CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX W: Values and Constraints Assessment: Groundwater East Trinity Report (2016)

22 November2016

EAST TRINITY BASELINE HYDROGEOLOGICAL ASSESSMENT

Cairns Shipping Development Project

REPORT

Report Number. 1546223-007-R-Rev2

Distribution:

1 x PDF

Golder Associates

Table of Contents

FIGURES

APPENDICES

GLOSSARY, ACRONYMS, ABBREVIATIONS

Term	Meaning
AHD	Australian Height Datum
bgl	Below Ground Level
CSD	Cairns Shipping Development
DEHP	Department of Environment and Heritage Protection
DNRM	Department of Natural Resources and Mines
EC	Electrical Conductivity
EIS	Environmental Impact Statement

1.0 INTRODUCTION

Flanagan Consulting Group (FCG) commissioned Golder Associates Pty Ltd (Golder) to provide advice and assessment of soil issues as part of the Revised Draft Environmental Impact Statement for the Cairns Shipping Development (CSD) project.

The recalibrated CSD project involves the following:

- Reduced channel widening and deepening plus dredging of the swing basin and berth pockets in the inner port area (capital dredging). This will result in a total capital dredging volume of 860 000m^3. This is an in-situ material volume calculated as occurring between current maintenance dredging depths and the enlarged channel target depths including insurance depth and appropriate minimal over-dredging allowances.
- Land placement of capital dredged material at the following sites (i.e. with both being the subject of the Revised Draft EIS):
  - Northern Sands (an existing void in the Barron River delta created by past sand extraction and now used for burial of 'inert' construction and demolition fill and a limited quantity of PASS).
  - East Trinity (a new bunded site or sites within the general East Trinity area).

This report is based on a desktop review of available information and addresses the placement of capital dredged material within a new bunded site or sites within the general East Trinity area, see Figure 1. Conceptual placement of dredged materials at East Trinity would have the following requirements:

- A pumping delivery line from Trinity Inlet to the dredged material placement ponds.
- A placement area of 60 ha (i.e. 1.9 M m^3 stored 3 m deep) plus an additional area of about 8 hectares for perimeter bund walls. It is expected that the bund walls would be formed using material sourced from the placement area footprint. This is expected to require excavation to depths of less than 0.5m across this area.
- A PASS treatment area ranging from about 6 ha to 12 ha (including allowance for bunding and stockpiling).
- Provision for tailwater treatment – subject to preliminary concept design.

The aims of this report are to describe the existing groundwater conditions associated with East Trinity and to identify:

- Key groundwater related constraints (and opportunities) to design and construction of the facilities required for placement of the dredged material.
- Potential groundwater related environmental impacts and mitigation/management measures.

2.0 SITE SETTING

2.1 Site Background Information

The East Trinity Reserve covers an area of about 774 hectares and is located on what was formerly an estuarine floodplain. In the early 1970s, CSR constructed a 7.2km bund wall along the southern, western and northern site boundaries as the first step in draining the land to facilitate sugar cane cultivation. The bund included one-way floodgates on Hills Creek and Firewood Creek and completely cut-off other creeks which essentially eliminated tidal influence to the landward side of the bund wall.

Following bund construction, extensive vegetation clearing was conducted and in areas above about 0.5m AHD a series of drains were installed. Mangrove communities were reported to have originally been found in areas below 1m AHD with samphire communities generally located between 1m and 2m AHD.

Bunding and drainage works resulted in lowering the groundwater level in the pyritic sediments present over most of the site. This resulted in a major acid sulfate soil problem which produced ongoing discharge of acid, iron, aluminium and other heavy metals into Trinity Inlet and contributed to the abandonment of cane cultivation. Internal creeks became acidified and contained high levels of metals, resulting in fish kills and aquatic ecosystem damage.

Ownership of the land passed through several developers who failed to obtain planning approvals for canal and marina developments in the 1990s and who finally became bankrupt. The site was then neglected until purchased by the Queensland State Government in 2000. The government requested the Department of Natural Resources and Mines to develop a remediation plan to deal with the environmental issues posed by acid sulfate soils at East Trinity.

Implementation of the remediation plan commenced in 2001 and involved a range of engineering solutions to achieve the desired hydrology and applied a lime-assisted tidal exchange remediation strategy, firstly on a trial basis and then (following positive results) on a long term basis. Management of the remediation works subsequently passed to Queensland Department of Science, Information Technology and Innovation (DSITI).

In March 2016, H. Luke (2016) reported that remediation works have produced a spectrum of stages of remediation in the site sediments, with large areas fully remediated.

DSITI (pers. communications) indicated that extensive surface and groundwater monitoring programs have been conducted across this site over the period 2010 to 2016, however QA/QC checks on the data had not been completed and was unavailable for review at the time of this report. This report draws upon earlier existing data to evaluate site conditions, constraints and potential impacts.

2.2 Climate

The climate of the Cairns region and that of the Study Area is tropical with weather patterns consisting of very wet summers and drier winters. Key climatological and weather data obtained from the nearest weather station, located at the Cairns Airport (Bureau of Meteorology Station Number 031011) and is summarised below:

- Mean annual monthly maximum temperature is 29.0º Celsius; with highest temperatures in December and January.
- Mean annual monthly minimum temperature is 20.8º Celsius; with lowest temperatures in July.
- Mean annual rainfall is 1999.7 mm with highest rainfall in January through March.
- Mean number of days of rain greater than or equal to 1 mm is 119.6 days per year.
- Mean annual 9 am humidity is 72%; with February, March, and April having highest humidity.
- Mean annual 3 pm humidity is 62% with February having highest humidity.

Mean monthly rainfall and mean monthly evaporation are reported in Table 1 and the annual rainfall from 2005 to 2015 is reported in Table 2.

Table 1: Mean rainfall (mm) and calculated evaporation data (mm) at the Cairns Airport (Weather Station Number 031011). Source: Bureau of Meteorology (2016).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean rainfall (1942 to 2016)	390	448	419	195	92	48	30	27	33	46	94	178
Mean evaporation (1965 to 2016)	198	164	180	162	152	141	155	174	201	233	225	223.

Note: data is rounded to the nearest millimetre

Table 2: Annual total rainfall data (mm) between 2005 and 2015 at the Cairns Airport (Weather Station Number 031011). Source: Bureau of Meteorology (2016).

Station	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*
Cairns	1471	2289.0	1813	2215	2199	2660	2623	2003	1269	1826	1897

Note: data is rounded to the nearest millimetre

*Not quality controlled by BOM (2016)

The Cairns region experiences cyclonic storms on a regular basis with extreme rainfall events occurring every two to eight years. Runoff intensity and storm surges from the sea would be expected. Significant rainfalls of 100 mm/day or greater can occur at any time of the year. Due to the proximity of the Study Area to tidally influenced creeks and the nature of the local hydrologic conditions, episodic extreme weather events would also be expected. The topography is low lying coastal plains that may be influenced by storm surge impacts and large storm run-off or flood events.

2.3 Drainage and Topography

The topography of the East Trinity area is characterised by relatively flat coastal plains which rise steeply to the hills of the Murray Prior Range to the east of the site. The site contains areas of marsh/wetland, open grassed areas and areas of native or recovering vegetation. Herbert *et al.,* (2003) reported that prior to its clearing and drainage the site comprised waterlogged mangrove and supratidal areas.

Levels across the site are typically below 2.5m AHD. Four westward flowing creek systems (Firewood Creek, Magazine Creek, Hills Creek and Georges Creek, see Figure 1) originally flowed through the site prior to construction of the perimeter bund. Levels in the vicinity of these creek lines are typically below 0.5m AHD.

Flood gates are present in the perimeter bund wall to allow controlled tidal exchange in Firewood and Hills Creeks. Magazine and Georges Creeks no longer flow into Trinity Inlet. A series of open (excavated) drains are present across portions of the site which generally direct surface water into the Firewood and Hills Creek systems

Hills Creek and Firewood Creek are the dominant drainage features in the site catchment with Trinity Inlet (located about 400m from the bunded site) the dominant drainage feature in the surrounding area. Herbert *et al.,* (2003) reported that Hills Creek is a permanent watercourse feature with flow throughout the year. The water course is up to 40 m wide and up to 6.5 m deep in sections with a mean depth of -3.17 m AHD.

2.4 Regional Geology and Hydrogeology

The site is located on the eastern side of Trinity Inlet, opposite the Cairns CBD. This site lithology is comprised of coastal tidal flats, mangrove flats, supratidal flats, saltpans and grasslands. Published geological information from *Queensland Digital Geological Map Data 1:100,000 Cairns 8064 series Department of Natural Resources and Mines* indicates the coastal plain (including the site) is dominated by Holocene aged alluvial deposits of silt, mud and sand sediments. A series of north east/south west trending, sand chenier ridges are also present across the site. The surficial geology is shown on Figure 2.

The basement rocks have low primary and secondary porosity (Herbert *et al.,* 2003). The contact between the Permian Granite and the overlying Quaternary and Holocene sediment may have a thin weathered zone capable of holding, or transmitting water (Herbert *et al.,* 2003).

The coastal alluvial deposits are comprised of alternative layers of fine and coarse materials, reflecting a changing depositional environment as a result of sea level fluctuations (increases and decreases of the water level in the Coral Sea) (Herbert *et al.,* 2003). This is supported by data from the Department of Natural Resources and Mines (DNRM) groundwater database (GWDB) in the surrounding area.

Significant groundwater resources are present within the Mulgrave River aquifer system to the south of the site. These freshwater aquifers are present in alluvial deposits of the Mulgrave-Russell River catchment and are important irrigation and possible water supply reserves for Cairns. Herbert et al. (2003) concluded that there appears to be no connection of the East Trinity aquifers to the major aquifer systems in Mulgrave Valley.

2.5 Groundwater Dependant Ecosystems

Groundwater Dependent Ecosystems (GDE) are defined as ecosystems whose ecological processes and biodiversity are wholly, or partially, reliant on groundwater. Examples of GDEs include wetlands, vegetation, mound springs, river base flows, and saline discharges, springs, mangroves. GDEs may include aquatic ecosystems in rivers and streams that receive groundwater baseflow.

Information on potential groundwater dependent ecosystems is available from the National Atlas of Groundwater Dependent Ecosystems. Based on the information from this atlas, the potential for groundwater dependent ecosystems in surface water bodies and for vegetation in the vicinity of the site is shown in Figure 3.

This figure indicates the presence of small areas of vegetation with a high potential for groundwater interaction towards the northern end of the site and a small GDE with a high potential for groundwater reliance (which coincides with a Chenier ridge) towards the western end of site.

3.0 GROUNDWATER CONDITIONS ON SITE

3.1 Stratigraphy

Sections of the interpreted shallow stratigraphy for the East Trinity site, Smith et al (2003) are reproduced on Figure 4, and indicate:

- The younger (Holocene age) alluvial deposits are generally present to depths of about 2m to 4m below the ground surface at the eastern end of the site, progressively increasing in depth towards the west. At the western margins of the site the thickness of Holocene deposits typically ranged between about 6.5m and 12m, increasing to a depth of about 22m between Hills Creek and Magazine Creek.
- The younger alluvial deposits are underlain by older (Pleistocene age), consolidated alluvial deposits.
- Permian age Granite bedrock underlie the alluvial deposits at depths of at least 90 m near Trinity Inlet (Herbert *et al.,* 2003).

CSRIO (1999) determined hydraulic conductivity of the soils to depths of about 3m on each side of the perimeter bund wall. In salt flats and drained areas where surface cracking was apparent, hydraulic conductivities in the range of 2×10^{-3} m/s and 7×10^{-5} m/s were reported in the upper 0.15m. Underlying soils had hydraulic conductivities in the range of 4×10^{-8} m/s and 8×10^{-12} m/s. Smith et al (2003) also identified soils profiles outside of Chenier ridges as low permeability soils.

3.2 Hydrogeology

Groundwater bores were installed at 12 locations (11100082 to 11100090 and 11100095 to 11100097 as shown on Figure 3) were installed across the site by Herbert et al (2003) in 2001 and used to define the soil and geological formations as well as to monitor groundwater levels and quality over a period of about 15 months from October 2001 to November 2002. Bore details are summarised in Table 3.

Table 3: Site Bore Details

Bore ID	Screened Interval (m bgl)	Bore Total Depth (m bgl)	Depth to Groundwater * (m bgl)	Groundwater Elevation (m AHD)	Aquifer
11100095	6.22 to 6.82	6.82	1.33	-1.10 to 0.20	Unconfined to semi confined
11100096	5.83 to 6.43	6.43	1.79	-1 to 0.50	Unconfined to semi confined
11100097	1.56 to 2.18	2.18	1.52	-2.20 to 0.30	Semi confined
11100089	NA	~5m	NA	NA	Shallow
11100090	NA	~4m	NA	NA	Shallow
11100082	32 to 38	69	0.76 to 0.93	1.21 to 1.38	Deep
11100083	16.70 to 18.20	18.2	0.88 to 1.11	1.1 to 1.33	Deep

Bore ID	Screened Interval (m bgl)	Bore Total Depth (m bgl)	Depth to Groundwater * (m bgl)	Groundwater Elevation (m AHD)	Aquifer
11100095	6.22 to 6.82	6.82	1.33	-1.10 to 0.20	Unconfined to semi confined
11100096	5.83 to 6.43	6.43	1.79	-1 to 0.50	Unconfined to semi confined
11100097	1.56 to 2.18	2.18	1.52	-2.20 to 0.30	Semi confined
11100084	24 to 28	30	0.41 to 0.49	1.0 to 1.47	Deep
11100085	29 to 32	36	0.09 to 0.54	1.19 to 1.64	Deep
11100086	23.50 to 25	26	0.77 to 0.86	1.09 to 1.18	Deep
11100087 A**	62 to 65 and 80 to 83	83	-0.75 to -0.80 above ground level	1.50 to 3.80	Deep
11100087 B**	34.7 to 36	83	0.19 to 0.2	2.28 to 3.30	Deep
11100088	18 to 24	24	0.90 to 0.98	1.0 to 1.45	Deep

**SWL data issued from QLD globe data (DNRM, 2016)*

***Standpipes were installed at two different depths at this location*

Herbert et al. (2003) categorised aquifers in this area as follows:

- Discontinuous shallow aquifers overlying and within the lower permeability Holocene sediments, comprising groundwater systems associated with relic dune systems and/or paleochannels related to recent stream meanderings.
- Deeper aquifers (up to 5 distinct sandy aquifers) in the Pleistocene sediments down to around 80 m, isolated from surface waters and shallow aquifers and discharging well out in Trinity Bay.

