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Adani Mining Pty Ltd

NORTH GALILEE BASIN RAIL PROJECT

Environmental Impact Statement

Chapter 9 Water resources

November 2013

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9. Water resources

9.1 Purpose of chapter

The purpose of this chapter is to assess the potential impacts of the North Galilee Basin Rail Project (NGBR Project) on water resources, including surface water and groundwater. It includes an overview of the existing environment, consideration of potential construction and operation impacts, and the identification of proposed mitigation and management measures. A detailed existing environment report for surface and groundwater resources, including water quality and water use, was prepared and is provided in Volume 2 Appendix H1 Water resources. A detailed hydrology and hydraulic investigation as well as a construction water supply strategy were also prepared for the NGBR Project and are provided in Volume 2 Appendix H2 Hydrology and hydraulics and Volume 2 Appendix H3 Construction water supply strategy - respectively.

The water resource values that are considered in this chapter include:

- Surface water flow
- Flood regime
- Surface water quality
- Water use
- Groundwater.

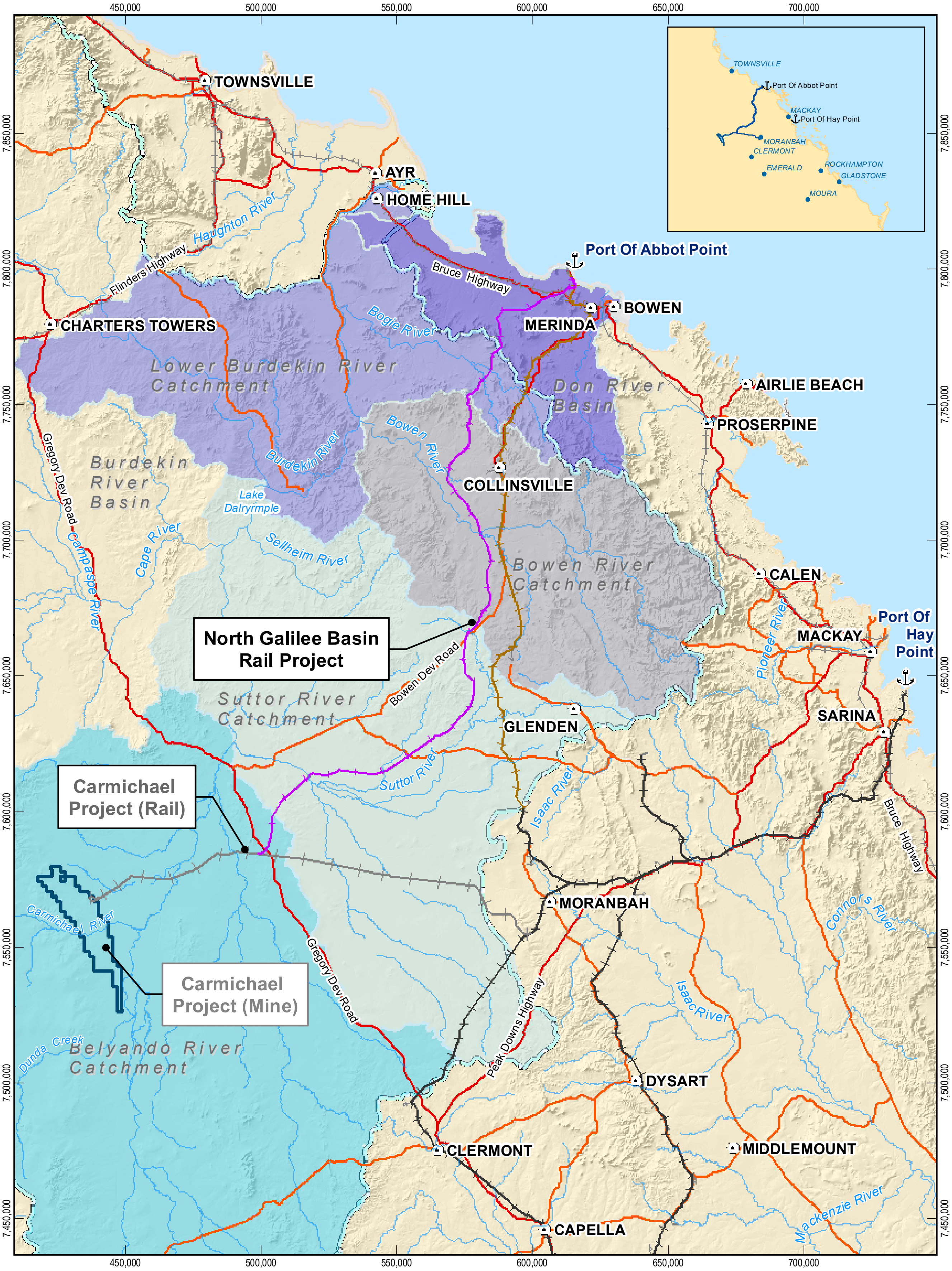
This water resources chapter was prepared in accordance with the Terms of Reference (TOR) for the NGBR Project. A table that cross-references the contents of this chapter and the TOR is included as Volume 2 Appendix A Terms of Reference cross-reference.

All mitigation and management measures identified within this chapter are included within Volume 2 Appendix P Environmental management plan framework.

9.2 Methodology

9.2.1 Study area

For the purpose of this chapter, 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 9-1). 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. A 15 km section at the southern end of the preliminary investigation corridor intersects the Belyando River catchment (within the Burdekin Basin) however no major watercourses are crossed in this catchment.



LEGEND

- Major Port
- Other Rail Network
- Goonyella System
- Newlands System
- Watercourse (Major)
- Road

Major Drainage Areas

- Belyando River Catchment
- Suttor River Catchment
- Bowen River Catchment
- Don River Basin
- Lower Burdekin River Catchment
- Burdekin River Basin
- Carmichael Project (Rail)
- Carmichael Project (Mine)
- North Galilee Basin Rail

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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

Job Number 41-26457
Revision A
Date 29 Aug 2013

Study area

Figure 9-1

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Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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

9.2.2 Data sources

The assessments undertaken as part of this water resources chapter were based 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 DNRM
- Interim floodplain assessment overlay from the 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 (as described in Volume 2 H1 Water Resources) and field inspections of the preliminary investigation corridor undertaken by GHD in May 2013.

9.2.3 Legislation and guidelines

The legislation and guidelines relevant to the water resources assessment 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 Resource (Burdekin Basin)Plan 2007*
- *Burdekin Resource Operations 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 above legislation and how it applies to the NGBR Project is provided in Volume 1 Chapter 20 Legislation and approvals.

9.2.4 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 DNRM websites (DNRM, 2013). The locations of rainfall stations as well as stream flow gauging stations are discussed in Section 9.3.2.

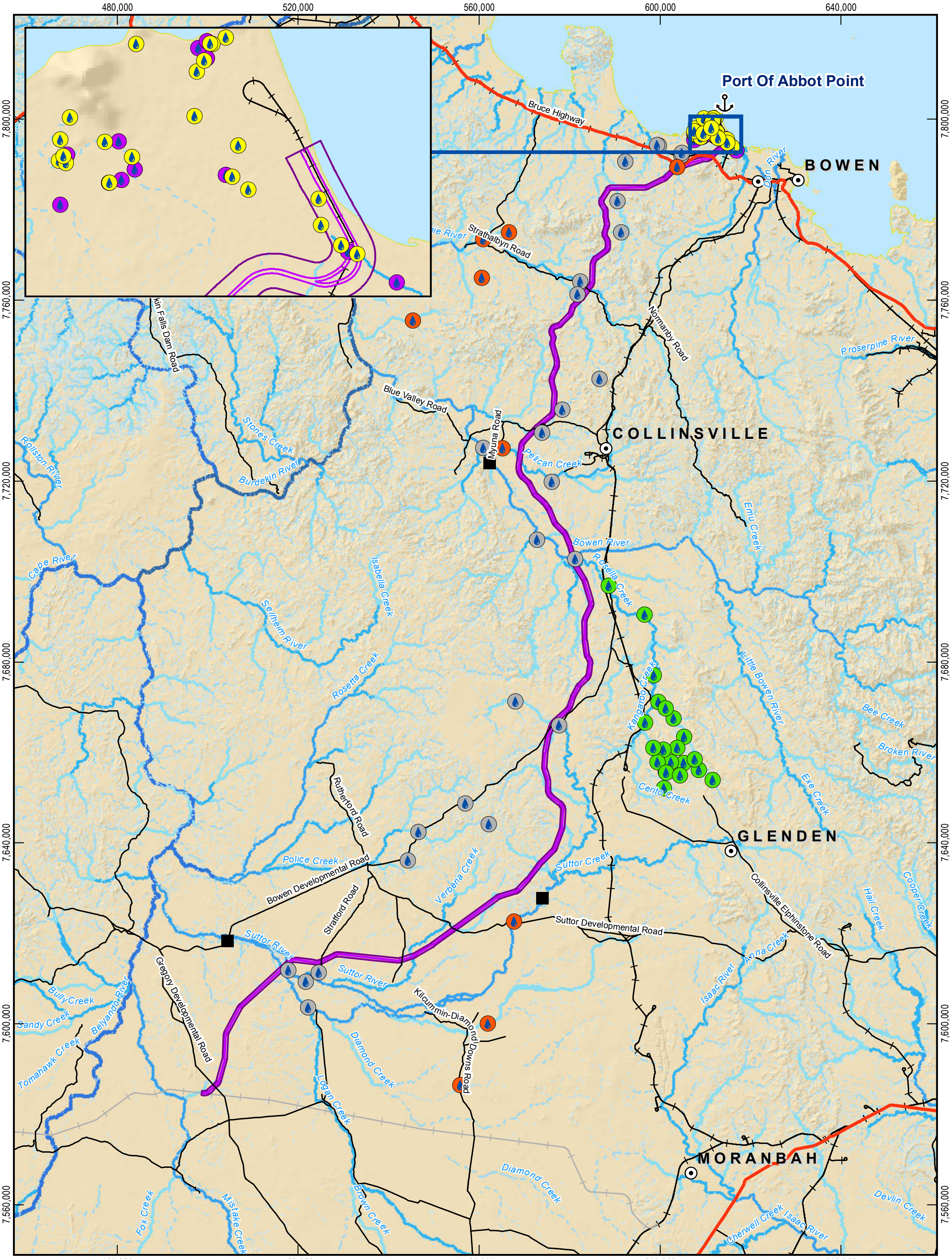
9.2.5 Surface water quality

Four studies previously undertaken to inform other environmental impact statements were used to gather information on watercourses intersected by the NGBR Project preliminary investigation corridor. These studies, undertaken over the past five years within the region, provided information regarding the spatial and temporal variability of the physical and chemical characteristics of surface water quality within the related catchments. The studies that were used to understand existing water quality conditions within the study area are as follows:

- 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.
- Waratah Coal Galilee Coal Project – Environmental Impact Statement (E3 Consulting 2011). Water quality, stream morphology and riparian vegetation field surveys were undertaken in October 2009 and March 2010 during the wet and dry seasons 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 field-based water quality investigations within the Caley Valley Wetland.

Figure 9-2 shows the location of the surface water quality sites sampled during the previous four studies in the region. In addition to the above studies, data from three Department of Natural Resource and Mines (DNRM) stream gauging stations were used to better understand existing water quality conditions within the preliminary investigation corridor.

Additionally, between 7 May and 9 May 2013, site assessments of major watercourses intersected by the preliminary investigation corridor were undertaken, including water quality sampling and assessment of geomorphic conditions. The locations of these watercourse site assessments are shown in Figure 9-3 and summarised in Table 9-1.



