12100506	603293	7786342	Not specified	Not specified	IN	22/01/1998	10.18	not specified
12100489	598854	7784962	Not specified	Not specified	IN	26/02/1998	11.71	not specified
12100486	590292	7784828	Not specified	Not specified	IN	22/01/1998	8.62	not specified
12100487	593855	7784774	Not specified	Not specified	IN	22/01/1998	11.39	not specified
25569	593445	7783759	Upper Carb	WZ	Not specified	24/07/1965	6.7	Intrusive deposits
25572	599545	7783689	Upper Carb	FR	Not specified	29/07/1965	11.2	Intrusive deposits
37902	598525	7783369	Upper Carb	FR	Not specified	5/07/1970	10	Intrusive deposits
37903	593585	7782849	Upper Carb	WZ	Not specified	7/07/1970	13.4	Intrusive deposits
32350	591265	7782589	Upper Carb	WZ	Not specified	25/02/1972	12.2	Intrusive deposits
25005	587745	7776109	Upper Carb	WZ	Not specified	22/08/1965	4.5	Intrusive deposits
125722	587387	7767273	Not specified	WZ	WS	Not specified	3	Intrusive deposits
25812	582965	7759909	Upper Carb	WZ	Not specified	14/09/1966	14.6	Intrusive deposits
125563	582531	7758605	not specified	FR	WS	Not specified	18	Intrusive deposits - fractured rock
25664	582725	7758119	Upper Carb	WZ	Not specified	18/10/1967	19.5	Intrusive deposits
25813	577505	7756639	Lizzckvolc	WZ	Not specified	15/09/1966	8.2	Lizzie Creek Volcanic Group

Well name	Easting	Northing	Formation monitored	Aquifer condition	Bore use	Reading date	Groundwater water level (mbgl)	Interpreted geology intersected
25192	576273	7741465	Allu	UC	WS	8/09/1965	10.6	Alluvium
140119	576644	7741286	Not specified	WZ	WS	Not specified	6	Lizzie Creek Volcanic Group
140127	577589	7740103	Not specified	WZ	WS	Not specified	8	Lizzie Creek Volcanic Group
12020027	580641	7704484	Not specified	Not specified	IN	23/01/1997	6.45	Not specified
12020026	580663	7703507	Not specified	Not specified	IN	23/01/1997	8.39	Not specified
60362	585264	7686260	Alluv	PS	Not specified	30/06/1981	45.7	Alluvium
12030094	577823	7666252	not specified	Not specified	IN	12/06/1975	58.26	Not specified
39400	553304	7621958	Alluvium	UC	Not specified	21/06/1972	4.2	Alluvium

Notes: Interpreted geology intersected represents a subjective assessment of potential zone intersected by the bore based all available information

mbgl = metres below ground level (approximate)

Bore use symbol – WS = Water Supply

Facility Status symbols – EX = Existing, AD = Abandoned and Destroyed

Aquifer Condition symbols – FR = Fractured Rock, UC = Unconsolidated, WZ = Weathered Zone

'-' = No data

Source: DNRW GWDB

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3.5.9 Groundwater quality

Regional data

Available groundwater quality data from GWDB bores within the preliminary investigation corridor is presented in Figure 3-11 and is summarised in Table 3-12.

Data is primarily available for bores intersecting weathered igneous intrusion deposits (seven bores) with one data point available for wells screened in coastal deposits, fractured igneous intrusive deposits, alluvium and sedimentary sandstones, siltstones and/or mudstones (Mt Hall Formation). The data are summarised below:

- The bore intersecting coastal dune, alluvium and deltaic deposits had a TDS of 1,404 mg/L. This suggests these aquifers are potentially suitable as a potable domestic and stock water supply, however, this conclusion is based on a single data point and groundwater quality may vary significantly from place to place in these sediments.
- Bores intersecting weathered intrusive igneous deposits have TDS values ranging between 282 mg/L and 2,424 mg/L with an average of 1,323 mg/L. This suggests these aquifers are potentially suitable as a potable domestic and stock water supply.
- The bore intersecting fractured igneous deposits had a TDS of 876 mg/L. This suggests these aquifers are potentially suitable as a potable domestic and stock water supply, however, this conclusion is based on a single data point and groundwater quality may vary significantly from place to place in these sediments.
- The bore intersecting alluvium had a TDS of 3,624 mg/L. This suggests these aquifers are marginal as a potable domestic and stock water supply, however, this conclusion is based on a single data point and groundwater quality may vary significantly from place to place in these sediments.
- The bore intersecting Mt Hall Formation (sedimentary sandstones etc) had a TDS of 2,940 mg/L. This suggests these aquifers are marginal as a potable domestic and stock water supply, however, this conclusion is based on a single data point and groundwater quality may vary significantly from place to place in these sediments.

A similar area was also reviewed by Hancock Prospecting (2010) which assessed a larger number of wells along the preliminary investigation corridor intersecting similar geologies. This information broadly suggests the following:

- Coastal dune, alluvial and deltaic systems and intrusive deposits associated with the Clarke Range (0 to 68 km chainage) have a collective TDS ranging between 318 mg/L and 6,952 mg/L with an average of 949 mg/L (69 bores). This suggests these aquifers are potentially suitable as a potable domestic and stock water supply.
- Quaternary alluvium, volcanic sediments associated with the Lizzie Volcanic Group and Permian sedimentary deposits (between chainages of approximately 68 and 170 km) have a collective TDS ranging between 742 mg/L and 3,303 mg/L with an average of 1,942 mg/L (4 bores). This suggests that groundwater in these areas is potentially suitable as a potable domestic supply but is likely to be suitable for stock water supply. It is noted, however, that there are only a few bores characterising a large area.

- Sedimentary deposits (Suttor Formation) and quaternary alluvium and residual soils (Draining to the Suttor River and Mistake Creek) between chainages of approximately 170 to 305 km have a collective TDS ranging between 495 mg/L and 37,140 mg/L with an average of 13,363 mg/L (6 bores). This suggests that groundwater in these areas is marginal for use as a potable domestic and stock water supply. It is noted, however, that there are only a few bores characterising a large area.

In summary, the data provides a reasonable understanding of the water quality within the coastal aquifer systems and within the igneous intrusive deposits associated with Mt Roundback and the Clarke Range (i.e. southward of chainage 68 km). The water quality of these areas has potential for use as a water supply for domestic and stock purposes. Water quality data is scarce at chainages greater than this and cannot be relied upon to provide a reasonable understanding of the water quality of aquifers in these areas.

Acid Sulfate Soils

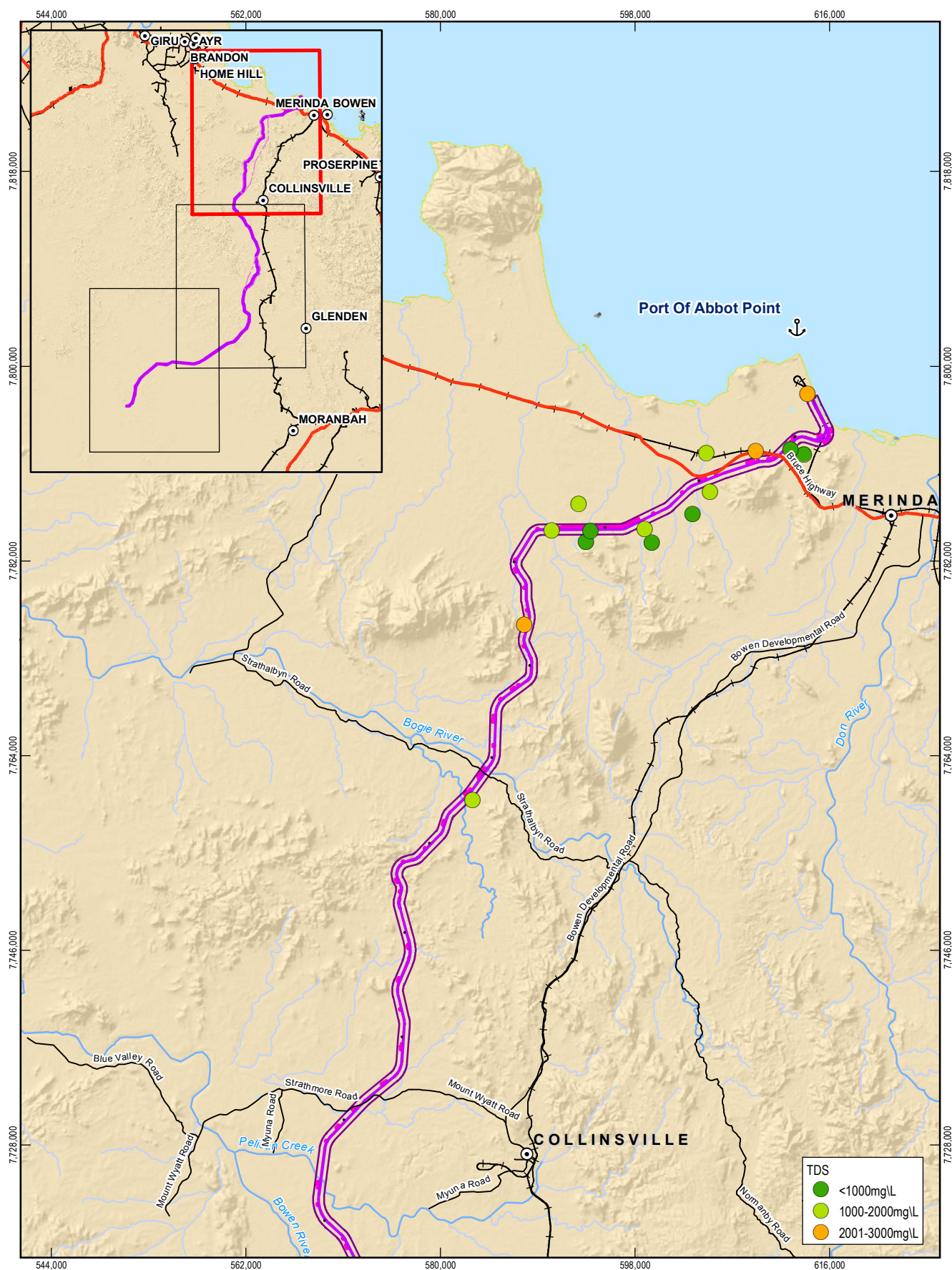
The Australian Soil Resource Information System (ASRIS) mapping database indicates there is a high probability for the presence of potential acid sulfate soils in the northern 5 km of the preliminary investigation corridor. This is due to the presence of acid sulfate soils occurring in sediments of marginal marine or estuarine origin, and predominantly being confined to coastal lowland areas with elevation below 20 m Australian height datum (AHD).

The area most likely to contain acid sulfate soils is the Quaternary aged coastal mud flat associated with the Caley Valley Wetlands and to a lesser extent the coastal sand dune geology and alluvial and deltaic deposits extending west from the Port of Abbot Point.

Two portions of the study area were identified as at or below 20 m AHD and are:

- A 400 metre portion between chainage 19.6 km and 22 km, which is associated with Splitters Creek
- The initial 9.3 km portion between chainages 3.4 km and 12.7 km, which has multiple minor ephemeral creeks, including Saltwater Creek.

The remainder of the preliminary investigation corridor is anticipated to have low to very low probability of acid sulphate soil occurrence. Further detailed assessment of potential acid sulfate soils is provided in Volume 2 Appendix F - Topography, geology, soils and land contamination.



LEGEND

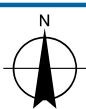
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- ⚓ Major Port
- Chainage Points
- Main Road
- Railway
- Watercourse (Major)
- Watercourse (Minor)
- Lakes
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin Rail 100m Corridor
- Construction Footprint
- Highway

TDS

- <1000mg/L
- 1000-2000mg/L
- 2001-3000mg/L

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0 4.5 9 18
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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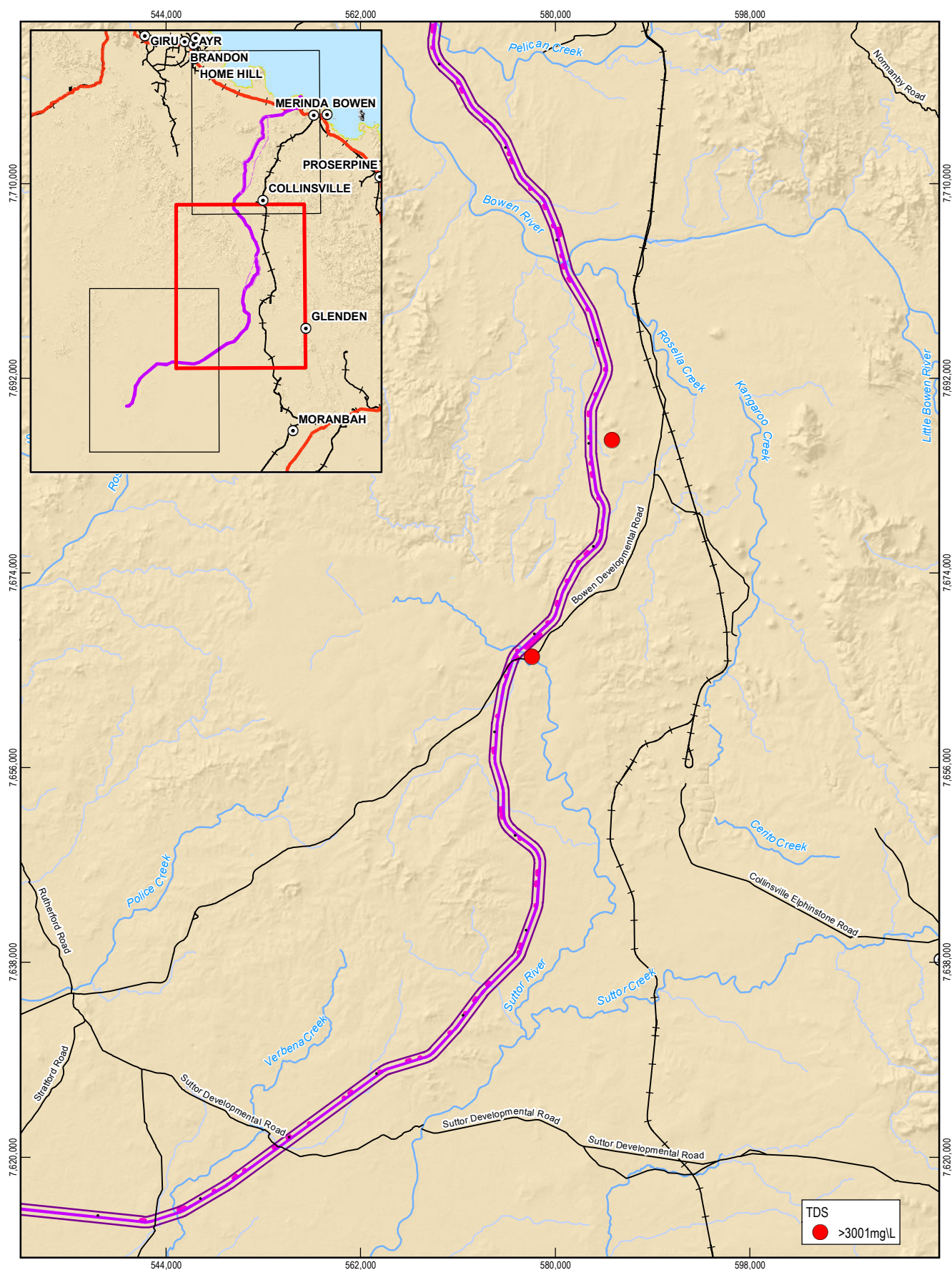
Groundwater Quality Data

Figure 3-11
Sheet 1 of 3

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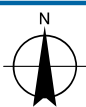
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LEGEND

- Population Centres
- Chainage Points
- Main Road
- Railway
- Watercourse (Major)
- Watercourse (Minor)
- Lakes
- Construction Footprint
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin Rail 100m Corridor

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 Kilometres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 55



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Groundwater Quality Data

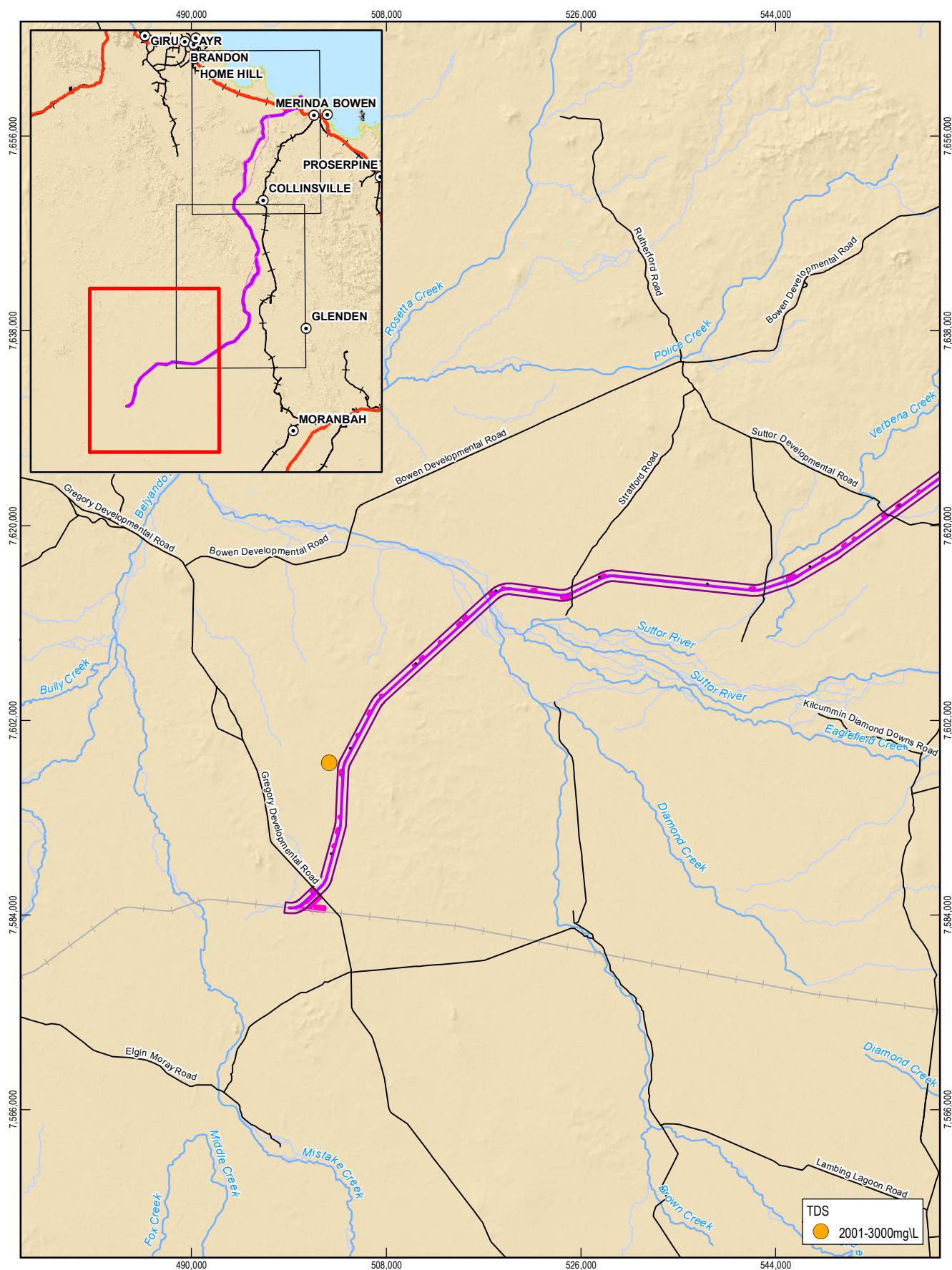
Figure 3-11
 Sheet 2 of 3

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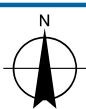


LEGEND

- Chainage Points
- Main Road
- Watercourse (Major)
- Carmichael Project (Rail)
- Watercourse (Minor)
- Lakes
- North Galilee Basin Rail 1000m Corridor
- Construction Footprint
- North Galilee Basin Rail 100m Corridor

TDS
● 2001-3000mg/L

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Kilometres
Paper Size A4
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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Date 29 Aug 2013

Groundwater Quality Data

Figure 3-11
Sheet 3 of 3

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Data source: GA: Populated Places, Railway, Watercourse, Lakes/2007; Adani: NGBR Corridor 06/06/2013, NGBR Corridor 03/05/2013, Carmichael Project Rail/2012, Construction Footprint/2013; DNRM: Roads, Rail, Groundwater Salinity/2010, Lakes/2008. Created by:MS

Table 3-12 Water quality

Well name	Easting	Northing	Formation monitored	Aquifer condition	Aquifer top	Aquifer bottom	Bore use	EC	TDS	pH	Drill date	Interpreted geology intersected
54547	613929	7797421	-	Not specified	Not specified	Not specified	Not specified	3440	2064	8	1/01/1978	-
36390	612358	7792333	Upper Carb	WZ	5	15	Not specified	470	282	8	10/12/1970	Intrusive deposits
25573	609165	7792129	Upper Carb	WZ	0	20	WS	4040	2424	8	30/07/1965	Intrusive deposits
60150	604565	7791979	Alluv Spli	UC	7	10	Not specified	1705	1023	7	22/07/1980	Intrusive deposits
32590	613585	7791869	Upper Carb	WZ	1	7	WS	1300	780	8	15/11/1972	Intrusive deposits
25170	604932	7788375	Alluv Don	UC	1	4	Not specified	2340	1404	7	22/02/1965	Coastal dunes and/or alluvial deposits
12100485	592782	7787299	Not specified	Not specified	Not specified	Not specified	IN	2170	1302	8	29/11/1997	Not specified
12100506	603293	7786342	Not specified	Not specified	Not specified	Not specified	IN	1132	679	8	8/12/1997	Not specified
12100489	598854	7784962	Not specified	Not specified	Not specified	Not specified	IN	2980	1788	8	1/12/1997	Not specified
12100486	590292	7784828	Not specified	Not specified	Not specified	Not specified	IN	3080	1848	8	30/11/1997	Not specified
12100487	593855	7784774	Not specified	Not specified	Not specified	Not specified	IN	1520	912	8	30/11/1997	Not specified
25569	593445	7783759	Upper Carb	WZ	9	17	Not specified	1310	786	8	24/07/1965	Intrusive deposits
25572	599545	7783689	Upper Carb	FR	7	15	Not specified	1460	876	8	29/07/1965	Intrusive deposits
25005	587745	7776109	Upper Carb	WZ	3	8	Not specified	3650	2190	8	22/10/1966	Intrusive deposits

Well name	Easting	Northing	Formation monitored	Aquifer condition	Aquifer top	Aquifer bottom	Bore use	EC	TDS	pH	Drill date	Interpreted geology intersected
25812	582965	7759909	Upper Carb	WZ	18	25	Not specified	2960	1776	9	14/09/1966	Intrusive deposits
60362	585264	7686260	Alluv	PS	51	74	Not specified	6040	3624	8	30/06/1981	Alluvium
12030094	577823	7666252	Not specified	Not specified	Not specified	Not specified	IN	9900	5940	8	12/06/1975	Not specified
89009	502704	7598109	Mt Hall Conglomerate	PS	105	142	Not specified	4900	2940	8	3/05/1990	Sedimentary

Notes:

EC = Electrical Conductivity mS/cm

TDS = Total Dissolved Solids (mg/L)

Top and Bottom data is relative to ground surface

Bore use symbol – WS = Water Supply

Facility Status symbols – EX = Existing, AD = Abandoned and Destroyed

Aquifer Condition symbols – FR = Fractured Rock, UC = Unconsolidated, WZ = Weathered Zone

‘-’ = No data

Source: DNRM GWDB

3.6 Surface water quality

No continuous surface water quality data has been collected in the preliminary investigation corridor. Interpretations of the existing water quality conditions were made based on existing water quality data, which are not continuous temporally or spatially.

Other studies (refer Section 2.4.1), were reviewed for water quality data to inform the following analysis. Water quality data collected in the waterways of the preliminary investigation corridor as part of these studies includes:

- Three DNRM stream gauging stations (Site 120310A, Site 120304A and Site 120205A) in the Suttor and Bowen River catchments. Parameters included conductivity, turbidity, pH, DO, TDS, total suspended solids, nutrients and metals
- Nine sites across all river basins (Don, Lower Burdekin, Bowen and Suttor) that were sampled in April 2010 (wet season). Parameters included conductivity, turbidity, TDS, pH and DO (Hancock Prospecting 2010)
- Twenty eight sites across all river basins (Don, Lower Burdekin, Bowen and Suttor) that were sampled in October 2009 (dry season) and March/April 2010 (wet season). Parameters included conductivity, pH, temperature, turbidity, DO, nutrients and metals (E3 Consulting 2011)
- Data for 26 sites within the Bowen River catchment that were sampled between 2007 and 2011 for the Newlands Coal Extension Project EIS. Parameters included conductivity, turbidity, total suspended solids, pH, DO and nutrients (Kellogg Brown and Root 2012)
- Data for 41 sites within the Caley Valley Wetland that was compiled from a number of previous studies as part of the Abbot Point Cumulative Impact Assessment. Parameters included conductivity, turbidity, total suspended solids, pH, nutrients, Chlorophyll a, DO and metals (Eco Logical and Open Lines 2012).

Results from these studies, as well as the current water quality sampling, is presented in the following sections for each catchment. No water samples were taken within the Belyando River catchment as no major watercourses are crossed by the preliminary investigation corridor within this catchment.

3.6.1 Don River Basin

The waterways within the Don River Basin are defined by the QWQG (DERM, 2009a) as lowland streams as they are less than 50 metres elevation above sea level.

Water quality data collected for the Hancock EIS in April 2010 (wet season) found that the conductivity at Elliot River and Splitters Creek was greater than the Water Quality Objectives (WQO) (Table 3-13).

Table 3-13 Hancock EIS water quality data - sites in the Don River Basin

Site	Water Temperature	Electrical Conductivity	Turbidity	pH	Dissolved Oxygen	TDS
Units	°C	µS/cm	NTU	-	%	mg/L
Splitlers Creek	17.6	1,535	0.31	7.8	86	690.3
Elliot River	21.9	786	1.96	7.5	86	425.7

Source: Hancock Prospecting 2010

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected for the Waratah EIS for waterways within the Don River Basin in October 2009 (dry season) and March/April 2010 (wet season) found that the water quality was outside the WQO for most sites for a number of parameters measures (E3 Consulting 2011).

The conductivity, concentration of iron and ammonia was greater than the WQOs for most sites. The concentration of total nitrogen and total phosphorus was greater than the WQO at WQ5. The concentration of total nitrogen was also greater than WQOs at WQ2, WQ6 and WQ7. The concentration of arsenic, chromium, copper, lead and zinc was greater than the WQOs at sites WQ5 and WQ6. The dissolved oxygen at all sites, except WQ3, WQ5, WQ8 and WQ9 was less than the WQO. The pH at WQ2 was outside the WQO range (Table 3-14).

Table 3-14 Waratah EIS water quality data for sites in the Don River Basin

		Temperature	pH	Electrical Conductivity	Dissolved Oxygen	Ammonia as N	Nitrite as N	Nitrate as N	Total Nitrogen	Total Phosphorus	Chlorophyll a	Calcium	Magnesium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Nickel	Zinc
Units		°C	pH Unit	µS/cm	%	µg/L	µg/L	µg/L	µg/L	µg/L	mg/m ³	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
WET	WQ2	22	7.9	693	82	20	<10	<10	<100	<10	<1	112	92	<1	<0.1	<1	2	100	<1	<1	<5
DRY	WQ2	25	8.2	6,680	50	30	<10	40	700	<10	2	40	269	2	<0.1	1	3	220	2	<1	5
WET	WQ3	22	7.9	678	86	30	<10	<10	<100	<10	<1	112	91	<1	<0.1	<1	<1	90	<1	<1	8
DRY	WQ3	24	7.8	2,396	72	40	<10	110	100	<10	2	115	112	<1	<0.1	<1	<1	270	1	<1	<5
WET	WQ5	29	7.2	24.2	113	960	<10	100	3,500	<10	2	397	589	3	2	1	<1	1,680	6	20	26
DRY	WQ5	25	7.9	157,000	45	610	<10	70	3,900	240	1	915	6,210	93	<0.1	57	25	4,780	42	10	52
WET	WQ6	24	7.3	16.2	82	50	<10	<10	1,000	<10	<1	181	366	8	<0.1	<1	<1	620	2	2	7
DRY	WQ6	26	7.9	134,000	62	540	<10	30	340	<10	3	1,000	5,140	76	<0.1	54	25	4,980	37	10	52
WET	WQ7	23	7.4	1,549	51	40	10	610	600	<10	<1	64	41	<1	<0.1	<1	<1	<50	<1	<1	<5
DRY	WQ7	26	7.4	2,122	40	90	<10	140	500	<10	<1	107	53	1	<0.1	<1	<1	3,200	1	<1	5
WET	WQ8	30	7.9	1,360	88	20	<10	<10	200	<10	<1	38	21	<1	0.2	<1	<1	<50	<1	<1	<5
WET	WQ9	29	7.6	1,000	93	10	<10	<10	<100	<10	<1	48	29	<1	<0.1	<1	<1	1,100	<1	<1	<5
DRY	WQ9	28	7.3	1,523	70	110	<10	180	500	40	2	55	33	<1	<0.1	<1	<1	460	<1	<1	<5

Source: E3 Consulting 2011

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected in May 2013 found that conductivity at Saltwater, Tabletop and Splitters Creeks was greater than the WQOs. Dissolved oxygen at all sites was less than WQOs (Table 3-15).

Table 3-15 Water quality data for the Don River Basin May 2013

Site	Flow Level	Water Temperature	Electrical Conductivity	Salinity	pH	Dissolved Oxygen		TDS	Redox
Units		°C	µS/cm	PSU		mg/L	%	mg/L	
Saltwater Creek	low	23.5	1,964	1	8.1	5.66	68	1274	146.3
Table Top Creek	low	22	1,228	0.61	7.6	3.33	38	799.5	141.6
Splitters Creek	low - moderate	22.5	1,860	0.94	7.8	7.24	84	1209	53.5

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

The high conductivity in the waterways sampled in the Don River Basin may be due to the influences of tidal intrusion. These creeks flow directly into Abbot Bay.

Caley Valley Wetland

The Caley Valley Wetland is within the Don River Basin. Surface water quality within the Caley Valley Wetland was collated for the Abbot Point Cumulative Impact Assessment (Eco Logical and Open Lines 2012). Water quality was sampled across the different wetland types including estuarine, palustrine and riverine within the Caley Valley Wetland (Wetland). The water quality within the Wetland was found to be both spatially and temporally variable.

During the wetter months, the Wetland upstream of the causeway trends towards freshwater conditions. Freshwater inputs from Saltwater Creek and other runoff during these periods dilute saline influences of tidal intrusion downstream. During drier months, when rainfall is reduced, the tidal inflow from downstream and greater evaporation contributes to greater salinity. There is also a temporal pattern of pH across the Wetland, with an increase in the drier months (April – June 2010) at sites in the central Wetland zone, hypersaline zone and adjacent to the causeway.

Turbidity was variable across sites and was greater in the wet season in comparison to the dry season (June and July). Concentrations of metals were generally highest in February (2010) which coincided with rainfall greater than 500 mm. Greater turbidity and metal concentrations in February 2010 than February 2011 are attributable to greater volumes of catchment runoff in February 2010 than 2011. The Abbot Point coal export terminal one stockpiles and sediment ponds may also present a source of metals to the Wetland if sediment pond overflows occur.

The results for total nitrogen, total phosphorus, chlorophyll a and dissolved oxygen in the Wetland showed no spatial or temporal patterns.

Water quality in the Wetland is largely determined by the relative contributions of marine waters during peak tides and freshwater from rainfall and runoff. Other influences to the water quality in the Wetland include discharges and overflows from the Abbot Point coal export terminal one sediment ponds and land use in the catchment.

Abbot Bay

The preliminary investigation corridor intersects a number of perennial and ephemeral streams within the Don River Basin which flow directly into Abbot Bay, or Caley Valley Wetland which then flows into Abbot Bay. Caley Valley Wetland is hydrologically disconnected from Abbot Bay in the dry season by a causeway and a bund wall. Abbot Bay is within the Great Barrier Reef World Heritage Area (GBRWA), Great Barrier Reef Marine Park (GBRMP), and Commonwealth marine area.

The marine water quality environment in Abbot Bay is influenced by coastal (currents and waves) and fluvial processes (discharges from coastal rivers and creeks), as well as weather conditions. These processes contribute to significant temporal, and particularly seasonal, variation in water quality. Nearshore coastal environments are known to exhibit a high degree of temporal variability and to a lesser degree, spatial variability in water quality parameters, given the marked influence of waves, currents and local discharges from rivers and creeks within shallow coastal environments (De'ath 2007, De'ath and Fabricius 2008).

3.6.2 Lower Burdekin River catchment

The waterways within the Lower Burdekin River catchment are defined by the QWQG (DERM 2009a) as lowland streams as they are between 130 and 150 metres elevation above sea level.

Water quality data collected for the Hancock EIS in April 2010 (wet season) found that the conductivity at Bogie River and Capsize Creek was greater than the WQOs. Turbidity and pH was greater than WQOs at Capsize Creek (Hancock Prospecting 2010). Water quality from the Hancock EIS is provided in Table 3-16.

Table 3-16 Hancock EIS water quality data for sites in the Lower Burdekin River catchment

Site	Water Temperature	Electrical Conductivity	Turbidity	pH	Dissolved Oxygen	TDS
Units	°C	µS/cm	NTU		%	mg/L
Bogie River	25.0	546.2	0.42	7.6	86.1	293.3
Capsize Creek	32.1	751.6	30.9	8.2	130.0	406.2

Source: Hancock Prospecting 2010

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected for the Waratah EIS for waterways within the Lower Burdekin River catchment in October 2009 (dry season) and March/April 2010 (wet season) found that the conductivity and concentration of ammonia and total phosphorus was greater than WQOs at all sites (E3 Consulting 2011).

The conductivity, concentration of iron and ammonia was greater than the WQOs for most sites. The concentration of chromium, copper and iron at WQ12 and the concentration of iron at WQ11 were greater than the WQOs. The dissolved oxygen at WQ11 and WQ12 was less than the WQO (refer Table 3-17).

Table 3-17 Waratah EIS water quality data for sites in the Lower Burdekin River catchment

	Site	Temperature	pH	Electrical Conductivity	Dissolved Oxygen	Ammonia as N	Nitrite as N	Nitrate as N	Total Nitrogen	Total Phosphorus	Chlorophyll a	Calcium	Magnesium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Nickel	Zinc
Units		°C	pH Unit	µS/cm	%	µg/L	µg/L	µg/L	µg/L	µg/L	mg/m ³	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
WET	WQ10	23	7.8	905	91	30	<10	10	200	160	<1	44	28	<1	<0.1	<1	<1	<50	<1	<1	<5
WET	WQ11	23	7.7	810	76	30	<10	50	300	270	2	84	64	<1	<0.1	<1	<1	670	<1	<1	<5
DRY	WQ11	30	7.3	1,689	48	30	<10	50	300	270	2	84	64	<1	<0.1	<1	<1	670	<1	<1	<5
WET	WQ12	30	7.6	1,149	128	50	<10	<10	200	140	3	59	41	<1	<0.1	2	4	2,400	<1	2	<5
DRY	WQ12	25	7.8	545	76	30	<10	30	<100	100	<1	30	17	1	<0.1	1	<1	170	<1	<1	<5

Source: E3 Consulting 2011

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected in May 2013 identified that conductivity at Bogie River and Sandy Creek was greater than the WQOs. Dissolved oxygen at both sites was less than WQOs (Table 3-23).

Table 3-18 Water quality data for sites in the Lower Burdekin River catchment May 2013

Site	Flow Level	Water Temperature	Electrical Conductivity	Salinity	pH	Dissolved Oxygen		TDS	Redox
Units		°C	µS/cm	PSU	-	mg/L	%	mg/L	-
Bogie River	low	23.6	929	0.46	8.1	6.6	78	604.5	143.8
Sandy Creek	low	24.8	1,304	0.65	7.6	2.3	28	845	119.2

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

3.6.3 Bowen River catchment

The waterways within the Bowen River catchment are defined by the QWQG (DERM 2009a) as lowland streams as they are approximately 100 metre elevation above sea level.

The median (or mean if median value was not available) concentration of nutrients (ammonia, total nitrogen and total phosphorus), sulfate, aluminium, copper and iron were greater than WQOs identified in Table 3-30 at the DEHP gauging stations for the Bowen River at Myuna (Site 120205A). The dissolved oxygen at this site was lower than the WQOs (Table 3-19).

Water quality data collected for the Waratah EIS for waterways within the Bowen River catchment in October 2009 (dry season) and March/April 2010 (wet season) found that the water quality was outside the WQOs for most sites for a number of parameters measures (E3 Consulting 2011). The conductivity, concentration of iron and ammonia was greater than the WQOs for most sites.

The concentration of total phosphorus was greater than the WQO at WQ13, WQ15, WQ16, WQ17 and WQ18. The concentration of chromium, copper and lead at sites WQ14 and WQ16 was greater than the WQOs. The concentration of copper at WQ17 and zinc at WQ16 was also greater than the WQOs. The concentration of Chlorophyll a was greater than WQO at WQ17 and WQ18. The dissolved oxygen at all sites, except WQ13 and WQ14 was less than the WQO. The pH at WQ14, WQ15, WQ17 and WQ18 was outside the WQO range (refer Table 3-20).

Table 3-19 Gauging station data for the Bowen River at Myuna (120205A)

	Water temperature	Electrical conductivity @ 25C	Turbidity	pH	Total alkalinity as CaCO ₃	Hardness as CaCO ₃	Total dissolved solids	Total suspended solids	Dissolved oxygen	Ammonia as N	Nitrate as NO ₃	Total nitrogen	Total phosphorus	Filterable reactive phosphorus	Fluoride	Magnesium	Sulphate	Aluminium	Boron	Copper	Iron	Manganese	Zinc
Units	°C	µs/cm	NTU	pH	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Number of samples	4	59	21	60	29	30	60	28	4	32	60	60	20	4	43	6	46	8	25	11	27	51	5
Minimum	30	110	3	6.6	7.6	0	35	0	0.2	0	7,300	9,000	5,600	0	0	0	2	0	0	0	0	1,000	0
Median	-	213	15	7.8	8.2	0	93	0	-	700	18,000	19,000	8,400	-	0.13	-	5.4	-	20	10	50	20,000	-
Maximum	37	510	202	9.2	9.5	0.3	251	0	0.6	25,000	46,000	60,000	12,900	20	0.8	0.02	14.2	-	50	50	200	1,880,000	10
Mean	33	222	33	7.7	8.4	0.0	109	0	0.3	1,700	19,900	22,800	8,400	20	0.2	0.005	5.8	40	20	20	60	107,600	2
Standard Deviation	3	77	49	0.5	0.5	0.1	47	0	0.2	4,500	7,000	12,800	1,600	2	0.1	0.008	3.3	70	10	20	50	286,100	5

Source: DEHP gauging station 2013

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Table 3-20 Waratah EIS water quality data for sites in the Bowen River catchment

	Site	Temperature	Electrical conductivity	pH	Dissolved oxygen	Ammonia as N	Nitrite as N	Nitrate as N	Total nitrogen	Total phosphorus	Chlorophyll a	Calcium	Magnesium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Nickel	Zinc
Units		°C	µS/cm	pH Unit	%	µg/L	µg/L	µg/L	µg/L	µg/L	mg/m ³	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
WET	WQ13	30	1,289	7.6	59	40	<10	<10	100	130	<1	91	48	<1	<0.1	<1	<1	<50	<1	<1	<5
DRY	WQ13	26	502	7.7	107	20	<10	50	300	<10	<1	32	15	2	<0.1	<1	<1	160	<1	<1	<5
WET	WQ14	30	2.8	7.3	90	30	<10	40	<100	<10	<1	346	428	1	<0.1	2	3	440	6	<1	<5
DRY	WQ14	29	7,800	8.4	55	10	10	20	<100	<10	<1	126	121	<1	<0.1	<1	1	780	<1	4	<5
WET	WQ15	32	3.2	7.4	80	<10	<10	30	<100	<10	<1	22	9	<1	<0.1	<1	<1	2,400	<1	<1	<5
DRY	WQ15	29	695	8.3	81	40	<10	120	400	120	<1	26	23	1	<0.1	<1	2	100	<1	<1	<5
WET	WQ16	33	1,222	7.5	80	20	<10	30	400	170	2	13	10	2	<0.1	6	5	6,980	3	7	10
DRY	WQ16	23	1,822	7.1	75	30	<10	30	200	<10	<1	54	52	2	<0.1	<1	1	180	1	<1	<5
WET	WQ17	31	508	7.0	58	20	<10	<10	<100	<10	<1	24	9	<1	<0.1	<1	<1	3,600	<1	<1	<5
DRY	WQ17	29	947	8.1	55	30	<10	40	400	70	12	43	31	2	<0.1	<1	2	330	2	<1	<5
WET	WQ18	31	302	6.4	62	<10	<10	40	200	20	<1	21	9	<1	<0.1	<1	<1	3,900	<1	<1	<5
DRY	WQ18	28	515	7.8	75	30	<10	50	400	150	6	28	15	2	<0.1	<1	<1	90	<1	<1	<5

Source: E3 Consulting 2011

Highlighted values are outside the WQOs, These are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data was collected at a number of tributaries which flow into the Bowen River via Rosella Creek between 2007 and 2011. The median conductivity, pH and total suspended solids were greater than the WQOs at all sites. The median concentration of ammonia was greater than the WQO at Wilson, Cerito, Kangaroo and Rosella Creeks and turbidity was greater than WQOs at Wilson, Kangaroo and Rosella Creeks (Table 3-21).

Table 3-21 Newlands Coal Extension EIS water quality data for sites in the Bowen River catchment

Site	Water temperature	Electrical conductivity	Turbidity	pH	Total suspended solids	Dissolved oxygen	Ammonia as N
Units	°C	µS/cm	NTU		mg/L	mg/L	µg/L
Eastern Creek upstream	31.8	1,410	9.3	8.3	53	-	-
Eastern Creek downstream	30.7	1,549	8.8	8.3	27	-	-
Wilson Creek	25.4	433	175.7	8.3	22	8.6	50
Cerito Creek	28.4	468	25.8	8.5	19	8.2	30
Kangaroo Creek	28.5	1,832	57.7	8.4	55	7.4	30
Rosella Creek	28.0	1,089	132.6	8.4	137	7.2	30

Source: Kellogg Brown and Root 2012

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected for the Hancock EIS in April 2010 (wet season) found that the conductivity and pH at Pelican Creek was greater than the WQOs (Hancock Prospecting 2010) (Table 3-22).

Table 3-22 Hancock EIS water quality data for Pelican Creek

Site	Water temperature	Electrical conductivity	Turbidity	pH	Dissolved oxygen	TDS
Units	°C	µS/cm	NTU		%	mg/L
Pelican Creek	25.0	992.8	0.78	8.1	110.8	552.7

Source: Hancock Prospecting 2010

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected in May 2013 found that conductivity at Pelican Creek and Bowen River was greater than the WQOs. Dissolved oxygen at Pelican Creek was less than WQOs and pH was greater than the WQOs (Table 3-23).

Table 3-23 Water quality data for the Bowen River catchment May 2013

Site	Flow Level	Water Temperature	Electrical Conductivity	Salinity	pH	Dissolved Oxygen		TDS	Redox
Units		°C	µS/cm	PSU		mg/L	%	mg/L	
Pelican Creek	moderate	22.3	1274	0.64	8.1	6.98	81	825.5	135.8
Bowen River	high	22.5	298.6	0.14	7.8	7.93	92	194.4	116.4

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow. If the measured values are outside more than one WQO the value is highlighted in orange.

3.6.4 Suttor River catchment

The waterways within the Suttor River catchment are defined by the QWQG (DERM 2009a) as upland streams as they are greater than 150 metres elevation above sea level.

The median (or mean if median value was not available) concentration of turbidity, nutrients (ammonia, total nitrogen and total phosphorus), sulphate, aluminium, copper, iron and zinc were greater than WQOs identified in Table 3-30 at the DEHP gauging stations for the Suttor River at Bowen Developmental Road (Site 120310A) and at Eaglefield (Site 120304A) (Table 3-24). The DO at both sites was lower than the WQOs.

Water quality data collected for the Waratah EIS for waterways within the Suttor River catchment in October 2009 (dry season) and March/April 2010 (wet season) found that the water quality was outside the WQO for most sites for a number of parameters measures (E3 Consulting 2011). The conductivity, concentration of iron, ammonia and total nitrogen was greater than the WQOs for most sites. The concentration of total phosphorus was greater than the WQO at WQ19, WQ20, WQ24, WQ25, WQ26, WQ27 and WQ28. The concentration of chromium, copper and lead at sites WQ19, WQ20, WQ27 and WQ28 was greater than the WQOs. The concentration of Chlorophyll a was greater than WQO at WQ27 and WQ28. The dissolved oxygen at all sites, except WQ22 in the wet season was less than the WQO. The pH at all sites, except WQ24 and WQ25 was outside the WQO range (Table 3-25).

Table 3-24 Gauging station data for the Suttor River catchment

	Water Temperature	Electrical Conductivity @ 25C	Turbidity	pH	Total Alkalinity as CaCO ₃	Hardness as CaCO ₃	Total Dissolved Solids	Total Suspended Solids	Dissolved Oxygen	Ammonia as N	Nitrate as NO ₃	Total Nitrogen	Total Phosphorus	Filterable Reactive Phosphorus	Fluoride	Magnesium	Sulphate	Aluminium	Boron	Copper	Iron	Manganese	Zinc
Units	°C	µs/cm	NTU	pH	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Site 120310A																							
Number of samples	21	21	21	21	19	19	19	19	21	5	19	19	19	5	19	19	19	19	19	19	19	19	19
Minimum	14	88	8	6.6	27	18	66	14	2.5	0	500	300	20	0	0.05	2	1	50	40	30	10	10	10
Median	25	201	133	7.6	65	51	131	78	6.0	-	1,000	1,000	100	-	0.09	6	5	70	80	30	100	10	20
Maximum	30	2,920	587	8.6	212	608	1470	458	10.5	40	4,500	1,900	300	30	0.2	96	36	1,800	370	40	2,000	10	100
Mean	25	486	221	7.6	80	111	282	144	6.3	20	1,400	1,000	100	10	0.1	16	9	300	100	30	300	10	40
Standard Deviation	5	780	197	0.5	52	169	398	150	2.0	20	1,200	400	100	10	0.05	27	11	500	90	0	500	0	30
Site 120304A																							
Number of samples	6	22	5	24	6	20	23	23	1	4	24	24	5	5	15	24	16	6	20	6	18	11	4
Minimum	17	30	17	6.5	7	0.1	19	67	0.7	600	8,300	2,200	5,100	30	6	4	0.4	0	0	0	0	0	0
Median	-	215	-	7.7	-	0.3	67	150	-	-	20,700	6,800	-	-	0.1	15	3	-	40	-	1,400	10	-
Maximum	31	570	295	8.2	8	1.2	205	317	0.7	1,500	44,700	23,000	11,100	160	0.3	44	13	250	100	50	4,600	30	40
Mean	24	229	90	7.6	8	0.4	77	158	0.7	1,100	22,600	8,000	8,600	70	0.1	17	4	60	50	20	1,400	10	20
Standard Deviation	6	130	116	0.5	0.4	0.3	46	55	0	400	11,000	4,900	2,600	50	0.06	11	3	100	30	20	1,400	10	20

Source: DEHP gauging station 2013

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow, human consumption of aquatic foods – pink and secondary recreation – purple.

