Appendix E  Hydrogeological Study
Colton Mine

Hydrogeological Study

Report No. 2008010001-RPT-001

Commissioned by
Northern Energy Corporation Limited

July 2010
Limitations statement

This report has been prepared for Northern Energy Corporation Limited solely for use in relation to the Colton Mine Project being undertaken by Northern Energy Corporation Limited.

In preparing the report, Streamline Hydro has relied on data and information from a variety of sources including water bore records provided by the Queensland Department of Natural Resources and Water and surface geological mapping. Unless explicitly stated in the report no attempt has been made to verify the accuracy or completeness of such information.

Figures in the report have been prepared from information supplied by government departments, Northern Energy Corporation Limited and Streamline Hydro. Streamline Hydro accepts no liability for the accuracy and correctness of the figures.

The findings of this report are based on the data available at the time of the investigation and the level of assessment requested by Northern Energy Corporation Limited. Should further data and information become available, the Project be altered or more detailed investigations be undertaken, the findings of this report may no longer be valid.

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## Key Terms and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>Australasian Groundwater and Environmental Consultants</td>
</tr>
<tr>
<td>AHD</td>
<td>Australian Height Datum</td>
</tr>
<tr>
<td>AMD</td>
<td>Acid and metalliferous drainage</td>
</tr>
<tr>
<td>ANZECC</td>
<td>Australian and New Zealand Environment and Conservation Council</td>
</tr>
<tr>
<td>ARMCANZ</td>
<td>Agriculture and Resource Management Council of Australia and New Zealand</td>
</tr>
<tr>
<td>bGL</td>
<td>Below ground level</td>
</tr>
<tr>
<td>BoM</td>
<td>Bureau of Meteorology</td>
</tr>
<tr>
<td>CHPP</td>
<td>Coal handling and preparation plant</td>
</tr>
<tr>
<td>DERM</td>
<td>Department of Environment and Resource Management</td>
</tr>
<tr>
<td>DNRW</td>
<td>Department of Natural Resources and Water</td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Authority</td>
</tr>
<tr>
<td>EMP</td>
<td>Environmental Management Plan</td>
</tr>
<tr>
<td>EP Act</td>
<td>Environmental Protection Act 1994</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>EPC</td>
<td>Exploration Permit for Coal</td>
</tr>
<tr>
<td>EPP Water</td>
<td>Environmental Protection (Water) Policy 2007</td>
</tr>
<tr>
<td>EV’s</td>
<td>Environmental values</td>
</tr>
<tr>
<td>GWDB</td>
<td>Groundwater database</td>
</tr>
<tr>
<td>LWBC</td>
<td>Land and Water Biodiversity Committee</td>
</tr>
<tr>
<td>ML</td>
<td>Mine lease</td>
</tr>
<tr>
<td>MLA</td>
<td>Mine lease application</td>
</tr>
<tr>
<td>NHMRC</td>
<td>National Health and Medical Research Council</td>
</tr>
<tr>
<td>NRMMC</td>
<td>Natural Resource Management Ministerial Council</td>
</tr>
<tr>
<td>QLUMP</td>
<td>Queensland Land Use Mapping Program</td>
</tr>
<tr>
<td>WERD</td>
<td>Water Entitlements Registration Database</td>
</tr>
<tr>
<td>WQO’s</td>
<td>Water quality objectives</td>
</tr>
</tbody>
</table>
Executive summary

Northern Energy Corporation Limited (NEC) is the proponent intending to develop an open cut coal mine north of Maryborough in south-east Queensland. The mine is to be known as the Colton Mine and NEC has made application for two mining leases (MLA50271 and MLA50274) which will occupy a portion of NEC’s current Exploration Permit for Coal (EPC) 923.

NEC commissioned Streamline Hydro Pty Ltd to undertake a groundwater study to address the groundwater specific requirements of an environmental management plan for the Colton Mine. This report is the culmination of this work and describes the hydrogeology of the Project area, provides an assessment of the potential impacts of the Project, proposes mitigation measures and describes a groundwater monitoring plan for the Project. As part of this study, groundwater modelling was required and NEC engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) for this task. This report should therefore be read in conjunction with the AGE (2010) report which has been included in Appendix 3.

This study includes discussion of relevant background information legislation, physical setting and geological setting, prior to detailing the field investigations that were undertaken. Field investigations included:

- installation of 14 groundwater monitoring bores and 2 production / test bores
- collection of groundwater level data over a 12 month period using both manual and automated methods
- collection of groundwater quality information from 4 field sampling events
- conduct of head tests within monitoring bores
- conduct of a step rate and 24 hour constant rate pumping test

As a result of this study, the water bearing zones present in the area are considered to be:

- Shallow, localised lensoidal zones associated with sandy or ferugenous gravels in the overlying Elliott Formation;
- Aquifers associated with fractured zones in the weathered overburden material; and
- Confined / semi-confined aquifers associated with coal seams.

The Burrum Coal Measures are considered to be the only aquifer within the Project area. Water intersection occurred at depths of 5-15 m below surface. Contours of the potentiometric surface from Laycock (1967) are presented in AGE (2010) along with the steady state modelled levels. The contours indicate a groundwater divide exists to the north of the Project site and is oriented southwest to northeast and approximates the surface drainage divide. On the southern side of the divide, groundwater flow is generally to the southeast while on the northern side flow is largely to the northwest.

Groundwater quality of the Burrum Coal Measures is poor with the field water quality results indicating that the groundwater is slightly acidic with the pH ranging from 5.5 to 7.1 and electrical conductivity ranging from approximately 7 mS/cm to 21 mS/cm indicating the groundwater varies from brackish to saline.
Key findings from the groundwater modelling conducted by AGE (2010) were as follows:

- The modelled inflow reaches 0.8 ML/day in the second year of mining and then gradually increases to 1.2 ML/day at the end of Year 4 after which it is relatively constant for the remaining four years of mining;
- The zone of influence, as indicated by the 1m drawdown contour, will extend about 2.9 km from the open cut pit;
- No registered bores are within the simulated zone of influence;
- Post mining, about 50% of the water level recovery will occur within the first 2 years and the void will be 75% recovered in about 9 years. The void will then slowly recover to an equilibrium level reached in about 100-150 years; and
- Sensitivity analysis indicates that the zone of influence extends between about 100m and 300m further when the hydraulic conductivity is increased by 10%, and less than 100 m when the recharge rate is reduced by 10%.

A wide range of potential impacts were identified and discussed and as no existing users were identified, those potential impacts requiring the most consideration were found to be:

- Acid and metalliferous drainage
- Impact of dams
- Groundwater depletion and recharge
- Groundwater dependent ecosystems
- Impacts on historic mine workings

In conclusion a groundwater monitoring program has been proposed to:

- provide a means of early detection and management of groundwater related impacts
- assess the progress of de-watering due to bores and seepage into the mine pit thus aiding in water supply/storage management
- identify any seepages and changes in groundwater quality as a result of de-watering or seepage from dam, spoil and stockpile areas
- to check for acid rock drainage generation and assess the performance of management strategies
- provide data for review of the groundwater model
1. **Introduction**

Northern Energy Corporation Limited (NEC) is the proponent intending to develop an open cut coal mine north of Maryborough in south-east Queensland. The mine is to be known as the Colton Mine and NEC has made application for two mining leases (MLA50271 and MLA50274) which will occupy a portion of NEC’s current Exploration Permit for Coal (EPC) 923. The Project location is shown in Drawing 1.

Prior to development of the mine, NEC must be granted a valid mining lease (ML). In order to be granted a mining lease, the Environmental Protection Act 1994 (EP Act) requires an Environmental Authority (EA) be granted. This process requires that an Environmental Management Plan (EMP) be developed.

NEC commissioned Streamline Hydro Pty Ltd to undertake a groundwater study to address the groundwater specific requirements of an EMP for the Colton Mine. This report is the culmination of this work and describes the hydrogeology of the Project area, provides an assessment of the potential impacts of the Project, proposes mitigation measures and describes a groundwater monitoring plan for the Project.

As part of this study, groundwater modelling was required and NEC engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) for this task. This report should therefore be read in conjunction with the AGE (2010) report which has been included in Appendix 3.

2. **Project overview**

NEC has identified a high quality coking coal resource within EPC923 following review of historical drilling and small-scale mining activities supported by NEC’s own recent drilling investigations. NEC intends to develop this resource by establishing the Colton Mine and associated infrastructure.

Mining will be conducted utilising excavators and trucks with a coal handling and preparation plant (CHPP) to be built within the proposed mine lease. The open cut pit will cover an area of approximately 115 ha with a depth of approximately 60-80 m below ground level.

The anticipated production rate is 0.5 Mtpa with a mine life of 8-10 years. It is intended that coal will be transported by train to Gladstone for export.

Water supply will be from surface water captured within the site, groundwater seepage and de-watering bores.
3. **Scope and methodology**

The scope of work provided by NEC was to provide a groundwater technical report sufficient to address the generic terms of reference for an environmental impact statement (EIS) provided by the Department of Environment and Resource Management (DERM), formerly the Environmental Protection Agency (EPA).

The groundwater investigation for the Project included the following key tasks:

- **Task 1 – Data Review** – existing hydrogeological information was reviewed to determine data gaps and where additional information should be collected (documented in this report).

- **Task 2 – Field Investigations** – an investigative program including installation of monitoring bores, permeability tests and water quality analysis was undertaken to address the data gaps (documented in this report).

- **Task 3 – Data Analysis and Numerical Modelling** – The information collected in the desktop study and the field investigations was analysed and used to construct a numerical model of the groundwater regime, which was used to assess the impact of the proposed open cut mine (documented in the AGE (2010) report).

- **Task 4 – Assessment Project Impact, Mitigation and Monitoring Plan** – The results of field investigations and modelling tasks were used to identify the impact of the project, the need for mitigation strategies and a long term monitoring plan (documented in this report).

Tasks 1, 2 and 4 are detailed under the headings below. Task 3 is presented in AGE (2010) which is included in Appendix 3 and only briefly discussed in the body of this report.

4. **Information sources**

The key information sources utilised for the study are listed in Table 4-1. There is a dearth of hydrogeological information in the Project area with only one regional hydrogeological study (Laycock, 1967) being previously undertaken co-operatively by the Geological Survey of Queensland and the Queensland Irrigation and Water Supply Commission. The aim of this investigation was to provide a preliminary assessment of the groundwater potential of the area between Tiaro and Pialba to indicate localities with promising supplies and areas where more detailed investigations may be warranted in the future (Laycock, 1967).

4.1 **Limitations and assumptions**

The study is limited to the proposed mining leases associated with the Colton Mine and does not include any assessment of groundwater in relation to the road, rail, port or other infrastructure activity that may occur external of the proposed mining leases. Field work was based on the initial intended mine design and mining leases, which have been revised since the field program was conducted.
Assessment of the potential for and impacts associated with any groundwater extraction for water supply purposes was not in the scope and has not been considered.

**Table 4-1  Key information sources**

<table>
<thead>
<tr>
<th>Data / information</th>
<th>Date provided / current at</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Databases</strong></td>
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<tr>
<td>DERM (formerly DNRW) GWDB</td>
<td>30 April 2008</td>
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<tr>
<td>DERM (formerly DNRW) WERD</td>
<td>9 July 2008</td>
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<td><strong>Mapping / GIS</strong></td>
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<td>GEODATA TOPO 250K Series 3</td>
<td>26 June 2006</td>
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<tr>
<td>1:250 000 Geological Map Series – Sheet SG56-06</td>
<td>1992</td>
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<tr>
<td>1:100 000 Queensland Geological Mapping Data</td>
<td>2007</td>
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<tr>
<td>Declared subartesian areas</td>
<td>5 January 2009</td>
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<tr>
<td>Water resource plan areas</td>
<td>5 January 2009</td>
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<tr>
<td><strong>Legislation</strong></td>
<td></td>
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<tr>
<td>Environmental Protection Act 1994</td>
<td>23 February 2009</td>
</tr>
<tr>
<td>Environmental Protection (Water) Policy 1997</td>
<td>1 January 2009</td>
</tr>
<tr>
<td>Water Act 2000</td>
<td>1 January 2009</td>
</tr>
<tr>
<td>Water Regulation 2002</td>
<td>1 May 2009</td>
</tr>
<tr>
<td>Water Resource (Mary Basin) Plan 2006</td>
<td>1 July 2008</td>
</tr>
</tbody>
</table>
5. **Legislative framework**

In Queensland, water resource management, use and protection are primarily governed by the following legislation:

- Water Act 2000
- Environmental Protection Act 1994 (EP Act)

In addition to these principal legislative instruments, there is also a range of subordinate legislation used to achieve the outcomes of these Acts including:

- Water Regulation 2002;
- Water resource plans;
- Resource operations plans; and
- Environmental Protection (Water) Policy 2007 (EPP Water).

5.1 **Water Act 2000**

The taking and interfering with water is not controlled in all areas of the State. The areas which are controlled have been prescribed so by either water resource plans or under the Water Regulation 2002. In each case the Water Regulation 2002 or the relevant water resource plan details the management and use of the water to which the plan applies.

The following can be concluded with regard to the Project location:

- The Project is not located within any currently declared artesian or subartesian areas (under the Water Act 2000); and
- The Project is located within the Water Resource (Mary Basin) Plan 2006 area.

Section 9 of the Water Resource (Mary Basin) Plan 2006 specifies water to which the plan applies:

9 **Water to which plan applies**

(1) This plan applies to the following water in the plan area—

(a) surface water;
(b) subartesian water in the Cooloola Sandmass subartesian area.

(2) In subsection (1)—

**surface water** means the following—

(a) water in a watercourse or lake;
(b) water in springs not connected to—

(i) artesian water; or
(ii) subartesian water connected to artesian water.
As the Project is not located within the Cooloola Sandmass subarteresian area, the Water Resource (Mary Basin) Plan 2006 has no bearing on groundwater (artesian or subarteresian) within the Project area.

In December 2007, amendments to the Water Resource (Mary Basin) Plan 2006 were made under sections 50 and 56 (4) of the Water Act 2000. These amendments do not affect the water to which the Plan applies as set out in Section 9 of the Plan.

A draft resource operations plan for the Mary Basin is yet to be released.

5.2 **Environmental Protection Act 1994**

The Environmental Protection (Water) Policy 1997, subordinate legislation to the EP Act, has the purpose of protecting Queensland’s waters (including groundwater) principally through:

- Identifying environmental values for these waters; and
- Deciding and stating water quality guidelines and water quality objectives (WQO’s) to enhance or protect the environmental values (EV’s).

The Policy also stipulates obligations for the chief executive (water resources) in relation to the development and implementation of environmental plans about environmental water provisions for Queensland waters and protecting ground waters.

