# Upper Hunter Valley Alliance Hexham Relief Roads Groundwater Assessment

June 2012

## KMH Environmental


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*Certified to ISO 9001, ISO 14001, AS/NZS 4801*
A+ GRI Rating: Sustainability Report 2009

2110501B-PR_1006_RevD

| Revision | Details | Date | Amended By |
|---|---|---|---|
| 00 | Original | 14 March 2012 | S Bish |
| A | Incorporate design details | 29 March 2012 | K Saflian |
| B | Incorporate design details and KMH comments | 26 April 2012 | K Saflian |
| C | Incorporate design details and KMH comments | 9 May 2012 | S Bish |
| D | Incorporate updated design information from KMH | 29 June 2012 | C Callipari |



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Signed: ..........................................................................................................

Date: .................................................................................29 June 2012

Distribution: .....................................................electronic copy to client (KMH)

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# Glossary

| | |
|---|---|
| Aquifer | Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs. |
| Confined aquifer | Where water-bearing rocks are overlain by a confining layer of low permeability strata. |
| Groundwater | The water contained in interconnected pores or fractures located below the water table in an unconfined aquifer or located in a confined aquifer. |
| Groundwater flow | The movement of water through openings in sediment and rock; occurs in the zone of saturation. |
| Hydrogeology | The study of the interrelationships of geologic materials and processes with water, especially groundwater. |
| Infiltration | The flow of water downward from the land surface into and through the upper soil layers. |
| Permeability | The capacity of porous medium for transmitting water. |
| Recharge area | An area in which there are downward components of hydraulic head in an aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area. |
| Unconfined aquifer | Where the groundwater surface (water table) is at atmospheric pressure and the aquifer is recharged by direct rainfall infiltration from the ground surface. |
| Water table | The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric. It can be measured by installing shallow wells extending a few metres into the zone of saturation and then measuring the water level in those wells. |

# List of abbreviations

| | |
|---|---|
| **ADWG** | Australian Drinking Water Guidelines |
| **AHD** | Australian Height Datum |
| **ANZECC** | Australian and New Zealand Environment and Conservation Council |
| **bgl** | Below ground level |
| **CoC** | Chain of Custody |
| **EC** | Electrical conductivity |
| **GDE** | Groundwater dependant ecosystem |
| **NATA** | National Association of Testing Authorities |
| **NHMRC** | National Health and Medical Research Council |
| **PB** | Parsons Brinckerhoff Australia |
| **TDS** | Total dissolved solids |
| **WA** | Water Act |
| **WMA** | Water Management Act |
| **WSP** | Water Sharing Plan |

# List of units

| | |
|---|---|
| **g/L** | gram per litre |
| **$km^2$** | square kilometres |
| **L/s** | litres per second |
| **m AHD** | metres Australian height datum |
| **m bgl** | metres below ground level |
| **mV** | milli Volt |
| **m/d** | metres per day |
| **mg/L** | milligram per litre |
| **µS/cm** | micro Siemens per centimetre |

# Executive summary

Australian Rail Track Corporation is undertaking a number of projects to improve rail capacity in accordance with the 2011-2020 Hunter Valley Corridor Capacity Strategy. As part of the strategy to improve rail capacity, the five 'Relief Roads' (tracks) project is proposed to be located between the existing 'up main' and a new 'down main', adjacent to the Pacific Highway and Hexham Railway Station. The proposed Hexham Relief Roads project is located 16 kilometres (km) to the north-west of the city of Newcastle. Parsons Brinckerhoff was engaged by KMH Environmental on behalf of the Upper Hunter Valley Alliance to undertake a groundwater assessment to support an Environmental Impact Statement for the Hexham Relief Roads project.

The proposed Project Area is covered by an existing Water Sharing Plan (WSP), namely the Hunter unregulated and alluvial groundwater sources WSP. Within this WSP, the Project Area forms part of Groundwater Management Area (GMA) 17, and specifically within the Coastal Alluvial Floodplain (GMA 17, type 1). The WSP considers that groundwater within this GMA are '*low to moderately connected*' to their parent streams (such as the Hunter River), and support a 'medium' dependence for connected surface water systems, such as the nearby Hunter estuary.

The Project Area is located within the 'western' floodplain of the Hunter River, at an elevation of approximately 1.0-2.0 m Australian Height Datum. The proximity of the Hunter estuary, located 60 to 900 m downstream of the Project Area, makes the project vulnerable to both fluvial and tidal surge flooding, particularly in the north. The rail corridor has been present on the Project Area for about 150 years, where the existing railway lines are constructed on ballast (fill) of up to approximately 1.5 m above the natural ground surface. The natural groundwater conditions at the Project Area have been disrupted by: the placement of the fill along the rail corridor; changed pattern of flow in the Hunter River and its tributaries; and land use activity in the Hexham Swamp. Changes have occurred in standing water level, flow direction, seepage velocity and transmissivity. Groundwater beneath the Project Area forms part of a (perched) water table aquifer within the underlying fill and alluvial sediments. Groundwater flow across the Project Area is influenced by differences in aquifer transmissivity, tides, flooding and topography. Groundwater at the Project Area is naturally saline and contains extensive pockets of contamination from historical industrial activity and the environmental groundwater value is considered to be industrial. There are no registered groundwater users within proximity of the Project Area.

Although the Project Area is mapped as a high risk acid sulphate soil area, due to the extent of fill beneath the Project Area, the potential for exposure of acid sulphate soil is reduced at depths above 0.8 m. Within the nearby Hexham Swamp, the ASS risk is high, where sulphuric acid impacts have historically been observed.

The overall potential impact to groundwater from activity at the Project Area and cumulative to the nearby Queensland Rail National Transport Support Facility project, is considered to be low. The main features of the Project likely to impact upon groundwater resources include excavation for topsoil removal, general cut and expansion of drainage channels; placement of fill and columns for ground improvement purposes, and dewatering. Potential impacts from activity on-site are considered to be of a short term, recoverable nature, occurring primarily during the construction phase. Mitigation measures to manage any potential impacts at the Project Area include: licensing/approving of any groundwater interception and/or dewatering activity; implementation of a groundwater monitoring plan; alignment (design) of excavation and discharge activity with the nearby QRN TSF project; and preparation of a soil and water quality management plan to protect receiving waters.

Groundwater beneath the Project Area occurs at shallow depths and may be aggressive to steel structures due to its salinity and potential acidity. These conditions would need to be considered in the design, excavation and installation of any subsurface structures or ground treatment.

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# 1. Introduction

## 1.1 Background

Due to the forecast increase in coal exports through the Port of Newcastle, Australian Rail Track Corporation (ARTC) is undertaking a number of projects to improve rail capacity in accordance with the 2011-2020 Hunter Valley Corridor Capacity Strategy Consultation Document. As part of the strategy to improve rail capacity, the five 'Relief Roads' (tracks) project is proposed to be located between the existing 'up main' and a relocated 'down main', adjacent to the Pacific Highway and Hexham Railway Station (KMH, 2011). The Hexham Relief Roads project is located on the existing straight between 103 and 104 points (pts) at Hexham, located 16 kilometres (km) to the north-west of the city of Newcastle along the banks of the Hunter River. The project is approximately 176 km north of Sydney by rail. The surrounding area is dominated by the Hexham Swamp, and the Pacific and New England Highways.

The area of the Hexham Relief Roads project (hereafter referred to as the 'Project Area') was historically a coal washery and part of an industrial development, although it is now predominantly grazing land.

Key components of the proposed Project are outlined in Volume 1 of this EIS, and comprise:

- Five Up Relief Roads (train lines) to the west of the existing Up Main, Down Main and Up Coal including:
  - The removal of the existing Down Coal (located to the west of the Up Coal).
  - The construction of five new train lines (tracks) for the Relief Roads.
  - The construction of a new Down Coal to the west and outside of the proposed Relief Roads.
  - Each Relief Road to accommodate trains generally comprising two or three locomotives and up to 91 wagons (1,543m long) requiring a minimum standing room of 1,670m; and
  - New turnouts, return curves and associated track changes.
- Installation of new signal infrastructure for the five Relief Roads including signal location cases, huts and gantries.
- Earth and civil works of approximately 265,000m$^3$, including cut to fill, track formation, drainage and minor structures.
- Ancillary infrastructure including vehicle access tracks, temporary construction compounds and stockpile sites.
- Land acquisition and the upgrading of existing rail infrastructure and public utilities as required.
- The estimated cost of the Project is approximately $90 million and it is expected to take approximately 18 months to construct.

## 1.2 Purpose

Parsons Brinckerhoff Australia Pty Ltd (hereafter Parsons Brinckerhoff) was engaged by KMH Environmental on behalf of the Upper Hunter Valley Alliance (UHVA) to undertake a groundwater assessment for the Hexham Relief Roads project. The groundwater assessment will support the Environmental Impact Assessment (EIS) for the overall project.

## 1.3 Assessment approach and objectives

The objective of this groundwater assessment was to address the Director General's Environmental Assessment Requirements (DGRs) for the project in respect of potential groundwater impacts. DGRs developed for this project are listed in Section 2.1.
The groundwater assessment was desktop based and gave particular consideration to the project's proximity to the Hunter River, wetland habitats and QRN TSF.

As part of the groundwater assessment the hydrogeological environment of the Project Area was evaluated, and baseline conditions for the project defined to form the basis of conceptual understanding. This was undertaken through the following tasks:

- Definition of the local and regional hydrogeological environment and major aquifer zones. Review of Coffey environmental (Coffey, 2012) and Douglas Partners (Douglas Partners, 2011) groundwater investigations.
- Consideration of historical groundwater level flux where sufficient water level information is available. Trends in groundwater movement will be considered.
- Definition of the groundwater relationship to dependent ecosystems.
- Consideration of groundwater quality data. The data will be assessed from both a potential contamination perspective, and connected groundwater/surface water salinity and acid sulphate soil perspective.
- Development of a conceptual hydrogeological model to describe aquifers, hydraulic connections, and flow directions in the Project Area.
- Identification of potential impacts and risks to the project and groundwater environment, including an assessment of the cumulative relationship and interaction with the nearby QRN TSF.
- Nomination of possible mitigation measures that may be considered to address any potential impacts from the project.

## 1.4 Scope of works

The groundwater assessment to support the EIS for this project included:

1. Review of relevant information, including:

    a) legislative requirements, including any recent changes to and development of new policy and planning instruments, and

   b) existing information including topography, geology, hydrogeology, aerial photos, rainfall and previous groundwater studies.

2. Site visit involving a walkover assessing location of groundwater dependent ecosystems (GDEs) and relationship to surface water.

3. Determination of baseline conditions, including:

   a) overall assessment of groundwater levels

   b) overall assessment of groundwater quality, including the comparison of analytical results with relevant guidelines, and

   c) characterisation of local and regional groundwater flow systems.

4. Identification of potential impacts on groundwater levels and quality during the project development (construction) and operation, including cumulative impacts from the nearby QRN TSF project.

5. Development of mitigation measures to address identified potential groundwater impacts.

6. Reporting, including the production of a draft for review and final with consideration of collated comments.

## 1.5 Review of existing information

A number of data sources and relevant documents where reviewed as part of this investigation. The following information from external sources has been used in this assessment:

- topographic data
- aerial photographs
- geological reports and maps (including *Newcastle 1:250,000 Geology Map, sheet number SI 56-2)*
- NSW Office of Water (NOW) registered groundwater database and reports (including Hunter unregulated and alluvial sources Water Sharing Plan)
- Department of Environment and Climate Change (DECC) Acid Sulfate Soils Risk Map for the Lower Hunter (2008)
- rainfall data and reports from the Bureau of Meteorology (BOM)
- project design information including:
  - earthworks quantities, and
  - ground improvement strategies.

- investigation reports, including:
  - Acid Sulphate Soils. Lower Hunter River Estuary (DPI, 2008)
  - Proposed Hexham Relief Roads, Hexham. Phase 1 and 2 Contamination Assessment. Upper Hunter Valley Alliance (UHVA, 2012a)
  - Report on proposed contamination assessment. Proposed Hexham redevelopment, Maitland Road and Woodlands Close, Hexham (Douglas Partners, 2011)
  - Hexham Relief Roads – Preliminary Environmental Assessment for ARTC (KMH, 2011)
  - Feasibility Assessment Report. Hexham Relief Roads. Phase 2 Feasibility Assessments (UHVA, 2011)
  - Hexham Relief Roads. Drainage Relief Strategy (UHVA, 2012b), and
  - Lower Hunter River Flood Study by NSW Public Works Department (2004).

## 1.6 Data and study limitations

The following limitations apply to the desktop groundwater assessment as described in this report, including:

- The analysis and conclusions in this report are based on data available at the time of preparing the report and are indicative of the known environmental conditions at the time.
- Parsons Brinckerhoff has formulated its analysis through a desktop study and limited field investigations undertaken by other consultants, namely geotechnical drilling conducted by Coffey environmental and Douglas Partners (to validate the desktop only). It has therefore relied on 'other' information sources for geology, groundwater levels and groundwater quality data.

# 2. Planning and legislation

## 2.1 Director General environmental assessment requirements

The Director General environmental assessment requirements (DGRs) were issued for this proposed project. The 'hydrology' section requires the EIS to address a number of issues that specifically consider groundwater, including: groundwater hydrology; groundwater dependent ecosystems (GDEs); and groundwater users and licences, where applicable. The EIS must consider the potential and residual environmental impacts from the project (both in the construction and operation phases), and propose mitigation measures to address risk. The DGRs have also specifically requested consideration of the relationship and interaction, addressed here as a cumulative assessment of groundwater impact, between the Project Area and the nearby proposed QRN TSF.

The NSW Office of Water (NOW) in a letter dated 24 November 2011, has specifically requested as part of the DGRs, a number of groundwater related issues to be considered and addressed in the EIS. In summary, these include:

- Consider water legislation requirements, including approvals and licences, and adherence to applicable water sharing rules.
- Identify sustainable and efficient water supply, considering source and planning compliance.
- Review compliance with policies relating to groundwater dependent ecosystems and quality protection.
- Identify groundwater issues and potential impact to the resource, including from acid sulphate soils and saline intrusion.
- Review impact to GDEs, licensed users and basic landholder rights, and
- Identify mitigation issues and monitoring.

## 2.2 Relevant groundwater legislation

The *Water Act 1912* (Water Act) and *Water Management Act 2000* (WMA) governs: the issue of existing and new water licences; the trade of water access licences and entitlements (shares) for groundwater; and extraction and use of groundwater in the State of NSW. Under this legislation, any development activity taking or using water must in principle:

- include an assessment of whether there is any adverse impact from the proposed development to a river or aquifer, and its dependent ecosystems, and
- protect basic landholder rights.