Table 3-25 Waratah EIS water quality data for sites in the Sutor River catchment

	Site	Water Temperature	Electrical Conductivity	pH	Dissolved Oxygen	Ammonia as N	Nitrite as N	Nitrate as N	Total Nitrogen	Total Phosphorus	Chlorophyll a	Calcium	Magnesium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Nickel	Zinc
Units		°C	µS/cm	pH Unit	%	µg/L	µg/L	µg/L	µg/L	µg/L	mg/m ³	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
WET	WQ19	31	470	5.3	50	10	<10	40	<10	<10	<1	6	10	<1	<0.1	<1	<1	160	<1	2	<5
DRY	WQ19	19	440	7.4	43	270	10	20	1,000	40	<1	15	11	<1	<0.1	2	4	2,930	4	4	<5
WET	WQ20	30	210	6.8	74	20	<10	80	<10	<10	<1	7	6	<1	<0.1	3	2	8,980	3	4	8
DRY	WQ20	23	210	6.3	72	280	<10	40	1,200	100	5	18	8	<1	<0.1	<1	2	160	5	<1	<5
WET	WQ21	31	290	7.7	80	20	<10	40	300	<10	<1	4	2	<1	<0.1	<1	<1	1,950	1	<1	<5
WET	WQ22	33	150	8.1	101	10	<10	20	<100	<10	1	3	2	4	<0.1	<1	<1	<50	<1	<1	<5
WET	WQ23	30	130	7.3	63	20	<10	<10	400	<10	3	3	2	<1	<0.1	<1	<1	730	<1	<1	<5
WET	WQ24	30	270	7.5	63	60	<10	<10	30	130	<1	4	4	<1	<0.1	<1	<1	590	<1	<1	<5
WET	WQ25	24	190	6.8	50	30	<10	30	<10	100	<1	30	17	1	<0.1	1	<1	170	<1	<1	<5
DRY	WQ25	20	490	6.8	49	20	<10	20	1,000	80	<1	19	13	2	<0.1	<1	4	470	4	<1	<5
WET	WQ26	23	120	6.4	50	<10	<10	20	800	50	4	16	7	1	<0.1	<1	2	1,890	<1	2	<5
WET	WQ27	22	90	6.3	63	50	10	<10	600	<10	6	6	3	2	<0.1	6	5	5,020	8	3	8
DRY	WQ27	30	120	6.6	80	60	<10	100	1,100	150	48	9	4	2	<0.1	40	14	1,940	22	3	<5
WET	WQ28	23	200	6.3	53	30	<10	<10	400	<10	1	10	5	<1	<0.1	3	3	1,780	5	<1	<5
DRY	WQ28	27	400	7.9	79	60	<10	100	1,100	150	48	9	4	2	<0.1	40	14	1,940	22	3	20

Source: E3 Consulting 2011

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow, human consumption of aquatic foods – pink and secondary recreation – purple. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected for the Hancock EIS in April 2010 (wet season) found that the turbidity at all sites and conductivity at the Suttor River was greater than the WQOs and dissolved oxygen at Suttor River and Eaglefield Creek was less than the WQOs (Hancock Prospecting 2010) (Table 3-26).

Table 3-26 Hancock EIS water quality data for sites in the Suttor River catchment

Site	Water temperature	Electrical conductivity	Turbidity	pH	Dissolved oxygen	TDS
Units	°C	µS/cm	NTU		%	mg/L
Suttor River	25.0	286.0	160.3	6.9	87.8	138.8
Eaglefield Creek	23.3	153.8	154.8	6.3	55.0	78.9
Myra Creek	24.4	147.4	27.9	7.0	91.6	82.6

Source: Hancock Prospecting 2010.

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow, human consumption of aquatic foods – pink and secondary recreation – purple. If the measured values are outside more than one WQO the value is highlighted in orange.

Water quality data collected in May 2013 found that conductivity at all sites greater than the WQOs. Dissolved oxygen at the Suttor River (upper), Rockingham and Gunn Creeks were less than WQOs. These sites had no flow at the time of the assessment (Table 3-27).

Table 3-27 Adani water quality data for sites in the Suttor River catchment May 2013

Site	Flow level	Water temperature	Electrical conductivity	Salinity	Dissolved oxygen		pH	TDS	Redox
Units		°C	µS/cm	PSU	mg/L	%		mg/L	
Suttor River (Upper)	no flow	19.8	293.9	0.14	2.9	32	7	191.1	150
Rockingham Creek	no flow	21.6	222.8	0.11	3.0	34	6.6	145.0	90.1
Gunn Creek	no flow	20.4	171.4	0.08	2.5	29	6.8	111.2	151.8
Suttor River (Lower)	low	24	627.0	0.3	8.0	94	8.3	409.5	133.3

Highlighted values are outside the WQOs, these are coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow, human consumption of aquatic foods – pink and secondary recreation – purple. If the measured values are outside more than one WQO the value is highlighted in orange.

3.6.5 Waterway habitats

The preliminary investigation corridor is comprised of a number of different surface water resources. A desktop based assessment of these resources was undertaken to identify defining characteristics. This information was used to supplement field observations made by GHD in May 2013. Three types of water resources were identified:

- Major waterway with established riparian zone
- Minor waterway with a standing pool or contained water only during flash flow events

- Palustrine and lacustrine wetlands (see aquatic ecology assessments in Volume 2 Appendix E Nature conservation).

Sites representative of the characteristics of the three water resource types and the two river basins were identified for this assessment. Sites that were sampled during the field investigation are shown in Figure 2-3. A short description and photo of each sites is included in Table 3-28.

Table 3-28 Summary of aquatic habitats surveyed within the study area

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
1 (AQ2) Saltwater Creek	Don River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 100 percent clay/silt <i>Disturbance:</i> Road and railway crossing over creek	A deep, slow flowing creek – depth to ~ 2 m, possibly deeper in parts. Reach dominated by slow runs and deep pools. Erosion and scouring absent. Undercut banks absent. Water fairly turbid. Mangroves provide overhanging and trailing vegetation along banks of creek. Bridge may act as a barrier to dispersal for aquatic organisms as it blocks light filtering through the water column.	 Saltwater Creek, May 2013.
2 (AQ5) Six Mile Creek	Don River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 70 percent sand, 10 percent pebble, 10 percent cobble, 5 percent gravel, 5 percent bedrock <i>Disturbance:</i> Cattle present, nearby box culvert and sealed road	Surface water absent at time of assessment. Moderate erosion of banks. Riparian zone dominated by grasses and herbs in large sections of the reach. Riparian zone generally narrow. Trailing vegetation present in places. Nearby rail line and concrete box culvert crossing. Culvert may impede the dispersal of aquatic organisms.	 Six Mile Creek, May 2013.

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
3 (AQ4) Maria Creek	Don River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 70 percent sand, 20 percent pebble, 10 percent gravel <i>Disturbance:</i> Nearby culvert and highway. Cattle also present	Surface water absent at time of assessment. Some undercut banks with exposed roots along reach. Moderate erosion and scouring along reach, particularly where grasses and herbs are the dominant vegetation. Riparian zone generally dense (riparian zone is absent in some places), but narrow – land cleared either side. Trees and shrubs growing in bed. Nearby concrete box culvert may present a barrier to the dispersal of aquatic organisms.	 Maria Creek, May 2013.
4 (AQ6) Tabletop Creek	Don River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 40 percent sand, 40 percent cobble, 20 percent gravel <i>Disturbance:</i> Pigs present – pugging observed on floodplain	Low surface flow present at time of assessment. Diverse habitat with shallow and deep water, riffles, runs, pools and woody debris. Also variable substrate – sandy through to rocky. Small patches of erosion along reach. Undercut banks moderately abundant. Riparian zone dominated by pandanus and mature melaleuca. Moderate abundance of trailing vegetation. Surface water clear.	 Tabletop Creek, May 2013.

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
5 (AQ7) Splitter's Creek	Don River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 90 percent sand, 10 percent gravel <i>Disturbance:</i> Nearby sealed surface bridge and vehicle tracks in creek bed	Shallow creek with clear, flowing water. Riffles present along reach. Moderate amounts of decomposing organic matter in surface water. Leaf litter moderately abundant and some filamentous algae observed in water column and on substrate. Small undercut banks presents in parts of reach. Riparian zone generally intact, but narrow. Moderate trailing vegetation.	 <i>Splitter's Creek, May 2013.</i>
6 (AQ8) Unnamed tributary of Finley Creek	Don River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 85 percent sand, 5 percent gravel, 5 percent cobble, 5 percent boulder <i>Disturbance:</i> Nearby farm track with creek crossing, cattle present	No surface water present at time of assessment, although flood debris was prevalent along creek bed and floodplain. Moderate trailing vegetation, some undercut banks along reach. Banks stable, erosion not evident.	 <i>Finley Creek, May 2013.</i>

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
7 (AQ9) Bogie River	Lower Burdekin River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 100 percent sand <i>Disturbance:</i> Pigs and cattle present	A braided channel within a wide, sandy river bed. Small patches of filamentous algae anchored to substrate. Stands of melaleuca present in bed of reach, indicating perennial subterranean flow. Water very clear, with low flow. Banks generally stable, with limited erosion.	 Bogie River, May 2013.
8 (AQ10) Sandy Creek	Lower Burdekin River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 80 percent sand, 10 percent gravel, 5 percent pebble, 5 percent bedrock <i>Disturbance:</i> Some cattle disturbance, pump extraction of surface water	Bed very wide in parts, with isolated pools of surface water. Banks fairly stable with limited erosion. Small patches of filamentous algae observed on substrate and water column. Trailing vegetation in some sections of reach. Undercut banks in parts.	 Sandy Creek, May 2013.

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
9 (AQ14) Pelican Creek	Bowen River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 80 percent sand, 10 percent gravel, 10 percent bedrock <i>Disturbance:</i> Pigs, cattle and wild dogs present. Some disturbance caused by vehicles	Filamentous algae anchored on large section of substrate. Water very clear, mostly shallow with deeper sections alongside undercut banks. Low, sandy benches in bed. Melaleuca in bed and banks – indicative of perennial subterranean flow.	 Pelican Creek, May 2013.
10 (AQ15) Bowen River	Bowen River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 30 percent boulder, 30 percent cobble, 10 percent pebble, 10 percent gravel, 10 percent sand, 10 percent clay/silt <i>Disturbance:</i> Nearby road and rail bridges. Cattle present	Large, wide (20 metre width), fast flowing river. Small patches of erosion, but banks generally stable. Undercut banks appear absent from reach. River is crossed by a large road/rail bridge, but structure is unlikely to impede the dispersal of aquatic organisms. Surface water slightly turbid. Moderate trailing vegetation, stands of melaleuca in bed (partially submerged) and on banks of reach.	 Bowen River, May 2013.

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
11 (AQ18) Suttor River (Upper)	Suttor River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 50 per cent clay, 30 per cent gravel, 20 per cent sand <i>Disturbance:</i> None evident	Moderately open riparian zone with tall, mature trees dominant. Riparian zone intact, and provides shade for waterway. Moss present in sheltered areas. Leaf litter, small sticks and woody debris provide habitat. Undercut banks frequent along reach. Sandy gravel deposits in bed. Water slightly turbid. Surface water a series of isolated pools. Banks steeply incised – banks to 3 m. Evidence of flood debris to ~ 2 m.	 <i>Suttor River, May 2013.</i>
12 (AQ19) Lily Creek	<i>Burdekin River Basin</i> <i>Suttor River catchment</i>	<i>Habitat type:</i> Riverine <i>Substrate:</i> 90 per cent sand, 10 per cent silt <i>Snags and woody debris:</i> Some snags and woody debris <i>Aquatic plants:</i> Moderate <i>Lomandra hystrix</i> and <i>Melaleuca</i> sp. <i>Variety of habitat:</i> Surface water absent, some woody debris <i>Disturbance:</i> Pig pugging observed on banks	A deeply incised creek with substantial erosion and scouring. Little shading and bank stability provided by riparian zone. Canopy very open. Large, mature trees sparsely distributed along banks. Grasses and weedy herbs dominant streamside cover. <i>Melaleuca</i> stands in creek bed – indicative of perennial subterranean flows. Surface water absent, but substrate damp in places. Patchy leaf litter and some woody debris may provide habitat when surface water is present. Evidence of flooding to ~ 1.2 m depth. Site may provide habitat values for fish, turtles and macroinvertebrates when surface waters are present.	 <i>Vegetated creek bed at Lily Creek, May 2013.</i>

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
13 (AQ21) Rockingham Creek	Suttor River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 55 per cent gravel, 40 per cent sand, five per cent silt <i>Disturbance:</i> Pigs and cattle present. Nearby farm track with creek crossing	Some leaf litter and moderate availability of woody debris. Bed, banks and floodplain mostly consist of sand and gravel, with residual silt. Sandy deposits frequent in bed. Lomandra common in bed and banks of creek. Riparian zone dominated by tall mature trees, with some shrubs and grassy groundcover. Creek shallow, but flowing. Average depth ~ 0.1 m. Surface water slightly turbid. Undercut banks also present along parts of the creek.	 Rockingham Creek, May 2013.
14 (AQ28) Gunn Creek	Suttor River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 30 per cent clay, 30 per cent sand, 20 per cent gravel, 10 per cent cobble, 10 per cent bedrock <i>Disturbance:</i> Cattle present, nearby farm track with creek crossing	Deep, standing water at time of survey. Water turbid, with some algae on margins of waterway. Undercut banks along most of the reach. Riparian zone open – consisting mostly of grasses and single trees. Little woody debris, but some overhanging and trailing vegetation Evidence of flooding to ~ 1.5 metre above bank. Erosion and scouring in parts. Waterway is crossed by a concrete causeway which may inhibit the dispersal of aquatic organisms.	 Gunn Creek, May 2013.

Site code and name	Catchment/Basin	Habitat assessment summary	General description and habitat characteristics	Representative photograph
15 (AQ31) Suttor River (Lower)	Suttor River	<i>Habitat type:</i> Riverine <i>Substrate:</i> 80 per cent clay, 20 per cent sand <i>Disturbance:</i> Vehicle tracks, minimal cattle impact, evidence of pigs	A riverine habitat with flowing surface waters. Tall, mature riparian trees. Abundant sedges and grasses on banks. Erosion is prevalent in reach – banks are extensively undercut, with mature trees being lost to bank erosion. Surface water moderately turbid. Tributary converges with Suttor River at this point.	 <i>Suttor River, May 2013.</i>

Note: AQ site numbers refer to the aquatic ecology assessment sites in Volume 2, Appendix F nature conservation)

3.6.6 Aquatic ecosystem

Detailed information on the aquatic ecosystem values at each site is provided in Nature Conservation Technical Report (Volume 2, Appendix F), including a description of the physical environment, aquatic habitat, flora and fauna at the site, existing pressures and representative photographs taken with a 100 metre radius of the sampling location (as indicated by GPS).

Aquatic habitats within the preliminary investigation corridor include riverine (drainage lines, creeks and rivers), palustrine (vegetated wetlands), lacustrine (farm dams and billabongs) and estuarine environments. Although a number of these aquatic waterways were ephemeral (and contained no surface water at the time of the assessment), they do provide habitat value for a number of aquatic species that are likely to occur in the landscape. Habitats with perennial surface waters are likely to support the most diverse and abundant aquatic communities; however, ephemerally available aquatic habitats provide periodically available habitat, and act as pathways for dispersal when hydrological connectivity is established. High value perennial aquatic habitats were identified at a number of locations:

- Saltwater Creek
- Caley Valley Wetland
- Splitter's Creek
- Bowen River
- Bogie River
- Oakey Creek
- Strathmore Creek
- Pelican Creek
- Suttor River.

Disturbance across aquatic habitats in the preliminary investigation corridor is mainly due to the direct and indirect impacts of land use (cattle grazing), exotic fauna (mostly pigs) and existing infrastructure (particularly roads and waterbody crossings).

The Burdekin Basin is known habitat for five freshwater turtle species and one crocodile species. Of these aquatic reptiles, only Krefft's river turtle (*Emydura macquarii krefftii*) was observed in the nature conservation study area. None of the turtle species are listed as threatened under the NC Act or EPBC Act; however, the estuarine crocodile (*Crocodylus porosus*) is listed as 'migratory' and 'marine' under the EPBC Act, and 'vulnerable' under the NC Act. Potential habitat for this species does occur throughout the preliminary investigation corridor, and it is considered that the estuarine crocodile may occur.

A total of 55 fish species are expected to occur within the Burdekin Basin, based on known presence and distributions. The fish community within the nature conservation study area is likely to consist of a diverse range of species, given the broad range (i.e. lacustrine, palustrine, riverine and estuarine) of habitats.

A single aquatic mammal, the platypus (*Ornithorhynchus anatinus*), has the potential to occur within the preliminary investigation corridor. This species is listed as 'special least concern' under the NC Act. Suitable habitat for the platypus was noted, and so it is considered that this species may occur within the preliminary investigation corridor.

Two species of aquatic macroinvertebrates (the freshwater crab (*Austrothelphusa transversa*) and the freshwater mussel (*Alathyria* sp.)) were observed within the preliminary investigation corridor and wider study area. It is likely the waterways of the preliminary investigation corridor provide habitat for a number of additional species. None of the aquatic macroinvertebrates that are known to occur within the preliminary investigation corridor are listed as being of conservation significance.

3.6.7 Environmental values

The QWQG (DERM 2009a) provide a suite of environmental values (EVs) that may be applicable to an area of interest. These EVs capture both aquatic ecosystem values and human use values. An assessment of information available relating to the preliminary investigation corridor, including information collated during the field investigation, has been used to determine which EVs are applicable to the preliminary investigation corridor (Table 3-29).

Table 3-29 Environmental values applicable to the preliminary investigation corridor

Environmental value	QWQG definition (DERM 2009a)	Relevance
Aquatic Ecosystems Level 1: High ecological / conservation value (HEV) ecosystem 	Effectively unmodified or other highly valued systems, typically occurring in national parks, conservations reserves or in remote and/inaccessible locations. The ecological integrity of HEV systems is regarded as intact.	✖ The catchments of the preliminary investigation corridor are considered to be SMD (see below)
Aquatic Ecosystems Level 2: Slightly-moderately disturbed (SMD) ecosystem 	Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. 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. SMD systems could include rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism.	✓ The catchments of the preliminary investigation corridor are considered to be SMD as the water resources receive runoff from land disturbed by grazing, watercourses are accessed by stock for watering and dams are artificial habitat
Aquatic Ecosystems Level 3: Highly disturbed (HD) ecosystem 	These are measurably degraded ecosystems of lower ecological value. Examples of HD systems include rural streams receiving runoff from intensive horticulture.	✖ The catchments of the preliminary investigation corridor are considered to be SMD (see above)

Environmental value	QWQG definition (DERM 2009a)	Relevance
Primary Industries Irrigation 	Suitability of water supply for irrigation	✓ Some downstream crop irrigation occurs The site drains to the Burdekin Falls dam which supplies a number of irrigation areas
Primary Industries Farm Water Supply 	Suitability of domestic farm water supply, other than drinking water.	✗ Farm dams used for stock watering only. This is captured under Stock Watering below
Primary Industries Stock Watering 	Suitability of water supply for production of healthy livestock.	✓ Water resources within and downstream of the preliminary investigation corridor are used for stock watering
Primary Industries Aquaculture 	Health of aquaculture species and humans consuming aquatic foods from commercial ventures.	✗ No aquaculture occurs within or immediately downstream of the preliminary investigation corridor. The ephemeral nature of the streams makes it unlikely that aquaculture would be introduced to the area
Primary Industries Human Consumers of Aquatic Foods 	Health of humans consuming aquatic foods from natural waterways.	✓ No aquaculture or recreational fisheries within or immediately downstream of the preliminary investigation corridor. The site drains to the Burdekin Falls dam which is used for recreational fishing.
Recreation and Aesthetics Primary Recreation 	Health of humans during recreation which involves direct contact and a high probability of water being swallowed.	✗ No water-based recreation activities occur within or immediately downstream of the preliminary investigation corridor. The ephemeral nature of watercourses would generally preclude primary recreation.
Recreation and Aesthetics Secondary Recreation 	Health of humans during recreation which involves indirect contact and a low probability of water being swallowed.	✓ No water-based recreation activities occur within or immediately downstream of the preliminary investigation corridor. The ephemeral nature of watercourses would generally preclude secondary recreation. The site drains to the Burdekin Falls dam which is used for boating.

Environmental value	QWQG definition (DERM 2009a)	Relevance
Recreation and Aesthetics Visual Recreation 	Amenity of waterways for recreation which does not involve any contact with water.	✓ No water-based recreation activities occur within or immediately downstream of the preliminary investigation corridor due to lack of public access and distance from settlements. The site drains to the Burdekin Falls dam which is used for recreation.
Drinking Water 	Suitability of raw drinking water supply. This assumes minimal treatment of water is required.	✗ Farm dams used for stock watering only
Industrial Uses 	Suitability of water supply for industrial use.	✗ Farm dams used for stock watering only
Cultural and Spiritual Values 	Indigenous and non-indigenous cultural heritage.	✓ Watercourses may be of cultural or spiritual value to traditional owners.

In summary, the following EVs are considered to be relevant to the preliminary investigation corridor:

- Aquatic ecosystems – slightly to moderately disturbed
- Primary industries – irrigation
- Primary industries – stock watering
- Primary industries – human consumers of aquatic foods*
- Recreation and aesthetics - secondary recreation*
- Recreation and aesthetics - visual recreation*
- Cultural and spiritual values.

* These values are only applicable for the Suttor River catchment as the value is at or within the Burdekin Falls dam which is approximately 168 km downstream of the preliminary investigation corridor section within the Suttor River catchment.

3.6.8 Water quality objectives

The National Water Quality Management Strategy (NWQMS) provides a framework for water quality management that is based on the principle of ecologically sustainable development. The ANZECC guidelines (ANZECC and ARMCANZ 2000) are national guidelines that were developed as part of the NWQMS. These guidelines suggest that in order to protect and improve water resources a three tiered approach, comprising national, state (or territory) and regional or catchment, is required.

When determining water quality objectives, locally derived objectives can be determined using processes set out in the Queensland Water Quality Guidelines (QWQG) 2009 (DERM 2009a) if sufficient data is available. If local data is not available, regional or catchment based water quality objectives are then relied on and if no such objectives exist, or objectives are not set for a certain variable, then reference is made to the Queensland and then national water quality guidelines. Thus, locally derived water quality objectives take precedence over regional or catchment objectives which in turn take precedence over state and national water quality objectives.

The study area is located in the Burdekin Basin, defined as part of the central coast region in the QWQG (DERM 2009a). The water types within the study area, as defined by the QWQG (DERM 2009a) for Central Coast, are upland (greater than 150 metre elevation above sea level) and lowland streams (less than 150 metre elevation above sea level).

As outlined in Section 1.2, WQOs for the Burdekin Basin are yet to be scheduled in the EPP (Water). The draft Burdekin Basin WQOs are consistent with the WQOs contained in the QWQG (DERM 2009a) and the ANZECC guidelines (ANZECC and ARMCANZ 2000). The water quality objectives adopted for this assessment to protect the EVs identified in Section 3.6.7 are provided in Table 3-30. The objectives are based upon the QWQG (DERM 2009a) and the ANZECC guidelines (ANZECC and ARMCANZ 2000), and are thus consistent with the draft WQOs for the Burdekin Basin (Dight 2009). The WQOs are colour coded with aquatic ecosystems - blue, irrigation – green, stock watering – yellow, human consumption of aquatic foods – pink and secondary recreation – purple.

Table 3-30 Water quality objectives adopted for the assessment

Parameter	Units	Aquatic ecosystems #		Primary industries*			Recreation and aesthetics*
		Upland streams (> 150 m)	Lowland streams (< 150 m)	Irrigation (long-term trigger values)	Stock watering	Human consumers of aquatic foods	Secondary recreation
pH		6.5 - 7.5	6.5 - 8.0	-	6.0 – 8.5	5.5 – 9.0	5.0 - 9.0
Dissolved oxygen	% saturation	90 - 110	85 - 110	-	-	< 105	> 80
Dissolved oxygen	mg/L	7.0 – 9.5		-	-	-	-
Electrical Conductivity^	µS/cm	168 - Suttor 271 – Burdekin-Bowen 680 - Don		-	2,985	-	-
Turbidity	NTU	25	50	-	-	-	-
Total Dissolved Solids	mg/L	-	-	-	2,000	-	1,000
Total Suspended Solids	mg/L	-	10	-	-	40	-
Chlorophyll a	µg/L or mg/m ³	-	5				
Faecal coliforms	cfu/100 mL	-	-	10 (direct contact) 1,000 (indirect contact)	1,000	-	1,000
Ammonia as N	µg/L	10	20	-	-	25	10
Nitrate (as N)	µg/L	-	-	-	400,000	50,000	10,000
Nitrite (as N)	µg/L	-	-	-	30,000	100	1,000
Nitrogen (Total)	µg/L	250	500	5,000	-	-	-
Organic Nitrogen	µg/L	225	420	-	-	-	-

Parameter	Units	Aquatic ecosystems #		Primary industries*			Recreation and aesthetics*
		Upland streams (> 150 m)	Lowland streams (< 150 m)	Irrigation (long-term trigger values)	Stock watering	Human consumers of aquatic foods	Secondary recreation
Phosphorus (Total)	µg/L	30	50	50	-	100	-
Filterable Reactive Phosphorus	µg/L	15	20	-	-	-	-
Hardness as CaCO ₃	µg/L	-	-	-	1,000,000	20,000	500,000
Calcium	mg/L	-	-	-	1,000	-	-
Magnesium	mg/L	-	-	-	2,000	-	-
Fluoride	mg/L	-	-	1,000	2,000	200	-
Sulphate	mg/L	-	-	-	1,000	-	400
Aluminium	µg/L	55	-	5,000	5,000	30	200
Arsenic	µg/L	13	-	100	500	50	50
Beryllium	µg/L	-	-	100	-	-	-
Boron	µg/L	370	-	500	5,000	-	1,000
Cadmium	µg/L	0.2	-	10	10	0.2	5
Chromium (III+VI)	µg/L	1	-	100	1,000	20	50
Cobalt	µg/L	-	-	50	1,000	-	-
Copper	µg/L	1.4	-	200	400	5	1,000
Iron	µg/L	-	-	200	-	10	300
Lead	µg/L	3.4	-	2,000	100	1	50
Manganese	µg/L	1900	-	200	-	10	100

Parameter	Units	Aquatic ecosystems #		Primary industries*			Recreation and aesthetics*
		Upland streams (> 150 m)	Lowland streams (< 150 m)	Irrigation (long-term trigger values)	Stock watering	Human consumers of aquatic foods	Secondary recreation
Mercury	µg/L	0.6		2	2	1	1
Molybdenum	µg/L	-		10	150	-	-
Nickel	µg/L	11		200	1,000	100	100
Selenium	µg/L	11		20	20	10	10
Silver	µg/L	0.05		-	-	3	50
Uranium	µg/L	-		10	200	-	-
Vanadium	µg/L	-		100	-	100	-
Zinc	µg/L	8		2,000	20,000	5	5,000

from the QWQG (DERM 2009a) ^ 75th percentile for salinity zones (DERM 2009a).

* from the ANZECC guidelines (ANZECC and ARMCANZ 2000).

3.6.9 Water quality summary

The key parameters influencing water quality within these catchments are salinity, turbidity, oxygen, nutrient and inorganic and organic chemical levels. Land use is considered to be the main influence on these parameters at a local scale and the presence of cattle in waterholes and riparian vegetation is known to be particularly degrading to water quality (CSIRO 2002). Disturbance to the banks and surrounds of waterways by cattle and pigs in the preliminary investigation corridor was common and widespread. Land clearing and erosion are also considered influences on the water quality within the preliminary investigation corridor.

The water quality parameters analysed displayed both spatial and temporal variations. Temporal patterns at the sites were attributed to seasonal variability associated with the influx of overland flows and subsequent drying of the water resources as the dry season progressed.

Electrical conductivity is an indicator used to measure the total concentration of inorganic ions (salts) in water. Freshwaters are generally defined by having a conductivity of less than 1,000 $\mu\text{S/cm}$ (ANZECC and ARMCANZ 2000). The QWQG defined the 75th percentile for salinity zones, Don River and Suttor, Burdekin-Bowen catchments, as 680 and 168, 271 $\mu\text{S/cm}$ respectively. The conductivity of a water body can be affected by a number of factors including concentrations of salts in catchment soils and groundwater, land use, climate and flow regime.

The conductivity was greater than the WQO for the protection of aquatic ecosystems at sites within each catchment. The conductivity at sites in the Suttor River catchment were less than 1,000 $\mu\text{S/cm}$, however, some sites in the other three catchments were greater than 1,000 $\mu\text{S/cm}$. Salinity has been identified as one of the main water quality issues within the Burdekin Basin and conditions are expected to worsen in the future as a result of vegetation clearing and its effects on the hydrological balance of the region. Vegetation clearing is suspected as the cause of dryland salinity in this area however there is little data available to confirm the extent and severity of this risk (CSIRO 2002).

The high conductivity in the waterways sampled in the Don River Basin may be due to the influences of tidal intrusion. The sites sampled in the Don River Basin flow directly into Abbot Bay.

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, with high turbidity often corresponding to catchment runoff events. Sources of suspended sediment can include point sources (such as stormwater drains), 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.

The turbidity and total suspended solids in the Bowen River and Suttor catchments were found to be up to four times the WQO for the protection of aquatic ecosystems at a number of sites. The land use and presence of cattle and pig disturbance may contribute to the high turbidity at these sites. Areas that have been particularly affected by the loss of riparian vegetation (e.g. Pelican Creek, Bowen River and Burdekin River) can have suspended sediment concentrations as high as 3000 – 6000 mg/L (Bainbridge *et al.* 2006a and b).

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. A number of sites in the Bowen River and Suttor catchments had a pH outside the WQOs pH range.

Dissolved oxygen is influenced by the balance between oxygen consuming processes, such as respiration, and oxygen releasing processes, such as photosynthesis and atmospheric input (ANZECC and ARMCANZ 2000). The amount of dissolved oxygen within a waterway can be affected by a number of environmental and biological factors including, temperature, salinity, rates of photosynthesis, rates of atmospheric input, and turbulence of the water body. The dissolved oxygen concentrations in the catchments were found to be relatively low at a number of sites on a number of occasions. These low values are likely associated with the low flow conditions experienced on a number of sampling occasions.

Nutrient pollution has the potential to impact upon a system via the stimulation of growth of nuisance plants and cyanobacteria (ANZECC and ARMCANZ 2000). A measure of chlorophyll a can provide an indication of the algal biomass in a water sample. Growth of nuisance plants and cyanobacteria can lead to changes in the biological community composition as well as affecting the water quality such as a depletion of dissolved oxygen.

The QWQG state that during periods of low flow increased organic nitrogen levels can result from a build-up of organic matter derived from natural sources. The concentrations of ammonia, total nitrogen and total phosphorus in the catchments were consistently greater than the WQO for the protection of aquatic ecosystems.

At sites in the Don River Basin and Suttor River catchment the concentration of ammonia was 10 to 30 times greater and the concentration of total nitrogen was two to eight times greater than the WQO for the protection of aquatic ecosystems. For some sites in the Lower Burdekin, Bowen and Suttor River catchments the concentration of total phosphorus is three to five times greater than the WQO for the protection of aquatic ecosystems. The high concentration of nutrients may be due runoff from the surrounding grazing land.

Despite the high concentrations of nutrients, few sites had chlorophyll a values greater than the WQO for the protection of aquatic ecosystems.

Metals were detected in the waterways of the catchments and included aluminium, arsenic, boron, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc.

At sites in the Don River Basin and Suttor River catchment the concentration of arsenic, chromium, copper, lead and zinc was greater than the WQO for the protection of aquatic ecosystems. In some instances, the concentrations of certain metals were up to 50 times greater than the WQO. The concentration of iron at sites in the four catchments was 10 to 40 times greater than the WQO for irrigation water at most sites. The metal concentrations are likely attributable to local soil characteristics and previous farming activities.

Collated information relating to the water resources of the preliminary investigation corridor identified the following EVs of relevance:

- Aquatic ecosystems – slightly to moderately disturbed
- Primary industries – irrigation
- Primary industries – stock watering
- Primary industries – human consumers of aquatic foods*
- Recreation and aesthetics – secondary recreation*
- Recreation and aesthetics – visual recreation*
- Cultural and spiritual values.

These values are only applicable for the Suttor River catchment as the value is at or within the Burdekin Falls dam which is downstream of the preliminary investigation corridor section within the Suttor River catchment.

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 identified WQOs. As outlined in Table 3-31, water quality conditions in the Don River Basin and Lower Burdekin, Bowen and Suttor catchments were outside the WQOs on a number of occasions.

As such, the identified WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the NGBR Project.

Water quality monitoring will be undertaken during construction based on an upstream/downstream comparative sampling approach (flow dependent), allowing a certain margin of difference/threshold for downstream results. The majority of waterways that intersect the preliminary investigation corridor are ephemeral and water quality varies markedly between waterways and seasons. Hence, the upstream/downstream monitoring approach (flow dependent) is considered the most appropriate.

Table 3-31 Water quality objectives

Catchment	Aquatic Ecosystems				Primary Industries												Recreation and Aesthetics			
	Upland streams	Lowland streams			Irrigation				Stock Watering				Human Consumption of Aquatic Foods				Secondary Recreation			
																				
	S	B	LB	D	S	B	LB	D	S	B	LB	D	S	B	LB	D	S	B	LB	D
Electrical conductivity					-	-	-	-					-	na	na	na	-	na	na	na
Turbidity					-	-	-	-	-	-	-	-	-	na	na	na	-	na	na	na
pH					-	-	-	-						na	na	na		na	na	na
Dissolved oxygen					-	-	-	-	-	-	-	-		na	na	na		na	na	na
Total dissolved solids	-	-	-	-	-	-	-	-					-	na	na	na		na	na	na
Total suspended solids	-		nd	nd	-	-	-	-	-	-	-	-		na	na	na	-	na	na	na
Ammonia as N					-	-	-	-	-	-	-	-		na	na	na		na	na	na
Nitrate as N	-	-	-	-	-	-	-	-						na	na	na		na	na	na
Nitrite as N	-	-	-	-	-	-	-	-						na	na	na		na	na	na
Total nitrogen									-	-	-	-	-	na	na	na	-	na	na	na
Total phosphorus									-	-	-	-		na	na	na	-	na	na	na
Filterable reactive phosphorus as P			nd	nd	-	-	-	-	-	-	-	-	-	na	na	na	-	na	na	na
Chlorophyll a	-				-	-	-	-	-	-	-	-	-	na	na	na	-	na	na	na
Calcium	-	-	-	-	-	-	-	-					-	na	na	na	-	na	na	na
Fluoride	-	-	-	-			nd	nd			nd	nd		na	na	na	-	na	na	na
Magnesium	-	-	-	-	-	-	-	-					-	na	na	na	-	na	na	na

Catchment	Aquatic Ecosystems				Primary Industries												Recreation and Aesthetics			
	Upland streams	Lowland streams			Irrigation				Stock Watering				Human Consumption of Aquatic Foods				Secondary Recreation			
	 S	B	LB	D	 S	B	LB	D	 S	B	LB	D	 S	B	LB	D	 S	B	LB	D
Sulphate	-	-	-	-	-	-	-	-			nd	nd	-	na	na	na		na	na	na
Aluminium			nd	nd			nd	nd			nd	nd		na	na	na		na	na	na
Arsenic														na	na	na		na	na	na
Boron			nd	nd			nd	nd			nd	nd	-	na	na	na		na	na	na
Cadmium														na	na	na		na	na	na
Chromium (III+VI)														na	na	na		na	na	na
Copper														na	na	na		na	na	na
Iron	-								-	-	-	-		na	na	na		na	na	na
Lead														na	na	na		na	na	na
Manganese			nd	nd			nd	nd	-	-	-	-		na	na	na		na	na	na
Nickel														na	na	na		na	na	na
Zinc														na	na	na		na	na	na

Red highlight indicates as least one value was outside of the WQO

Green highlight indicates that the values were within the WQO –no WQO available

na – not applicable to this catchment, nd – no data

S – Suttor River catchment

B – Bowen River catchment

LB – Lower Burdekin River catchment

D – Don River Basin

3.7 Water usage

Water usage within the Don River Basin and Burdekin River is dominated by urban, industrial, stock watering and domestic uses. Water resource infrastructure includes channels, pipelines, pumps, pumping stations, weirs such as the Bowen Weir and major dams like Burdekin Falls Dam. Stock water is supplied directly from the rivers in the wet season and for the rest of the year by residual natural waterholes or constructed impoundments of wet season runoff. Water usage for each of the relevant catchments and basin is provided in the sections below.

3.7.1 Don River Basin

The Don River Basin provides water for irrigation, stock watering and domestic use. Water is also supplied for urban use to towns such as Bowen and is potentially used by traditional owners for spiritual purposes.. Information on the exact allocation of water usage based on sectors was not available on public domain for the study area within the Don River Basin.

3.7.2 Lower Burdekin River catchment

The Lower Burdekin catchment provides water mostly for industrial and irrigation uses. Sugar cane is a major crop in this catchment and a significant amount of water is allocated for its irrigation and production. Irrigation in this area is also known to extract large quantities of groundwater. A small percentage of water is used for urban, farming, stock watering, spiritual and cultural purposes. Traditional owners are the Juru People (Greiner and Hall 2006).

Water use by sector for the Lower Burdekin-Haughton sub-catchment is as provided in Table 3-32 below. Water use for Lower Burdekin catchment is presented together with water use in the Haughton catchment, as described by Greiner and Hall (2006). This report is the only known publicly available report to describe environmental values relevant to this study area. The water allocation provided in Table 3-32 excludes 10,500 ML/a notional provision for riparian pumpers.

Table 3-32 Water use for the Lower Burdekin-Haughton sub-catchment

Sector	Water use (ML/a)
Urban	55,800
Industrial	5,200
Agriculture	792,530
Stock and Domestic	800
Total	854,330

(Source: Greiner, R. and Hall, N., 2006)

3.7.3 Bowen River catchment

Water use within the Bowen River catchment is mainly dominated by industrial uses. Bowen River Weir supplies mining operations at Newlands and Collinsville. It also supplies water for the Collinsville Power Station and provides town water supply for both Collinsville and Glendon. Water is also used for irrigation such as the irrigated horticulture around Birralelee, stock watering, urban, cultural and spiritual (custodial use of water by Wirri traditional owners) purposes (Greiner, R. and Hall, N., 2006).

Existing and projected water use for the Bowen-Broken sub-catchment is as provided in Table 3-33 below. The Broken River sub-catchment forms part of the Bowen River catchment.

Table 3-33 Water use for the Bowen-Broken sub-catchment

Sector	Current use (ML/a)	Maximum projected use (ML/a)
Urban	1,785	1,785
Urban/Industrial	28,770	39,270
Stock and Domestic	790	790
Total	31,345	41,845

(Source: Greiner, R. and Hall, N., 2006)

3.7.4 Suttor River catchment

The Suttor River catchment provides water for farm uses, stock watering and domestic use for the population scattered on pastoral holdings. Water is also supplied for industrial uses as well as cultural and spiritual purposes for the traditional owners (Greiner and Hall 2006).

Existing and projected water use for the Suttor River catchment is provided in Table 3-34.

Table 3-34 Water use for the Suttor River catchment

Sector	Current use (ML/a)	Maximum projected use (ML/a)
Urban	140	140
Urban/Industrial	610	1,090
Stock and Domestic	710	2,000
Total	1,460	3,230

(Source: Greiner and Hall 2006)

3.7.5 Belyando River catchment

The surface water allocation within the Belyando River catchment is provided in Table 3-35.

Table 3-35 Surface water allocation in the Belyando River catchment

Use type	Diversion volume (ML/year)	Allocation (ML/year)	Diversion: allocation (%)
Rural (including stock watering)	204	188	92.16
Irrigation (crops)	78,450	78,450	100
Total	78,638	78,654	99.97

Source: Australian Natural Resources Atlas (ANRA),

4. Key findings

4.1 Catchment hydrology, climate and flooding

The existing surface water resources within the study area include major rivers, ephemeral creeks, palustrine and lacustrine wetlands. The flow regime of the rivers and creeks crossed by the preliminary investigation corridor are subject to seasonal variability as wet season overland flow drains from the catchments. Late in the dry season the ephemeral creeks are reduced to a low or no flow environment, interspersed with pools.

The Don River, Lower Burdekin, Bowen and Suttor Basins exhibit distinct seasonal climatic conditions, with a pronounced wet summer and dry winter. Total seasonal rainfall in the region ranges from less than 100 mm in the dry season to over 1,000 mm in the wet season.

Rainfall patterns across the relatively large study area are broadly similar in terms of maximum summer and winter volumes, and annual totals. The pronounced annual variations in rainfall, including the persistence of both dry years and wet years, affects the annual discharges at the stream gauging stations, where flow patterns are observed to be similar to rainfall trends.

The lower winter rainfalls typically experienced in the region coincide with the stalling of large stable anticyclones over central Australia that cause cool dry, west to southwesterly airflow to predominate over Queensland. Rainfall in this season is associated with short southerly fronts originating in the southern oceans that affect the southern and eastern coasts of Australia.

From the stream flow data obtained, it was evident that short-duration flood events, which can occur anytime between November and May (wet season), dominate the discharge regime and long-term averages. Intervening dry periods are frequent, although their length is unpredictable. The episodic, short-lived and unpredictable nature of these wet and dry events tends to mask the summer seasonality of flows in the study area.

Based on the desktop investigation, the preliminary investigation corridor bisects a number of major and minor waterways via an undulating terrain with wide floodplains. Although most of these creeks are known to be ephemeral, some are prone to flood inundation particularly during the wet season. In addition to this, the preliminary investigation corridor bisects a number of minor catchments and flow paths of varying sizes within the Burdekin River and Don River Basins.

Detailed hydrological and hydraulic investigations have been undertaken separately for the study area and are not included in this report.

4.2 Geomorphology

Six broad waterway geomorphic types are encountered along the preliminary investigation corridor as follows:

- Confined valley systems - While not encountered at any of the field investigation sites, aerial imagery indicates confined valley systems may potentially be encountered along the preliminary investigation corridor in upper catchment positions.
- Valley fill systems - While not encountered at any of the field investigation sites, aerial imagery indicates valley fills may potentially be encountered along the rail corridor in middle to upper catchment positions.

- Channelised fill systems - While not encountered at any of the field investigation sites, aerial imagery indicates channelised fills may potentially be encountered along preliminary investigation corridor in middle to upper catchment positions.
- Bedrock controlled sand/gravel systems - Bedrock controlled systems were present at nine of the sites investigated in the field. Of these, only the Bowen River and Tabletop Creek exhibited a morphology dominated by gravel-sized sediments. Bed sediments at all other sites were dominantly composed of sand-sized sediments. Aerial imagery indicates this system is also likely to be intersected by the preliminary investigation corridor along other streamlines in middle to lower catchment positions.
- Single channel alluvial sand systems - Alluvial sand systems were encountered within the preliminary investigation corridor crossings of Rockingham Creek and the Suttor River (northern crossing). Aerial imagery indicates this system is also likely to be present where the preliminary investigation corridor crosses other waterways including the Eliot River, Verbena Creek and Strathmore Creek.
- Multi-channel alluvial systems - Of the sites investigated, the Multi-channel alluvial system was only present along the southern crossing of the Suttor River. Aerial imagery indicates this system is not likely to be present along any other waterways intersected by the preliminary investigation corridor.

Waterways along the preliminary investigation corridor are predominately set within rural or semi-rural/bushland settings and have been modified over time by land clearance and other agricultural practices. Catchment responses to land clearance include increased runoff, increased drainage density, increased erosion and sediment yields within the catchment. In response to altered hydrological regimes channel morphology changes can occur as the result of bank erosion, channel incision and floodplain scour, which are generally associated with increasing stream power and sediment transport capacity.

As a result, most waterways are considered to be in moderate to poor geomorphic condition, with many exhibiting evidence of excessive sand sedimentation as a result of past upstream disturbances.

Most of the larger catchment waterways along the preliminary investigation corridor are considered to be relatively laterally stable. This is a reflection of the landscapes and the type of waterway systems that the preliminary investigation corridor traverses. For the most part, the waterways along the preliminary investigation corridor are set within partly confined valleys which provide a high degree of bedrock control on the channel, limiting the potential for waterways to adjust and erode.

Nevertheless, some waterways displayed existing instabilities in the form of either headward erosion or bank erosion. These instabilities include:

- Bed Instability – Headward Erosion - Rockingham Creek exhibited channel forms indicative of past channel incision via headward erosion. While the assessed waterways displayed no or limited signs of headward erosion, headward erosion may still be present along sections of any channelised fill systems that may be encountered along the preliminary investigation corridor.
- Bank Instability - Bank erosion was evident along some of the waterways investigated as part of this study. In particular, the alluvial single and multi-channel systems can exhibit active outside bank erosion on bends. 'Breakaways' (gulying of channel banks) can also

develop within the banks of these alluvial systems at locations where concentrated flood flows or local run-off drains from floodplains over these banks.

4.3 Groundwater

Data along the first 110 km of the preliminary investigation corridor is relatively abundant. Beyond chainage 110 km, available data within 2 km of the preliminary investigation corridor is limited. Given the overall frequency of data along the corridor, additional location specific investigations will be required where key infrastructure is to be installed.

There may be a significant volume of domestic and stock wells present along the route that are not registered with DNRM.

Shallow groundwater of potentially potable water quality appears to be present within the coastal dune, alluvium and deltaic deposits, the intrusive deposits through the Clarke Range and within the Lizzie Creek Volcanics (3.46 – 110 km). There are a number of water use bores in this area and there may be more used for domestic and stock supplies (for the primary land use of “native grazing”) that are not registered with DNRM.

Groundwater within alluvium surrounding the following major water systems may be relied upon by groundwater dependent ecosystems (GDE).

- Coastal swamplands (especially for the generation of acid sulphate soils)
- Bogie River
- Sandy Creek
- Pelican Creek
- Bowen River
- Verbena Creek
- Suttor River.

Other areas are anticipated to have a low potential for groundwater dependence.

Coastal areas and swamplands are susceptible to saline intrusion and the exposure of potential acid sulphate soils.

The primary sensitive receptors identified in this assessment include:

- GDE with “high potential” for groundwater interaction and surface water systems located within coastal areas where there is a greater potential for exposure of acid sulphate soils. Based on an understanding of the groundwater conditions elsewhere along the route the locations of “low” to “moderate” potential for GDE’s are not considered to be significant.
- Groundwater supply wells located along the route. This may include water supply wells not registered on the DNRM database.
- Groundwater of potable quality in the vicinity of potential acid sulphate soils around the coastal area, due to the potential for interaction
- Groundwater of potable quality potentially impacted by intrusion of saline water in the coastal fringe area.
- Any shallow unconfined groundwater system along the route that has potential to be sourced for stock and domestic purposes in the future. These are largely uncharacterised

along the route, but are anticipated to primarily be associated with alluvium flanking surface water features.

4.4 Surface water quality

The key parameters influencing water quality within these catchments are salinity, turbidity, oxygen, nutrient and inorganic and organic chemical levels. Land use is considered to be the main influence on these parameters at a local scale and the presence of cattle in waterholes and riparian vegetation is known to be particularly degrading to water quality (CSIRO 2002). Disturbance to the banks and surrounds of waterways by cattle and pigs in the preliminary investigation corridor was common and widespread. Land clearing and erosion are also considered to influence water quality within the preliminary investigation corridor.