LEGEND

- Population Centres
- Major Port
- Previous Surface Water Quality Sites: Hancock, Newlands Coal EIS, Waratah, GHD, WBM
- Gauging Station
- Highway
- Main Road
- Carmichael Project (Rail)
- Railway
- Stream Order: 1, 2, 3, 4, 5, 6, 7, 8, 9
- 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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Previous surface water quality sampling sites

Job Number	41-26457
Revision	A
Date	21 Aug 2013

Figure 9-2

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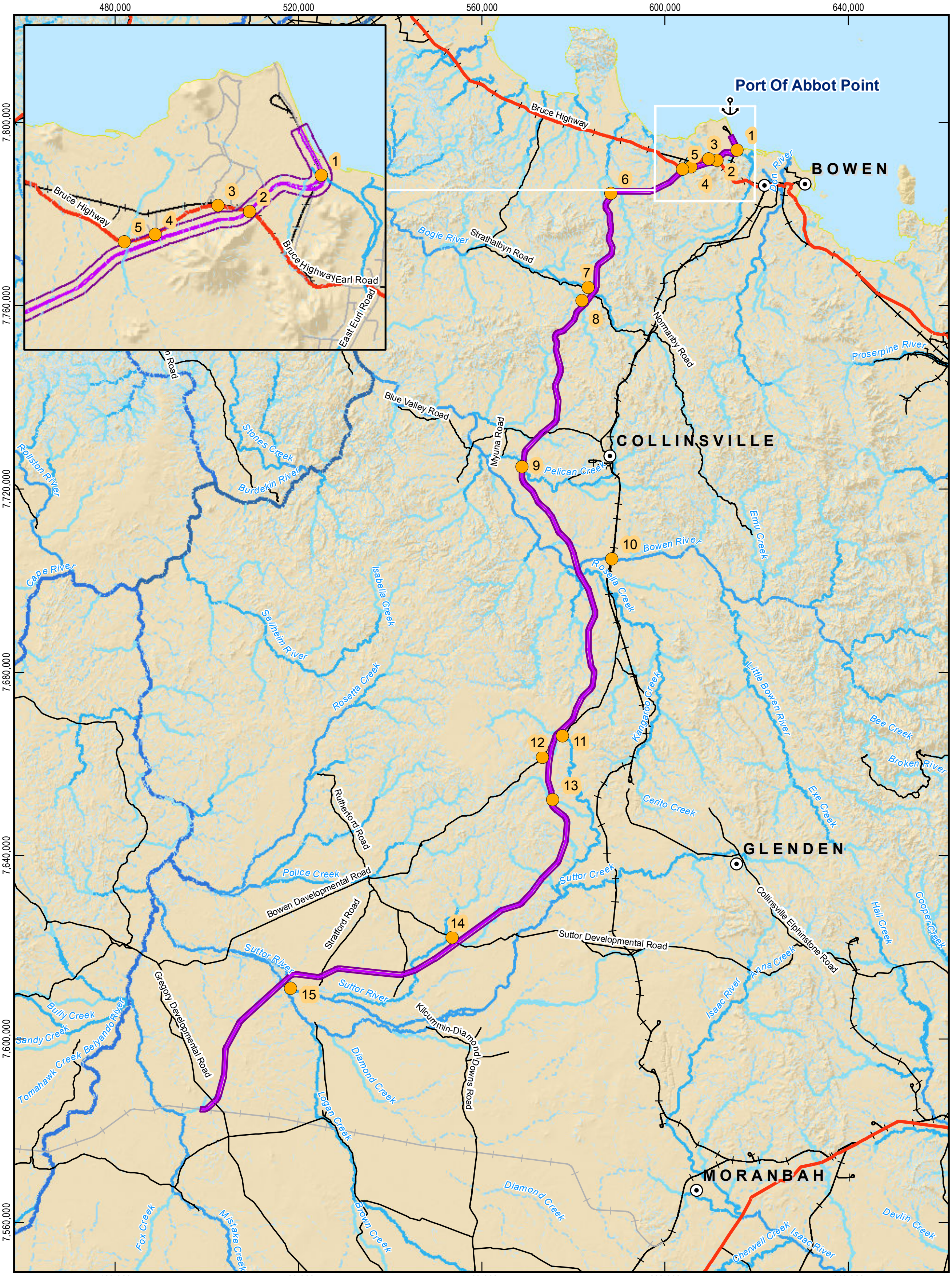
Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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



LEGEND

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

Based on or contains data provided by the State of QLD (DNRM) [2013]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

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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	21 Aug 2013

Field assessment sites

Figure 9-3

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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

Table 9-1 Water quality sampling sites

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)

Water quality sampling at the sites listed in Table 9-1, was undertaken in accordance with Monitoring and Sampling Manual 2009 (DERM 2009b) and ANZECC Guidelines (ANZECC and ARMCANZ 2000). Water quality was sampled in-situ using a hand held water quality meter that measured:

- 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 were taken at each site.

9.2.6 Waterway geomorphology

During the field investigation between 7 May and 9 May 2013, the physical characteristics of waterways at accessible locations within or close to the preliminary investigation corridor were also assessed. These site assessments were undertaken at the same locations as water quality sampling, as shown in Figure 9-3. At each site, the following information was recorded:

- 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 based on the methods and principles of the River Styles® framework (Brierley and Fryirs, 2005). The assessment of watercourse geomorphic condition was based on Outhet and Cook 2004, who describe a rapid method of condition assessment based on natural and human induced variability. The characteristics of each condition category are described as good, moderate or poor.

9.2.7 Groundwater

The groundwater assessment for the NGBR Project utilised data from the following sources:

- Hancock Prospecting Pty Ltd Alpha Coal Project Environmental Impact Statement, Volume 6 Rail Corridor Appendices (Hancock Prospecting 2010). An Environmental Impact Statement (EIS) for a proposed rail line between the Port of Abbot Point and 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 2012a) and Adani Mining Pty Ltd. report for Carmichael Coal Mine and Rail Project: Mine Technical Report. Hydrogeology Report 25215-D-RP-0026. Revision 2. (GHD 2012b). EIS for a proposed rail line connecting the Carmichael mine to the existing line Goonyella and Newlands rail system.
- 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
  - Mount Coolon, Sheet SF55-7, 1:250,000 scale
  - Bowen, Sheet SF55-3, 1:250,000 scale
  - Buchanan, Sheet SF55-6 1:250,000 scale.

9.2.8 Hydrology and hydraulics

A hydrology and hydraulic assessment was undertaken of the NGBR Project's cross drainage infrastructure to assess the potential impacts of these structures on existing surface water flow paths and associated flooding regime. The hydrology and hydraulic assessment included:

- A desktop review of previous studies undertaken within the region, existing (LIDAR) ground survey data and hydro-meteorological data (rainfall and runoff records)
- Site investigations including visual assessment of waterways, flow, drainage patterns and bed/bank sedimentation material
- Identifying major and minor watercourses and catchment delineation using topographical maps from Geoscience Australia, aerial photography, LIDAR data, Shuttle Radar Topography Mission (SRTM) data and drainage mapping from Australian Geospatial Fabric (Geofabric; BOM 2011b).
- Estimating peak flow rates for catchments smaller than 25 km^2 (minor catchments).
- Estimating peak flow rates for catchments larger than 25 km^2 but smaller than 100 km^2 (moderate catchments).
- Estimating peak flow rates for catchments larger than 100 km^2 (major catchments).
- Undertaking one-dimensional hydraulic analysis of ephemeral gullies and well defined creeks, using Hydrologic Engineering Centre's River Analysis System (HEC-RAS).
- Analysing complex flow patterns and floodplain interaction between multiple streams for major catchments, using two-dimensional hydrodynamic model XPSWMM+XP2D software to determine flood inundation, velocity maps and hydraulic impacts. Inundation, afflux and velocity maps were produced for pre-development and post-development conditions from two-dimensional model outputs relating to each major catchment crossing point.

The results from the one-dimensional and two-dimensional model outputs informed the design parameters of cross drainage, transverse drainage and longitudinal drainage infrastructure for the NGBR Project. Further details regarding design criteria for afflux and flood immunity are provided in Volume 1 Chapter 02 Project description. Further details on the hydrology and hydraulic assessment methodology are provided in Volume 2, Appendix H2 Hydrology and hydraulics.

9.3 Existing environment

9.3.1 Catchment description

The preliminary investigation corridor traverses varied topography with dominant features including gentle undulating slopes, slight rises and shallow depressions. The northern and central extents of the preliminary investigation corridor traverse more undulating topography associated with the Clarke Range and the Leichhardt Range. The final rail corridor will intersect a number of regional surface water features and smaller ephemeral streams. The major waterway and bridge structure crossings along the preliminary investigation corridor are listed in Table 9-2. The preliminary investigation corridor with respect to major watercourses and catchments is shown in Figure 9-1.

Table 9-2 Significant major and moderate waterway crossings

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)	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)	Burdekin River

Source: Volume 2 Appendix H2 Hydrology and hydraulics

Don River Basin

The Don River Basin spans from the Clarke Ranges up to Bowen and has a catchment area of approximately 3,695 km^2. 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 and Hall, 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 also intersects many minor tributaries and flow paths within this catchment.

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).

Burdekin Basin

Lower Burdekin River catchment

The Lower Burdekin River catchment drains an area of approximately 9,300 km^2 and is made up of seven coastal and non-coastal sub-catchments. The preliminary investigation corridor bisects the Bogie River and its tributary, Sandy Creek at an almost perpendicular angle. The preliminary investigation corridor also intersects many minor tributaries and flow paths within this catchment.

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.

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 (Stones and Landers Creek) consist of mostly dry, ephemeral creeks.

Bowen River catchment

The Bowen River catchment is approximately 8,200 km^2 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.

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 per cent in high cover category, 43 per cent within the moderate cover category, eight per cent in low cover and 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 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 the 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 Suttor River catchment is approximately 18,000 km^2, 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 the 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 and Hall (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 threat 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 the Suttor River with the Belyando River (Greiner and Hall, 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 km^2. 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 the Suttor River. 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.

9.3.2 Climate

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). A brief overview of climatic conditions within the study area is provided below and further detail is provided in Volume 2 Appendix H1 Water resources and Volume 1 Chapter 17 Climate and natural hazards.

Rainfall

The main factor influencing the hydrology of waterways crossed by the NGBR Project preliminary investigation corridor is rainfall patterns. Monthly rainfall data for the study area was obtained from the following BOM rainfall stations:

- Don River Basin – Gatton Vale and Wattlevale Station
- Lower Burdekin River catchment – Strathbogie and Eton Vale
- Bowen River catchment – Bowen Cheetham Salt and Strathmore
- Suttor River catchment – Mt Douglas and Wollombi Station.

Information from these rainfall stations indicates the following:

- Rainfall patterns, in terms of maximum summer and winter volume, and annual totals are broadly similar across the study area particularly for inland areas, with a pronounced wet summer and dry winter. Rainfall totals for the coastal areas are comparatively higher.
- Although the typical wet season spans from November to May, this does not mean that rainfall depths will be the highest during this period. In any month of the year, including in the typical wet season months, there can be zero rainfall.

Total seasonal rainfall in the region, based on BOM rainfall stations, ranges from less than 100 mm in the dry season to over 1,000 mm in the wet season.