The WMA is progressively being introduced, with the conversion of existing Water Act licences and its provisions/rules through the development of Water Sharing Plans. When a Water Sharing Plan (WSP) is commenced, the licensing provisions of the WMA also come into effect and existing Water Act licences are automatically converted to WMA water access licences (WAL), and water supply works and use approvals. The Project Area is covered by an existing WSP, namely the Hunter unregulated and alluvial groundwater sources WSP, which came into effect on 1 August 2009. This WSP has effect on surface water and alluvial groundwater management at the Project Area.

Within this WSP, the Project Area forms part of Groundwater Management Area (GMA) 17, and specifically within the Coastal Alluvial Floodplain (GMA 17, type 1). The alluvial aquifers that occur on the coastal floodplains of the Lower North Coast (and include this Project Area) are '*low to moderately connected*' to their parent streams (such as the Hunter River). It is of necessity that the WSP protect against saltwater intrusion and to properly consider the impact of groundwater extraction on estuary values. The sensitivity of the estuary near the Project Area is explored further in Section 4.6. Where highly connected GDEs are known to occur, these are identified within the WSP and protected by its rules, including that new or replacement bores will not be permitted within a buffer zone around the identified GDE.

Each WSP provides the relevant mandatory conditions for extraction, including that all licences undertake measurement of use (extraction). Measurement of use may be via meters or other forms of monitoring devices fitted to approved works, or via alternative monitoring systems, in order to provide water extraction estimates. Different types of devices may be required depending on the nature of the water supply work installation, the size of the work, and the effect that the operation of the work may have on the water source and other water users.

To construct a production bore to extract a water supply or a test bore, a WMA licence and works approval is required. Bore construction must be in accordance with the 'Minimum Construction Requirements for water Bores in Australia' (L&WBC, 2003). Any discharge to receiving waters will also require approval under the WMA and *Environmental Planning and Assessment Act* (1979) (EP&A Act). The necessary forms can be downloaded from the NOW website, to be completed and submitted to the nearest NOW office (at Newcastle) or on the NOW website (www.water.nsw.gov.au).

Recently, the Minister for Primary Industries announced a draft 'NSW Aquifer Interference Policy' to manage activities that intercept groundwater and that are not for production/supply purpose (DT&I, 2012). This policy is being rolled out across the State under the WMA 2000. Under the WMA, an aquifer interference (AI) activity may require both an access licence and a separate aquifer interference approval (AIA). The AIA is similar to the works approval under the WMA, which confers a right on the holder to undertake specific activities at a defined location over a given period. The EP&A Act is applied consistently with the WMA to prevent duplication of necessary approvals, particularly for State significant development/infrastructure applications.

Initially, areas that underlie 'Biophysical Strategic Agricultural Land' are targeted by the AI policy, with other areas of the State to be considered at a later stage (DT&I, 2012). According to the AI policy, the Project Area is not considered to be part of 'Biophysical Strategic Agricultural Land', and therefore any activity that occurs as part of the rail infrastructure will not require an aquifer access licence, as it is deemed to be covered by the *Transport Administration Act 1988*. However, any excavation that 'supports' a rail project (such as a flood channel), although not actually part of the rail infrastructure itself and which intercepts groundwater, could require a licence if the rate of discharge is >5 L/s or equivalent to 3 Megalitres (ML)/year. It is noted that the policy is currently in a draft form and is subject to change.

### 2.2.1 Water supply

It is understood that the water supply for the project will be obtained from the Hunter Water Corporation (HWC), and sourced from an existing standpipe that runs parallel to the Project Area. Therefore, provided groundwater is not extracted at the Project Area, no (groundwater) licence or works approval for water supply purposes will be required. However, should this assumption change, this report provides discussion on licensing requirements.

## 2.3 Local and State government policies

The proposed development will be governed by both local and state government policies, including the NSW Groundwater Policy Framework (Department of Land and Water Conservation (DLWC, 1997) which comprises a set of three policy documents:

- NSW Groundwater Quality Protection Policy (DLWC, 1998).
- NSW Groundwater Quantity Management Policy (draft) (DLWC, n.d.).
- NSW Groundwater Dependent Ecosystem Policy (DLWC, 2002).

The aims of the NSW Groundwater Policy Framework are to' *slow, halt or reverse degradation in groundwater resources, ensure long-term sustainability of the biophysical characteristics of the groundwater system, maintain the full range of beneficial uses of these resources, and maximise the economic benefit to the region and state'*. Any excavation or disposal at the Project Area is bound by the policies described above, and therefore must not cause off-site impact to other users including the environment and particularly designated GDEs such as the SEPP14 Wetland (No. 787), part of the wider Hexham Swamp (Nature Reserve).

The (NSW) State Groundwater Dependent Ecosystems Policy (DLWC, 2002) specifically aims to protect valuable ecosystems that depend on groundwater for survival. The WSP's are an effective management tool designed to consider the intent of this policy, through the expression of rules to protect GDEs and allow groundwater extraction/interaction around GDEs to be sustainably managed.

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# 3. Physical setting

## 3.1 Topography and land use

The Project Area is located within the Hunter Sub-Region of the NSW Sydney Basin bio-region, which is characterised by undulating hills and wide valleys containing meandering river systems and numerous fluvial and estuarine swamps (NSW Parks and Wildlife Service, 2003). The Project Area is located within the floodplain of the Hunter River, at an elevation of approximately 1.0-2.0 m AHD. The floodplain is several kilometres across, bisected by the Hunter River, as shown in Figure 3.1. The Project Area is located on the western bisect of the floodplain with steeply sloping hills over 4 km to the west of the Project Area.

The land surrounding the Project Area is occupied by a mixture of land uses. The area immediately to the east and north of the Project Area, between the rail line and the Hunter River, is occupied largely by an industrial estate. In contrast, to the west and south of the Project Area is the Hexham Swamp, listed as a SEPP14 wetland (No. 787). The remainder of the floodplain extending to the west and north is occupied primarily by agricultural activities.

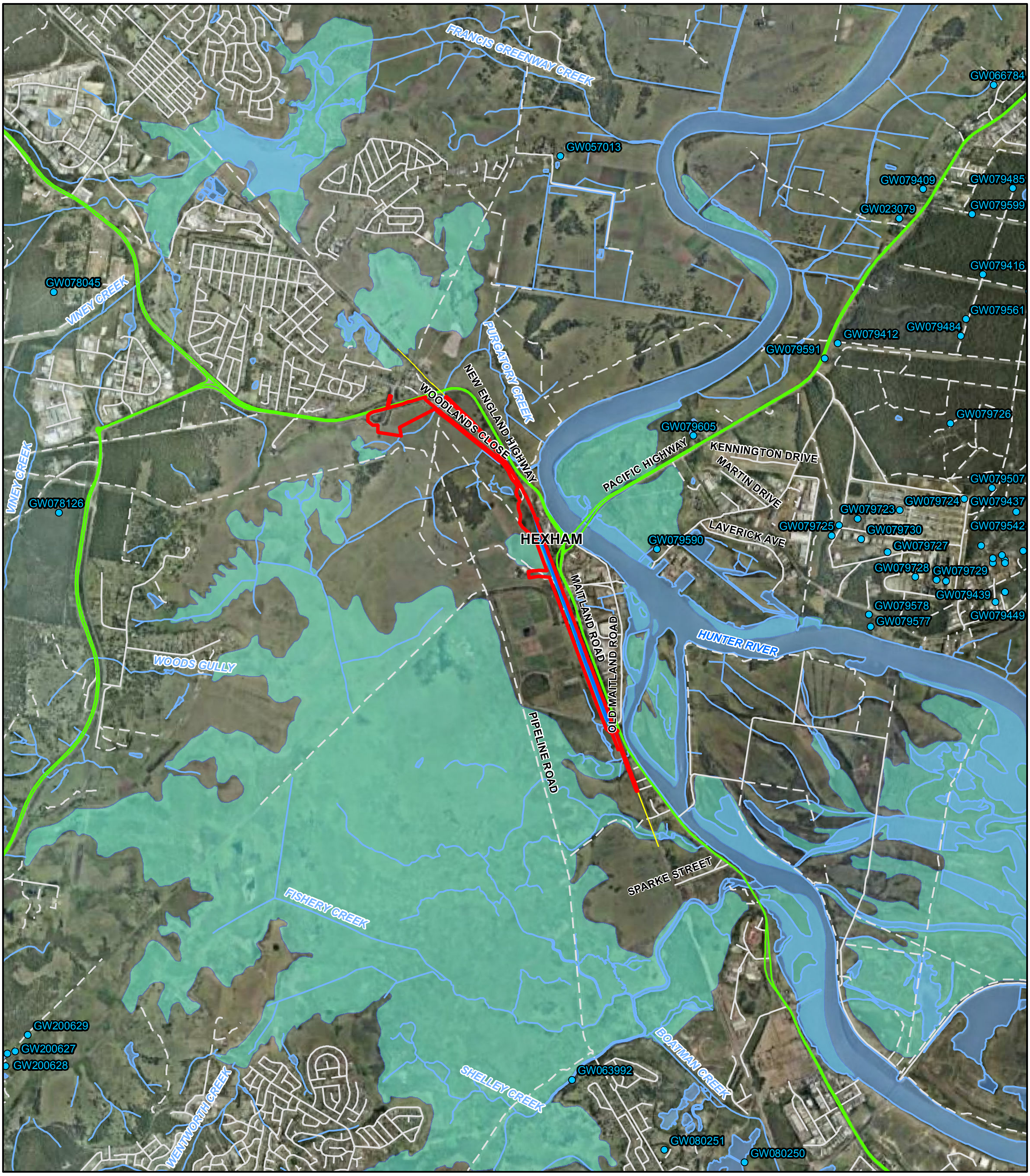
The rail corridor has been present on the Project Area for about 150 years. The existing railway lines are situated on ballast (fill) of up to approximately 1.5 m above the natural ground surface level (Douglas Partners, 2012).

## 3.2 Climate

The climate of the Hexham area is characterised by warm summers and cold winters (BOM, 2011). The Hunter Region is located within a transition zone where temperatures range from 18 to 27$^{o}$C in summer, and 7 to 17$^{o}$C in winter (DPI, 2008). Rainfall records have been sourced from the Bureau of Meteorology (BOM) at Raymond Terrace (Station Number 61031), approximately 8 km from the Project Area. Period of record is 1894 to present.

Average monthly rainfall records from these two sites indicate rainfall is highest in the months between December and June. The average annual rainfall for the Project Area is approximately 1080 mm/year. A plot of the cumulative deviation from average monthly rainfall at Raymond Terrace is shown in Figure 3.2.

Cumulative deviation from the mean rainfall illustrates periods of above or below average rainfall: whereby a positive gradient (upward trend) represents a period of above average rainfall; and a negative gradient (falling trend) represents a period of below average rainfall. Periods of below average rainfall (as shown in Figure 3.2) occur across the record with extended periods between the start of record (1894) and 1910, and 1934 to 1947. The earlier period of below average rainfall reflects the drought experienced by most of the country, in what is known as the Federation Drought. The period 1934 to 1947 reflects the dry conditions experienced across Australia during World War II. Since this time, a steadily rising trend of above average rainfall is observed through to the present time, with two main periods of below average rainfall coinciding with the droughts of the early 1990s and early 2000s, both also part of nation-wide droughts.




Major Road
Local Road
Minor Road
Proposed Alignment
Existing Alignment
Project Area
Access Road
Registered bores
Watercourse
Water body
SEPP 14 Wetlands

A4 Original

0 250 500 750

Metres

GDA 1994 MGA Zone 56

N

UHVA

ARTC

ARTC
Hexham Relief Roads

| | |
|---|---|
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| Revision | A4 |
| Date | 09.03.2012 |
| Scale | 1:50,000 |

**Site location**

**Figure 3.1**

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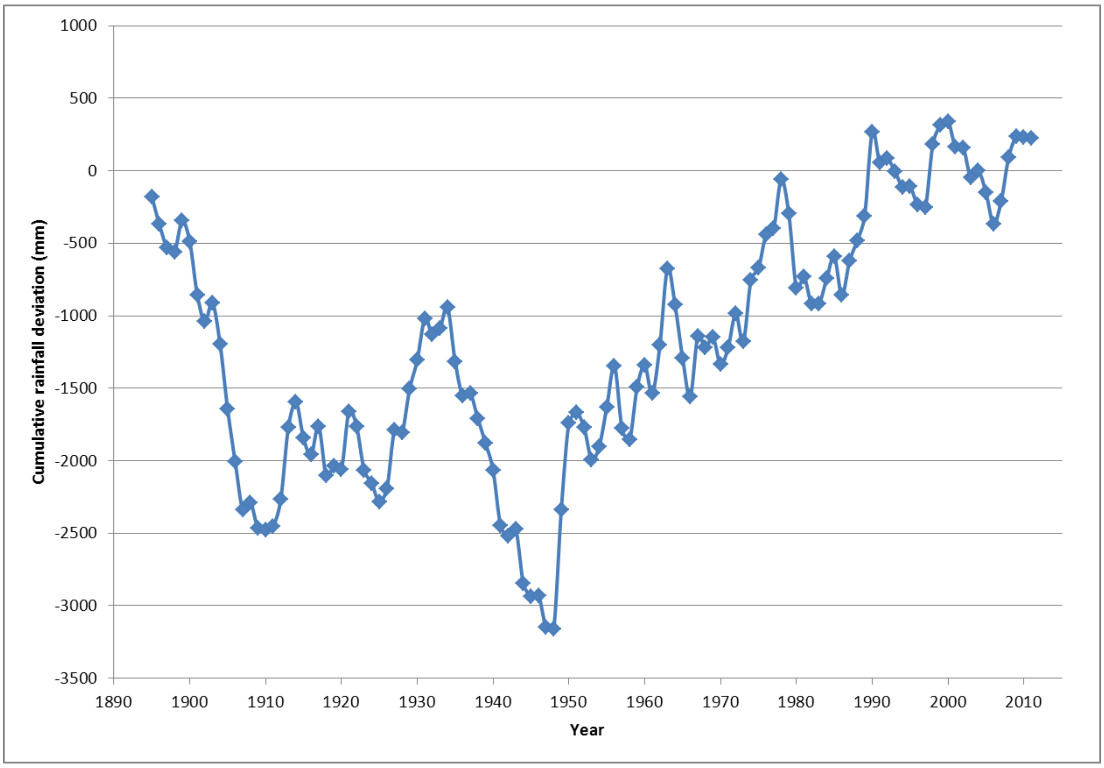



**Figure 3.2 Cumulative rainfall deviation at Raymond Terrace (Station Number 61031)**

## 3.3 Surface water

The Project Area lies within the Hunter River Catchment, as shown in Figure 3.1. The Hunter River is located towards the east of the Project Area, and is regulated above Hexham. It feeds the Hexham Swamp through to the Hunter estuary, flowing towards the south-east, discharging into the Pacific Ocean near Newcastle. The Hunter River is fed by numerous tributaries flowing from surrounding hills across the floodplain, including Fishery Creek located south of the Project Area.