The water quality parameters analysed displayed both spatial and temporal variations. Temporal patterns at the sites were attributed to seasonal variability associated with the influx of overland flows and subsequent drying of the water resources as the dry season progressed.

Conductivity was greater than the WQO for the protection of aquatic ecosystems at sites within each catchment. Conductivity at sites in the Suttor River catchment were less than 1,000 $\mu\text{S}/\text{cm}$, however, some sites in the other three catchments were greater than 1,000 $\mu\text{S}/\text{cm}$. Vegetation clearing is suspected as the cause of dryland salinity in this area however there is little data available to confirm the extent and severity of this risk (CSIRO 2002).

The high conductivity in the waterways sampled in the Don River Basin may be due to the influences of tidal intrusion. The sites sampled in the Don River Basin flow directly into Abbot Bay.

The turbidity and total suspended solids in the Suttor and Bowen River catchments were found to be up to four times the WQO for the protection of aquatic ecosystems at a number of sites. The land use and presence of cattle and pig disturbance may contribute to the high turbidity at these sites. Areas that have been particularly affected by the loss of riparian vegetation (e.g. Pelican Creek, Bowen River and Burdekin River) can have suspended sediment concentrations as high as 3000 – 6000 mg/L (Bainbridge *et al.* 2006a and b).

A number of sites in the Suttor and Bowen River catchments had a pH outside the WQOs pH range. The dissolved oxygen concentrations in the catchments were found to be relatively low at a number of sites on a number of occasions. These low values are likely associated with the low flow conditions experienced on a number of sampling occasions.

The QWQG state that during periods of low flow increased organic nitrogen levels can result from a build-up of organic matter derived from natural sources. The concentrations of ammonia, total nitrogen and total phosphorus in the catchments were consistently greater than the WQO for the protection of aquatic ecosystems.

At sites in the Don River Basin and Suttor River catchment, the concentration of ammonia was 10 to 30 times greater and the concentration of total nitrogen was two to eight times greater than the WQO for the protection of aquatic ecosystems. For some sites in the Lower Burdekin, Bowen and Suttor River catchments the concentration of total phosphorus is three to five times greater than the WQO for the protection of aquatic ecosystems. The high concentration of nutrients may be due runoff from the surrounding grazing land.

Metals were detected in the waterways of the catchments and included aluminium, arsenic, boron, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc. At sites in the Don River Basin and Suttor River catchment, the concentration of arsenic, chromium, copper, lead and zinc was greater than the WQO for the protection of aquatic ecosystems. In some instances, the

concentrations of certain metals were up to 50 times greater than the WQO. The concentration of iron at sites in the four catchments was 10 to 40 times greater than the WQO for irrigation water at most sites. The metal concentrations are likely attributable to local soil characteristics and previous farming activities.

4.5 Environmental values and water quality objectives

Collated information relating to the water resources of the preliminary investigation corridor identified the following EVs of relevance:

- Aquatic ecosystems – slightly to moderately disturbed
- Primary industries – irrigation
- Primary industries – stock watering
- Primary industries – human consumers of aquatic foods*
- Recreation and aesthetics - secondary recreation*
- Recreation and aesthetics - visual recreation*
- Cultural and spiritual values.

* These values are only applicable for the Suttor River catchment as the value is at or within the Burdekin Falls dam which is over 20 km downstream of the preliminary investigation corridor section within the Suttor River catchment.

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 identified WQOs. As outlined in Table 3-31, water quality conditions in the Suttor, Bowen and Lower Burdekin catchments as well as the Don River Basin were outside the WQOs on a number of occasions.

As such, the identified WQOs are not considered to be appropriate for the management of surface water quality during construction and operation of the NGBR Project. Water quality monitoring will be undertaken during construction based on an upstream/downstream comparative sampling approach (flow dependent), allowing a certain margin of difference/threshold for downstream results. The majority of waterways that intersect the preliminary investigation corridor are ephemeral and water quality varies markedly between waterways and seasons. Hence, the upstream/downstream monitoring approach (flow dependent) is considered the most appropriate.

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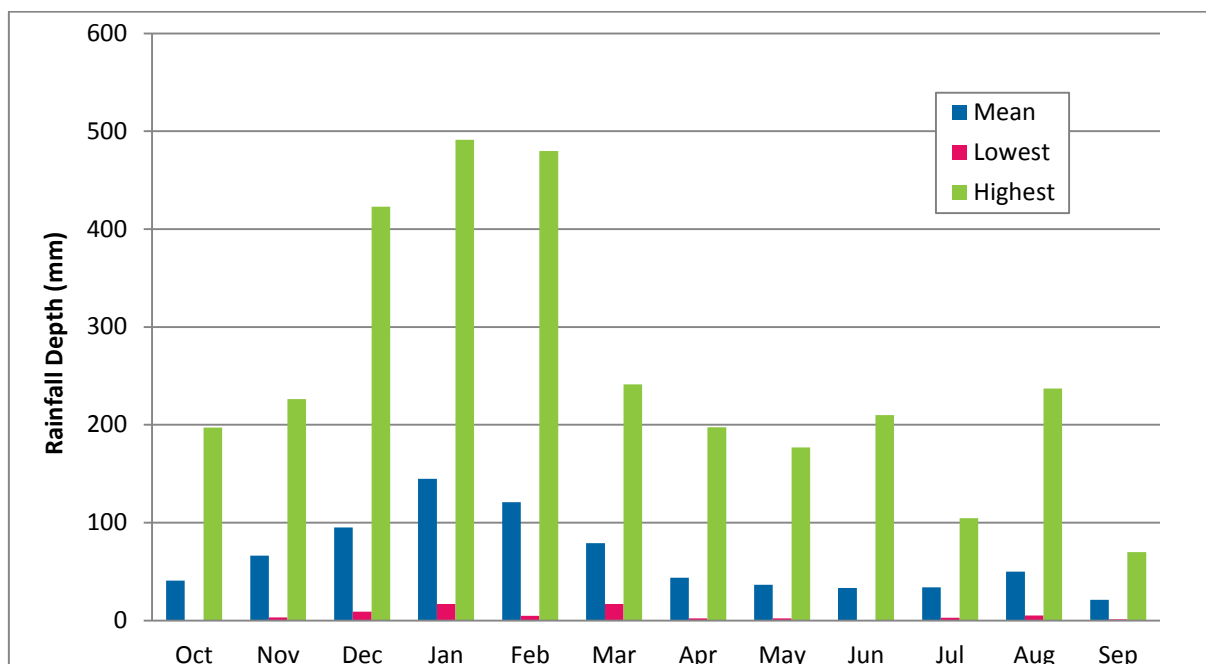
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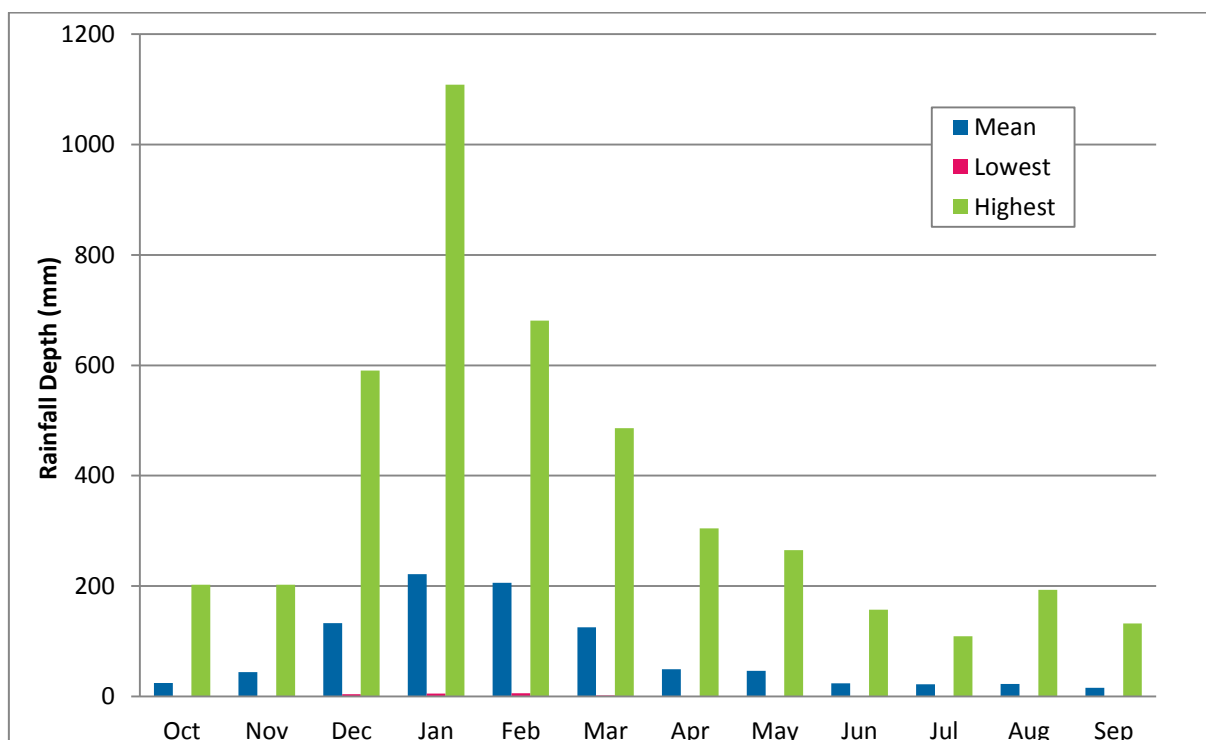
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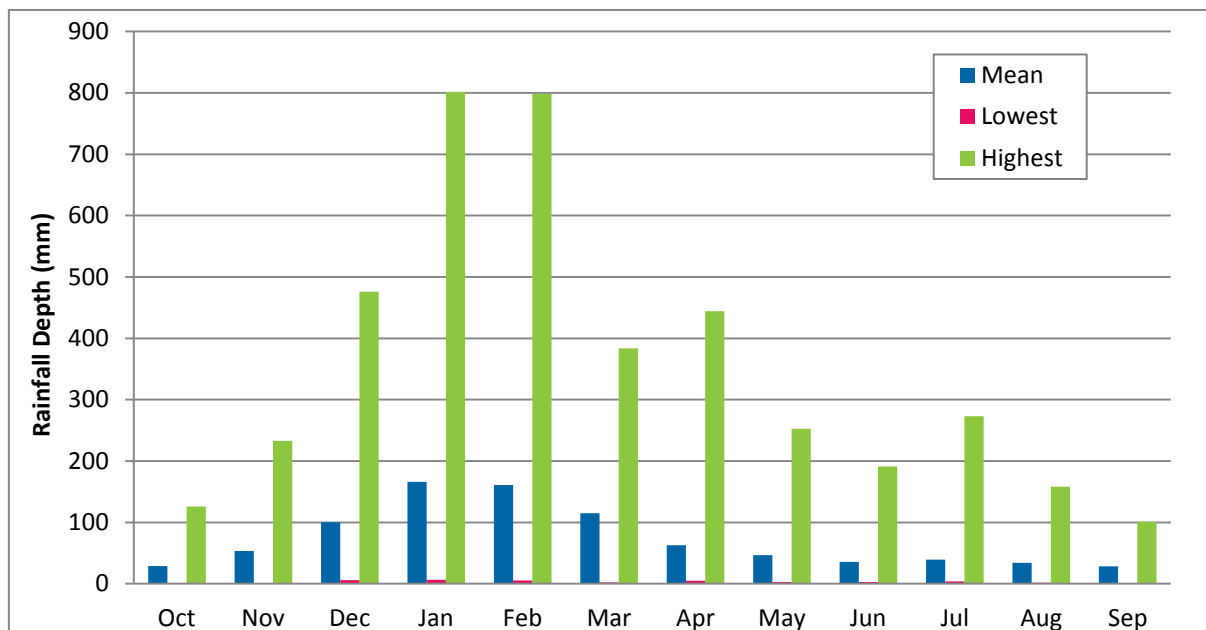
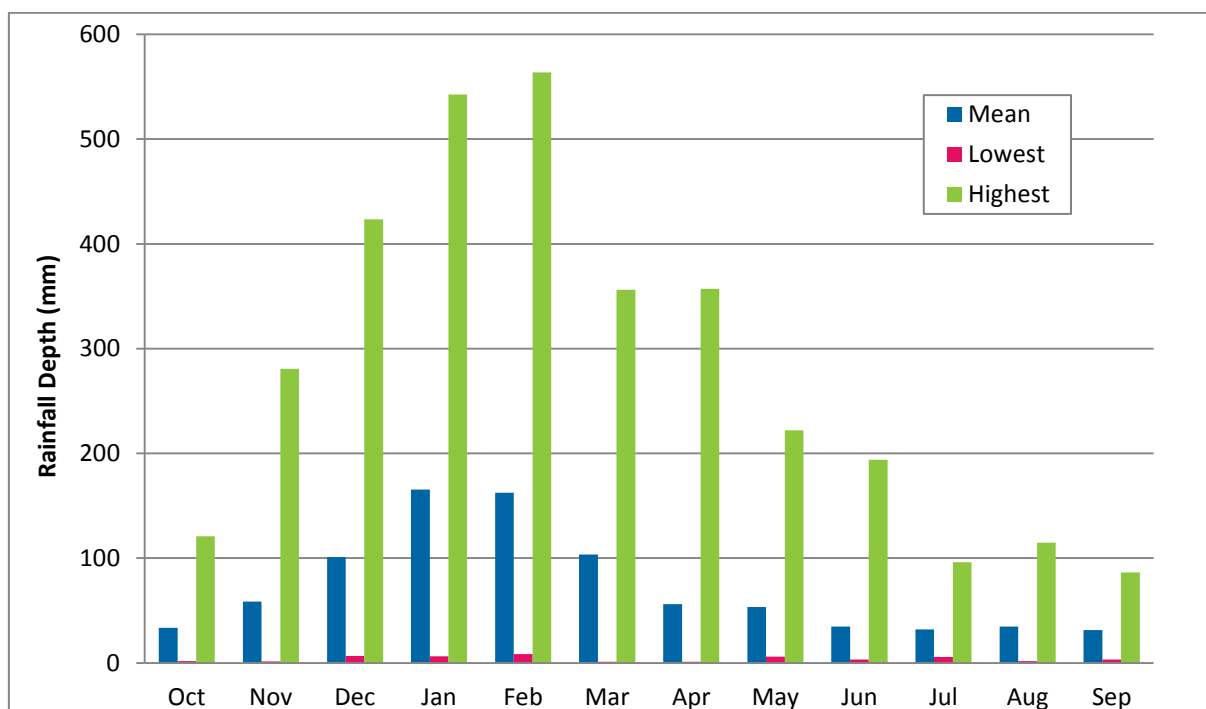
Appendix A – Assessment of rainfall data

Appendix A 1 Monthly rainfall depths – Gatton Vale (33176)

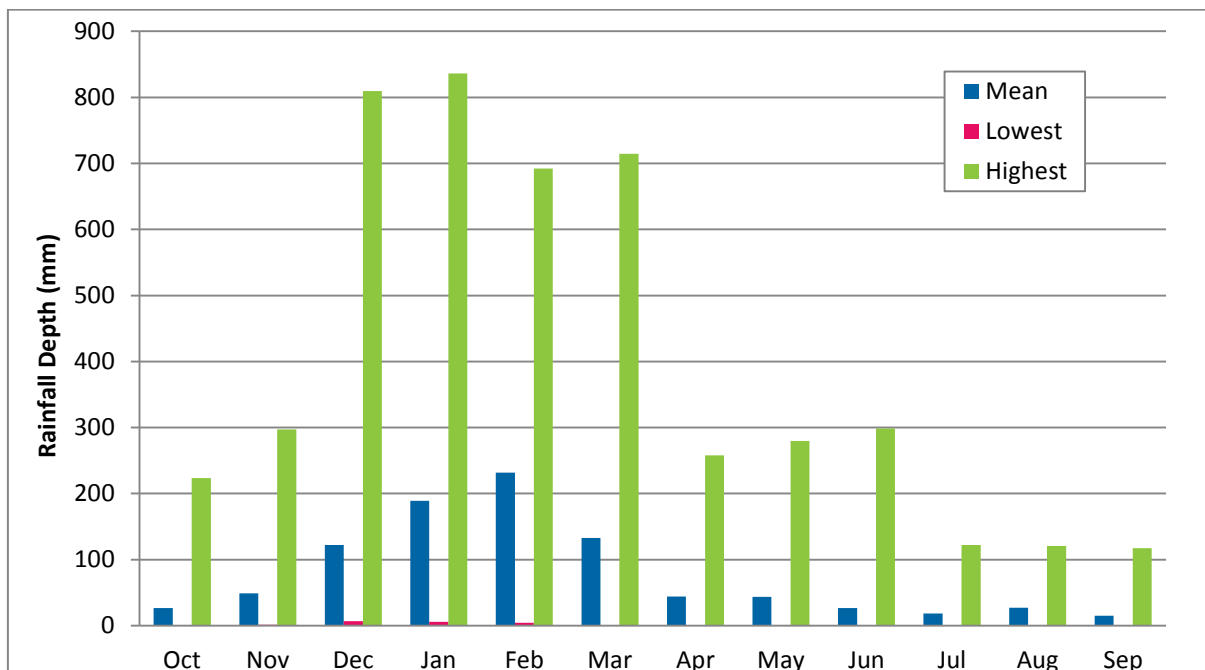


Appendix A 2 Monthly rainfall depths – Wattlevale Station (33150)

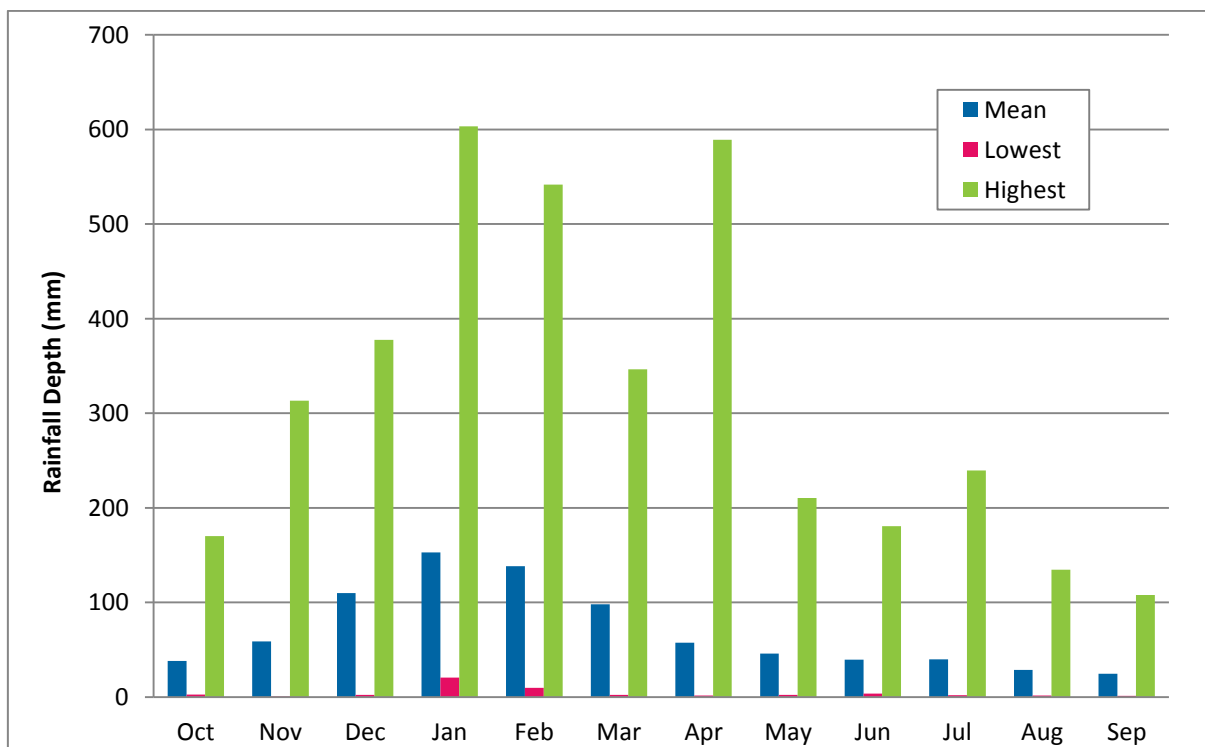


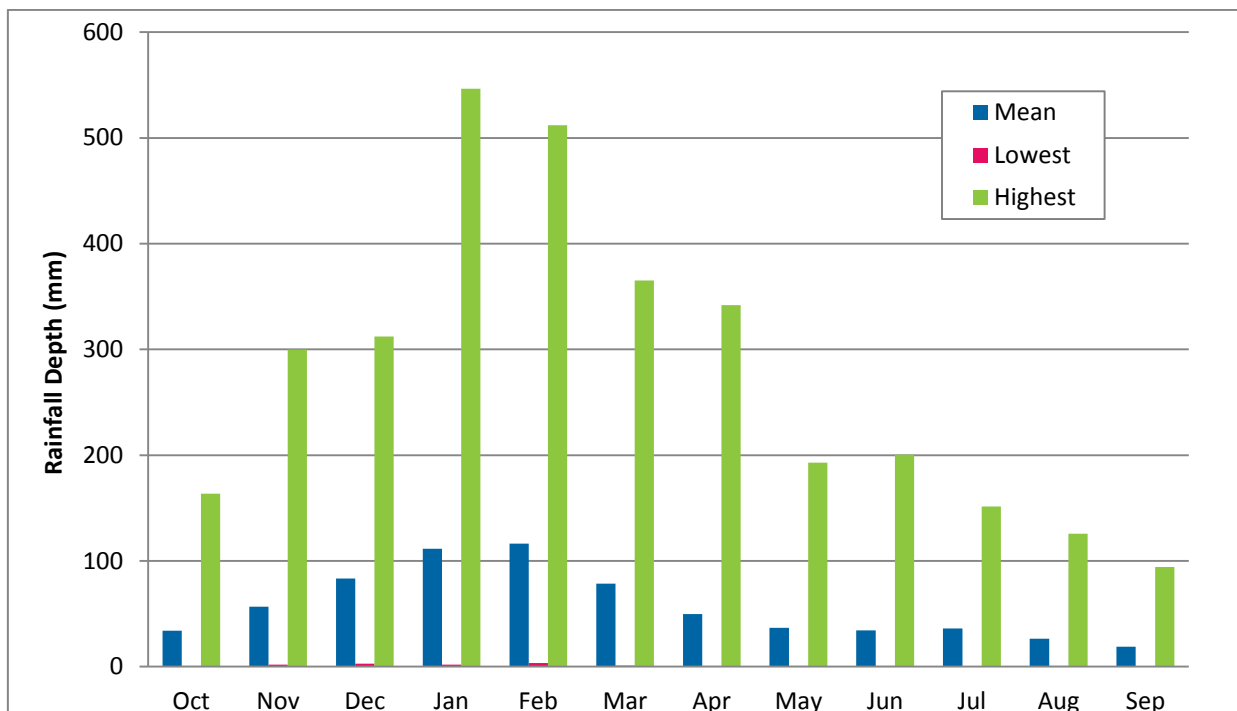
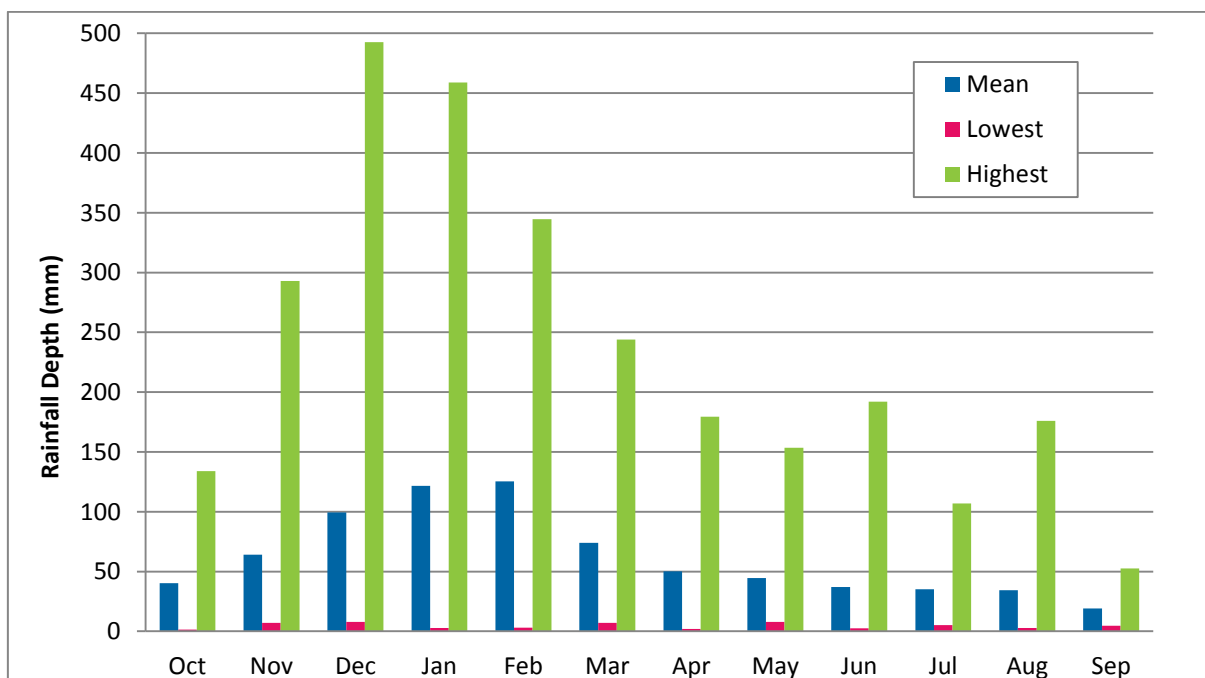
Appendix A 3 Monthly rainfall depths – Strathbogie (33070)**Appendix A 4 Monthly rainfall depths – Eton Vale (33175)**

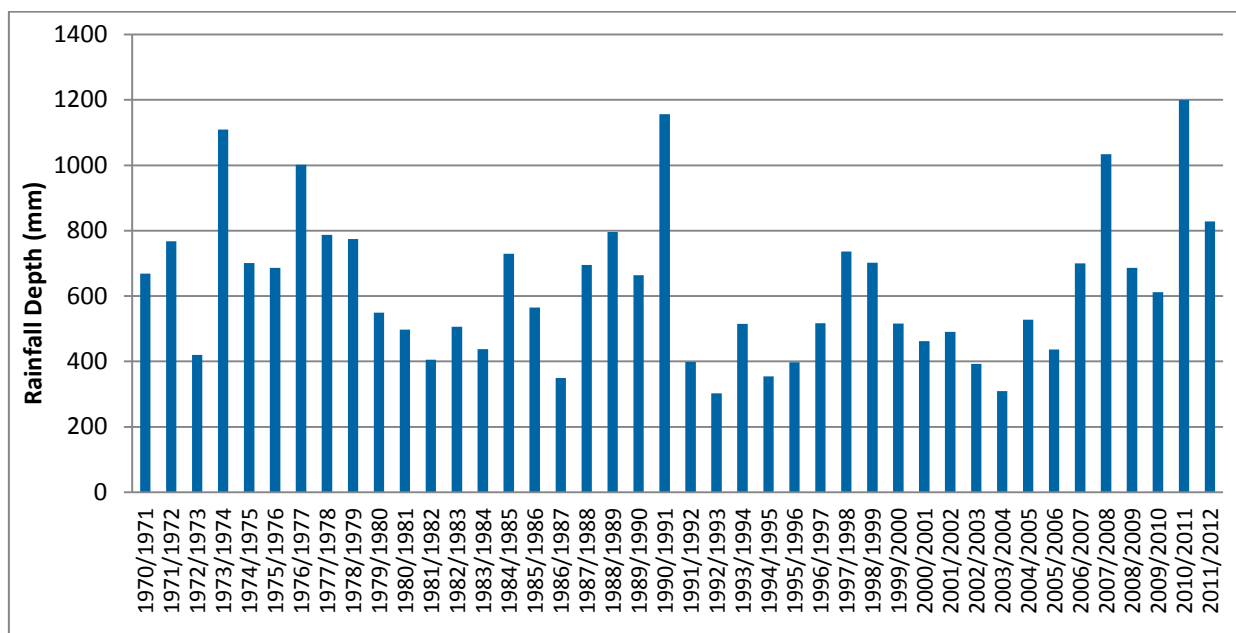
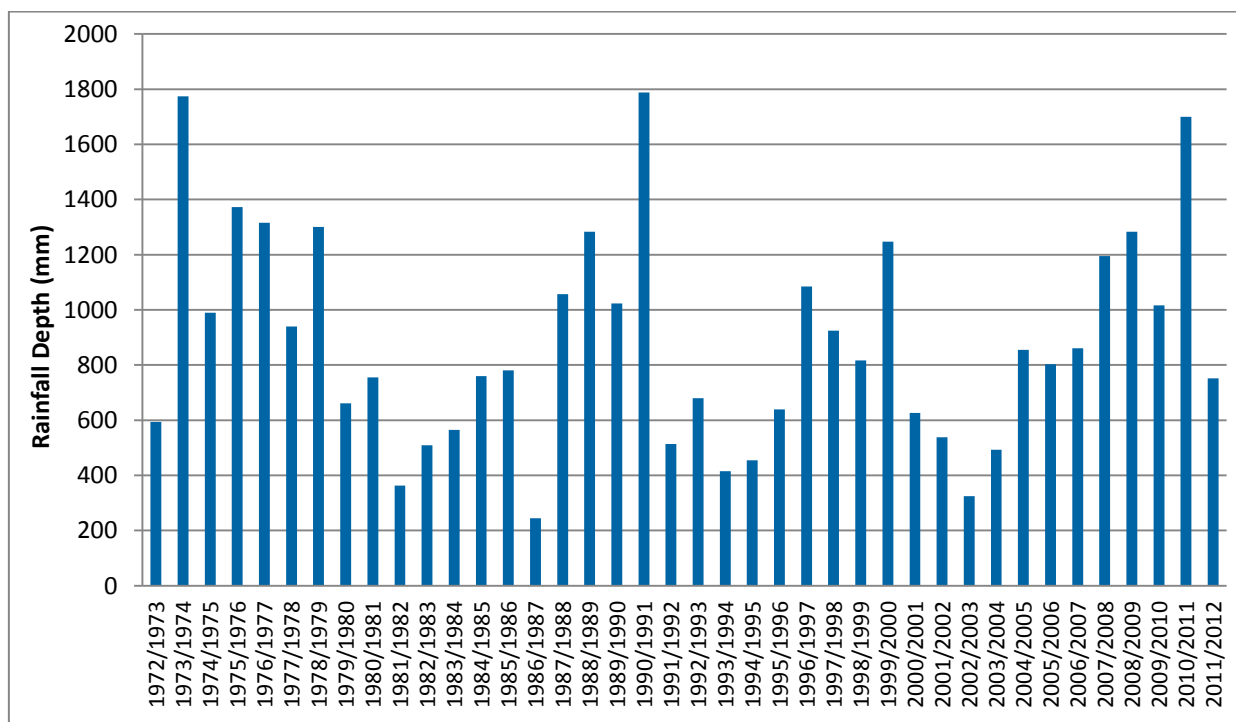
Appendix A 5 Monthly rainfall depths – Bowen Cheetham Salt (33094)



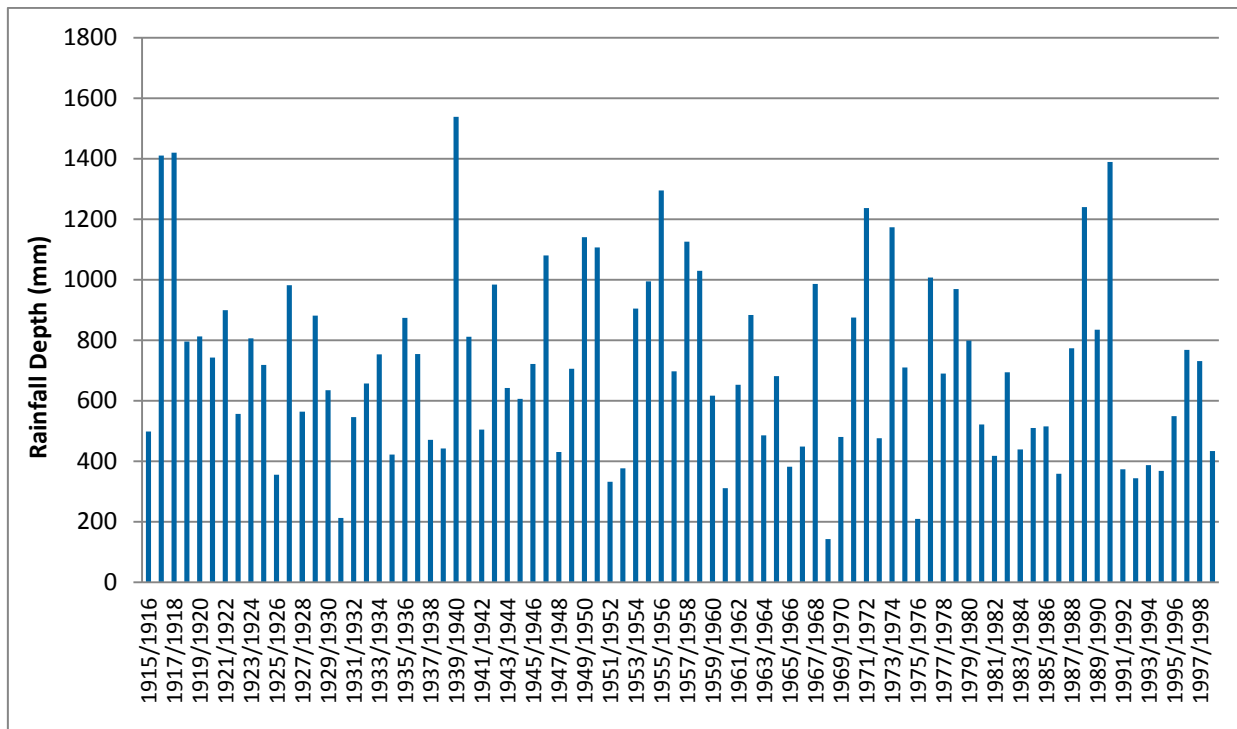
Appendix A 6 Monthly rainfall depths – Strathmore (33082)



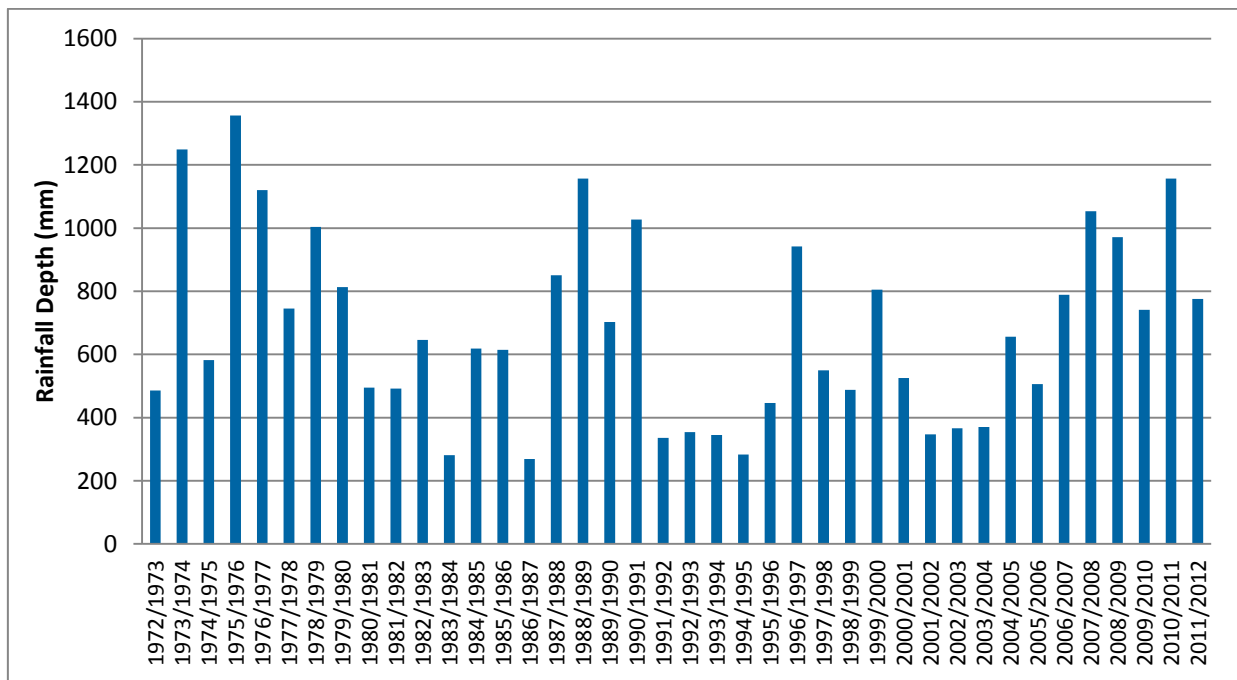
Appendix A 7 Monthly rainfall depths – Mt Douglas (34022)**Appendix A 8 Monthly rainfall depths – Wollombi Station (34020)**

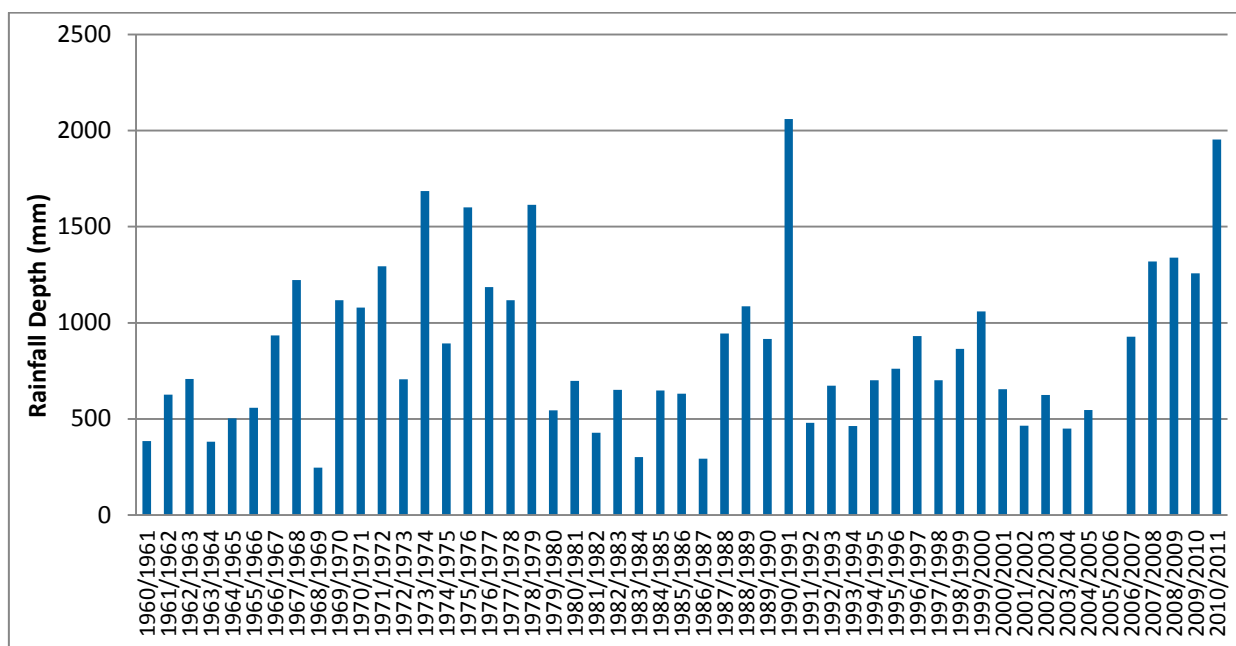
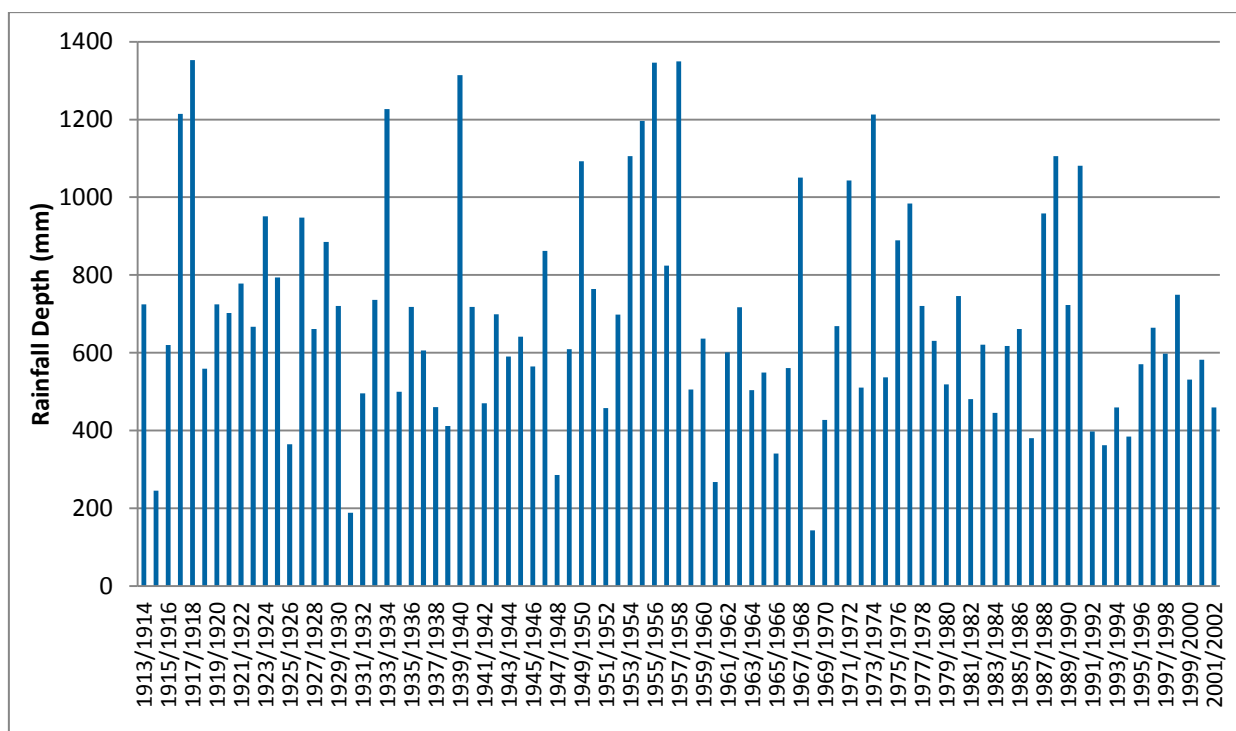
Appendix A 9 Annual rainfall depths – Gatton Vale (33176)**Appendix A 10 Annual rainfall depths – Wattlevale Station (33150)**

Appendix A 11 Annual rainfall depths – Strathbogie (33070)

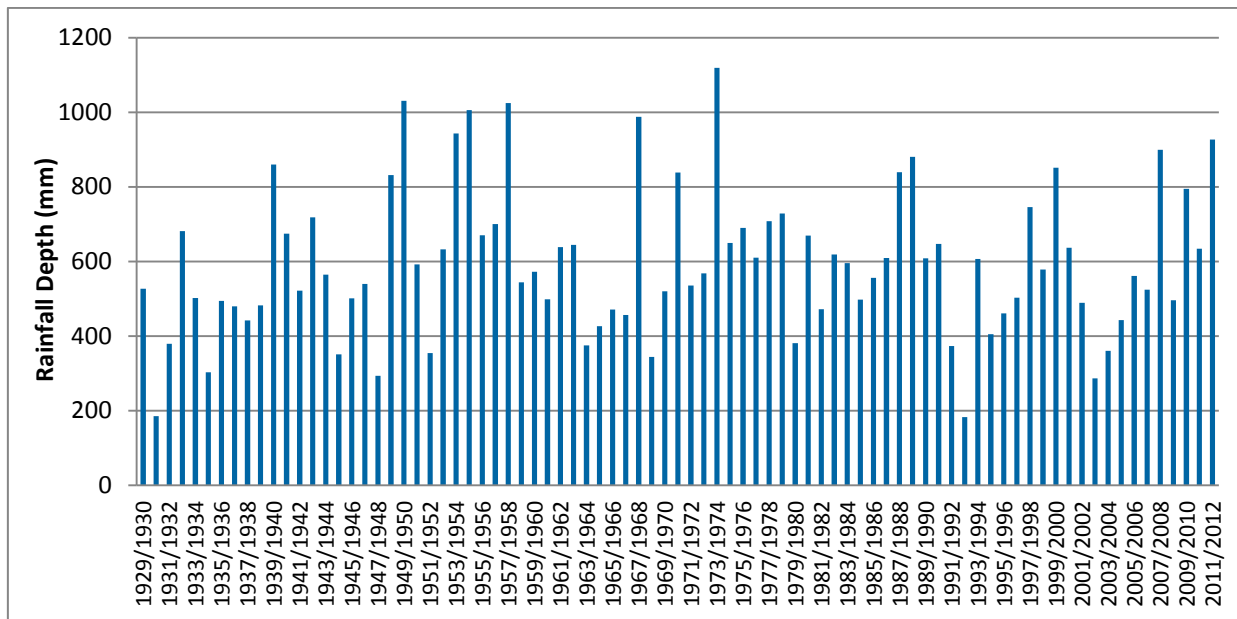


Appendix A 12 Annual rainfall depths – Eton Vale (33175)

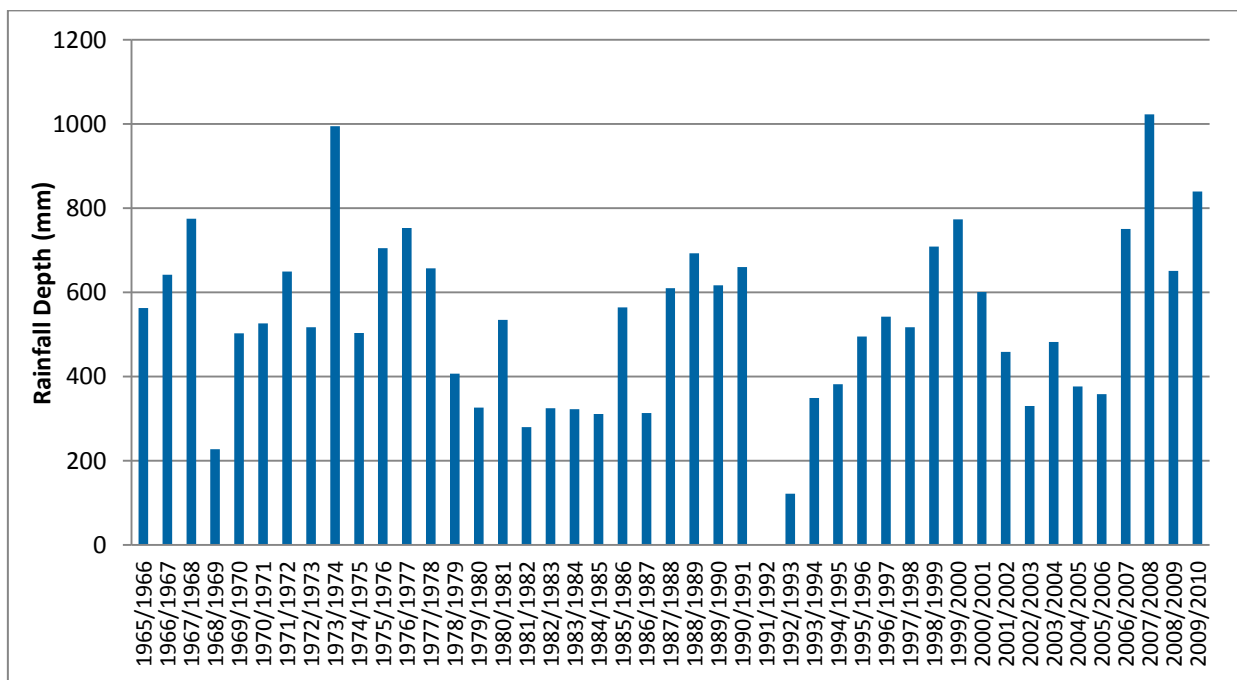


Appendix A 13 Annual rainfall depths – Bowen Cheetham Salt (33094)**Appendix A 14 Annual rainfall depths – Strathmore (33082)**