Schedule 1 of the EPP Water lists the waters for which environmental values are to be enhanced or protected and specifies the document that details the environmental values and water quality objectives in each instance.

Following review of Schedule 1 and associated plans available from DERM, it was determined that the Project lies within the Mary River catchment as represented in plan WQ1381 (refer Appendix 1). The relevant document is therefore the Mary River Environmental Values and Water Quality Objectives (EPA, 2007). Section 1.1 of this document describes the waters to which it applies as:

- *all freshwaters and tributaries of the Mary River;*
- *the upper, mid and lower estuary/enclosed coastal water of the Mary River and Susan River and tidal tributaries including Tinana Creek;*
- *tidal canals, constructed estuaries, marinas and boat harbours and entrance buffers;*
- *wetlands, and*
- *ground waters.*

As the Mary River Environmental Values and Water Quality Objectives include ground waters, further consideration of the document is required from which it is determined that for ground waters, the environmental values to be protected are:

- aquatic ecosystems;
- drinking water;
• irrigation;
• stock water; and
• farm supply.

6. Physical setting

6.1 Location

The proposed Colton Mine is located within the Fraser Coast Regional Council local government area in southeast Queensland, the Project itself being approximately 8 km north of Maryborough as shown on Drawing 1.

The main population centres are Maryborough (approximate population 21,000) located 8 km south of the Project and Hervey Bay (approximate population 41,000) located 20 km to the northeast. The township of Aldershot (approximate population 500) is situated 3 km to the southwest of the Project. St Helens and Dundathu are two other small populated localities that exist to the south-southeast of the Project.

The North Coast Railway and Bruce Highway run parallel and pass through the western side of EPC923 over most of its north-south length. Access to the proposed mine lease area is principally from the Maryborough-Hervey Bay Road via Churchill Mine Road (graded road). Access to the east and northern parts of EPC923 is provided by Torbanlea-Pialba Road.

6.2 Topography and drainage

The topography of the Project area is relatively flat, consisting of a low remnant surface controlled by the Elliott Formation, typically ranging in elevation from 5 m AHD to 25 m AHD.

Drainage within and north-northeast of the Project is to the east via non-perennial tributaries of the Susan River which meets the Mary River near its mouth. The area to the south and west of the Project is drained by Saltwater Creek and its non-perennial tributaries which also flow to the Mary River.

Further to the north within EPC923, drainage is to the west via non-perennial tributaries of the Burrum River and to the north via Beelbi Creek and its non-perennial tributaries.

6.3 Land use

The land use in the immediate vicinity of the Project is remnant native cover. Data from the Queensland Land Use Mapping Program (QLUMP) conducted by the Department of Natural Resources and Mines in 1999 incorrectly classifies much of the land use in this area as Livestock Grazing. Small areas of low intensity livestock grazing may occur within EPC923 but are not within close proximity to the Project.

An area bounding the Project and extending to the north and north east is classified as Recreation and Culture in the QLUMP. This area relates to the recreational shooting range.
The areas of the Hervey Bay City Planning Scheme that are in closest proximity to the Project are zoned Rural Land. The township of Aldershot is zoned Low Density Residential with some Special Purposes Zoning for government, community and cultural uses. The locality of Dundathu is zoned Rural Residential with some Special Purposes Zoning for government and cemetery uses.

Plantation forestry exists to the west of the North Coast Railway which is within the western margin of EPC923. Several small plantation forestry test plots exist within 700 m of the Project. It is unknown whether these trials remain active.

Over 5 km to the north of the Project at Burgowan exists a number of water reservoirs which form part of Hervey Bay’s drinking water supply system which sources water from Lake Lenthall via the Burrum River. This infrastructure and associated tenure is held by Wide Bay Water Corporation.

To the south in the vicinity of Saltwater Creek, exists some agricultural plantation / cropping land use which is zoned Rural under the Maryborough Town Plan.

The Burrum Coal Measures have been commercially mined within and to the north of EPC923 for 132 years up to 1997 when the Burgowan No. 12 Colliery was closed. By June 1985, 9.3 Mt had been extracted by shallow underground mining (Thornton, 1995). All workings up to the end of Burgowan No. 12 were by hand with assistance to later operations provided by cutters and explosives. The product was primarily used for steam generation at the Howard Powerstation, local hospitals and industry.

### 6.4 Climate

Maryborough experiences a subtropical climate with significant variation in annual rainfall. Mean daily temperatures range from 9-23 °C in winter and 20-31°C in summer.

The closest Bureau of Meteorology (BoM) stations to the Project site with long-term rainfall records are listed in Table 6-1. As can be seen from Table 6-1, station 40050 closed in 1980 while both stations 40126 and 40098 are currently in operation.

**Table 6-1** BoM long-term rainfall stations in proximity to the Project

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>Distance from Project Site (km)</th>
<th>Latitude (Degrees)</th>
<th>Longitude (Degrees)</th>
<th>Station Height (m above MSL)</th>
<th>Start of Record</th>
<th>Closed</th>
<th>Length of Record (Years)</th>
<th>Completeness of Record (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40050</td>
<td>Colton Railway Station</td>
<td>2.5</td>
<td>-25.343</td>
<td>152.650</td>
<td>35.0</td>
<td>Jan-1899</td>
<td>Aug-1980</td>
<td>81.5</td>
<td>78</td>
</tr>
<tr>
<td>40098</td>
<td>Howard Post Office</td>
<td>16</td>
<td>-25.318</td>
<td>152.563</td>
<td>26.0</td>
<td>Jan-1899</td>
<td>Open</td>
<td>110.5</td>
<td>98</td>
</tr>
<tr>
<td>40126</td>
<td>Maryborough</td>
<td>10</td>
<td>-25.516</td>
<td>152.716</td>
<td>10.3</td>
<td>Feb-1870</td>
<td>Open</td>
<td>139.5</td>
<td>88</td>
</tr>
</tbody>
</table>

There is no BoM pan evaporation station in close proximity to the project site with the nearest stations being:

- 39174   Bundaberg Sugar Research Station   January 1966 – present
- 39128   Bundaberg Aero                   December 1997 – present
Figure 6-1 provides a summary of monthly rainfall and evaporation for Maryborough. The rainfall data presented is for station 40126 from 139 years of records while the evaporation data is from the SILO Patched Point Data set for station 40126. The evaporation data provided from SILO has been generated from long term average data from surrounding stations.

It can be seen from Figure 6-1 that mean monthly evaporation exceeds rainfall for all months except February and March and that the wet season occurs from December through March while the driest months are June through September. The mean annual rainfall and evaporation for Maryborough is 1151 mm and 1660 mm respectively while the lowest recorded annual rainfall for Maryborough is 325 mm in 1902 and the highest is 2248 mm occurring in 1956.

A technique used for examining long-term trends is known as the residual mass method, which involves summing the difference in actual monthly rainfall from the long-term mean monthly rainfall for each month over the period of interest. Where long-term groundwater or surface water level data exists this technique can also be applied or used to assess correlation between parameters. The rainfall residual mass curve for Maryborough is shown in Figure 6-2. A positive slope of the curve indicates a period of above average rainfall while a negative slope indicates below average rainfall. From Figure 6-2 it can be seen that the prevailing trend for approximately the last 30 years has been a negative slope, indicating below average rainfall during this period.
7. Geological setting

The Project site is situated within the north-northwest trending Maryborough Basin which occupies areas of 9,100 km² onshore and 15,500 km² offshore (Geoscience Australia, 2003).

7.1 Stratigraphy

The general stratigraphy of the Maryborough Basin is summarised in Table 7-1. The geological setting of the area is presented in Drawing 2 and is dominated by a duricrusted deep weathering profile, the Elliot Formation and the Burrum Coal Measures.

The geological units of relevance to this study are the Elliott Formation and the Burrum Coal Measures. Within the Project area, the Burrum Coal Measures have a conformable contact with the underlying Maryborough Formation and are unconformably overlain by the Elliott Formation.

Coal occurrence is limited to the Burrum Coal Measures and the Tiaro Coal Measures. The coal seams targeted by the Project are within the Burrum Coal Measures which comprise a three-fold lithological subdivision: upper and lower (non-productive) sandstone-siltstone-shale facies with little coal and a middle 500 m thick (productive) shaley sequence with economic coal seams centred on the Burrum Syncline (Cranfield, 1994). The surficial exposure of the Burrum Coal Measures is very poor due to superficial cover of Elliott Formation and alluvium and the presence of a deep-weathering, duricrust profile (Cranfield, 1994).
Figure 7-1 shows the coal seam stratigraphy adopted for NEC’s exploration in EPC923 which has been adapted from previous work by Hawthorne (1954, 1960) and Pearce (1963). Figure 7-1 illustrates only the upper portion of the Burrum Coal Measures as mining is not intended to extend beyond the base of the B seams.

Table 7-1  Maryborough Basin General Stratigraphy

<table>
<thead>
<tr>
<th>Age</th>
<th>Unit</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td>Elliott Formation</td>
<td>Sandstone, siltstone and clay with minor mudstone, conglomerate and shale</td>
<td>&lt; 50 m</td>
</tr>
<tr>
<td>Early Cretaceous</td>
<td>Burrum Coal Measures</td>
<td>Sandstone, siltstone, mudstone, shale, coal</td>
<td>0 to &gt; 1000 m</td>
</tr>
<tr>
<td></td>
<td>Maryborough Formation</td>
<td>Mudstone, shale, siltstone and sandstone with minor conglomerate, tuff and limestone</td>
<td>&gt; 3000 m</td>
</tr>
<tr>
<td>Jurassic to Cretaceous</td>
<td>Grahams Creek Formation</td>
<td>Intercalated volcanic and minor volcaniclastic sediments, trachyandesite and trachytes flows</td>
<td>0 to &gt; 1200 m</td>
</tr>
<tr>
<td>Jurassic</td>
<td>Tiaro Coal Measures</td>
<td>Sandstone, siltstone, coal, shale, mudstone and ferruginous oolite marker</td>
<td>&lt; 800 m</td>
</tr>
<tr>
<td>Triassic to Jurassic</td>
<td>Myrtle Creek Sandstone</td>
<td>Sandstone, siltstone and shale</td>
<td>&lt; 800 m</td>
</tr>
</tbody>
</table>

7.2 Structure

The dominant structure within the area is the Burrum Syncline (refer Drawing 2) which is a basin shaped syncline with a northwest to southeast axis plunging to the northwest. Within EPC923, the Burrum Syncline has approximate dimensions of 20 km x 6.5 km. Dips on the limbs of the Burrum Syncline have been reported to range from 7° to 25° (Laycock, 1967).

Cranfield (1994) reported periods of block faulting synchronous with folding of both the Maryborough Formation and Burrum Coal Measures including considerable faulting during deposition of the Burrum Coal Measures. The existence of steep dips in the Pine Creek area near the Burrum River are suggested to indicate faulting (Cranfield, 1993). Laycock (1967) on the other hand states that no zones are expected to exist where intense faulting would have increased the open space available for the flow of groundwater.
Figure 7-1 NEC adopted stratigraphy for southern area of EPC923
8. Field investigations

8.1 Coal exploration boreholes

Prior to the commencement of the groundwater field investigations, NEC had conducted two exploration drilling programs in the area of the Project, totalling 2436 m and comprising 23 core holes and 17 chip holes:

- November 2006 – January 2007  Holes NMB-001 to NMB013
- April 2008 – July 2008  Holes NMB-014 to NMB-040

The maximum hole depth was 115 m for hole NMB-021 with an average depth of 61 m. The location of these holes is shown in Drawing 3.

Only one groundwater intersection was recorded in the first program at a depth of 8-8.8 m where a “large amount of water” was noted. Groundwater intersection data was more commonly noted during the second exploration program with seven intersections recorded.

Groundwater flows were measured in seven bores during the second program by airlifting over a 10 minute period and measuring the water captured in a bucket. Flow rates ranged from 0.8 l/s at 15 m depth in hole NMB-016 to 4 l/s at 100 m depth in hole NMB-017. The measured flows are likely to be an underestimate due to the measurement method used.

The limited groundwater intersection and flow data recorded is not uncommon for exploration datasets and is not necessarily a reflection on the existence or otherwise of groundwater.

On 15th May 2008 a site inspection was made by Streamline Hydro personnel to liaise with the NEC geologist, inspect drilling chip samples and to record measurements of depths to water and field water quality parameters (pH and electrical conductivity (Ec)) in recently completed open exploration holes. Depth to water, pH and Ec measurements were collected for 13 boreholes. This information was used to assist in defining the groundwater field program.

8.2 Groundwater drilling program

As essentially no groundwater information existed for the Project area, a groundwater drilling program was necessary to facilitate the collection of relevant information including:

- Existence of groundwater;
- Groundwater level data;
- Groundwater quality data; and
- Aquifer hydraulic data.

The selection of monitoring bore locations was based on the need to:

- provide adequate spatial spread for characterisation of the groundwater regime including determination of groundwater flow directions, groundwater quality and variability of hydraulic parameters;
ascertain relationships between different strata;

provide monitoring points located between the proposed operations and potential receptors (e.g. existing users); and

maximise the life of as many of the monitoring points as possible by minimising the risk of damage to these by the Project itself.

The selection of the test / pumping bore location(s) was based primarily on the results of exploration drilling which indicated locations where the highest probability of intersecting notable quantities of groundwater would occur. A secondary consideration was siting of the bore where it may prove useful as a dewatering or water supply bore for the Project.

It is noted that the mine pit and proposed lease areas were revised after the groundwater drilling program had been completed.

NEC commissioned Underdale Drillers to undertake the groundwater drilling program which was conducted under the supervision of a Streamline Hydro hydrogeologist. The drilling program was undertaken from 22nd October 2008 to 1st November 2008. The drilling was undertaken by Paul Juett, a Class 3 Queensland licensed driller (license number 3086) using a Schramm T450 Rotadrill top head drive rotary rig.

The groundwater drilling program targeted the Elliott Formation and Burrum Coal Measures to depths of less than 100 m and included:

- Construction of three monitoring bores in previously drilled exploration boreholes;
- Drilling and construction of eleven monitoring bores;
- Drilling and construction of two production bores; and
- Grouting / rehabilitation of two open exploration holes.

All boreholes were drilled by the rotary mud method using a light mud (AMC polymer CR-650) and tungsten carbide stepped blade bits. Chip samples were collected at 1 m intervals and logged on-site by Streamline Hydro’s hydrogeologist.

The drilling typically intersected 8-22 m of clay overlying the sedimentary sequences of the Burrum Coal Measures comprised of sandstone, claystone, mudstone and coal. Due to the drilling method used, intersection of groundwater was not readily identifiable, although the majority of groundwater appeared to be intersected in the coal seams with only small amounts or no groundwater in the other strata.