The proximity of the Hunter estuary, located 60 to 900 m downstream of the Project Area, makes the project vulnerable to both fluvial and tidal surge flooding, particularly at the northern end (PWD, 2004). A report by the UHVA (2012b) indicates that flood levels are higher in the northern (upstream) end of the Project Area. The flood mapping described in this report indicates that the Project Area is protected from inundation for a 1:20 year event.

The Project Area is both flat and low lying. The tidal variation of the estuary (adjacent to the Kooragang Wetland) is 0.1 to 2.0 m AHD (DPI, 2008). The tidal limit extends up to 45 km inland, from the sea up to Oakhampton near Maitland. Floodgates and drainage works along the Hunter River limit tidal exchange and are designed to remove surface waters on the floodplain. Recently tidal gates have been removed from near the confluence of Ironbark Creek (located 2 km south of Project Area) and the Hunter River.

Natural drainage across the Project Area has been disrupted by the placement of the rail corridor and fill and the historical industrialisation of the western portion of Hexham Wetland (Douglas Partners, 2012).

Drainage of the Hexham Swamp principally occurs through Ironbark Creek which discharges to the Hunter River about 2 km to the south of the Project Area. Since the removal of the tidal gates, drainage is now likely to occur through either recharge into the surface soils or via the several drainage lines and culverts constructed along the railway corridor that shed water both to the east (Hunter River) and the west (Hexham Swamp and Ironbark Creek).

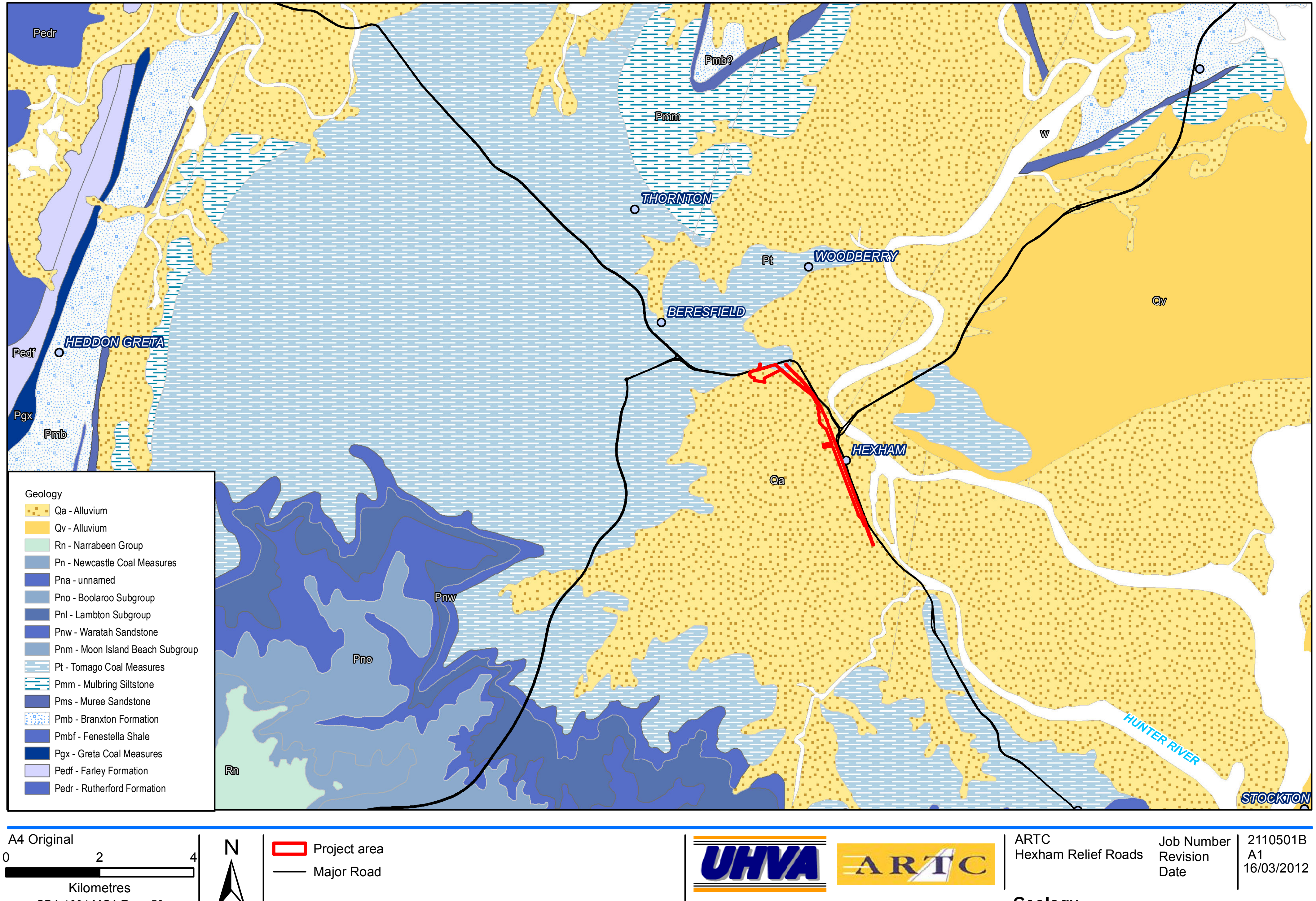
## 3.4 Geology

The Project Area is located within the north-eastern portion of the Sydney Basin. The Project Area is bounded by the Mooki Thrust system to the north and the Hornsby Plateau to the south (Bembrick et al, 1973). Regionally, the Study Area is underlain by Quaternary alluvial and estuarine sediments associated with the tidally influenced Hunter River system.
The alluvium expands across the Hunter River floodplain. It has accumulated in the low-lying coastal outlet floodplain of the Hunter River system, and comprises of interbedded layers of gravel, sand, silt and clay up to depths of 40 m (Rose et al, 1966). These alluvial sediments are further underlain by the Tomago Coal Measures, consisting of interbedded coal, sandstone and shale. A geological map of the Project Area is shown in Figure 3.3.

Information from the geological logs of NOW registered bores (discussed further in Section 4.2) suggests that the geological conditions on the east side of the Hunter River (floodplain) are considerably different from those encountered in the floodplain on the western side of the River (where Project Area is located). Geological logs for bores in the eastern floodplain suggests that sandstone is exposed at or near surface, whereas the only available geological log (GW063992) that exposes bedrock within 5 km of Project Area on the west (side) floodplain indicates alluvial sediments occur up to depths of 19 m.

Locally, the shallow subsurface directly beneath the Project Area is highly disturbed due to historical land use activities. In general, the subsurface conditions of the Project Area comprise, in stratigraphic order:

- Fill, predominately comprising gravelly sand/clay, coal reject and rail ballast ranging in depth of between 1 to >4 m.
- Estuarine/alluvial soils, typically comprising deposits of clay, silt and sand and gravel associated with sedimentary deposition from the Hunter River to depths of about 20 m; and
- Weathered sedimentary rock, typically interbedded sandstone, siltstone, tuff, and mudstone.




ARTC
Hexham Relief Roads

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**Geology**

**Figure 3.3**

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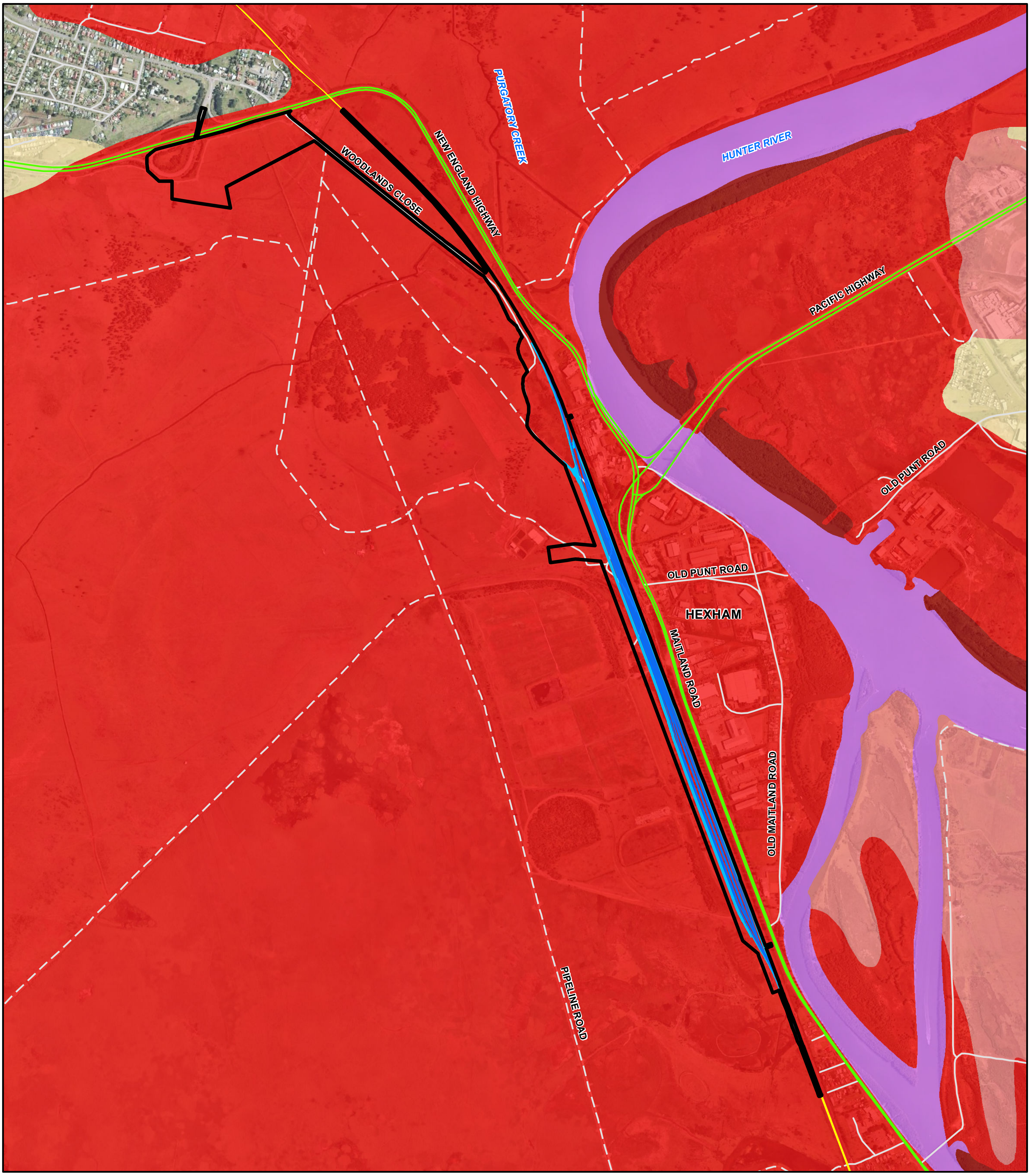
### 3.4.1 Acid sulphate soils

The Project Area is underlain by soils consistent with river terraces, levees, flood plains and tidal flats. These soils include dark friable loam, underlain by either sand or clay. The estuarine flats consist of peaty /organic soils overlying acid clay.

The NSW DECC (2008) ‘Acid Sulfate Soils Risk Map’ for the Lower Hunter indicates that the Project Area is located within an area having a high probability of acid sulfate soils (ASS) within 1.0m of the ground surface. Therefore, site activities, such as excavations have the potential to expose the estuarine soils. However, it is important to note that due to the extent of fill beneath the Project Area, the presence of ASS is now limited. Drill logs for bores across the Project Area indicate that estuarine soils (potentially ASS) have been observed at depths of between 0.8 and 2.5 m (UHVA, 2012a). A map of the extent of acid sulphate soils across the Project Area and floodplain are shown in Figure 3.4.

The area within the Hexham Swamp, to the south of the Project Area, has high ASS risk (DPI, 2008). Ironbark and Fishery Creeks are considered high risk areas where a sulphide layer can receive large amounts of water from surrounding hills, which ponds at the surface accumulating sulphide near the surface. DPI (2008) noted that acidification of shallow soils, leaching of sulphuric acid and iron flocculate has been observed in Fishery Creek at Hexham Swamp. Corrosion of concrete structures has also been observed at Hexham Swamp due to acidification of its waters. Due to the shallow nature of local groundwater, the potential for these shallow soils to be exposed due to fluctuating water tables is high. Therefore, any excavation activities near the Hexham Swamp, must ensure that associated groundwater drawdown does not desaturate acid sulphate soils within the Hexham Swamp itself.




| | | | |
|---|---|---|---|
| Major Road | Existing Alignment | Acid Sulfate Risk | High Risk 2-4m |
| Local Road | Project Area | High Risk 0-1m | High Risk Bottom Sediments |
| Minor Road | Access Road | High Risk 1-2m | Low Risk above 4m |
| Proposed Alignment | | | |

A4 Original

0 250 500 750

Metres

GDA 1994 MGA Zone 56

N

UHVA

ARTC

ARTC
Hexham Relief Roads

| | |
|---|---|
| Job Number | 2110501B |
| Revision | A2 |
| Date | 27.01.2012 |
| Scale | 1:20,000 |