3.3 Groundwater Levels

3.3.1 Shallow Aqufier System

Groundwater levels for bores installed in the shallow groundwater system (11100095 (SW7), 11100096 (SW8) and 11100097(SW9)) are summarised in Table 3 and hydrographs for the period monitored by Herbert *et al. (*2003) are reproduced in Appendix A. Water levels between 2001 and 2002 ranged between approximately -2.2 m AHD to 0.5 m AHD, and were generally below 0 m AHD.

3.3.2 Deeper Aquifer System

Groundwater levels for the deep monitoring bores are summarised in Table 3 and hydrographs for the period monitored by Herbert *et al. (*2003) are reproduced in Appendix B. Water levels between 2001 and 2002 ranged between approximately -2.2 to 3.3 m AHD within the monitored 'deep' aquifers.

Monitoring bores which are located near the Trinity inlet are generally affected by tidal variations and results in hydrostatic loading typically is of the order of 0.2 m per day (Herbert *et al.,* 2003).

Herbert *et al.,* 2003 speculated that due to the minor fluctuation in water levels and time delays in water levels to tidal response, direct connection between the aquifers and the seawater occurs at a considerable distance from the actual shoreline.

3.4 Groundwater Quality

3.4.1 Shallow Aquifer system

Groundwater monitoring was carried out at the shallow groundwater monitoring bores as part of the investigations conducted by Herbert *et al, (*2003). Groundwater monitoring of pH and EC was conducted at fortnightly intervals from October 2001 to November 2002 with measurements taken in the top 0.1 m for all monitored bores in addition to either the bottom of the shallow monitoring bore, or at 4 m depth (Herbert *et. al.,* 2003).

In general, groundwater quality within the shallow groundwater system is variable and considered of low quality. Electrical conductivity ranges from 1500 microSiemens per centimetre (µS/cm)) to 120 000 µS/cm (i.e. fresh to hypersaline) while pH ranges 2.1 to 8. A summary of water quality results is presented Table 4.

Table 4: Shallow Aquifer Groundwater Quality Results

Bore	pH	Electrical Conductivity (µS/cm)
11100095	5 to 8 (acidic to slightly alkaline)	6 000 to 47 000 (slightly brackish to saline)
11100096	4 to 7.8 (acidic to slightly alkaline)	65 000 to 120 000 (hyper saline)
11100097	6.3 to 7.5 (slightly acidic to neutral)	1 500 to 3 800 (slightly brackish)
1110089*	2.1 (highly acidic)	24000 (saline)
1110090*	7.8 (neutral)	44100 (saline)

*Only one round of monitoring at these locations at the time of installation in 2001.

3.4.2 Deeper Aquifer System

Groundwater monitoring was carried out at the deeper groundwater monitoring bores as part of the investigations conducted by Herbert *et al., (*2003). The range of water quality results over the period October 2001 to November 2002 is summarised in Table 5.

Table 5: Deeper Aquifer Groundwater Quality Results

Bore	pH	Electrical Conductivity (µS/cm)
11100082	5.2 to 7.2	4000 to 11650
11100083	5.3 to 7.9	5000 to 12000
11110084	5 to 6.9	3500 to 5500
1110087 B	5.2 to 7.3	3200 to 5000
1110088	5.8 to 7.8	400 to 1000
1110085	6.7	1910 to 1990
1110086	6.9	2418 to 2520

The deeper aquifer was generally less acidic and less saline than the shallow aquifer. Conductivity can be related to distance from the sea, with a steady increase in readings towards the coast (Herbert *et al.,* 2003).

3.5 Conceptual Hydrogeological Model

A conceptual hydrogeological model for East Trinity is described below:

- Predominantly low permeability Holocene alluvial soils are present from surface to depths ranging from around 2 m at the eastern edge of the site, to in excess of 20 m at the western edge of the site. Discontinuous aquifers comprising groundwater systems associated with relic dune systems and/or paleochannels related to recent stream meanderings are present overlying and within the lower permeability sediments. Shallow aquifers are typically brackish to hypersaline and acidic in some locations. Surface aquifers associated with relic dune systems will be recharged directly by rainfall. Groundwater systems associated with paleochannels within the lower permeability sediments will not be directly recharged, and groundwater flow through these systems is likely to be limited. The overall direction of groundwater flow in the shallow groundwater system is towards Trinity Inlet. Close to creeks and manmade drains, groundwater exchange will occur as a result of seasonal fluctuations in the streams. Tidal gates installed on the watercourses prevent unimpeded surface water flow from the site out to sea.
- Deeper aquifers in the Pleistocene sediments. Up to 5 distinct sandy aquifers were identified by Herbert et al. (2003), within confining clayey aquitards between these aquifers. Water quality varies considerably between the shallow and deeper aquifers. There is sufficient information available to

confirm that deeper aquifers will not be impacted by placement of dredged spoil at this site. These aquifers are not considered further in this assessment.

4.0 CONSTRAINTS AND OPPORTUNITIES

Dredged spoil will be placed in bunded areas along with significant volumes of seawater. Tailwater will be removed and (following suitable treatment) returned to the sea.

The rate of saline (seawater) seepage through the base of bunded areas during placement of dredged spoil is generally expected to be low, given the low permeability soils (soil permeability will need to be confirmed at the design stage). Where Chenier ridges occur (see Figure 2 for these locations) within the proposed bund footprint, a liner may be required to prevent preferential flow through these sandy areas.

5.0 POTENTIAL IMPACTS

Seepage from the bunded areas is likely to occur at relatively low rates, but nevertheless has the potential to increase water levels both under and around the bunded area. Water quality on the site is generally quite poor, with high levels of salinity in the low permeability soils. Increased water levels surrounding the bund may impact on terrestrial vegetation with low salt tolerance. This is more of an issue in less saline areas towards the eastern margins of the site.

Seepage from the bunded area also has the potential to increase hydraulic gradients and increase rates of movement of any acidic groundwater, if such conditions are present in close proximity to the bunded area.

The potential for increases in groundwater level and increased rates of movement of acidic groundwater should be assessed further once the proposed location of the bunded area has been identified. This assessment would require further field investigations, and may require the development of a groundwater model.

6.0 REFERENCES

- Department of Natural Resources and Mines (DNRM), Groundwater Database, QLD Globe, 2016, State of Queensland <accessed 09 August 2016.
- Smith CD, Graham TL, Barry EV, Adams JJ and Ahern CR (2003). Acid Sulfate Soil and Stratigraphic Assessment. In: Demonstration of Management and Rehabilitation of Acid Sulfate Soils at East Trinity: Technical Report. Smith CD, Martens MA, Ahern CR, Eldershaw VJ, Powell B, Barry EV, Hopgood GL and KM Watling (eds). Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.
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- Hicks WS, Bowman GM, Fitzpatrick RW (1999). East Trinity Acid Sulfate Soils Part 1 – Environmental Hazards. CSIRO Land and Water Technical Report 14/99.
- GHD (2007). Mulgrave Aquifer Feasibility Study Hydrogeological Report.

7.0 IMPORTANT INFORMATION

Your attention is drawn to the document - “Important Information relating to this report”, which is included as an attachment to this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

Report Signature Page

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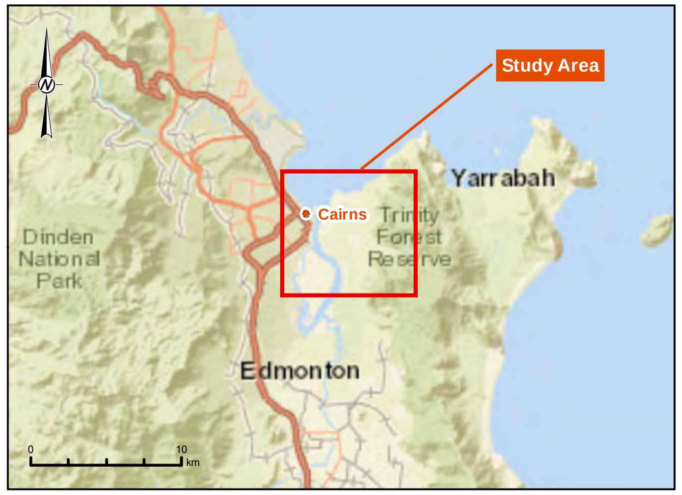
FIGURES

LOCATION MAP



LEGEND

- ● Localities
- Roads and Tracks
- Drainage (25k)

0 1 2

1:30,000 at A3 Kilometres

PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS
BASELINE GROUNWATER REPORT
EAST TRINITY

TITLE
SITE LOCATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-01
PREPARED	DP
DESIGNED	DP
REVIEWED	PS
APPROVED	PS

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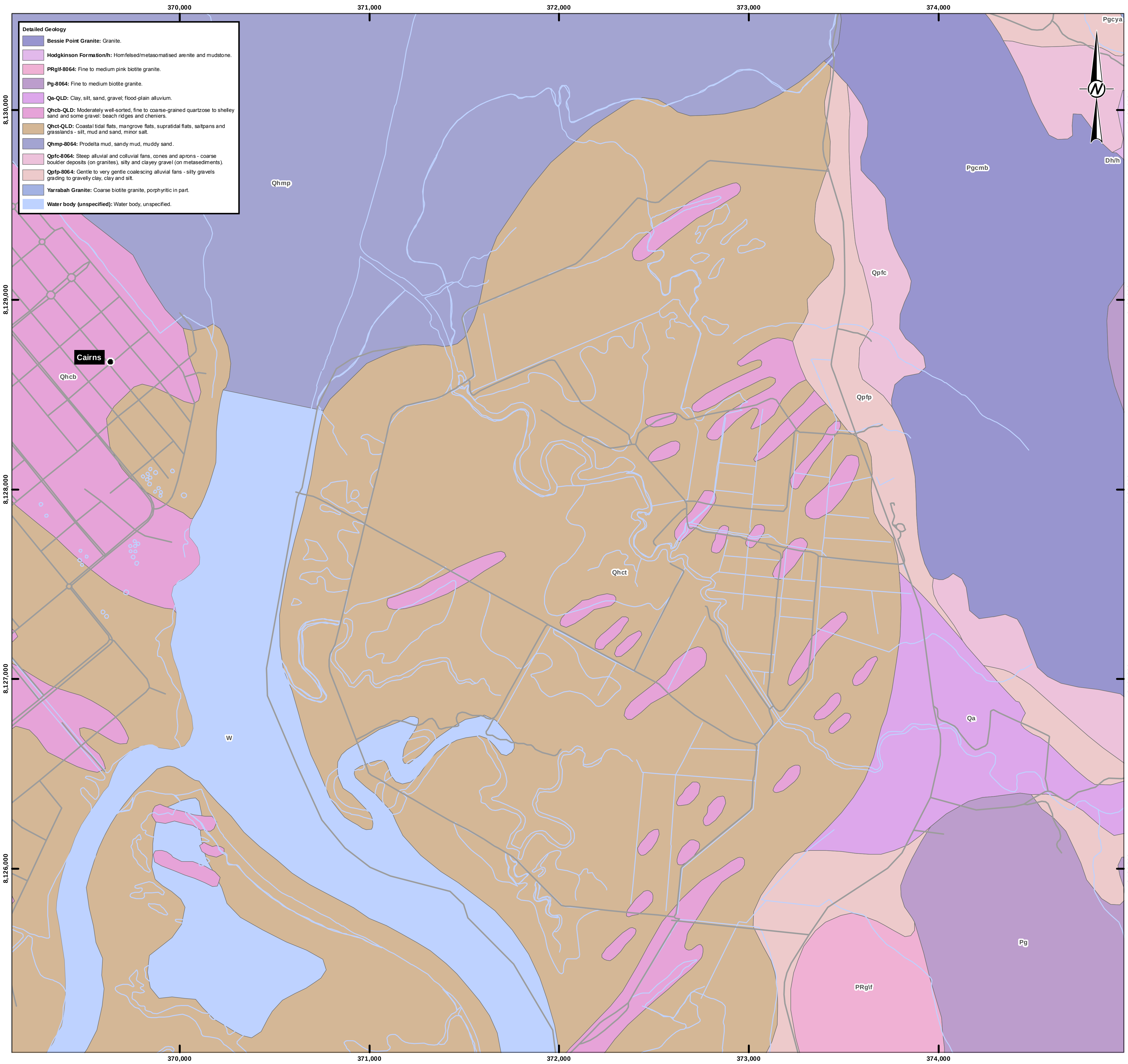

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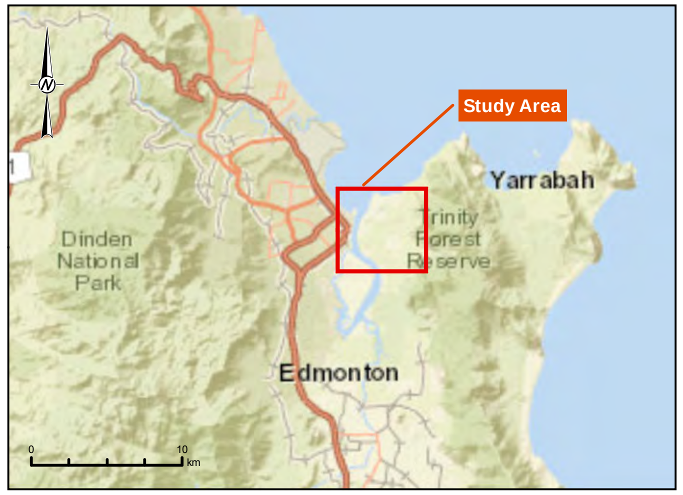

LEGEND

- Localities
- Drainage (25k)
- Roads and Tracks

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CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS
BASELINE GROUNDWATER REPORT
EAST TRINITY