Following completion of bore construction and having allowed sufficient time for the bentonite and grout to seal / cure, the bores were airlift developed for between twenty minutes and one hour to removing drilling fines and polymer mud thus maximising the hydraulic connection between the bore and the aquifer. On average, four measurements of Ec and pH were made during development and three measurements of airlift yield. Airlift yield was determined by
measuring the flow of water discharging through a PVC pipe from the first mud pit into a bucket of known volume.

PVC caps were installed on all monitoring bores to prevent surface water or other contamination entering the bores along with steel casing protectors which were locked with padlocks to prevent tampering. Padlocks were also fitted to both production bores.

Photographs of the groundwater drilling program are provided in Figure 8-1.

8.2.1 Monitoring bore construction

The locations of the monitoring bores are shown in Drawing 3. Bore construction details are summarised in Table 8-1 with full borehole logs provided in Appendix 2. All of the monitoring bores are constructed to intersect the Burrum Coal Measures.

Existing exploration boreholes

Monitoring bores were constructed in three existing (and still open) exploration boreholes: NMB-020, NMB-026 and NMB-029. These holes had originally been drilled at 121 mm diameter with the exception of the top 12-20 m which had been drilled to accommodate a PVC surface control casing of 150 mm diameter which remains in place.

Some debris (fall-in) was found in each hole prior to construction of the monitoring bore. For boreholes NMB-026 and NMB-029, the depth was such that no additional clean out of backfill was required prior to seating of the PVC for the bore construction. Borehole NMB-029 was open to a greater depth than required for the monitoring bore construction, and hence was backfilled with clean fill to the desired depth, on top of which a bentonite seal was placed.

These bores were cased with solvent welded DN 50 mm Class 12 PVC. The screen zone was manually slotted in a horizontal configuration with an aperture of 1.5 mm. A PVC end cap was solvent welded to the bottom of the PVC casing which included a one metre sump beneath the screen zone. A filter pack consisting of No.5 gravel (3-6 mm nominal size) was placed by gravity around the screen zone with bentonite and cement grout seals placed between the top of the filter pack and the ground surface as decided by the driller.

New boreholes

Eleven monitoring bores were constructed in holes drilled as part of the groundwater drilling program. The first 2 m of these holes were drilled at 279 mm diameter to accommodate DN 150 mm PVC surface casing while the remainder of each hole was drilled at 178 mm diameter.

These bores were cased with solvent welded DN 80 mm Class 12 PVC. The screen zone was manually slotted with 25 horizontal slots per metre in three rows and with an aperture of 1.5 mm. A PVC end cap was solvent welded to the bottom of the PVC casing which included a one metre sump beneath the screen zone. A filter pack consisting of No.5 gravel (3-6 mm nominal size) was placed by gravity around the screen zone with bentonite and cement grout seals placed between the top of the filter pack and the ground surface as deemed appropriate and in
8.2.2 Production bore construction

Two production bores were constructed as part of the groundwater drilling program. These holes were drilled at 279 mm diameter to accommodate DN 150 mm PVC casing. Two bores were constructed (rather than one) as at the time of drilling it was not clear what level of connectivity existed between the coal seams, and where the majority of water was being made.

Bore NMB-049 (the deeper of the two production bores) was cased with solvent welded DN 150 mm Class 12 PVC, while bore NMB-053 was cased with solvent welded DN 150 mm Class 9 PVC due to a shortage of Class 12 PVC on-site. Pins were also installed at the joints for additional support.

The screen zone was manually slotted in eight alternating / offset vertical rows. Slots were 180 mm long and 2 mm aperture with 400 mm vertical separation between slots on the same row. A PVC end cap was solvent welded to the bottom of the PVC casing which included a one metre sump beneath the screen zone. A filter pack consisting of No.5 gravel (3-6 mm nominal size) was placed by gravity around the screen zone with bentonite and cement grout seals placed between the top of the filter pack and the ground surface as deemed appropriate and in accordance with the Minimum Construction Requirements for Water Bores in Australia (LWBC, 2003).

The locations of the production bores are shown in Drawing 3. Bore construction details are summarised in Table 8-1 with full borehole logs provided in Appendix 2. Both production bores are constructed to take water from the Burrum Coal Measures.

8.2.3 Grouting / rehabilitation of two open exploration holes

As two exploration boreholes (NMB-019 and NMB-038) remained open in the immediate vicinity of bores NMB-049 through NMB-053, it was decided that these boreholes should be grouted up prior to sampling and test pumping to eliminate the potential for cross-contamination and hydraulic connection between different strata.
Figure 8-1 Photos from the groundwater drilling program
Table 8-1 Bore construction details

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Lithology / Aquifer Monitored</th>
<th>Coordinates (MGA94)</th>
<th>Surface Elevation</th>
<th>Borehole Depth</th>
<th>Bore Depth</th>
<th>Screen Zone</th>
<th>Ec2,3</th>
<th>pH3</th>
<th>Airlift Yield3</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Easting (m)</td>
<td>Northing (m)</td>
<td>(m AHD)1</td>
<td>(m bGL)</td>
<td>(m bGL)</td>
<td>(m bGL)</td>
<td>(mS/cm)</td>
<td>(l/s)</td>
<td></td>
</tr>
<tr>
<td>NMB-020</td>
<td>Coal seams</td>
<td>46732.67</td>
<td>7187875.48</td>
<td>26.88</td>
<td>50.00</td>
<td>53.80</td>
<td>28.0</td>
<td>52.0</td>
<td>8.37</td>
<td>7.25</td>
</tr>
<tr>
<td>NMB-026</td>
<td>Fine grained sandstone</td>
<td>467797.41</td>
<td>7187186.90</td>
<td>27.41</td>
<td>50.00</td>
<td>50.22</td>
<td>32.0</td>
<td>47.0</td>
<td>10.04</td>
<td>7.90</td>
</tr>
<tr>
<td>NMB-029</td>
<td>Fine grained sandstone with minor coal</td>
<td>467015.50</td>
<td>7187332.92</td>
<td>29.02</td>
<td>45.00</td>
<td>45.10</td>
<td>28.3</td>
<td>48.3</td>
<td>17.86</td>
<td>7.20</td>
</tr>
<tr>
<td>NMB-041</td>
<td>Coal seams</td>
<td>469197.27</td>
<td>7186407.04</td>
<td>19.20</td>
<td>54.00</td>
<td>51.38</td>
<td>34.0</td>
<td>50.0</td>
<td>15.28</td>
<td>7.82</td>
</tr>
<tr>
<td>NMB-042</td>
<td>Claystone (minor sandstone)</td>
<td>469196.66</td>
<td>7186407.92</td>
<td>19.22</td>
<td>54.00</td>
<td>21.00</td>
<td>14.0</td>
<td>20.0</td>
<td>12.90</td>
<td>7.85</td>
</tr>
<tr>
<td>NMB-043</td>
<td>Clay, sandstone &amp; mudstone</td>
<td>467407.96</td>
<td>7186614.26</td>
<td>28.27</td>
<td>49.50</td>
<td>49.48</td>
<td>31.5</td>
<td>49.5</td>
<td>19.95</td>
<td>8.00</td>
</tr>
<tr>
<td>NMB-044</td>
<td>Sandstone</td>
<td>467407.91</td>
<td>7186612.21</td>
<td>28.12</td>
<td>49.50</td>
<td>24.92</td>
<td>19.0</td>
<td>24.0</td>
<td>14.62</td>
<td>6.82</td>
</tr>
<tr>
<td>NMB-045</td>
<td>Claystone with minor coal seams</td>
<td>467061.71</td>
<td>7188824.24</td>
<td>31.05</td>
<td>60.00</td>
<td>56.22</td>
<td>42.0</td>
<td>59.0</td>
<td>11.35</td>
<td>7.33</td>
</tr>
<tr>
<td>NMB-046</td>
<td>Clay &amp; coal</td>
<td>467062.89</td>
<td>7188823.59</td>
<td>31.05</td>
<td>60.00</td>
<td>12.35</td>
<td>9.0</td>
<td>11.0</td>
<td>10.05</td>
<td>5.91</td>
</tr>
<tr>
<td>NMB-047</td>
<td>Claystone with minor coal seams</td>
<td>468799.79</td>
<td>7187598.21</td>
<td>20.09</td>
<td>97.00</td>
<td>60.70</td>
<td>44.4</td>
<td>60.0</td>
<td>14.85</td>
<td>7.54</td>
</tr>
<tr>
<td>NMB-048</td>
<td>Sandstone, mudstone &amp; claystone with coal</td>
<td>468799.91</td>
<td>7187599.21</td>
<td>20.09</td>
<td>97.00</td>
<td>30.60</td>
<td>27.0</td>
<td>31.0</td>
<td>13.47</td>
<td>8.16</td>
</tr>
<tr>
<td>NMB-049</td>
<td>Clay &amp; coal</td>
<td>467178.11</td>
<td>7187997.10</td>
<td>28.39</td>
<td>60.00</td>
<td>54.44</td>
<td>39.0</td>
<td>53.0</td>
<td>8.07</td>
<td>6.87</td>
</tr>
<tr>
<td>NMB-050</td>
<td>Coal &amp; clay</td>
<td>461819.81</td>
<td>7188007.46</td>
<td>28.30</td>
<td>54.00</td>
<td>54.04</td>
<td>39.0</td>
<td>53.0</td>
<td>7.76</td>
<td>7.01</td>
</tr>
<tr>
<td>NMB-051</td>
<td>Coal &amp; clay</td>
<td>461819.82</td>
<td>7188006.56</td>
<td>28.25</td>
<td>54.00</td>
<td>36.46</td>
<td>32.0</td>
<td>36.0</td>
<td>6.94</td>
<td>7.17</td>
</tr>
<tr>
<td>NMB-052</td>
<td>Clay &amp; sandstone</td>
<td>467189.75</td>
<td>7188007.70</td>
<td>28.26</td>
<td>54.00</td>
<td>21.60</td>
<td>15.0</td>
<td>21.0</td>
<td>11.20</td>
<td>8.05</td>
</tr>
<tr>
<td>NMB-053</td>
<td>Clay &amp; coal</td>
<td>467171.50</td>
<td>7188007.71</td>
<td>28.86</td>
<td>35.00</td>
<td>35.18</td>
<td>30.0</td>
<td>34.0</td>
<td>7.13</td>
<td>7.10</td>
</tr>
</tbody>
</table>

1 m bGL - metres below ground level
2 Ec - electrical conductivity
3 Ec, pH and airlift yield are the values at the completion of development

ID: 2008010001-RPT-001  
29 July 2010
8.3 Groundwater level monitoring

Groundwater level data was collected during the groundwater drilling program to provide preliminary information for planning sampling and instrumentation activities. This data is of limited use for further assessment as much of the data is influenced by airlift development or variations in reference point due to bore completion status at the time of measurement.

Table 8-2 provides a summary of manual water level data collected to date which is unaffected by bore construction or sampling activities. This data was collected using an electronic water level meter with an accuracy of better than 1 cm. From Table 8-2 it can be seen that water levels within the Burrum Coal Measures range between 15 m AHD and 26 m AHD at the Project site.

In addition to the manual water level data, NEC purchased seven Cera-Diver pressure transducer water level loggers and one Baro-Diver for monitoring atmospheric pressure to allow on-going collection of time series water level data. As seven loggers was insufficient to instrument all of the bores, rotation of loggers between bores has taken place. The logging intervals used have been 30 minutes and 60 minutes.
Table 8-2  Manual groundwater level data

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Ground/Concrete Elevation (m AHD)</th>
<th>Stickup Top of Steel Protector (m)</th>
<th>Depth to Water (m bRP)</th>
<th>Groundwater Elevation (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMB-020</td>
<td>26.28</td>
<td>0.60</td>
<td>26.88</td>
<td>5.69</td>
</tr>
<tr>
<td>NMB-026</td>
<td>26.90</td>
<td>0.51</td>
<td>27.41</td>
<td>9.74</td>
</tr>
<tr>
<td>NMB-029</td>
<td>28.52</td>
<td>0.50</td>
<td>29.02</td>
<td>4.28</td>
</tr>
<tr>
<td>NMB-041</td>
<td>18.74</td>
<td>0.46</td>
<td>19.20</td>
<td>0.91</td>
</tr>
<tr>
<td>NMB-042</td>
<td>18.78</td>
<td>0.44</td>
<td>19.22</td>
<td>2.24</td>
</tr>
<tr>
<td>NMB-043</td>
<td>27.69</td>
<td>0.58</td>
<td>28.27</td>
<td>5.28</td>
</tr>
<tr>
<td>NMB-044</td>
<td>27.55</td>
<td>0.57</td>
<td>28.12</td>
<td>4.52</td>
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<td>NMB-045</td>
<td>30.61</td>
<td>0.44</td>
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<td>NMB-046</td>
<td>30.63</td>
<td>0.42</td>
<td>31.05</td>
<td>5.95</td>
</tr>
<tr>
<td>NMB-047</td>
<td>19.63</td>
<td>0.46</td>
<td>20.09</td>
<td>4.22</td>
</tr>
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<td>27.66</td>
<td>0.73</td>
<td>28.39</td>
<td>4.34</td>
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<td>NMB-050</td>
<td>27.88</td>
<td>0.42</td>
<td>28.30</td>
<td>4.15</td>
</tr>
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<td>NMB-051</td>
<td>27.85</td>
<td>0.40</td>
<td>28.25</td>
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<tr>
<td>NMB-052</td>
<td>27.88</td>
<td>0.38</td>
<td>28.26</td>
<td>4.92</td>
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<tr>
<td>NMB-053</td>
<td>28.15</td>
<td>0.71</td>
<td>28.86</td>
<td>4.87</td>
</tr>
</tbody>
</table>

1 bRP - metres below reference point. Reference point (RP) for all bores is the top of steel casing protector.
2 Read on 07-Jan-09
3 Read on 21-Aug-09
4 Read on 22-Aug-09
5 Read on 29-Oct-09
6 Read on 30-Oct-09
7 Water level at top of casing protector with very small flow.
8.4 Water quality sampling

Following installation of the monitoring and production bores, four water quality sampling events were undertaken:

- Event 1: 13-16 November 2008
- Event 2: 18-20 December 2008
- Event 3: 20-22 August 2009
- Event 4: 28-31 October 2009

All of the newly constructed bores were sampled during these events with the exception of the two production bores (NMB-049 and NMB-053) as adjacent monitoring bores were sampled which intersect the same stratigraphic zones. Bore NMB-052 was vandalised sometime after the December 2008 sampling event and can no longer be sampled.

For comparative purposes, water samples were collected from the old bridge at Saltwater Creek as detailed in Table 8-3. The bridge is located approximately 1100 m from the confluence of Saltwater Creek and the Mary River. Samples were collected by lowering a small container from the bridge to the creek and recovering a sample from near to the water surface. Samples were analysed for both total and dissolved metals along with a range of other parameters in the groundwater suite detailed below.