Watercourse flow

A detailed description of existing flow conditions of watercourses in the study area, based on data published by DNRM 2013, is presented in Volume 2 Appendix H1 Water resources. In general, flow patterns mimic rainfall patterns. However, while there are more flow events in the wet season, periods of zero flow can occur in any month of the year. Large, short duration flood events, which can occur anytime from November to May, dominate the discharge regime and long-term flow averages. Intervening dry periods are frequent, although their length is unpredictable. The episodic, short-duration, unpredictable nature of these wet and dry events tends to disguise the summer seasonality of flows.

Temperature

Monthly mean temperatures for BOM climate stations situated along the preliminary investigation corridor show that daytime summer temperatures are between 24°C and 36°C with overnight temperatures between 8°C and 23°C. Long-term temperature records from the last 100 years show temperature values ranging between -3.5°C and 46°C. 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.

Evaporation

Potential evaporation along the preliminary investigation corridor increases from north to south, 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.

9.3.3 Geomorphology

Waterways along the preliminary investigation corridor are predominately set within rural or semi-rural/bushland settings and have been substantially modified over time by land clearance and other agricultural practices. Catchment changes due to land clearance include increased runoff, increased drainage density, and increased erosion and sediment yields within the catchment. In response to altered hydrological regimes, channel morphology changes have also occurred due to bank erosion, channel incision and floodplain scour. 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 a result of past upstream disturbances.

Waterway types

There are six broad waterway geomorphic types encountered along the preliminary investigation corridor. These include confined valley systems, valley fill systems, channelised fill systems, bedrock controlled sand/gravel systems, single channel alluvial sand systems and multi-channel alluvial systems. A detailed description of the waterway type and waterway geomorphology at each site shown in Figure 9-3 is provided in Volume 2 Appendix H1 Water resources. An overview of each waterway type and its occurrence along the preliminary investigation corridor is provided below:

- Confined valley systems - while not encountered at any of the field investigation sites, aerial imagery indicates confined valley systems may potentially occur along the preliminary investigation corridor in upper catchment areas.
- Valley fill systems - while not encountered at any of the field investigation sites, aerial imagery indicates valley fill systems may potentially occur along the preliminary investigation corridor in middle to upper catchment areas.
- Channelised fill systems - while not encountered at any of the field investigation sites, aerial imagery indicates channelised fill systems may potentially occur along the preliminary investigation corridor in middle to upper catchment areas.
- Bedrock controlled sand/gravel systems - bedrock controlled systems were present at nine of the sites investigated in the field surveys. 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 type of system is also likely to be intersected by the preliminary investigation corridor along other streamlines in middle to lower catchment areas.
- Single channel alluvial sand systems - alluvial sand systems were encountered within the preliminary investigation corridor at Rockingham Creek and the Suttor River (northern crossing). Aerial imagery indicates this type of system is also likely to occur where the preliminary investigation corridor crosses other waterways including the Elliot River, Verbena Creek and Strathmore Creek.
- Multi-channel alluvial systems - of the sites investigated during field surveys, the multi-channel alluvial system only occurred along the southern crossing of the Suttor River. Aerial imagery indicates this system is not likely to occur along any other waterways intersected by the preliminary investigation corridor.

Waterway stability

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 traversed by the preliminary investigation corridor. 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.

Rockingham Creek exhibited channel forms indicative of past channel incision via headward erosion. This is considered to be associated with the dominant 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 and erosion was evident along some of the waterways observed 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. While this is a natural process of channel migration due to meandering, disturbances such as land clearance can exacerbate the rate and extent of bank erosion. ‘Breakaways’ (gullying 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. 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.

9.3.4 Flooding

The frequency and extent of flooding in catchments within the study area was determined based on available historical flood data. Flood levels recorded for recent major events at locations within the Don River Basin are presented in Table 9-3.

Table 9-3 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

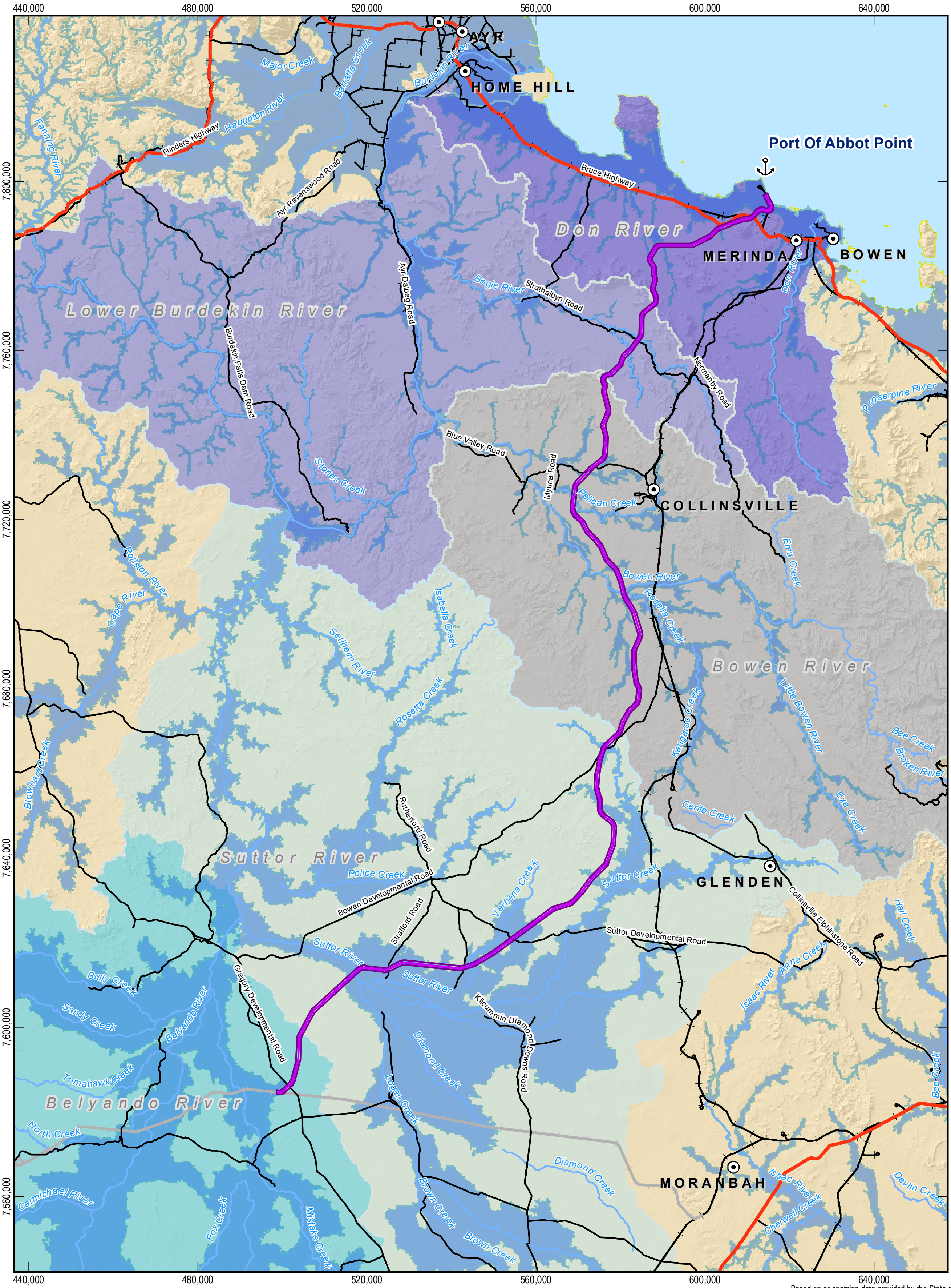
Flood levels recorded for major events at locations within the Lower Burdekin River Basin catchment are presented in Table 9-4.

Table 9-4 Recorded gauge heights (m) 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
Birralee (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

The extent of flooding within the Don River Basin and Burdekin Basin for the 2010/2011 flood event is provided in Figure 9-4.



LEGEND

- Population Centres
- Major Port
- Highway
- Main Road
- Carmichael Project (Rail)
- Railway
- Watercourse (Major)
- Flooding Assessment

River Basins

- Belyando River
- Suttor River
- Bowen River
- Don River
- Lower Burdekin River
- North Galilee Basin Rail 1000m Corridor
- North Galilee Basin 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

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Adani Mining Pty Ltd
North Galilee Basin Rail Project

Job Number	41-26457
Revision	A
Date	29 Aug 2013

The 2010/2011 flood event

Figure 9-4

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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

9.3.5 Groundwater

Geological conditions

A summary of geology along the preliminary investigation corridor, including depositional history and stratigraphy, is provided in Volume 2 Appendix E Topography, geology, soils and land contamination.

Hydrogeological data collection

The DNRM 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 identified 81 bores within a two kilometre buffer of the preliminary investigation corridor. These bores are dispersed throughout the preliminary investigation corridor, predominantly between Bowen and Collinsville. The bores were drilled to depths of up to 142 metres, but average 24 metres below ground level (mbgl). There are currently only nine bores located south of Pelican Creek and the Lizzie Creek Volcanic Group.

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 preliminary investigation corridor (around the Port of Abbot Point), several clusters of bores were identified within the vicinity of Bowen and Guthalungra. Available information pertaining to these observation bores was strictly locational however it is likely these bores monitor the alluvial aquifers which local townships and agricultural industries rely upon.

Hydrogeological units

The primary geological units along the preliminary investigation corridor were determined from the geological information summarised in Section 9.2.2, geomorphological field surveys completed by GHD in May 2013 and available borehole information. The geological units have been categorised into the following primary units for assessment of hydrogeological properties:

- Unconsolidated floodplain alluvium comprising clays, silts, sands and gravels. Floodplain alluvium sediments are expected to be present for a total distance of approximately 98 km (32 per cent) beneath the preliminary investigation corridor and are primarily present along the edges of rivers and creeks.
- Unconsolidated coastal dunes, mud flats, alluvial and deltaic deposits comprising clays, silts, sands and gravels. They are located in the coastal plains zone and are expected to be present for a total distance of 13 km (approximately four per cent) of the preliminary investigation corridor.
- Colluvium and residual soils comprising clays, silts, sands and gravels are expected to be present for approximately 67 km (22 per cent) of the preliminary investigation corridor. These deposits are generally associated with weathering of underlying and out cropping bedrock, and generally accumulate on slopes and in valley floors (Hancock Prospecting Pty Ltd, 2010).
- Intrusive igneous deposits comprised predominantly of granite and granodiorite. These deposits may be extensively weathered in the near surface environment and are expected to be present for approximately 53 km (17 per cent) of the preliminary investigation corridor.

- Sedimentary deposits comprised of siltstones, sandstones, mudstones, coal measures and conglomerates. These deposits may be extensively weathered in the near surface environment and are expected to be present for approximately 77 km (25 per cent) of the preliminary investigation corridor.
- Volcanic sediments (extrusive igneous deposits) comprised of the rhyolites, basalts, breccia and tuffs. These deposits may be extensively weathered near the surface environment and are expected to be present for approximately 25 km (eight per cent) of the preliminary investigation corridor.

The hydrogeological properties of these systems are discussed in more detail in Volume 2 Appendix H1 Water resources.

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 activated through related Resource Operations Plans (ROPs) which provide detail on how the water resources will be managed to achieve the objectives set out in the WRP.

A groundwater area is an area identified in the *Water Regulation 2002*, a water resource plan or a wild river declaration within which management requirements for groundwater exist. In Queensland, groundwater areas are referred to in various ways under subordinate legislation such as subartesian areas, groundwater management areas (GMAs), groundwater management units (GMUs) and unincorporated areas (UAs).