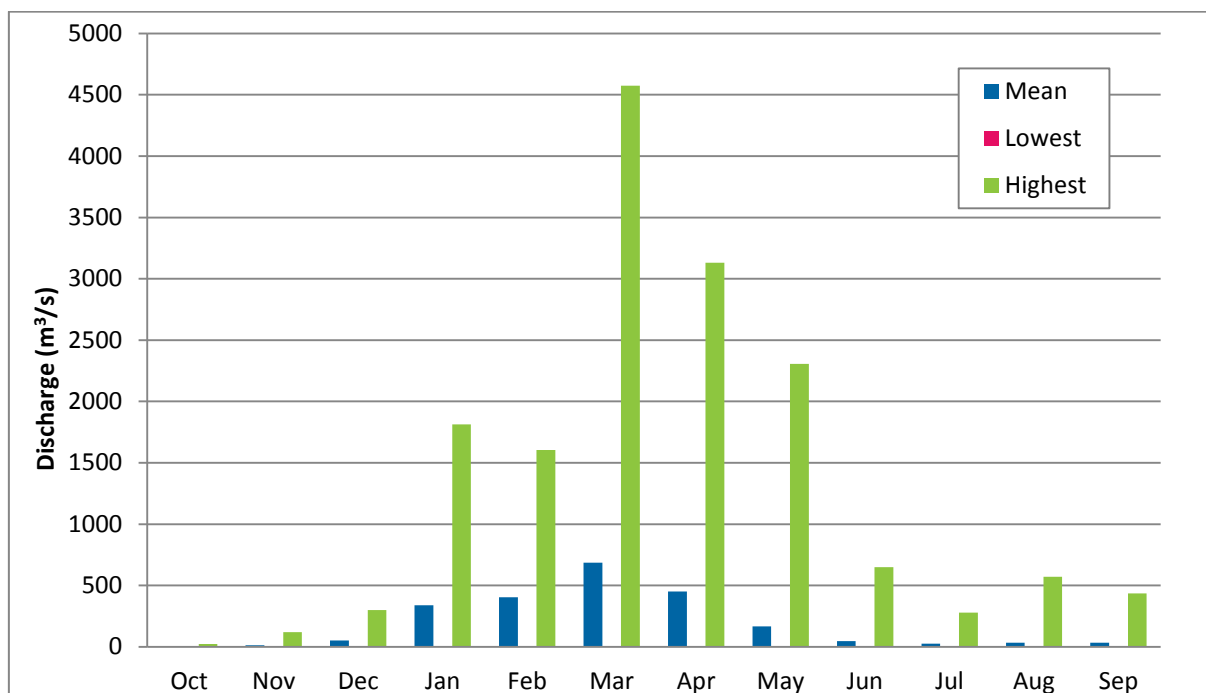
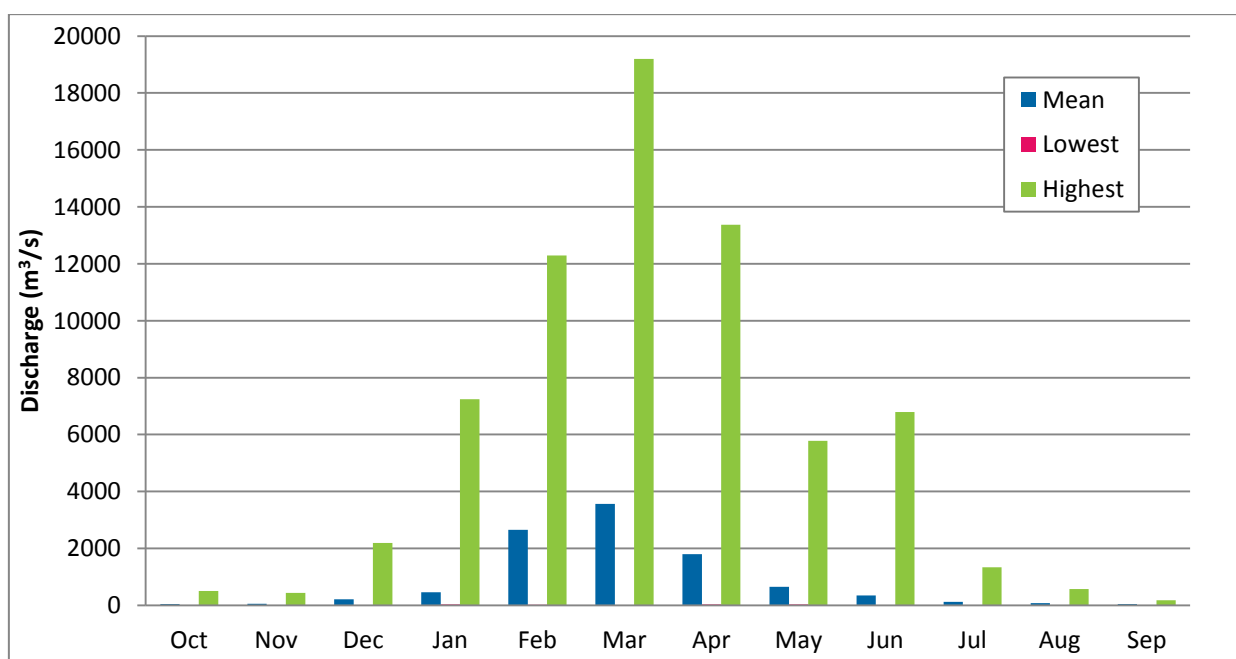
Appendix A 15 Annual rainfall depths – Mt Douglas (34022)

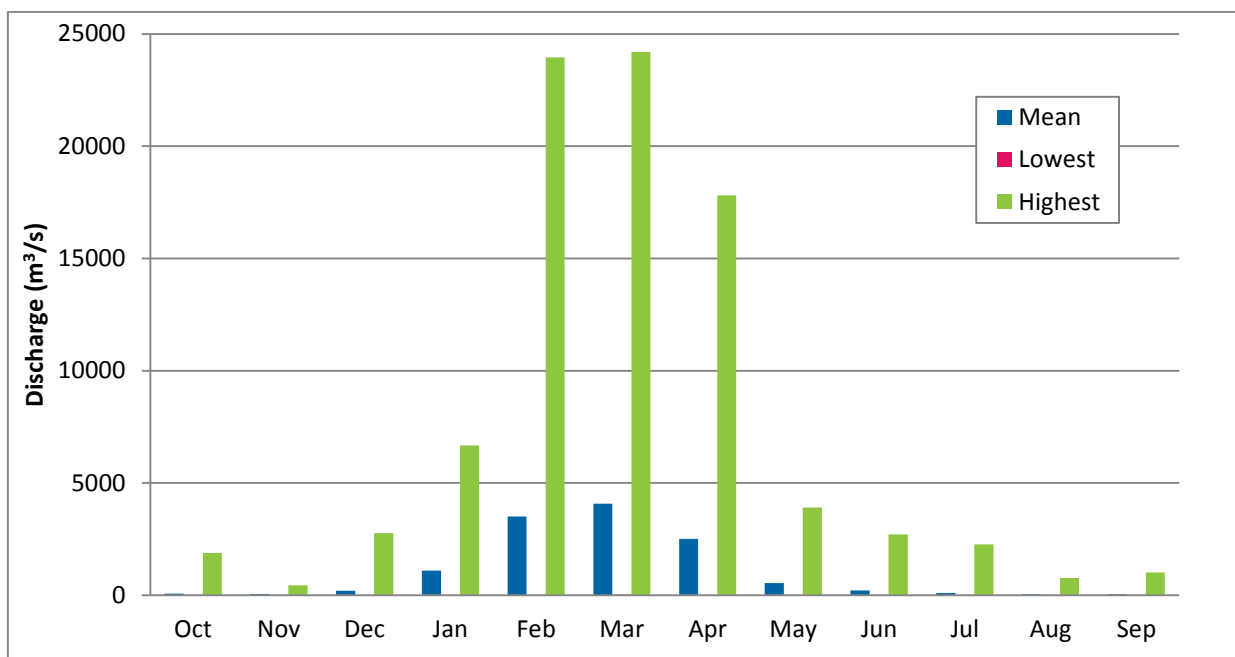
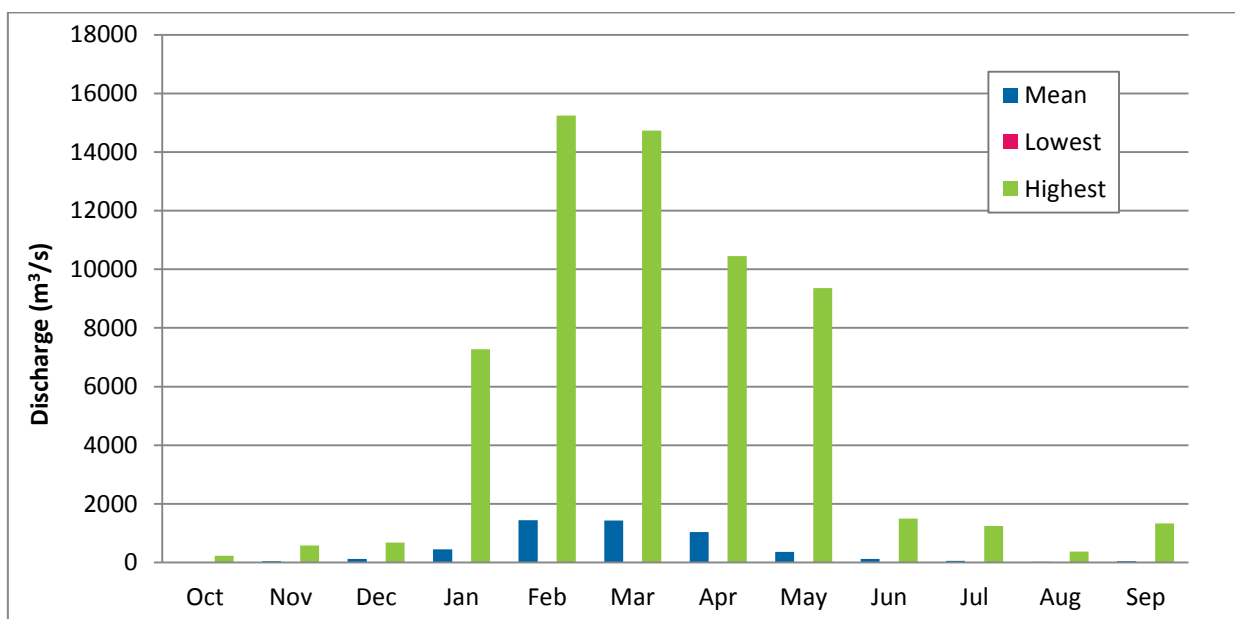


Appendix A 16 Annual rainfall depths – Wollombi Station (34020)

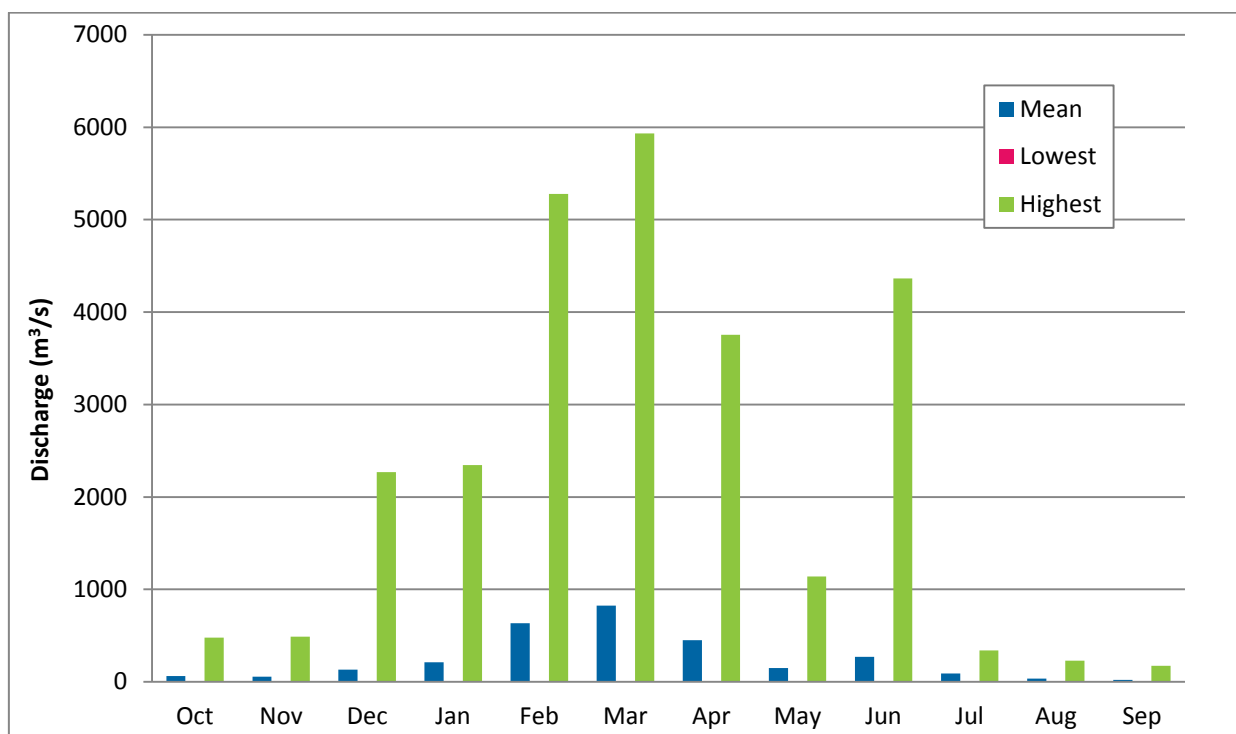


Appendix B – Assessment of stream gauging data

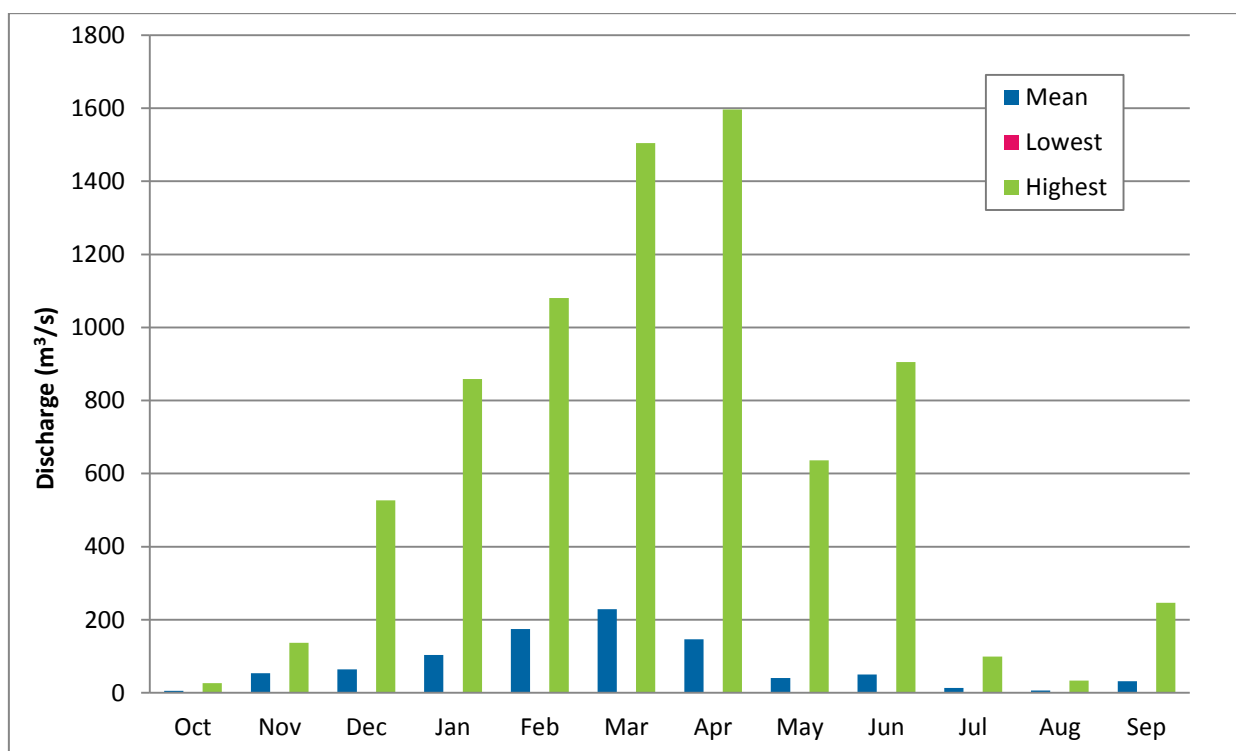
Appendix B 1 Monthly flows in Don River at Reeves (121003A)**Appendix B 2 Monthly flows in Burdekin River at Hydro Site (120015A)**

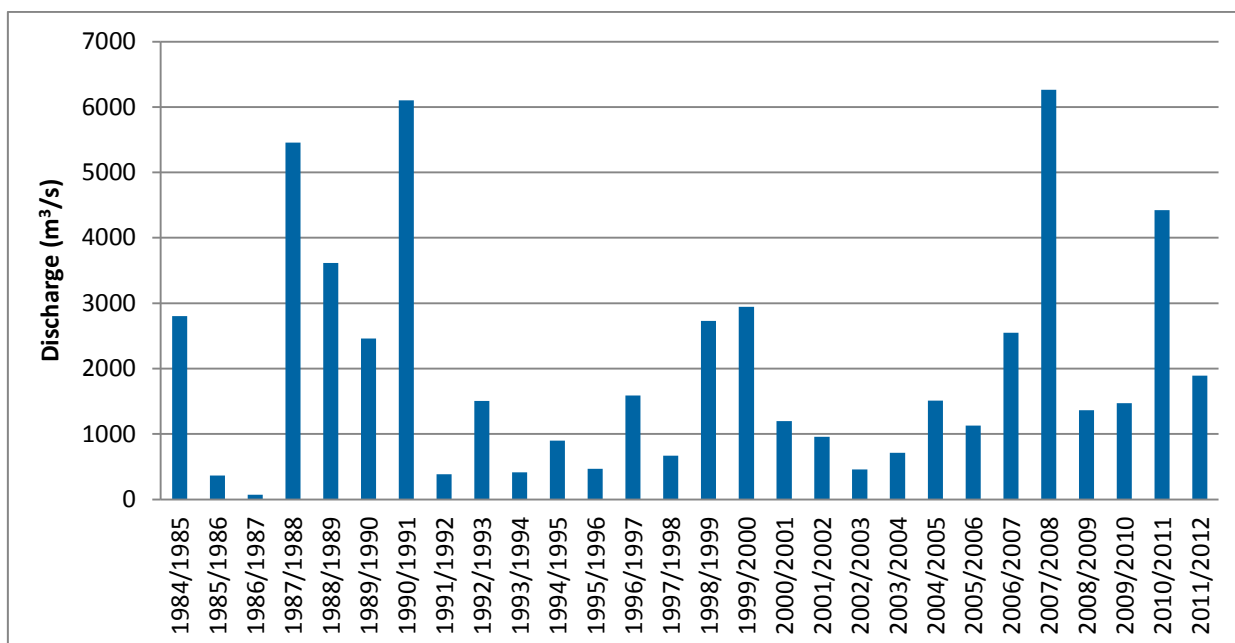
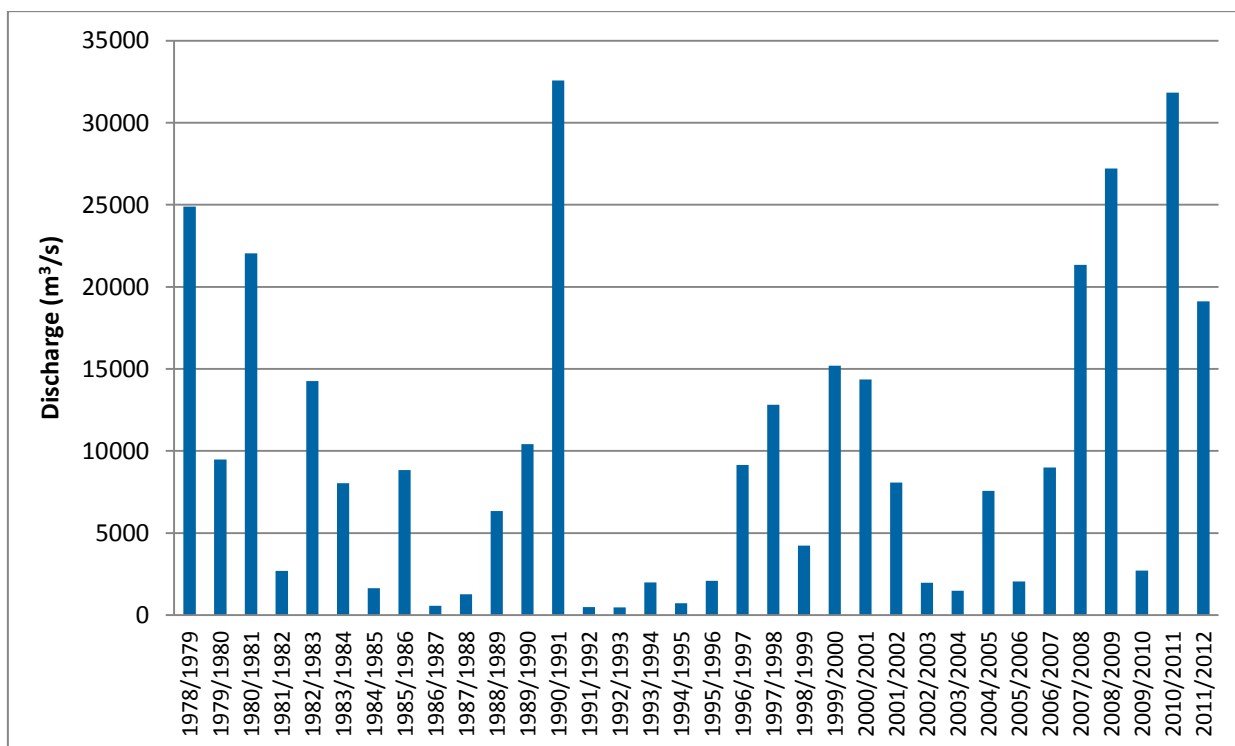
Appendix B 3 Monthly flows in Burdekin River at Sellheim (120002C)**Appendix B 4 Monthly flows in Bowen River at Myuna (120205A)**

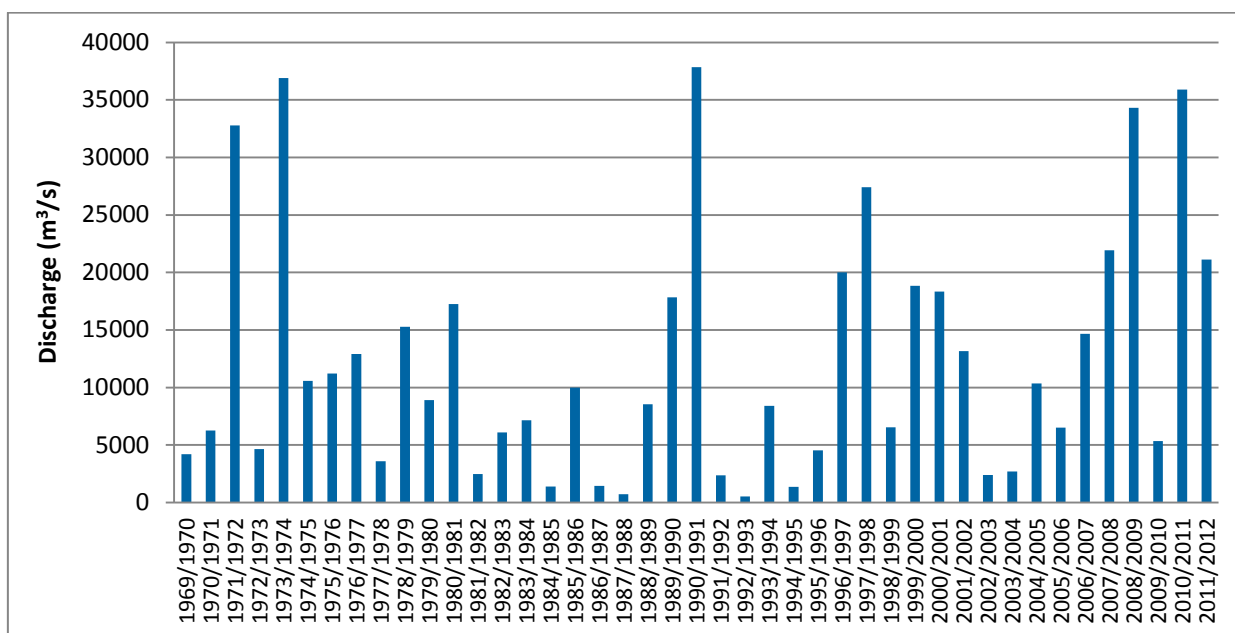
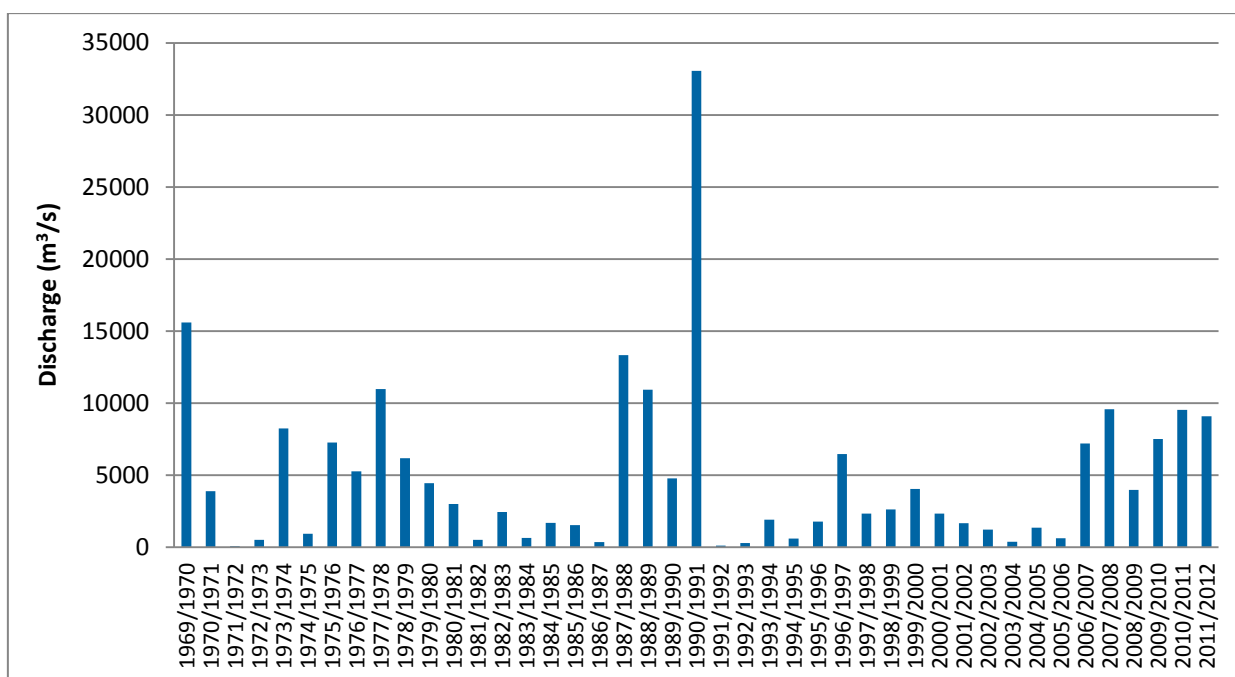
Appendix B 5 Monthly flows in Suttor River at St Anns (120303A)



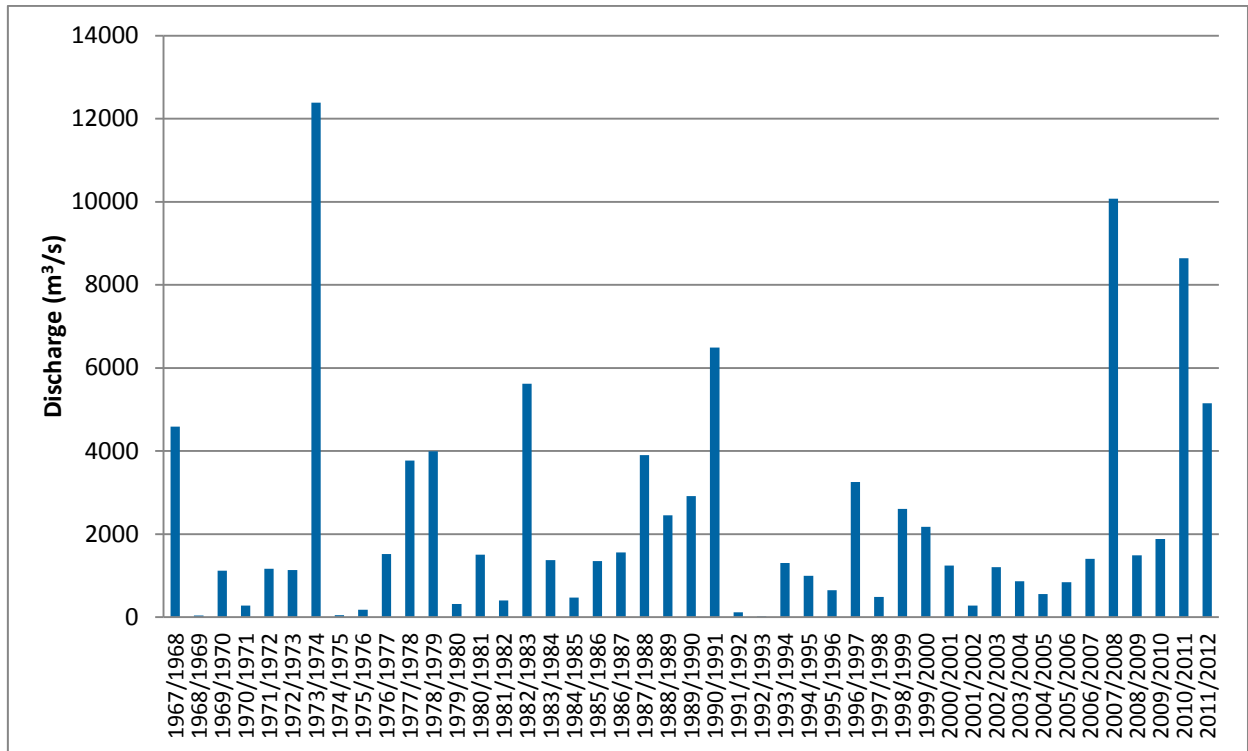
Appendix B 6 Monthly flows in Suttor River at Eaglefield (120304A)



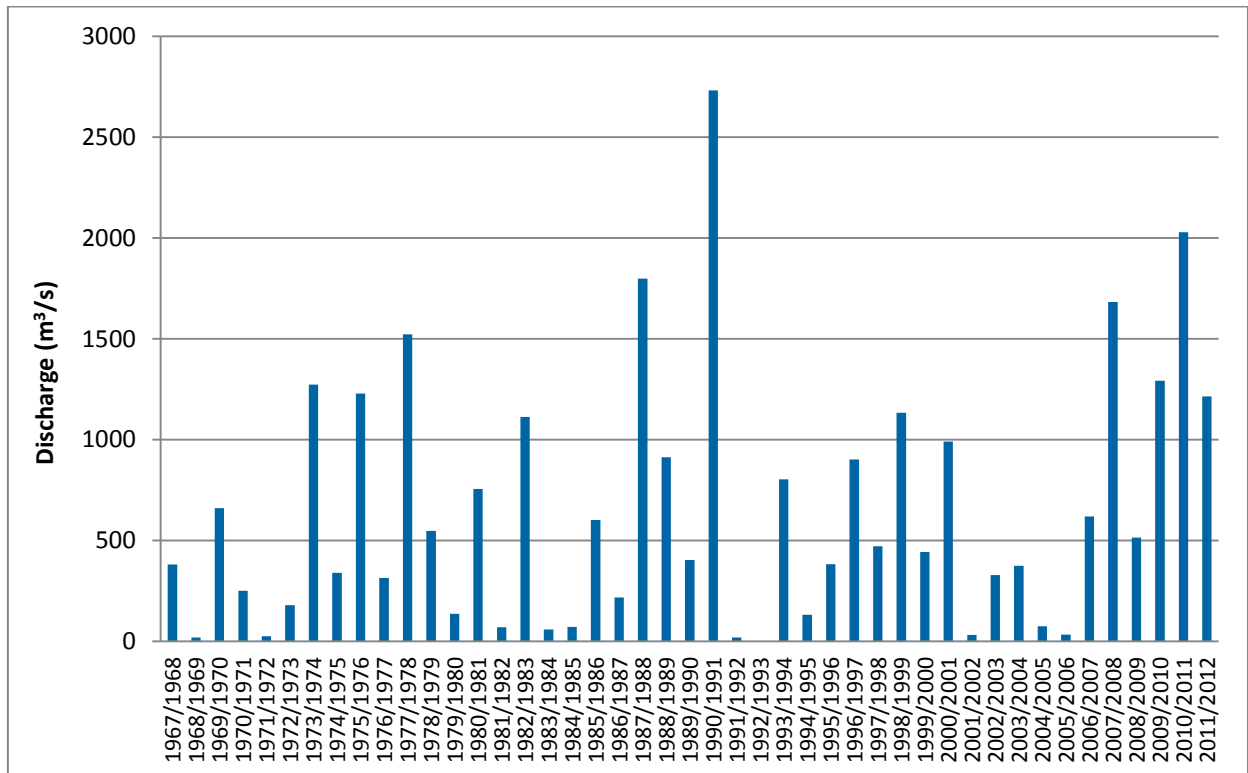
Appendix B 7 Annual flows in Don River at Reeves (121003A)**Appendix B 8 Annual flows in Burdekin River at Hydro Site (120015A)**

Appendix B 9 Annual flows in Burdekin River at Sellheim (120002C)**Appendix B 10 Annual flows in Bowen River at Myuna (120205A)**

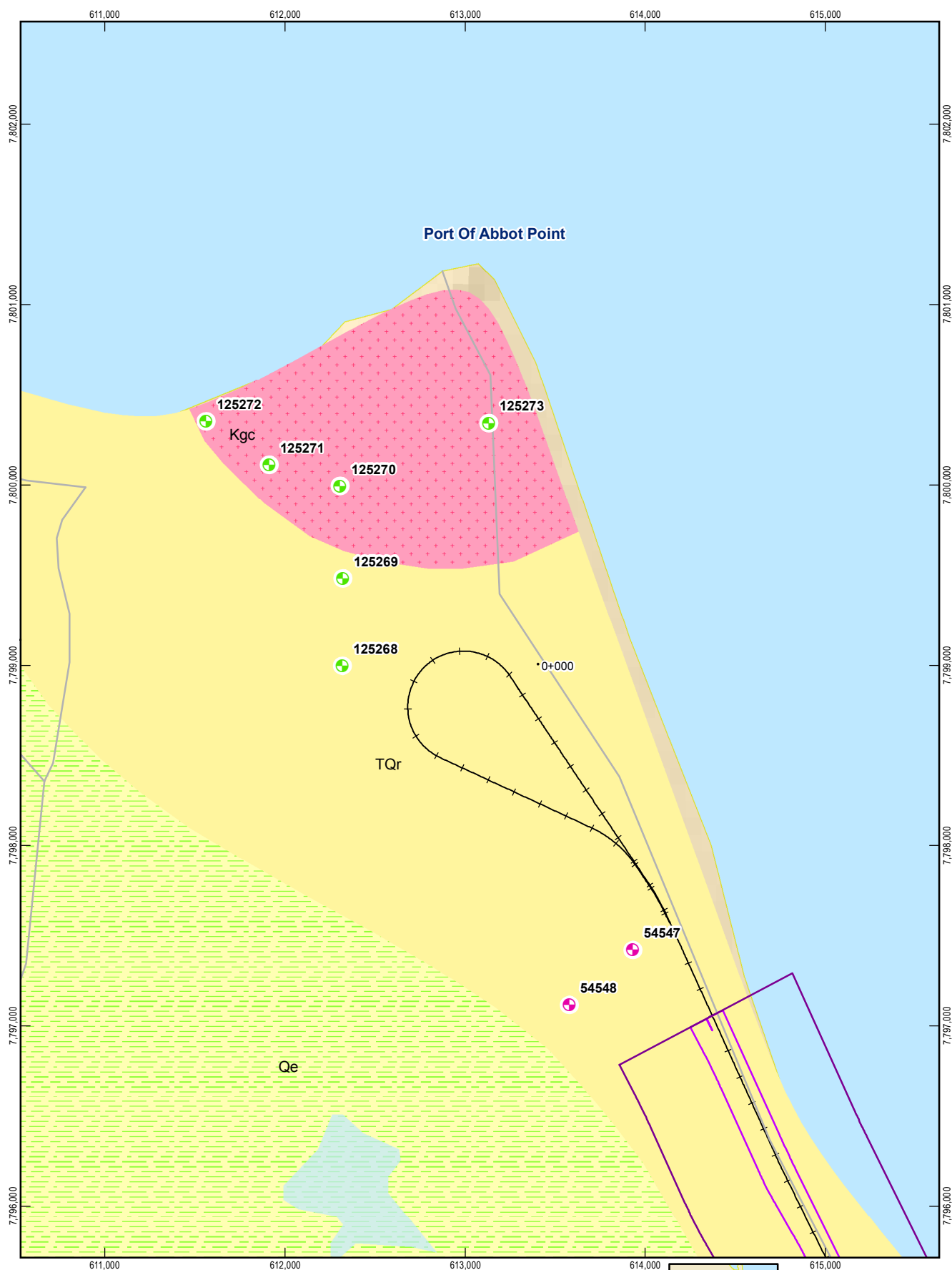
Appendix B 11 Annual flows in Suttor River at St Anns (120303A)



Appendix B 12 Annual flows in Suttor River at Eaglefield (120304A)



Appendix C – Borehole locations and localised geology



LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

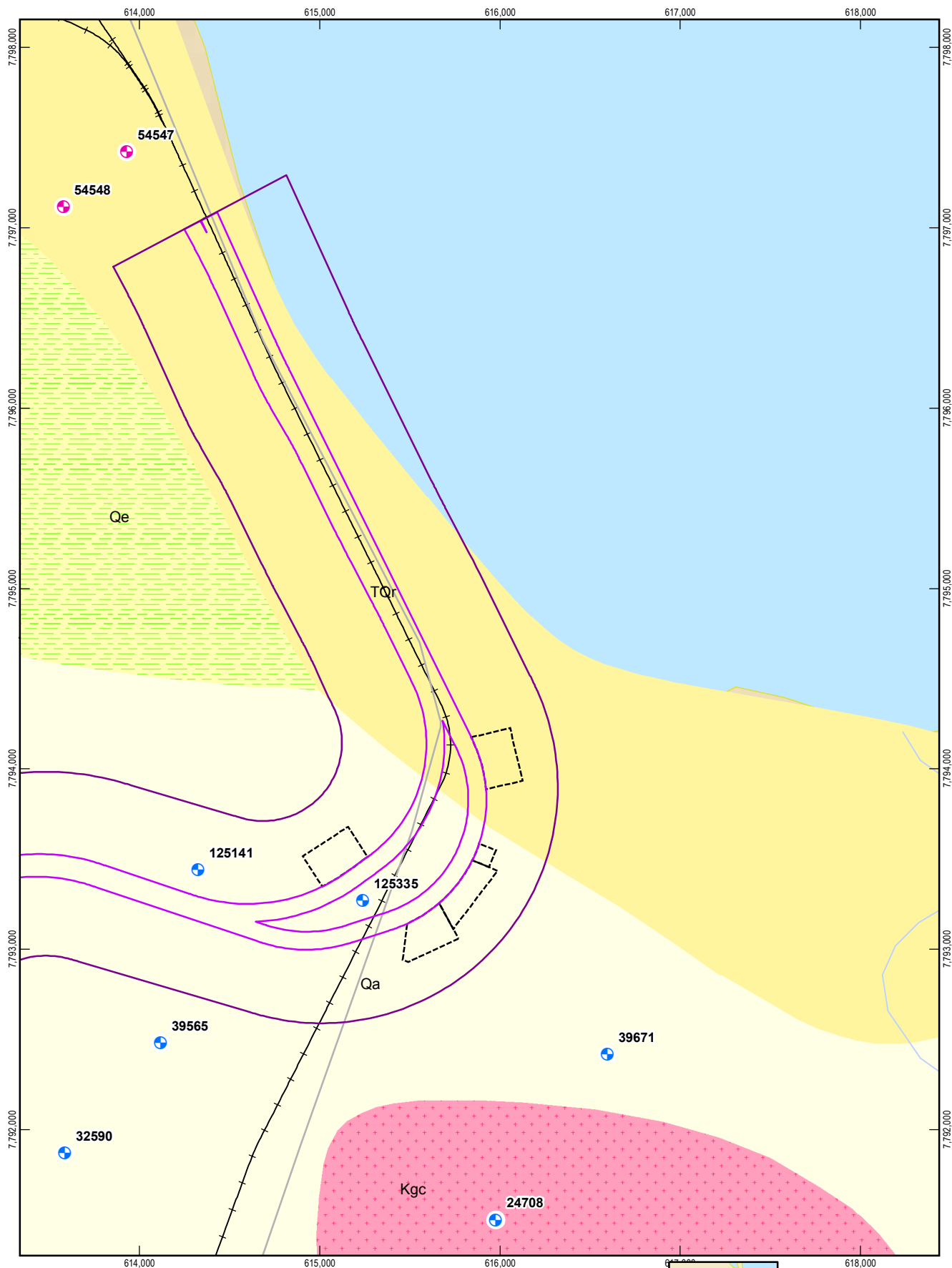
Job Number 41-26457
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

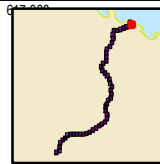
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

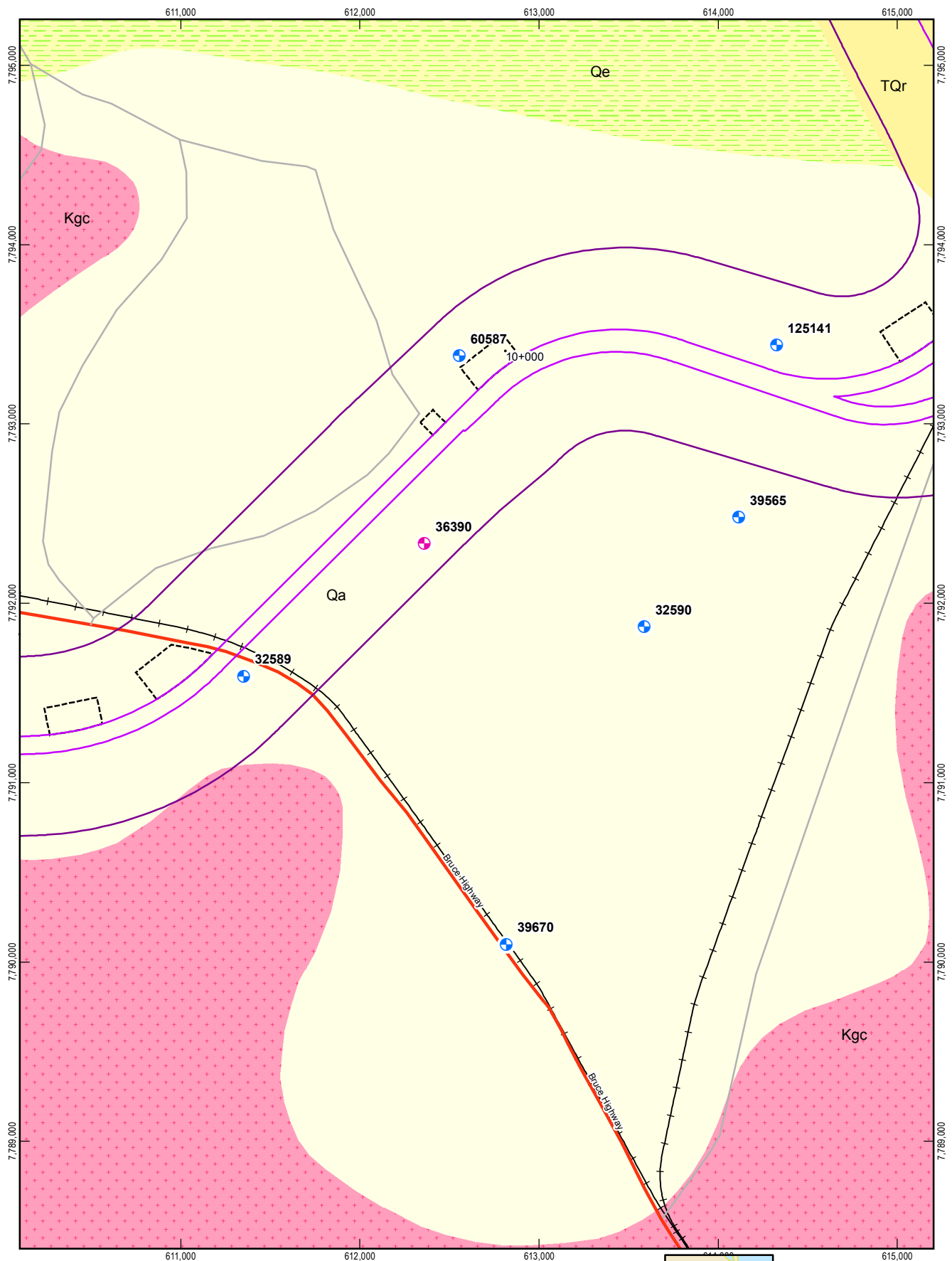
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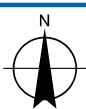
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