Table 8-3 Saltwater Creek sampling details

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Approximate Point in Tide Cycle</th>
<th>Distance to Water Level Below Bridge (m)</th>
<th>Ec (ms/cm)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-Oct-2008 15:55</td>
<td>2 hours prior to low tide</td>
<td>4.65</td>
<td>10.71</td>
<td>6.60</td>
<td>Strong current, dirty brown</td>
</tr>
<tr>
<td>01-Nov-2008 10:09</td>
<td>2 hours prior to high tide</td>
<td>3.46</td>
<td>14.71</td>
<td>7.17</td>
<td>Strong current, dirty brown</td>
</tr>
</tbody>
</table>

The full analysis suite for the Project site is provided in Table 8-4 with some variations between bores and sampling events. One such example is hydrocarbon screening which was conducted on bores NMB-041, NMB-045 and NMB-050 during Event 2.

The sampling procedure involved purging each bore with an electric pump until at least three bore volumes had been purged. During purging the pH and Ec were monitored immediately after commencement and after each bore volume. Samples were collected after three bore volumes had been purged at which time the pH and Ec readings were stable. Figures 8-2 and 8-3 present the stabilised Ec and pH readings from each bore for the four sampling events as well as the readings obtained at the completion of bore development in October 2008.

Due to the slow recovery of bores NMB-026 and NMB-046, less than one bore volume was able to be purged prior to sampling which occurred on the day after purging commenced once sufficient water was available in the bores. The readings presented in Figures 8-2 and 8-3 for NMB-026 and NMB-046 are the readings taken at the time of sampling.

The samples were collected and preserved in bottles provided by the NATA registered laboratories and were chilled in eskies with ice up until delivery at the laboratories for analysis.
Chain of custody procedures were followed and documented. Samples for dissolved metal analysis were field filtered using 0.45 μm Stericups with a hand-operated vacuum pump. The total metals analysis reported by the laboratory for the December sampling event were also analysed on filtered samples and hence represent dissolved metals also.

Quality control samples were collected during each sampling event which included duplicate samples sent to the primary laboratory (ALS) and duplicate samples sent to the secondary laboratory (Amdel-Labmark).

**Table 8-4  Laboratory analytical suite**

<table>
<thead>
<tr>
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<tr>
<td>Electrical conductivity</td>
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<td>Hydroxide Alkalinity as CaCO₃</td>
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<td>Carbonate Alkalinity as CaCO₃</td>
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<td>Total Alkalinity as CaCO₃</td>
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<td>Magnesium</td>
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<tr>
<td>Sodium</td>
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<td>Potassium</td>
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<tr>
<td>Nitrate</td>
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<td>Fluoride</td>
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<table>
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<td>Cyanide</td>
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<table>
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<th>Hydrocarbons</th>
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<td>C6-C9 Fraction</td>
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<td>C10-C14 Fraction</td>
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</tr>
<tr>
<td>C15-C28 Fraction</td>
<td></td>
</tr>
<tr>
<td>C29-C36 Fraction</td>
<td></td>
</tr>
</tbody>
</table>
8.5 Hydraulic testing

Hydraulic property data is essential to quantify the movement of groundwater within and around the site including the magnitude and extent of any variations. As NEC had commissioned AGE to conduct the groundwater modelling component of the study, a field
program to determine the in-situ hydraulic properties of the site was agreed by Streamline Hydro and AGE. This program included the conduct of falling head tests in selected monitoring bores to provide data on spatial variations and variations between different strata, as well as an extended duration pumping test to provide data across a larger area.

The field component of the hydraulic testing program was conducted by Streamline Hydro, with the data provided to AGE for analysis and input to the groundwater modelling.

### 8.5.1 Falling head tests

Hydraulic testing was carried out in a total of eleven monitoring bores using falling head methods. The procedure used for each test was as follows:

- the static water level in the bore was measured;
- a Cera-Diver pressure transducer data logger set to record the water level at one-second intervals was installed in the bore below the water level;
- a “slug” of water previously taken from the bore (typically 20 litres or sufficient to fill to the top of the casing) was introduced to each bore as quickly as possible. This volume is equivalent to a maximum theoretical head increase of approximately 4 m inside an 80 mm PVC bore casing;
- the rate of decline of the water level was then monitored using an electric water level tape and the Cera-Diver; and
- the test was terminated after the water level recovered close to the static water level.

Analysis of the falling head test data is described in AGE (2010) (refer Appendix 3), with results included in Section 9 of this report.

### 8.5.2 Test pumping

The airlift yields at the completion of construction of NMB-049 and NMB-053 were both 6 l/s. NMB-049 was selected as the bore to be test pumped as its total depth was greater and hence nearer the maximum proposed mining depth and it allowed for greater drawdown within the pumping bore due to the depth at which the slotted casing commenced.

Test pumping was undertaken using a Grundfos SP14A-25 submersible pump powered by an diesel generator. The pump intake was set at 38.8 m, 0.2 m above the top of the slotted casing.

Water level measurements were collected in the pumped bore and three monitoring bores located adjacent to each other and approximately 15 m from the pumping bore: NMB-050, NMB-051 and NMB-052. These measurements were recorded at 30 second intervals using Cera-Diver instruments and also at less regular intervals using an electric water level meter.

The three monitoring bores were constructed to different depths with different screened and filter packed zones to enable any connectivity or otherwise between the different strata to be
identified. These details along with the distance of each monitoring bore from the pumping bore are provided in Table 8-6.

From Table 8-6 it can be seen that monitoring bore NMB-050 is filter packed across a similar zone to the pumping bore to enable determination of the storage coefficient from the pumping data. NMB-051 is filter packed across a shallower coal bearing zone while NMB-052 is filter packed across a yet again shallower zone comprised of clay and fine grained sandstone.

Table 8-5  Details of bores utilised for test pumping program

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Purpose</th>
<th>Filter Pack Zone (m bGL)</th>
<th>Distance from Pumping Bore (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMB-049</td>
<td>Pumping bore</td>
<td>37.0 – 60.0</td>
<td>-</td>
</tr>
<tr>
<td>NMB-050</td>
<td>Monitoring bore</td>
<td>38.0 – 54.0</td>
<td>15.6</td>
</tr>
<tr>
<td>NMB-051</td>
<td>Monitoring bore</td>
<td>29.7 – 37.0</td>
<td>15.0</td>
</tr>
<tr>
<td>NMB-052</td>
<td>Monitoring bore</td>
<td>12.0 – 22.0</td>
<td>14.4</td>
</tr>
</tbody>
</table>

The flow rate was measured using a 40 mm ARAD Multi-jet magnetic water meter and checked by measuring the time taken to fill a drum of known volume. The flow rate was controlled by means of a manually operated valve forming part of the discharge headworks at the bore head. The pumped water was discharged at the surface through two high capacity rotating sprinklers located over 100 m from the pumping bore.

The test pumping program comprised of:

- A short pre-test conducted on 15th December 2008;
- A three-stage variable rate step test conducted on 16th December 2008;
- A 24 hour constant rate test conducted from 17-18th December 2008; and
- 24 hours of recovery monitoring following the constant rate test.

No rainfall was recorded on site during the test pumping program.

The variable rate step test was commenced at 07:30 on 16th December 2008 comprising three 90 minute steps at flow rates of 1.57 l/s, 3.00 l/s and 4.51 l/s followed by 2 hours of manual recovery readings. Based on the results of the step test, it was decided to undertake the constant rate test at a flow rate of 4 l/s.

The 24 hour constant rate test commenced at 10:05 on 17th December 2008 and pumping ceased at 10:05 on 18th December. The constant rate test was immediately followed by 24 hours of water level recovery monitoring. Throughout the test the flow rate was maintained at a relatively constant rate of 4.05 l/s.
Field water quality measurements (pH and Ec) were recorded at the start of both the step test and constant rate test and at one hour intervals during both tests. During the constant rate test the pH ranged from 5.77 to 6.07 with no apparent trend. The Ec during the constant rate test ranged from 7.55 mS/cm to 7.87 mS/cm with the first three readings being above 7.80 mS/cm and all subsequent readings below this value.

During the constant rate test, water samples were collected from the pumping bore one hour after pumping commenced and immediately prior to the cessation of pumping (i.e. after 24 hours). Samples were stored in bottles provided by the laboratory (with appropriate preservation) and were kept chilled until received at the NATA registered ALS laboratory for analysis. Sample collection, storage and transportation were conducted while adhering to chain of custody controls.

Analysis of the test pumping data is described in AGE (2010) (refer Appendix 3), with results included in Section 9 of this report.

9. **Existing hydrogeological regime**

Prior to NEC’s coal exploration activities, limited information existed in the Project area in relation to the hydrogeological regime. The discussion below relates to information available from NEC exploration records, the regional investigation of Laycock (1967) and work undertaken in this study.

9.1 **Groundwater occurrence**

Due to the rotary mud drilling method adopted for the groundwater program, groundwater inflow was difficult to identify. Exploration drilling was conducted using either rotary air methods with water or foam injection and by coring allowing better detection of water intersection. A review of the exploration logs found that where noted, water intersection occurred at depths of 5-15 m predominantly within the Burrum Coal Measures. This is consistent with the findings of Laycock (1967) who reported water intersection depths of 15-30 ft from 10 bores that intersected the Burrum Coal Measures.

During the groundwater drilling program seepage / flows were noted in the wall of the mud pits dug for drilling holes NMB-041 / 042 (see Figure 9-2) and NMB-050 / 051 / 052. A very small seepage was also noted in the mud pit beside NMB-053. The inflows were at the interface between lateritic ironstone gravel and the pallid clays beneath. These seepages were very localised, point sources that did not cease to flow over the duration which they were observed (several hours).
There have also been anecdotal reports from the drillers and site geologists that sufficient water could be obtained for exploration drilling purposes by digging shallow trenches (<0.5 m deep) and allowing seepage to accumulate. The water is understood to have come from both localised sandy lenses and cracks within the clay. Based on the understanding of the site at present, this is likely only to be the case following significant wet periods when free water is able to accumulate.

Other than the minor water occurrences noted above, the Elliott Formation was not found to be an aquifer of any significance which is consistent with the findings of Laycock (1967) who reported that this unit was thin, had low permeability and generally exists above the water table. The Elliott Formation is therefore not discussed in any further detail in this report.

In summary, the water bearing zones present in the area are considered to be:

- Shallow, localised lensoidal zones associated with sandy or ferugenous gravels in the overlying Elliott Formation;
- Aquifers associated with fractured zones in the weathered overburden material; and
- Confined / semi-confined aquifers associated with coal seams.

### 9.2 Burrum Coal Measures

#### 9.2.1 Distribution and depth to groundwater

Groundwater was located in the Burrum Coal Measures at all sites drilled during the groundwater investigation. It was found to occur in strata comprised of coal, sandstone, mudstone and claystone, as evidenced by the existence of water in monitoring bores
constructed to intersect the discrete lithological zones. As noted earlier, water intersection typically first occurred at depths of 5 m to 15 m below surface.

Comparison of the depths to groundwater measured for the monitoring and production bores with the screen and filter packed zone of the bores has identified that the Burrum Coal Measures are a confined / semi-confined aquifer. On average the water level rose by 21 m above the filter packed zone. In the majority of monitoring bores the water rose to within 6 m of the land surface.

Prior to drilling bores NMB-041 and NMB-042 water was observed to be flowing (a small trickle) from exploration hole NMB-017 nearby which was drilled to a total depth of 100 m. Water has since been found to flow from bore NMB-041 which is filter packed from 32.5 m bGL to 54 m bGL. Water did not originally flow from NMB-041 which perhaps indicates a more rapid response to recharge than might have been expected, and could provide some support to the generally high hydraulic conductivity values determined from field tests. It is noted that several substantial recharge events have occurred at the site from mid-2008 to early 2009.

9.2.2 Potentiometric elevation, recharge and flow

Contours of the potentiometric surface from Laycock (1967) are presented in AGE (2010) along with the steady state modelled levels. The contours indicate a groundwater divide exists to the north of the Project site and is oriented southwest to northeast and approximates the surface drainage divide. On the southern side of the divide, groundwater flow is generally to the southeast while on the northern side flow is largely to the northwest.

Data collected from all bores using Diver pressure transducer logging instruments is presented in Figure 9-2 along with rainfall for Maryborough (BoM station 40126). When considering the groundwater data in the context of the rainfall data, it is important to note that significant variation between both the timing and quantity of rainfall has been noted by those working on the Project between what occurs on site and in Maryborough.

As can be seen from Figure 9-2, the data records for bores NMB-026, NMB-041, NMB-044, and NMB-048 are relatively short (approximately 3 weeks) compared to data for the other bores. This relates to the fact that initially bores in the southern area of the site were instrumented before the instruments were relocated to the northern portion of the site ahead of the pumping test.

All of the monitoring bores exhibit diurnal fluctuations of the order 2-3 cm per day which upon examination can be attributed to evapotranspiration and associated effects such as moisture redistribution, rather than other phenomenon such as earth tides.

The data presented for NMB-026 displays a prolonged recovery trend, which is related to the sampling event undertaken in mid-November and the fact that this bore is constructed in fine grained sandstone which has limited permeability. A similar trend is noted for the first three weeks of data for NMB-050, which relates to recovery following the completion of the 24 hour pumping test in bore NMB-049. For the same period it is noted that the potentiometric
elevation of bore NMB-052 is declining. This can be explained by the fact that this bore is
screened in strata overlying the coal seams from which water was extracted during the test
pumping and hence, water is slowly draining from the overlying strata to the coal seams.

Figure 9-2 illustrates that in most cases, recharge is comprised of a small yet rapid response
followed by a prolonged gradual response. The rapid response suggests that some preferential
flow pathways such as fractures, root channels or interfaces between soil / rock types exist.
Between January and March 2009, bores NMB-020, NMB-051 and NMB-052 have recorded
potentiometric elevation increases of approximately 0.40 m to 0.80 m.

The direction of vertical hydraulic gradient indicated by the nested bore locations varies across
the site as follows:

- Downward gradient: NMB-043 / 044, NMB-045 / 046 and NMB-047 / 048
- Upward gradient: NMB-041 / 042 and NMB-050 / 051 / 052

The most feasible explanation of these findings is the existence of complex geology with varying
locations and mechanisms of recharge and drainage which are likely to be structure controlled.
Faults can act as drains, lowering the water table and thus affecting the distribution of
groundwater but can also act as barriers to the flow of groundwater if filled with impermeable
material and hence can increase water levels.

Vegetation across the site is expected to intercept and transpire significant amounts of rainfall
and soil moisture. Significant recharge is therefore only expected during periods of prolonged or
persistent high intensity rainfall. Recharge to the Burrum Coal Measures is expected to occur by
direct infiltration where the formation is exposed in outcrop or by leakage through the Elliott
Formation.