A GMU is a hydraulically connected groundwater system that is actively managed. UAs are all groundwater resources that are not part of GMUs and which have no requirements for allocations of groundwater abstraction for livestock or domestic use. Subartesian areas are areas where water that occurs naturally in an aquifer, which if tapped by a bore, would not flow naturally to the surface.

The water resources in 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 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. Figure 9-5 shows the locations of these GMUs and UAs relative to the preliminary investigation corridor, while Table 9-5 provides their chainage.

Table 9-5 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 UA	15	67
Bowen UA	67	306.9

(Source: Adapted from Hancock Prospecting, 2010; Volume 2 Appendix H2 Construction water supply strategy)

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 compared to an estimated sustainable yield of 260,000 ML/yr National Land and Water Resources Audit (Australian Government 2009). 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 (Australian Government 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 2000* and defines sub artesian groundwater areas. It also details the purpose of use (such as stock / 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, the Highlands Declared Subartesian Area, undeclared areas and the Bowen Declared Subartesian Area (refer Figure 9-6). The NGBR Project is situated within the Galilee Basin and is outside the eastern boundary of the Great Artesian Basin.

Highlands Subartesian Area

From its southern extent to the Suttor River, 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.

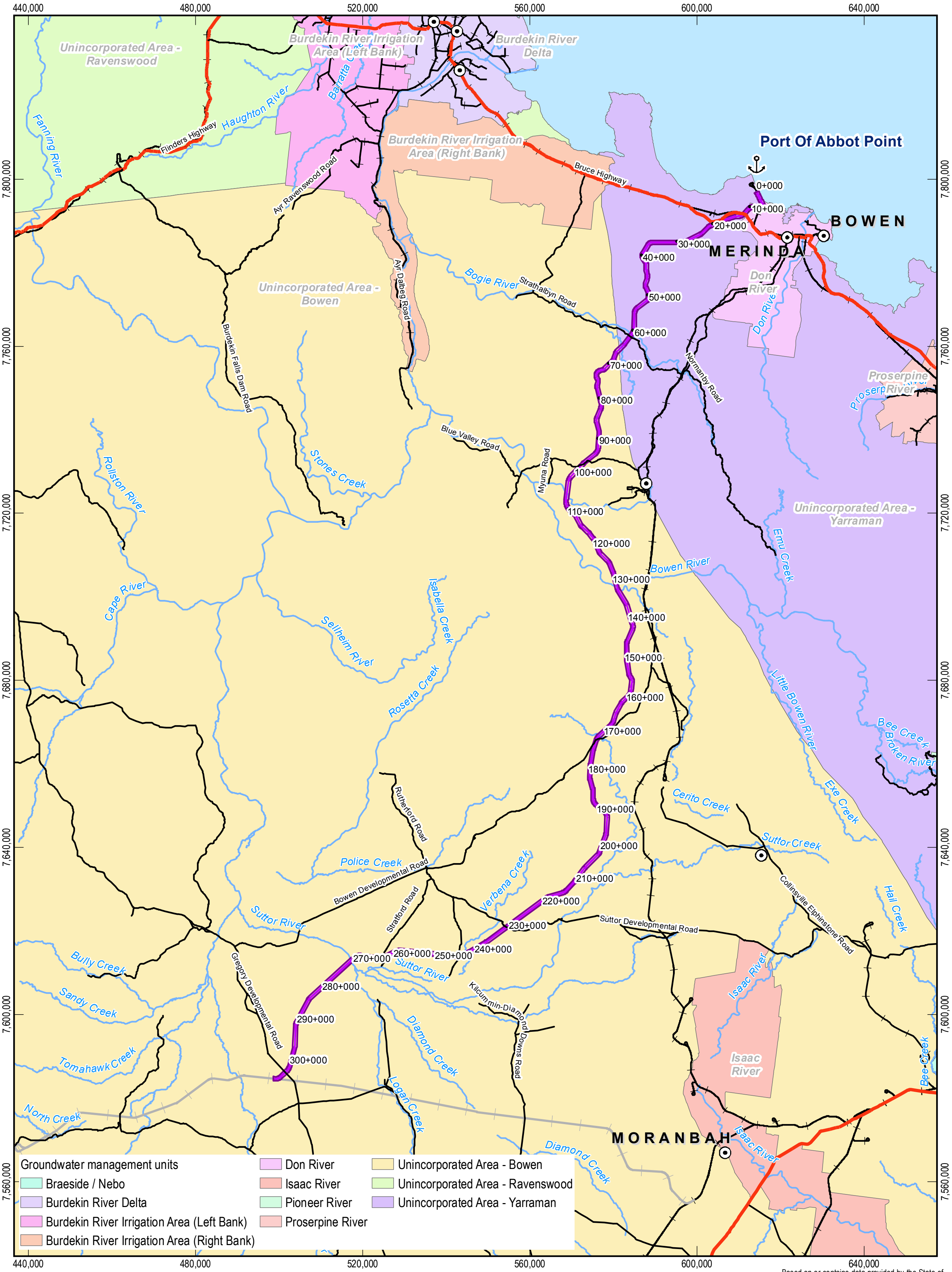
Long-term extraction of groundwater or interference (whether actively via bores or passively via drainage to mine workings) with surface water or other groundwater sources requires authorisation by way of a licence.

Undeclared Areas

From the Suttor River to the Bruce Highway, approximately 13 km southwest of Abbot Point, there are no identified groundwater management areas. No water licenses and/or development permit are required for groundwater extraction in undeclared areas.

Bowen Declared Subartesian Area

From the Bruce Highway, approximately 13 km southwest of Abbot Point, to Abbot Point, 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 similar to the Highlands Subartesian Area.



LEGEND

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

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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

Job Number	41-26457
Revision	B
Date	29 Aug 2013

Groundwater Management Units

Figure 9-5

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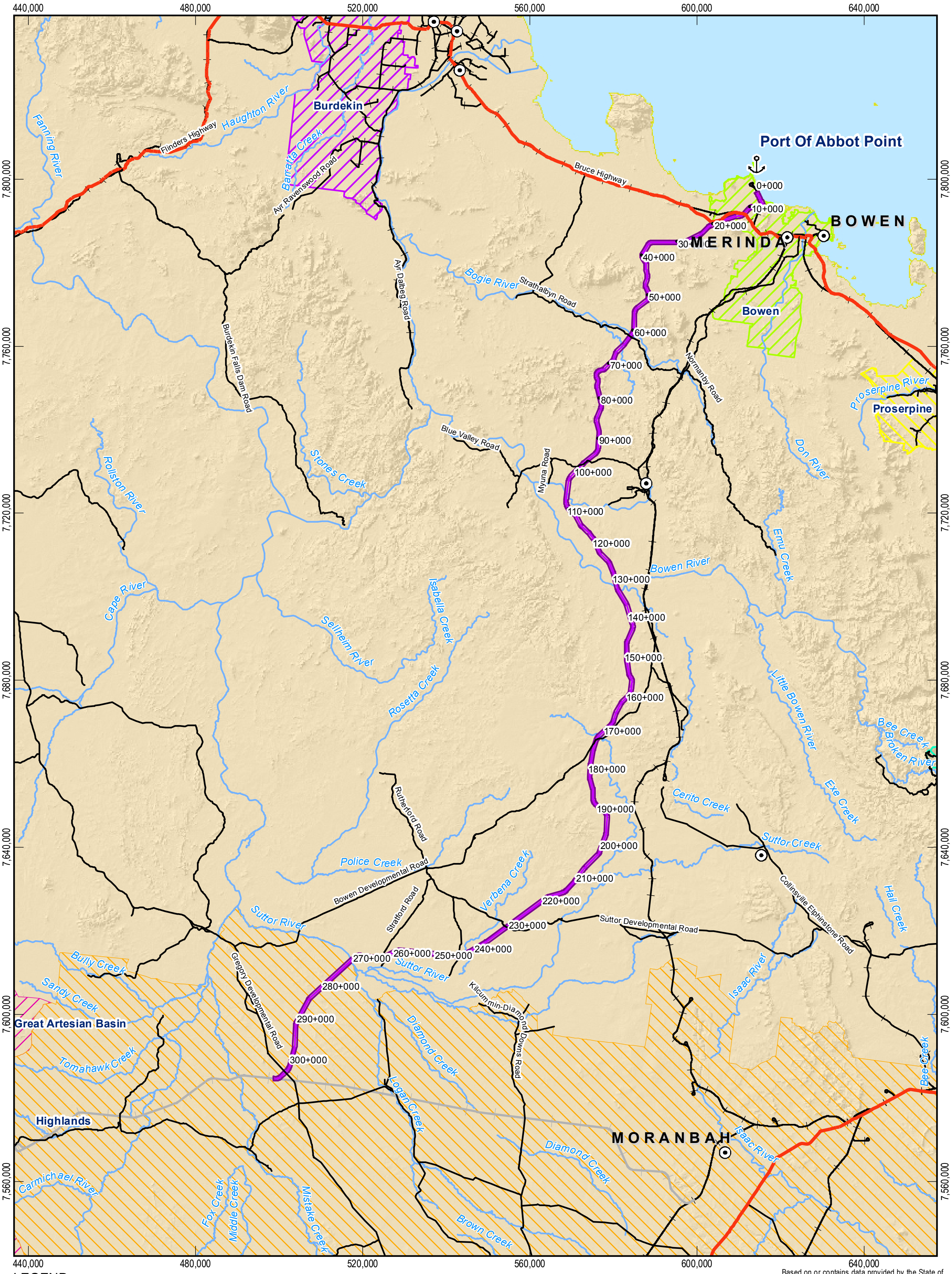
Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: NGBR Corridor 13/05/2013, NGBR Corridor 06/06/2013, Camichael Rail Project/2012; DNRM: Roads/2010; DAFF:GMU/2010. Created by:MS



LEGEND

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

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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

Subartesian management units

Figure 9-6

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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

Groundwater use

The study area is dominated by livestock grazing on native vegetation. The primary demand for groundwater is stock and domestic water supply purposes. At the Port of Abbot Point land use is primarily manufacturing and industrial, suggesting that there may also be some demand for industrial related supplies of groundwater in this location. Near Collinsville, approximately four km east of the preliminary investigation corridor (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 types of facilities is expected to be for stock and domestic uses only.

Within the vicinity of the preliminary investigation corridor (within 2 km either side), 43 of the identified 81 bores had bore use data available. This data is provided in Volume 2 Appendix H1 Water resources and summarised below:

- 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.
- 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.

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 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.

Additionally, there may 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 the area and that the primary land use probably results in demand primarily being for domestic and stock purposes.