**Acid Sulfate Soil Risk** **Figure 3.4**

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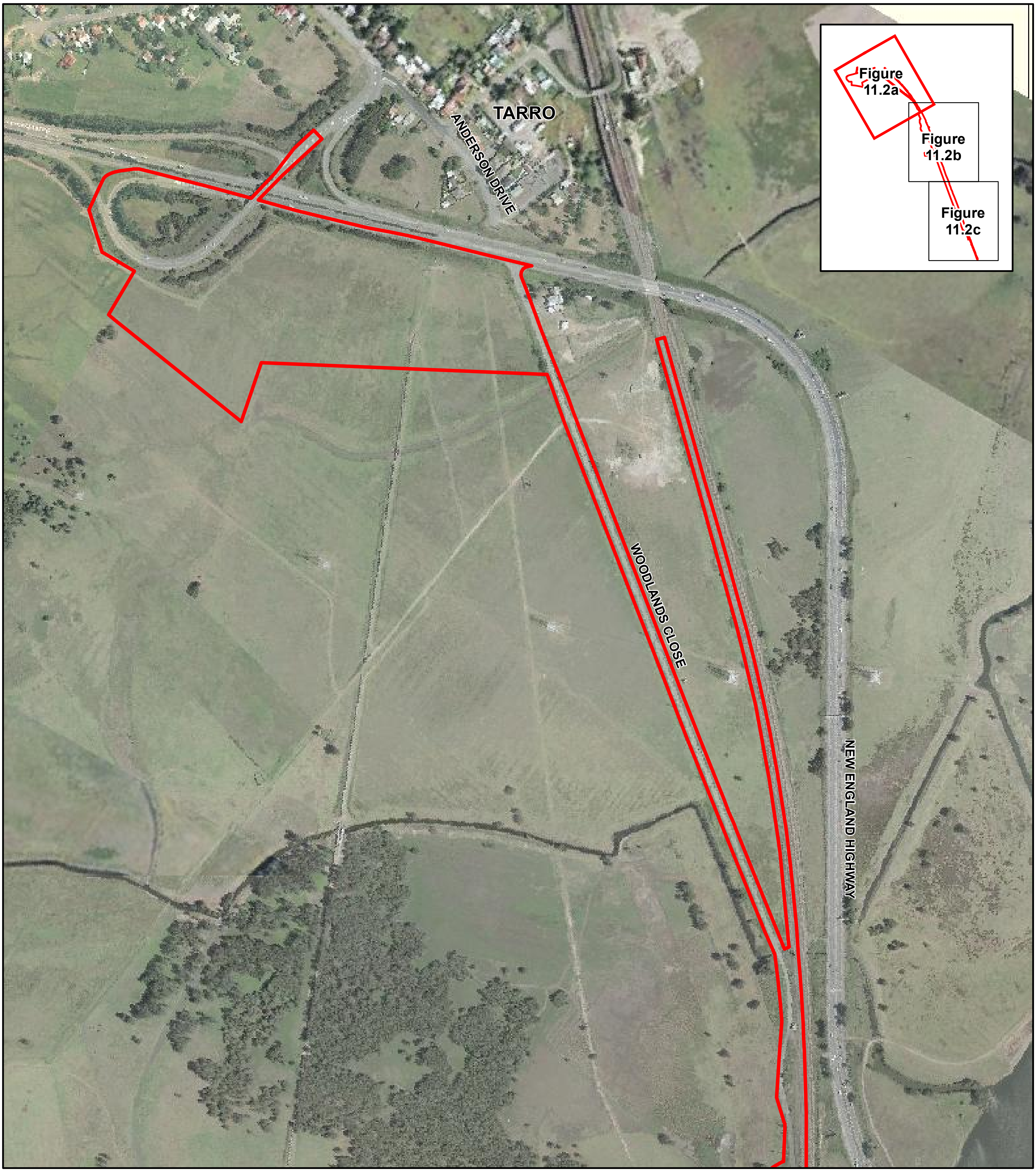


Project Area

Groundwater monitoring wells

Coffey test pits

A4 Original

0 50 100 200 300

Metres

GDA 1994 MGA Zone 56

N

UHVA

ARTC

ARTC
Hexham Relief Roads

| | |
|---|---|
| Job Number | 2110501A |
| Revision | A1 |
| Date | 09.03.2012 |
| Scale | 1:7,000 |

**Site investigation plan** **Figure 3.5a**

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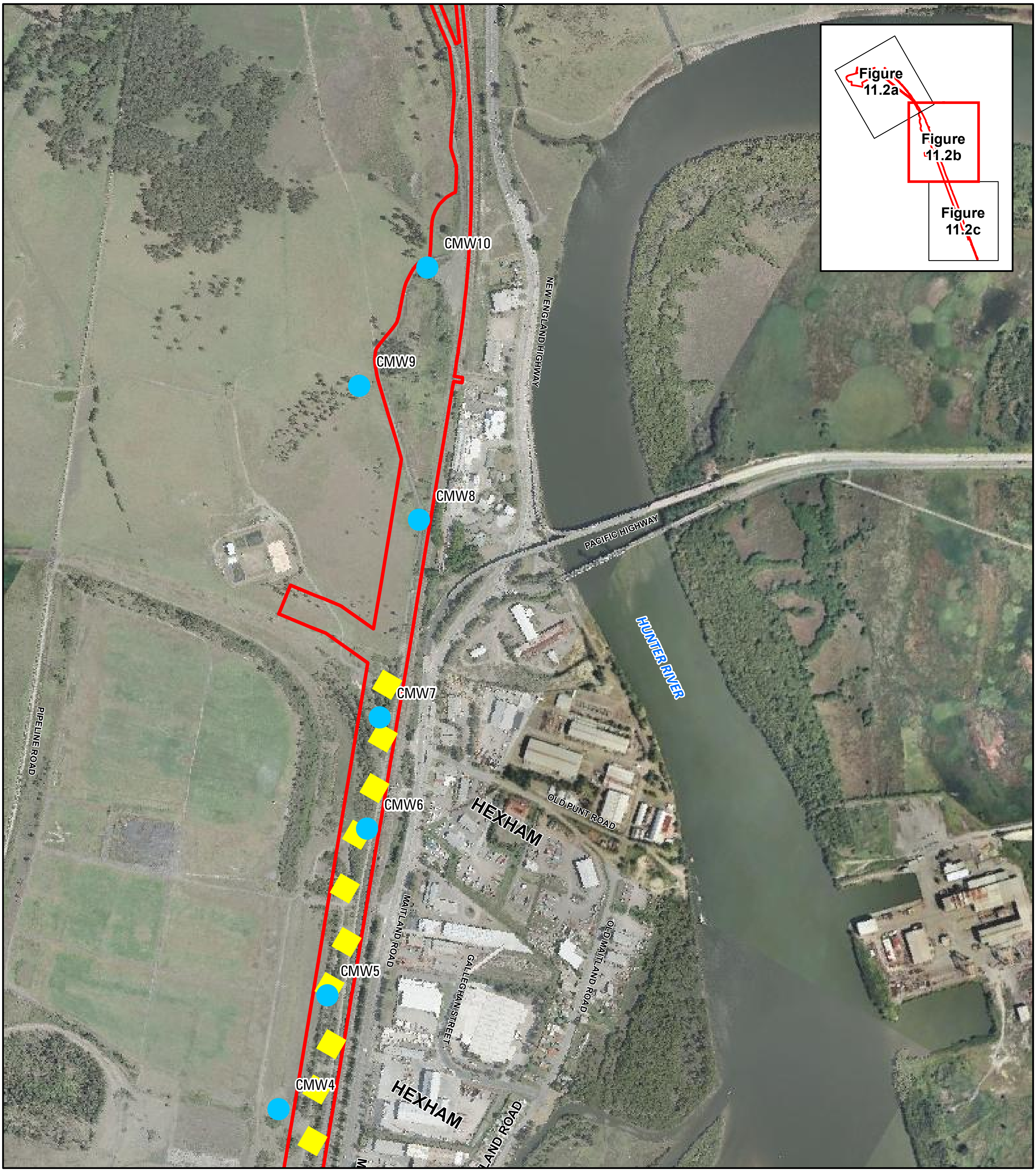



Project Area

Groundwater monitoring wells

Coffey test pits

A4 Original

0 50 100 200 300

Metres

GDA 1994 MGA Zone 56

N

UHVA

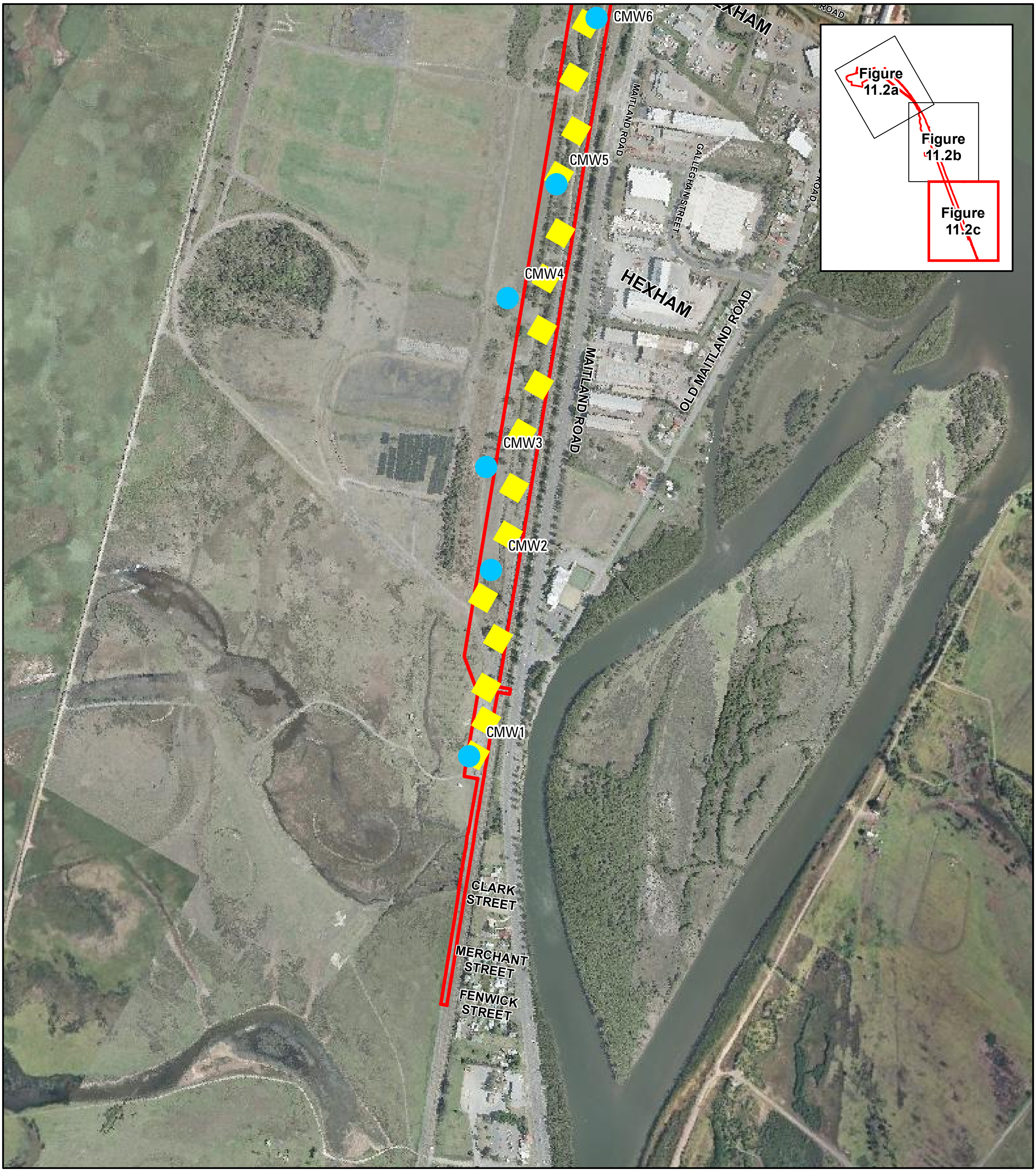
ARTC

ARTC
Hexham Relief Roads

| | |
|---|---|
| Job Number | 2110501A |
| Revision | A1 |
| Date | 09.03.2012 |
| Scale | 1:7,000 |

**Site investigation plan** **Figure 3.5b**

O:\GIS_Temp\HR - Hexham Relief GIS\Projects\ESRI\2110501B_HR_GIS_F014_A3.mxd Author: CasenasM 16/03/2012




Project Area

Groundwater monitoring wells

Coffey test pits

A4 Original

0 50 100 200 300

Metres

GDA 1994 MGA Zone 56

N

UHVA

ARTC

ARTC
Hexham Relief Roads

| | |
|---|---|
| Job Number | 2110501A |
| Revision | A1 |
| Date | 09.03.2012 |
| Scale | 1:7,000 |

**Site investigation plan** **Figure 3.5c**

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# 4. Groundwater

The assessment of groundwater conditions at the Project Area has been developed through a desktop analysis of registered bore data, geological maps, together with review of previous and current geotechnical and contamination investigations undertaken both at the Project Area (by Coffey environmental) and at the nearby QRN TSF project (by Douglas Partners).

The natural groundwater conditions at the Project Area have been disrupted by: the placement of the fill along the rail corridor; changed pattern of flow in the Hunter River and its tributaries; and the historical industrialisation of the western portion of Hexham Swamp. Changes are most likely to have occurred in standing water level (SWL), flow direction, seepage velocity and hydraulic conductivity. The following is an assessment of the hydrogeological conditions currently observed at the Project Area, and which are likely to influence the current proposed development. The main water bearing zones are found within:

- Shallow, unconsolidated: Fill and alluvial (estuarine) sediments, and
- Deep, porous: Tomago Coal Measures.

## 4.1 Registered groundwater bores

Based on a bore search from the NOW groundwater database, there are 224 registered bores within 5 km of the Project Area. There are no registered bores within 1 km of the Project Area, and the majority of registered bores are located on the east side of the Hunter River (opposite side to the Project Area). The closest bores to the Project Area located within the floodplain on the west side of the Hunter River are over 3 km to the south of the Project Area near Ironbark Creek. The location of identified registered bores is provided in Figure 3.1, with summary details shown in Appendix A.

Also shown in Figure 3.5 (a-c) is the location of 21 geotechnical pits and 10 bores drilled by Coffey environments as part of the Hexham Relief Roads project. Summary details for these bores are provided Appendix A.

### 4.1.1 Use

Of the registered bores identified, the following licensed purposes were nominated:

- 17 bores are used for monitoring (identified as part of the GW 070000 series)
- 14 bores for either stock, domestic or farming purpose
- 4 test bores
- 11 bores for either recreation, industrial or irrigation purpose, and
- 1 bore for mineral exploration.

Bores located on the western side of the Hunter River floodplain are primarily licensed for stock/domestic and test bore purposes. There are only two monitoring bores located on the western margin of the Hunter River floodplain, near Viney Creek located > 5 km from the Project Area.

## 4.2 Groundwater levels

A recent investigation undertaken by Coffey on behalf of the UHVA (2012a), suggest that water levels are between 0.5 to 1.7 m below ground surface (ranging in elevation between 0.8 to 3.2 m AHD), located within the fill (gravelly clay) and alluvial sediments (sandy clay). There appears to be no consistent pattern in groundwater levels and flow direction, however groundwater is assumed to be tidally influenced. Depths to groundwater observed in bores drilled across the Project Area are shown in Appendix A.