TITLE
SURFICAL GEOLOGY

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Golder Associates	PREPARED	DP
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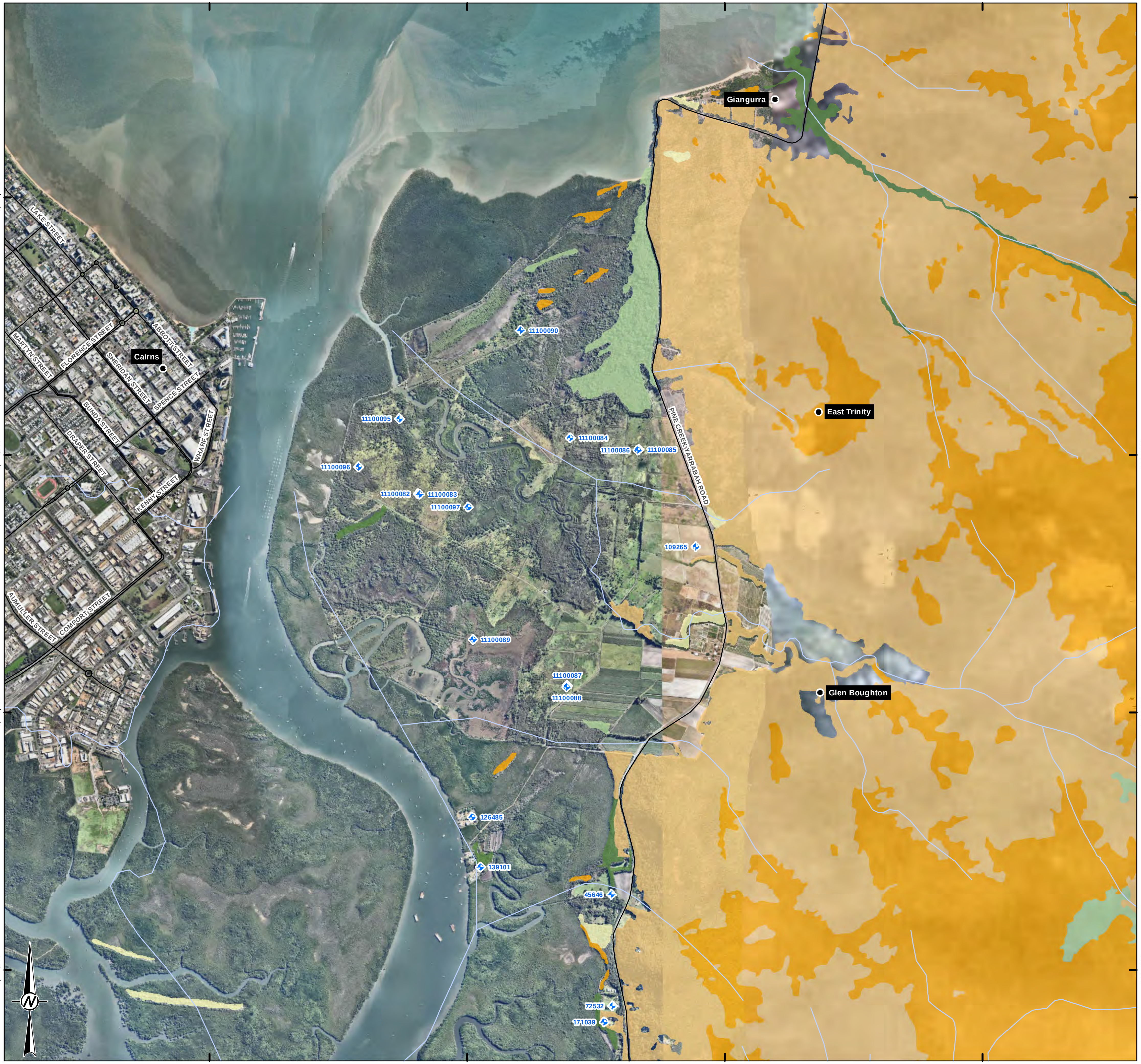
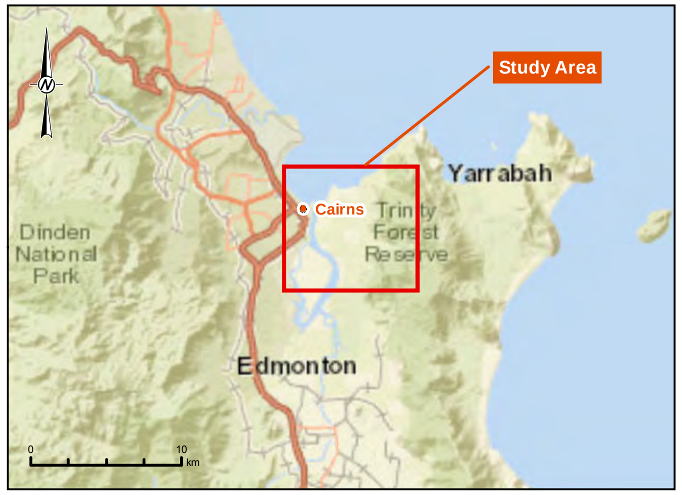


LOCATION MAP



LEGEND

- ● Localities
- Monitoring Boreholes Locations
- Roads and Tracks
- Watercourses (major)

Groundwater Dependent Ecosystems (GDE)

GDE Relient on Surface Expression of Groundwater (rivers, springs, wetlands)

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

GDE Relient on Subsurface Groundwater (vegetation)

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

0 1 2
Kilometres
1:30,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS
BASELINE GROUNDWATER REPORT
EAST TRINITY

TITLE
GROUNDWATER DEPENDENT ECOSYSTEMS: EAST TRINITY

CONSULTANT
Golder Associates

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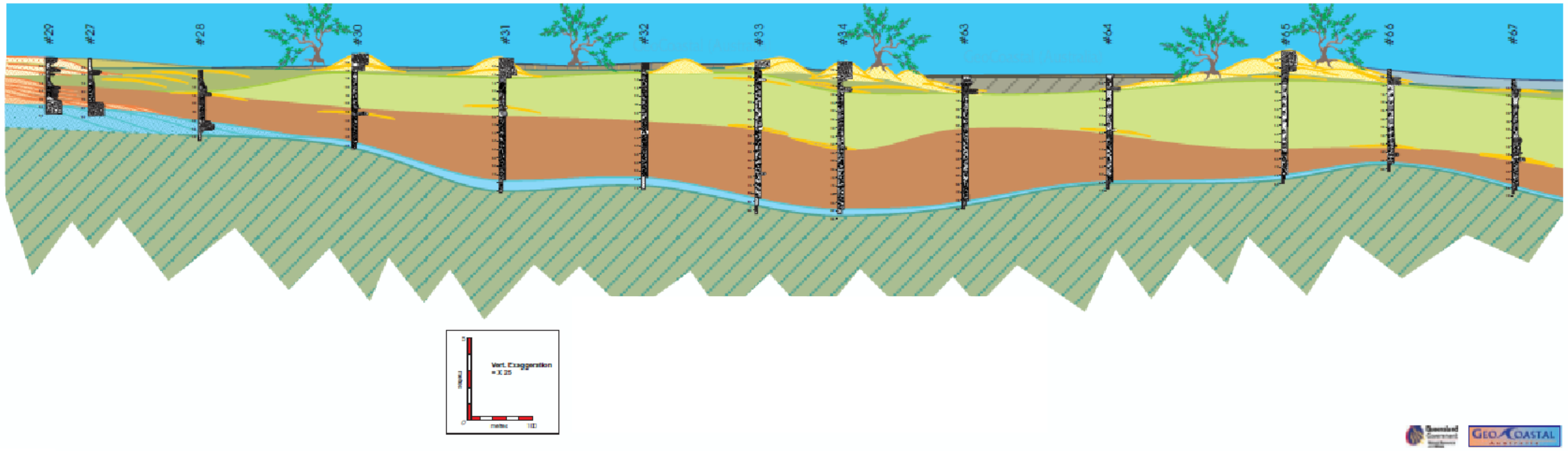
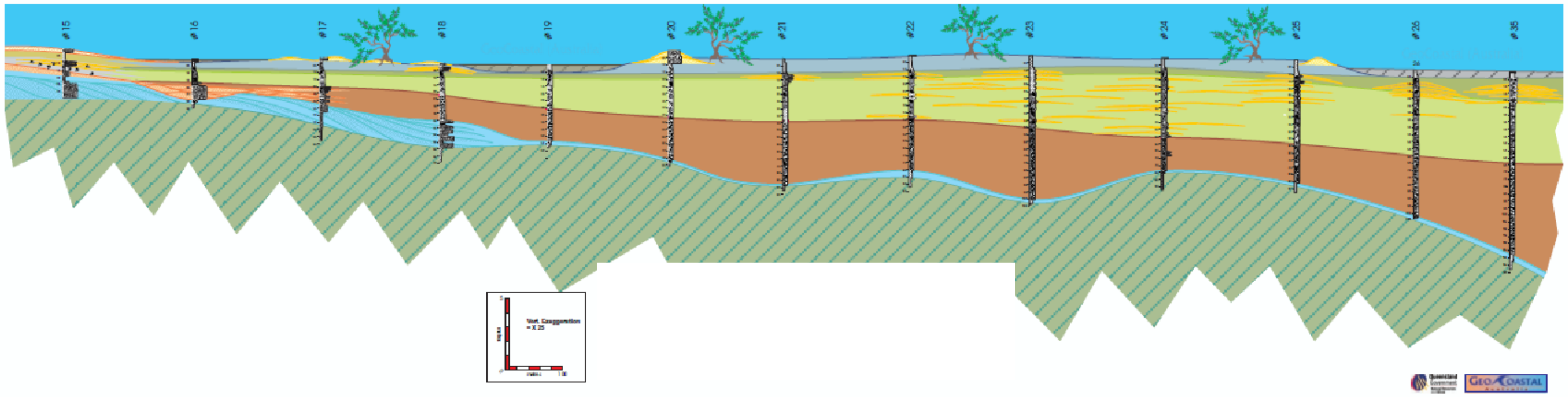


Stratigraphic cross-section along Transect 1, East Trinity.



Stratigraphic cross-section along Transect 2, East Trinity.

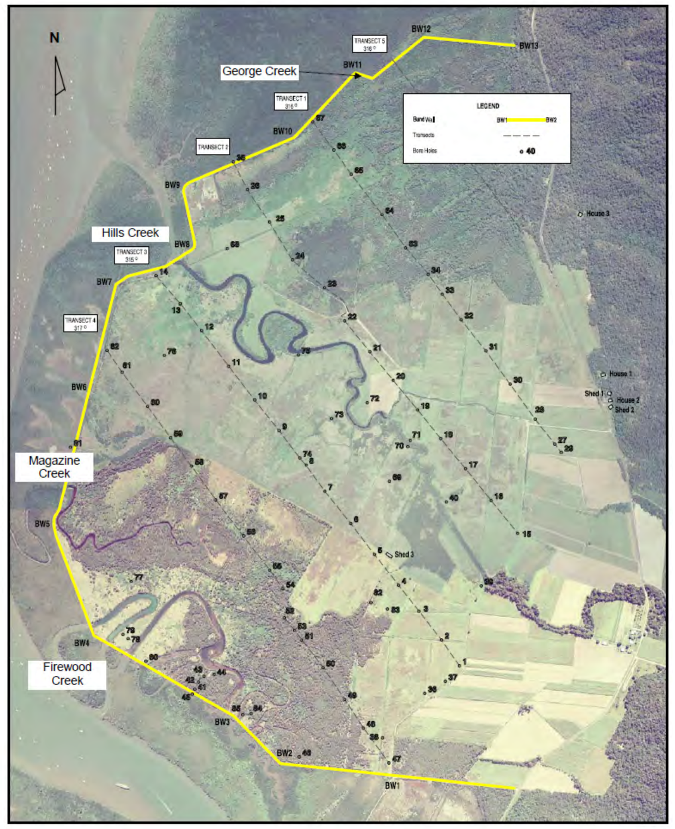
Depositional Facies

Primary chenier plain evolution — *Holocene*:
- Chenier Ridge
- Supratidal plain
- Wave-energy influenced winnowing zone
- Estuary bay/ marine muds
- Transgressive mangrove muds
- Backstepping fluvial delta gravelly, coarse sands
- Modern fluvial delta sands
- Alluvial clay
- Transgressive maximum shelly, sand silt/clay

Post-chenier plain evolution secondary deposition — *Holocene*:
- Organic soil
- Modern tidal mangrove mud
- Secondary stream excavation and estuarine mud backfill

Pleistocene depositional facies — *Pleistocene*:
- Zone of Holocene marine infiltration into upper Pleistocene substrate
- Pleistocene fluvial delta
- Pleistocene clay substrate

TRANSECT MAP



Smith CD, Graham TL, Barry EV, Adams JJ and Ahern CR (2003). Acid Sulfate Soil and Stratigraphic Assessment. In: Demonstration of Management and Rehabilitation of Acid Sulfate Soils at East Trinity: Technical Report. Smith CD, Martens MA, Ahern CR, Eldershaw VJ, Powell B, Barry EV, Hopgood GL and KM Watling (eds). Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

CLIENT
FLANAGAN CONSULTING GROUP

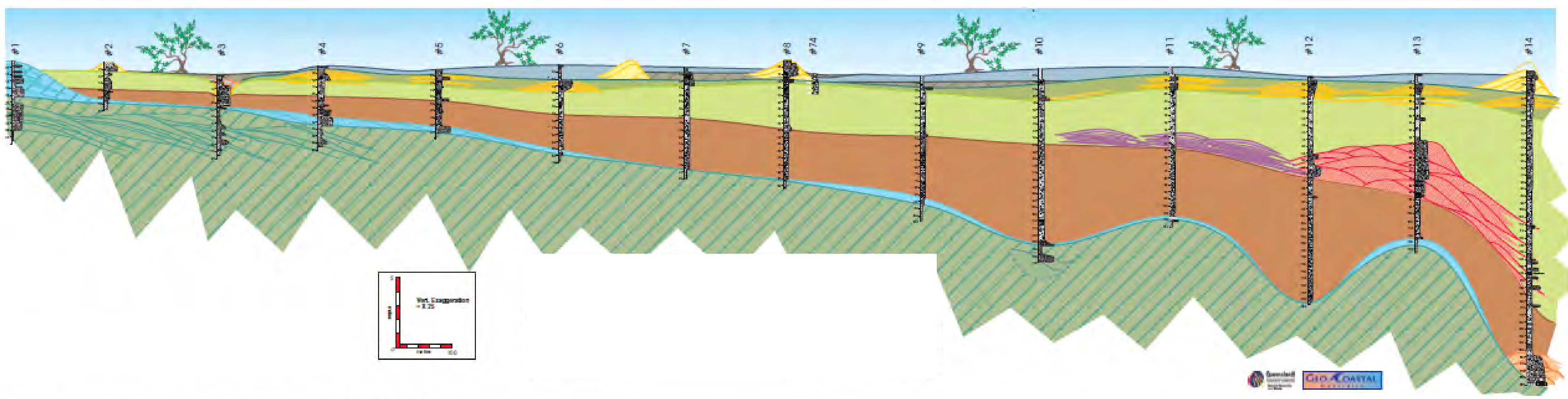
PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS
BASELINE GROUNDWATER REPORT
EAST TRINITY

