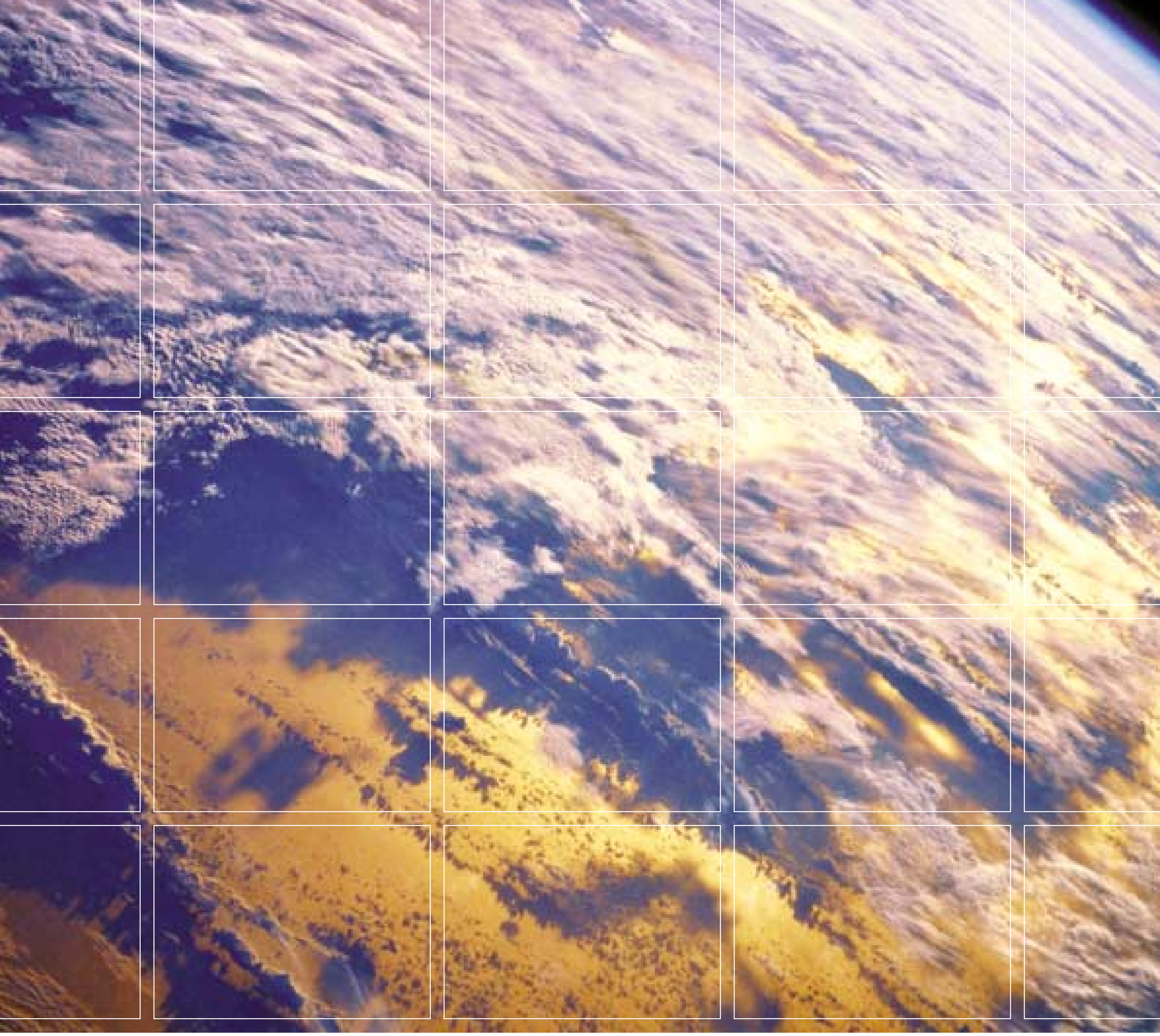

# Wool and Jervis Bay Road, Vincentia

## Hydrogeological Study

Stockland

January 2006

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ERM

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|---|---|
| Approved by: | *Lange Jorstad* |
| Position: | Project Manager |
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| Date: | *24 January 2006* |
| Approved by: | *Belinda Ingpen* |
| Position: | Project Director |
| Signed: | Belinda J Ingpen |
| Date: | *24 January 2006* |