There are no registered groundwater bores located in the immediate vicinity of the Project Area, and therefore long term groundwater levels and movement are unknown. The depth to groundwater in the alluvium is likely to fluctuate with rainfall and stage height of the Hunter River. The Project Area is both flat and low lying, where water levels at high tide are between 0.0-0.7 m below ground. Tidal movement affects shallow groundwater levels, which move in harmony with the tides. The tidal variation of the estuary (adjacent to the Kooragang Wetland) is 0.1 to 2.0 m AHD (DPI, 2008).

There is insufficient information to define the regional groundwater system within the bedrock material of the Tomago Coal Measures beneath the Project Area. On the eastern floodplain of the Hunter River, the regional aquifer within the bedrock material lies at depths between 6 and 30 m depth.

## 4.3 Groundwater flow

Groundwater inflows from bores and pits constructed as part of ongoing geotechnical investigations were observed to occur predominantly within the fill material emplaced directly beneath the Project Area, except for a few locations in the centre of the Project Area where water was encountered in underlying lenses of sandy clay and gravelly clay within the alluvial sediments. The presence of groundwater represents both: a localised perched water table formed within the fill due to filling above natural land surface and variations in transmissivity; and as part of the local shallow water table aquifer within the underlying alluvium. Variations in groundwater depth occur primarily due to differences in transmissivity of the fill, but also due to factors such as rainfall, tides and surface water flow. A study undertaken on the nearby QRN TSF project has suggested that hydraulic conductivity is low, in the range of $2 \times 10^{-6}$ to $7 \times 10^{-6}$ meters/second (Douglas Partners, 2011).

Groundwater flow within the shallow groundwater system is multi-directional (both vertical and horizontal), depending on: the amount of fill present; the proximity of discharge zones; and influence of tidal movement. The hydraulic connection between the fill and the local alluvial aquifer is unknown, however there is likely to be a high degree of vertical flow connection. There is also likely to be a small component of (horizontal) flow to the east towards (and recharging) the Hunter River during low flow, and also west and south towards the Hexham Swamp. Flooding across the area will contribute to groundwater recharge over the period of the event, although the effect will be limited due to the low transmissivity of the underlying sediments.

The Tomago Coal Measures forms a semi-confined aquifer. The regional groundwater flow direction in the Tomago Coal Measures is likely towards the east. The hydraulic connection between the local aquifer and the regional aquifer is unknown.

## 4.4 Groundwater quality

Groundwater salinity is influenced by location in the topography, aquifer media, connection to saline surface waters and availability of rainfall recharge. The groundwater quality of the sediments beneath the Project Area (including in the fill) is likely to be saline to brackish, as shown in Appendix A. A registered bore (GW063992) located south of the Project Area near Ironbark Creek was drilled into the alluvium and indicates total dissolved solids (TDS) of between 1000-3000 parts per million (ppm). With increased proximity to the River, it is anticipated that the groundwater will correspondingly increase in salinity. Additionally, where groundwater is associated with ASS and other contaminant sources, water quality impacts can be expected, as described further in Section 4.4.1.

Observed water quality from samples taken after recent drilling across the Project Area, indicate that electrical conductivity (EC) is highly variable, with values up to 6700 microSiemens/centimetre (µS/cm). Groundwaters are sodium-chloride-sulphate dominated. Observed pH is also highly variable across the Project Area, tending towards acidic with values as low as 5.4 recorded. Ammonia and phosphorous were detected in most groundwater samples. A range of aromatic and petroleum hydrocarbons, including methane and benzene derivatives were detected most bore samples.

The investigation as part of the nearby QRN TSF project suggest a similar groundwater salinity as that observed in bores constructed around the Project rea. EC values of between 1800 and 6500 µS/cm, with pH of between 5.6 and 7.4 were observed in the QRN TSF project.

Taking into account the observed relatively high salinity, low pH, and existing hydrocarbon contamination within the shallow aquifers beneath the Project Area, the environmental (groundwater) value, according to ANZECC guidelines, is considered to be commercial/industrial.

### 4.4.1 Contamination sources

The Project Area has coal reject and ash present in numerous areas (UHVA, 2012a). Waste materials were observed in a number of test pits. The Project Area was also historically used for agricultural purposes, potentially a source for nitrogen and phosphorous contaminants. The geotechnical investigation undertaken by Coffey has shown that concentrations of industrial contaminants in groundwater are generally within commercial/industrial land use criteria.

## 4.5 Groundwater dependent ecosystems

According to DPI (2008), the Project Area forms part of a transition zone for many plant and animal species between the sub-tropical influence in the north and cooler, less fertile conditions in the south. As a consequence there are a diverse range of species, including many endangered, threatened and vulnerable ecological communities.

The Lower Hunter estuary contains numerous wetland areas, including Kooragang (Ash Island), Shortland, Tomago and Fullerton Cove which are located to the east and south of the Project Area, as well as at Hexham Swamp located immediately south of the Project Area. The Hunter estuary contains the second largest area of mangroves in NSW (DPI, 2008).

Groundwater dependent ecosystems (GDEs) typically occur where the water table is at or near the surface. While the degree of groundwater dependency is variable, groundwater plays a critical role in the wetlands found on alluvial floodplains (DWE, 2009).
Some estuaries are highly sensitive to freshwater inflows, whilst others are quite resilient to changed inflows. The size and shape of estuaries vary and this, combined with the amount of freshwater inputs, determines the estuaries overall sensitivity to freshwater extraction. Estuarine values can also be threatened from water extraction. As described in the Hunter unregulated and alluvial WSP (DWE, 2009), during periods of low flow the tidal pool is supported by inflows from the adjacent alluvial deposits giving it a medium sensitivity to groundwater extraction. Overall, the Hunter River estuary has been rated as ‘medium’ for groundwater sensitivities (DWE, 2009). It is inferred from this information, although not confirmed, that potentially the Hexham Swamp, which is hydraulically connected to the estuary, also has a medium sensitivity to groundwater.

The Project Area forms part of the coastal alluvial floodplain, where the aquifer has a low to moderate connection to surface water systems (DWE, 2009), including the Hunter River.

An ecological survey undertaken by Parsons Brinckerhoff as part of the EIS process has identified that within and surrounding the Project Area there are two types of estuarine communities: mangroves; and coastal saltmarsh. Identified ecological habitats are shown in Figure 3.1. The ecological assessment notes that these estuarine environments are heavily degraded and affected by grazing, constructed channels, tracks and reclamation works. The habitat at the southern end of the Project Area extends into a wider saltmarsh and introduced grassland to the west, which forms part of the (SEPP14 Wetland No. 787) Hexham Swamp (Nature Reserve). A coastal saltmarsh community is present to the north of the mangrove site on the Hunter River opposite the culvert. This saltmarsh community is relatively undisturbed and does not display any effects of anthropogenic disturbance, likely due to the lack of accessibility to the site. Due to the shallow nature of alluvial groundwater resource, it is highly likely that these estuarine ecological habitats are dependent on groundwater to some extent.

The water quality across the Study Area and within the Lower Hunter (River) estuary is of industrial value and above the ANZECC/ARMCANZ Guideline ecosystem values.
The Project Area and area of the Hunter River located within the Ironbark Creek catchment has historically been characterised by water quality with high nutrient levels and undesirable variability in dissolved oxygen (NWC, 2004). Highly polluted and possibly toxic fine sediments from urban areas flush through the system and are likely deposited within the Hunter estuary or into the Hexham Swamp when overbank flooding occurs. Poor water quality due to pollutants including solid matter, sediments, scum, oils, toxins, nutrients and bacterial inputs and possible leachate from nearby garbage dump fill sites affect in the Hunter River catchment. The water quality of the estuary is particularly vulnerable given the mixture and extent of industry, agriculture and urban development along the river.

## 4.6 Conceptual hydrogeological model

Shallow groundwater beneath the Project Area is inextricably linked to nearby surface waters. The actual connections between surface and groundwater systems are likely to vary over time across the Project Area. The Hunter unregulated river and alluvial WSP considers that in the Project Area, due to the fine grained nature of the alluvial sediments, the groundwater/surface connectivity is low to moderate, and that the travel time between the groundwater system and the Hunter River occurs across a season (i.e. up to 3 months). During periods of high river flow, after heavy rainfall/flooding or during high tide, the surface water system is likely to recharge the groundwater system, which will reverse during periods of low flow, drought and low tide. This groundwater/surface water interaction is however not considered to extend far beyond the banks of the River, due to the poor connectivity conditions.

In summary, the groundwater conditions beneath the Project Area are conceptually understood to:

- Form part of a water table aquifer within 1.0-2.0 m of the surface located within the fill and underlying alluvial sediments.
- Have low transmissivity with low to moderate connection to surface water systems, including the Hunter River and local GDEs such as the Hexham Swamp.
- Have tidally influenced groundwater flow and water level fluctuations responsive to tides, rainfall recharge and extraction.
- Provide a limited source of saline to brackish water to surrounding GDEs including the Hexham Swamp and Hunter estuary, which are considered to have medium dependence.
- Be highly saline with pockets of inorganic and organic contamination, due to historic agricultural and industrial activity.
- Interact with locally present shallow acid sulphate soils present at depths below 0.8 m.

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# 5. Potential impacts

The potential impacts from the proposed Project and associated activity can be characterised as occurring during the construction phase and over the (operational) life of the project. Groundwater related impacts have been assessed across a range of areas, including:

- to the groundwater resource and associated GDEs
- to the Hexham Relief Roads project
- to other users, and
- cumulative with the nearby QRN TSF project.

## 5.1 Potential impacts to groundwater systems and GDEs

Groundwater beneath the Project Area is shallow, generally within < 1.0 m of the surface. Groundwater flow direction and depths are influenced by a number of factors including: low transmissivity of aquifer; tidal movements; surface flow regime in the nearby Hunter River and Swamp; and rainfall recharge. Impacts from a range of activities to the local groundwater system and GDEs are considered with respect to:

- water levels and flow direction
- yield, and
- water quality.

### 5.1.1 Construction phase

**Excavation**

Planned excavation in the Project Area is described in Section 1.1. In total, approximately 265 000$m^3$ of earthworks is proposed, including track formation, drainage and minor structures. Excavation works are proposed to primarily comprise of topsoil removal, ground improvement works, swale/drainage cut, and general cut.

Excavation depths will likely vary across the site based on soil conditions encountered. Based on cut and fill information available, excavation depths are expected to be less than 0.5 m below existing ground level on average. Interception of groundwater and potential ASS is therefore expected to be localised to areas of deeper excavation and/or areas of groundwater/ASS above this depth. Interception of groundwater and ASS is also expected to occur in localised areas where ground improvement columns are constructed. Dewatering of groundwater ingress may be required during construction in either these circumstances.

These works have the potential to impact on groundwater levels and flow direction between the site and the GDE habitat. It is anticipated that this effect would be minor and temporary and that the aquifer will naturally equilibrate once the excavation is filled (including with water) with minor long term drawdown. Excavation/s located close to the boundary of a GDE, such in the extreme south and central-north of the Project Area, could potentially impact these GDE habitats if water levels or flow directions are substantially changed.

Due to the low transmissivity of the aquifer, drawdown response is expected to be limited to within close proximity of the excavation site. The lowering of water tables around an excavation has the potential to expose ASS to oxygen, which could lead to the formation of sulphuric acid in the groundwater. This contaminated water could then potentially discharge into the excavation/drainage channel, and receiving surface waters. Any drawdown of groundwater has the potential to expose ASS. This is not anticipated to be a significant impact because ASS will be managed through implementation of an ASS Management Plan.

**Ground improvement works**

Three options have been proposed to address ground stability in soft clay areas within the Project Area. These include installation of columns to a depth of up to 10 m below ground level. The types of columns which have been proposed are:

- Stone columns (SC); excavating a column structure and backfilling with granular material to improve the ground bearing capacity and accelerate consolidation.
- Controlled modulus columns (CMC); an auger is pushed into soft ground and as the auger is removed concrete is injected into the ground to form the columns.
- Deep soil mixing columns (DSM); an auger is pushed into soft ground and as it is removed cement is injected and mixed with soft clays to form an improved column material. Improved column material can have increased permeability relative to unimproved clays.

These construction methods all have the potential to impact temporarily on the groundwater conditions beneath the Project Area as they change the ground conditions. This in turn has the potential to impact on standing water levels, groundwater flow direction, seepage velocity and hydraulic conductivity. In particular the Stone Column method has the potential to reduce standing water levels and change local groundwater flow directions during construction if water ingress into the excavations is not managed and may also expose acid sulphate soils to oxygen.

**Dispersal of surface fill**

It is proposed that inert engineering fill, comprising granular fill material and gabion rock, are be placed over the site at varying depths, depending on ground conditions encountered. Based on cut and fill information available, fill depths are expected to within the top 0.5 m on average. Granular fill thickness required for the railway formation is expected to vary between 0.4 and 2.1 m, and between 0.6 to 1.2 m for gabion rock placed on the levelled site.

Considering the shallow fill depth, potential for attenuation, low transmissivity and existing contamination, impact to groundwater from disposal of inert material onsite is expected to be low.

**Disposal of groundwater**

Disposal of groundwater ingress may be required during construction. It is expected that if required, water will be pumped from an excavation to either temporary holding tanks or to the proposed drainage system. Disposing of groundwater intercepted during construction to open surface water systems has the potential to deteriorate (surface) receiving environments, particularly considering the saline and contaminated nature of the local groundwater resource. Discharge of potentially contaminated groundwater is further discussed in Section 5.2.1.

**Groundwater extraction for supply**

It is understood that groundwater is not prospective and will not be required as a supply for construction purposes. However, should the decision be made that groundwater is to be utilised as a supply, then potential groundwater resource impacts may include: rapid water level drawdown reducing overall yield of bore capacity; oxygenation of ASS and mobilisation of contaminated groundwater, resulting in reduced water quality of pumped water. These impacts are considered to be short term, occurring over the life of the pumping with the aquifer able to re-equilibrate once this activity ceases.

Potential impact to GDEs from any groundwater extraction for supply purposes is expected to be minimal provided bore construction is undertaken consistent with the rules established in the WSP.

### 5.1.2 Operational phase

It is understood that there would be no new or residual excavations that would require dewatering through pumping during the operational phase. However, should groundwater dewatering and/or the construction (and filling) of excavations be required during the operational phase, then it is anticipated that similar minor impacts to groundwater and GDEs to those discussed above in the construction phase could be encountered.

It is understood that groundwater will not be a water supply source during the operational phase. However, should it be considered, then similar impacts to those discussed in the construction phase could be anticipated.