TITLE
SOIL STRATIGRAPHIC SECTIONS

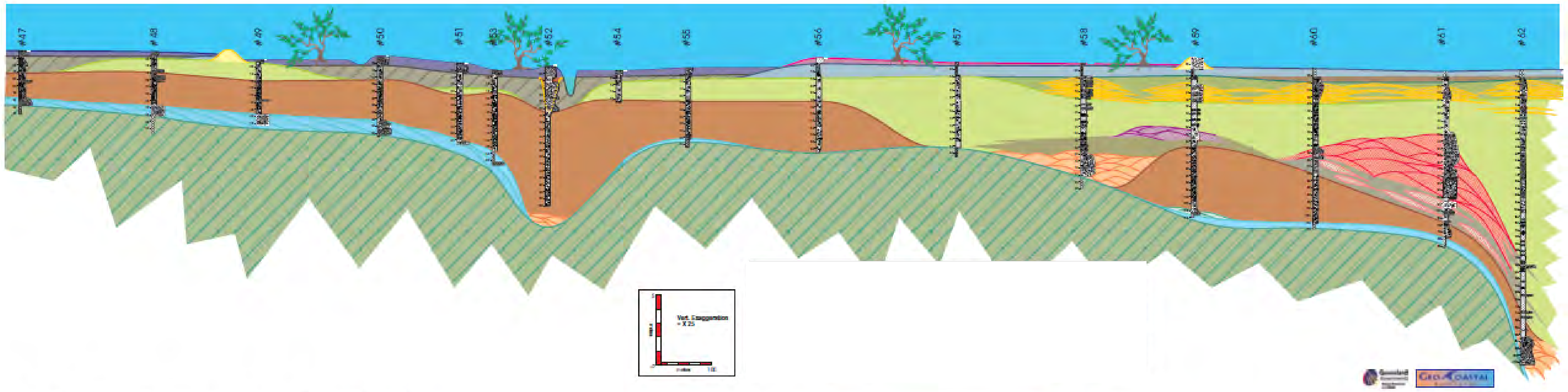
CONSULTANT: Golder Associates

YYYY-MM-DD	2016-08-25
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	007	2	4A



Stratigraphic cross-section along Transect 3, East Trinity.



Stratigraphic cross-section along Transect 4, East Trinity.

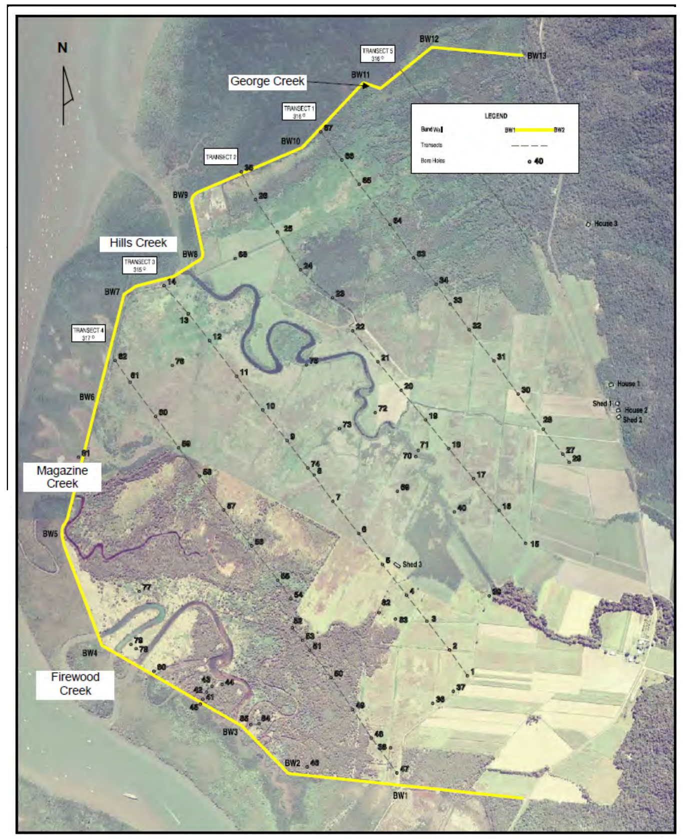
Depositional Facies

Primary chenier plain evolution — *Holocene*
- Chenier Ridge
- Supratidal plain
- Wave-energy influenced winnowing zone
- Estuary bay/ marine muds
- Backstepping fluvial pro-delta fine, laminated sands
- Pro-delta influenced estuary bay deposits
- Backstepping fluvial delta gravelly, coarse sands
- Shelf-edge backstepping fluvial delta deposits
- Fluvial delta influenced estuary bay sandy muds
- Transgressive mangrove muds
- Transgressive sandy lag deposits

Post-chenier plain evolution secondary deposition — *Holocene*
- Feather of Firewood Creek levee deposits
- Alluvial levee and sandy surface veneer
- Secondary stream excavation and estuarine mud backfill

Pleistocene depositional facies — *Pleistocene*
- Zone of Holocene marine infiltration into upper Pleistocene substrate
- Pleistocene fluvial delta
- Pleistocene clay substrate

TRANSECT MAP



Smith CD, Graham TL, Barry EV, Adams JJ and Ahern CR (2003). Acid Sulfate Soil and Stratigraphic Assessment. In: Demonstration of Management and Rehabilitation of Acid Sulfate Soils at East Trinity: Technical Report. Smith CD, Martens MA, Ahern CR, Eldershaw VJ, Powell B, Barry EV, Hopgood GL and KM Watling (eds). Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

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DESIGNED	DP
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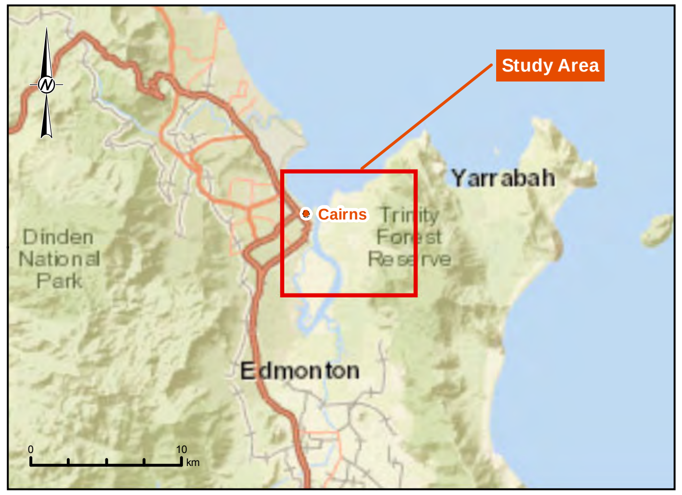
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	007	2	4B

LOCATION MAP



LEGEND

- Localities
- Roads and Tracks
- Drainage (25k)

0 1 2
1:30,000 at A3 Kilometres
PROJECTION: GDA 1994 MGA Zone 55

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TITLE
SITE LOCATION

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PREPARED	DP
DESIGNED	DP
REVIEWED	PS
APPROVED	PS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	007	2	1

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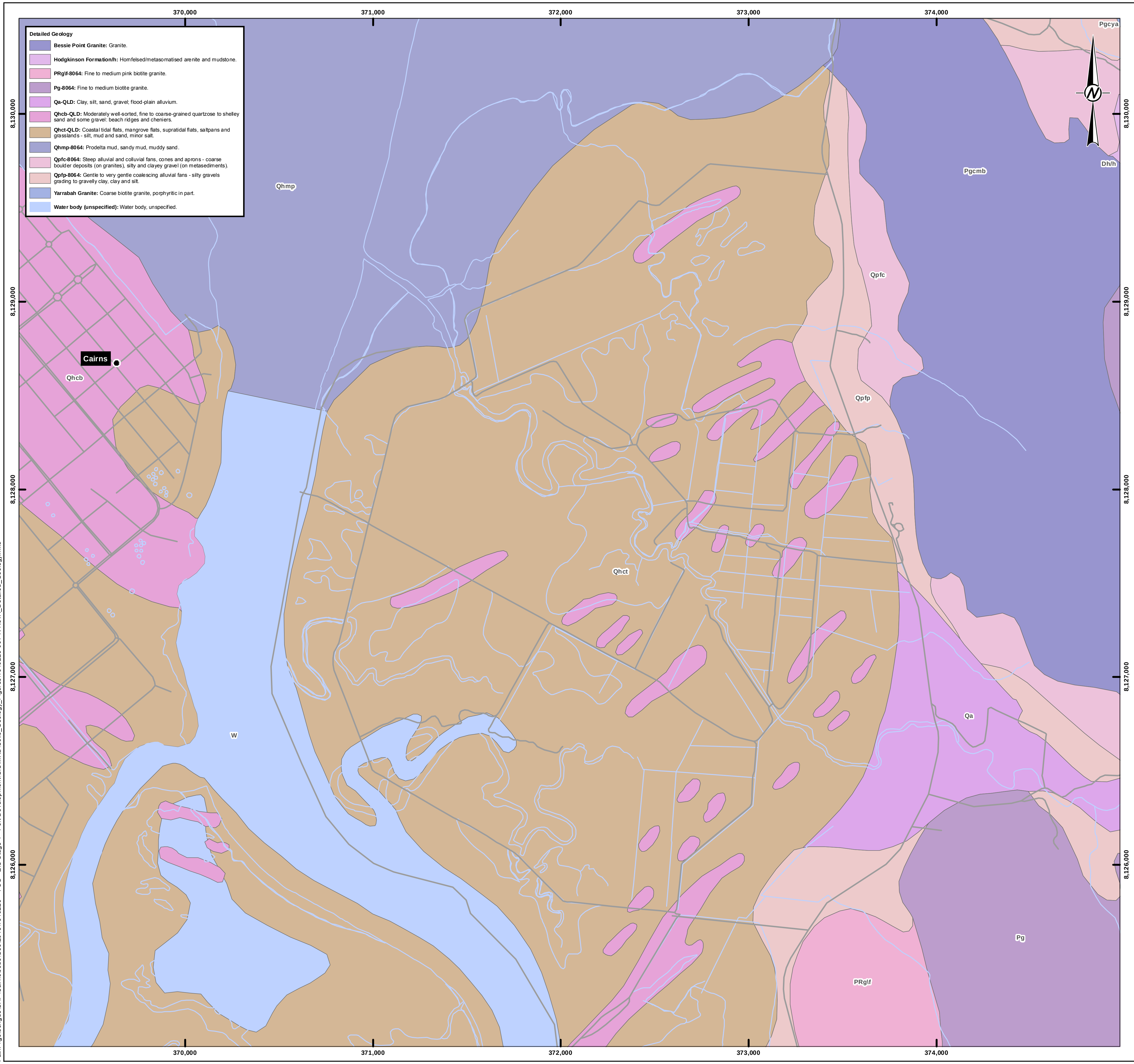
25mm



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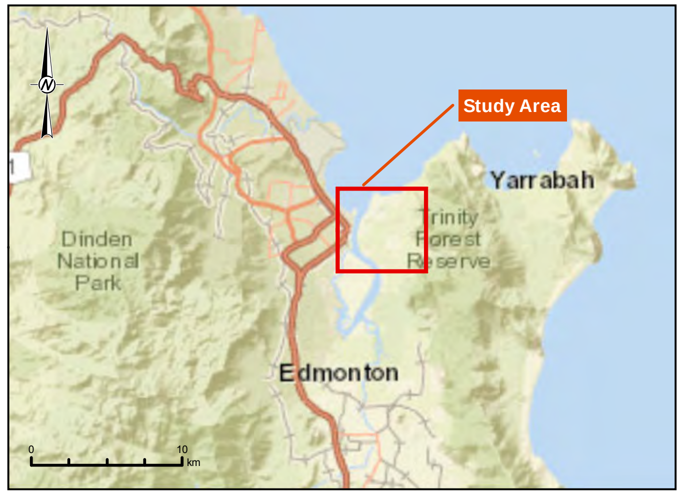

LEGEND

- Localities
- Drainage (25k)
- Roads and Tracks

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0 250 500 750 1,000
1:20,000 at A3 METRES
PROJECTION: GDA 1994 MGA Zone 55

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PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS
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TITLE
SURFICAL GEOLOGY