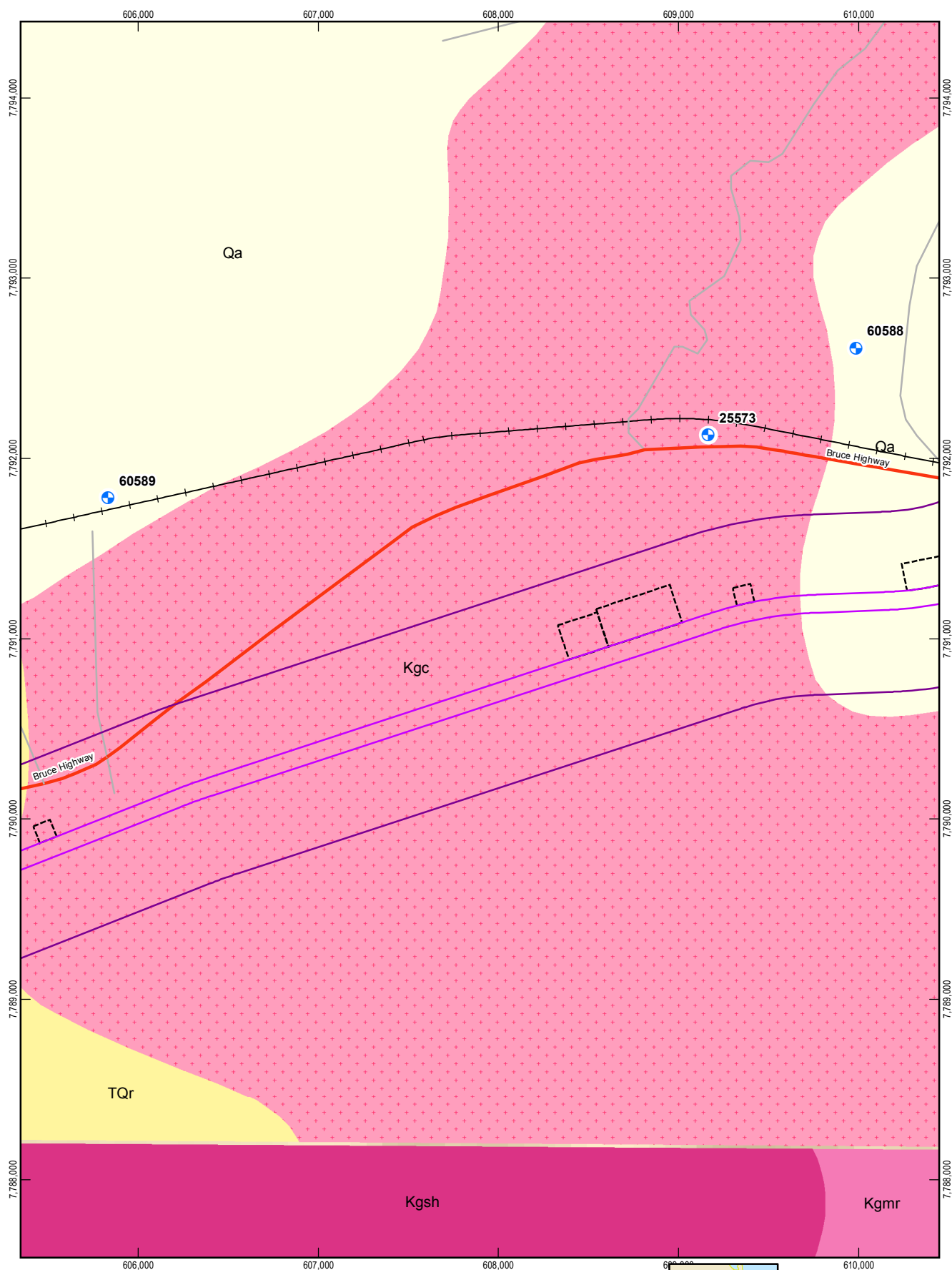
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Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

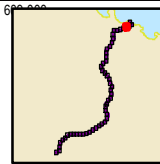
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

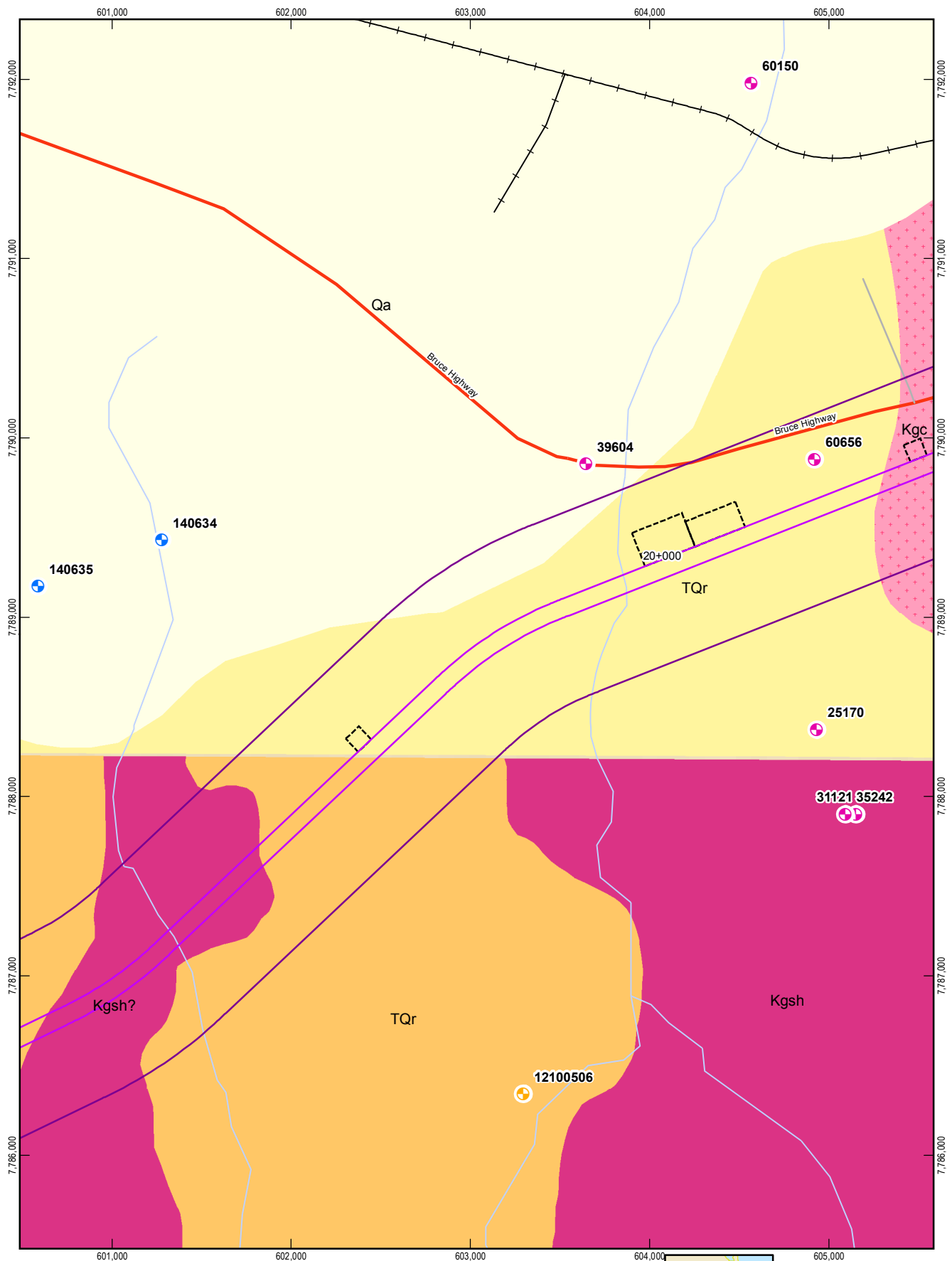
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Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

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Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

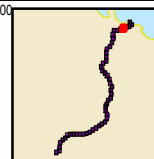
Watercourse (Minor)

Lakes

Construction Infrastructure

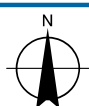
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

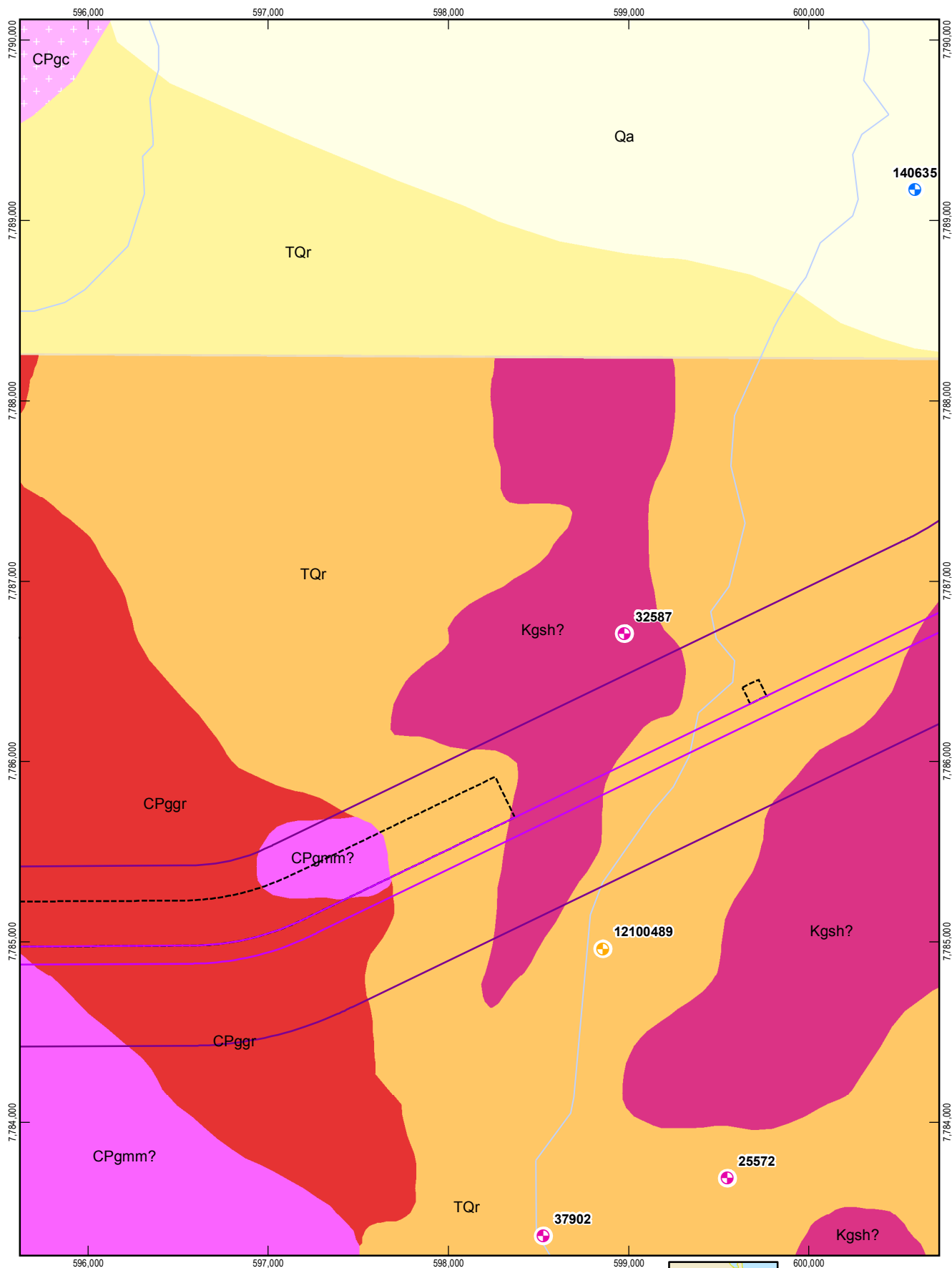
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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

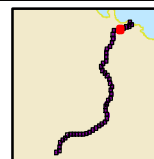
Watercourse (Minor)

Lakes

Construction
Infrastructure

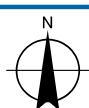
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

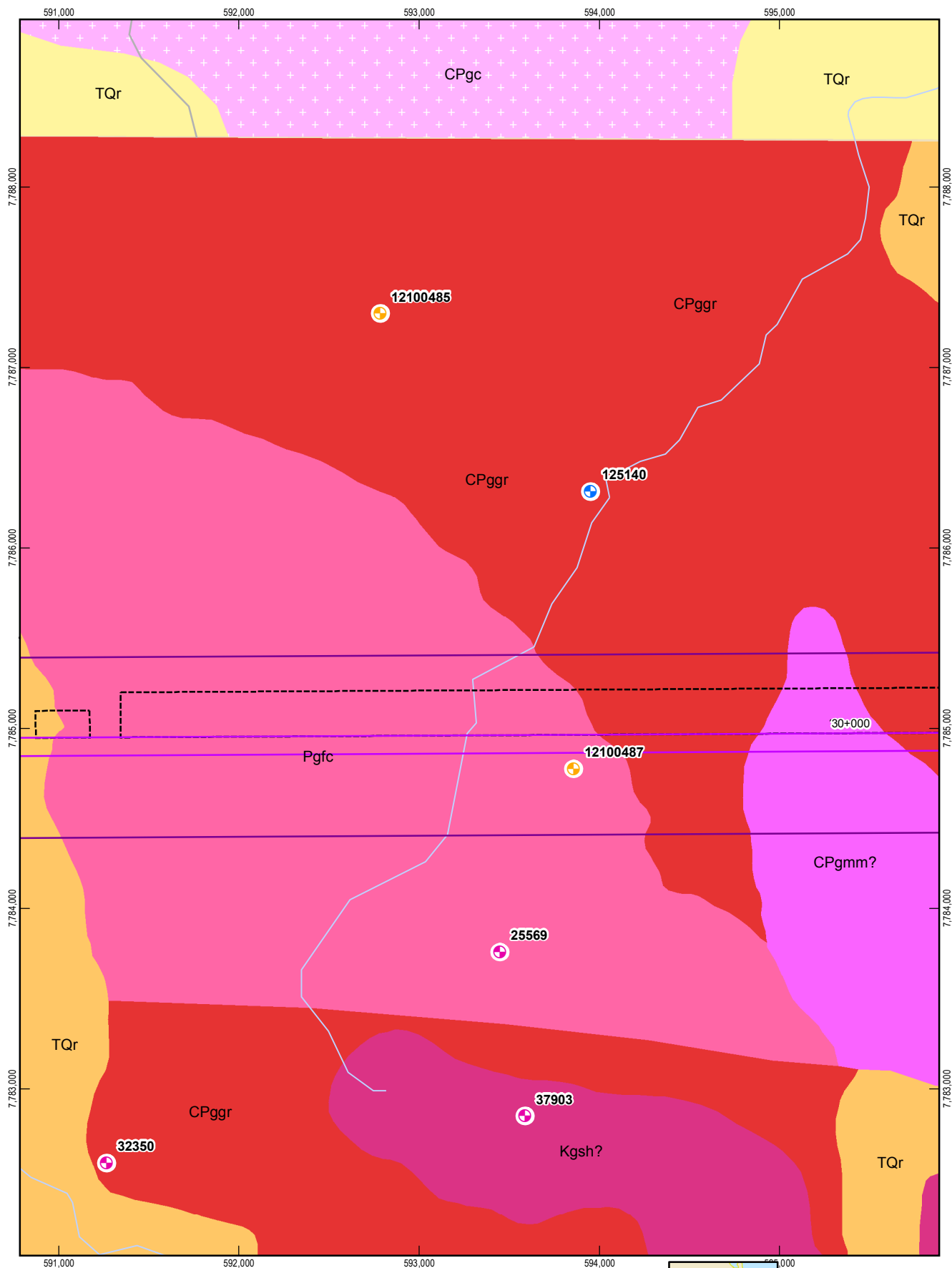
Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction

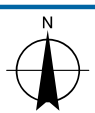
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

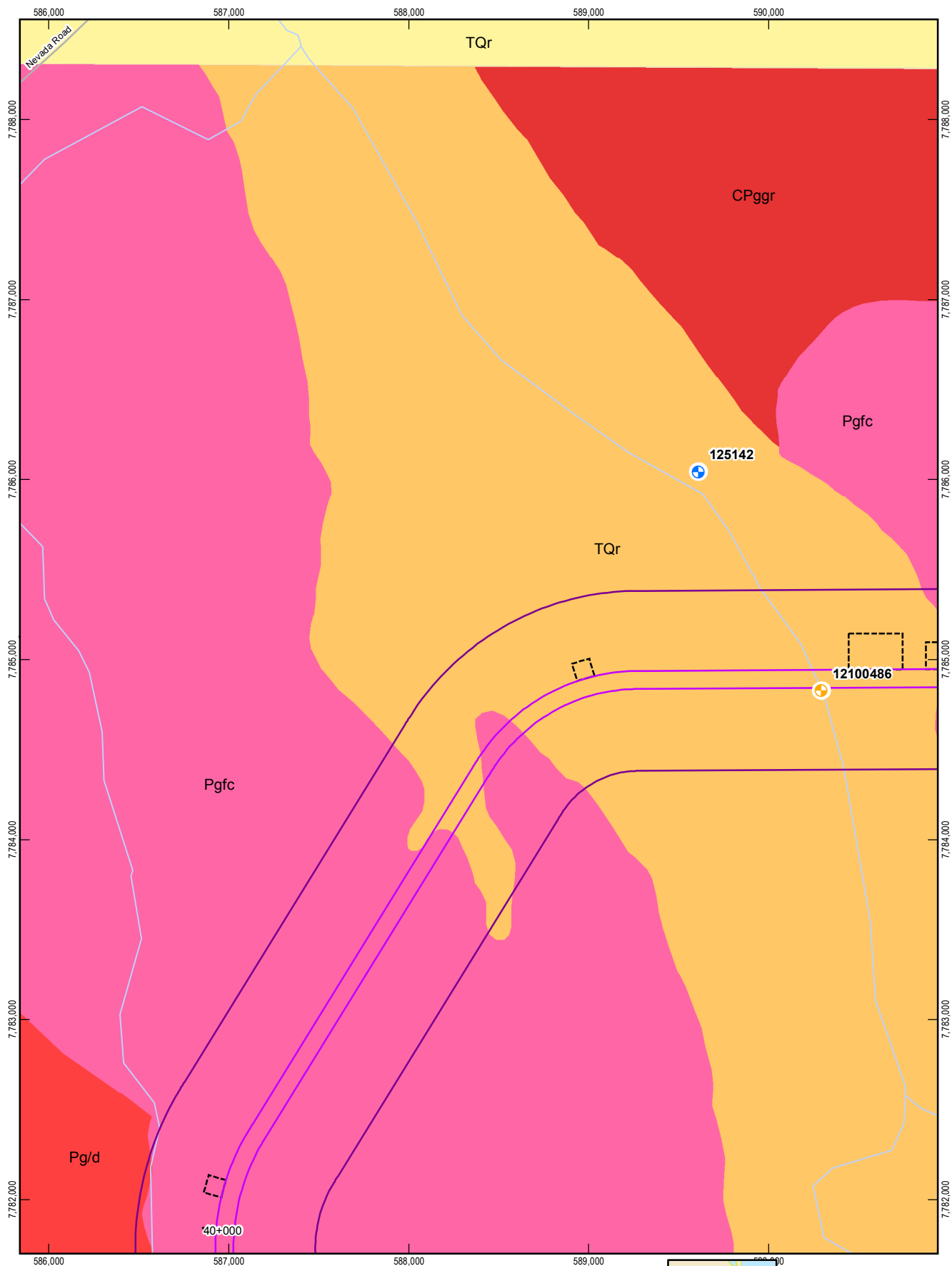
Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

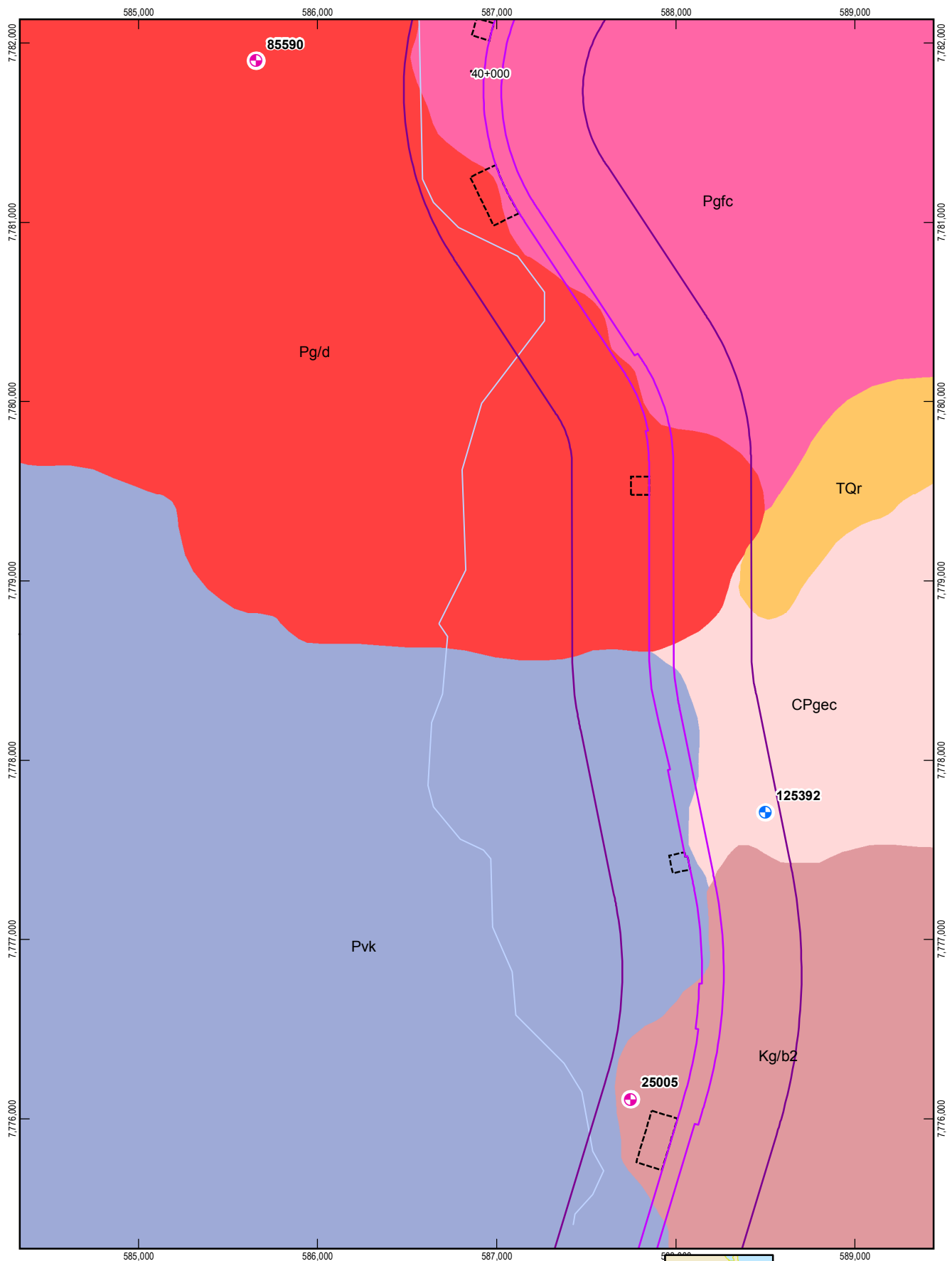
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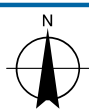
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|------------------------------------|------------------------------|---------------------------|---------------------|---|
| Population Centres | Water Resource Investigation | Highway | Railway | Construction Infrastructure |
| Queensland State Observation Bores | Water Supply | Main Road | Watercourse (Major) | North Galilee Basin Rail 1000m Corridor |
| Queensland Groundwater Database | Not Specified | Local Road | Watercourse (Minor) | North Galilee Basin Rail 100m Corridor |
| Stratigraphic Investigation | | Carmichael Project (Rail) | Lakes | |



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Map Projection: Transverse Mercator
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

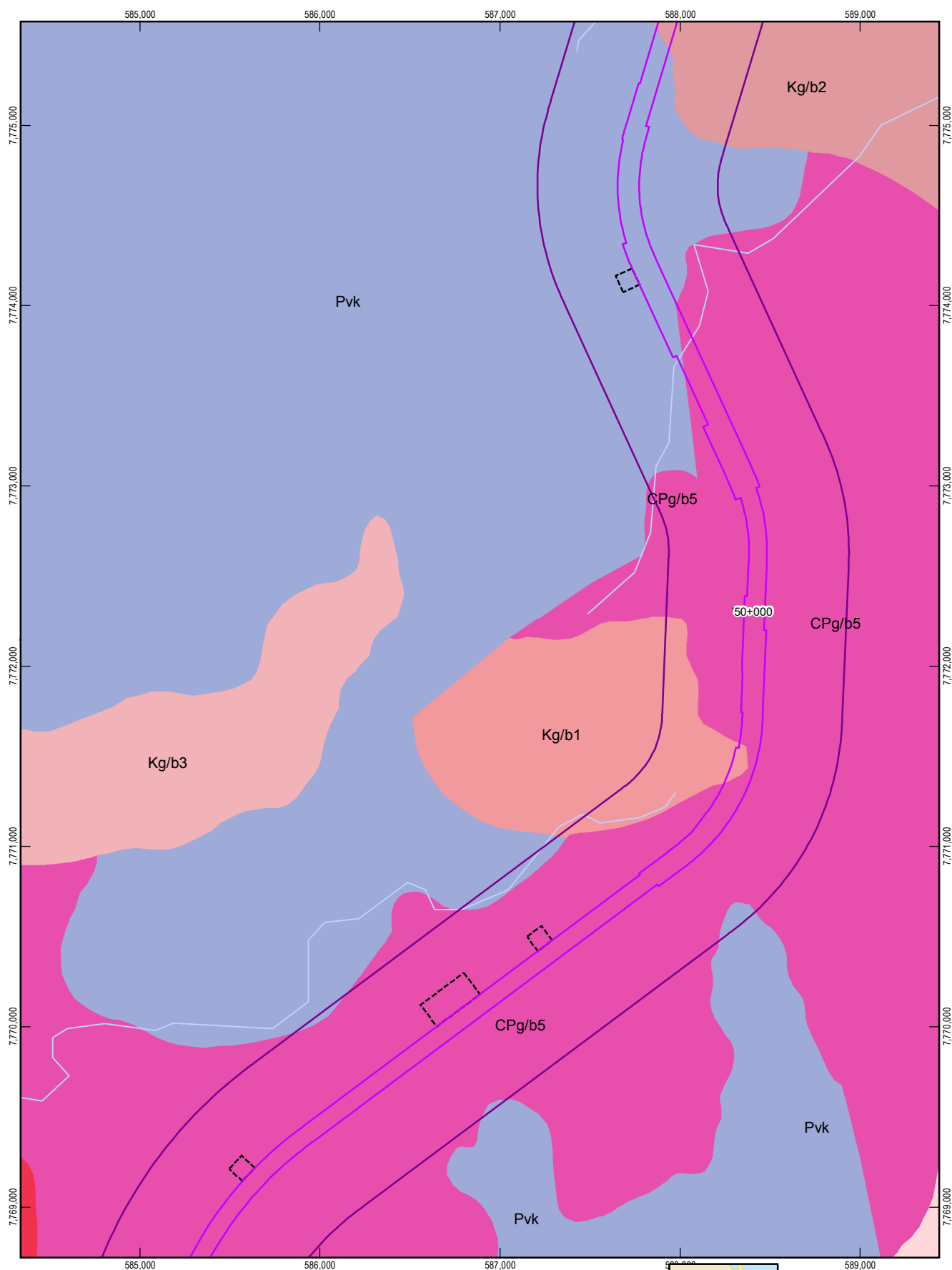
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

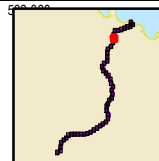
Watercourse (Minor)

Lakes

Construction Infrastructure

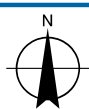
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

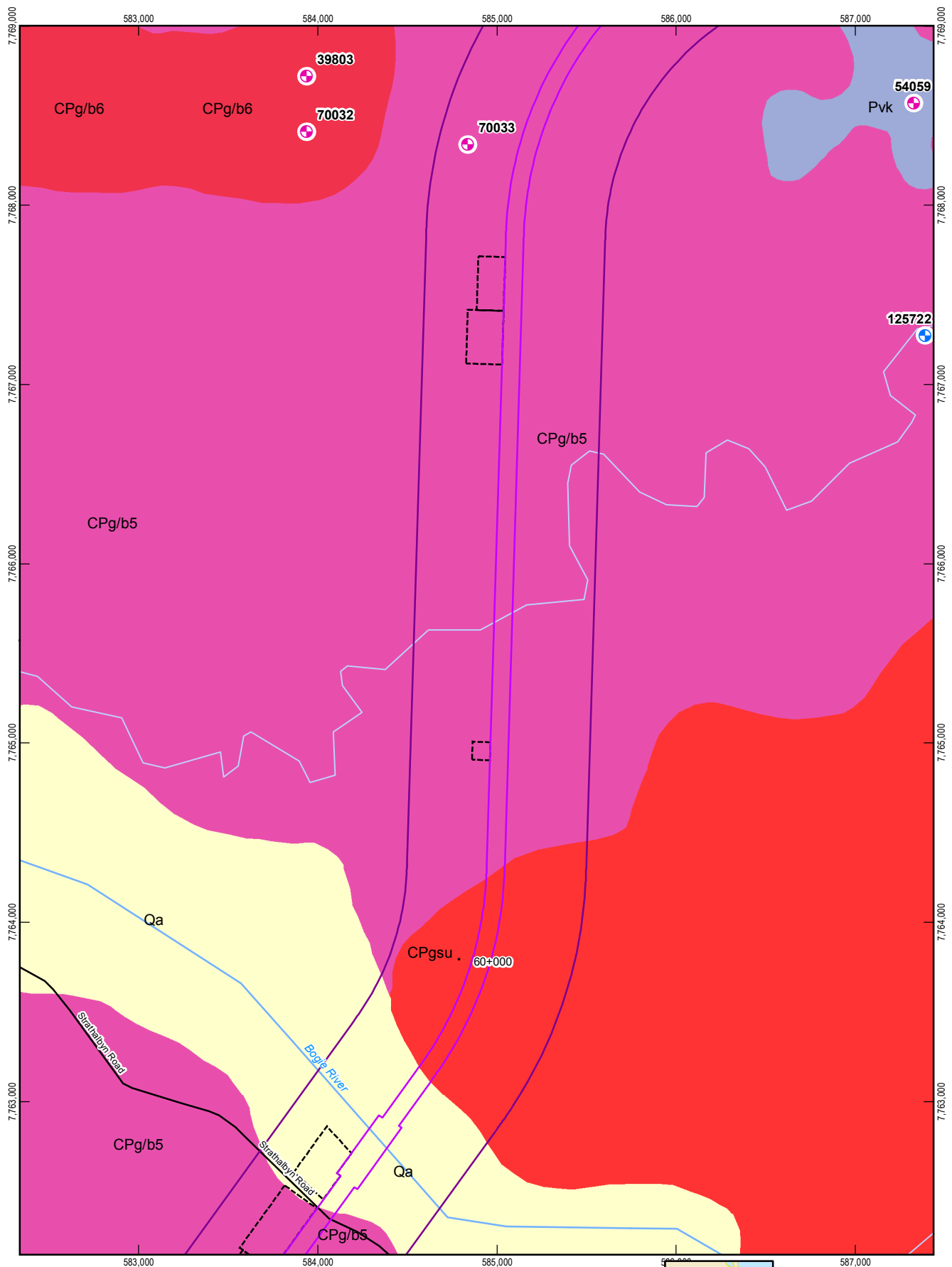
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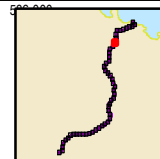
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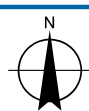
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|--|---|---|--|



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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number	41-26457
Revision	B
Date	07 Aug 2013

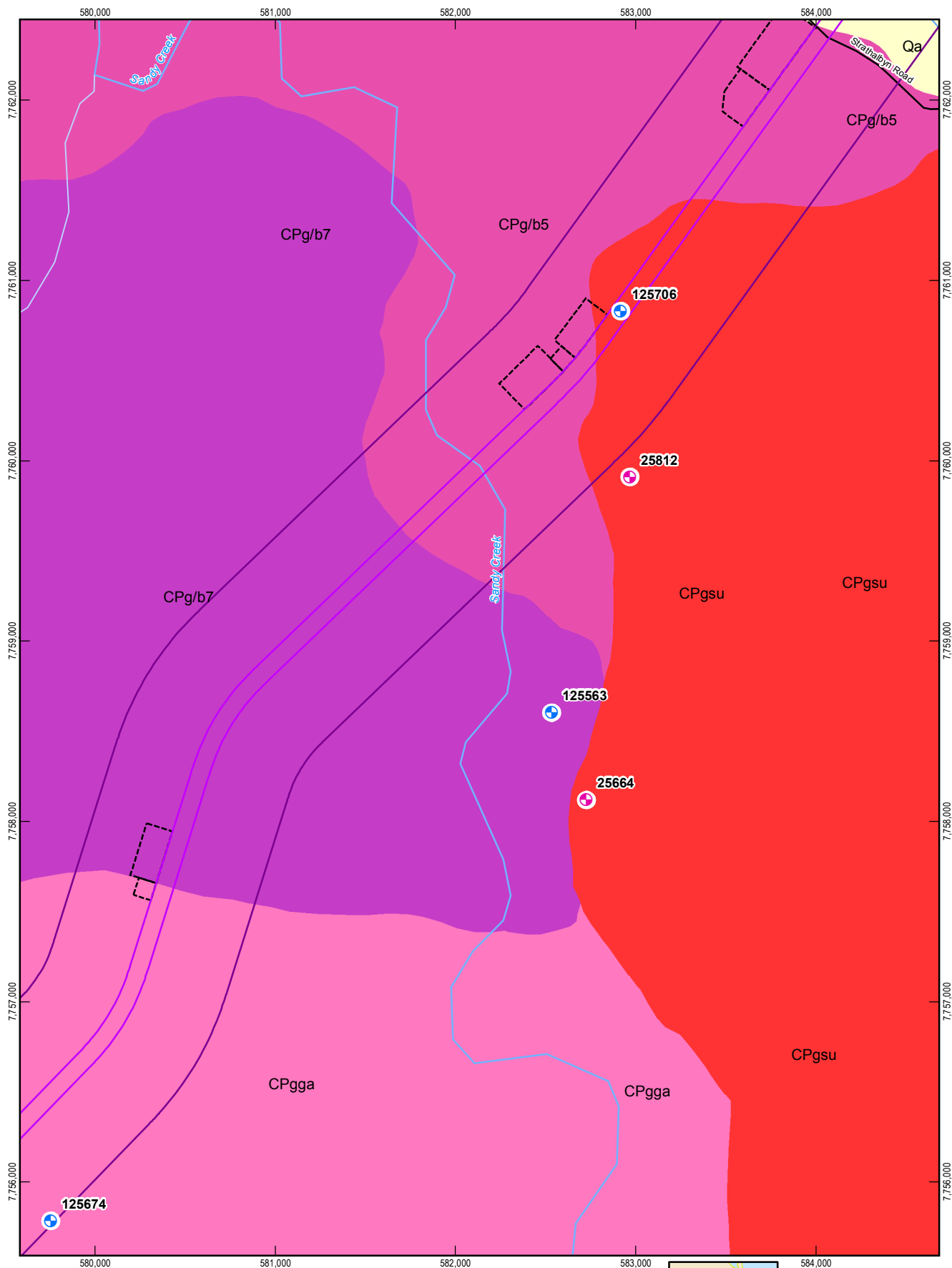
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor

584,000
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

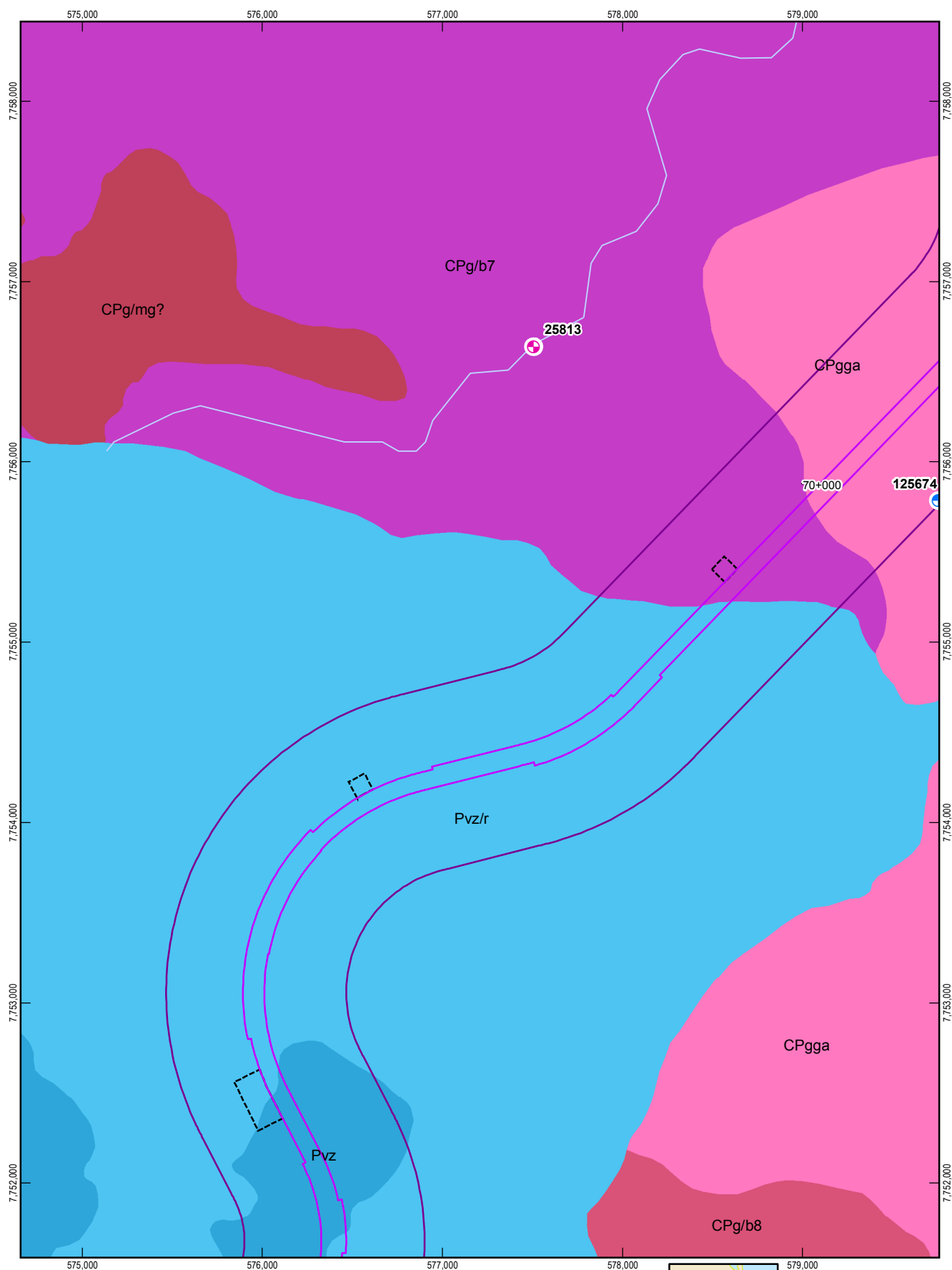
Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction
Infrastructure

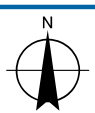
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Map Projection: Transverse Mercator
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

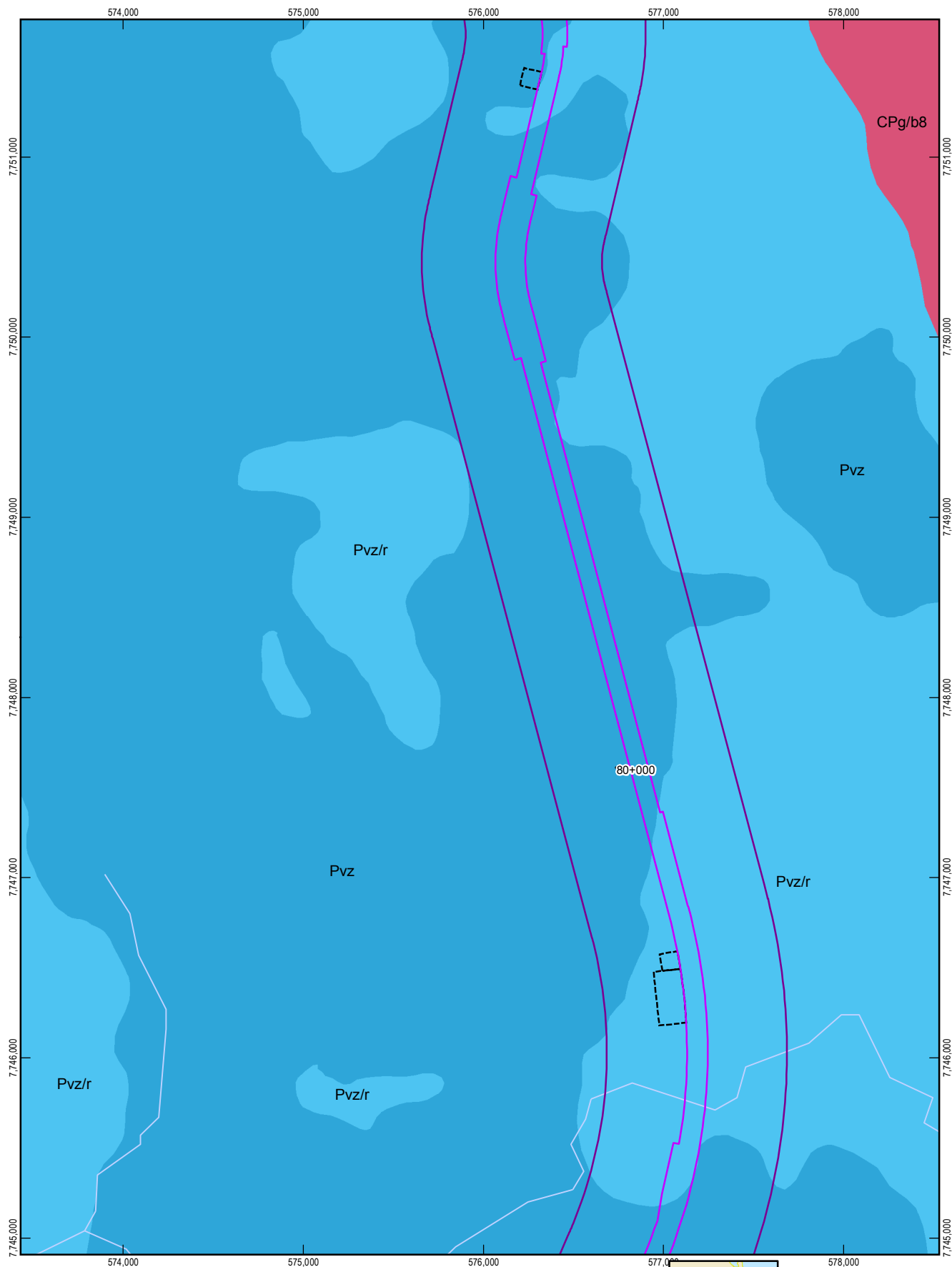
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

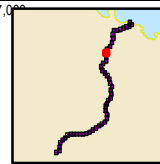
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

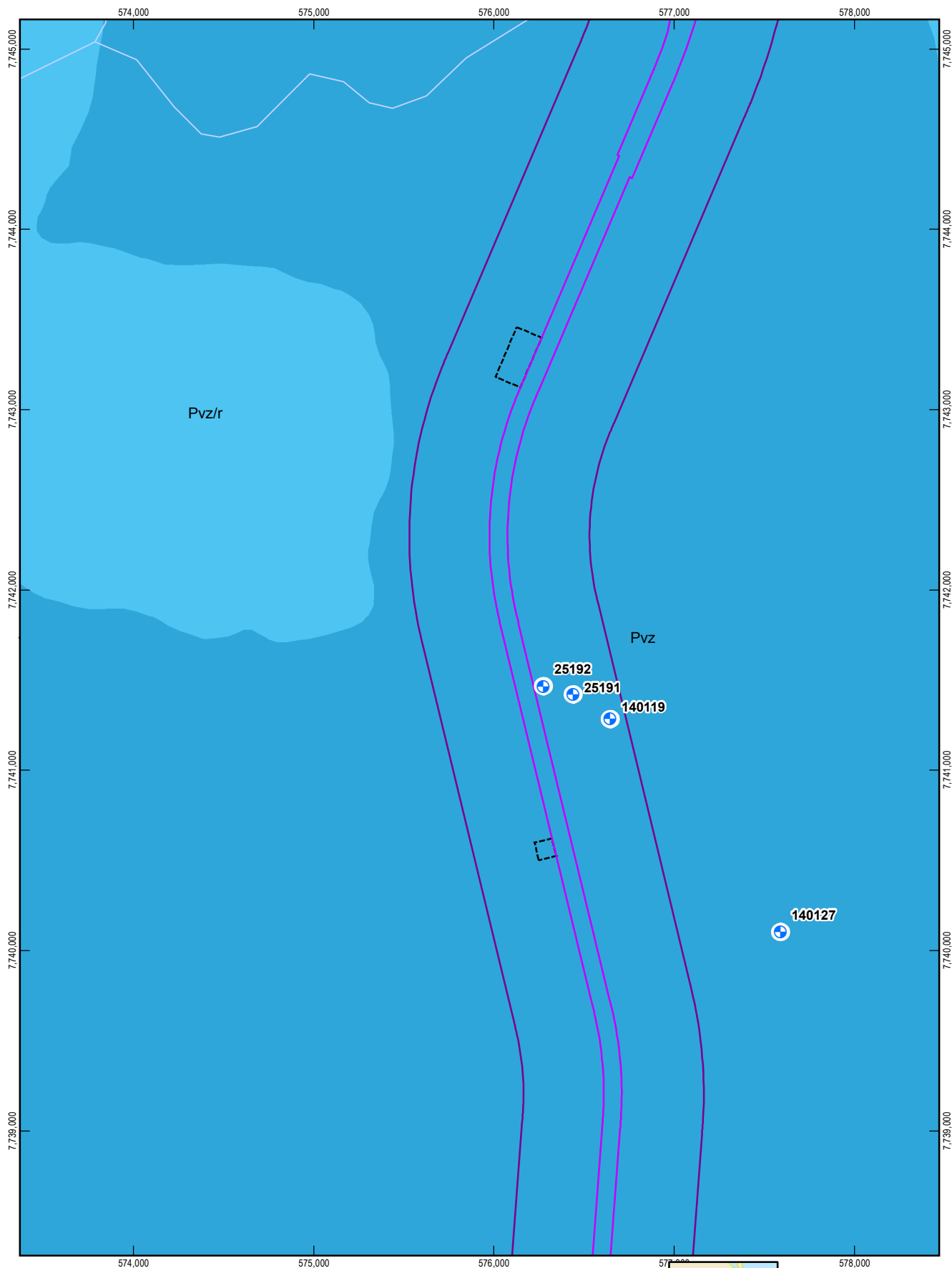
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

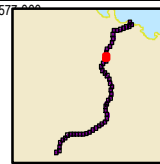
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