Once the ground improvement columns have been installed it is anticipated that standing water levels would stabilise, however the ground conditions would have been altered permanently and minor alterations to groundwater flow conditions would continue. It is not anticipated that the foundation columns, once installed, will impact significantly on the availability of groundwater to GDEs.

### 5.1.3 Summary of impacts

The overall potential impact from proposed activity at the Project Area is considered to be minor. Some minor changes in groundwater level may be experienced within GDEs if dewatering activity occurs nearby, however this would be of a short term, recoverable nature. The following factors have been considered in determining impact, including:

- Moderate groundwater connectivity to surface water systems.
- Existing poor (saline and contaminated) water quality in surrounding groundwater resource.
- Risk of ASS exposure within the Project Area and surrounding GDEs.
- Medium groundwater ‘dependence’ to an existing highly modified and degraded ecological (GDE) habitat, and
- Short term proposed disturbance of the subsurface and interaction with groundwater from potential site activity.

## 5.2 Potential impacts to the Hexham Relief Roads proposed project

Impacts to the Hexham Relief Roads project, from a range of potential activities during both the construction and operational phase with respect to groundwater are primarily related to:

- water table
- yield, and
- water quality.

### 5.2.1 Construction phase

The presence of shallow groundwater (<1.0 m depth) could potentially impact the project during the construction phase. Works directly associated with the rail infrastructure will not require licencing under the WMA, as it is deemed to be covered by the *Transport Administration Act 1988* and section 111 of the EP&A Act (DT&I, 2012). However, it is understood that works that intercept groundwater such as subsurface excavations, that 'support' a rail infrastructure project although not part of the actual rail infrastructure, are managed under the WMA. Further to this, activities (such as excavations for flood control or drainage) that do not result in groundwater ingress/discharge at a rate exceeding 5 L/s or 3 ML/year, are exempt from requiring a licence under the AI policy. Due to the low transmissivity of the shallow aquifer beneath the Project Area, it is expected that discharge volumes are likely to be low and therefore within this exemption rate established in the AI policy.

It should be noted however that should the final design for flood control/drainage infrastructure be more extensive than currently proposed or existing across the Project Area (in depth, width or area), then a cumulative volume may potentially exceed the exception (discharge) limit, and therefore licensable under the WMA. According to the WMA and draft AI policy (DT&I, 2012), any groundwater extraction/discharge at a rate exceeding 3 ML/year will require application to NOW for an (aquifer) access licence. Should this become necessary, the groundwater assessment undertaken as part of the EIS would support and provide significant input to addressing the licensing requirements.

Due to the shallow nature of the groundwater resource, and therefore likely aquifer interference, all subsurface excavations and groundwater monitoring bores across the Project Area are likely to require an aquifer interference approval (AIA) under the WMA or other relevant approvals (DT& I, 2012). As part of a State significant infrastructure project, the requirements for approval/s under the WMA will be assessed consistent the requirements of the EP&A Act to ensure appropriate water management outcomes.

The presence of saline (and contaminated) groundwater and limited potential for ASS across the Project Area, could also impact the project, particularly with respect to: available discharge locations of intercepted (and contaminated/saline) groundwater; occupational health and safety (OH&S) requirements to handle contaminated groundwaters; and limited use options of extracted groundwater. Discharge of saline and potentially contaminated groundwater to (surface) receiving waters would require consideration under the WMA and EP&A Act.

It is understood that groundwater will not be used for water supply purposes during construction. Any use of groundwater for supply is licensable under the WMA, and should consider the saline and contaminated nature of the resource, particularly with respect to ensuring: OH&S is maintained during handling of contaminated water; and legislative requirements for extraction and disposal (as discussed above). Due to the limited areal extent of the Project Area, there is a potential for impact to GDEs if multiple extraction sites are required, which must adhere to the distance rules established in the WSP to protect GDEs to minimise potential impact.

The shallow standing water levels on the site will need to be considered in relation to the installation of the ground improvement columns and excavation associated with the Jemena pipeline. Minor groundwater ingress into excavations can be expected and dewatering may be required. Furthermore, there is potential for potential acid sulphate soils to be exposed to oxygen thereby causing acid drainage. The groundwater is saline to brackish and will be aggressive to concrete and steel structures. Accordingly, the nature of the groundwater will need to be considered in the design of the columns and selection of material. Water extracted from excavations for dewatering will require disposal and potentially treatment under an EPL licence. There is the potential to reuse the water on site (such as for dust suppression) however water quality will need to be considered.

### 5.2.2 Operational phase

The issues discussed above in the construction phase of the Project (Section 5.2.1) are also potentially applicable in the operational phase of the project. Any activity that intercepts groundwater is licensable. Licences/approvals granted in the construction phase are potentially transferrable to the operational phase of the project.

### 5.2.3 Summary of impacts

Overall, the impacts to the Project from groundwater are expected to primarily occur during the construction phase, and that with appropriate investment of time and resources into necessary licences and approvals would result in minimal impact to the operational phase project. There are some activities where impact will need to be managed, which include:

- Dewatering of excavations during the construction and operational phase that may intercept contaminated groundwater. Appropriate management of OH&S, and approvals/licences for discharge to receiving waters are required. Extraction should be minimised within close proximity to a GDE to prevent oxidation of ASS.

- Interception of groundwater exceeding 5 L/s or 3 ML/year is licensable under the WMA, (except if part of construction of rail infrastructure) with the volume of water required for extraction to be obtained on the water market (as shares). Any activity that intercepts groundwater will likely require assessment for an AIA.

- Groundwater at the site occurs at shallow depths and may be aggressive to concrete and steel structures due to its salinity and potential acidity. These conditions will need to be considered in the design, excavation and installation of the proposed foundation columns.

## 5.3 Potential impacts to groundwater users

### 5.3.1 Construction phase

There are no registered groundwater users within close proximity of the Project Area. There is no observed hydraulic connection between the west and east side of Hunter River floodplain, and therefore registered users on the east bank of the floodplain are unlikely to be impacted by activities at the Project Area. Impacts to registered groundwater users during the construction phase at the Project Area are therefore considered to be negligible.

### 5.3.2 Operational phase

Due to the existing salinity, presence of ASS and presence of existing contamination within the alluvial groundwater resource on the western side of the Hunter River floodplain around the Project Area, it is not anticipated that groundwater use will become a significant resource in the future. Therefore, there is considered to be a negligible potential for impact to future extractive groundwater users from the proposed operational activity at the Project Area.

### 5.3.3 Summary of impacts

There are no anticipated impacts to registered groundwater users from either the construction or operational activities at the Project Area.

## 5.4 Cumulative assessment: QRN TSF

Queensland Rail National (QRN) is currently preparing plans for a Train Support Facility (TSF) located immediately to the west of the Relief Roads. The QRN TSF project is not currently approved. The layout and key features of both projects are shown in Volume 1 of this EIS. QRN National is liaising with ARTC to co-ordinate the design and approval processes.

As part of this study and report, the QRN National 2008 EAR has been reviewed. Where updated (2011) reports are available, these have also been reviewed. Relevant documents reviewed comprise:

- Report on proposed contamination assessment. Proposed Hexham redevelopment, Maitland Road and Woodlands Close, Hexham (Douglas Partners, 2011).

The QRN TSF project is located on approximately 40 hectares of land and includes: wagon storage roads; locomotive maintenance sheds; fuel storage area; wash bays; a second provisioning facility; wheel lathe building; turntable; and administration offices.

A study undertaken by Douglas Partners (2011) on the QRN TSF project has identified a highly altered shallow subsurface where in a number areas of groundwater contamination exist due to the presence of contaminated fill and historic surface industrial activity.

Hydrogeological conditions beneath the QRN TSF project are similar to those observed beneath the Hexham Relief Roads Project Area. The Project Areas are expected to have a limited hydraulic connected through a (low) transmissive shallow alluvial aquifer.

Potential cumulative groundwater impacts, during both the construction and operational phase of the projects have been assessed with respect to:

- water levels, and
- water quality.

### 5.4.1 Construction phase

The cumulative groundwater impacts from the QRN TSF and the Hexham Relief Roads projects during construction are due to the following activities:

- excavation, and
- extraction of groundwater.

**Excavation**

Activities involving excavation for the Hexham Relief Roads Project and resulting potential impacts are outlined in Section 5.1.1 Douglas Partners (2011) indicate that cut and fill could be undertaken in the construction at the QRN TSF project, although the depth and exact location was not available for this review. Excavation activity is likely to have a minimal cumulative impact on groundwater, primarily because: groundwater flow directions are currently multidirectional; any effect would be temporary effect and highly localised due to low transmissivity; and the aquifer will naturally equilibrate once the excavation is filled (including with water).

The central-north of the QRN TSF project is located partially within a GDE. Excavation(s) at the QRN TSF project within the GDE could potentially impact the habitat due to a lowering of the water table. According to the drainage strategy for the Project Area, there is no planned excavation for flood control in the north of the Project Area (UVHA, 2012b).

Lowering of the water table around a subsurface excavation has the potential to expose ASS. Exposure of ASS within the relatively undisturbed GDE on the QRN TSF project could impact the Hexham Relief Roads Project Area if allowed to discharge on the site. ASS impact will be managed through implementation of an ASS Management Plan.

**Disposal of contaminated water and waste**

Disposal of groundwater ingress may be required during construction, and is likely to be localised. There is no proposed disposal of contaminated waste on the Project Area. Any fill used at the Hexham Relief Roads Project Area is proposed to be inert ‘engineering fill’. There is a low potential for cumulative impact from these activities, due to: the inert nature of proposed fill; the existing presence of contaminated groundwater at both Project Areas; limited hydraulic connectivity between the Project Areas; and the potential for attenuation in the poorly transmissive sediments.

**Groundwater extraction for supply**

It is understood that groundwater will not be required as a supply source for construction purposes at either Project Area, with the preferred option being to obtain a supply from the nearby Hunter Water Corporation pipeline.

### 5.4.2 Operational phase

Provided any observed cumulative impacts from the construction phase at each Project Area are appropriately managed, minimal cumulative groundwater impact is expected during the operational phase. It is also anticipated that in the operational phase at both Project Areas, activities will be limited to those occurring at the surface, and therefore groundwater interaction would be minimised.

### 5.4.3 Summary of impacts

The overall potential cumulative impacts from the proposed activity at each Project Area are considered to be low and if at all, short term during the construction phase. There is some potential cumulative impact to the Project Area from the oxidation of ASS in GDEs if discharge of contaminated water from the QRN TSF project is not managed appropriately and leads to accumulated load on a hydraulically connected drainage system.

# 6. Mitigation measures

Impacts to local groundwater resources from activity in the Project Area are likely to occur primarily during the construction phase. Following consideration of the final design of any potential aquifer interfering activities, mitigation measures to address the potential long term and cumulative groundwater impacts should include:

- **Soil and water quality management plan:** Preparation and implementation of a Soil and Water Quality Management Plan (Refer to EIS Volume 1, Chapter 12, Soils and Water) to manage groundwater discharge and exposed ASS in line with surface environment quality requirements.
- **Drainage management plan:** Preparation of a drainage plan for the Project Area and the QRN site, to address drainage channel alignment, drainage flow velocity, water quality, excavation and fill materials.
- **Regulatory approvals:** Attainment of necessary licences and approvals prior to any extraction (i.e. aquifer access licence) and discharge (EPL) of groundwater from relevant regulating authorities, such as NOW and Office of Environment and Heritage (OEH). Any licences in addition to the EPL to be identified as part of this process.
- **Groundwater monitoring:** Formation of a monitoring plan utilising existing monitoring bores located on Project Area. Where possible, the monitoring network will be aligned with that proposed with the QRN TSF project to assist with monitoring cumulative impacts. Monitoring will focus on defining long term patterns of groundwater response, with respect to:
  - flow direction
  - elevation, and
  - quality, particularly from oxidation of ASS and mobilisation of contaminants.

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# 7. Conclusion and recommendations

Groundwater observed at the Hexham Relief Roads Project Area forms part of a shallow water table aquifer primarily within fill that elevates many areas of the Project Area, and also within the underlying estuarine alluvial sediments. The groundwater system is influenced by local tidal movements and recharged during frequent flooding events. The fill and other waste material buried across the Project Area is a remnant of historical industrial activity which has resulted in extensive areas of contaminated groundwater, including nutrients and hydrocarbons. Groundwater in the shallow aquifer is naturally saline, with a low to moderate hydraulic connection to the nearby (saline) Hunter River. The River also supports sensitive estuarine habitats, within the Hunter estuary.

Groundwater beneath the Project Area is managed under the WMA within the Hunter River and alluvial sediments WSP, which provides rules to protect the groundwater resource and identified GDEs. The WSP provides the regulatory mechanism to protect GDEs and affect the principles of related groundwater policies, such as the NSW Groundwater Quality Framework. Due to the presence of high salinity and contamination, the environmental value of groundwater at the Project Area is commercial/industrial, based on AZECC guidelines.

To the south and in the central north of the Project Area is a SEPP14 wetland, locally known as the Hexham Swamp (Nature Reserve). This habitat has a medium dependence on groundwater (for habitat survival). Due to historical land-use activity the Hexham Swamp, particularly in the south of the Project Area, is now highly altered and in many areas degraded.

Naturally occurring across the Project Area are acid sulphate soils, although replaced in many areas by up to 0.8 m of fill. These soils are a common feature across the Hunter River floodplain. When ASS are exposed to oxygen, such as through drawdown of water tables in shallow excavations, sulphuric acid is produced, which leads to contamination of receiving waters.

Activities that may increase the potential for impact to groundwater in the Project Area and surrounding Project Area include: excavations, groundwater interception, installation of ground improvement columns and the expansion of existing drainage systems. Activity at the Project Area is expected to have a limited and short term impact on the local groundwater resources (including GDEs), primarily occurring during the construction phase, and negligible cumulative impact to the nearby QRN TSF project, due to the following:

- low (to moderate) hydraulic connection to surface waters and GDEs
- low transmissivity and long travel time for flow within the aquifer
- no registered bores within proximity of the Project Area
- highly altered condition of surrounding GDEs
- any drawdown of groundwater has the potential to expose acid sulphate. ASS will be managed through implementation of a soil and water quality management plan, and
- existing highly saline and contaminated nature of the shallow aquifer.

Mitigation measures to ensure any impact is minimised and appropriately managed, include the preparation and implementation of a water quality and soil management plan, a drainage management plan, utilisation of the existing groundwater monitoring network and adherence to WSP to protect GDEs from extraction activity.