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	REVIEWED	DS
	APPROVED	DS

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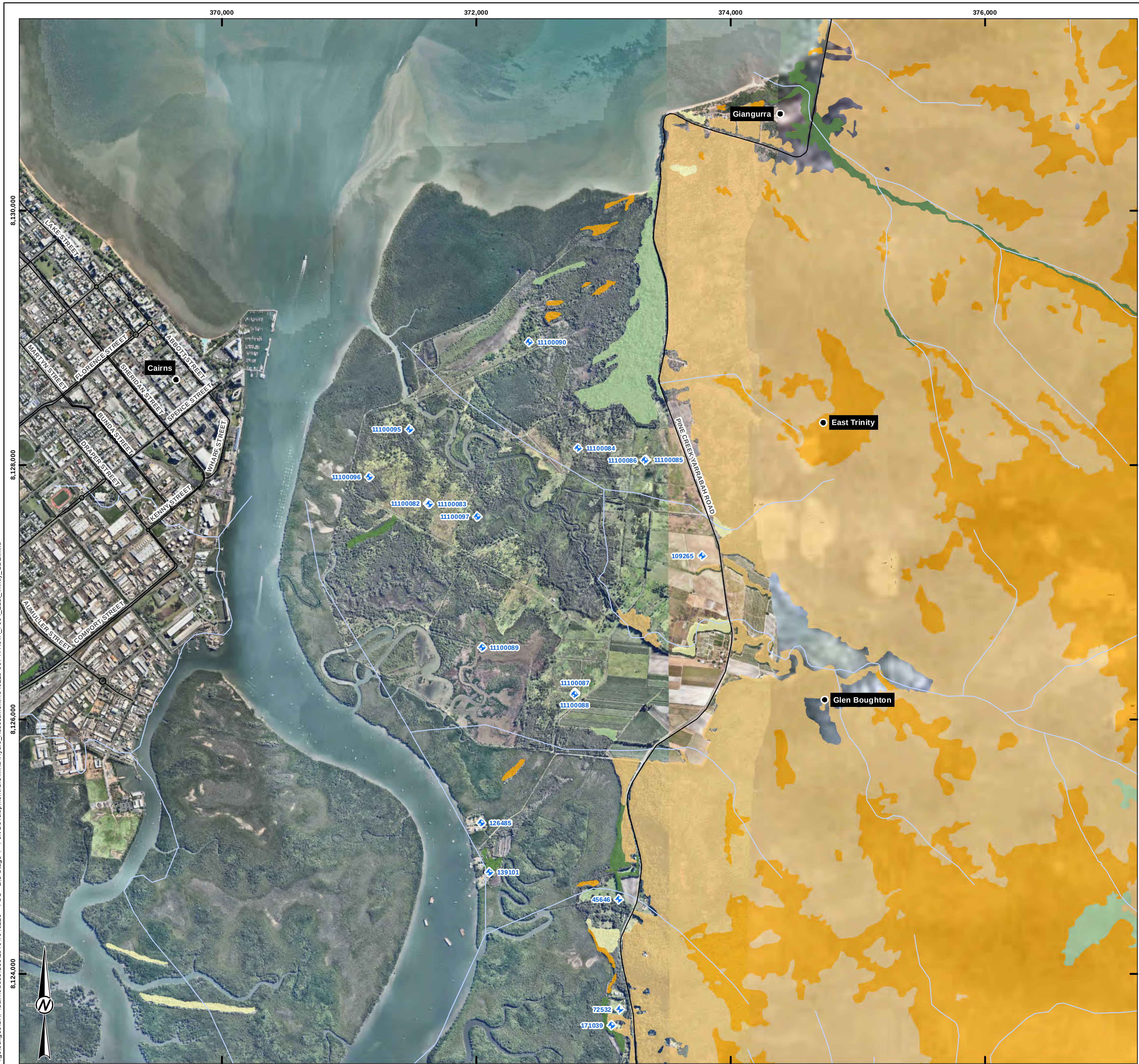
1546223	007	2	2

25mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3



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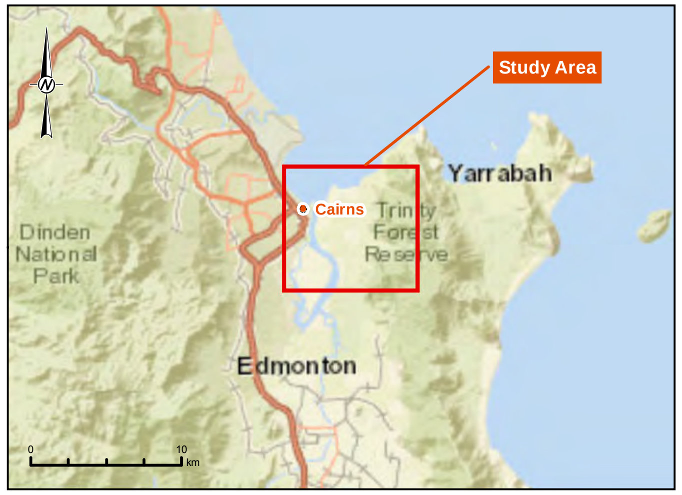
LOCATION MAP



LEGEND

- Localities
- Monitoring Boreholes Locations
- Roads and Tracks
- Watercourses (major)

Groundwater Dependent Ecosystems (GDE)

GDE Relient on Surface Expression of Groundwater (rivers, springs, wetlands)

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

GDE Relient on Subsurface Groundwater (vegetation)

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

0 1 2
1:30,000 at A3 Kilometres
PROJECTION: GDA 1994 MGA Zone 55

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PROJECT
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BASELINE GROUNDWATER REPORT EAST TRINITY

TITLE
GROUNDWATER DEPENDENT ECOSYSTEMS: EAST TRINITY

CONSULTANT: Golder Associates

YYYY-MM-DD	2016-09-01
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APPROVED	DS

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1546223	007	2	3

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25mm
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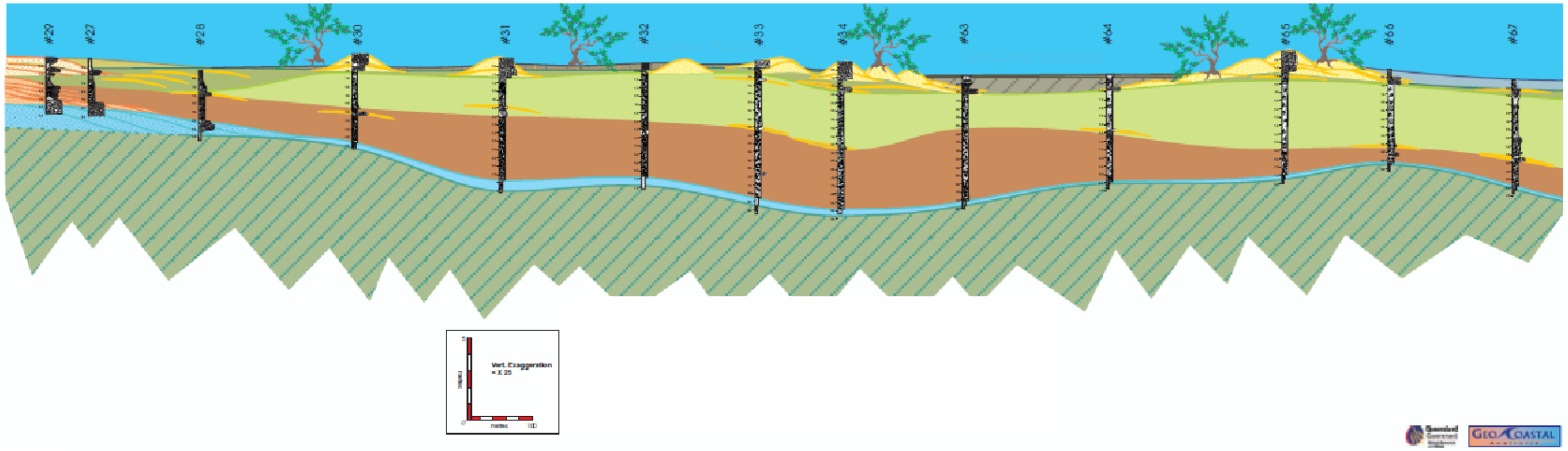
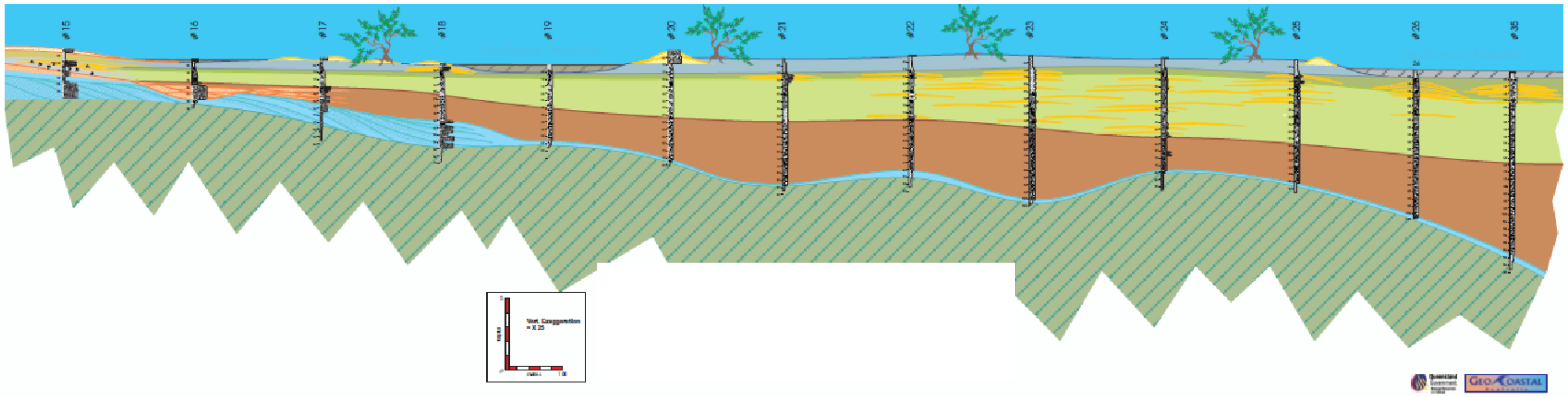


Stratigraphic cross-section along Transect 1, East Trinity.



Stratigraphic cross-section along Transect 2, East Trinity.

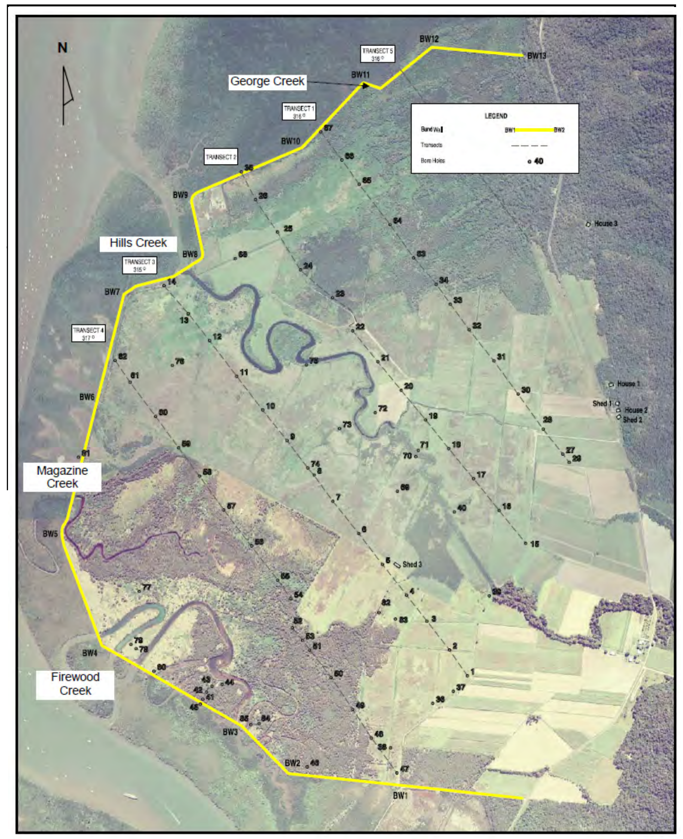
Depositional Facies

Primary chenier plain evolution — *Holocene*
- Chenier Ridge
- Supratidal plain
- Wave-energy influenced winnowing zone
- Estuary bay/ marine muds
- Transgressive mangrove muds
- Backstepping fluvial delta gravelly, coarse sands
- Modern fluvial delta sands
- Alluvial clay
- Transgressive maximum shelly, sand silt/clay

Post-chenier plain evolution secondary deposition — *Holocene*
- Organic soil
- Modern tidal mangrove mud
- Secondary stream excavation and estuarine mud backfill

Pleistocene depositional facies — *Pleistocene*
- Zone of Holocene marine infiltration into upper Pleistocene substrate
- Pleistocene fluvial delta
- Pleistocene clay substrate

TRANSECT MAP



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BASELINE GROUNDWATER REPORT EAST TRINITY

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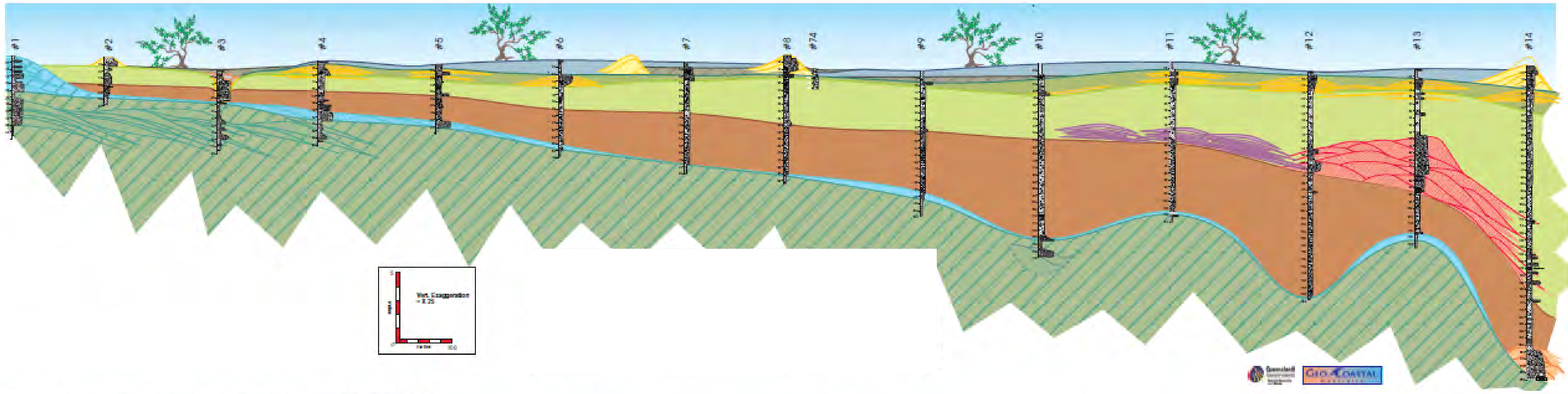
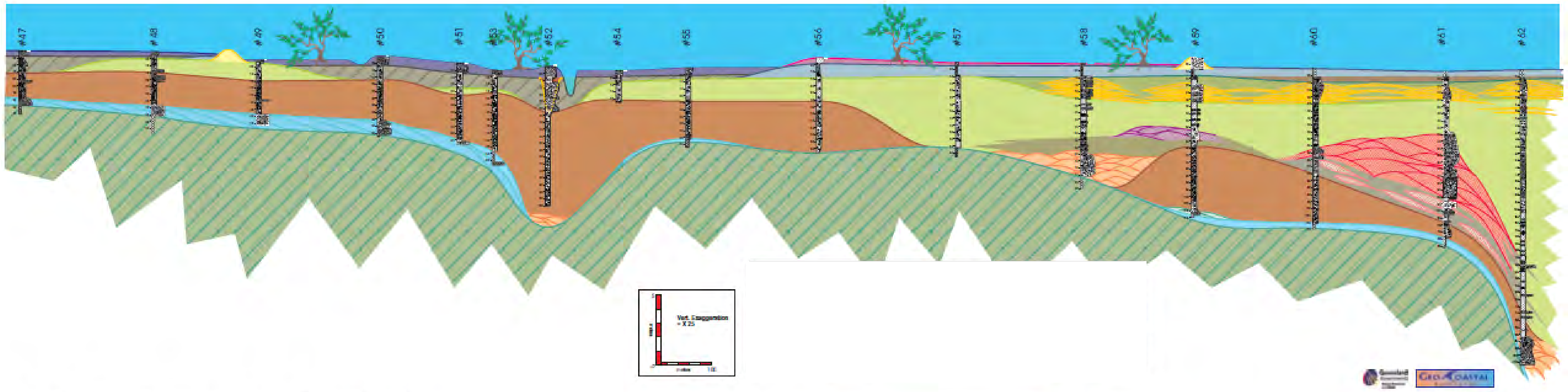
CONSULTANT		
Golder Associates	YYYY-MM-DD	2016-08-25
	PREPARED	DP
	DESIGNED	DP
	REVIEWED	DS
	APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	007	2	4A



Stratigraphic cross-section along Transect 3, East Trinity.