Groundwater dependent ecosystems

Potential groundwater dependant ecosystems (GDEs) (refer Figure 9-7) have been inferred along the preliminary investigation corridor using data published by BOM (BOM, 2013). Much of the data is the result of high level probability assessment and has not been ground-truthed. Surface features identified within the study area that have high potential for groundwater interaction include:

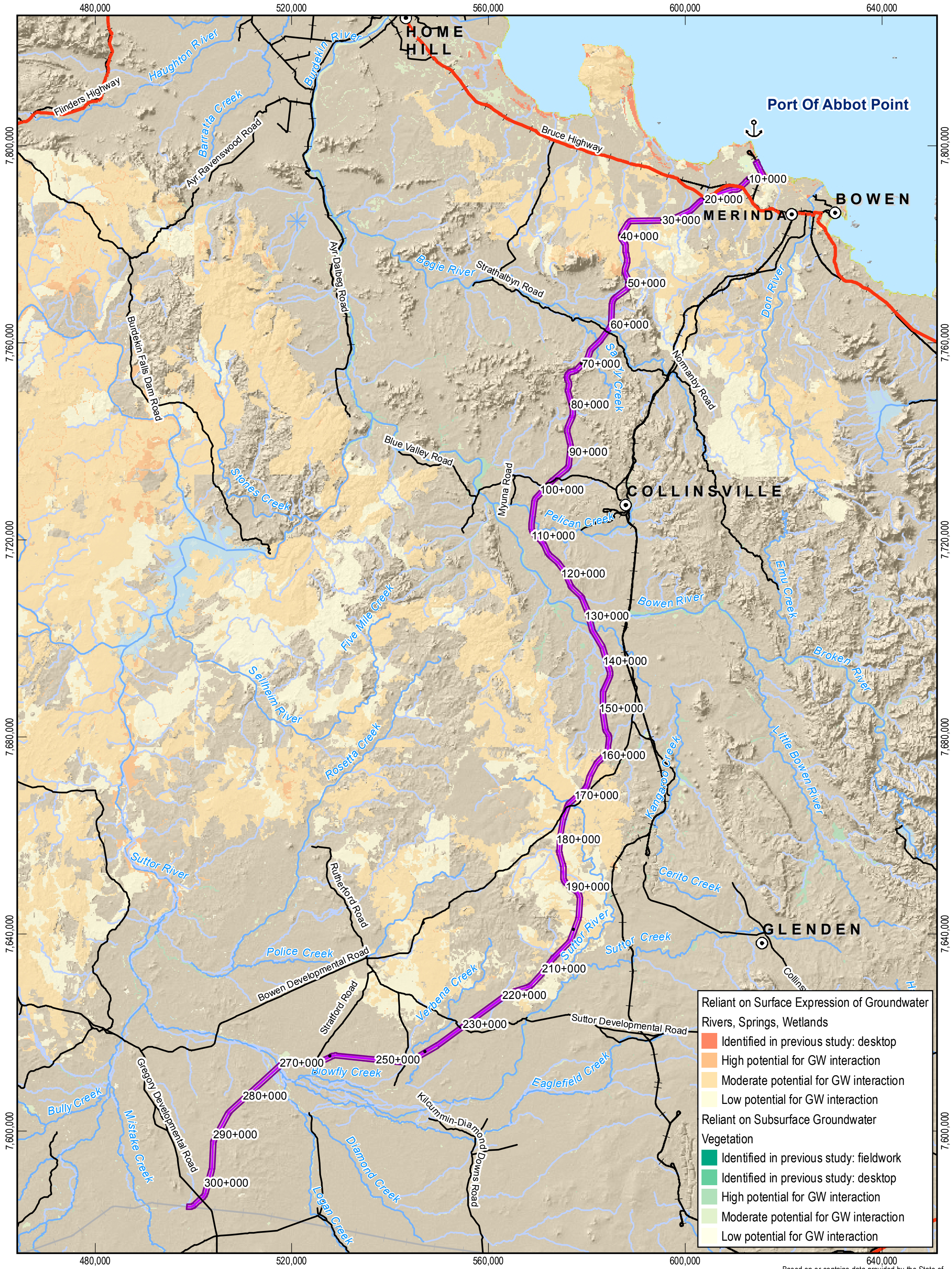
- Bogie River
- Sandy Creek
- Pelican Creek
- Bowen River
- Verbena Creek
- Suttor River.

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.

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 include:

- 3.46 to eight kilometres
- 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.



LEGEND

- Population Centres
- Major Port
- Chainage Points
- Spring
- Highway
- Main Road
- Carmichael Project (Rail)
- Railway
- Watercourse (Major)
- Watercourse (Minor)
- Lakes
- 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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North Galilee Basin Rail Project

Job Number 41-26457
Revision A
Date 28 Aug 2013

Potential groundwater dependant ecosystems

Figure 9-7

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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

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, there are no reported spring complexes within the study area. The nearest is Doongmabulla Springs (listed under the Directory of Important Wetlands), approximately 70 km west of the NGBR Project.

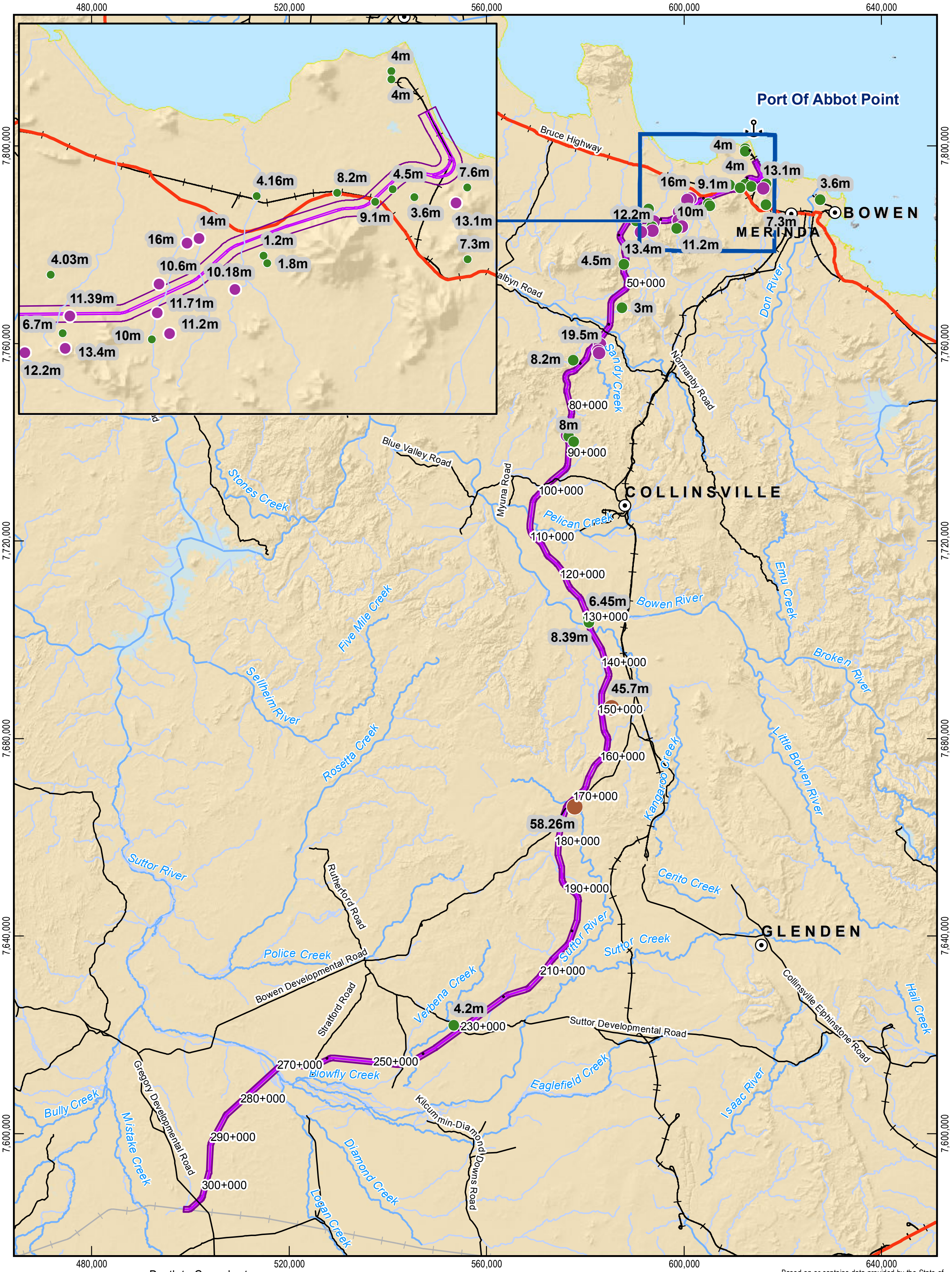
Groundwater levels and flow

There are approximately 40 bores along the preliminary investigation corridor with groundwater elevation data, including:

- 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 nine mbgl with an average of 4.5 mbgl
- Fifteen bores with groundwater elevation data within weathered intrusive deposits mainly within the Clarke Range area. The groundwater elevations in these bores generally range between three and 19.5 mbgl with an average of 9.7 mbgl
- Four bores with groundwater elevation data within fractured 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
- 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
- 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
- Eight bores with the geology 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 9-8 shows the depth to groundwater from data obtained from the DNRM GWDB.

There is currently insufficient data to establish regional flow directions, however, it is expected that shallow groundwater systems in alluvium, 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.



LEGEND

- Population Centres
- Major Port
- Chainage Points

Depth to Groundwater (metres below ground surface)

- 0-10m
- 10-20m
- >20m

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

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1:1,100,000 Paper Size A4

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

Job Number	41-26457
Revision	A
Date	21 Aug 2013

Depth to groundwater

Figure 9-8

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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

Groundwater quality

Groundwater quality 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). 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.

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 (up to 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 (i.e. southward of chainage 68 km) and cannot be relied upon to provide a reasonable understanding of the water quality of aquifers in these areas. Water quality data is presented in Volume 2 Appendix H1 Water resources.

9.3.6 Surface water quality objectives

The key parameters of water quality within the catchments discussed in Section 9.3.7 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 is common and widespread. Land clearing and erosion are also considered influences on the water quality within the preliminary investigation corridor.

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 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.

The Queensland Water Quality Guidelines (QWQG) (DERM 2009a) provides 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 during the field investigations has been used to determine the following EVs of relevance 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 downstream of the preliminary investigation corridor within the Suttor River catchment.

As required by the QWQG (DERM 2009a), Water Quality Objectives (WQOs) for the protection of the EVs were identified. Data obtained during the assessment has been compared to the nominated WQOs and is provided in Volume 2 Appendix H1 Water resources. Existing water quality conditions in the Don River Basin and Lower Burdekin, Bowen and Suttor catchments did not meet the WQOs on a number of occasions.

As such, the nominated 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. This threshold level will be determined in consultation with DNRM prior to construction commencing and would be outlined in the NGBR Project conditions of approval. The threshold limit will include a maximum acceptable per cent increase above upstream back ground levels as well as an acceptable maximum duration for changes to any water quality parameter. 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.

9.3.7 Surface water quality

Based on other studies (refer Section 9.2.2) and water quality sampling (refer Section 9.2.5), water quality data collected in the waterways of the preliminary investigation corridor includes:

- Three DEHP 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 under each catchment, and in more detail in Volume 2 Appendix H1 Water resources. No water samples were taken within the Belyando River catchment as no major watercourses are crossed by the preliminary investigation corridor within this catchment.

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 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 WQOs.

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 greater than the WQOs for most sites for a number of parameters measured (E3 Consulting 2011). 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. 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. The Port of Abbot Point Terminal 1 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 Port of Abbot Point Terminal 1 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 the Caley Valley Wetland which then flows into Abbot Bay. Abbot Bay is within the Great Barrier Reef World Heritage Area (GBRWHA), Great Barrier Reef Marine Park (GBRMP), and Commonwealth marine area.

Water quality in the marine environment of 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).

Burdekin Basin

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 above sea level.

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

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 conductivity and the concentration of ammonia and total phosphorus were greater than WQOs at all sites (E3 Consulting 2011).

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 at the DEHP gauging stations for the Bowen River at Myuna (Site 120205A).

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 did not meet the WQOs for most sites for a number of parameters measured (E3 Consulting 2011). Conductivity, iron and ammonia were greater than the WQOs for most sites.