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# 8. References

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# Appendix A

Registered groundwater bore search results

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| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW007416 | NOW | 377379 | 6376030 | 9.1 | Bore | | 0 | | | | | 7001-10000 ppm |
| GW017544 | NOW | 381393 | 6366900 | | Battery Spears | Sand Nominal Water Supply | 9.1 | | | | 18.95 | Fresh |
| GW019518 | NOW | 380369 | 6376313 | | Bore | Loam Sandy Fine Soak | 19.2 | 19.2 | 19.2 | | | V.Salty |
| GW023079 | NOW | 380099 | 6370611 | | Battery Spears | Sand Soft | 8.5 | 3.4 | 8.6 | 3.4 | 25.01 | Good |
| GW026942 | NOW | 381309 | 6367361 | | Battery Spears | Sand Black White Mixed | 10.7 | 1.5 | 10.6 | 1.2 | 37.89 | Good |
| GW042652 | NOW | 376204 | 6374198 | | Well | | 0 | | | | | |
| GW042652 | NOW | 376204 | 6374198 | | Well | | 0 | | | | | |
| GW042653 | NOW | 376230 | 6374229 | | Well | | 0 | | | | | |
| GW042653 | NOW | 376230 | 6374229 | | Well | | 0 | | | | | |
| GW047734 | NOW | 382455 | 6360660 | | Well | | 0 | | | | 0.93 | 501-1000 ppm |
| GW050254 | NOW | 384675 | 6368602 | | Battery Spears | | 0 | | | | | |
| GW051395 | NOW | 382434 | 6373350 | | Spear | | 0 | 6.5 | 9.7 | 6.5 | 0.09 | |
| GW052226 | NOW | 385475 | 6369135 | | Spear | Sand Grey | 11 | 6 | 11 | 8.5 | | |
| GW053186 | NOW | 377409 | 6358935 | | Bore | Topsoil | 32 | 31 | 32 | 2.4 | | V.Salty |
| GW053226 | NOW | 384293 | 6361236 | | Spear | | 0 | 2 | 4.5 | 2 | | |
| GW053493 | NOW | 375205 | 6358538 | | Bore | Topsoil | 60 | | | | 0.00 | |
| GW056973 | NOW | 382309 | 6359827 | | Spear | | 0 | | | | 1.30 | |
| GW057013 | NOW | 376788 | 6371218 | | Bore | Topsoil Black | 26 | 11.4 | 11.6 | 4 | 0.46 | Brackish |
| GW057300 | NOW | 382382 | 6373380 | | Spear | Sand Water Supply | 8 | 6 | 8 | 6 | 0.30 | |
| GW058760 | NOW | 371142 | 6371207 | | Bore | | 0 | 27 | 33 | 27 | 0.10 | 0-500 ppm |
| GW059317 | NOW | 381132 | 6366959 | | Battery Spears | Sand | 11 | 7 | 11 | 2.5 | 7.20 | |
| GW061003 | NOW | 382383 | 6373319 | | Spear | | 0 | 6 | 8 | 6 | 0.30 | 0-500 ppm |
| GW061307 | NOW | 371299 | 6371148 | | Bore | Clay | 30 | 25 | 25.5 | | 0.40 | 501-1000 ppm |
| GW063992 | NOW | 376900 | 6362194 | | Bore | Clay Grey Silty | 24.4 | 17 | 19 | 1.2 | 0.37 | 1001-3000 ppm |
| GW064149 | NOW | 381432 | 6372260 | | Spear | Sand | 9 | | | | 7.20 | |
| GW066784 | NOW | 381020 | 6371916 | 10 | | | | 2 | 10 | 2 | 25.01 | |
| GW066787 | NOW | 382305 | 6373287 | 12 | | | | 5 | 9 | 5 | 6.82 | |
| GW066797 | NOW | 382408 | 6373380 | 10 | | | | 5 | 9 | 5 | | |
| GW078044 | NOW | 370428 | 6370151 | | Bore | SILTSTONE | 30.1 | 13.7 | 30.1 | 13.7 | | |
| GW078045 | NOW | 371836 | 6369892 | | Bore | SANDSTONE | 30.5 | 17.3 | 30.5 | 17.3 | | |
| GW078046 | NOW | 368651 | 6368741 | | Bore | SILTSTONE/MUDSTONE | 30.4 | 13.6 | 30.4 | 13.6 | | |
| GW078047 | NOW | 370784 | 6368800 | | Bore | SILTSTONE | 54.3 | 22.8 | 54.3 | 22.8 | | |
| GW078120 | NOW | 371176 | 6368590 | | Bore | SILTSTONE/MUDSTONE | 24 | 6.1 | 24 | 6.1 | | |
| GW078121 | NOW | 368619 | 6367262 | | Bore | SILTSTONE/SHALE | 43 | 22.3 | 43 | 22.3 | | |
| GW078122 | NOW | 368666 | 6367663 | | Bore | SANDSTONE/SILTSTONE | 35.4 | 23.1 | 51.3 | 23.1 | | |
| GW078123 | NOW | 369309 | 6368165 | | Bore | SANDSTONE/SILTSTONE | 33 | 24.4 | 33 | 24.4 | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW078124 | NOW | 369883 | 6368018 | | Bore | sandstone | 37 | 18.6 | 40 | 18.6 | | |
| GW078125 | NOW | 370970 | 6368464 | | Bore | siltstone/sandstone | 30 | 10.2 | 30 | 10.2 | | |
| GW078126 | NOW | 371890 | 6367736 | | Bore | sandstone | 30 | 9 | 30 | 9 | | |
| GW078127 | NOW | 369073 | 6366406 | | Bore | siltstone/mudstone | 30 | 16.6 | 30 | 16.6 | | |
| GW078128 | NOW | 370912 | 6366923 | | Bore | siltstone | 30 | 7.8 | 30 | 7.8 | | |
| GW078161 | NOW | 372698 | 6359492 | | Bore | Overburden - Surface Coal Pump | 84 | 28 | 31 | 28 | | |
| GW078201 | NOW | 373395 | 6360150 | | Bore | Overburden & Soil/Clay | 31 | | | | | |
| GW078223 | NOW | 382020 | 6373160 | | Bore | top soil | 10 | 6.5 | 9.8 | 7.2 | | |
| GW078243 | NOW | 382434 | 6373350 | | Bore | | | | | | | |
| GW078581 | NOW | 377717 | 6374680 | | Bore | | | | | | | |
| GW079061 | NOW | 372859 | 6359576 | | Bore | | | | | | | |
| GW079063 | NOW | 373130 | 6359725 | | Bore | Topsoil overburden | 47 | | | | | |
| GW079065 | NOW | 372696 | 6360132 | | Bore | | | | | | | |
| GW079409 | NOW | 380331 | 6370896 | | Bore | | | | | | | |
| GW079412 | NOW | 379499 | 6369390 | | Bore | | | | | | | |
| GW079414 | NOW | 382379 | 6370445 | | Bore | | | | | | | |
| GW079416 | NOW | 380917 | 6370063 | | Bore | | | | | | | |
| GW079421 | NOW | 383910 | 6368807 | | Bore | | | | | | | |
| GW079422 | NOW | 386221 | 6370035 | | Bore | | | | | | | |
| GW079423 | NOW | 384226 | 6368952 | | Bore | | | | | | | |
| GW079427 | NOW | 382776 | 6369839 | | Bore | | | | | | | |
| GW079437 | NOW | 380736 | 6367871 | | Bore | | | | | | | |
| GW079439 | NOW | 380557 | 6367067 | | Bore | | | | | | | |
| GW079442 | NOW | 386455 | 6368394 | | Bore | | | | | | | |
| GW079446 | NOW | 377585 | 6367178 | | Bore | | | | | | | |
| GW079447 | NOW | 383533 | 6372559 | | Bore | | | | | | | |
| GW079449 | NOW | 381041 | 6366863 | | Bore | | | | | | | |
| GW079451 | NOW | 381133 | 6367270 | | Bore | | | | | | | |
| GW079452 | NOW | 381133 | 6367245 | | Bore | | | | | | | |
| GW079453 | NOW | 385814 | 6371044 | | Bore | | | | | | | |
| GW079455 | NOW | 381616 | 6368154 | | Bore | | | | | | | |
| GW079456 | NOW | 381565 | 6368203 | | Bore | | | | | | | |
| GW079457 | NOW | 381504 | 6367452 | | Bore | | | | | | | |
| GW079463 | NOW | 381013 | 6367242 | | Bore | | | | | | | |
| GW079464 | NOW | 381013 | 6367292 | | Bore | | | | | | | |
| GW079465 | NOW | 381102 | 6367319 | | Bore | | | | | | | |
| GW079466 | NOW | 383410 | 6368706 | | Bore | | | | | | | |
| GW079467 | NOW | 384078 | 6368555 | | Bore | | | | | | | |
| GW079482 | NOW | 382851 | 6369867 | | Bore | | | | | | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW079483 | NOW | 383074 | 6370243 | | Bore | | | | | | | |
| GW079484 | NOW | 380702 | 6369460 | | Bore | | | | | | | |
| GW079485 | NOW | 381208 | 6370907 | | Bore | | | | | | | |
| GW079486 | NOW | 386237 | 6370011 | | Bore | | | | | | | |
| GW079488 | NOW | 384919 | 6371747 | | Bore | | | | | | | |
| GW079505 | NOW | 385842 | 6370473 | | Bore | | | | | | | |
| GW079507 | NOW | 381007 | 6367977 | | Bore | | | | | | | |
| GW079508 | NOW | 381685 | 6367826 | | Bore | | | | | | | |
| GW079509 | NOW | 381507 | 6368127 | | Bore | | | | | | | |
| GW079510 | NOW | 381452 | 6368449 | | Bore | | | | | | | |
| GW079511 | NOW | 381454 | 6368303 | | Bore | | | | | | | |
| GW079512 | NOW | 380901 | 6367414 | | Bore | | | | | | | |
| GW079513 | NOW | 385800 | 6371009 | | Bore | | | | | | | |
| GW079518 | NOW | 385565 | 6371368 | | Bore | | | | | | | |
| GW079530 | NOW | 384944 | 6371959 | | Bore | | | | | | | |
| GW079540 | NOW | 383170 | 6369188 | | Bore | | | | | | | |
| GW079542 | NOW | 381242 | 6367742 | | Bore | | | | | | | |
| GW079551 | NOW | 386435 | 6368752 | | Bore | | | | | | | |
| GW079552 | NOW | 386454 | 6368369 | | Bore | | | | | | | |
| GW079555 | NOW | 381816 | 6372346 | | Bore | | | | | | | |
| GW079556 | NOW | 384461 | 6373394 | | Bore | | | | | | | |
| GW079561 | NOW | 380752 | 6369627 | | Bore | | | | | | | |
| GW079562 | NOW | 384019 | 6370520 | | Bore | | | | | | | |
| GW079563 | NOW | 383704 | 6368243 | | Bore | | | | | | | |
| GW079574 | NOW | 384780 | 6369212 | | Bore | | | | | | | |
| GW079577 | NOW | 379819 | 6366621 | | Bore | | | | | | | |
| GW079578 | NOW | 379801 | 6366741 | | Bore | | | | | | | |
| GW079586 | NOW | 385659 | 6371130 | | Bore | | | | | | | |
| GW079590 | NOW | 377731 | 6367380 | | Bore | | | | | | | |
| GW079591 | NOW | 379370 | 6369241 | | Bore | | | | | | | |
| GW079592 | NOW | 381364 | 6369900 | | Bore | | | | | | | |
| GW079593 | NOW | 385067 | 6370478 | | Bore | | | | | | | |
| GW079594 | NOW | 384568 | 6372426 | | Bore | | | | | | | |
| GW079599 | NOW | 380811 | 6370651 | | Bore | | | | | | | |
| GW079600 | NOW | 382066 | 6369112 | | Bore | | | | | | | |
| GW079601 | NOW | 383023 | 6370323 | | Bore | | | | | | | |
| GW079602 | NOW | 384963 | 6370434 | | Bore | | | | | | | |
| GW079605 | NOW | 378090 | 6368487 | | Bore | | | | | | | |
| GW079637 | NOW | 385498 | 6370227 | | Bore | | | | | | | |
| GW079644 | NOW | 385018 | 6370668 | | Bore | | | | | | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW079645 | NOW | 385303 | 6370923 | | Bore | | | | | | | |
| GW079649 | NOW | 386426 | 6368889 | | Bore | | | | | | | |
| GW079656 | NOW | 384142 | 6369855 | | Bore | | | | | | | |
| GW079674 | NOW | 385323 | 6370398 | | Bore | | | | | | | |
| GW079675 | NOW | 384221 | 6369207 | | Bore | | | | | | | |
| GW079721 | NOW | 386148 | 6370313 | | Bore | | | | | | | |
| GW079722 | NOW | 379509 | 6367614 | | Bore | | | | | | | |
| GW079723 | NOW | 379693 | 6367677 | | Bore | | | | | | | |
| GW079724 | NOW | 380104 | 6367760 | | Bore | | | | | | | |
| GW079725 | NOW | 379439 | 6367513 | | Bore | | | | | | | |
| GW079726 | NOW | 380598 | 6368609 | | Bore | | | | | | | |
| GW079727 | NOW | 379987 | 6367348 | | Bore | | | | | | | |
| GW079728 | NOW | 380256 | 6367108 | | Bore | | | | | | | |
| GW079729 | NOW | 380462 | 6367077 | | Bore | | | | | | | |
| GW079730 | NOW | 379729 | 6367478 | | Bore | | | | | | | |
| GW079802 | NOW | 386030 | 6370557 | 6.48 | Bore | | | | | | | |
| GW079804 | NOW | 385877 | 6370694 | 6.98 | Bore | | | | | | | |
| GW079805 | NOW | 385692 | 6370460 | 7.6 | Bore | | | | | | | |
| GW079806 | NOW | 385664 | 6370890 | 6.19 | Bore | | | | | | | |
| GW079807 | NOW | 385684 | 6370880 | 6.12 | Bore | | | | | | | |
| GW079808 | NOW | 385694 | 6370900 | 6.19 | Bore | | | | | | | |
| GW079809 | NOW | 385596 | 6371029 | 8.37 | Bore | | | | | | | |
| GW079811 | NOW | 385768 | 6370926 | 5.46 | Bore | | | | | | | |
| GW079815 | NOW | 386018 | 6370687 | 7.99 | Bore | | | | | | | |
| GW079816 | NOW | 385535 | 6370847 | 7.26 | Bore | | | | | | | |
| GW079817 | NOW | 385535 | 6370847 | 6.05 | Bore | | | | | | | |
| GW079818 | NOW | 385201 | 6371561 | 4.08 | Bore | | | | | | | |
| GW079819 | NOW | 385487 | 6371776 | 5.7 | Bore | | | | | | | |
| GW079825 | NOW | 385865 | 6370304 | 5.68 | Bore | | | | | | | |
| GW079829 | NOW | 385320 | 6370543 | 6.45 | Bore | | | | | | | |
| GW079834 | NOW | 385617 | 6371259 | 5.96 | Bore | | | | | | | |
| GW079835 | NOW | 385970 | 6370576 | 7.11 | Bore | | | | | | | |
| GW079836 | NOW | 386020 | 6370577 | 7.22 | Bore | | | | | | | |
| GW079871 | NOW | 385715 | 6370301 | 5.78 | Bore | | | | | | | |
| GW079872 | NOW | 385607 | 6370189 | 5.44 | Bore | | | | | | | |
| GW079873 | NOW | 385449 | 6370096 | 5.01 | Bore | | | | | | | |
| GW079874 | NOW | 385405 | 6370305 | 7.12 | Bore | | | | | | | |
| GW079875 | NOW | 385510 | 6370547 | 6.3 | Bore | | | | | | | |
| GW079879 | NOW | 386357 | 6369663 | 6.84 | Bore | | | | | | | |
| GW079880 | NOW | 385942 | 6369375 | 8.64 | Bore | | | | | | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW079881 | NOW | 385974 | 6369796 | 8.31 | Bore | | | | | | | |
| GW079882 | NOW | 386187 | 6369660 | 5.37 | Bore | | | | | | | |
| GW079883 | NOW | 385882 | 6369384 | 6.12 | Bore | | | | | | | |
| GW079884 | NOW | 384977 | 6369687 | 4.58 | Bore | | | | | | | |
| GW079885 | NOW | 384985 | 6369767 | 5.65 | Bore | | | | | | | |
| GW079886 | NOW | 384869 | 6371165 | 4.82 | Bore | | | | | | | |
| GW079887 | NOW | 384833 | 6370954 | 4.79 | Bore | | | | | | | |
| GW079888 | NOW | 384510 | 6370568 | 3.91 | Bore | | | | | | | |
| GW079889 | NOW | 384632 | 6370480 | 3.88 | Bore | | | | | | | |
| GW079890 | NOW | 384876 | 6370755 | 7.15 | Bore | | | | | | | |
| GW079891 | NOW | 385161 | 6371050 | 5.91 | Bore | | | | | | | |
| GW079900 | NOW | 385081 | 6369989 | 5.37 | Bore | | | | | | | |
| GW079901 | NOW | 385193 | 6369891 | 5.74 | Bore | | | | | | | |
| GW079902 | NOW | 384854 | 6369845 | 6.6 | Bore | | | | | | | |
| GW079903 | NOW | 384877 | 6369685 | 4.5 | Bore | | | | | | | |
| GW079948 | NOW | 370081 | 6372613 | 9.87 | Bore | | | | | | | |
| GW080020 | NOW | 385152 | 6370393 | 5.2 | Bore | | | | | | | |
| GW080021 | NOW | 384969 | 6370212 | 3.8 | Bore | | | | | | | |
| GW080022 | NOW | 384576 | 6370114 | 3.33 | Bore | | | | | | | |
| GW080023 | NOW | 384531 | 6369805 | 3.04 | Bore | | | | | | | |
| GW080024 | NOW | 384892 | 6370605 | 4.43 | Bore | | | | | | | |
| GW080025 | NOW | 385346 | 6370063 | 4.55 | Bore | | | | | | | |
| GW080026 | NOW | 384800 | 6369788 | 5.24 | Bore | | | | | | | |
| GW080027 | NOW | 384793 | 6369780 | 5.03 | Bore | | | | | | | |
| GW080028 | NOW | 384771 | 6369760 | 4.59 | Bore | | | | | | | |
| GW080029 | NOW | 384522 | 6370870 | 4.33 | Bore | | | | | | | |
| GW080030 | NOW | 385132 | 6370665 | 5.94 | Bore | | | | | | | |
| GW080031 | NOW | 385098 | 6370683 | 5.91 | Bore | | | | | | | |
| GW080032 | NOW | 385258 | 6370943 | 6.31 | Bore | | | | | | | |
| GW080033 | NOW | 385249 | 6370947 | 6.17 | Bore | | | | | | | |
| GW080035 | NOW | 385358 | 6371164 | 6.34 | Bore | | | | | | | |
| GW080036 | NOW | 385322 | 6371182 | 5.83 | Bore | | | | | | | |
| GW080037 | NOW | 385564 | 6371753 | 5.6 | Bore | | | | | | | |
| GW080038 | NOW | 385338 | 6371797 | 5.03 | Bore | | | | | | | |
| GW080039 | NOW | 385142 | 6371834 | 4.27 | Bore | | | | | | | |
| GW080040 | NOW | 385042 | 6371853 | 4.04 | Bore | | | | | | | |
| GW080041 | NOW | 384994 | 6371863 | 3.65 | Bore | | | | | | | |
| GW080042 | NOW | 384908 | 6370911 | 4.55 | Bore | | | | | | | |
| GW080043 | NOW | 384916 | 6370016 | 4.7 | Bore | | | | | | | |
| GW080044 | NOW | 384873 | 6370931 | 4.66 | Bore | | | | | | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW080116 | NOW | 385011 | 6370567 | | Bore | | | | | | | |
| GW080117 | NOW | 385034 | 6370644 | | Bore | | | | | | | |
| GW080118 | NOW | 385069 | 6370757 | | Bore | | | | | | | |
| GW080222 | NOW | 385086 | 6368991 | 0 | Spear | | | | | | | |
| GW080222 | NOW | 385086 | 6368991 | 0 | Spear | | | | | | | |
| GW080223 | NOW | 385045 | 6369031 | 0 | Spear | | | | | | | |
| GW080224 | NOW | 385099 | 6368955 | 0 | Spear | | | | | | | |
| GW080225 | NOW | 385078 | 6368949 | 0 | Bore | | | | | | | |
| GW080226 | NOW | 385169 | 6368861 | 0 | Bore | | | | | | | |
| GW080250 | NOW | 378589 | 6361387 | | Bore | | 4.5 | | | | | |
| GW080251 | NOW | 377804 | 6361511 | | Bore | | 10.5 | | | | | |
| GW080365 | NOW | 384799 | 6369292 | 0 | Spear | | | | | | | |
| GW200053 | NOW | 385842 | 6370473 | 7.62 | Bore | | | | | | | |
| GW200055 | NOW | 385565 | 6371368 | 5.42 | Bore | | | | | | | |
| GW200068 | NOW | 385153 | 6370655 | 6.4 | Bore | | | | | | | |
| GW200077 | NOW | 384875 | 6370424 | 7.06 | Bore | | | | | | | |
| GW200078 | NOW | 384864 | 6370446 | 6.82 | Bore | | | | | | | |
| GW200079 | NOW | 384689 | 6370329 | 6.82 | Bore | | | | | | | |
| GW200080 | NOW | 384679 | 6370351 | 6.29 | Bore | | | | | | | |
| GW200083 | NOW | 384964 | 6370517 | 5.91 | Bore | | | | | | | |
| GW200084 | NOW | 384907 | 6370675 | 4.36 | Bore | | | | | | | |
| GW200085 | NOW | 384970 | 6370498 | 6.17 | Bore | | | | | | | |
| GW200087 | NOW | 380322 | 6360914 | | Bore | | 23.7 | | | | | |
| GW200414 | NOW | 369960 | 6373761 | | Bore | fill (silty sand, dark brown, medium grained sand) | 10 | | | | | |
| GW200415 | NOW | 369986 | 6373738 | | Bore | clay (silty, sandy, light to dark brown) | 20.1 | | | | | |
| GW200626 | NOW | 371366 | 6362331 | | Bore | silt (sandy, gravelly, dark brown) | 4.2 | | | | | |
| GW200627 | NOW | 371461 | 6362472 | | Bore | silt (sandy, dark brown) | 4.2 | | | | | |
| GW200628 | NOW | 371384 | 6362453 | | Bore | silt (sandy, gravelly) | 4.2 | | | | | |
| GW200629 | NOW | 371585 | 6362633 | | Bore | sand (gravelly, dark brown) | 4.2 | | | | | |
| TP501B | Coffey-UHVA 2012 Report | 377345 | 6365470 | 1.61 | Geotechnical | Fill (clayey, sandy gravel) | 1.7 | 0.9 | | 0.9 | | |
| TP502A | Coffey-UHVA 2012 Report | 377331 | 6365538 | 1.82 | Geotechnical | Clayey Sand and sandy clay) | 2.3 | 2 | | | | |
| TP503B | Coffey-UHVA 2012 Report | 377299 | 6365595 | 1.77 | Geotechnical | Fill (clayey, sandy gravel) | 2.4 | 0.15 | | | | |
| TP504A | Coffey-UHVA 2012 Report | 377271 | 6365689 | 2.22 | Geotechnical | Fill (clayey, sandy gravel) | 2.2 | 1.25 | | | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TP505B | Coffey-UHVA 2012 Report | 377207 | 6365743 | 1.43 | Geotechnical | Fill (Gravel/ Sandy Gravel/Clayey Sandy Gravel) | 2.8 | 0.7 | | 0.7 | | |
| TP506B | Coffey-UHVA 2012 Report | 377187 | 6365872 | 3.11 | Geotechnical | Fill (Gravel/Sandy Gravel) | 2.4 | 1.9 | | 1.9 | | |
| TP507B | Coffey-UHVA 2012 Report | 377152 | 6365958 | 3.52 | Geotechnical | Fill (sandy gravel) | 2.6 | 0.3 | | | | |
| TP508B | Coffey-UHVA 2012 Report | 377113 | 6366058 | 3.5 | Geotechnical | N/A | 2.6 | N/A | | | | |
| TP509A | Coffey-UHVA 2012 Report | 377094 | 6366155 | 1.75 | Geotechnical | Fill (Gravel/Sandy gravel) | 1.7 | 0.7 | | 0.7 | | |
| TP510A | Coffey-UHVA 2012 Report | 377046 | 6366251 | 2.44 | Geotechnical | Fill (Sandy Clayey gravel) | 2.3 | 1.05 | | 1.05 | | |
| TP511B | Coffey-UHVA 2012 Report | 377004 | 6366342 | 1.86 | Geotechnical | Fill (Sandy gravel) | 1.7 | 0.2 | | | | |
| TP512B | Coffey-UHVA 2012 Report | 376983 | 6366432 | 1.92 | Geotechnical | Fill (sandy clayey gravel) | 3 | 0.9 | | | | |
| TP513B | Coffey-UHVA 2012 Report | 376925 | 6366527 | 1.96 | Geotechnical | Fill (sandy gravel) | 2.2 | 1.2 | | | | |
| TP514B | Coffey-UHVA 2012 Report | 376911 | 6366619 | 1.74 | Geotechnical | Silty clay | 1.8 | 1 | | 1 | | |
| TP515B | Coffey-UHVA 2012 Report | 376856 | 6366707 | 2.32 | Geotechnical | Fill (Sandy Clayey gravel) | 2.3 | 1.6 | | 1.7 | | |
| TP516B | Coffey-UHVA 2012 Report | 376824 | 6366810 | 1.59 | Geotechnical | Fill (Clayey sandy gravel) | 2 | 0.7 | | 0.7 | | |
| TP517A | Coffey-UHVA 2012 Report | 376808 | 6366905 | 1.75 | Geotechnical | Fill (Clayey sandy gravel) | 2.8 | 0.9 | | 0.9 | | |
| TP518B | Coffey-UHVA 2012 Report | 376773 | 6366998 | 1.72 | Geotechnical | Fill (sandy gravel) | 2.4 | 0.6 | | | | |
| TP519B | Coffey-UHVA 2012 Report | 376729 | 6367091 | 2.11 | Geotechnical | Gravelly clay/ sandy clayey gravel) | 2.3 | 0.95 | | 0.95 | | |
| TP523B | Coffey-UHVA 2012 Report | N/A | N/A | N/A | Geotechnical | Clay | 2.4 | 1.4 | | | | |
| TP525A | Coffey-UHVA 2012 Report | N/A | N/A | N/A | Geotechnical | Fill (Sandy gravel) | 1.5 | 0.45 | | | | |
| CMW1 | Coffey-UHVA 2012 Report (new) | 377336 | 6365463 | 1.883 | Geotechnical | Fill (Gravelly sand) | | 1.5 | | 1.1 | | |
| CMW2 | Coffey-UHVA 2012 Report (new) | 377193 | 6365798 | 2.072 | Geotechnical | Fill (Gravelly sand) | | 1.2 | | 0.462 | | |