Bores NMB-029 and NMB-050 exhibit unusual but similar behaviour beginning with relatively
instantaneous rises between the 7th and 9th of January 2009 coinciding with a high intensity and
sustained rainfall event that occurred on site and resulted in parts of the site flooding during
this period. The actual rises were not captured on the data loggers during this period as they
had been removed and were in the process of being downloaded. NMB-029 recorded a rise of
0.49 m while NMB-050 rose 1.99 m. The magnitude of the rises, particularly that for NMB-050
indicate a source of preferential recharge. Such a source of recharge is supported by the log for
NMB-029 which identified calcite veins and a potentially faulted zone at a depth of 38-39 m.

Water levels in bores NMB-029 and NMB-050 began to drain on the 5th of March and the 8th of
March 2009 respectively as seen in Figure 9-2. The cause of this water level decline is unclear,
however given that both bores exhibit similar behaviour suggest that the observed responses
are a natural phenomenon.

Bore NMB-042 recorded a significant rise in water level in May 2009 and June 2009 followed by
a rapid decline. With the available data for the site, it is unclear whether this is a naturally
induced response. The data from late June to early August 2009 is quite noisy which may indicate an instrument fault. A new instrument was installed in mid-August 2009.

The extreme rises and falls observed in NBM-020 and NMB-050 between September 2009 and December 2009 relate to effects from the exploration drilling program that was being conducted during this period. Water was reported by exploration personnel to have been flowing out of several monitoring bores at different time when drilling was being conducted nearby (<200 m). Based on available data, the depth to water in NMB-050 would have been 3-4 m below surface in mid September when a water level rise of approximately 4.5 m was recorded by the water level logging instrument as shown in Figure 9-2.

The water level records for bores NMB-043, NMB-045, NMB-046 and NMB-047 best illustrate the overall temporal trend for the site over the available 12 months of record.

It is concluded that the potentiometric elevation, recharge and flow of groundwater at the site appear to be strongly influenced by localised faults and confining strata. This conclusion can be drawn from the following:

- Spatial water quality data variability with no obvious pattern;
- Test pumping data which identified a geological boundary;
- Exploration drilling causing localised/preferential water flow;
- Observations from drilling logs; and
- Airlift yields which were highest at locations of apparent faulting (e.g. NMB-029 and NMB-050).
Figure 9-2 Monitoring bore potentiometric level data from with rainfall from Maryborough (BoM station 40126)
### 9.2.3 Hydraulic parameters

Analysis of the falling head test data is described in AGE (2010) with the results summarised in Table 9-1 below. AGE (2010) note that there is a wide range in hydraulic conductivity spanning four orders of magnitude. This is noted by AGE (2010) to be typical for fractured rock aquifers where the permeability is controlled by a combination of primary porosity (from the pore space matrix) and secondary porosity created by features such as fractures, bedding planes and coal cleats. The median value (0.36 m/day) is considered by AGE (2010) to be relatively high when compared to typical values for the Bowen Basin, although the values obtained for the Project site fall within the expected range for consolidated shale and mudstones from coal bearing sequences.

**Table 9-1 Summary of falling head test analysis**

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Gravel Pack Zone (m bGL)</th>
<th>Test Zone Geology</th>
<th>Hydraulic Conductivity (m/s)</th>
<th>(m/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMB-026</td>
<td>27.0 - 48.0</td>
<td>Fine grained sandstone</td>
<td>$1.6 \times 10^{-7}$</td>
<td>0.014</td>
</tr>
<tr>
<td>NMB-029</td>
<td>25.5 - 44.3</td>
<td>Fine grained sandstone with minor coal</td>
<td>$5.3 \times 10^{-4}$</td>
<td>45.7</td>
</tr>
<tr>
<td>NMB-043</td>
<td>29.5 - 49.5</td>
<td>Clay, sandstone and mudstone</td>
<td>$6.9 \times 10^{-7}$</td>
<td>0.059</td>
</tr>
<tr>
<td>NMB-044</td>
<td>17.0 – 25.0</td>
<td>Sandstone</td>
<td>$7.3 \times 10^{-6}$</td>
<td>0.627</td>
</tr>
<tr>
<td>NMB-045</td>
<td>40.0 – 60.0</td>
<td>Claystone (with coal seams)</td>
<td>$4.2 \times 10^{-6}$</td>
<td>0.363</td>
</tr>
<tr>
<td>NMB-046</td>
<td>6.5 – 12.0</td>
<td>Clay and coal</td>
<td>$5.1 \times 10^{-8}$</td>
<td>0.004</td>
</tr>
<tr>
<td>NMB-047</td>
<td>35.5 – 64.0</td>
<td>Claystone (with coal seams)</td>
<td>$6.4 \times 10^{-6}$</td>
<td>0.553</td>
</tr>
<tr>
<td>NMB-048</td>
<td>24.5 – 32.0</td>
<td>Sandstone, mudstone &amp; claystone with coal</td>
<td>$5.5 \times 10^{-7}$</td>
<td>0.048</td>
</tr>
<tr>
<td>NMB-050</td>
<td>38.0 – 54.0</td>
<td>Clay &amp; coal</td>
<td>$3.5 \times 10^{-5}$</td>
<td>3.033</td>
</tr>
<tr>
<td>NMB-051</td>
<td>29.7 – 37.0</td>
<td>Coal &amp; clay</td>
<td>$7.0 \times 10^{-5}$</td>
<td>6.074</td>
</tr>
<tr>
<td>NMB-052</td>
<td>12.0 – 22.0</td>
<td>Clay &amp; sandstone</td>
<td>$1.9 \times 10^{-6}$</td>
<td>0.164</td>
</tr>
</tbody>
</table>

A 24 hour constant rate pumping test was used to assess the hydraulic properties of the coal measures over a larger area. Analysis of the test pumping data is described in AGE (2010) with an excerpt provided below along with a summary of the results in Table 9-2.

*Pumping bore NMB-049 recorded 14.7m drawdown after 24 hours of continuous pumping at a rate of 4.05L/s.*

*Observation bore NMB-050, located at 15.6m from the pumping bore, recorded 9.2m drawdown at the end of the*
test. In contrast observation bores NMb-051 (0.5m) and NMb-052 (0.07m) showed only a very limited response to the pumping test.

The differing water level response in the bores is explained by the bore construction. The pumping bore NMb-049 is filter packed across coal seams from 37m to 60m, with the observation bore NMb-050 filter packed across a similar zone from 38m to 54m. The other observations bores were constructed at a shallower depth with NMb-051 having the filter pack from 29.7m to 37m and NMb-052 from 12m to 22m.

The limited drawdown in the observation bores constructed at shallower depth indicates a contrasting lower permeability of the overburden material and a slower drainage from this material.

The recovery of water levels at the cessation of pumping in both the pumping bore and observation bores was relatively slow. After 24 hours monitoring, 2.7m residual drawdown remained in the pumping bore, with 2.66m recorded in observation bore NMb-050. The shallow observation bores NMb-051 and NMb-052 both continued to decline during the recovery phase by 0.16m and 0.04m respectively.

The poor recovery in the pumping and observation bores indicates an aquifer of limited extent with low recharge rates from overlying and underlying zones in the formation. This is demonstrated by the shallow observation bores that recorded a continual drainage of water from the overlying zones to the deeper aquifer to replace water removed during the pumping test.

The water levels recorded during the pumping test also indicate a limited aquifer extent with a gradual stepping of the drawdown curve shown in Figure 2, indicating a boundary condition in the aquifer gradually reducing the supply of water to the bore.

Table 9-2  Summary of analysis of test pumping data

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Maximum Drawdown (m bTOC)¹</th>
<th>Transmissivity (m²/d)</th>
<th>Hydraulic Conductivity² (m/d)</th>
<th>Storage Coefficient (-)</th>
<th>Method of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMB-049</td>
<td>14.73</td>
<td>3.78 x 10⁻⁴</td>
<td>0.65</td>
<td></td>
<td>Cooper-Jacob</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.28 x 10⁻⁴</td>
<td>0.91</td>
<td></td>
<td>Theis Recovery</td>
</tr>
<tr>
<td>NMB-050</td>
<td>9.17</td>
<td>4.04 x 10⁻⁴</td>
<td>0.70</td>
<td>3.49 x 10⁻⁴</td>
<td>Cooper-Jacob</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0 x 10⁻⁴</td>
<td>1.04</td>
<td></td>
<td>Theis Recovery</td>
</tr>
</tbody>
</table>

¹m bTOC – metres below top of casing
²based on an assumed aquifer thickness of 50 m

9.2.4  Groundwater quality

Where available, figures in this section include comparison with guideline values from the following sources:

- Australian Drinking Water Guidelines (NHMRC & NRMMC, 2004); and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000).
Available guideline values may include:

- Drinking water – taste, aesthetic or health
- Livestock – poultry, beef cattle or sheep
- Irrigation – long-term or short-term
- Farm supply

Where the data table cells in the figures are empty, either the analyte was not assessed for that monitoring point or no guideline value exists. Where the value of a cell is “0”, the result was below the detection limit or limit of reporting.

**Physico-chemical parameters**

The field water quality results from the groundwater sampling events indicate that the groundwater is slightly acidic with the pH ranging from 5.5 to 7.1. Measurements from October 2008 are typically in the range of 7 to 8 and are believed to be influenced by drilling and bore construction activities.

Electrical conductivity (Ec) provides a rapid indication of groundwater quality and total dissolved solids. Ec measurements from the groundwater sampling events range from approximately 7 mS/cm to 21 mS/cm indicating the groundwater varies from brackish to saline. This is confirmed by the total dissolved solids concentrations for all monitoring bores which are presented in Figure 9-3 with data for Saltwater Creek.

![Figure 9-3 Total dissolved solids concentrations](image-url)
The preliminary field Ec and pH readings taken from the open exploration boreholes in May 2008 suggested two distinct Ec groupings, however at that time no correlation with depth or strata could be determined. Review of the Ec measurements from the groundwater field program suggest that in some instances Ec can be correlated with depth or lithology but in others it cannot. This suggests that the Ec has / is being influenced by recharge, discharge and / or structural features. The apparent random distribution of salinity values was also noted by Laycock (1967).

Levels of alkalinity provide an indication of the capacity of a solution to neutralise acids to the equivalent level of calcium carbonate or calcium bicarbonate. Total alkalinity as shown in Figure 9-4, varied across all bores from a low of 30 mg/L at bore NMB-046 in October 2009, to a high of 618 mg/L at bore NMB-048 in December 2008. Therefore the groundwater has a varied capacity to resist changes in its pH by addition of acidic solutions, which is likely related to localised geology.

---

**Figure 9-4** Total alkalinity for monitoring bores and Saltwater Creek

**Ion chemistry**

An ionic balance is a means of checking whether there is a problem with the chemical analysis or whether any ionic species have not been identified that are present in significant amounts (Fetter, 1994). The ionic balance for all samples taken during the project are less than 5% and hence the analyses are deemed acceptable.

Figure 9-5 presents the chloride concentration data for the monitoring bores from which it can be seen that chloride is present in high concentrations, and exceeds the available guidelines for
all bores. Most end uses such as food processing and general industries require less than 250 mg/L (Todd and Mays, 2005).

Figure 9-5 Chloride concentration for monitoring bores

Figure 9-6 presents the sulfate concentration data for the monitoring bores from which it can be seen that the NHMRC & NRMMC (2004) aesthetic health based value is exceeded for nearly all bores with only three bores exceeding the NHMRC & NRMMC (2004) drinking health based value. Sulfate combines with calcium to form an adherent, heat retarding scale with more than 250 mg/L being objectionable in some industries (Todd and Mays, 2005).
Metals and metalloids

A broad suite of metals and metalloids was analysed to assist in establishing a baseline and identify which analytes should form the basis of any future monitoring program. All of the results from the four sampling events are presented graphically in Figures 9-7 to 9-23 with built-in data tables and are discussed in Table 9-3.

Included in these figures are the results for Saltwater Creek and any relevant guideline values. Analytes with no readings above the laboratory limit of reporting / detection limit include antimony, beryllium, mercury, silver and vanadium.