Water quality data was collected at a number of tributaries which flow into the Bowen River via Rosella Creek between 2007 and 2011. 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 the WQO at Wilson, Kangaroo and Rosella Creeks.

The existing turbidity and total suspended solids in the Suttor and Bowen River catchments were found to be up to four times the WQOs for the protection of aquatic ecosystems at a number of sites (refer Section 9.3.7). These existing levels of turbidity and total suspended solids are likely due to current land use activities including livestock movements causing disturbance of soils. Water quality data also shows that areas that have been particularly affected by the loss of riparian vegetation, such as Pelican Creek, Bowen River and the Burdekin River have suspended sediment concentrations as high as 3,000 – 6,000 mg/L (Bainbridge *et al*. 2006a and b). High turbidity in disturbed catchments with intensive agricultural land use can be correlated with rainfall volumes and subsequent surface runoff in these areas. Spikes in turbidity levels typically occur after rain events, and reduce as flow velocity reduces, which allows suspended sediment to settle.

Within all the study area catchments, concentrations of ammonia, total nitrogen and total phosphorus in the catchments were consistently greater than the WQOs for the protection of aquatic ecosystems. As with turbidity, aquatic ecosystems are adaptive to the existing seasonal variation in nutrients however increases in magnitude and frequency of peaks in this variable may have the potential to adversely impact ecosystems.

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 above sea level.

The median (or mean if median value was not available) concentration of turbidity, nutrients (ammonia, total nitrogen and total phosphorus), sulfate, aluminium, copper, iron and zinc were greater than the WQOs at the DEHP gauging stations for the Suttor River at Bowen Developmental Road (Site 120310A) and at Eaglefield (Site 120304A).

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 did not meet the WQO for most sites for a number of parameters measured (E3 Consulting 2011). Conductivity, iron, ammonia and total nitrogen were greater than the WQOs for most sites.

9.3.8 Water supply infrastructure

Water usage within the Don River Basin and Burdekin River is dominated by urban, industrial, stock watering and domestic uses. Water resources 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. Stock water and domestic water use is also supplied via ground water abstraction. Water use data is provided in Volume 2 Appendix H1 Water resources. Table 9-6 provides a summary of existing water usage within the study area.

Table 9-6 Catchment water usage

Catchment	Water usage
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.
Lower Burdekin River catchment	Provides water for industrial and irrigation uses, particularly for sugar cane as a major crop in this catchment. 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, and is potentially used by traditional owners for spiritual and cultural purposes.
Bowen River catchment	Water use dominated by industrial uses. Bowen River Weir supplies mining operations at Newlands and Collinsville, as well as Collinsville Power Station, and town water supply for Collinsville and Glendon. Water is also used for irrigation (including irrigated horticulture around Birralee), stock watering, urban purposes and is potentially used by traditional owners for spiritual and cultural purposes.

Catchment	Water usage
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 potential uses for cultural and spiritual purposes by the traditional owners.
Belyando River catchment	Provides water for farm uses, stock watering and domestic use for the population scattered on pastoral holdings. Water is potentially uses for cultural and spiritual purposes by the traditional owners.

9.4 Potential impacts and mitigation measures

This section assesses the potential impacts of the NGBR Project on water resources within the study area, including potential construction and operation impacts. The water resource values that have the potential to be impacted include:

- Surface water flow
- Flood regime
- Surface water quality
- Water use
- Groundwater.

9.4.1 Construction

Surface water flow

During construction, temporary structures in watercourses will be required which have the potential to impact surface water flow and hydrology. Temporary structures may include culvert causeways for construction access roads and coffer dams for the construction of bridge piers and cross drainage culverts. The application of coffer dams will be limited and will only be used where dry river bed construction methodology is not an option. The impact of temporary structures in waterways has the potential to alter channel flow velocities causing bed and bank disturbances. A total of 196 watercourses along the final rail corridor have been identified as requiring cross drainage structures.

All temporary waterway barriers (including partial barriers) required during construction would be designed in accordance with the *Fisheries Act 1994* and *Sustainable Planning Act 2009* (refer Volume 1 Chapter 20 Legislation and approvals and Volume 1 Chapter 6 Nature conservation).

At the completion of construction works within the waterway, the in-stream barrier would be removed and the waterway bed and banks returned to their original profile and stability so that channel morphology and surface water flow at the site is not compromised once the temporary barrier is removed.

Flood regime

The construction of temporary barriers in waterways is a potential barrier to waterway flows and overland flow paths. Therefore, these barriers have the potential to alter the flooding regime at these locations particularly if there is insufficient hydraulic capacity to convey flood flows, or if the waterway becomes blocked by debris. Blocked waterways could also potentially cause temporary afflux issues upstream of the channels. As identified in Volume 2 Appendix H2 Hydrology and hydraulics, the risk of potential flooding at cross drainage structures due to temporary waterway barriers would be low due to the temporary nature of the structures (i.e. only for the duration of works at that waterway) and barrier structures will be designed to provide sufficient capacity to ensure minimal impact on natural waterway flows. Construction within waterways will be limited to the dry-season wherever practicable to minimise potential flood-related impacts during construction.

Surface water quality

Construction activities including vegetation clearing, earthworks, operation of machinery, storage of fuels and chemicals, and disturbance of acid sulfate soils have the potential to directly or indirectly impact the water quality of waterways and sensitive downstream aquatic habitats. Mitigation and management measures will be implemented to address each of these potential impacts during construction, as outlined below.

The clearing of vegetation within the final rail corridor will result in an increase in the amount of exposed ground surfaces, increasing the risk of erosion and sedimentation during high rainfall events or periods of high wind. The mobilisation of soils through surface runoff and dust are sources that can lead to suspended particulates, nutrients and other contaminants attached to particulates entering waterways. Construction activities within or adjacent to watercourses, particularly at proposed waterway crossings, will disturb bed and bank substrates and also potentially lead to localised erosion and sediment transport into waterways and downstream aquatic habitats. Sediment loads in waterways are also likely to increase in the vicinity of hard surfaces such as roads and compacted developed areas such as construction laydown sites, due to increased surface runoff. Potential water quality impacts as a result of erosion and sedimentation will be actively managed at the source through the implementation of an Erosion and Sediment Control Plan and in accordance with the Best Practice Erosion and Sediment Control. International Erosion Control Association (Australasia) (IECA 2008) (refer Volume 1 Chapter 5 Topography, geology, soils and land contamination and Volume 2 Appendix P Environmental management plan framework).

Construction activities also have the potential to disturb land containing contaminants deposited through previous land use activities and release these contaminants into the environment (including nearby waterways), however this is considered to be a low risk for the NGBR Project (refer Volume 1 Chapter 5 Topography, geology, soils and land contamination). A preliminary site investigation to identify existing contaminated land will be conducted within the final rail corridor and ancillary infrastructure areas, followed by a ground-truthing exercise if required (refer to Volume 2 Appendix P Environmental management plan framework).

Potential acid sulfate soils acid sulfare soils in the vicinity of Abbot Point (i.e. the first 6.5 km of the preliminary investigation corridor) may also be exposed during construction. When acid sulfate soils are exposed to oxygen through disturbance, the sulfides in these soils oxidise to produce sulfuric acid that can alter the pH of water bodies and act to release metals bound within sediments. The disturbance of acid sulfate soils therefore has the potential to impact surface water quality. An Acid Sulfate Soils Management Plan (ASS Management Plan) will be employed during construction within areas identified to be of high risk for potential acid sulfate soils (refer to Volume 2 Appendix P Environmental management plan framework).

Oils, fuel, lubricants and other substances containing chemicals will be used during construction. Accidental spills or leaks of these chemicals have the potential to occur within the vicinity of watercourses resulting in contaminants being transported to the aquatic environment via rainfall runoff. These contaminants can result in both short and long-term degradation of water quality and can be toxic to aquatic organisms. The discharge of pollutants into local receptors has the potential to adversely affect both the local surface water quality at the point of discharge as well as downstream environments. The potential for impacts for accidental spills will be reduced as a result of mitigation measures including routine inspection and maintenance of all vehicles, plant and machinery, appropriate storage and management through a Hazardous Substances Management Plan and the Waste Management Plan and the creation of an emergency spill response plan (refer to Volume 2 Appendix P Environmental management plan framework).

During construction, works within and around waterways will be kept to a minimum. Where waterway crossing works are required, potential impacts on water quality as a result of land based activities such as clearing, will be minimised through the implementation of construction specific management measures including implementation of a Water Quality Management Plan (refer Table 9-9). An Erosion and Sediment Control Plan, Dust Management Plan and Acid Sulfate Soils Management Plan will also be implemented (refer to Volume 1 Chapter 5 Topography, geology, soils and land contamination, Volume 1 Chapter 21 Environmental management and Volume 2 Appendix P Environmental management plan framework).

The Construction Erosion and Sedimentation Control Plan will also include measures for the management of stormwater runoff from construction areas to minimise the impacts of sediment laden runoff entering adjacent water courses and drainage lines. Stormwater management measures during construction will include provision sedimentation ponds and the diversion of clean water around construction areas as defined during detailed design.

With respect to water quality impacts on water use, there are potential impacts to stock watering and farm use associated with the potential for contamination and increased turbidity through sedimentation and additional total suspended solids. Good water quality is essential for successful stock production and potable use of these water supplies would require increased treatment. In the unlikely event elevated sediment levels or hydrocarbon spillages as a result of the NGBR Project localised farm water supply would be diminished in the short term. In should be further noted Section 9.3.7, elevated sediment levels above WQO were observed at numerous sites with the Don River and Burdekin basin. The NGBR Project construction phase is limited to a period of approximately two years. As such no long-term impacts on water quality for existing users are anticipated. The implementation of mitigation measures outlined in Table 9-9 will minimise the potential impacts of the NGBR Project on water quality and therefore subsequent potential water quality impacts on water use for potable or farm supply.

Water use

During construction, water will be required for a number of activities including concrete batch plants, earthworks compaction and dust suppression, and construction camps (refer Volume 1 Chapter 2 Project description). Potential water sources comprise a combination of groundwater bores, surface water storage, local government supplies and waterway extraction (refer to Volume 2 Appendix H3 Construction water supply strategy). The extraction of water from waterways and groundwater resources may reduce the base flow of these resources. Impacts on base flows will vary depending on the timing and amount of water extracted from the various sources.

The total construction water requirement for the NGBR Project is anticipated to be approximately 20 megalitres of water per day during peak periods. This water requirement will be distributed across the 300 km final rail corridor and will be limited to approximately two years during construction. As such it is considered to be minimal in the context of the regional catchments. Therefore, localised impacts on downstream water users, including existing downstream discharge licences, are anticipated to be minimal, undetectable decreases in flow. Aquatic communities that inhabit these ephemeral aquatic ecosystems are tolerant of highly variable flow conditions. As such, small decreases in flow are unlikely to impact aquatic communities within the preliminary investigation corridor.

A detailed construction water supply strategy for the NGBR Project and an assessment of the potential impacts on existing water resources is provided in Volume 2 Appendix H3 Construction water supply strategy. The study investigated surface water extraction from a number of waterways crossed by the NGBR Project and concluded that these seasonal water sources when combined with supplemental groundwater abstraction would provide a viable supply, with relatively large flows occurring at each crossing during the months of December to May. It is important to note, however, that flows in the region do diminish significantly outside of this time period. And where a year-round water supply is required, the use of supplemental groundwater abstraction in conjunction with a waterway crossing will provide a more reliable water supply.