Stratigraphic cross-section along Transect 4, East Trinity.

Depositional Facies

Primary chenier plain evolution — *Holocene*
- Chenier Ridge
- Supratidal plain
- Wave-energy influenced winnowing zone
- Estuary bay/marine muds
- Backstepping fluvial pro-delta fine, laminated sands
- Pro-delta influenced estuary bay deposits
- Backstepping fluvial delta gravelly, coarse sands
- Shelf-edge backstepping fluvial delta deposits
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Post-chenier plain evolution secondary deposition — *Holocene*
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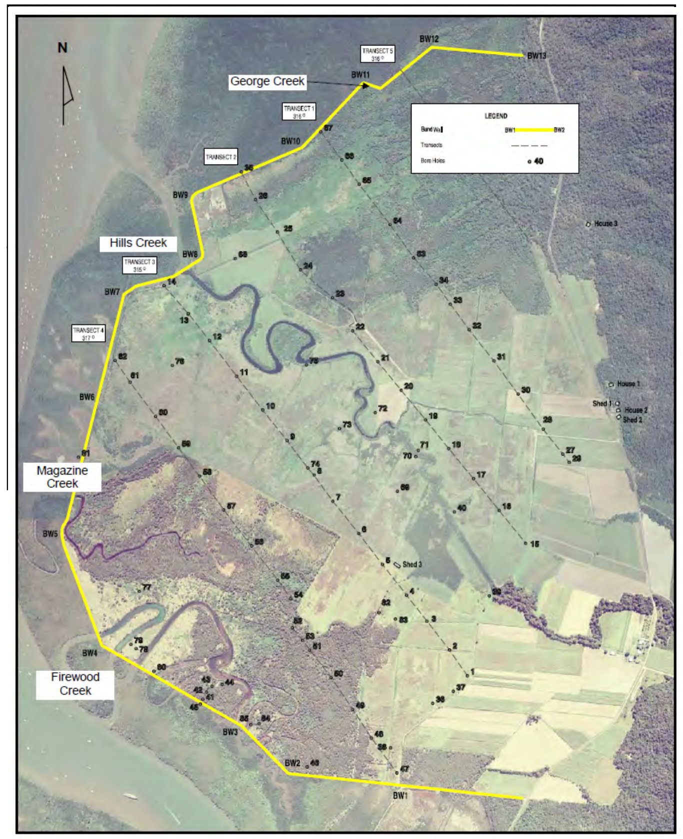
Pleistocene depositional facies — *Pleistocene*
- Zone of Holocene marine infiltration into upper Pleistocene substrate
- Pleistocene fluvial delta
- Pleistocene clay substrate

TRANSECT MAP



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Smith CD, Graham TL, Barry EV, Adams JJ and Ahern CR (2003). Acid Sulfate Soil and Stratigraphic Assessment. In: Demonstration of Management and Rehabilitation of Acid Sulfate Soils at East Trinity: Technical Report. Smith CD, Martens MA, Ahern CR, Eldershaw VJ, Powell B, Barry EV, Hopgood GL and KM Watling (eds). Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

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PROJECT NO.	CONTROL	REV.	FIGURE
1546223	007	2	4B

APPENDIX A

Shallow Aquifer Hydrographs

Piezometer 11100096 data (Figures D2-a and D2-b) show both the delayed response to rainfall events and EC measurements unaffected by alterations to the surface water system that are evident in the data from piezometer 95. The pH increase after June 2002 (Figure D2-b) corresponds to the cessation of rainfall and therefore is likely to be influenced by a decrease in the acid flushing from the soil, where it is formed *in situ*, and into the groundwater system. This is further supported by the pH drop following the small rainfall event in October 2002.

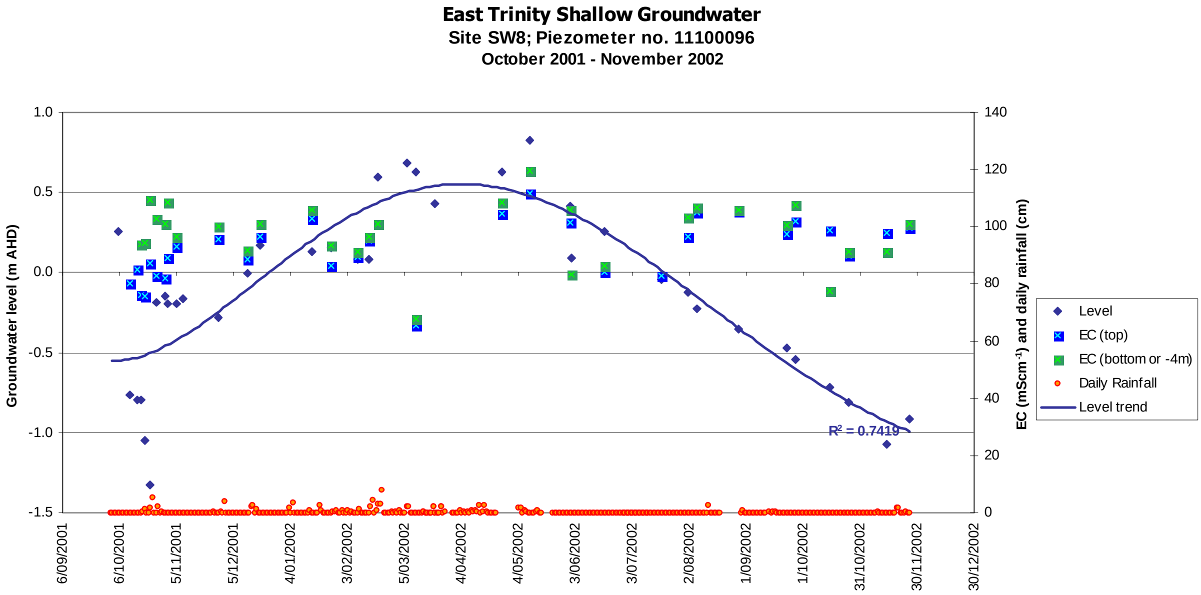

Figure D2-a. EC, groundwater level and daily rainfall data for shallow groundwater piezometer 11100096 at site SW8.

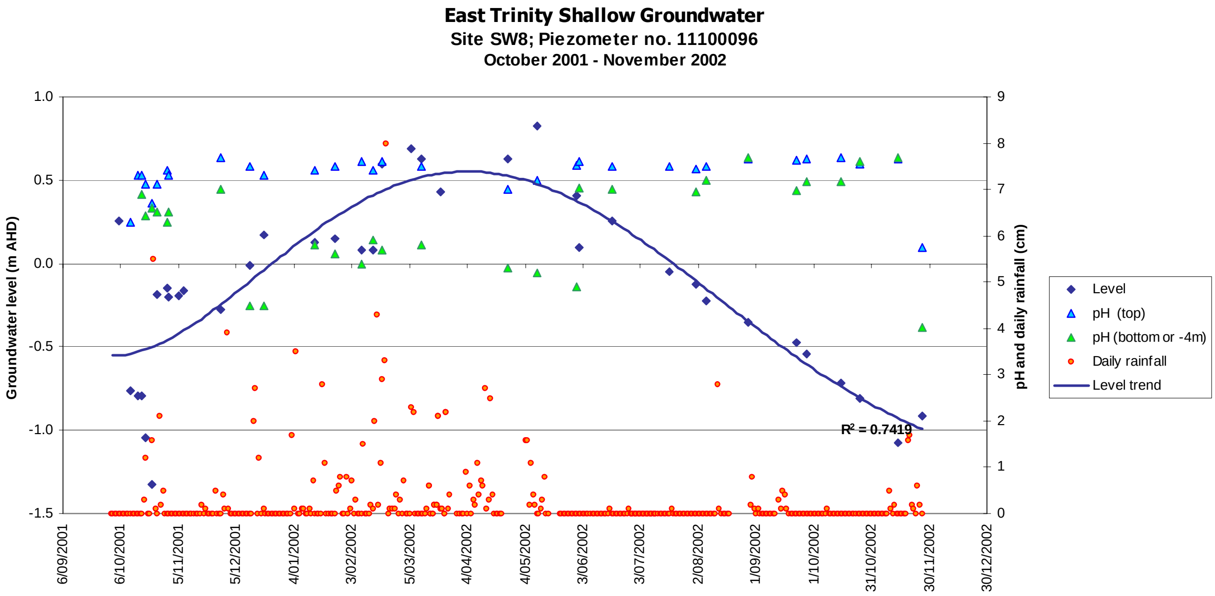

Figure D2-b. pH, groundwater level and daily rainfall data for shallow groundwater piezometer 11100096 at site SW8.

Data from piezometer 11100097 are shown in Figures D3-a and D3-b. This is obviously a very dynamic system. The spike in groundwater levels in September 2002 may have been influenced by the particularly high water levels in the drainage lines on-site. Increased drain water levels were due to the confluence of the automatic tidal regulators (ATRs) allowing an increased amount of water into the site's drainage system and the mid-point of the tidal cycle where low tides are relatively high an prohibit the opening of the ATRs on the ebb tide, therefore backing up the water in the on-site drainage system.

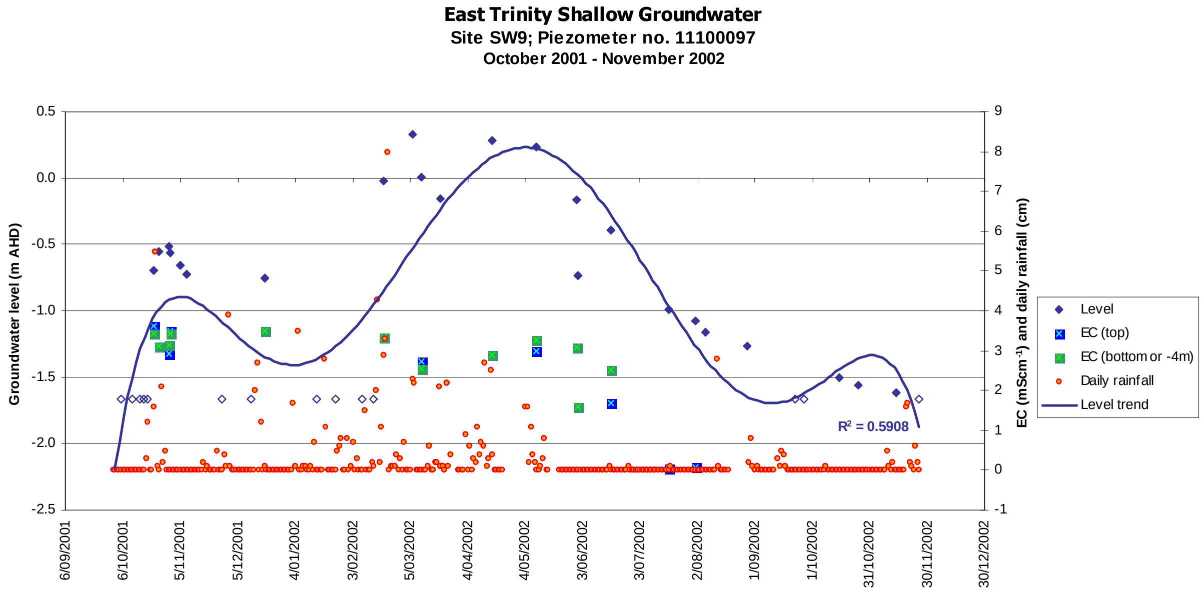

Figure D3-a. EC, groundwater level and daily rainfall data for shallow groundwater piezometer 11100097 at site SW9.