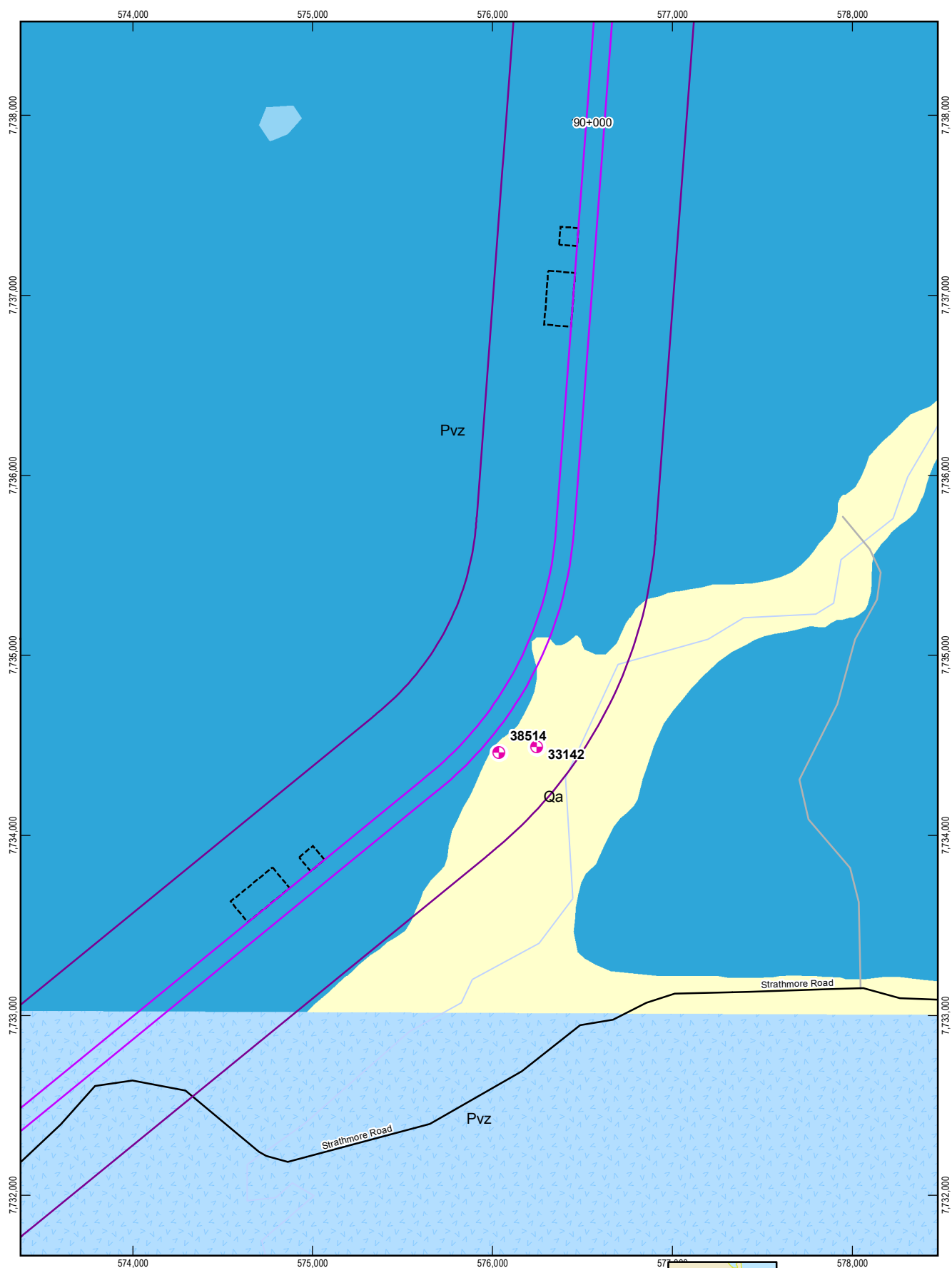
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

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Highway

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Railway

Watercourse (Major)

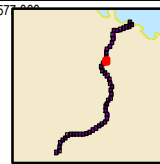
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

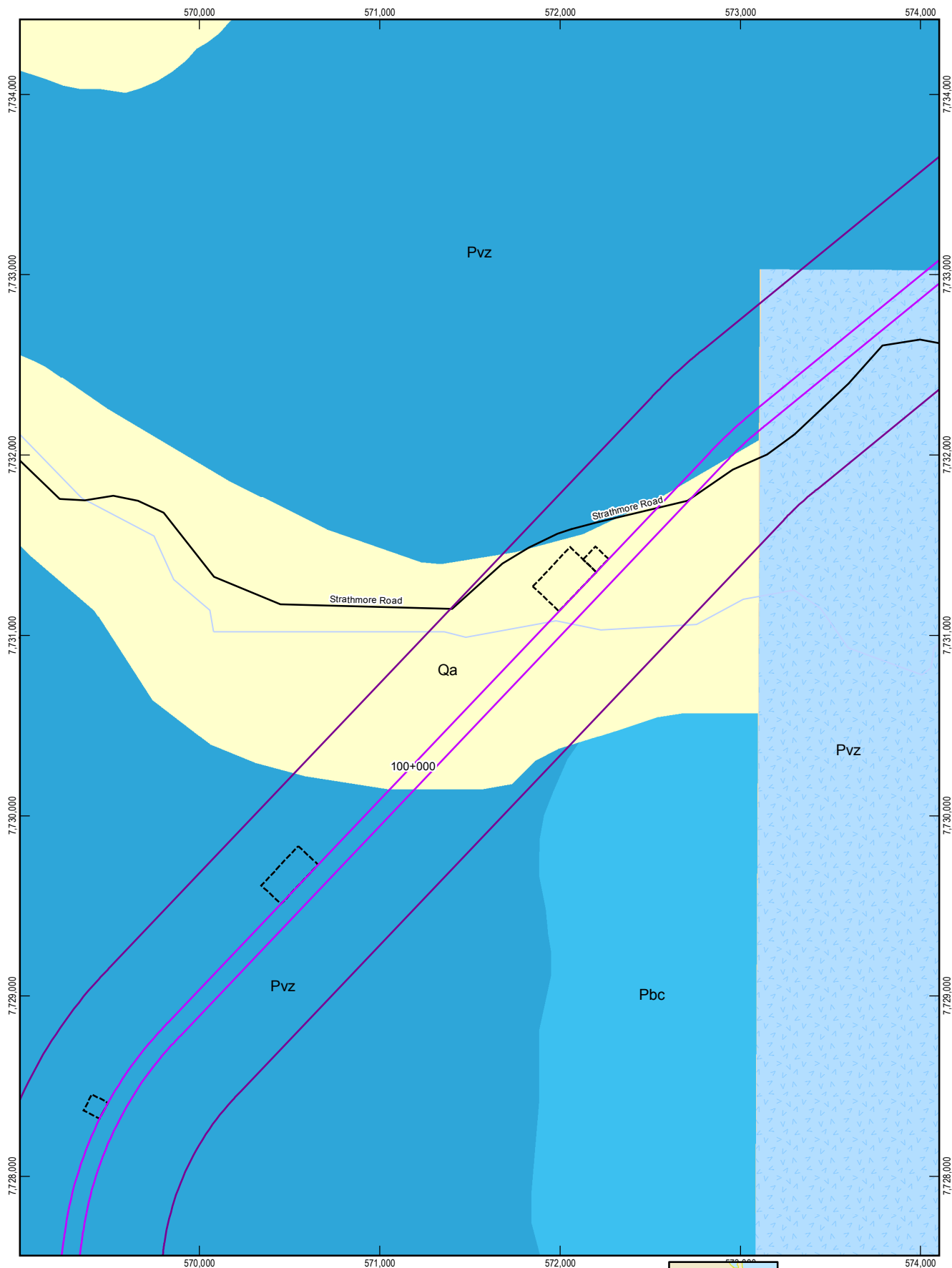
Job Number 41-26457
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Date 07 Aug 2013

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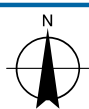
LEGEND

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|--|---|---|--|



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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

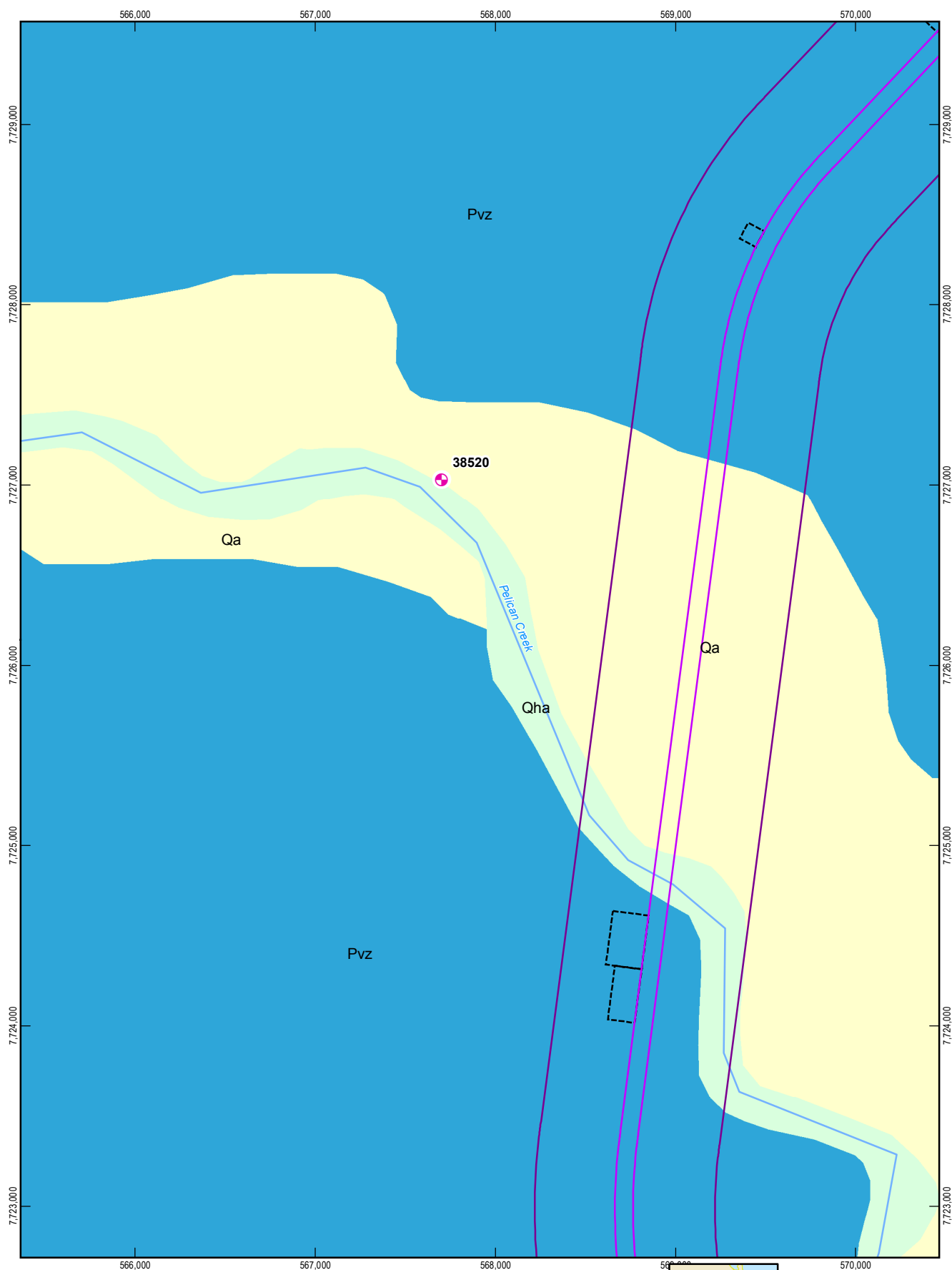
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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

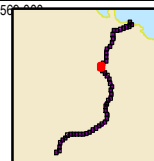
Watercourse (Minor)

Lakes

Construction
Infrastructure

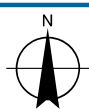
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



adani

Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

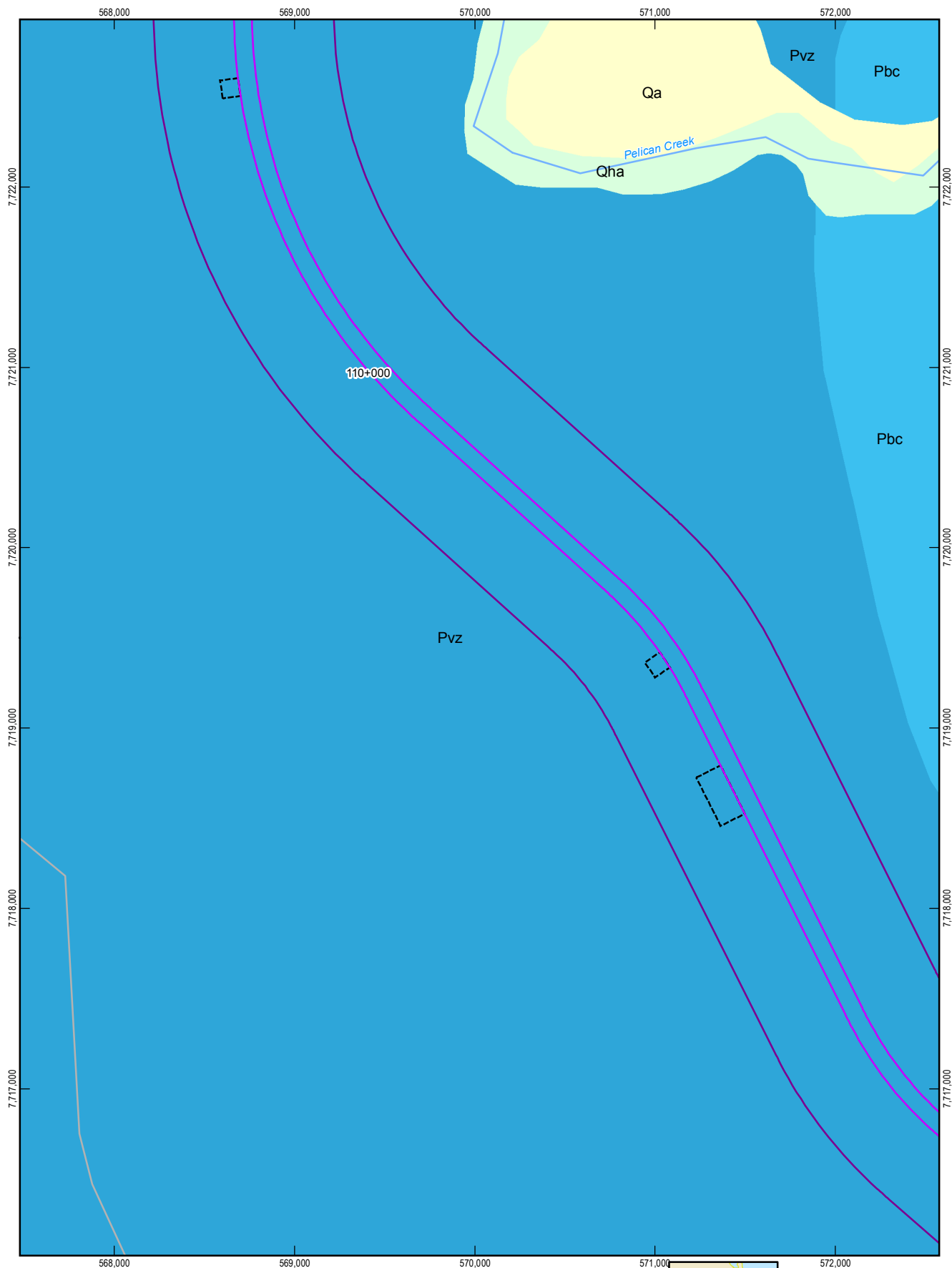
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

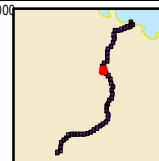
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

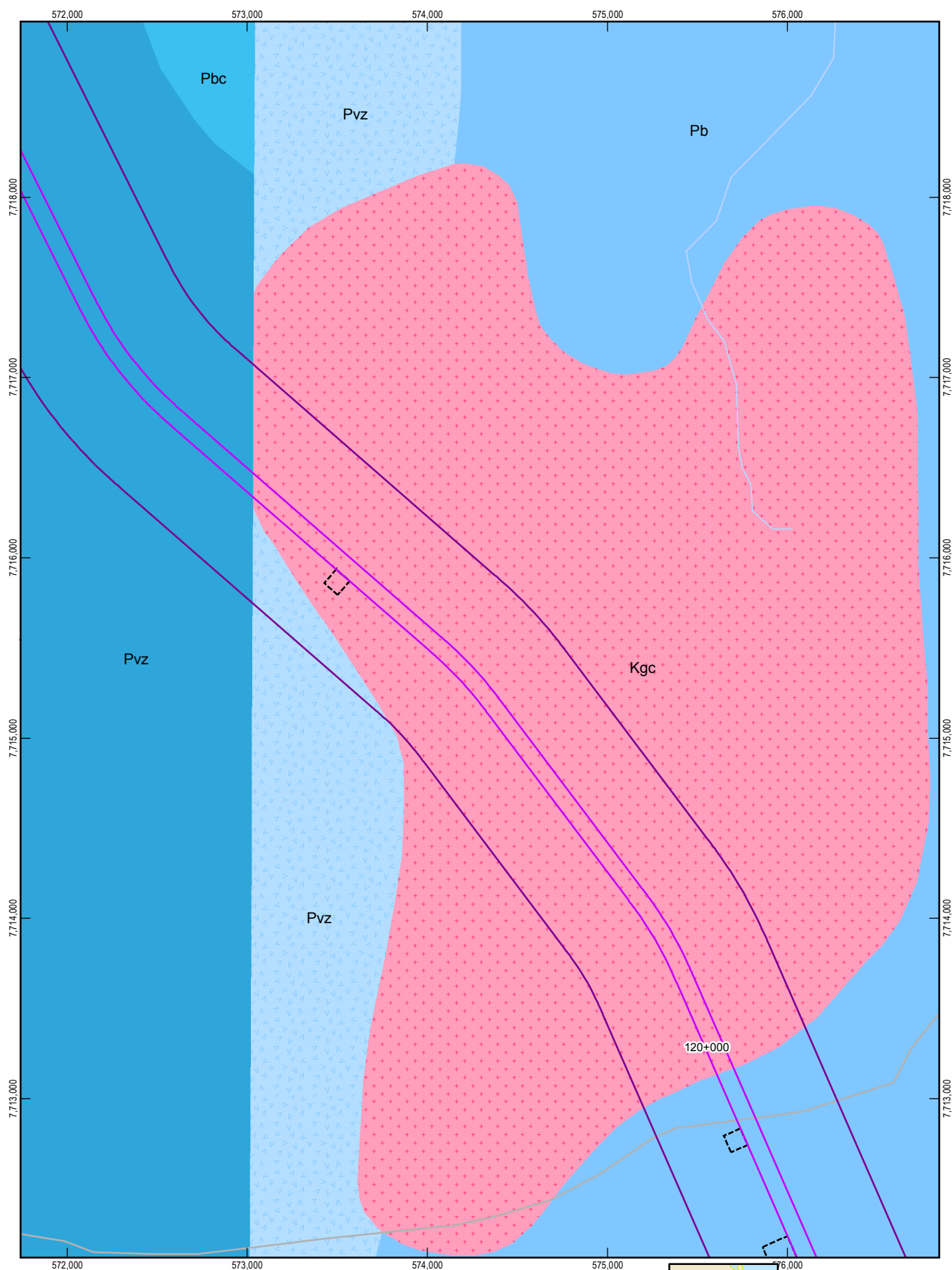
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



adani

Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

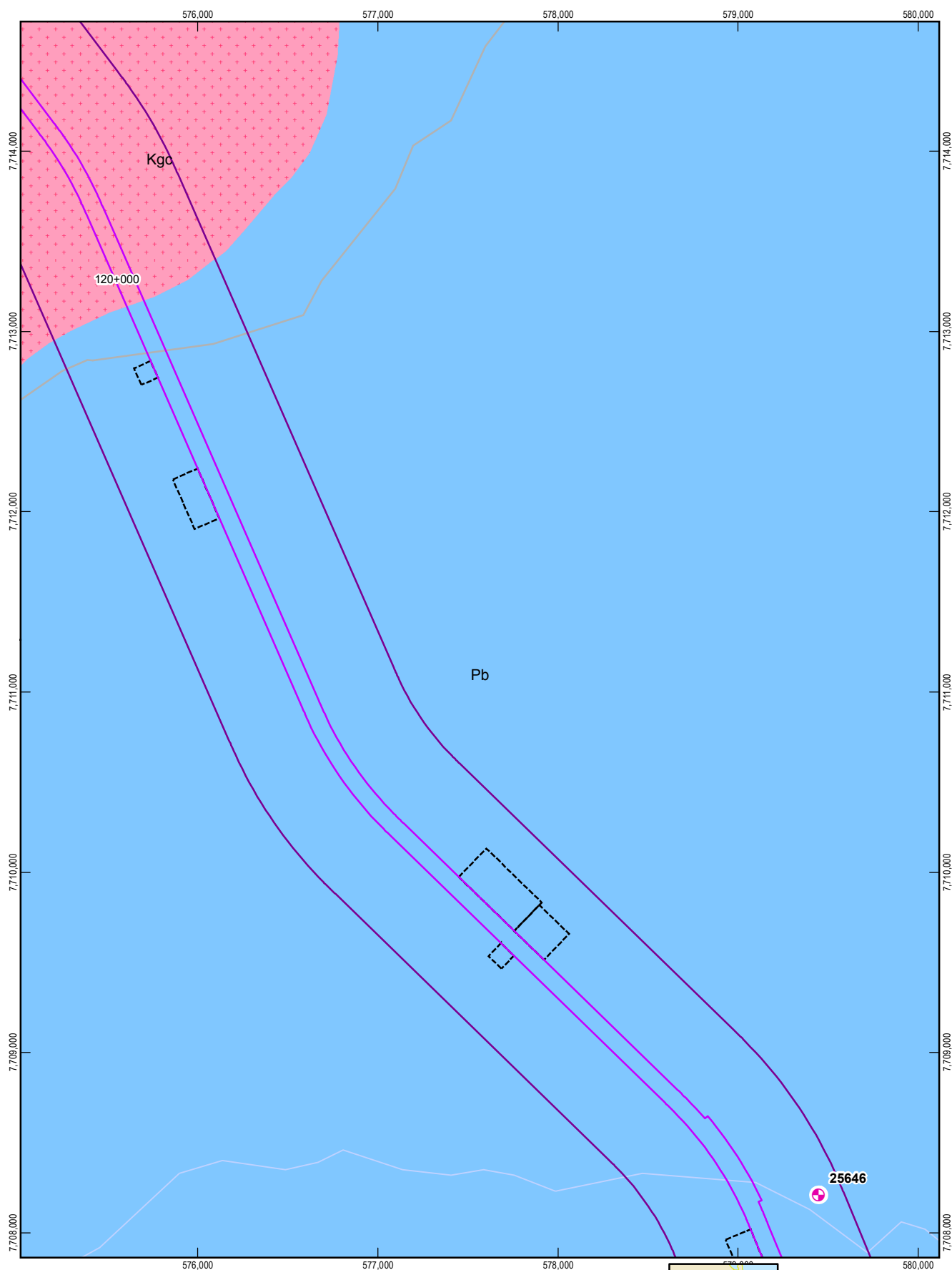
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

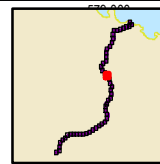
Watercourse (Minor)

Lakes

Construction Infrastructure

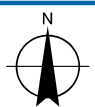
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

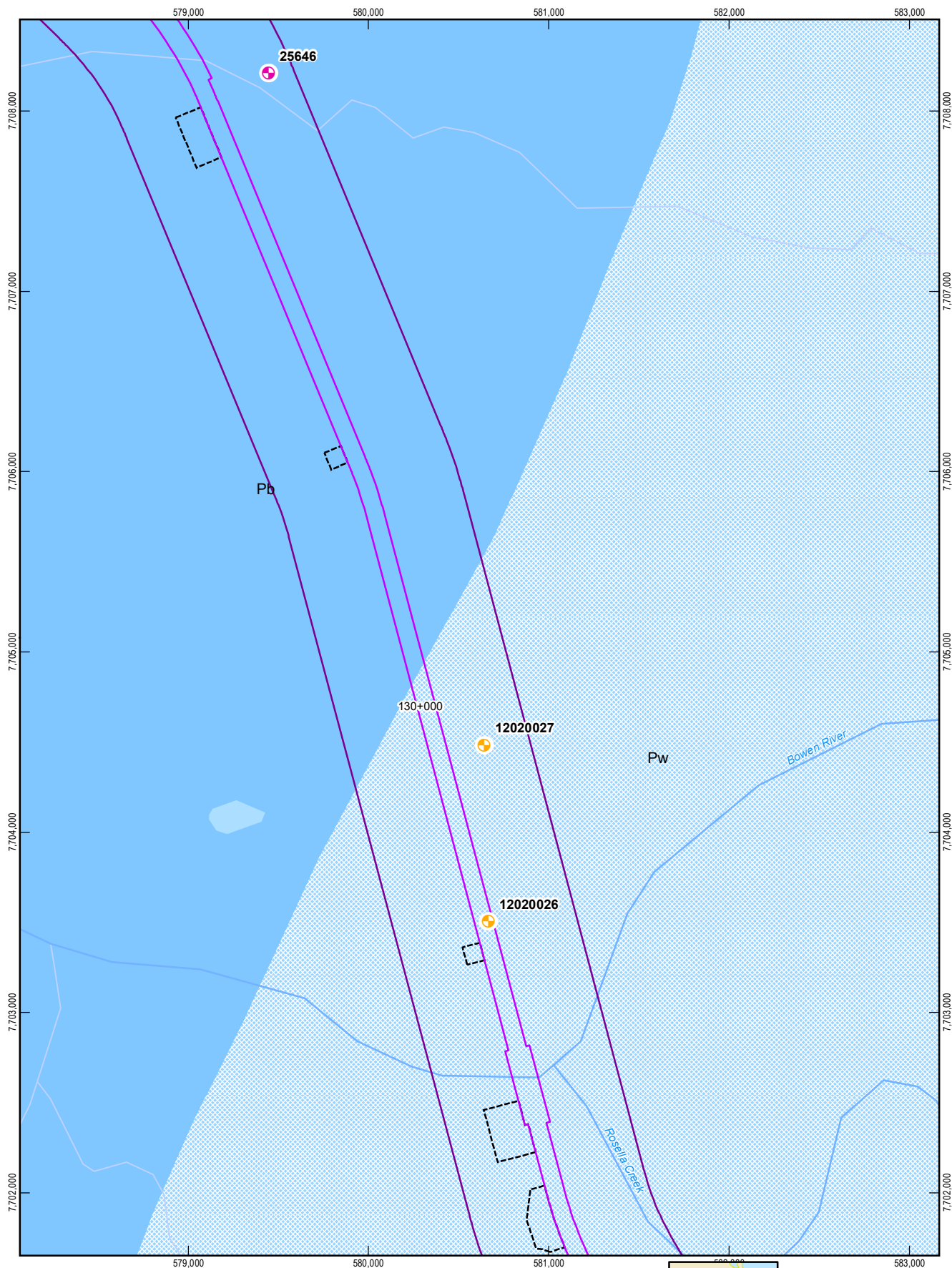
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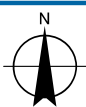
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| Population Centres | Water Resource Investigation | Highway | Railway |
| Queensland State Observation Bores | Water Supply | Main Road | Watercourse (Major) |
| Queensland Groundwater Database | Not Specified | Local Road | Watercourse (Minor) |
| Stratigraphic Investigation | | Carmichael Project (Rail) | Lakes |
| | | | Construction Infrastructure |
| | | | North Galilee Basin Rail 1000m Corridor |
| | | | North Galilee Basin Rail 100m Corridor |



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Kilometers
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
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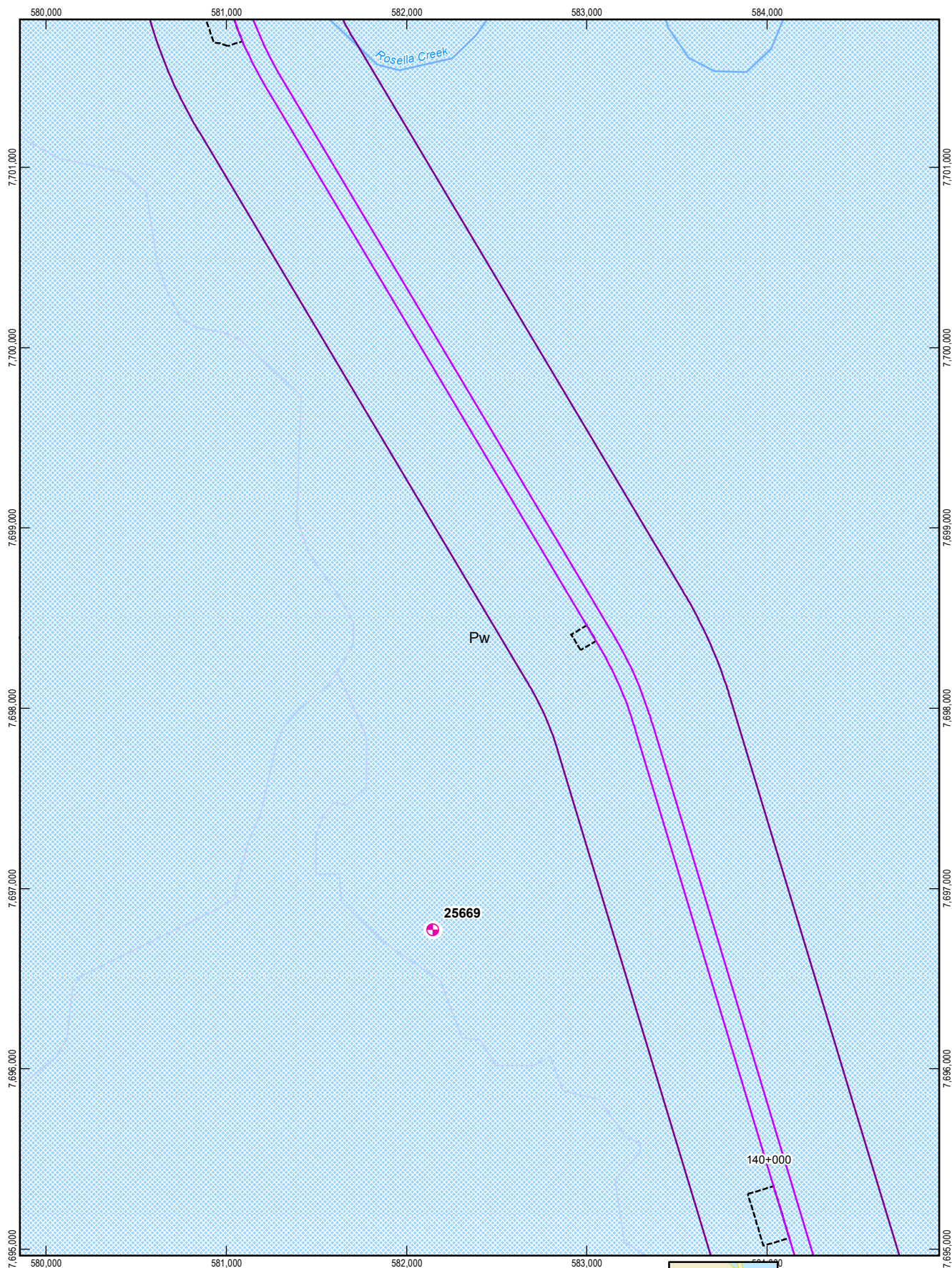
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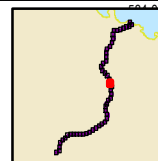
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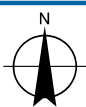
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- Population Centres
- Queensland State Observation Bores
- Queensland Groundwater Database
- Stratigraphic Investigation
- Water Resource Investigation
- Water Supply
- Not Specified
- Highway
- Main Road
- Local Road
- Carmichael Project (Rail)
- Railway
- Watercourse (Major)
- Watercourse (Minor)
- Lakes
- Construction Infrastructure
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin Rail 100m Corridor



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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

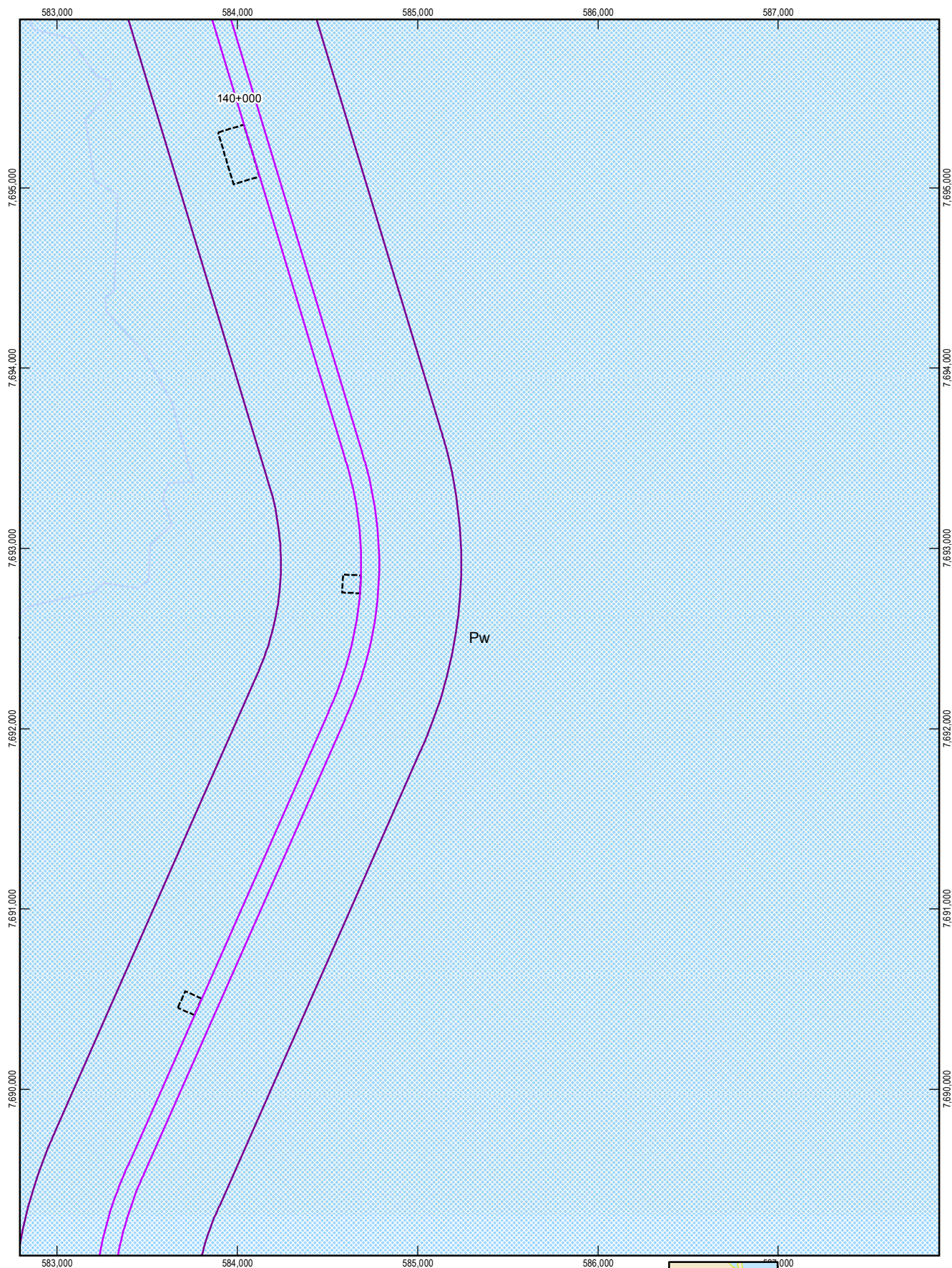
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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction
Infrastructure

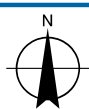
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Map Projection: Transverse Mercator
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

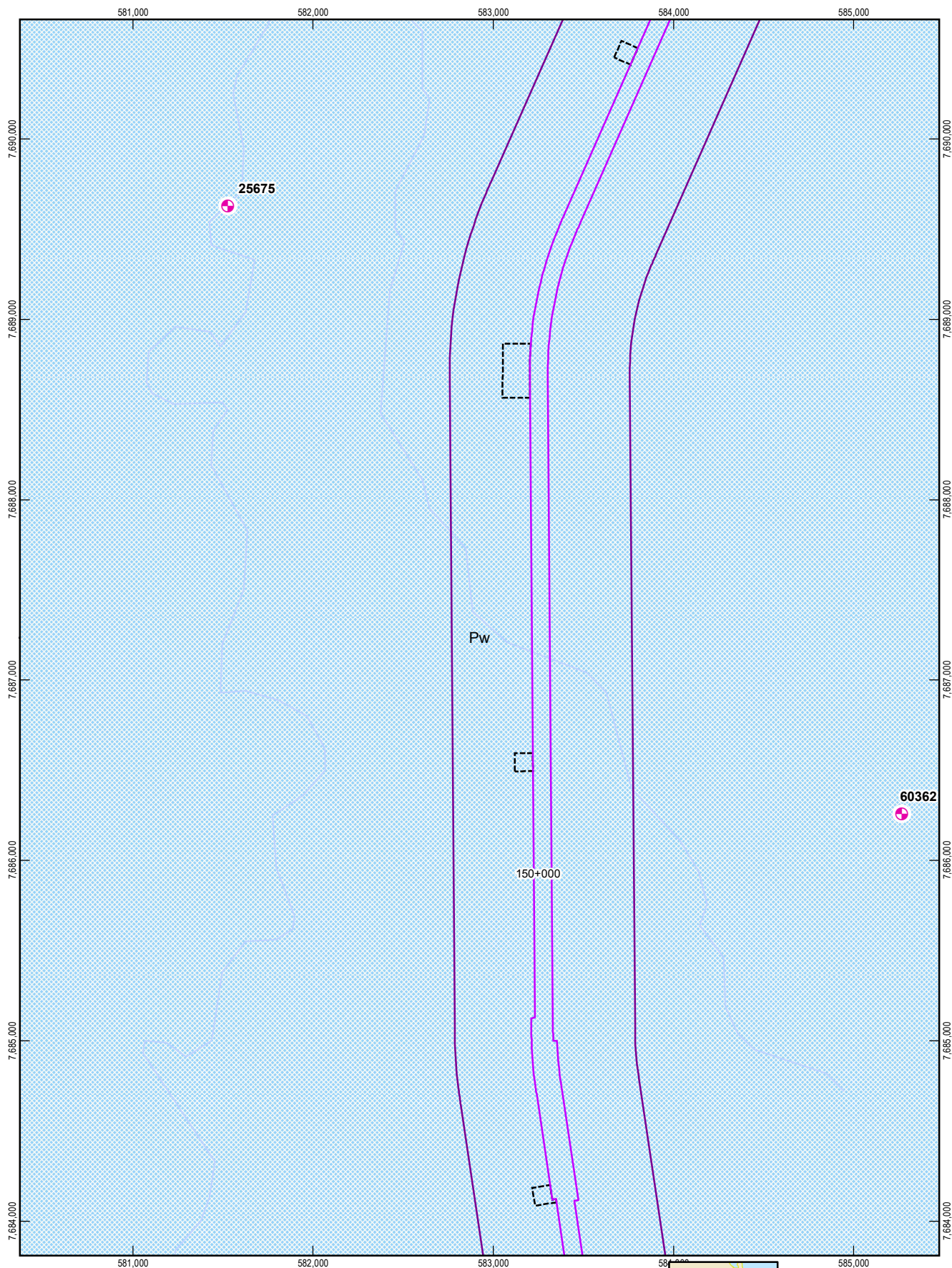
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

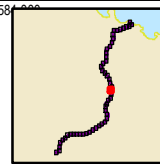
Watercourse (Minor)

Lakes

Construction Infrastructure

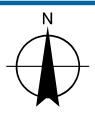
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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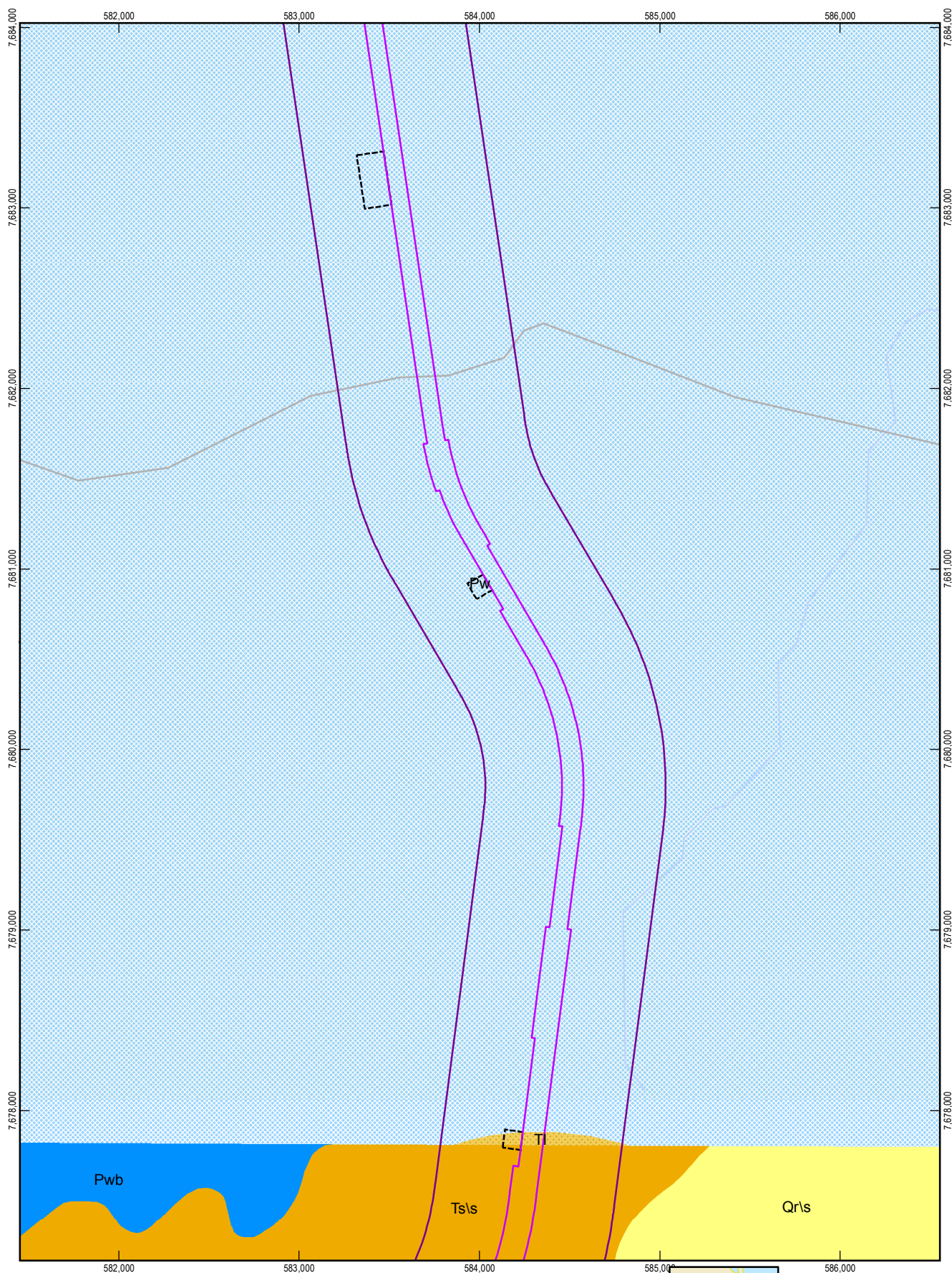
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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

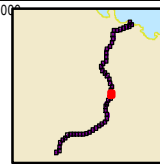
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

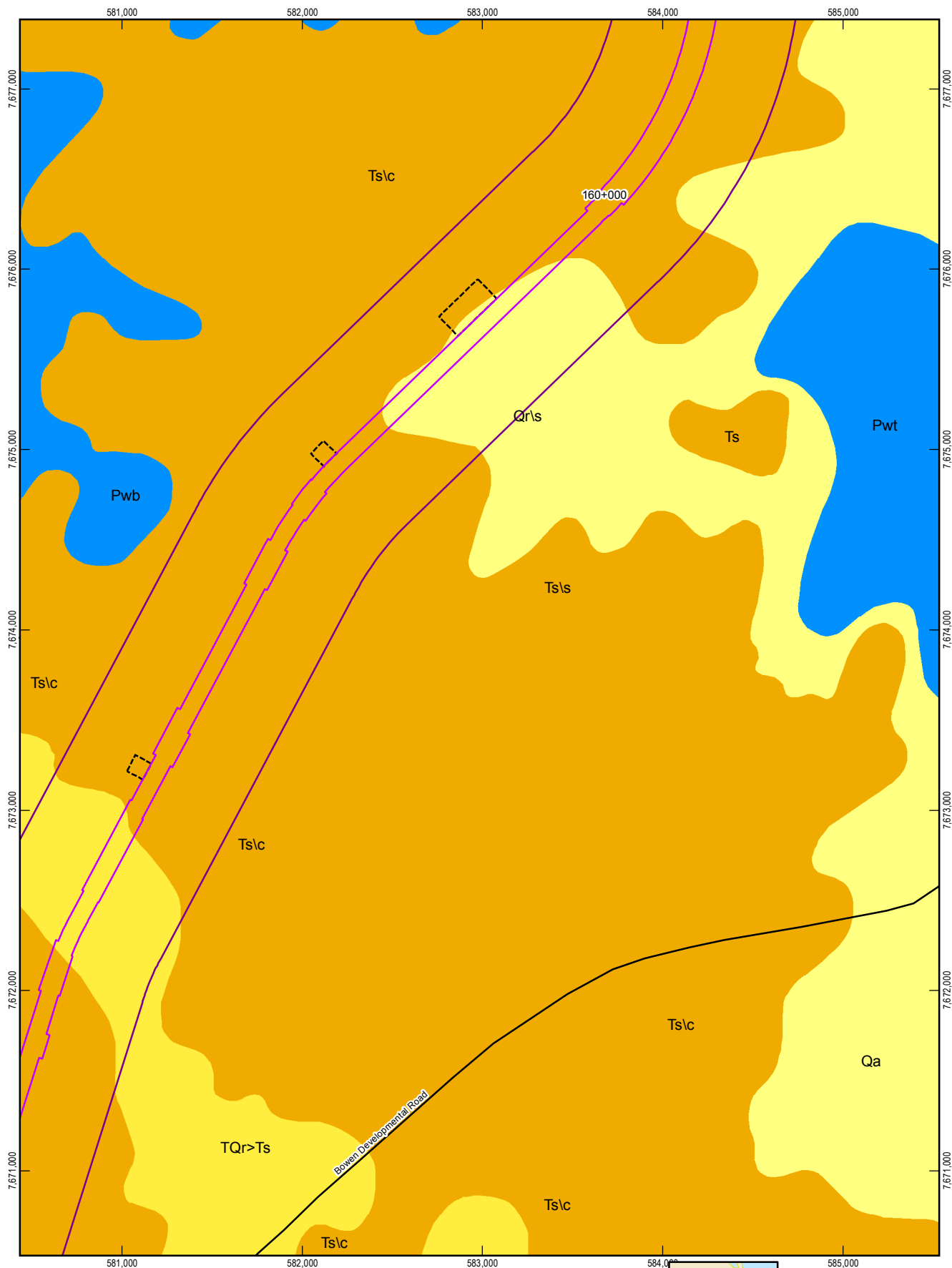
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

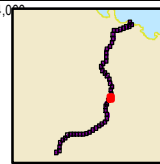
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