Potential impacts to groundwater elevations at construction water supply bores may occur due to extraction for construction water supply. An assessment of potential impacts on water supply bores as a result of construction water extraction from groundwater resources is provided in Volume 2 Appendix H3 Construction water supply strategy. In general, extraction has the potential to result in short-term, localised impacts on shallow groundwater however no significant impacts on groundwater resources, groundwater quality or downstream users are expected.

The design of any groundwater bores constructed for construction water supply will focus on reducing potential impacts to any GDEs or other existing groundwater users. This will be achieved by allowing suitable distance between the bores and any known GDE sites, other user extraction points or sensitive environmental sites such as wetlands or watercourses. Bore locations will take into consideration the expected cone of influence associated with the groundwater drawdown. Bore pumping times and desired flow rates will be managed to ensure that the aquifer is not over utilised.

Construction of the NGBR Project has the potential to directly and indirectly impact water resources within the study area including flow and quality to downstream users. Through the implementation of management and mitigation measures the potential residual impacts on surface and groundwater flow and quality for downstream water use is anticipated to be minimal. At a regional level, the downstream impact of any sediment released from localised erosion during construction at waterway crossings are expected to be significantly less than the impact from other land uses and existing sediment sources in the catchment. Impacts to local surface water quality through accidental spills or leaks from equipment and the resulting potential impacts to downstream users will be minimised through the implementation of a Dust Management Plan, Erosion and Sediment Control Plan and Water Quality Management Plan.

No impacts to the availability of surface water for stock watering and farm use is anticipated during construction as changes to downstream flow volumes are anticipated to be negligible.

Any riverine protection permits required under the *Water Act 2000* will be obtained for the construction of watercourse structures (refer Chapter 20 Legislation and approvals) which will also ensure that potential water quality impacts to downstream water users are minimised.

Groundwater

The potential impacts on groundwater from construction activities include degradation of groundwater quality, intersection of groundwater flows, reduced groundwater levels, and an increase in aquifer permeability. Construction activities that have the potential for adverse impacts on groundwater in the study area include earthworks, quarries and borrow areas, watercourse crossings, blasting, construction camps, concrete batching plants and construction yards. The implementation of mitigation and management measures outlined in Table 9-9 will minimise the potential for impacts on existing groundwater quality and availability.

The impacts to groundwater elevations from earthworks and bridge piling works will primarily be associated with potential dewatering requirements. However, groundwater infiltration rates into bridge foundation bore holes or cuttings would be minor and temporary given the depth to groundwater in most locations and the relatively short-term nature of these types of works.

There is also the potential for groundwater quality impacts associated with blasting in quarries and cuts. Adverse impacts may include a net loss in groundwater supply to impacted receptors where shallow aquifers are intersected by quarries and cuttings. Sensitive receptors include those in the vicinity of any perennial water bodies, near shallow water supply bores, and within the coastal dune, alluvium and deltaic deposits. At these locations additional field investigations may be required to better characterise the groundwater conditions and impacts.

Wastewater

Wastewater generated by construction camp operation will include grey water and sewage. Maintenance fluids generated during plant and equipment operation may include paints, solvents, lubricants and oils. Hydrocarbon and water mixtures or emulsions, including oil and water mixtures or emulsions will be generated in plant and equipment wash-down areas.

Improper management of wastewater could impact on a range of environmental values including surface water and groundwater quality.

The waste management strategy, including mitigation and management measures, for the NGBR Project is described in Volume 1 chapter 13 Waste. The waste management strategy will continue to be developed and refined during detailed design.

9.4.2 Operation

Surface water flow

Operation of the NGBR Project requires a number of permanent waterway crossing structures that have the potential to impact existing surface water flows and hydrology. Changes in waterway hydrology including flow speeds and flow paths may subsequently cause local erosion (bed and bank scouring) within the watercourses or existing infrastructure structures. The presence of existing waterway instabilities in the vicinity of crossings that may pose a risk to the infrastructure and/or become exacerbated by changes in localised hydraulic conditions due to the presence of the structures will be investigated and appropriate mitigation and management strategies incorporated during ongoing detailed design.

Detailed design of the cross drainage structures will involve the selection of appropriate types of crossings for waterways to minimise impacts to the existing geomorphic form and integrity of the watercourse. This will be particularly important for the crossing of major waterways, where multi-channelled waterways mean a number of bridge and culvert structures will be required to reduce impacts on hydraulic conditions at these location. The proposed structures at major water crossings and an assessment of the potential hydrologic and hydraulic impacts of these structures are provided below. Bridges, culverts and transverse drainage features will be periodically maintained during operation, which may include removal of debris and maintenance of scour protection as necessary, to ensure operational impacts on surface water flows are minimised. Concept design drawings of typical cross drainage structures are provided in Volume 2 Appendix T Concept Design Drawings.

Flood regime

Introducing permanent drainage infrastructure along or across an existing waterway can potentially alter existing drainage patterns in the short-term, leading to temporary changes in afflux upstream of the flow path. The concept design stage of the NGBR Project includes preliminary sizing for waterway crossings such as bridges and drainage culverts based on hydrological and hydraulic investigations. Volume 2 Appendix H2 Hydrology and hydraulics presents the hydrology and hydraulic investigations for the NGBR Project. The design approach for bridge and drainage structures at waterway crossings aims to minimise effects such as flow velocity, ponding, change in flow directions, or increases in flood levels (afflux) on the surrounding environment and infrastructure.

The cross drainage structures proposed at major and moderate watercourses intersected by the final rail corridor are summarised in Table 9-7.

Table 9-7 Major and moderate waterway crossings and proposed structures

Watercourse name	Chainage (km)	Catchment size (km^2)	Peak flow ARI[1] 50 years (m^3/s)	Crossing structure
Splitters Creek	20.23	76.24	592.68	3 x 20.2 m span bridge and drainage structures
Elliot River	35.08	128.08	999.44	4 x 20.2 m span bridge
Bogie River	61.22	432.51	2732.63	9 x 20.2 m span bridge
Sandy Creek	64.78	149.45	663.77	3 x 20.2 m span bridge
Strathmore Creek	98.78	155.55	558.71	2 x 20.2 m span bridge
Pelican Creek	106.05	563.74	2136.05	8 x 20.2 m span bridge
Bowen River	132.20	5806.25	12560.80	20 x 20.2 m span bridge and drainage structures
Suttor River (upper)	172.06	296.42	543.01	2 x 20.2 m span bridge
Lily Creek	176.58	40.12	126.05	Drainage structures

Watercourse name	Chainage (km)	Catchment size (km^2)	Peak flow ARI[1] 50 years (m^3/s)	Crossing structure
Rockingham Creek	187.00	138.48	301.44	3 x 20.2 m span bridge
Murray Creek	206.51	100.37	311.27	3 x 20.2 m span bridge
Upper Gun Creek	220.86	39.09	84.13	Drainage structures
Gunn Creek	231.20	115.39	157.28	Drainage structures
Verbena Creek	242.53	399.25	526.03	3 x 20.2 span bridge
Serpentine Creek	244.49	101.92	171.30	Drainage structures
Suttor River (lower)	271.06 - 273.37	10541.82	8217.43	30 x 20.2 span bridge, 9 x 20.2 span bridge, 11 x 20.2 span bridge, 5 x 20.2 span bridge and drainage structures

Note 1. ARI is the Annual Recurrence Interval

Hydrology and hydraulic modelling was undertaken (refer Section 9.2.8) to assess the potential impacts of the cross drainage structures identified in Table 9-7. A number of one-dimensional HEC-RAS model hydraulic simulations were undertaken to assess peak water levels, velocities and afflux for the 10, 20 and 50 ARI events for both the existing and post development scenarios for each waterway crossing.

The one-dimensional modelling was applicable to watercourses that have a well-defined channel and simple flow regimes. Preliminary two-dimensional hydraulic modelling was conducted for the major waterway crossings (catchment sizes greater than 100 km^2) where channels are meandering, braided complex or floodplain flow occurs. The preliminary two-dimensional modelling results are detailed in Volume 2 Appendix H2 Hydrology and hydraulics including maps showing peak flood inundation depths, water surface elevations, velocities, inundation extents and afflux. These models are preliminary and further refinement of the models will be undertaken during detailed design to ensure cross drainage structures are designed to minimise any changes to afflux levels. Average inundation time was predicted for significant major watercourses to identify increases to duration of inundation at critical locations.

Achieving afflux design criteria is a process that seeks to achieve a balance between minimising the impacts of afflux and achieving a practical and cost effective design. Some amount of afflux is unavoidable due to the proposed structures, and infrastructure assets in the floodplain such as roads and farm tracks, will most likely be affected by any increased depth and duration of flooding. For the purpose of the hydrology and hydraulics study, it was considered that any increase in duration of flood inundation should not exceed an average of 72 hours or 20 per cent of existing duration (whichever is greater) during the 50 year ARI event. Consultation with landholders regarding these issues, including mitigation of potential afflux-related access issues is ongoing, as reported in Volume 2 Appendix B Public consultation.

Modelled afflux and duration for the post development case met the nominated design criteria at all critical locations (refer Volume 2 Appendix H2 Hydrology and hydraulics). The results of one-dimensional hydraulic modelling indicated that afflux levels adjacent to proposed cross drainage structures predominantly meet the 50 year afflux design criteria of 0.5 m for non-critical infrastructure/housing and uninhabited areas. It was also observed that the afflux reduces to around 0.1 m within a reasonable distance of 100 m to 200 m from the final rail corridor.

Predicted increases in the duration of inundation also met the nominated design criteria. Table 9-8 contains the predicted increase in the duration of inundation on major watercourses, at the nearest point on the watercourse to a potentially affected homestead.

None of the homesteads identified in Table 9-8 were predicted to be inundated in developed case modelling. Property level flood mapping has been undertaken and is provided in Volume 2 Appendix H4 Flood mapping.

Table 9-8 Average inundation time for major watercourses at nearest point to nearby homesteads

Watercourse	Nearest homestead	Duration pre-development (hours)	Duration post-development (hours)	Increase in duration (hours)
Splitters Creek	Homestead 2	36	38	2
Finley Creek Elliot River	Homestead 3	31	32	1
Butchers Creek Elliot River	Homestead 4	29	30	1
Bogie River	Homestead 8	26	27	1
Sandy Creek	Homestead 9	20	22	2
Pelican Creek	Homestead 14	47	49	2
Bowen River	NA[1]	67	68	1
Rosella Creek	Homestead 16	52	54	2
Suttor River (upper)	NA[1]	45	48	3
Rockingham Creek	NA[1]	18	20	2
Murray Creek	NA[1]	18	20	2
Verbena Creek	NA[1]	53	55	2
Serpentine Creek	NA[1]	52	55	3

Watercourse	Nearest homestead	Duration pre-development (hours)	Duration post-development (hours)	Increase in duration (hours)
Suttor River (lower)	Homestead 22	144	156	12

1 No homestead considered sufficiently close to the final rail corridor

Infrastructure associated with the NGBR Project has the potential to alter the characteristics of the flooding regime within the study area, however, the extent of these changes in the vicinity of existing infrastructure (including homesteads and roads) is predicted to be within acceptable levels. The design approach for bridge and drainage structures at waterway crossings has been aimed at the safe passage of flood flows with minimal effects on flow velocity, ponding, change in flow directions, or increases in flood levels on the surrounding environment and infrastructure.

Results of modelling indicate that the use of drainage structures along the NGBR Project can mitigate hydraulic impacts to an acceptable level.