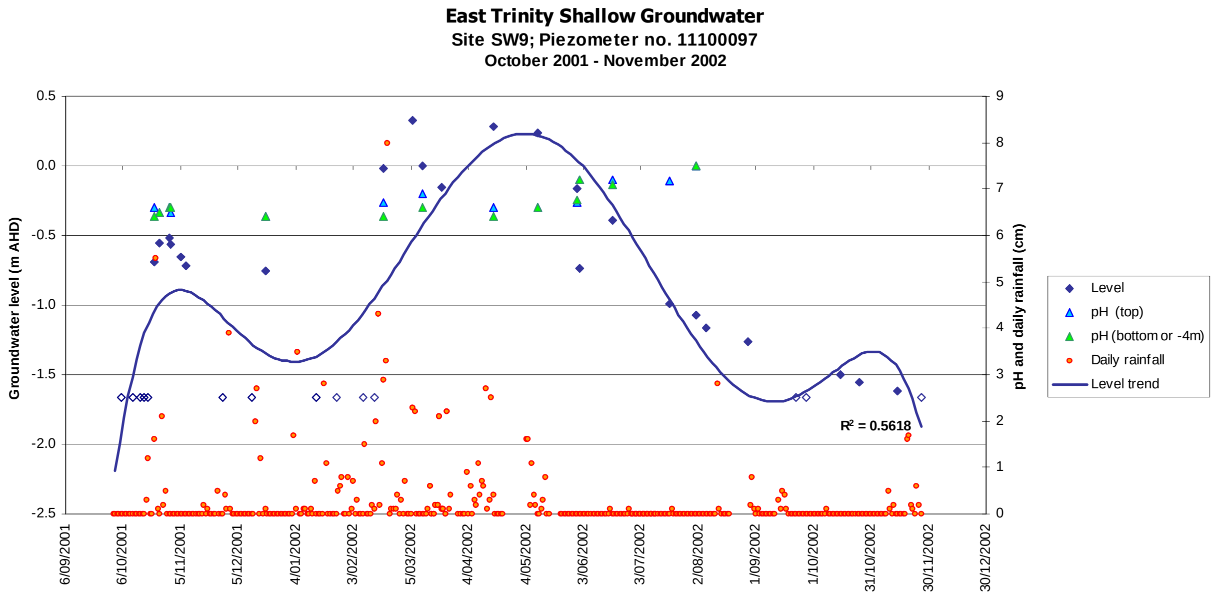

Figure D3-b. pH, groundwater level and daily rainfall data for shallow groundwater piezometer 11100097 at site SW9.

APPENDIX B

Deep Aquifer Hydrographs

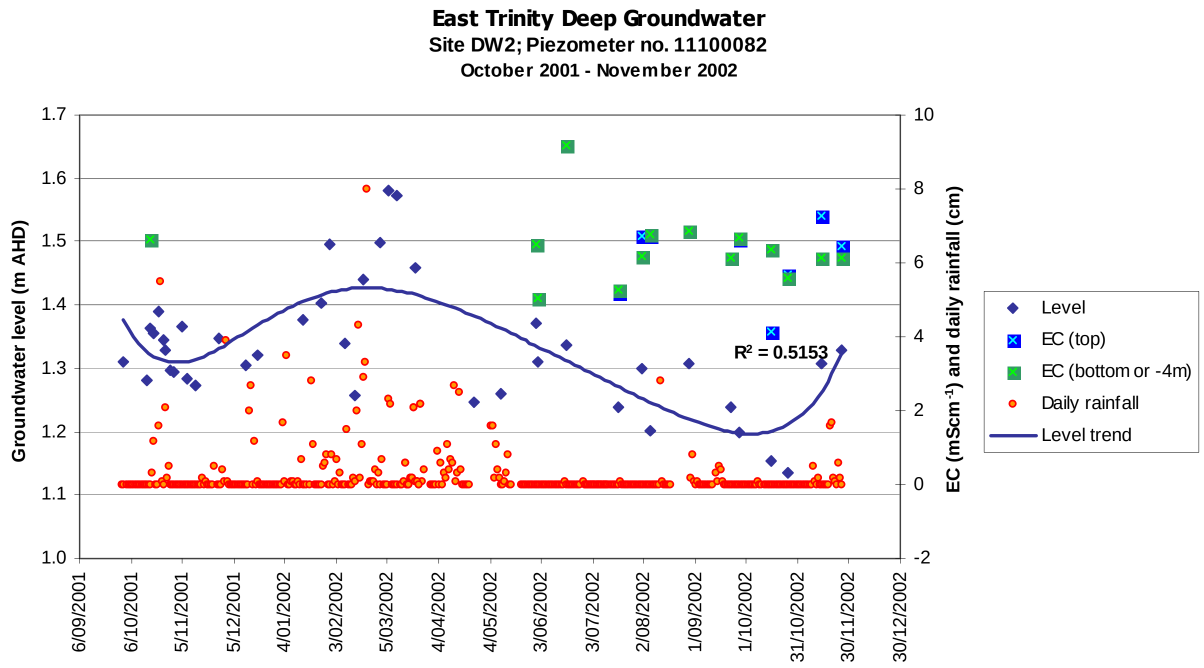

Figure C1-a. EC, groundwater level and daily rainfall data for deep groundwater bore 11100082 at site DW2.

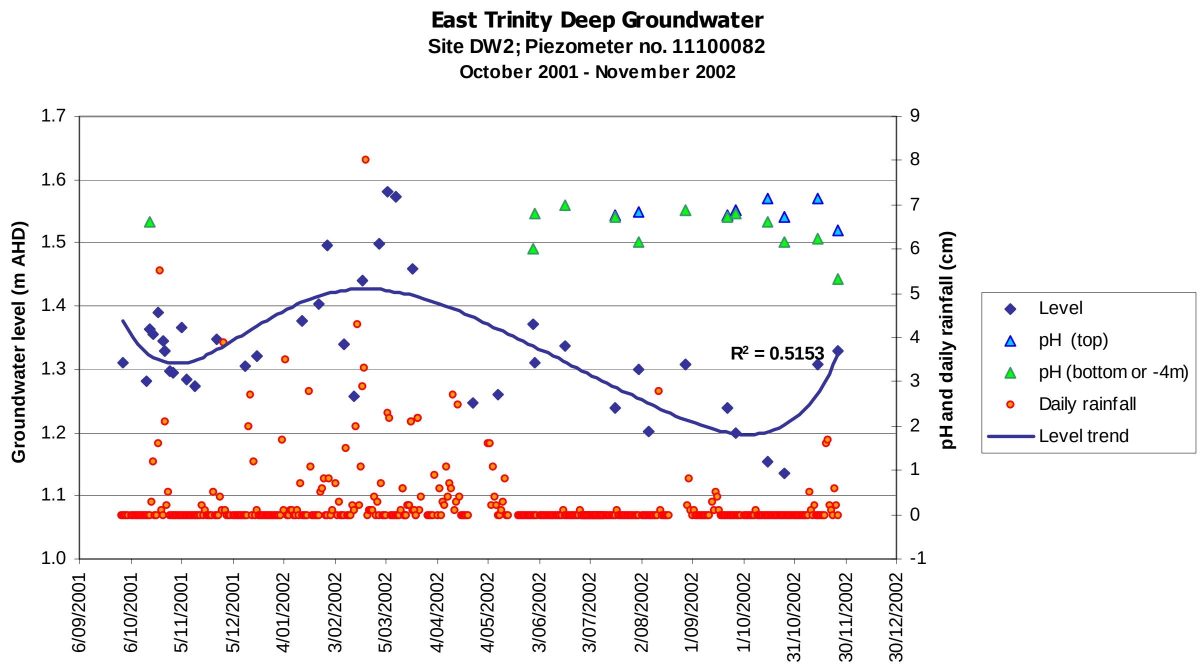

Figure C1-b. pH, groundwater level and daily rainfall data for deep groundwater bore 11100082 at site DW2.

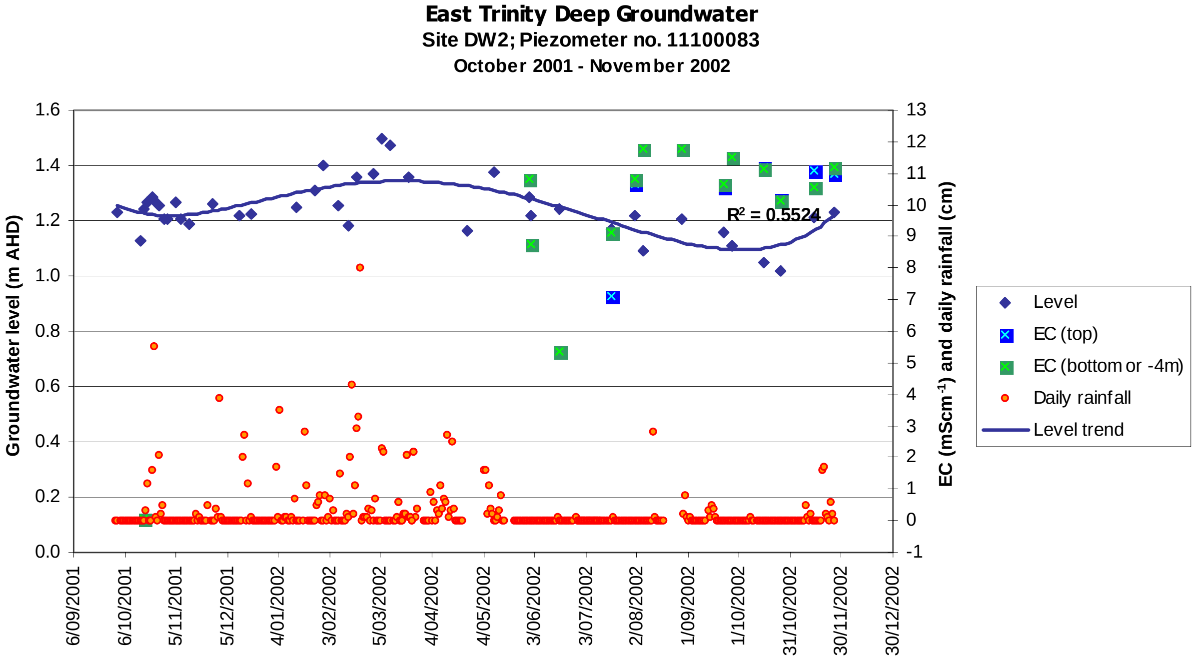

Figure C2-a. EC, groundwater level and daily rainfall data for deep groundwater bore 11100083 at site DW2.

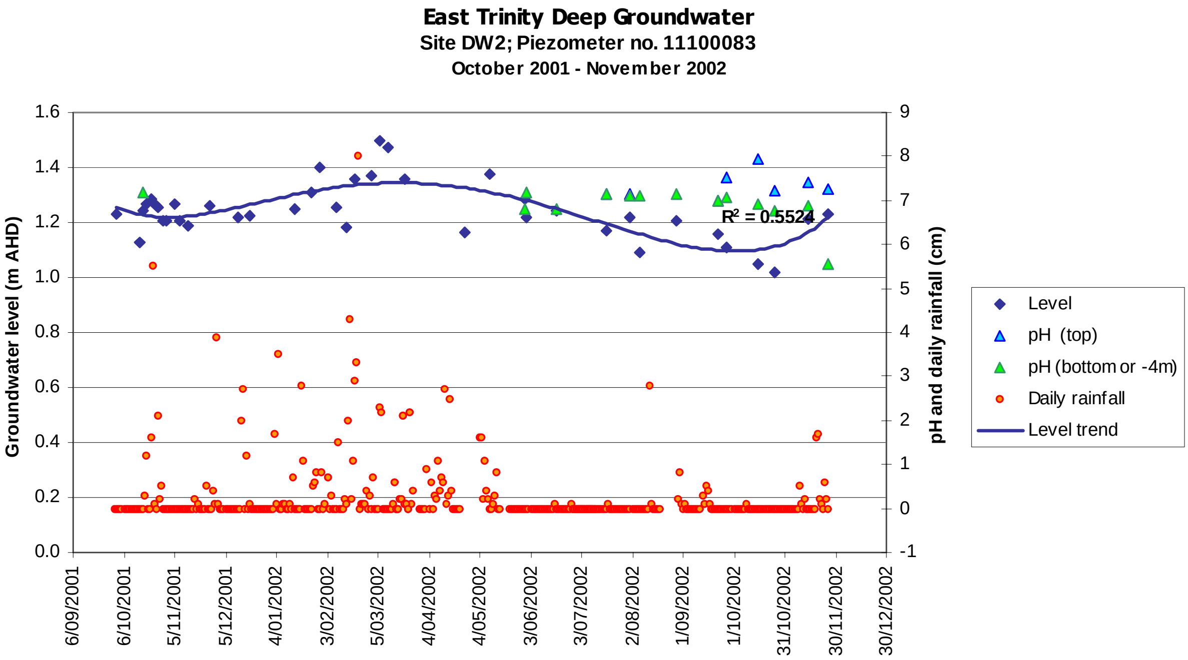

Figure C2-b. pH, groundwater level and daily rainfall data for deep groundwater bore 11100083 at site DW2.

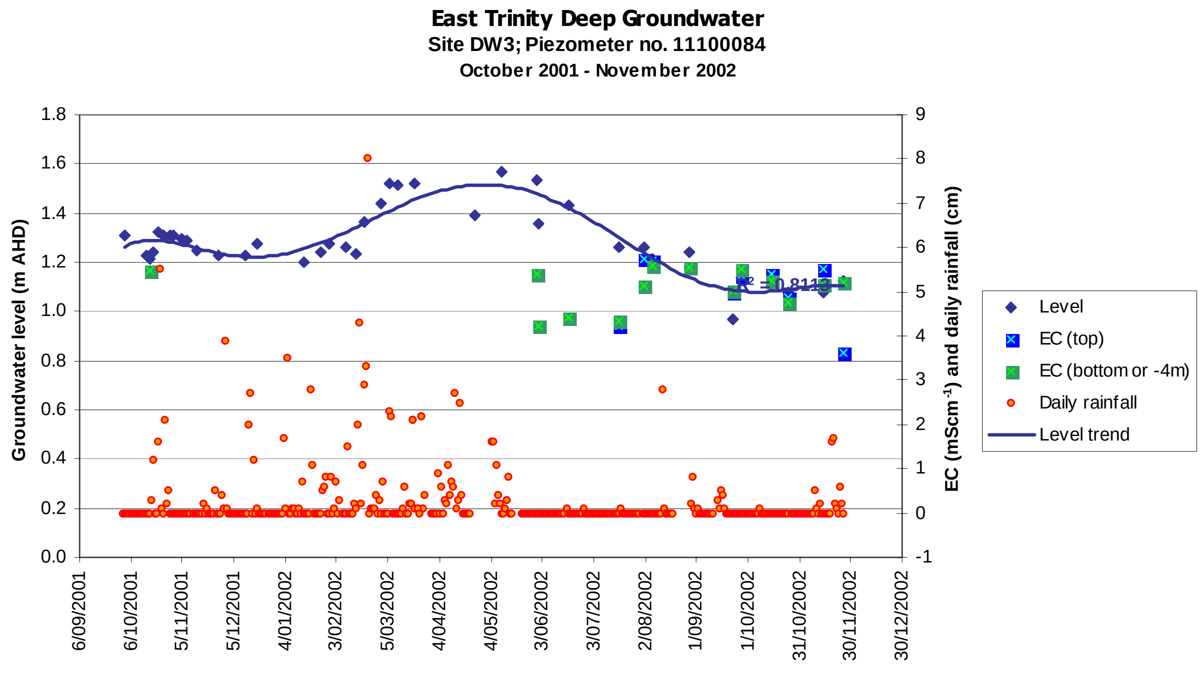

Figure C3-a. EC, groundwater level and daily rainfall data for deep groundwater bore 11100084 at site DW3.