Figure 9-6  Sulfate concentration for monitoring bores
<table>
<thead>
<tr>
<th>Metal or metalloid</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Values above the laboratory detection limits were recorded in six bores but never for all four sampling events for any of these bores. Other than for bore NMB-042, all results are below the available guideline values. Due to the low values recorded and the lack of repeated recordings above the detection limits, aluminium is not a significant constituent in the groundwater on site and some of the values may in fact be false positives. Aluminium was not included in the analysis suite for Saltwater Creek.</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Low levels of arsenic were reported in the majority of the bores for the November 2008, August 2009 and October 2009 sampling events. Given these values were only marginally above the laboratory detection limits and that no bores recorded any values above the detection limit for the December sampling event, it is concluded that arsenic is not a significant constituent in the groundwater on site and some of the values may in fact be false positives. A low level of arsenic was detected in Saltwater Creek which was below all available guideline values except the NHMRC &amp; NRMMC (2004) health based value.</td>
</tr>
<tr>
<td>Barium</td>
<td>Barium was reported in all bores and Saltwater Creek for the November 2008 and December 2008 sampling events, as well as in all sampled bores in the August 2009 and October 2009 sampling events, indicating that the readings are true positives. Barium is a trace element associated with coal and results from NMB-041 suggest that in this instance it is associated with sulphate. No guideline values exist other than the NHMRC &amp; NRMMC (2004) health based value which is exceeded in NMB-041 in all four sampling events. Barium can also be a component of drilling grease.</td>
</tr>
<tr>
<td>Boron</td>
<td>Boron was reported in all monitoring bores for at least one sampling event. Boron is a trace element associated with coal but can also be a component of drilling grease. The concentration of boron in all of the monitoring bores was below all available guideline values. Comparatively, elevated boron concentrations were recorded in Saltwater Creek that exceeded the long-term irrigation guideline value.</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Low levels of cadmium were reported in the majority of the monitoring bores for the November 2008, August 2009 and October 2009 sampling events, however no Cadmium was detected in any of the bores in the December 2008 sampling event. Many of the values are only marginally above the laboratory detection limits, and may in fact be false positives. However, bore NMB-020 showed elevated levels of Cadmium in both the August 2009 and October 2009 sampling events, despite the fact the presence of Cadmium was not recorded in either the November 2008 or December 2008 sampling events. The levels of Cadmium recorded in the August 2009 sampling event exceeded the NHMRC &amp; NRMMC (2004) health based value. Cadmium is also a trace element associated with coal. Cadmium was not detected in Saltwater Creek.</td>
</tr>
<tr>
<td>Chromium</td>
<td>Low levels of chromium were reported in 80% of the monitoring bores for the November 2008 sampling event. Given these values were only marginally above the laboratory detection limits and only one bore (NMB-026) showed detectable levels across all four sampling events, (values that were only marginally above the detection limit), it is concluded that chromium is not a significant constituent in the groundwater on site and some of the values may in fact be false positives. Low levels of chromium were detected in Saltwater Creek and were sufficiently above the detection limit to conclude they are true positives. The values in the creek were below all available guideline values.</td>
</tr>
<tr>
<td>Metal or metalloid</td>
<td>Comments</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Low levels of cobalt were reported in all sampled monitoring bores during the November 2008 sampling event with higher levels noted in NMB-026, NMB-044 and NMB-046. With bores NMB-044 and NMB-046 reporting values above the detection limits in the December 2008, August 2009 and October 2009 sampling events. Cobalt usually occurs with other metals such as nickel and manganese. Due to the recorded presence of these metals, the values are likely true positives. The concentrations reported were all below the available guideline values, with the exception of bore NMB-046 which exceeded the long-term irrigation value. Cobalt was not detected in Saltwater Creek.</td>
</tr>
<tr>
<td>Copper</td>
<td>Low levels of copper were reported in all sampled bores for the November 2008 sampling event and in most bores in the August 2009 and October 2009 sampling events. However, no bores recorded any values above the detection limit for the December 2008 sampling event. In most bores copper was found to be only marginally above the laboratory detection limits, and therefore could indicate false positive values. However, during the August 2009 sampling event elevated levels of copper were detected in bore NMB-042, and during the October 2009 sampling event, highly elevated levels of copper were indicated in bores NMB-020, NMB-042, NMB-044 and NMB-047. For the October 2009 sampling event, in most cases the levels exceeded the ANZECC &amp; ARMCANZ (2000), long-term irrigation guidelines, and in many cases exceeded the ANZECC &amp; ARMCANZ (2000) livestock guideline values. The spikes in the copper concentration detected at these bores during the 2009 sampling events clearly contrast with the low levels reported from the same bores during the 2008 sampling events. They also contrast with the lower levels detected at the other bores during the 2009 sampling events. The spikes in copper concentration may possibly be explained by drilling operations that were known to have occurred on site during September 2009 through to December 2009. On the whole however, it is unlikely that copper is a significant constituent of the groundwater on site due to the very low values recorded in the November 2008 and December 2008 sampling events, many that are likely to be false positives. A low level of copper was detected in Saltwater Creek which was below all available guideline values and was only recorded in the high tide sample. Therefore in most cases copper is not a significant constituent of the sites groundwater.</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Low levels of fluoride were reported in all sampled bores except NMB-046 during the November 2008 sampling event. These levels were equal to or only marginally above the detection limit. During the December 2008, August 2009 and October 2009 sampling events, in many cases the same bores showed levels of Fluoride that were completely undetectable. Others were again equal to or only marginally above the detection limit, therefore it is likely that some of the results are false positives, particularly NMB-026 and NMB-041. Slightly higher values were recorded for Saltwater Creek and were below the lowest of the available guideline values.</td>
</tr>
</tbody>
</table>
| Iron              | Moderate levels of iron were reported in over half of the bores with a maximum concentration of 37.7 mg/L reported in NMB-046. The concentration of iron is influenced by the acidity of the groundwater and its availability within the soils and sediments. Given that limonite, ironstone gravel, pyrite (FeS₂) and siderite (FeCO₃) have all been recorded on drilling logs the observed concentrations of iron are not unexpected. In most instances it appears the iron present in the groundwater is associated with coal lithologies. Groundwater with a pH of 8.0 may contain as much as 10 mg/L of Iron, and rarely as
<table>
<thead>
<tr>
<th>Metal or metalloid</th>
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<tbody>
<tr>
<td>Metal or metalloid</td>
<td>much as 50 mg/L may occur (Todd and Mays, 2005). Concentrations of Iron above 0.1 mg/L precipitates after exposure to air, causes turbidity, stains plumbing fixtures and laundry, and imparts objectionable tastes and colours to foods and drinks, while more than 0.2 mg/L is objectionable for most industrial uses (Todd and Mays, 2005). All bores on-site reported at least one value above 0.2 mg/L and exceed the NHMRC &amp; NRMMC (2004) aesthetic and ANZECC &amp; ARMCANZ (2000) long-term irrigation guideline values. Moderate levels of total iron (~4 mg/L) were reported for Saltwater Creek, however levels of dissolved iron in the creek were low (&lt;0.5 mg/L) as would be expected, compared with groundwater concentrations.</td>
</tr>
<tr>
<td>Lead</td>
<td>Lead was not found to be significantly above the detection limit in any of the bores, except NMB-026 where it was well above the limits during the November 2008 and December 2008 sampling events. However, this contrasts with the levels encountered during the August 2009 and October 2009 sampling events, where lead levels were only marginally above or below the detectable limits. The exploration drill log for NMB-026 is not overly informative compared to the other logs and provides no explanation. Pyrite has been noted in other logs and as lead exists within pyrite this may be its source. Lead also remains a constituent in some grease products used in drilling. The values recorded for bore NMB-026 are above the NHMRC &amp; NRMMC (2004) and ANZECC &amp; ARMCANZ (2000) livestock guideline values.</td>
</tr>
<tr>
<td>Lithium</td>
<td>Lithium was reported in all sampled bores across all four sampling events, except NMB-043, where its occurrence was not detected in the December 2008 sampling event. Lithium is a component of grease used in the drilling industry, however the relatively consistent concentrations between sampling events suggest the lithium reported is occurring naturally. The concentrations of lithium detected in Saltwater Creek were lower than all groundwater concentrations. All lithium concentrations reported are below the available guideline values.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Low to moderate levels of manganese were reported in all bores with a maximum concentration of 4.08 mg/L reported in NMB-046 during the December 2008 sampling event. The concentration of manganese is influenced by the acidity of the groundwater and its availability within the soils and sediments. Given that limonite, ironstone gravel and siderite have all been recorded on drilling logs, and that manganese is often associated with these minerals and lithologies, the observed concentrations of manganese are not unexpected. Concentrations higher than 0.2 mg/L precipitate upon oxidation, cause undesirable tastes, stains plumbing fixtures and fosters growths in reservoirs, filters and distribution systems. Groundwater and acid mine water may contain more than 10 mg/L (Todd and Mays, 2005). All values reported for the bores on-site were above 0.2 mg/L and exceed the NHMRC &amp; NRMMC (2004) aesthetic and ANZECC &amp; ARMCANZ (2000) long-term irrigation guideline values. Over half of the bores exceeded the NHMRC &amp; NRMMC (2004) health value of 0.5 mg/L. Low levels of total manganese (~0.2 mg/L) were reported for Saltwater Creek, however levels of dissolved manganese in the creek were low (&lt;0.01 mg/L) compared with groundwater concentrations.</td>
</tr>
</tbody>
</table>
| Molybdenum | Low levels of molybdenum were reported in seven of the bores. However, none of the bores detected molybdenum across all four sampling events, therefore it is likely that many of the readings are false positives. Bores NMB-026, NMB-042, NMB-047 and NMB-048 detected molybdenum in three of the four sampling events, which could be a
<table>
<thead>
<tr>
<th>Metal or metalloid</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal or metalloid</td>
<td>natural occurrence, possibly associated with pyrite. However it may also be explained by the presence of drilling grease, especially in the case of NMB-026, where elevated levels of elements found in drilling greases have also been detected. Concentrations reported are below all guidelines values, except the long-term irrigation values for three of the bores, and Saltwater Creek which also recorded low levels.</td>
</tr>
<tr>
<td>Nickel</td>
<td>Low levels of nickel were detected in all bores for the November 2008 sampling event, and in all sampled bores in the August 2009 and October 2009 sampling events. Nickel was also detected in the December 2008 sampling event for 6 bores, four of which were concentrations equal to the detection limit. As the detection limit for the December 2008 sampling event was not as low as that for the November 2008, August 2009 and October 2009 sampling events, it is not possible to conclude whether these readings are true or false positives. Bores NMB-026 and NMB-046 reported notably higher nickel concentrations than the other bores and these occurrences are consistent with the presence of other elements such as cobalt which commonly occur together. Further, nickel is an element found in laterite minerals including limonite which has been noted in drilling logs for the site. The concentrations of nickel in NMB-026 and NMB-046 (along with several other bores) exceeds the NHMRC &amp; NRMMC (2004) health value, but does not exceed any other guideline values. Low levels of nickel were reported in Saltwater Creek and were below guideline values.</td>
</tr>
<tr>
<td>Selenium</td>
<td>No selenium was detected in any bores for the November 2008 sampling event. Six bores reported low level concentrations equal to or marginally above the detection limits for the December 2008 sampling event. The discrepancy between results may therefore indicate false positives in many cases. However, bore NMB-042 recorded detectable levels of Selenium across three of the four sampling events, and therefore may indicate a natural presence of Selenium. In the bores where Selenium was detected, the levels equalled or exceeded the NHMRC &amp; NRMMC (2004) health value, and the values in some bores equalled the ANZECC &amp; ARMCANZ (2000) long-term irrigation guideline value. No selenium was detected in Saltwater Creek.</td>
</tr>
<tr>
<td>Uranium</td>
<td>Concentrations of uranium equal to or marginally above the detection limits were reported in four bores. However, in only one of the bores was uranium detected in all four sampling events, (bore NMB-026). However the levels encountered were equal to or marginally above the detection limits, hence it is probable that the values reported were false positives. Uranium was not detected in Saltwater Creek.</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zinc was detected in all bores for the November 2008 sampling event, and all sampled bores in the August 2009 and October 2009 sampling. In December 2008, zinc was only detected in bores NMB-026, NMB-046 and NMB-048. Its occurrence in these bores is consistent with occurrences of other elements found in pyrite. Zinc is also a component of greases used in drilling activities. All zinc concentrations reported were below available guideline values. Zinc was not included in the analysis suite for Saltwater Creek.</td>
</tr>
</tbody>
</table>
Figure 9-7  Aluminium concentrations for monitoring bores and Saltwater Creek

Figure 9-8  Arsenic concentrations for monitoring bores and Saltwater Creek
Figure 9-9 Barium concentrations for monitoring bores and Saltwater Creek

Figure 9-10 Boron concentrations for monitoring bores and Saltwater Creek
Figure 9-11  Cadmium concentrations for monitoring bores and Saltwater Creek

Figure 9-12  Chromium concentrations for monitoring bores and Saltwater Creek
Figure 9-13  Cobalt concentrations for monitoring bores and Saltwater Creek

Figure 9-14  Copper concentrations for monitoring bores and Saltwater Creek
Figure 9-15  Fluoride concentrations for monitoring bores and Saltwater Creek

Figure 9-16  Iron concentrations for monitoring bores and Saltwater Creek
### Figure 9-17

Lead concentrations for monitoring bores and Saltwater Creek

<table>
<thead>
<tr>
<th>Date</th>
<th>Monitoring Bores</th>
<th>Saltwater Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov-08 (or low tide)</td>
<td>0.146 0.001 0.012</td>
<td>0.000</td>
</tr>
<tr>
<td>Dec-08 (or high tide)</td>
<td>0.220 0.001 0.012</td>
<td>0.000</td>
</tr>
<tr>
<td>Aug-09</td>
<td>0.002 0.001 0.001</td>
<td>0.000</td>
</tr>
<tr>
<td>Oct-09</td>
<td>0.000 0.001 0.001</td>
<td>0.000</td>
</tr>
<tr>
<td>Drinking - Aesthetic</td>
<td>0.01 0.01 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Drinking - Health</td>
<td>0.01 0.01 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Livestock</td>
<td>0.1 0.1 0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Irrigation - Long-term</td>
<td>2 2 2</td>
<td>2</td>
</tr>
<tr>
<td>Irrigation - Short-term</td>
<td>5 5 5</td>
<td>5</td>
</tr>
</tbody>
</table>

### Figure 9-18

Lithium concentrations for monitoring bores and Saltwater Creek

<table>
<thead>
<tr>
<th>Date</th>
<th>Monitoring Bores</th>
<th>Saltwater Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov-08 (or low tide)</td>
<td>0.122 0.011 0.299</td>
<td>2.5</td>
</tr>
<tr>
<td>Dec-08 (or high tide)</td>
<td>0.116 0.096 0.241</td>
<td>2.5</td>
</tr>
<tr>
<td>Aug-09</td>
<td>0.097 0.063 0.283</td>
<td>2.5</td>
</tr>
<tr>
<td>Oct-09</td>
<td>0.121 0.064 0.28</td>
<td>2.5</td>
</tr>
<tr>
<td>Drinking - Aesthetic</td>
<td>0.1 0.1 0.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Drinking - Health</td>
<td>0.1 0.1 0.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Livestock</td>
<td>0.1 0.1 0.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Irrigation - Long-term</td>
<td>2.5 2.5 2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Irrigation - Short-term</td>
<td>2.5 2.5 2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Figure 9-19  Manganese concentrations for monitoring bores and Saltwater Creek

Figure 9-20  Molybdenum concentrations for monitoring bores and Saltwater Creek
Nickel concentrations for monitoring bores and Saltwater Creek

Selenium concentrations for monitoring bores and Saltwater Creek
Figure 9-23  Zinc concentrations for monitoring bores and Saltwater Creek

Silica

Silica is a non-ionic species and is the most abundant chemical component of the Earth. Silica concentrations in groundwater are a function of rock type with the lowest silica concentrations found in rocks containing quartz and/or minor amounts of clay, such as quartz rich-sandstones and carbonate rocks (Langmuir, 1997). Not easily dissolvable in water, but held in suspension, silica is often found in concentrations as high as 100 mg/L. Concentrations lower than this are usually considered normal.

From Figure 9-24 it can be seen that the silica concentration ranges between 18 mg/L and 68 mg/L, with an average value of 32 mg/L. The solubility of silica increases at high pH’s (>9). No guideline values are available. In extreme cases, silica can precipitate from solution and cause scaling within pipes and impede the flow of water.
Nitrogen species

From Figure 9-25 it can be seen that the total nitrogen (as N) concentration ranges between 0.5 mg/L and 3.8 mg/L which is below the trigger value for nitrogen in irrigation water of 5 mg/L.

Nitrite is not a significant constituent of the groundwater on-site with bore NMB-048 being the only bore to record a detectable level (0.0443 mg/L) which was equal to the detection limit. Levels of nitrate equal to the detection limit were reported for 50% of bores. The maximum level of nitrate recorded from all monitoring bores was 14 mg/L in NMB-047 in October 2009 with all other readings being less than 6 mg/L. Nitrate levels reported for Saltwater Creek were 2.44 mg/L (low tide) and 2.26 mg/L (high tide). The NHMRC & NRMMC (2004) health value for nitrate is 50 mg/L and the ANZECC & ARMCANZ (2000) livestock value is 400 mg/L.
Phosphorus

Concentrations of phosphorus above the detection limit occurred in six of the observation bores. Of these, only two were notably above the detection limit: 0.55 mg/L in NMB-020 and 0.18 mg/L in NMB-051. The general lack of phosphorus is to be expected.