Surface water quality

During operation, surface water runoff from the final rail corridor will be managed through a longitudinal drainage system that connects to cross drainage infrastructure at existing drainage lines and waterways. The design of the longitudinal and cross drainage system will include measures such as scour protection at culvert outlets to minimise the potential for scouring and erosion. Where appropriate, drainage channels or culvert outlets will be lined with riprap or similar to minimise scouring. The design of culvert outlets will also aim to restrict the velocity of surface water at the culvert outlet to 2.5 m/s for the designed flood event.

Scour protection will also be included at bridge abutments and embankments adjacent to bridges in accordance with the Austroads 1994 Waterway Design Manual.

Surface runoff from the final rail corridor may also contain sediment, traces of fuel, dissolved metals and other contaminants deposited in the corridor from operation activities that can alter water quality. The majority of waterways crossed by the final rail corridor are all moderately disturbed as a result of existing land use practices with elevated turbidity and conductivity levels, and any contribution of contaminants due to surface runoff from the final rail corridor is anticipated to be minimal. The implementation of suitable management and mitigation measures will reduce the likelihood of impact in these areas (refer to Volume 1 Chapter 21 Environmental management and Volume 2 Appendix P Environmental management plan framework)

Potential impacts to surface water quality during operation of the NGBR Project may also include coal dust emissions from coal trains that are transported into waterways via surface runoff. Contamination of waterways may also occur if heavy metals are associated with deposited coal dust particles (Swer and Singh, 2003). Modelling of coal dust deposition rates as a result of the NGBR Project operation indicate that dust deposition rates will be very low (<10% of criterion values for the protection of human health) prior to implementation of mitigation measures (Volume 2 Appendix I Air quality). Therefore, potential impacts to surface waters from operational coal dust emissions are expected to be minimal.

An increase in vehicle traffic for the purpose of operational maintenance may also result in a minor increase in dust generation from the movement of maintenance vehicles along dirt access tracks, particularly during dry and windy conditions. Dust can settle within the waterways or in the terrestrial environments, where runoff can mobilise settled dust to waterways and has the potential to decrease water quality. Operational vehicle traffic within the final rail corridor during operation is predicted to be low, and therefore impacts from such dust generation are expected to be insignificant (refer Volume 1 Chapter 14 Transport).

Works involving operational maintenance within and adjacent to the waterways have the potential to introduce contaminants to the aquatic environment in the event there are accidental spills or leaks from equipment. Any introduction of contaminants has the potential to influence both the local surface water quality at the source as well as downstream. The implementation of a Dust Management Plan, Erosion and Sediment Control Plan, Water Quality Management Plan and other suitable management measures will reduce the potential impacts of dust and contaminants on water quality (refer to Volume 1 Chapter 21 Environmental management and Volume 2 Appendix P Environmental management plan framework).

Given the implementation of these mitigation measures, impacts to water quality during operation of the NGBR Project are anticipated to be minimal.

Water use

No impacts to the availability of surface and groundwater for stock watering and farm use are anticipated during operation as the NGBR Project is not expected to permanently divert, abstract or take surface water or groundwater from any waterway or aquifer.

The purpose of the *Environmental Protection (Water) Policy 2009* (EPP Water) is to ensure the objective of the EP Act is upheld in relation to all Queensland waters, including those in rivers, streams, wetlands, lakes, aquifers, estuaries and coastal areas. Environmental values and water quality guidelines are determined according to a process detailed in the National Water Quality Management Strategy, Implementation Guidelines and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC). Environmental values and water quality objectives are categorised by region and sub-basin and documented under Schedule 1 of the EPP Water.

The environmental values of waters traversed by the NGBR Project are not defined under Schedule 1 of the EPP Water; however, given the design criteria of the NGBR Project to minimise impacts to surface water quality and flow (refer to Volume 1 Chapter 02 Project description), and the implementation of mitigation and management measures outlined in Section 9.4.3, impacts on downstream water infrastructure and water users are anticipated to be minimal.

Groundwater

Any minor impacts to groundwater levels during construction due to dewatering at cutting locations are anticipated to normalise relatively quickly after construction completion. Therefore, adverse impacts to groundwater water levels are anticipated to be negligible. Permanent subsurface structures such as bridge foundations are anticipated to have a negligible impact on groundwater flow after the completion of construction.

Storage of chemicals, fuels, machinery and waste has the potential to impact groundwater quality where significant spills and leaks occur. Contaminants have the potential to enter groundwater through infiltration and runoff and cause degradation of water quality and impact on groundwater users. Camp sites, concrete batching and the rolling stock maintenance facility are the primary infrastructure for storage of fuel related products and refuelling points, and represents the key source of contaminants that could impact groundwater qualities. The potential of spills and leaks impacting groundwater quality would be managed through the implementation of the mitigation and management measures outlined in Table 9-9.

During the operation of the final rail corridor, spillage of transported coal could provide a source of potentially slightly acidic run-off. However, impacts from spilled resources along the final rail corridor are anticipated to be low, and close to zero if appropriately managed through wagon maintenance and inspection (refer to Volume 2 Appendix P Environmental management plan framework).

Due to the nature of the rail corridor and the extent of haul roads it is not anticipated that there will be significant reduction in recharge to groundwater other than at larger facility locations such as the rolling stock maintenance facility. The final rail corridor may result in the dislocation of landholders from their water supplies; however, these impacts are not anticipated to be significant as they can be effectively dealt with by implementation of mitigation measures such as additional water supplies (new bores and/or dams) and appropriate access across the final rail corridor for stock and land use practices (refer to Volume 2 Chapter 3 Land use and tenure and Volume 2 Appendix B Public consultation).

Wastewater

Maintenance fluids generated during rolling stock maintenance operation will include paints, solvents, lubricants and oils. Hydrocarbon and water mixtures or emulsions, including oil and water mixtures or emulsions will be generated by train washing or rainwater runoff from the track formation.

Improper management of wastewater during operation of the NGBR Project has the potential to impact on a range of environmental values including surface water and groundwater quality. A waste management strategy will be developed and implemented for the NGBR as discussed in Volume 1 chapter 13 Waste. Wastewater, including sewage and grey water, will be treated onsite at modular aerobic treatment units. The method of disposal of treated wastewater will be dependent on treated effluent water quality, however is expected to be via irrigation to land/landscaping and/or disinfection for reuse in train washing facilities. Waste water discharge limits and thresholds will be developed based on site location, ground conditions, vegetation, and proximity to waterways and groundwater sources. Site based management plans (SBMP) will be developed to ensure that site-specific treatment and discharge requirements are clearly identified, managed and compliance is audited and reported.

9.4.3 Summary of mitigation and management measures

The mitigation and management measures outlined in Table 9-9 will be implemented to reduce and avoid the potential impacts of the NGBR Project on water resources within the study area. These mitigation and management measures will be implemented in conjunction with the measures outlined in the following chapters:

- Volume 1 Chapter 5 Topography, geology, soils and land contamination
- Volume 1 Chapter 10 Air quality
- Volume 1 Chapter 18 Hazard, risk, health and safety.

Table 9-9 Mitigation and management measures

Timing	Mitigation measure
Pre-construction and construction	Water quality during construction will be managed through a Water Quality Management Plan, which includes the following management measures: • Storing fuels, chemicals, wastes and other potentially environmentally hazardous substances in contained areas away from watercourses • Refuelling to take place away from watercourses. Spill kits are available during refuelling • Regular checks of vehicles and equipment for oil leaks • Dewatering procedures for the management of construction groundwater inflow or stormwater collection on site including appropriate capture, treatment and disposal measures • Emergency response protocols and procedures for implementation in the event of a contaminant spill or leak • Waterway profiles at temporary construction access roads and temporary construction facility areas will be reinstated and disturbed areas promptly stabilised following completion of construction works • Existing disturbed areas will be utilised to access waterways • The construction of waterway crossings will be scheduled during dry or low flow periods, where practicable • The construction of waterway crossings will be completed promptly to minimise impacts • All construction camp stormwater captured on site will be reused for irrigation, dust suppression or stored within sediment basins before being appropriately treated and discharged. • The route used by machinery in and out of the work sites on waterways will be controlled and the need for access of heavy machinery to the bed of the waterways will be avoided, where practicable. Works will be undertaken from the top of waterway banks where possible. • Emergency spill response procedures. The Water Quality Management Plan will perform in conjunction with the Erosion and Sediment Control Plan (refer Volume 1 Chapter 5 Topography, geology, soils and land contamination).
Pre-construction	Detailed design of watercourse structures will include: • Further investigations, including detailed identification and consideration of all afflux affected property and assets, to determine afflux levels and appropriate drainage structure dimension requirements. Additional hydrology and hydraulic modelling will be

Timing	Mitigation measure
	undertaken during detailed design to refine bridge design, culvert design and afflux values. • Causeways and other temporary drainage structures will be designed to provide sufficient hydraulic capacity such that there is minimal increase in velocity of natural flows • Further investigation into scour protection to determine the appropriate depth of cover or scour protection required at each crossing and the appropriate permanent scour protection measures provided for abutments, piers, culverts, inlets and outlets.
Pre-construction	Rail bridges will be designed for a 100 year ARI discharge plus 300 mm freeboard to mitigate impacts from flooding.
Pre-construction	At quarry locations, further investigation into potential groundwater impacts will be undertaken to better characterise the groundwater conditions and impacts at these locations.
Pre-construction	Cuts/excavations and ground support will be designed to reduce the need for dewatering through the alteration of construction techniques. Increased construction effort, for example, may reduce the duration over which dewatering may be required.
Construction	Wastewater from concrete batching plants will be captured, stored and either reused in concrete batching or treated and disposed appropriately
Construction	Appropriate permits and/or licences will be obtained for all water required during construction, including groundwater abstraction, overland flow harvesting, in-stream and off-stream storages. In addition, appropriate permits for operational works that affect waterways will be obtained for all waterways to be affected during construction.
Construction	Upstream and downstream water quality monitoring will be undertaken during construction. Allowable threshold levels for downstream results will be determined in consultation with DNRM prior to construction commencing and would be outlined in the NGBR Project conditions of approval. The threshold limit will include a maximum acceptable per cent increase above upstream back ground levels as well as an acceptable maximum duration for changes to any water quality parameter.
Operation	Any flood damage to infrastructure adjacent to the NGBR Project as a result of changes to hydrology during operation, will be reinstated in consultation with the relevant infrastructure owner.
Operation	During operation, all cross drainage and longitudinal drainage structures will be maintained and kept clear of debris.

9.5 Conclusion

Construction and operation of the NGBR Project has the potential to directly and indirectly impact water resources within the study area. Through the implementation of management and mitigation measures the potential residual impacts on surface water, flood regime, water quality, water use and groundwater are anticipated to be minimal.

It is expected that any residual impacts on the morphology of waterways and water quality are expected to be minimal, but may include infrequent localised minor erosion and scour limited to crossing locations of the rail corridor. At a regional level, the downstream impact of any additional sediment released from any ongoing localised erosion at waterway crossings would be expected to be significantly less than the impact from other land uses and existing sediment sources in the catchment.

Based on hydrological and hydraulic investigations of proposed structures at waterways traversed by the NGBR Project, including culverts and bridges, afflux impacts on the upstream side of structures are anticipated to be within 0.5 m of design objectives (Aarvee Associates, 2013). Flood modelling and analysis will continue to be undertaken during detailed design to further refine hydrological estimates and design of structures to minimise afflux or flooding extent (refer to Volume 2 Appendix H2 Hydrology and hydraulics).

No residual impacts have been predicted to stock watering and farm use. It is also unlikely that any adverse effects upon stock water and irrigation will occur due to afflux generated by the proposed drainage structures required for the NGBR Project.