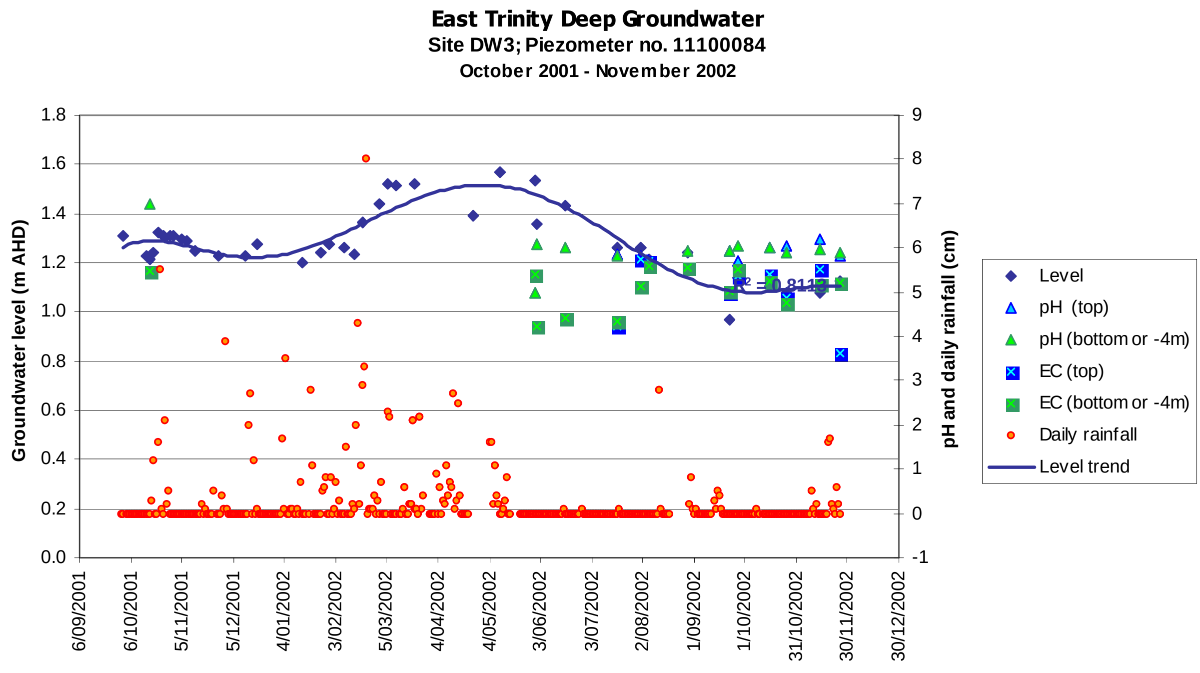

Figure C3-b. pH, groundwater level and daily rainfall data for deep groundwater bore 11100084 at site DW3.

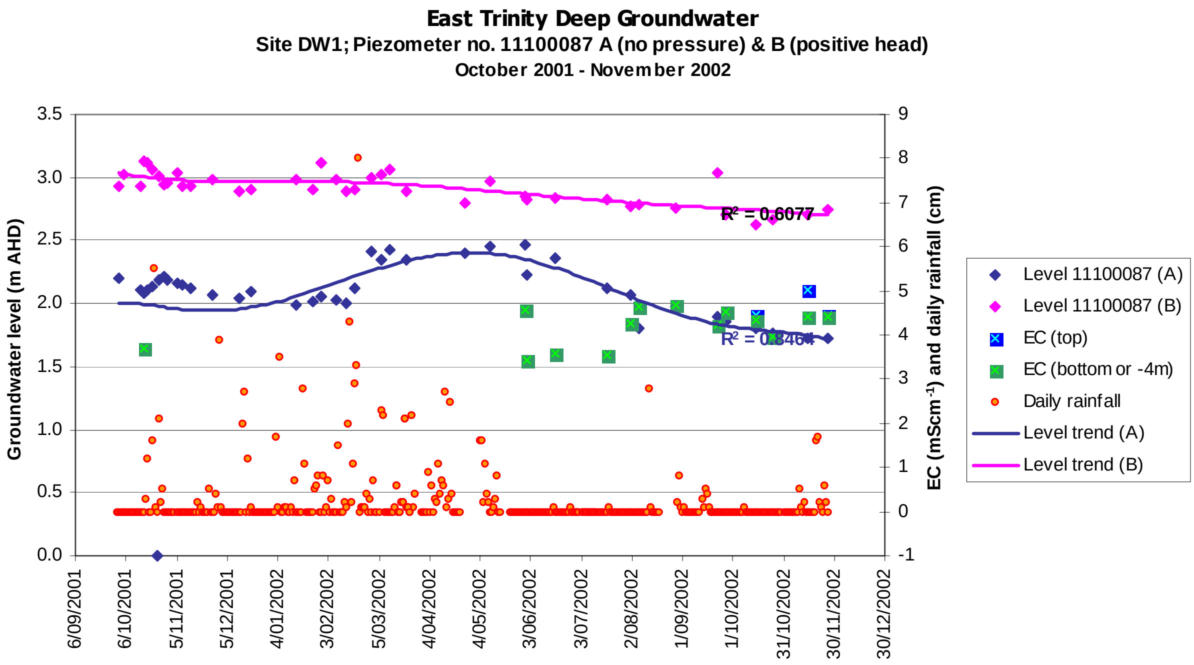

Figure C4-a. EC, groundwater levels [no pressure (A) and positive head (B)] and daily rainfall data for deep groundwater bore 11100087 at site DW1.

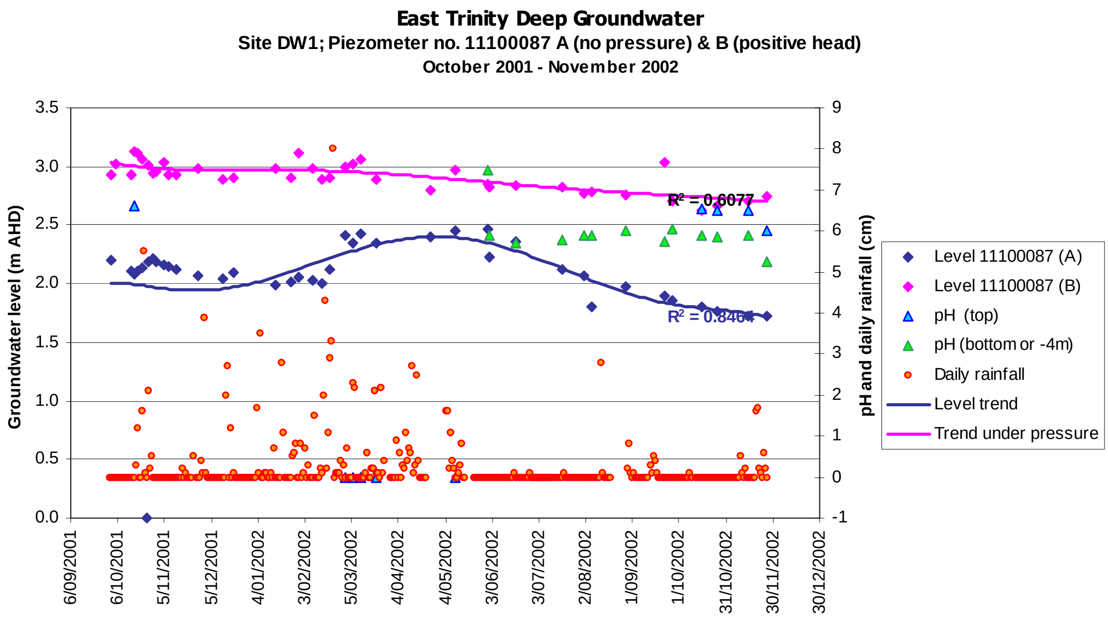

Figure C4-b. pH, groundwater levels [no pressure (A) and positive head (B)] and daily rainfall data for deep groundwater bore 11100087 at site DW1.

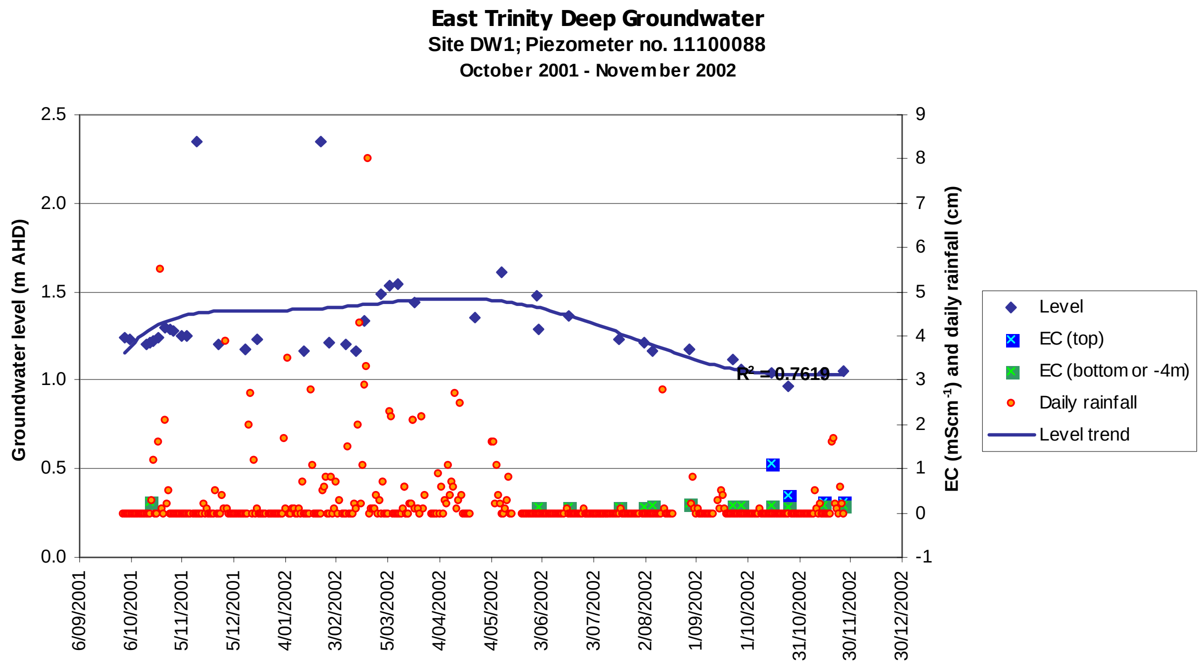

Figure C5-a. EC, groundwater level and daily rainfall data for deep groundwater bore 11100088 at site DW1.

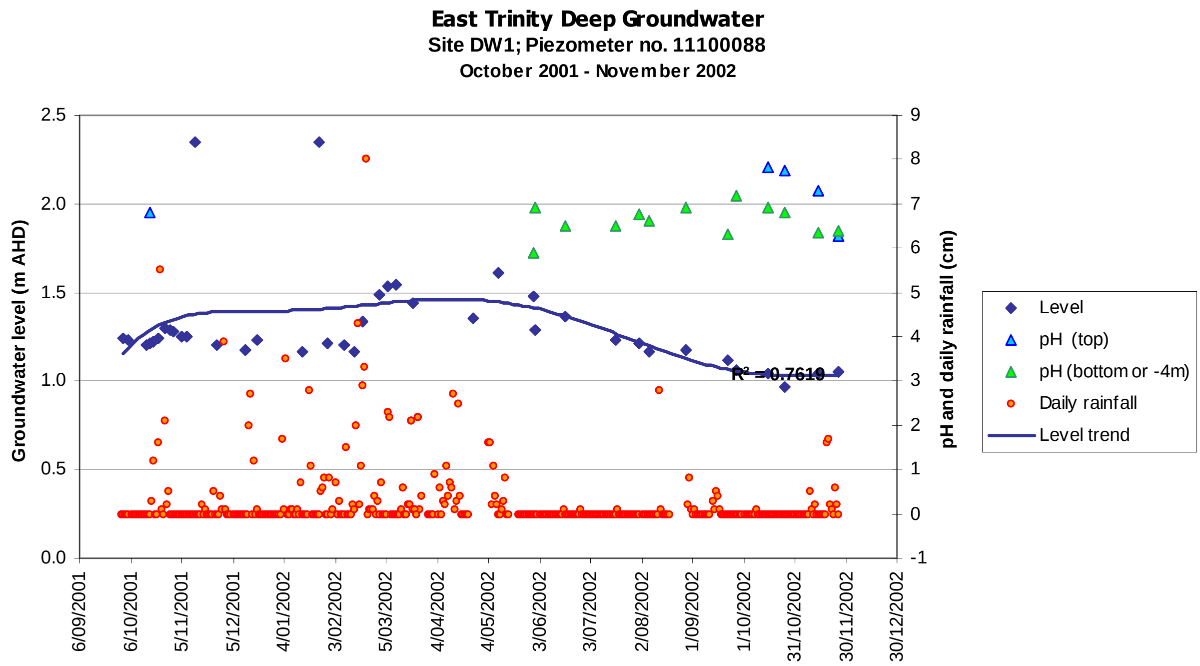

Figure C5-b. pH, groundwater level and daily rainfall data for deep groundwater bore 11100088 at site DW1.

APPENDIX C

Important Information Relating to This Document

IMPORTANT INFORMATION RELATING TO THIS REPORT

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