*Environmental Resources Management Australia Pty Ltd Quality System*

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**FINAL REPORT**

Stockland

# Wool and Jervis Bay Road Vincentia
## *Hydrogeological Study*

15 January 2006

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CONTENTS

# 1 INTRODUCTION

Environmental Resources Management Australia Pty Ltd (ERM) was commissioned by Stockland to carry out a hydrogeological study comprising several properties located to the north of the intersection of The Wool Road and Jervis Bay Road near the village of Vincentia, NSW (*Figure 1, Annex*). The legal description of the entire site is Lots 801 and 802 in DP 1022286 and Lots 72 – 75 in DP 874040 (the site) which include all public roads contained on these lots. The scope of works described herein forms part of the hydrogeological investigations performed on Lot 801 which is to be integrated into the Vincentia Stockland proposal being submitted to the Department of Planning for concept project approval.

## 1.1 DESCRIPTION OF STOCKLANDS PROPOSAL

Stockland is seeking project approval for a residential subdivision and concept approval for a district town centre in the south east corner of the site and an adaptable housing area adjacent to the Bay and Basin Leisure centre. A description is summarised below.

The residential subdivision includes:

- a total of 604 lots;
- approximately 60 hectares (47 percent of the site) of open space area, which would be comprised of environmental conservation areas, asset protection zones and urban parks;
- an internal road network with three access points to Naval College Road; and
- construction works related to providing physical infrastructure and services including some vegetation clearing.

The concept plan for the district town centre includes:

- building footprints;
- an indicative total floor area of 32,000 square metres with approximately 20,000 square metres proposed in Stage 1 and 12,000 square metres proposed in Stage 2;
- a range of uses including a discount department store, supermarket, library, medical centre, child care centre, restaurants, bulky goods, potential housing and specialty retail;
- a site (Stage 3) for future bulky goods development;
- a road network that includes a main street, access to The Wool Road and access to a proposed road in the subdivision;

- an indicative total of 1,399 car parking spaces to be provided in two car parking areas and at the upper level of future buildings; and
- a water feature and open space areas.

The concept plan for the adaptable housing area adjacent to the Bay and Basin Leisure centre includes an internal road network, indicative residential lot layout and access to The Wool Road. Refer to *Figure 2 in Annex A*.

## 1.2 *PURPOSE OF THE STUDY*

The purpose of the study was to obtain detailed information concerning the hydrogeological characteristics of Lot 801 DP 1022286 within the subject site. It is understood that this portion of the site contains the endangered Jervis Bay Leek Orchid (*Prasophyllum affine*), which is currently the subject of a Draft Recovery Plan prepared by the National Parks and Wildlife Service. It is anticipated that a commercial development will be accommodated on Lot 801 and consideration therefore must be given to potential impacts on the Leek Orchid.

A potential change to groundwater hydrology is a critical consideration in assessing the potential impacts of the commercial development on the Leek Orchid. In consultation with ERM's ecology team, the study is designed to consider the needs of the Leek Orchid from a groundwater perspective and what measures are required to mitigate potential impacts to the Orchid resulting from the development of Lot 801.

### 1.2.1 *Project Scope And Methodology*

To achieve the project objective of providing appropriate hydrogeological input to the Stockland proposal the following scope of work has been completed:

- Obtain and review relevant information from government departments, Council and other specialist consultants, including maps, reports and monitoring data;
- Attend a meeting with the hydrogeological and ecological consultants during the data review stage to understand relevant information and constraints;
- Review existing geotechnical reports and liaise with geotechnical consultants to establish existing water levels and groundwater flow regimes in the study area;
- Map area within Lot 801 under threat of water logging, water table drawdown, contamination and salinisation and make recommendations on suitable management;

- Determine the prevailing climatic conditions within the locality (in particular, average rainfall) and the effect on hydrological processes. This task included the interpretation of information provided from the Bureau of Meteorology and the hydrological consultant;

- Identify the geology of the region, specifically with reference to Lot 801. This information was compiled from available geological maps and from interpretation of information provided by the geotechnical consultant;

- In consultation with ERM's ecology team, consider the potential impact of development, from a hydrogeological perspective, on the Jervis Bay Leek Orchid and other threatened or endangered species, and recommend appropriate groundwater management strategies; and

- Prepare a report that addresses the issues raised above.