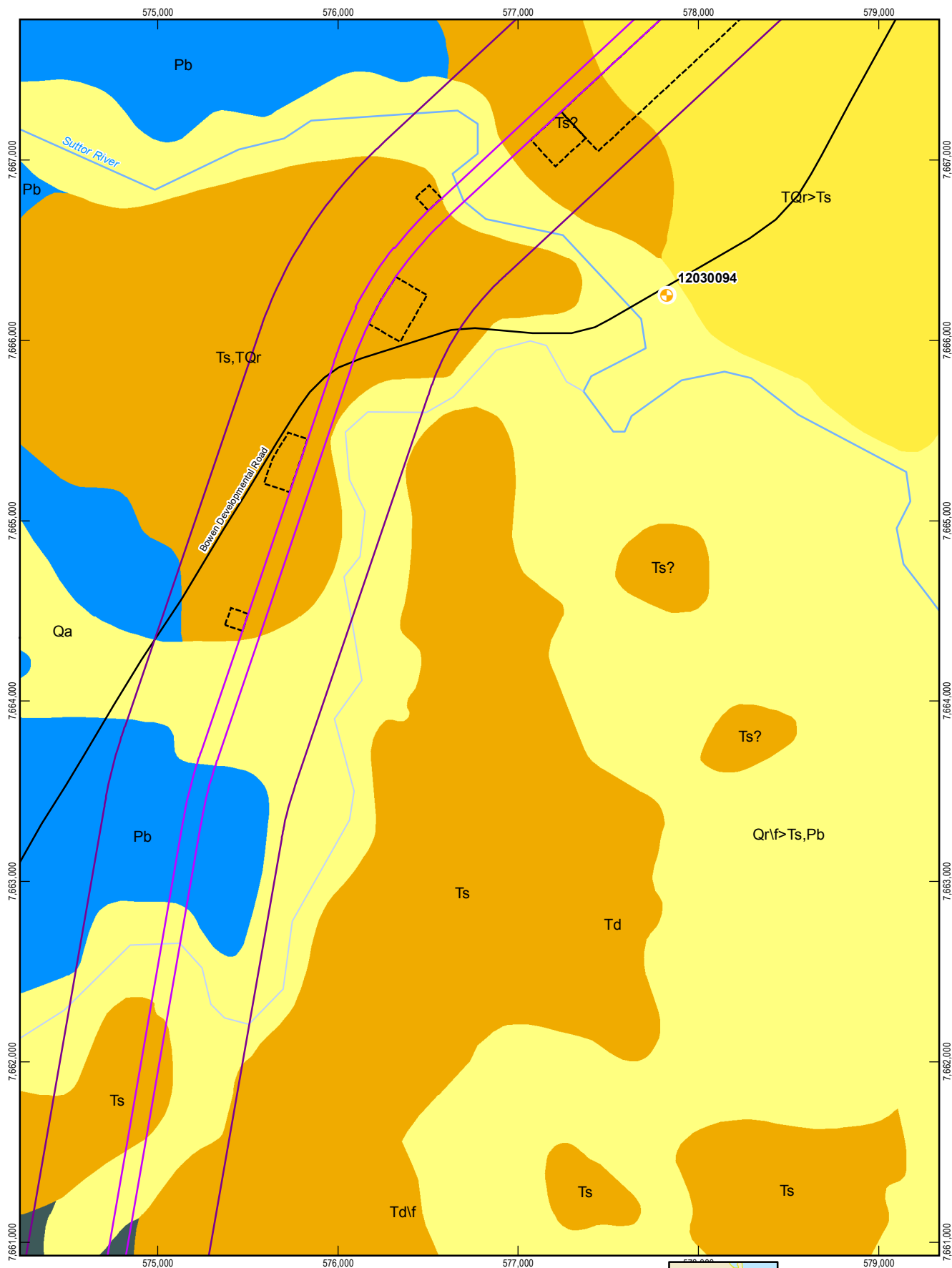
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Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

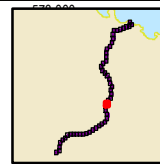
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

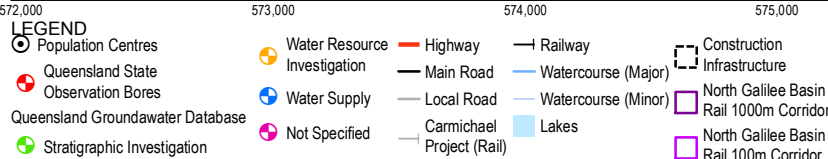
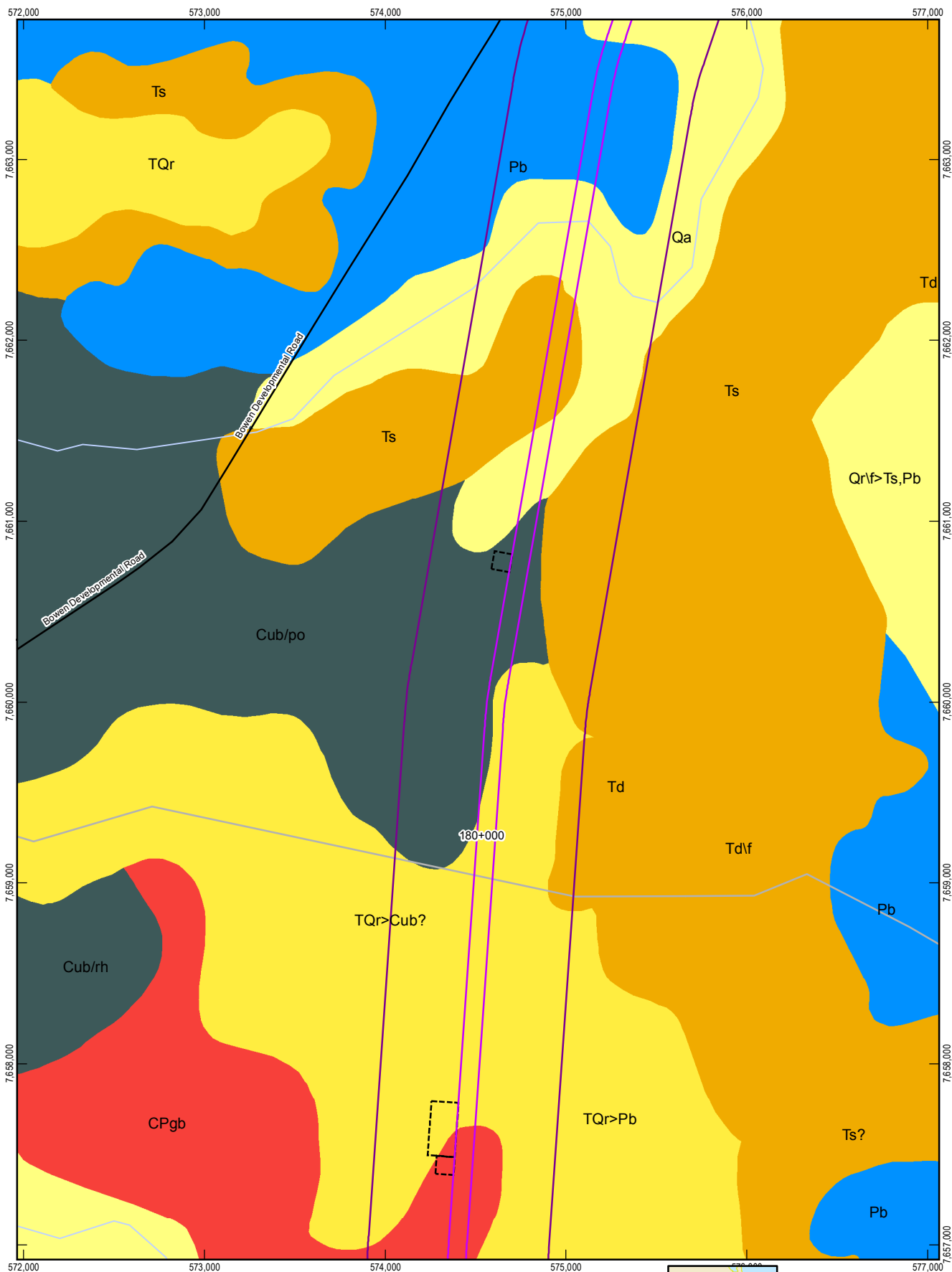
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Date 07 Aug 2013

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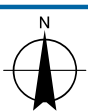
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

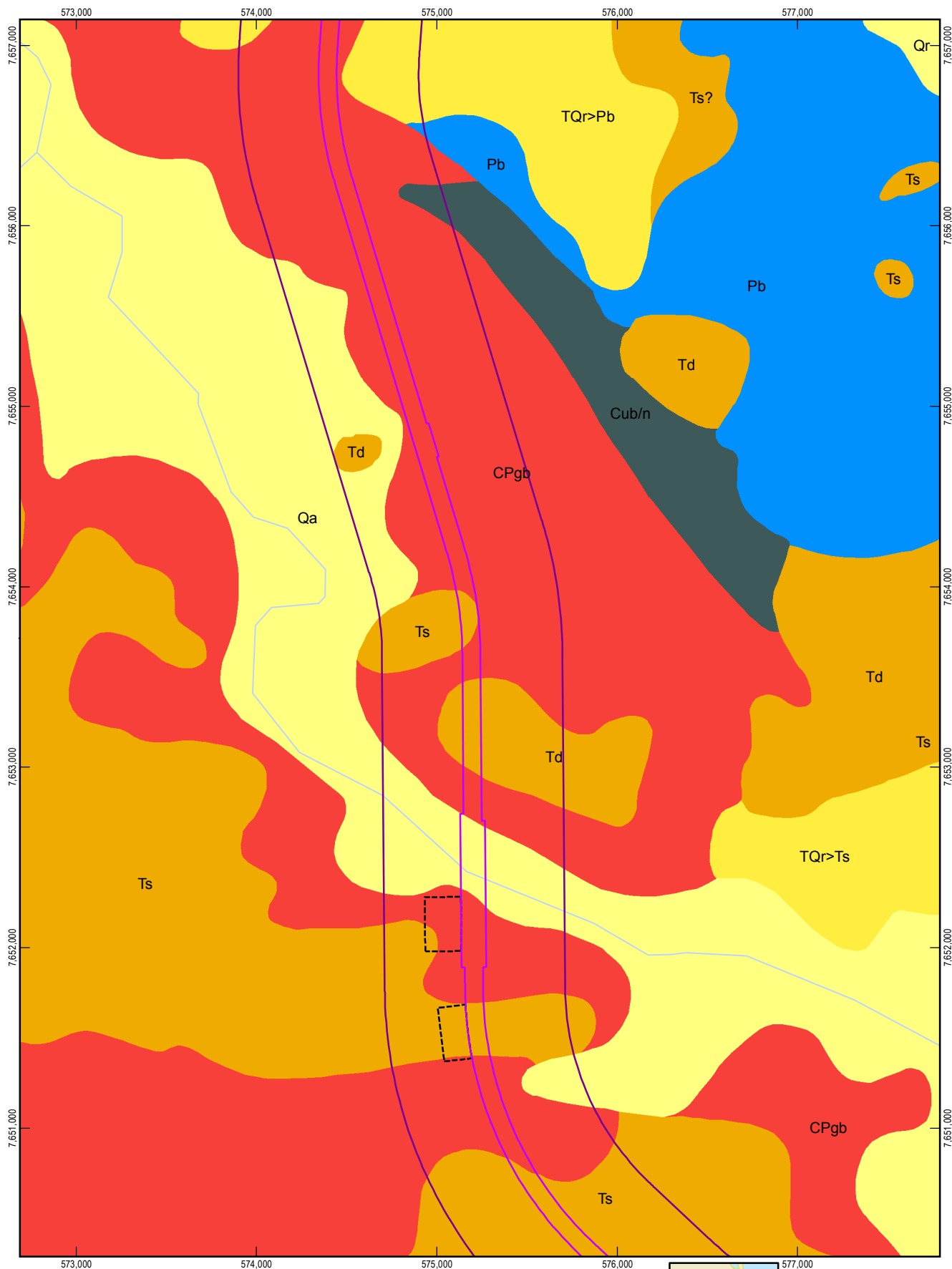
Job Number 41-26457
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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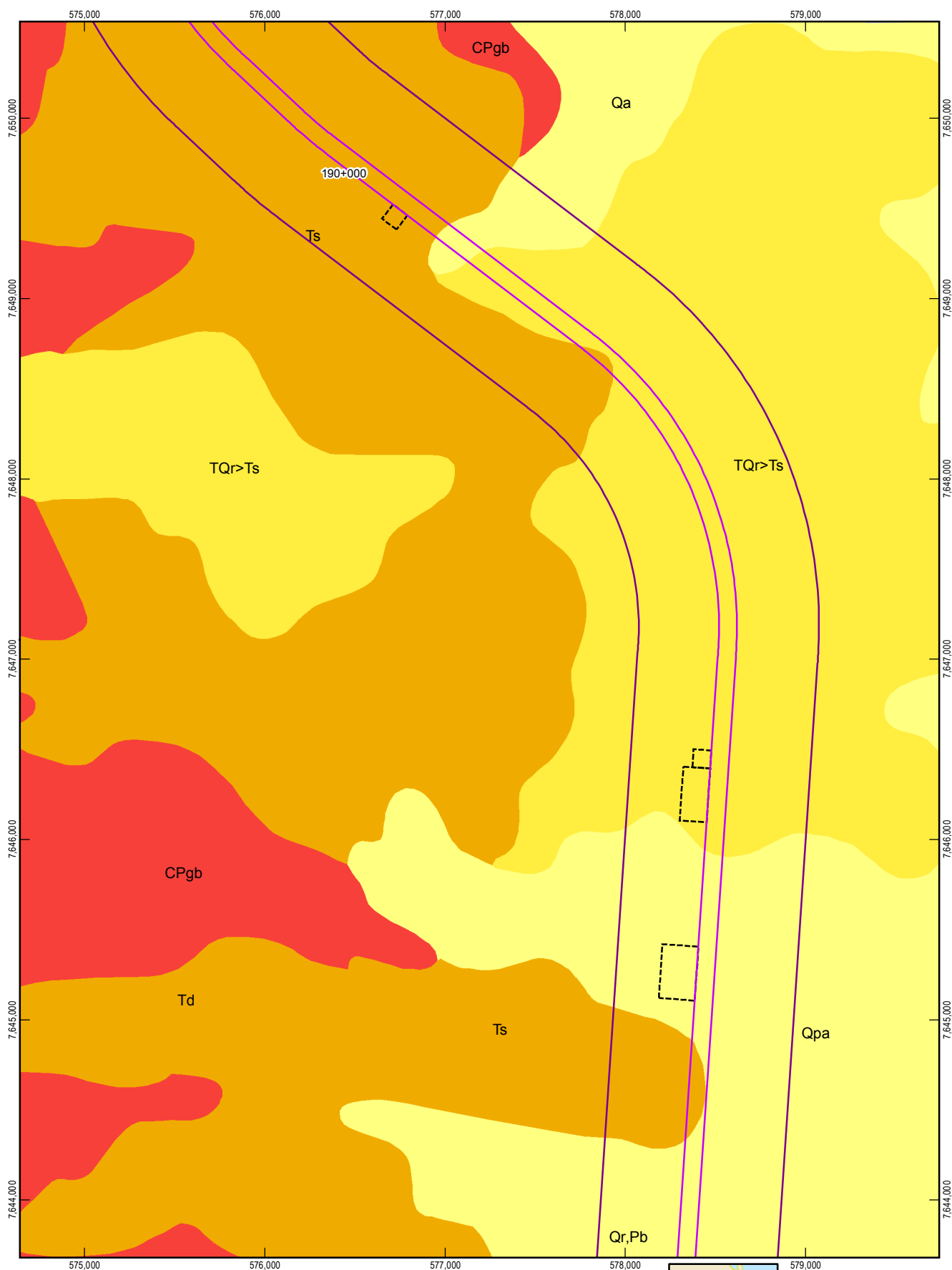
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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

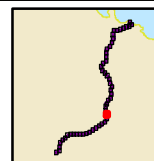
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

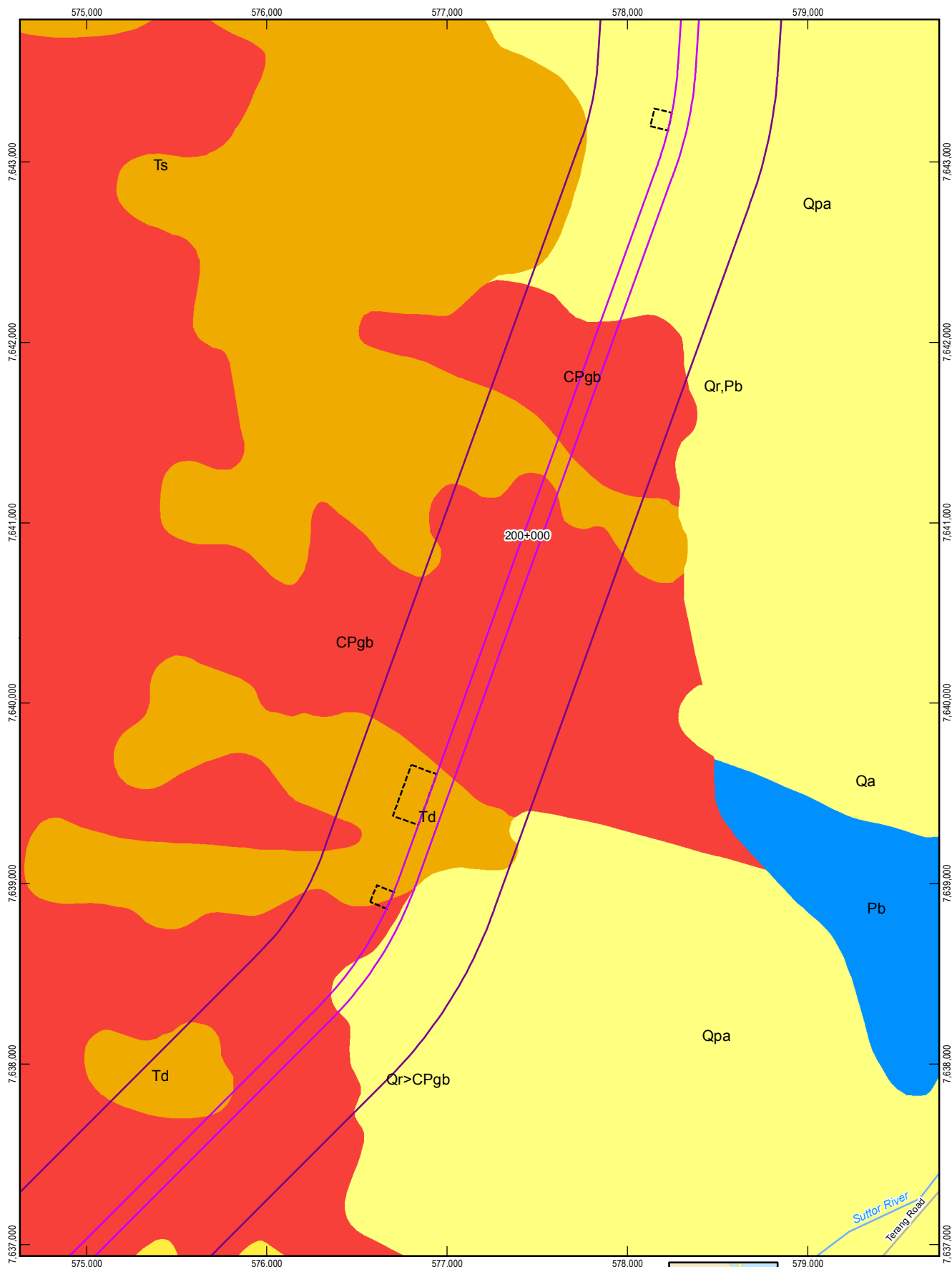
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

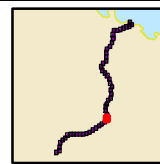
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

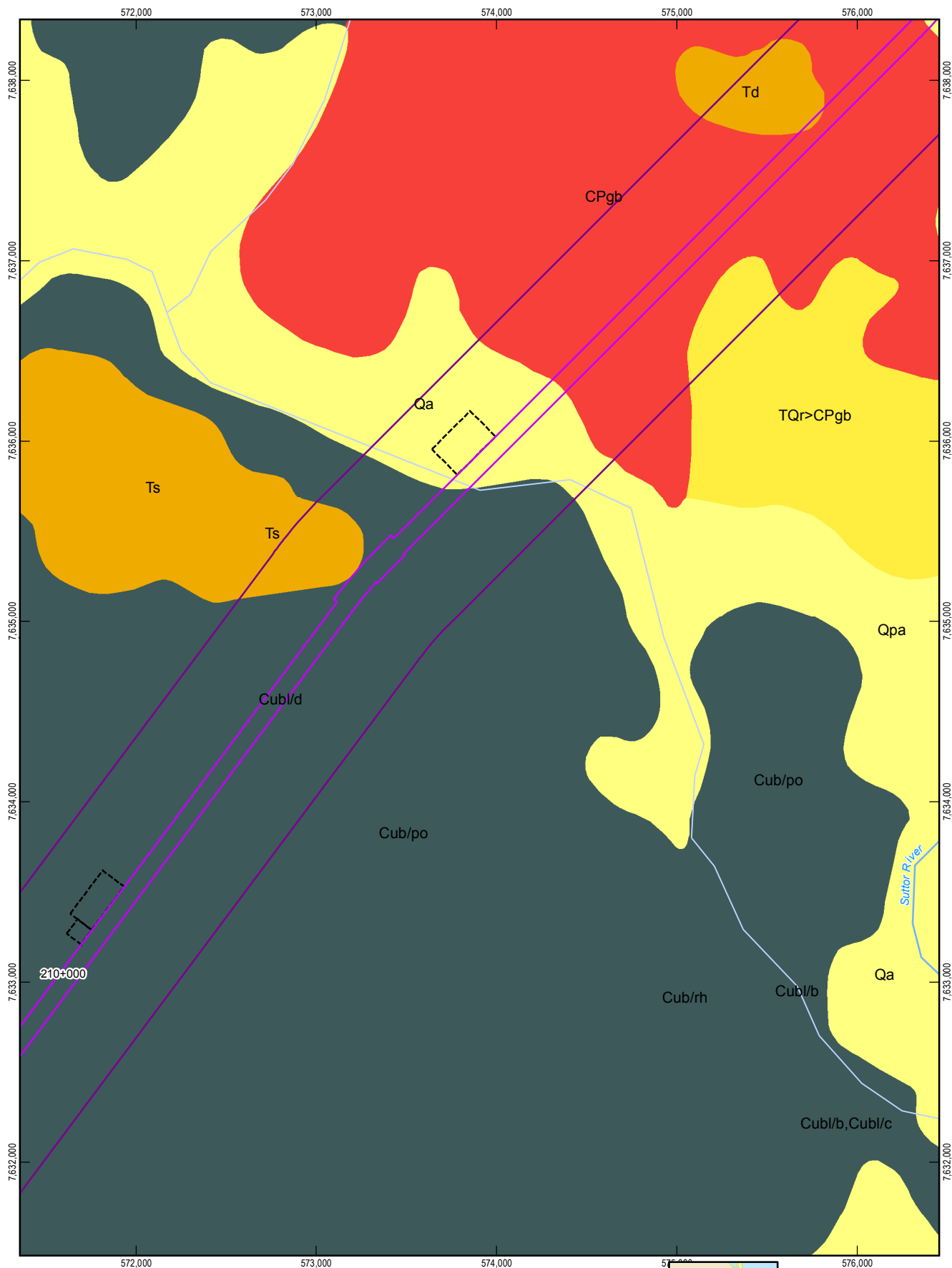
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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

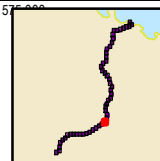
Watercourse (Minor)

Lakes

Construction
Infrastructure

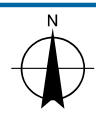
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

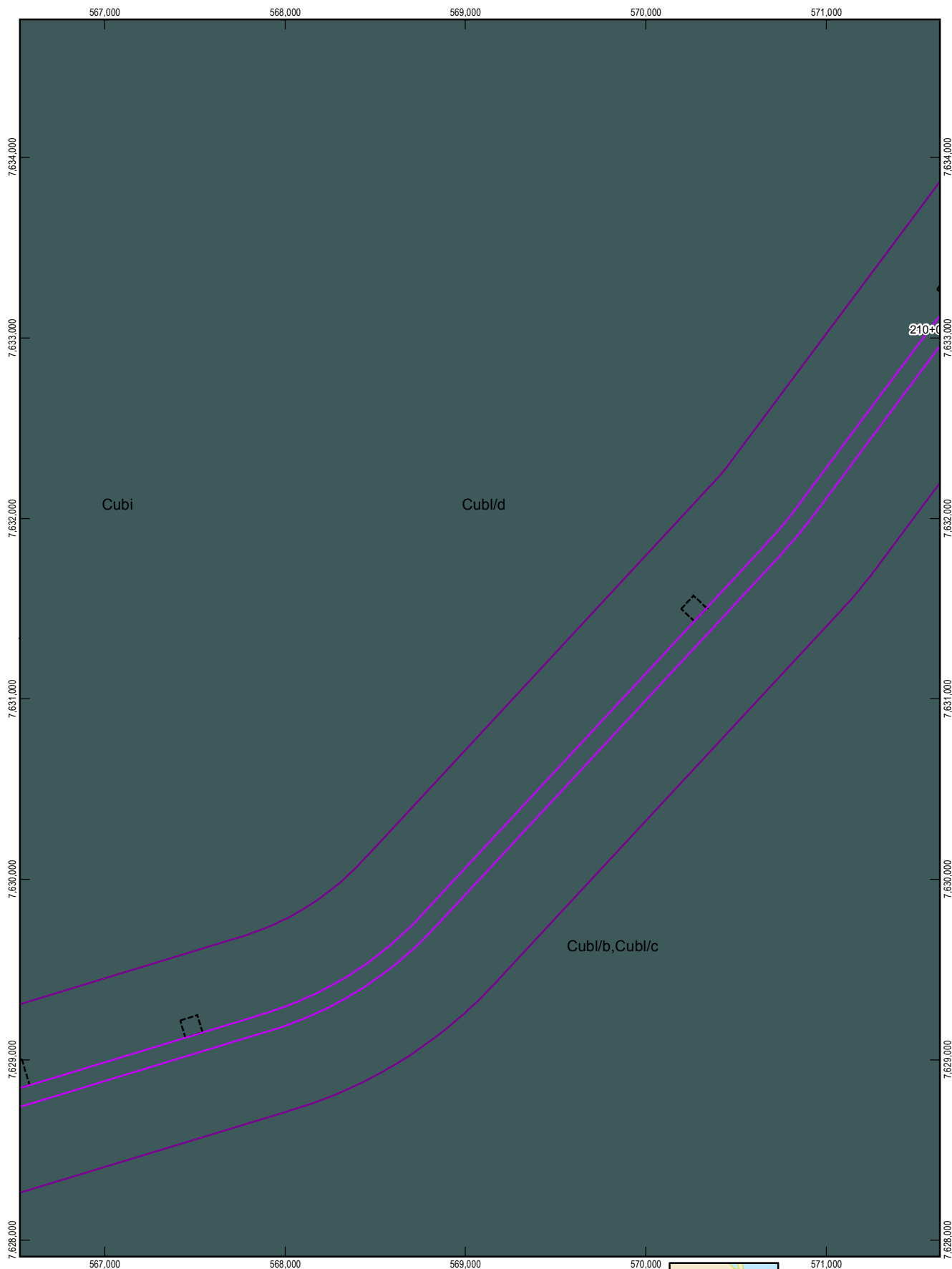
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

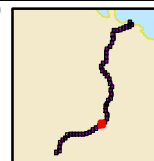
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
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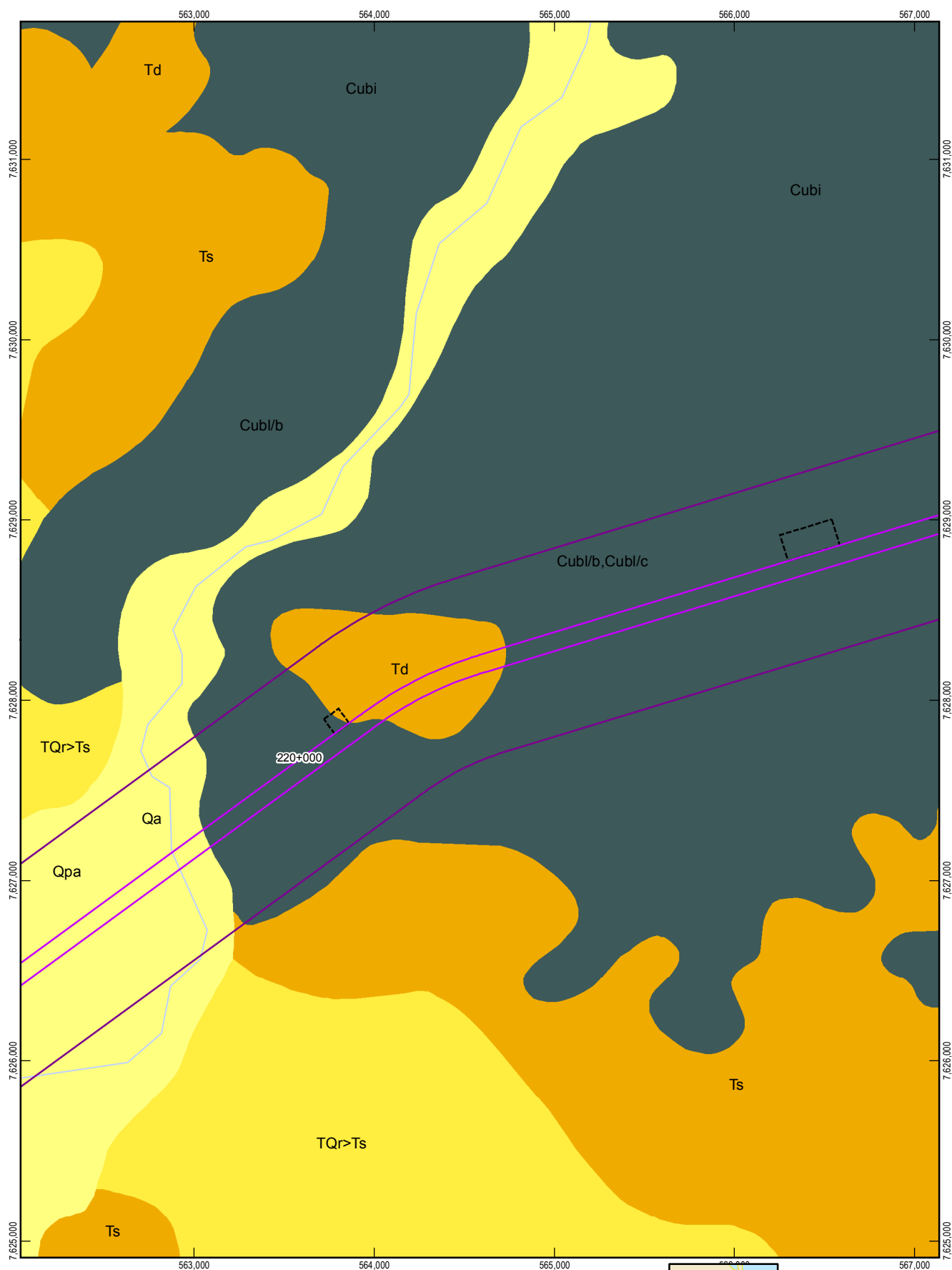
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

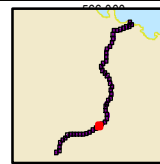
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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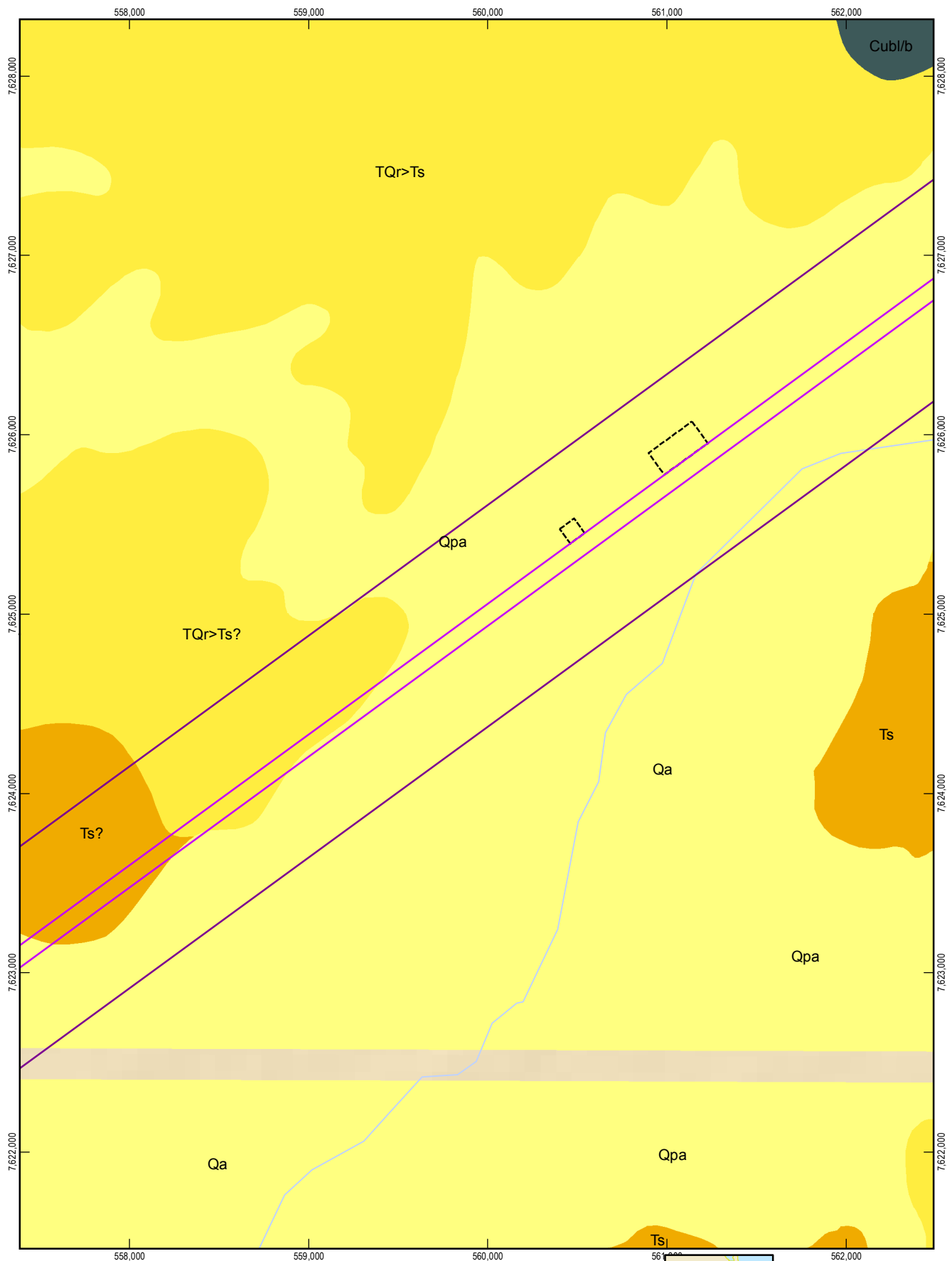
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Grid: GDA 1994 MGA Zone 55



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North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

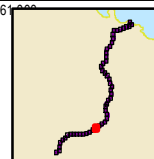
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Date 07 Aug 2013

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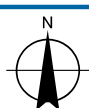
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- Population Centres
- Queensland State Observation Bores
- Queensland Groundwater Database
- Stratigraphic Investigation
- Water Resource Investigation
- Water Supply
- Not Specified
- Highway
- Main Road
- Local Road
- Carmichael Project (Rail)
- Railway
- Watercourse (Major)
- Watercourse (Minor)
- Lakes
- Construction Infrastructure
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

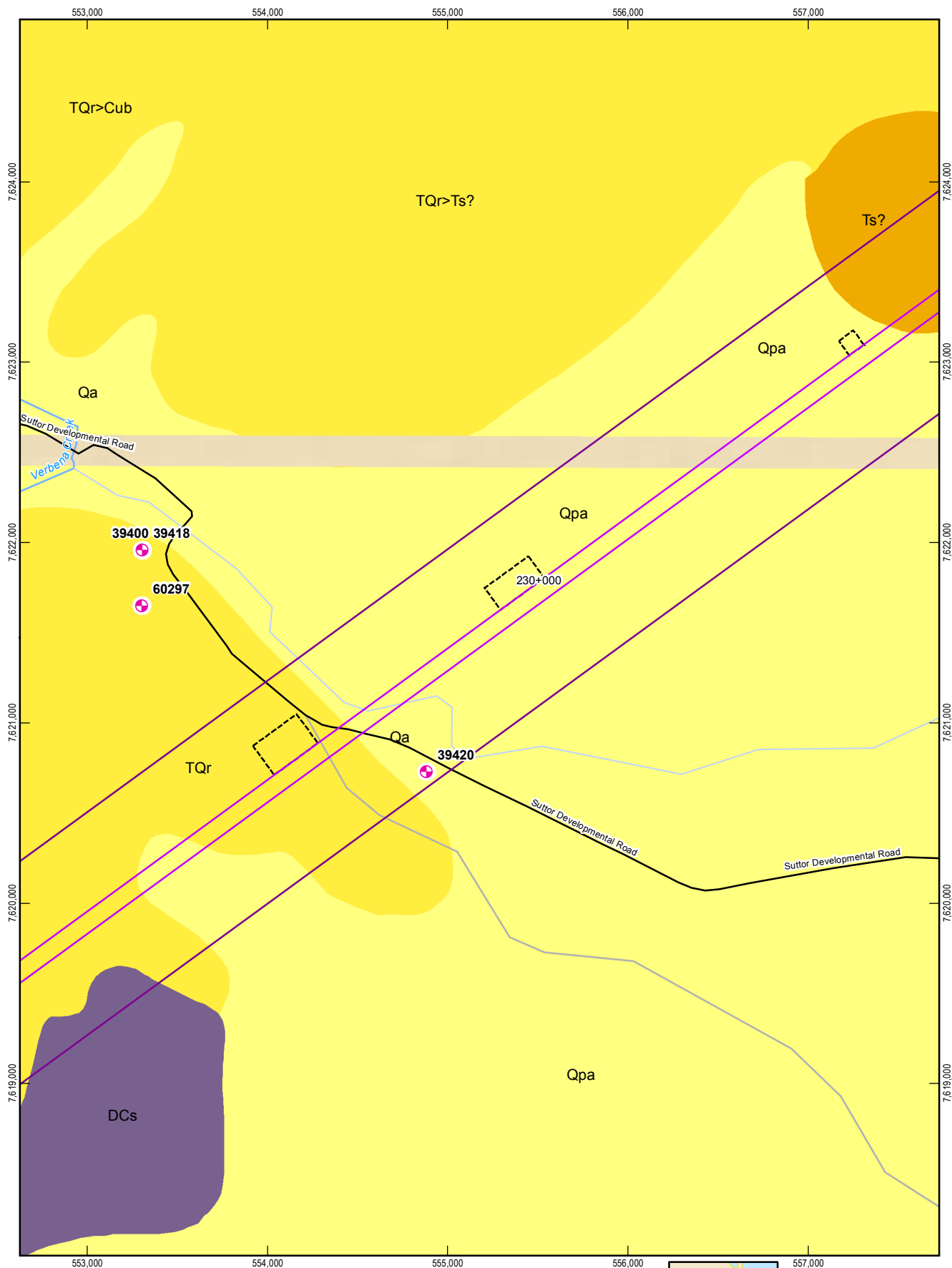
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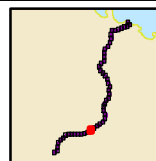
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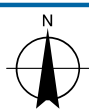
LEGEND

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|--|---|---|--|



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

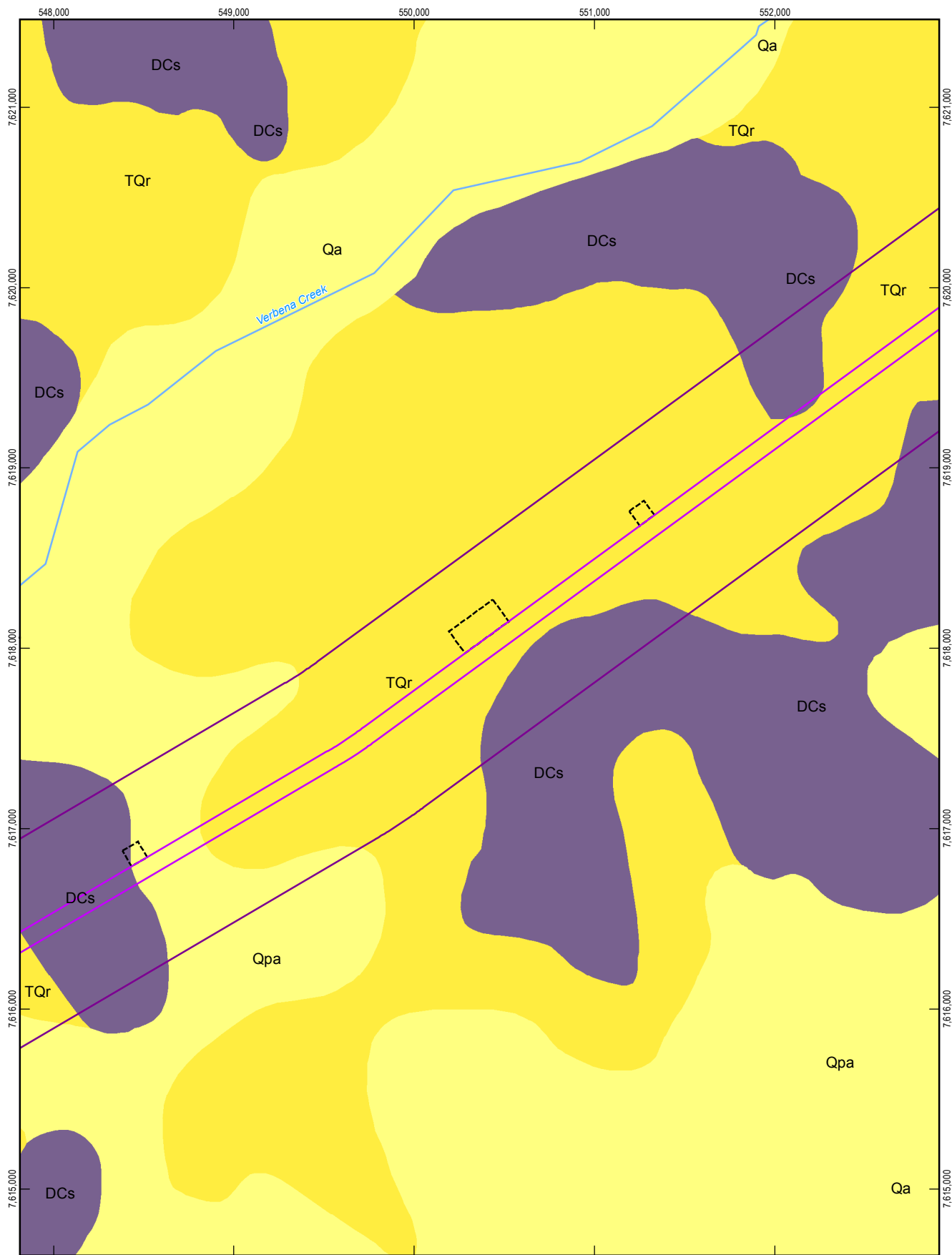
Job Number 41-26457
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Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

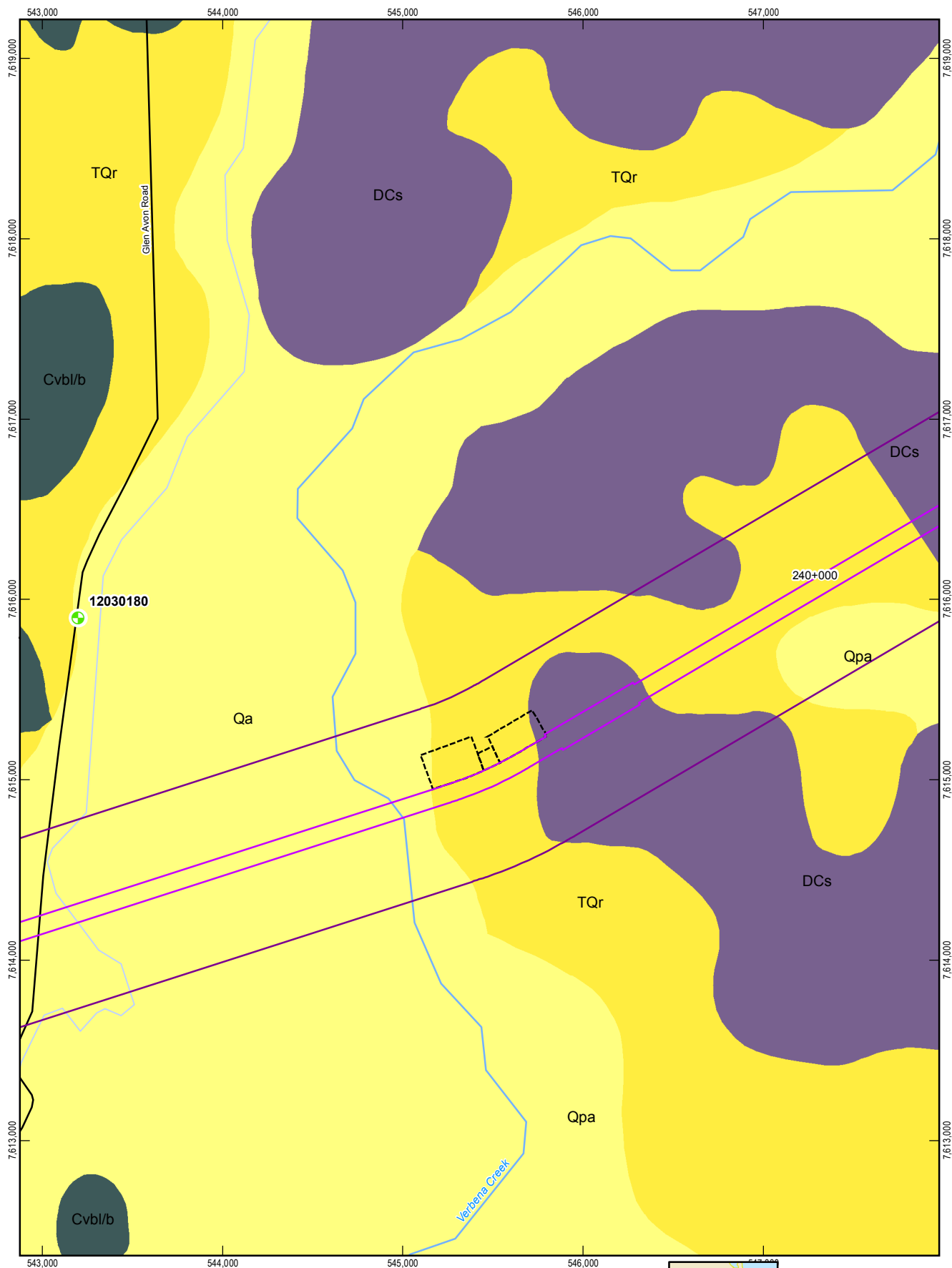
Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

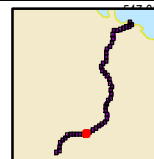
Watercourse (Minor)

Lakes

Construction
Infrastructure

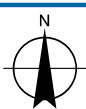
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