Hydrocarbons

Total petroleum hydrocarbon screening was performed by ALS on samples collected from bores NMB-041, NMB-045 and NMB-050 during the December 2008 sampling event. No hydrocarbons were detected in these bores which all intersect coal seams, hence it would appear unlikely that any hydrocarbons are associated with the coal being targeted by the Project.

Dissolved gases

No dissolved gas sampling was undertaken, however hydrogen sulphide was evident in holes NMB-017, NMB-019, NMB-041 / 042.

9.2.5 Surface water interactions

No perennial watercourses or surface water bodies exist within or in close proximity to the Project. Small water holes have been observed within the non-perennial watercourses draining the Project site (as shown in Figure 9-26). These water holes are typically less than 2 m deep and not more than 10 m in length and 5 m in width. Due to the soils on site consisting...
predominantly of clay with occasional localised silty-sand lenses, it is not believed that the non-perennial watercourses or water holes on-site have a significant link to groundwater.

![Water hole with low turbidity during drier period](image1)
![Water hole with highly turbid water following rainfall](image2)

**Figure 9-26** Examples of water holes within watercourses on-site

There is some possibility that on occasion groundwater may locally discharge to watercourses on site. This would occur following periods of high rainfall which have recharged near surface localised aquifers in sand lenses or on ferruginous gravel and would not be expected to be of sufficient volume to generate flow in a watercourse. Groundwater discharge may also occur under similar circumstances where the coal measures outcrop or subcrop near surface and a sufficient hydraulic gradient exists. Such groundwater discharges have not been observed or reported to the best of our knowledge by any persons involved with the Project.

It has been reported by Laycock (1967) that the Burrum Coal Measures are “known from the Saltwater Creek-Maryborough River junction north westerly to the Cherwell River.” Review of the GWDB and boreholes drilled as part of the Laycock (1967) investigation confirms the existence of the Burrum Coal Measures in the vicinity of the Saltwater Creek-Mary River junction at depth of 15-25 m below surface. Contours of the potentiometric surface were prepared by Laycock (1967) assuming that water in all geological units is continuous, which would on the whole be a valid assumption in this situation. This indicates that groundwater flows to the southeast and east across the site. Discharge from the near surface Burrum Coal Measures targeted by the Project is therefore expected to be via local creeks and the Mary River, possibly indirectly (e.g. via alluvial aquifers).
10. **Groundwater use and environmental values**

10.1 **Groundwater use**

In order to gain a broad understanding of groundwater occurrence and use within the study area a search of the DERM (formerly DNRW) GWDB was undertaken. The GWDB contains records of bores drilled dating back over 100 years and are what is often referred to as registered bores.

Historically it has not always been a requirement in Queensland to register a bore with the government agency of the time. Therefore the GWDB does not contain records of all bores within the State and the quality of the data in the GWDB is quite variable. What are referred to as “stock and domestic bores” are those most commonly not included in the GWDB and these are low extraction bores for domestic and minor stock watering purposes.

The GWDB search identified only one bore within 5 km of the Project, as shown in Drawing 4. The registered number (RN) of this bore is 110673. While the GWDB lists the status of the bore as existing, there is no data in the casing table suggesting that it may have been a test or exploration hole.

Review of Hydrogeological Plan Sheet 9447-III of the Mary Valley Groundwater Investigations (Laycock, 1967) identified an investigation bore in approximately the same location as RN 110673. The data from this bore which is identified as 9447/3/7 (or just “7” on the plan) in Laycock (1967) was found to be identical to the data for RN 110673 in the GWDB. Hence it is concluded that RN 110673 was a groundwater investigation borehole and is not a cased water bore.

A search of the DERM Water Entitlements Registration Database (WERD) was also undertaken which did not identify any groundwater licences in the Project area.

At this time no groundwater hydrocensus has been undertaken to identify any unregistered bores in the vicinity of the Project. The most likely locations for any unregistered bores in close proximity to the Project would be the shooting club 2 km north of the Project and the town of Aldershot 3km to the south-southwest.

10.2 **Environmental values**

The Mary River Environmental Values and Water Quality Objectives (EPA, 2007) specify the environmental values to be protected with respect to groundwater as:

- aquatic ecosystems;
- drinking water;
- irrigation;
- stock water; and
• farm supply.

Each of these values is discussed in the following sections.

10.2.1 Aquatic ecosystems

The Mary River Environmental Values and Water Quality Objectives (EPA, 2007) define the level of protection of groundwater as “Aquatic ecosystem – high ecological value (level 1)” and stipulates that groundwater quality should not compromise identified EV’s and WQO’s for surface water where groundwaters interact with surface waters. It is also noted (EPA, 2007) that insufficient information is available to establish current water quality for groundwaters.

In the vicinity of the Project, the available information indicates that the relationship between the Burrum Coal Measures aquifer and surface water is one whereby the Burrum Coal Measures discharge to local creeks and the Mary River, possibly indirectly via other aquifers (e.g. alluvium). The mechanisms, locations and discharge water quality cannot readily be ascertained, although the contribution of groundwater to surface water flows is expected to be low.

For high ecological value waters, the generic ANZECC & ARMCANZ (2000) guideline is that there should be no change to the existing condition (i.e. no change beyond natural variability for physical, chemical and biological indicators).

While it is likely that any anthropogenic impacts on the groundwater in the immediate vicinity of the Project have been minimal, extensive coal mining has occurred in the area for over 130 years. The closest notable mining activity was the Globe and Churchill mines 3 km to the northeast as shown in Drawing 6. Based on available groundwater contour information, it is unlikely previous mining activities would have had an influence on water quality in the vicinity of the Project as the direction of groundwater flow has not historically been toward the Project site (from the previous mines).

As can be seen from many of the figures in Section 9.2.4, there exists substantial variability across the Project site for a broad suite of analytes for water within the Burrum Coal Measures aquifer. Both this study and that by Laycock (1967) have identified an apparent random distribution of salinity values, and it appears that such randomness may also exist for other constituents. Considerable natural variation of water quality within coal measure aquifers is therefore not uncommon.

Significant natural variability is further demonstrated when comparing the TDS results of Laycock (1967) for boreholes in the Burrum Coal Measures with those of the current study. Laycock (1967) reported a range in TDS from 120 mg/L to 6321 mg/L for 27 samples from 10 boreholes and a mean of 2447 mg/L. These results differ notably to the current study which identified a range from 3330 mg/L to 14,300 mg/L for 54 samples from 14 bores and a mean of 7947 mg/L.

Explanations for this variation include geological variability but also a significant change in climatic conditions for the periods preceding each investigation program. From the rainfall
residual mass curve (Figure 6-2) it was noted that the general trend for the last 30 years has been that of below average rainfall while for the period preceding the Laycock (1967) investigation, rainfall had predominantly been above average.

It is also important to note that the historic mine workings could be expected to have altered recharge and groundwater connectivity in general by providing preferential flow pathways and between different strata. This will have had primarily local implications for groundwater flow and quality.

10.2.2 Drinking water

Water from the Burrum Coal Measures is unsuitable for use as drinking water without considerable treatment to reduce / remove the following constituents to levels deemed acceptable in NHMRC & NRMMC (2004):

- Iron – for aesthetic reasons
- Manganese – for health and aesthetic reasons
- Alkalinity – for operating reasons (scaling)
- TDS – for taste

Treatment may also be necessary to remove nickel, selenium and lead based on the results available to date.

It is also noted that the local water quality objectives for iron and manganese specified in the Mary River Environmental Values and Water Quality Objectives (EPA, 2007) are an order of magnitude more stringent than the NHMRC & NRMMC (2004) (i.e. 0.05 mg/L compared to 0.5 mg/L).

10.2.3 Irrigation

With respect to the environmental value being suitability for irrigation, the Mary River Environmental Values and Water Quality Objectives (EPA, 2007) refers back to ANZECC & ARMCANZ (2000).

The maximum ANZECC & ARMCANZ (2000) electrical conductivity threshold values of irrigation water for all crops growing in clay is 4.2 mS/cm for barley and some pastures. Given that the Ec of the Burrum Coal Measures was found to range between 7 mS/cm and 21 mS/cm with an average of 13 mS/cm, it is clear that water from the Burrum Coal Measures is unsuitable for direct use as irrigation water.

Water from the Burrum Coal Measures typically exceeds the highest ANZECC & ARMCANZ (2000) trigger values of chloride and sodium causing foliar injury to crops by no less than three times.
Further, water from the Burrum Coal Measures is unsuitable for use as irrigation water without treatment to reduce/remove the following constituents to levels deemed acceptable by the ANZECC & ARMCANZ (2000):

- Iron
- Manganese

Treatment may also be necessary to remove localised occurrences of cobalt and molybdenum based on the results available to date.

Based on the assessment to date, testing for other parameters such as coliforms has not been warranted.

### 10.2.4 Stock water

With respect to the environmental value being suitability for stock watering, the Mary River Environmental Values and Water Quality Objectives refers back to the ANZECC & ARMCANZ (2000) guidelines.

Total dissolved solids is the main constituent of concern for use of water from the Burrum Coal Measures for stock water. Based on the results from all monitoring bores and consideration of ANZECC & ARMCANZ (2000) livestock tolerances, water from the Burrum Coal Measures is not suitable for poultry, dairy cattle and beef cattle without loss of production and a decline in animal condition. Pigs and horses may be able to adapt to some supplies without loss of production while sheep are the most suited to this water and should be able to adapt without loss of production up to a TDS of 10,000 mg/L (ANZECC & ARMCANZ (2000)).

Whilst levels of iron and manganese are high, ANZECC & ARMCANZ (2000) states that iron and manganese are not deemed sufficiently toxic to livestock.

### 10.2.5 Farm supply

With respect to the environmental value being suitability for farm supply/use, the Mary River Environmental Values and Water Quality Objectives refers back to ANZECC & ARMCANZ (2000).

Water from the Burrum Coal Measures is likely to cause some corrosion of pumping, irrigation and stock water equipment due to the slightly acidic pH. The average alkalinity of all groundwater samples collected from the monitoring bores is 299 mg/L CaCO₃ which is below the ANZECC & ARMCANZ (2000) trigger value of 350 mg/L CaCO₃ above which increased fouling can be expected. Six of the monitoring bores did however record values of alkalinity higher than the trigger value, hence some fouling could be expected.
11. Groundwater modelling

Groundwater modelling was undertaken by AGE and the full report is provided in Appendix 3. The objectives of the modelling were to:

- Estimate groundwater inflow to the open cut workings over the mine life;
- Predict the zone of influence of dewatering and the level and rate of drawdown at specific locations;
- Identify any areas of potential risk where groundwater impact mitigation/control measures may be necessary; and
- Predict the impact of mine dewatering on groundwater discharges and other groundwater users.

Development of an appropriate conceptual model which as accurately as possible represents the groundwater regime is an essential step in the modelling process. The conceptual model was developed by AGE in consultation with Streamline Hydro and was based on (AGE, 2010):

- Geological and topographical maps of the Project area;
- Geological information from coal exploration bores drilled across the Project area;
- Hydrogeological testing including falling head tests and test pumping undertaken for the Project;
- Previous hydrogeological investigations undertaken by Laycock (1967) in the region; and
- Data from the NRW groundwater database.

Numerical simulation of groundwater flows was undertaken using the MODFLOW-SURFACT code, Version 3. Following calibration of the numerical model, a number of predictive scenarios were run including:

- Mine advancement for the proposed 8 years of operation
- Groundwater recovery following cessation of mining
- Sensitivity analysis to assess the response of the model to variations in modelling parameters.

Key findings from AGE (2010) were as follows:

- The modelled inflow reaches 0.8 ML/day in the second year of mining and then gradually increases to 1.2 ML/day at the end of Year 4 after which it is relatively constant for the remaining four years of mining;
- The zone of influence, as indicated by the 1m drawdown contour, will extend about 2.9 km from the open cut pit;
12. Potential impacts and mitigation options

12.1 Impacts on environmental values

Under the Mary River Environmental Values and Water Quality Objectives (EPA, 2007), the groundwater environmental values to be protected are:

- aquatic ecosystems;
- drinking water;
- irrigation;
- stock water; and
- farm supply.

The existing groundwater identified in the vicinity of the Project was assessed against the water quality objectives defined to protect the above environmental values and the following was concluded:

- Groundwater of the Burrum Coal Measures exceeds the WQO’s specified for drinking water;
- Groundwater of the Burrum Coal Measures exceeds the WQO’s specified for irrigation, specifically with regard to concentrations of iron and manganese with rare exceedances of other metals;
- Groundwater of the Burrum Coal Measures generally exceeds the WQO’s specified for stock water, specifically with regard to total dissolved solids concentrations with one isolated exceedance of lead. Some stock (e.g. sheep) may be able to tolerate water from the Burrum Coal Measures;
- Groundwater from the Burrum Coal Measures is generally suitable for farm supply with some corrosion and fouling likely.

No WQO’s currently exist for water in the Burrum Coal Measures, although this water has been classified as having a high ecological value. The generic ANZECC & ARMCANZ (2000) guideline
for these waters is that there should be no change to the existing condition (i.e. no change beyond natural variability for physical, chemical and biological indicators).

The most likely sources of potential impact on the environmental values are:

- Contamination from fuel and chemical storages
- Seepage / infiltration from coal stockpiles
- Seepage / infiltration from waste rock piles
- Seepage from dams
- De-watering of the mine pit
- Recharge from the mine void

These potential sources of impact and their mitigation measures are discussed below.

### 12.2 Groundwater quality

#### 12.2.1 Contamination

The risk of groundwater contamination exists due to the storage and use of materials such as fuels, oils, grease and cleaning solvents as well as from waste water storage or treatment facilities. The risk is increased due to the relatively shallow depth to groundwater but reduced due to the relatively impermeable surface profile consisting predominantly of clay overlying the groundwater. Contamination of water in the near surface (i.e. held within the clay-sand and ironstone gravel) is considered more likely than contamination of the main aquifer on site – the Burrum Coal Measures.

Measures to eliminate or reduce the risk of contamination include:

- Minimising the quantities transported and stored on site;
- Having designated and appropriately designed and located storage, refuelling, service and maintenance facilities with containment and mitigation equipment (e.g. bunding and spill kits);
- Keeping mobile bunding and spill kits with machinery and at appropriate site locations; and
- Providing appropriate waste / wastewater treatment and storage facilities on site.