## 2 SITE DESCRIPTION

### 2.1 LOCATION AND TOPOGRAPHY

The study area is situated on the northern corner of the intersection of Jervis Bay Road and the Wool Road at Vincentia, New South Wales (*Figures 1 and 2, Annex A*). The site is bounded to the:

- Southeast by the Wool Road and park/woodland;
- Southwest by Jervis Bay Road and existing rural residential development;
- Northwest by National Park and crown land; and
- Northeast by National Park and the existing Council-operated Bay and Basin Leisure Centre.

The topography of the site is dominated by two northeast trending ridgelines dissected by three ephemeral natural watercourses flowing north to northeast into adjacent wetlands within the National Park. Vegetation over the site varies from heathland and closed shrubland to woodland and open forest. The site topography comprises gently sloping valleys (approximately 3° - 6° for valley slopes, to <1° in the low-lying wetland area) from a reduced level of 1 m AHD in the east to 24 m AHD along Jervis Bay Road.

### 2.2 JERVIS BAY LEEK ORCHID (PRASOPHYLLUM AFFINE)

According to the Recovery Plan for the Jervis Bay Leek Orchid (National Parks and Wildlife, April 2003), the Jervis Bay Leek Orchid is a ground orchid that is only readily visible for about a month after flowering commences in late October. The areas where this species occurs are characterised by poorly drained grey-brown clay soils that support low heathland and sedgeland communities. The general botany of the leek orchids indicate that the flowering plants consist of a single hollow, ephemeral, leek-like leaf, and an underground tuber that is replaced annually.

Leek orchids do not necessarily flower every year, often skipping years when rainfall has not occurred prior to the flowering period (Jones, pers. comm.). Leek orchids generally die back after the flowering and fruiting phases and exist only as a dormant tuber for much of the year. The Jervis Bay Leek Orchid is dormant over summer and it is believed to begin producing a leaf in late winter/early spring.

The recovery plan also indicates that as a result of the drought conditions experienced in 2002, none of the marked Jervis Bay Leek Orchids had produced either a leaf or a flower spike as of mid November 2002. Similarly no flowers or leaves were observed outside of the monitoring plots. Climatic data for this period indicated that the average rainfall over the period March to August 2002 was 74 mm compared to the average of 118 mm for the historical record. Detailed surveys undertaken by ERM during the 2003 flowering season recorded a total of 301 plants of *P. affine* within the subject site. The successful flowering of orchids during the 2003 season was attributed to rain periods prior to flowering.

## 2.3 CLIMATE

### 2.3.1 *Temperature*

Average maximum temperatures lie in the range 15.1°C (July) to 23.9°C (February) with average minimum temperatures in the range 9.2°C (July) to 18°C (February). This temperature range is typical of the temperate climate zone of the southeastern Australian coastline.

### 2.3.2 *Rainfall*

Annual rainfall in the Vincentia area ranges from 585.9 mm (1940) to 2493.6 mm (1961) per annum with average rainfalls of 1243.4 mm per annum.

A hydrograph showing total annual rainfall recorded since 1899 at gauging station 68034 (Point Perpendicular Lighthouse), located approximately 10 km from the site, is presented in *Figure 2.1.* This hydrograph indicates that over the past 40 years average annual rainfalls are in concurrence with those observed over the historical record, and no significant increasing or decreasing rainfall trends are currently evident.

Highest rainfall occurs in the March to August period with the lowest rainfalls in the period September to December. It should be noted that the lowest average rainfalls occur over the period immediately prior to and during the flowering period of the Jervis Bay Leek Orchid.

Average monthly rainfall ranges from 134.2 mm in May to 78.9 mm in September over the historic record. Tabulated data is included in *Table 2.1*.