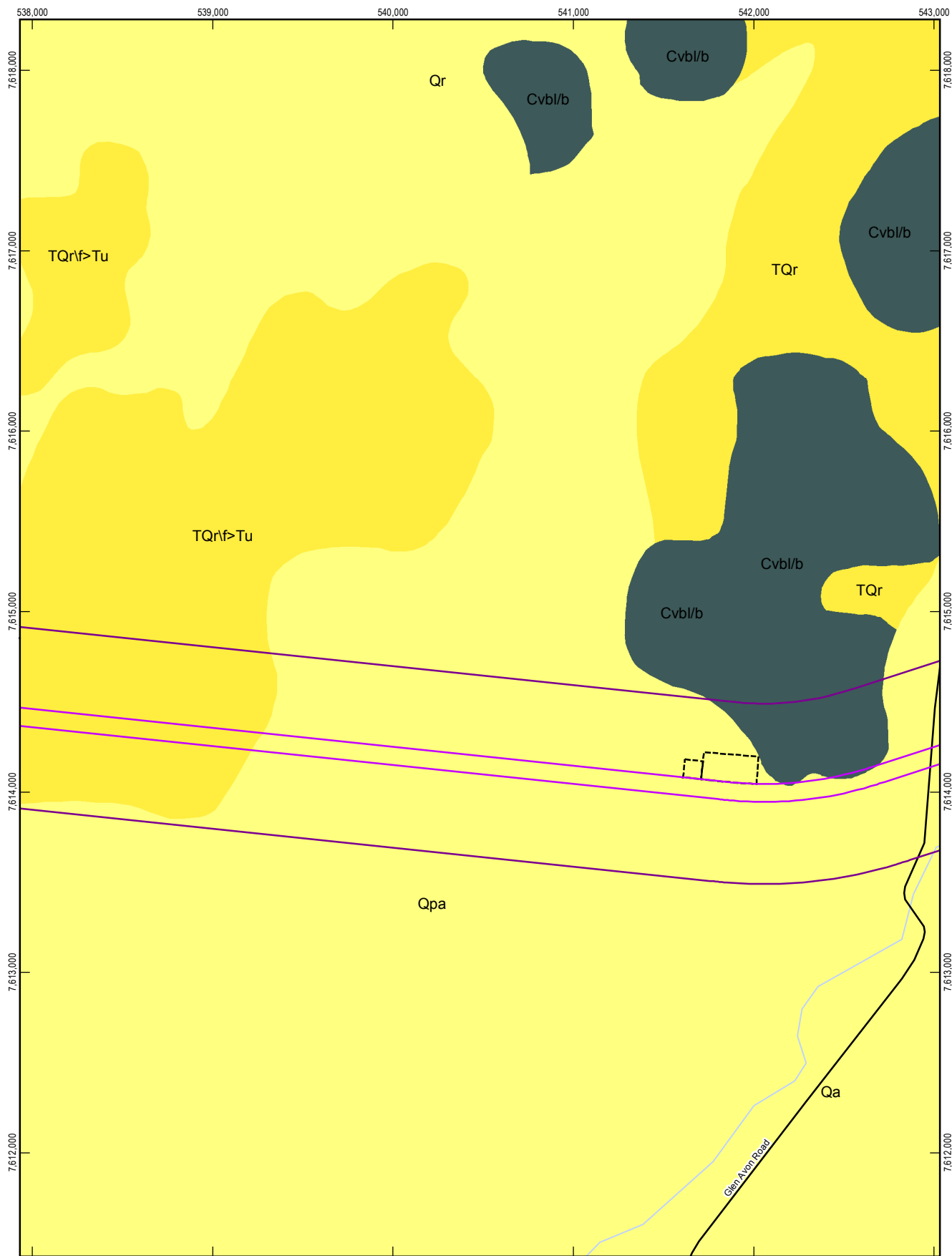
Job Number 41-26457
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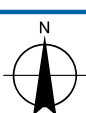


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|--|---|---|--|--|



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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

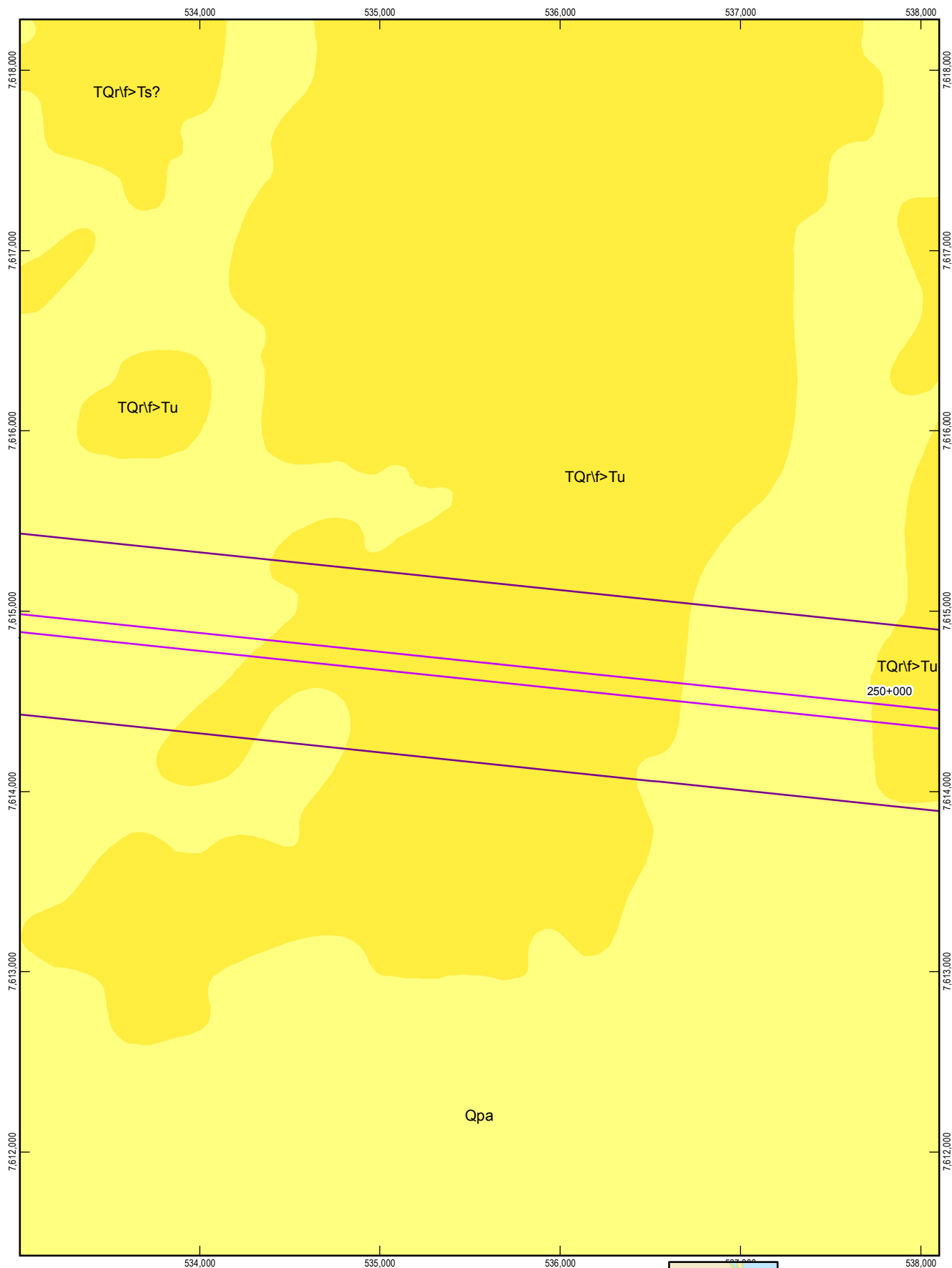
Job Number 41-26457
Revision B
Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource

Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

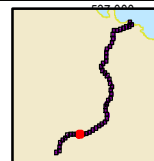
Lakes

Construction

Infrastructure

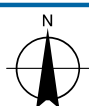
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

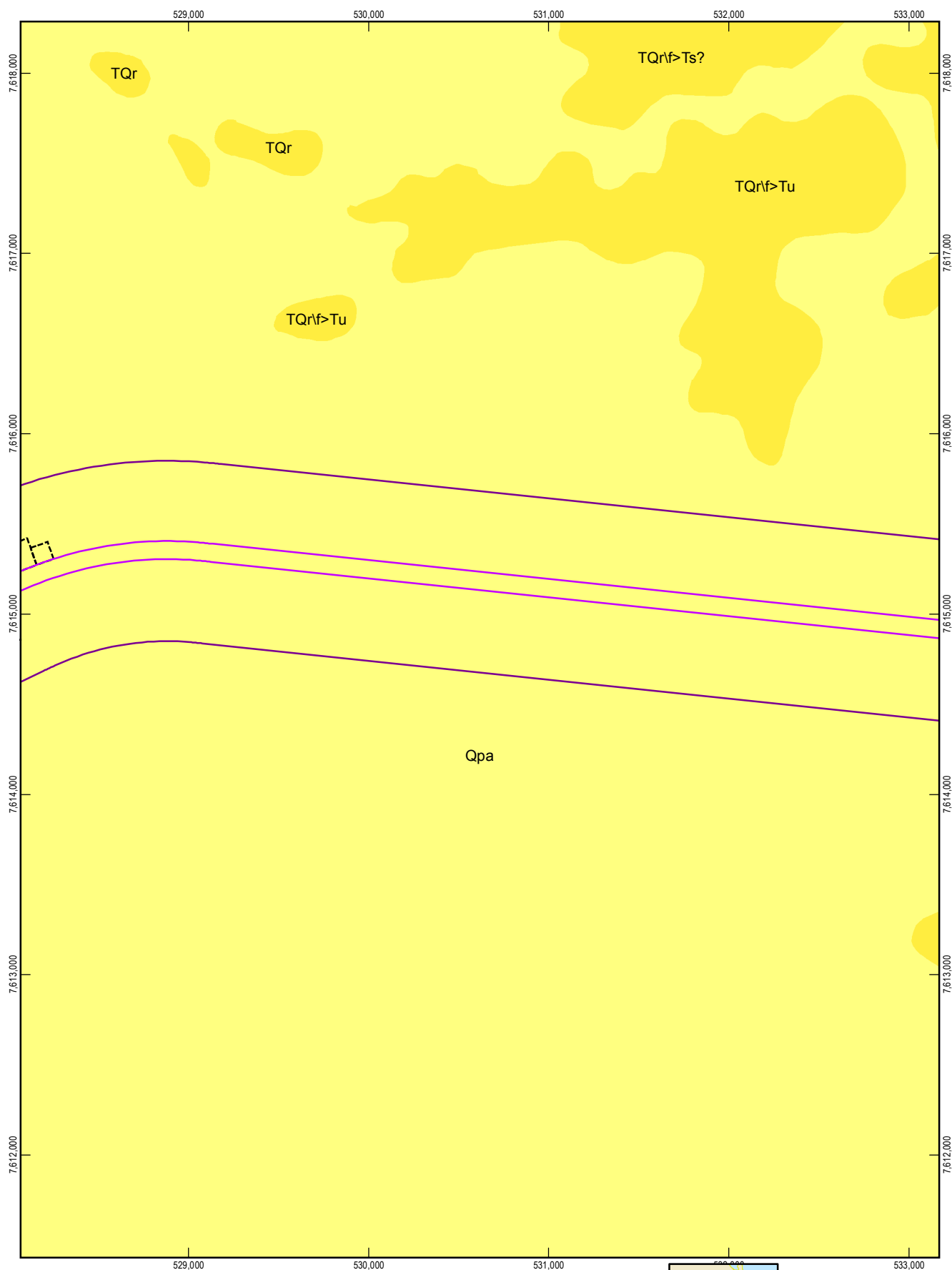
Job Number 41-26457
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Date 07 Aug 2013

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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

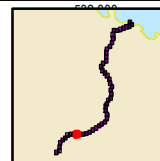
Watercourse (Minor)

Lakes

Construction
Infrastructure

North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

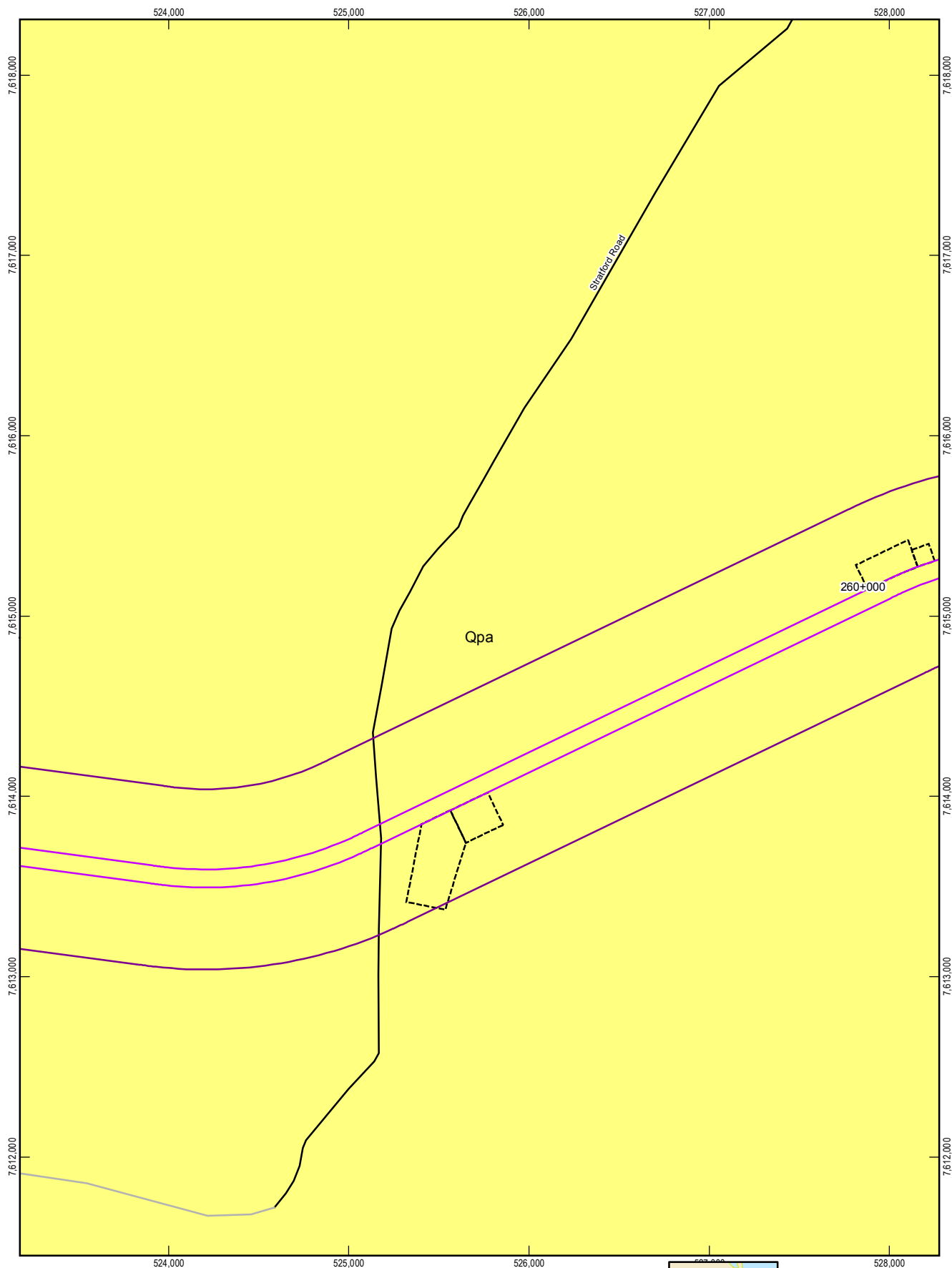
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

Watercourse (Minor)

Lakes

Construction Infrastructure

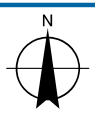
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

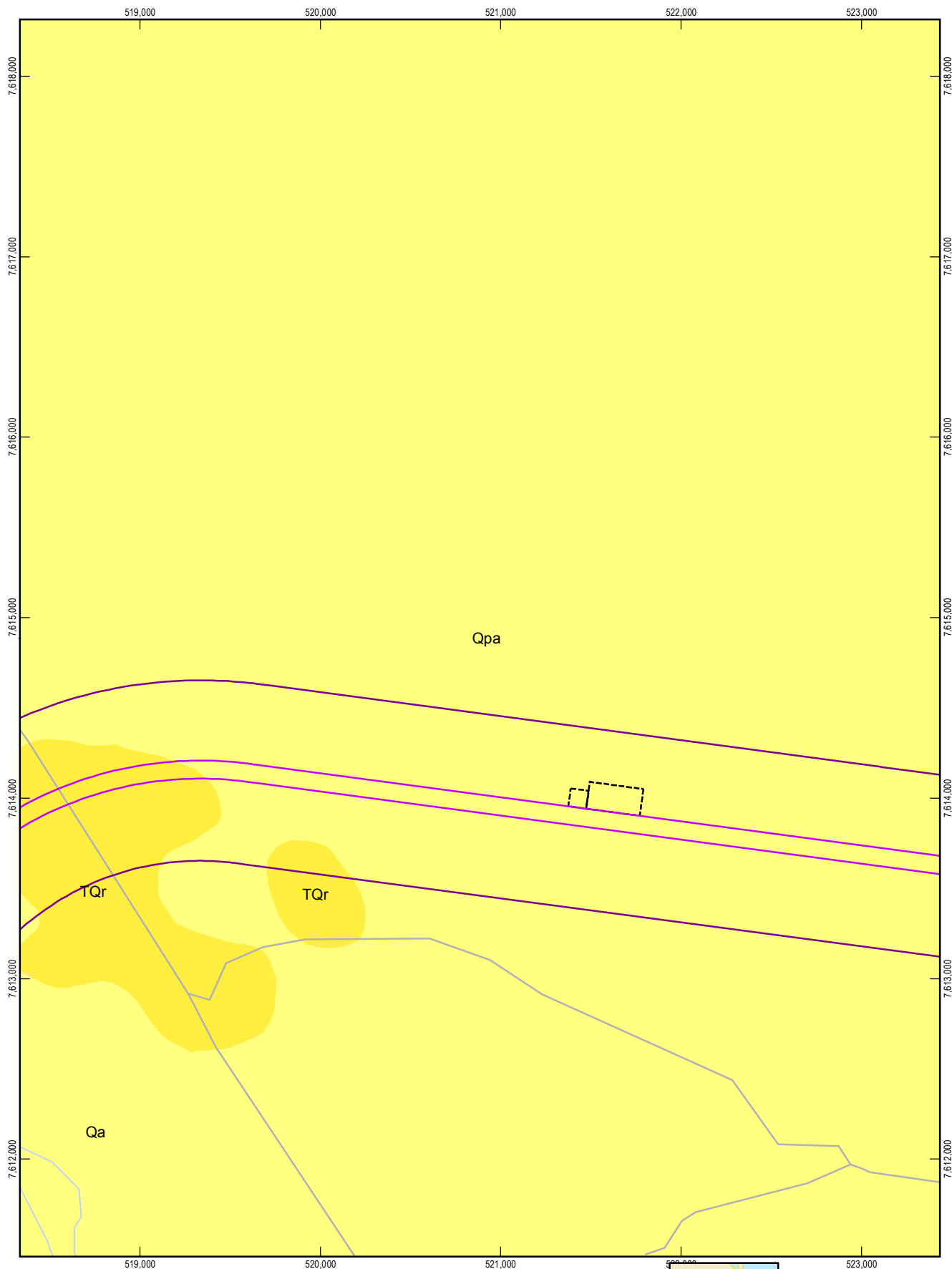
Job Number 41-26457
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

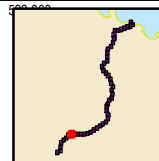
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

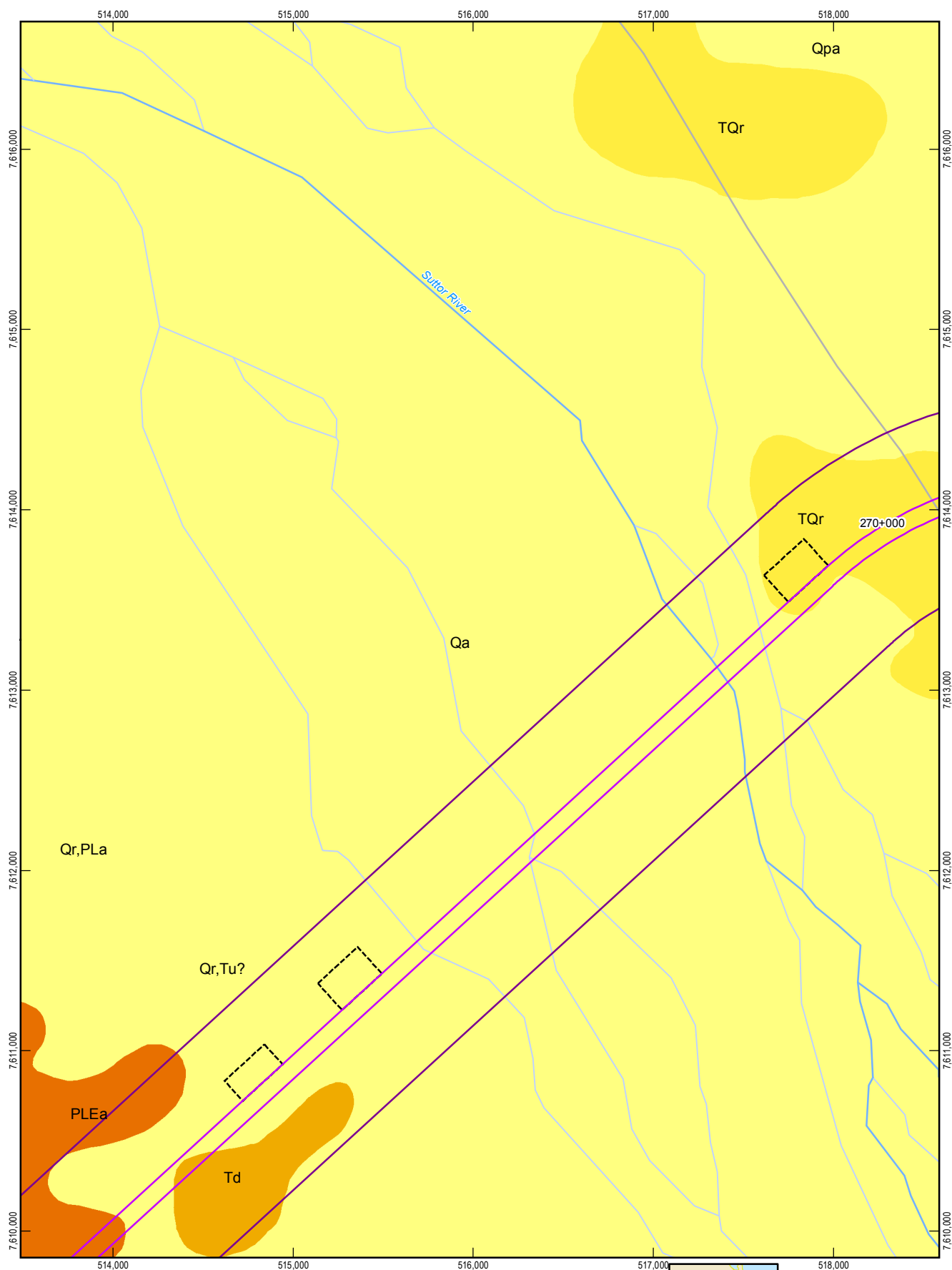
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

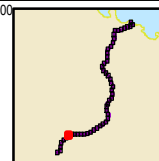
Watercourse (Minor)

Lakes

Construction Infrastructure

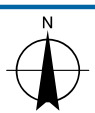
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

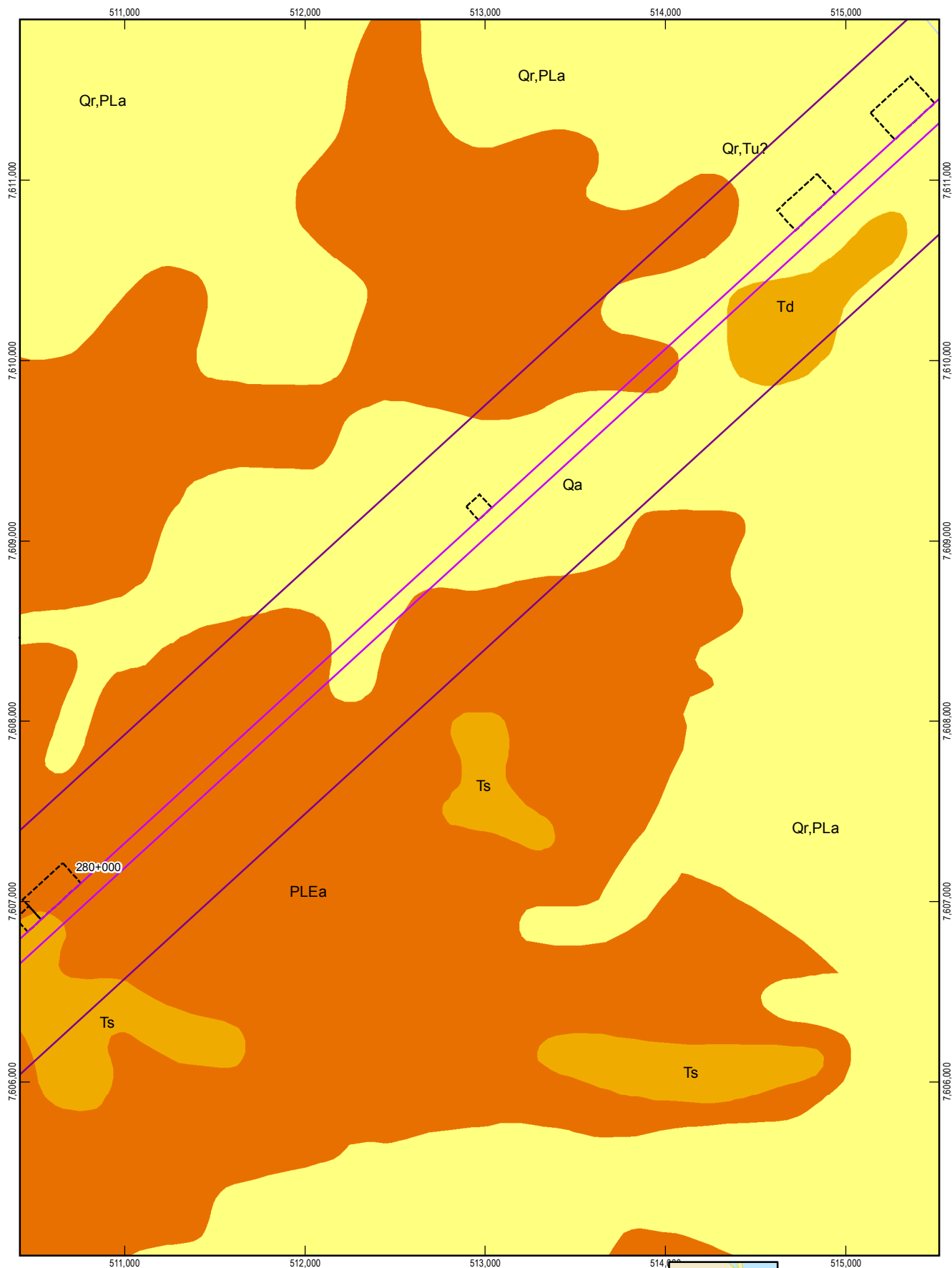
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

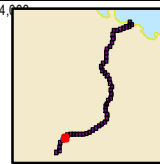
Watercourse (Minor)

Lakes

Construction Infrastructure

North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

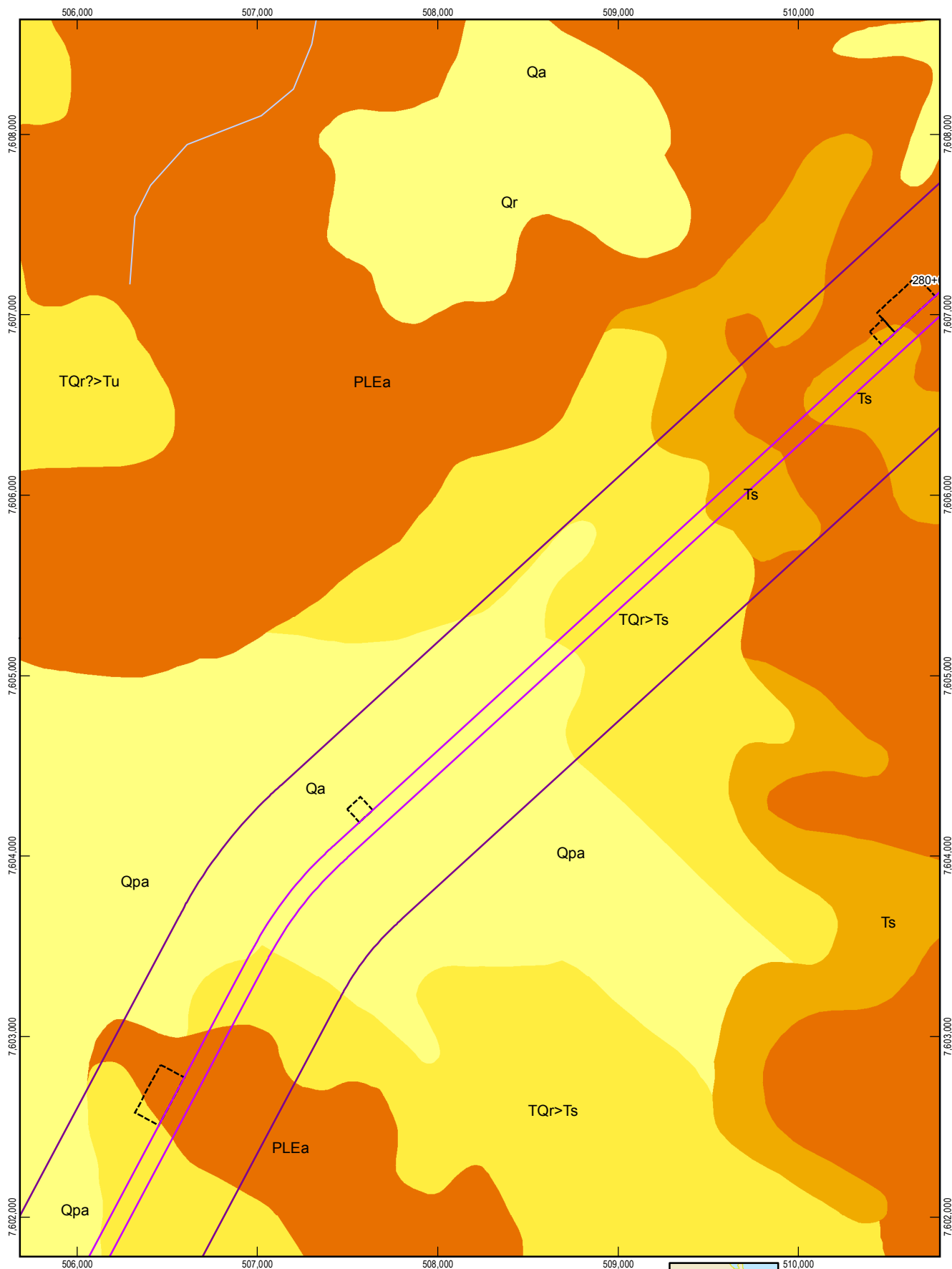
Job Number 41-26457
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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

Main Road

Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

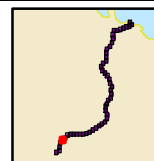
Watercourse (Minor)

Lakes

Construction
Infrastructure

North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Kilometers
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

Job Number 41-26457
Revision B
Date 07 Aug 2013

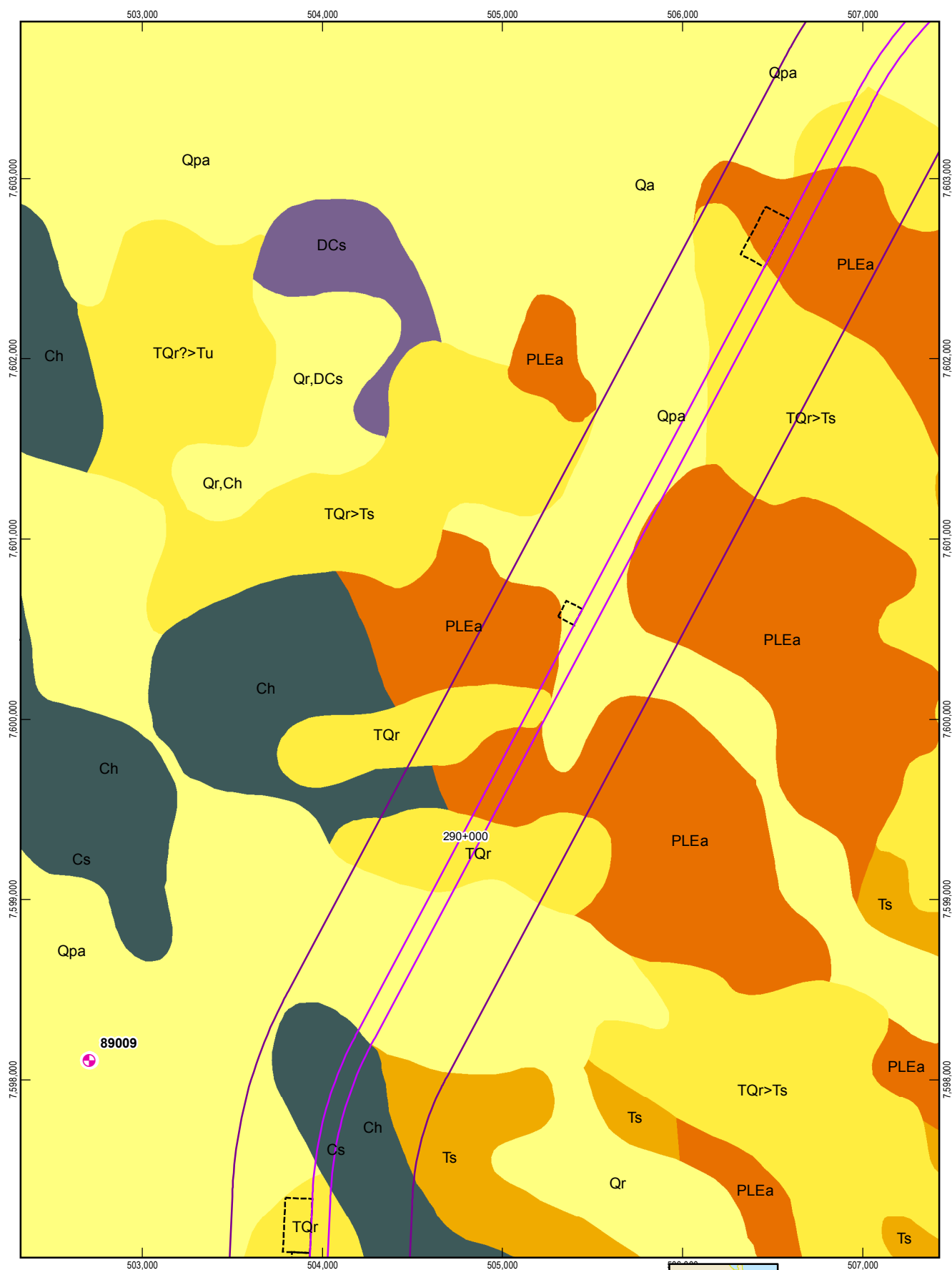
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LEGEND

Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource Investigation

Water Supply

Not Specified

Highway

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Local Road

Carmichael Project (Rail)

Railway

Watercourse (Major)

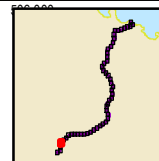
Watercourse (Minor)

Lakes

Construction Infrastructure

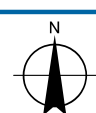
North Galilee Basin Rail 1000m Corridor

North Galilee Basin Rail 100m Corridor



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Kilometers
Map Projection: Transverse Mercator
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
and Groundwater Observation
Bore Plan

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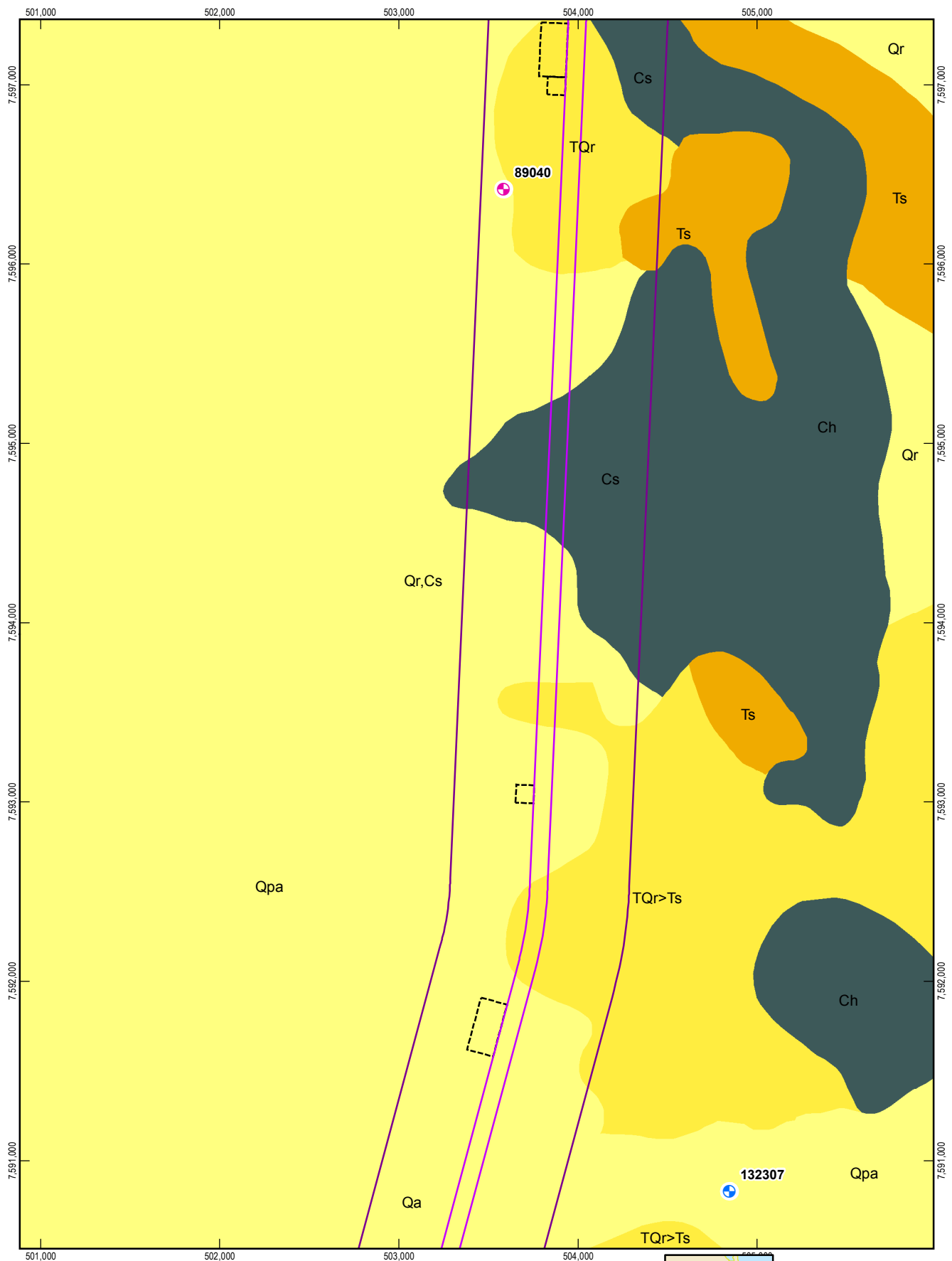
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LEGEND

Population Centres

Queensland State
Observation Bores

Queensland Groundwater Database

Stratigraphic Investigation

Water Resource
Investigation

Water Supply

Not Specified

Highway

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Local Road

Carmichael
Project (Rail)

Railway

Watercourse (Major)

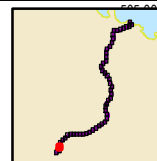
Watercourse (Minor)

Lakes

Construction
Infrastructure

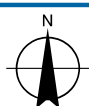
North Galilee Basin
Rail 1000m Corridor

North Galilee Basin
Rail 100m Corridor



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Kilometers
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Adani Mining Pty Ltd
North Galilee Basin Rail Project
Borehole Location (GWDB)
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Bore Plan

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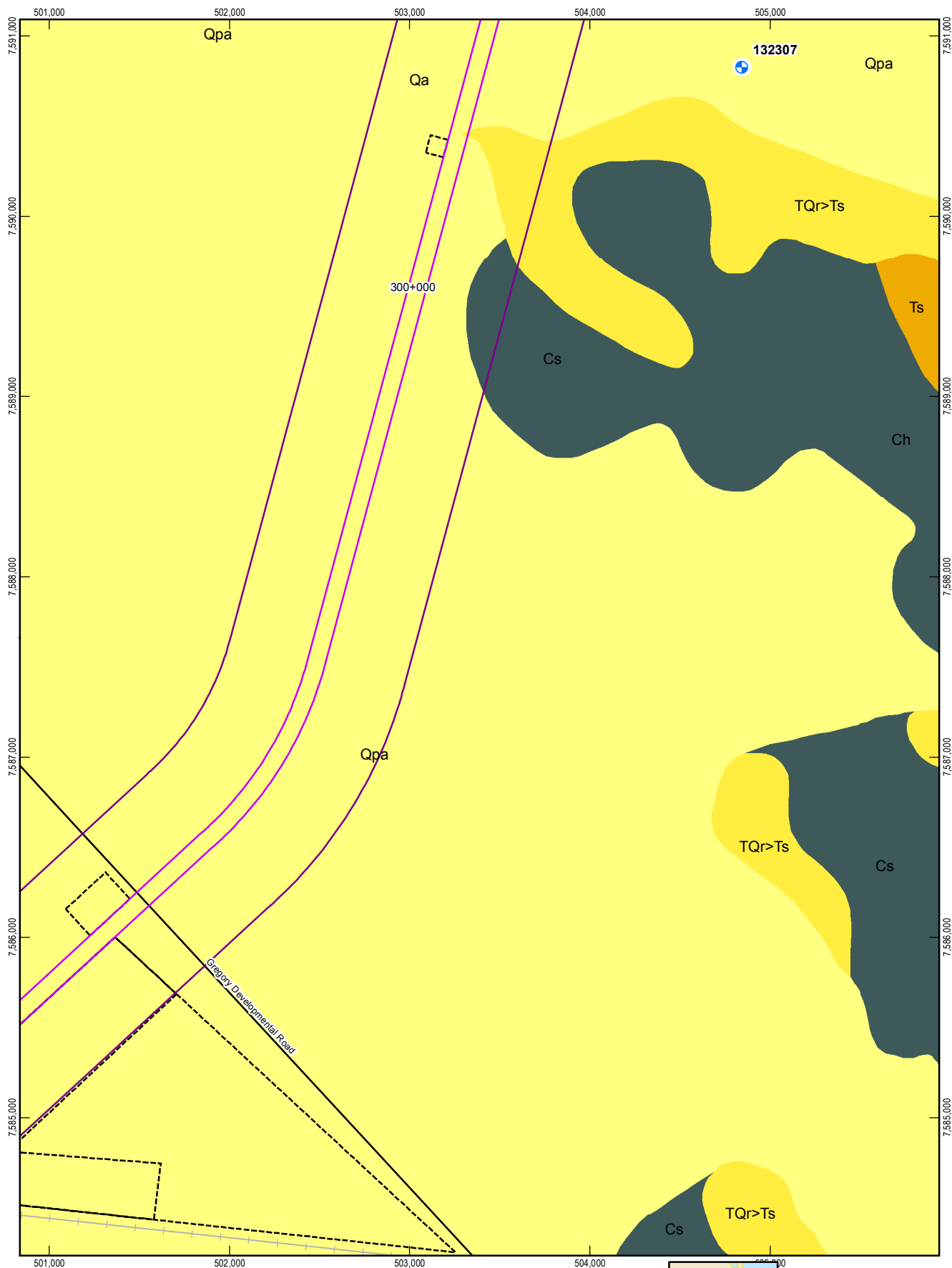
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Population Centres

Queensland State Observation Bores

Queensland Groundwater Database

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Water Resource Investigation

Water Supply

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Highway

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Watercourse (Major)

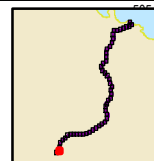
Watercourse (Minor)

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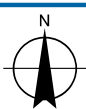
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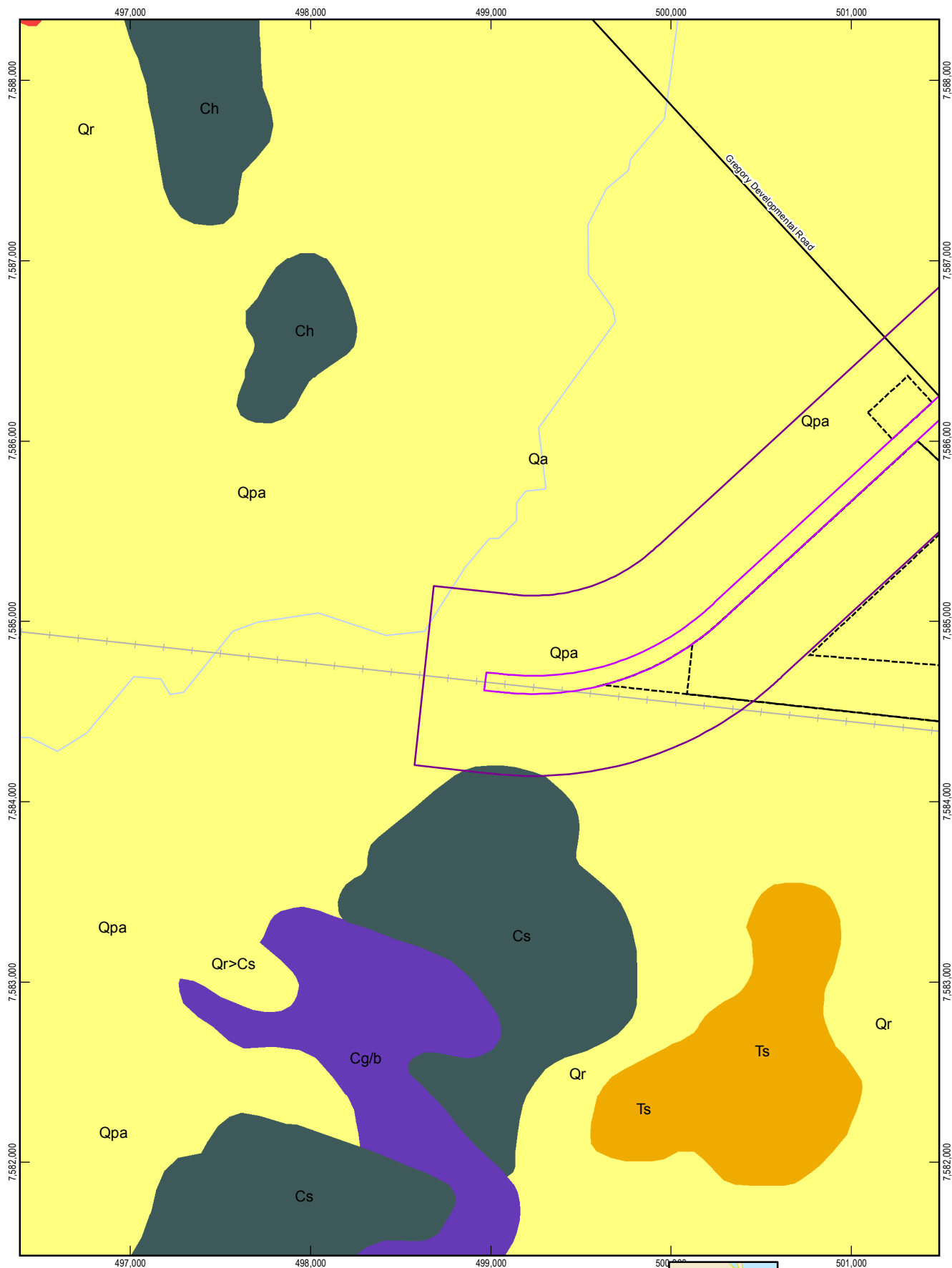
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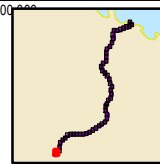
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North Galilee Basin Rail 100m Corridor



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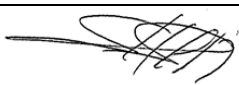
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		Name	Signature	Name	Signature	Date
Draft	SR, SC, SC	Sjors Hein		Phil Bradley		1/07/13
0	SR, SC, SC	Sjors Hein		Phil Bradley		17/07/13

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