#### 12.2.2 Acid and metalliferous drainage

Results of work undertaken by EGI (2009) has identified the existence of acid forming material within the deposit. Testing to date indicates that the bulk of the overburden and inter-burden is likely to be non-acid forming (NAF) while coal seams, seam roof, seam floor, rejects and tailings are likely to be mainly potentially acid forming (PAF) (EGI, 2009).
While EGI (2009) identified an excess of NAF material compared to PAF material, it was also noted that the readily available portion of the acid neutralising capacity (ANC) was lower than that measured.

Kinetic net acid generation (NAG) testing by EGI indicated that PAF materials are likely to be fast reacting, producing acid within weeks of exposure to atmospheric oxidation conditions. The constituents likely to be associated with acid rock drainage include (EGI, 2009):

- Aluminium
- Cobalt
- Copper
- Iron
- Nickel
- Sulfate
- Zinc
- Arsenic (some slight enrichment indicated)

Uncontrolled, acid, metalliferous and saline drainage can present serious risks to environmental values including aquatic ecosystems, vegetation and water resources, if not appropriately managed. Mitigation options are proposed by EGI (2009) and prior to commencement of operations, the Colton Mine will need to have in place a plan for the management of acid, metalliferous and saline drainage. At a minimum, this plan will need to include:

- Additional materials characterisation
- Mitigation strategy (incorporating materials management)
- Monitoring program

Further specific requirements and recommendations to be considered for inclusion in this plan are provided in EGI (2009).

12.3 Impact of dams

Two dams are to be constructed on-site: a Worked Water Dam located within the CHPP and facilities area, and a Mine Water Management Dam. As previously discussed the surface geology is dominated by clay with localised sand lenses and ironstone gravels overlying the only aquifer identified on site - the Burrum Coal Measures. On the whole the near surface permeability is therefore expected to be low and the dams are not expected to have any significant impact on the groundwater regime if appropriately constructed. The main risk would be localised alteration of water quality within the surface profile surrounding the dams which may affect the condition of vegetation using this water. As noted previously, the vegetation
species present on site are tolerant of high moisture content and in many cases saturated soil conditions.

During the investigation, design and construction phases of the dams, the necessity for groundwater monitoring bores or vibrating wire piezometers around the dams to monitor for seepage will be assessed. If deemed necessary, an appropriate monitoring plan will be developed and implemented.

12.4 Groundwater inflow to mine pit

AGE (2010) predicted groundwater inflows to the mine pit from the model they developed. Inflow reaches approximately 0.8 ML/d in the second year of mining and then gradually increases to 1.2 ML/d at year 4 after which it is relatively constant over the remaining four years of mining (AGE, 2010).

The predicted inflows are believed to be an over-estimate for the follow reasons (AGE, 2010):

- Some of the predicted water inflows will be removed as bound moisture in the coal;
- Some groundwater will evaporate directly from the pit face and floor; and
- The model assumes the mine pits stay open over the life of the mine; in reality the mine will be gradually backfilled as mining advances and this will allow groundwater levels in spoil areas to gradually recover, resulting in a lower inflow than reported by the model;
- The aquifer is believed to be compartmentalised (i.e. semi-continuous) which will likely reduce inflows, while the model assumes a continuous system.

12.4.1 Control strategies

Due to the relatively shallow depth to water, advance de-watering using bores may be desirable to facilitate appropriate mining conditions including for geotechnical considerations, with ongoing management via in-pit sumps. Drains may also be required in the overburden to intercept localised flows. Groundwater collected from bores or sumps will be stored and used on-site for activities ranging from dust suppression to coal washing. In some instances blending or treatment of water may be required for water quality reasons. The total volume of groundwater to be managed over the Project life can be minimised by commencing mining of shallower areas and progressing to deeper areas. This approach would also be expected to minimise any potential AMD issues.

The quality of bore and pit water would initially be expected to be similar to that identified in the monitoring bores with the main exception that precipitation of iron and manganese can be expected in water draining to the mine pit. Over time the water quality is expected to deteriorate (more so in the pit sumps than any bores continuing to be used) due to AMD generation as identified in (EGI, 2009). It is therefore anticipated that pit water quality would need to be monitored and possibly separated or given appropriate consideration when being used or stored on site.
12.5 Groundwater depletion and recharge

No significant groundwater was identified within the Elliott Formation and hence there is no resource to be depleted in this instance. Changes in porosity and alteration to site topography / drainage due to earthworks as well as clearing of vegetation may result in increased infiltration. AGE (2010) determined the annual recharge to the Burrum Coal Measures was 1.5-2.0 mm/year/m² from chloride mass balance and during calibration of the groundwater model. The low recharge rate is considered to be the result of the extensive tree cover lowering recharge through interception and evapotranspiration. With the removal of vegetation, increased infiltration may result in the formation of localised perched aquifers within isolated sand lenses or on the ironstone gravel. There are also areas where recharge and infiltration may be reduced such as roads, hardstands and spoil heaps where the infiltrating water may not penetrate. Post mining rehabilitation and re-vegetation of the site should negate these temporary impacts.

Test pumping indicated that the aquifer in the vicinity of NMB-049 (the pumping bore) was of limited extent controlled by some form of geological / hydrogeological boundary. It was noted by AGE (2010) that the aquifer was partially de-watered during the test and that over time the drawdown would increase and the bore eventually fail (go dry). As the target coal seams are typically beneath the groundwater level, de-watering of the aquifer is a necessity for mining hence depletion of the groundwater resource will occur. Based on the results of modelling from AGE (2010), the area of depletion may extend over a distance of up to 3 km from the open cut pit.

Post mining the two mine voids will generally act as evaporative sinks, but may experience short term increases in water level following high intensity or prolonged rainfall events. Groundwater flow direction will be driven by dynamics of these processes. In the initial period post-mining, the mine void will provide an additional source of recharge to the Burrum Coal Measures.

Post-mining, the groundwater level is predicted to recover to within 50% of the pre-mining level within the first 2 years, 75% within about 9 years and an equilibrium level in 100 to 150 years (AGE, 2010).

No mitigation measures are proposed in relation to groundwater depletion as no existing users who may be impacted have been identified and depletion is not expected to result in any adverse impact on any of the identified environmental values.

12.6 Impacts on existing users

A review of the DERM GWDB did not identify any bores in the immediate vicinity of the Project, however it is noted that historically bores may have been registered as this was not required. Given the modelled drawdown by AGE (2010), and the undeveloped area within which the Project is located, NEC choose not to proceed with a hydrocensus to identify existing bores that may not be in the GWDB.
12.7 **Groundwater dependent ecosystems**

Diurnal fluctuation in groundwater bores monitoring the Burrum Coal Measures was identified, which may suggest the existence of groundwater dependent ecosystems. The diurnal fluctuations observed may however be the result of changes in the weight of overlying material, due to evapotranspiration of water from the near surface.

As the area outside the Project site is naturally vegetated and significant drawdown in water levels are expected outside the Project site (e.g. up to 15 m), there was some concern as to whether the drawdown in groundwater may affect the ability of the vegetation to access groundwater. Advice was sought from NEC’s consultant AustralAsian Resource Consultants (AARC) who sought advice from the Queensland Herbarium.

The following advice was provided by AARC and is pertinent to all of the species listed which occur on site:

*Roots grow generally within 30 cm of surface (feeding roots), a deeper root system occurs which is a supporting system. Damaging soils within top 30 cm will have fatal impact (Pers. com. Qld Herbarium).*

- **Melaleuca quinquenervia** – closely related to *M. viridiflora* (Qld Herbarium) *M.* quinquenervia is a hardy plant which can tolerate many types of soils (Australian Native Plant Society) It tolerates poorly drained soils of very low fertility but only low levels of salinity (Australian Government Species Bank) A surface water thriving plant, grows on sand and swampy grounds (DERM, Coastal Sand Dunes and Their Environment).

- **Melaleuca viridiflora** – very hardy, tolerates droughts (Qld Herbarium). Occurs in sandy surface soils in coastal lowland areas, thrives off groundwater close to the surface or surface water (Plants of Central Queensland) Stands of this species may indicate a clay subsoil and poor drainage (Trees and Shrubs of NW Qld).

- **Eucalyptus intermedia** – occurs on waterlogged habitat, deeply leached soils and coastal lowlands (Maroochy Biodiversity Strategy)

- **Eucalyptus latisinensis** – sandy soil and grows in healthlands and woodlands, close to coast (Qld Herbarium).

As the vegetation sources water from the near surface, and is tolerant of only low levels of salinity, it is concluded that de-watering of the Burrum Coal Measures is not expected to directly impact the surrounding vegetation. It is however noted that water from the overlying strata may drain more rapidly as the Burrum Coal Measures are de-watered due to an increased hydraulic gradient between this material and the Burrum Coal Measures. It has also been noted that the direction of vertical hydraulic gradient does vary across the site, however this is within the coal measures and the relationship between the coal measures and overlying soil has been determined. Further investigation may be warranted to determine the groundwater dependence or otherwise) of the vegetation.

Several wetlands have been mapped in and surrounding the Project site as shown in Drawing 5. It is noted that wetland mapping data is frequently based on remote sensing methods and requires on the ground surveys to confirm these preliminary assessments. Flora surveys
conducted by AARC targeted the Regional Ecosystem shown as “B” on Drawing 5 and determined it did not exist based on plant species present. The wetland marked “A” on Drawing 5 has been classified by AARC as a wetland by definition, following a post rainfall inspection which identified significant standing water on the surface. Drilling of bores NMB-043 and NMB-044 on the north eastern edge of this area as part of the groundwater investigation program did not identify any shallow groundwater. Further investigation of potential groundwater surface water interaction at this site may be warranted.

12.8 Impacts on historic mine workings

Groundwater modelling by AGE (2010) indicates that the extent of drawdown may extend to the historic Globe and Churchill Mines to the northeast of the Project. If this were to be the case then changes in the saturation status of the workings may result in cracking or subsidence in these areas and there may also be implications for localised AMD issues at these sites.

12.9 Cumulative impacts

At this time there are no known users or other activities in the vicinity of the Project which could lead to the Project having a cumulative impact on the groundwater regime. Any future activities in the area may result in cumulative impacts that would need to be assessed if and when such activities are proposed.

13. Groundwater monitoring plan

The purpose of groundwater monitoring is to:

- collect baseline / background data prior to mining, during operation and after mine closure
- provide a means of early detection and management of groundwater related impacts
- assess the progress of de-watering due to bores and seepage into the mine pit thus aiding in water supply/storage management
- identify any seepage from dams, spoil and stockpile areas
- identify any changes in groundwater quality as a result of de-watering or seepage from dam, spoil and stockpile areas
- to check for acid rock drainage generation and assess the performance of management strategies
- provide data for review of the groundwater model
- satisfy regulatory requirements

Groundwater monitoring will be undertaken using the existing network of monitoring bores, with further monitoring bores to be installed prior to commencement and during mining in
areas where potential adverse impacts may occur. In some instances the use of alternative monitoring methods such as vibrating wire piezometers may be more appropriate than monitoring bores, where the detection of seepage is of interest. Replacement monitoring bores will also be required at some time during the project to replace monitoring bores which are within the mine footprint and will be lost from the monitoring network.

The groundwater monitoring network will be required to monitor groundwater within:

- The Burrum Coal Measures
- The overlying / surface Elliot Formation

As noted previously, within the overlying Elliot Formation, groundwater may occur within:

- Shallow, localised lensoidal zones associated with sandy or ferugenous gravels
- Fractured zones in the weathered overburden material

The above zones should therefore be targeted for monitoring seepage from dams, spoil and stockpiles.

Minimum requirements for groundwater monitoring include:

- Compliance with applicable guidelines and standards
- Measurement of water levels using a combination of manual and automated data logging methods to provide redundancy and ensure different time scales can be captured
- Measurement of water level to an accuracy of not less than 1 cm
- Calibration of water quality instrumentation immediately prior to each sampling event (and not less than weekly)
- Analysis of water quality samples by a NATA accredited laboratory

Tables 13-1 and 13-2 set out the Project groundwater monitoring requirements, with the current monitoring bore locations shown in Drawing 3. Additional monitoring bores will be added prior to and over the project life to replace existing bores which may be lost by mining and to monitor for seepage from dams or spoil.

The volume of groundwater removed by way of bores or in-pit sumps should form part of the water accounting regime of the site and be recorded for each facility on a weekly basis and include the location / details of its end use. The frequency of monitoring may need to be increased should variations in level,

Due to localised and highly variable nature rainfall, climatic data is to be collected via the following automated logging devices:

- site weather station (including rain gauge)
at least one other rain gauge within the immediate vicinity of the project.

Prior to the commencement of operations, the following is recommended:

- Installation of additional monitoring bores to monitor the progression of the drawdown in the early stages of the operation;
- Installation of additional monitoring bores outside the proposed ML’s to expand the background data network; and
- Installation of additional monitoring bores in the vicinity of the historic Globe and Churchill Mines.

The adequacy of the monitoring network is to be reviewed no less than annually as part of the site Water Management Plan review.

**Table 13-1** Groundwater monitoring

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameters</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>All monitoring bores</td>
<td>Depth to water</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuous (data loggers to be installed in select bores)</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>Full analyte suite (Table 13-2)</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Groundwater supply / dewatering bores</td>
<td>Hours run</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td>Flow rate (L/s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total flow (ML/day)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depth to water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical conductivity</td>
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</tr>
<tr>
<td></td>
<td>pH</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Full analyte suite (Table 13-2)</td>
<td>Quarterly</td>
</tr>
<tr>
<td>In-pit sump pumps</td>
<td>Hours run</td>
<td>Weekly</td>
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<tr>
<td></td>
<td>Flow rate (L/s)</td>
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<td>pH</td>
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<tr>
<td></td>
<td>Full analyte suite (Table 13-2)</td>
<td>Quarterly</td>
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</table>
### Table 13-2 Suite of analytes for groundwater quality analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical properties</td>
<td>Electrical conductivity, pH, temperature, total dissolved solids</td>
</tr>
<tr>
<td>Acidity &amp; alkalinity</td>
<td>Acidity as CaCO$_3$, alkalinity (bicarbonate, carbonate, hydroxide and total as CaCO$_3$)</td>
</tr>
<tr>
<td>Major ions</td>
<td>Calcium, magnesium, sodium, potassium, chloride, sulfate, silicon</td>
</tr>
<tr>
<td>Metals (dissolved &amp; total)</td>
<td>Aluminium, arsenic, barium, boron, cobalt, copper, iron, lithium, manganese, nickel, selenium, zinc</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Ammonia, nitrate, total nitrogen, total phosphorus</td>
</tr>
</tbody>
</table>
14. References


Department of Resource Industries, Queensland 1992, Maryborough, Australia 1:250 000 Geological Series, Sheet SG 56-6, Department of Resource Industries, Queensland.

Environmental Protection Agency 2007, Mary River Environmental Values and Water Quality Objectives, Environmental Protection Agency, Queensland Government.