| Work No | Data Source | Easting | Northing | Elevation (RL m) | Work Type | Drillers Description | Drilled Depth | WL From Depth | WL To Depth | Standing Water Level | Yield | Salinity Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMW3 | Coffey-UHVA 2012 Report (new) | 377085 | 6365966 | 2.454 | Geotechnical | Fill (Gravelly sand) | | 0.9 | | 0.938 | | |
| CMW4 | Coffey-UHVA 2012 Report (new) | 376958 | 6366271 | 3.902 | Geotechnical | Fill (Gravelly sand) | | 1.5 | | 0.704 | | |
| CMW5 | Coffey-UHVA 2012 Report (new) | 376930 | 6366510 | 2.356 | Geotechnical | Fill (Gravelly sand) | | 1.2 | | 0.781 | | |
| CMW6 | Coffey-UHVA 2012 Report (new) | 376836 | 6366829 | 1.97 | Geotechnical | Fill (Sandy gravel) | | 0.65 | | 0.57 | | |
| CMW7 | Coffey-UHVA 2012 Report (new) | 376749 | 6367029 | 2.161 | Geotechnical | Fill (Gravelly sand) | | 1.5 | | 0.751 | | |
| CMW8 | Coffey-UHVA 2012 Report (new) | 376624 | 6367399 | 1.626 | Geotechnical | Fill (Gravelly sand) | | 1.2 | | 0.593 | | |
| CMW9 | Coffey-UHVA 2012 Report (new) | 376394 | 6367567 | 1.347 | Geotechnical | Fill (Gravelly sand) | | 1.2 | | 0.414 | | |
| CMW10 | Coffey-UHVA 2012 Report (new) | 376394 | 6367832 | 1.961 | Geotechnical | Fill (Sandy gravel) | | 1.2 | | 0.895 | | |
| 101 | Coffey-UHVA 2012 Report (new) | N/A | N/A | 3.039 | Geotechnical | | | | | 1.55 | | |
| 109 | Coffey-UHVA 2012 Report (new) | N/A | N/A | | Geotechnical | | | | | 1.678 | | |