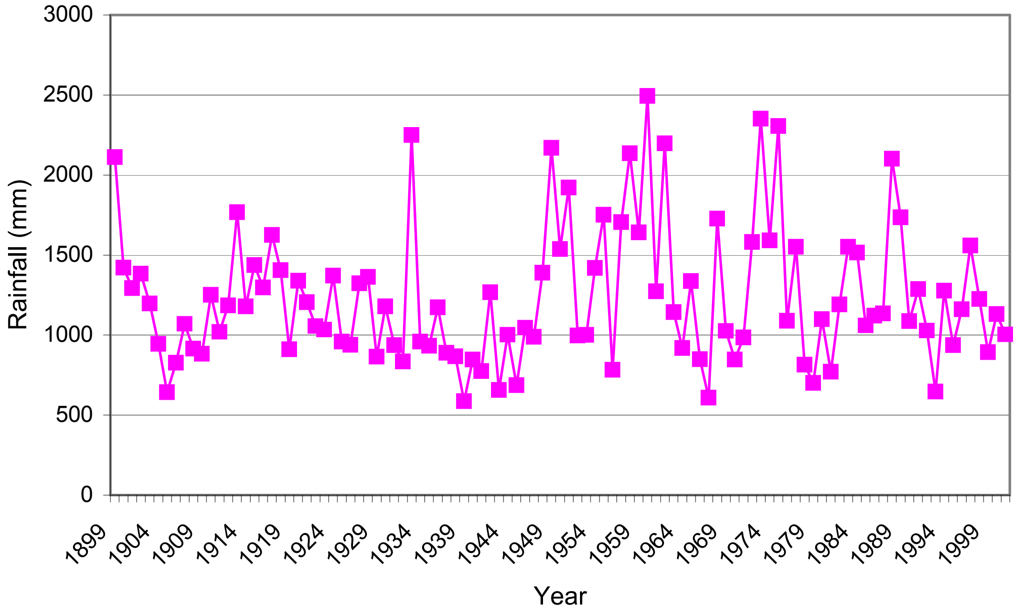


*Figure 2.1* *Annual Rainfall from 1899 to May 2004: Point Perpendicular Lighthouse Gauging Station (68034)*

*Table 2.1* *Total Monthly Rainfall: Point Perpendicular Lighthouse Gauging Station (68034)*

| Month | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max | 378.6 | 426.7 | 572.3 | 566 | 515.9 | 422.6 | 483.8 | 436.9 | 329.2 | 539.8 | 667.1 | 260.6 | 2493.6 |
| Min | 3.8 | 2 | 10.6 | 0.8 | 2 | 5.4 | 0.6 | 1.4 | 2.6 | 2.4 | 3.8 | 0 | 585.9 |
| Avg | 97.2 | 98.9 | 122.7 | 131.9 | 134.2 | 129.9 | 107.4 | 90.1 | 78.9 | 85.3 | 84.2 | 83.5 | 1243.4 |

## 2.4 HISTORICAL LAND USE

A review of historical documents was conducted to assess the historical land use and existing relevant hydrogeological information both within and in the vicinity of the subject properties. The file review included a review of available historical aerial photographs, a review of reports and documentation on file with the Shoalhaven City Council regarding development and/or environmental investigations on neighbouring properties, and a bore information search conducted through the Department of Planning (DoP).

### 2.4.1 *Aerial Photographs*

Aerial photographs from 1961, 1975, 1980, 1997 and 2002 were obtained from DoP in Sydney. The results of the aerial photograph review were similar to those of Network Geotechnics Pty Ltd, and are summarised below:

- In 1961 the site appeared to be vacant and undisturbed except for an unsealed road (Moona Creek Road) that extended north from Jervis Bay Road through the centre of the site;

- In 1975, an electricity easement close to the southern boundary was installed;

- No significant changes in site conditions was observed between the 1975 and 1980 aerial photographs;

- In 1997, the appearance of a bare soil area is noted. This has formed due to the extraction of topsoil from the site. A track now known as Colossus Avenue had appeared and part of the main easement track within Lot 802 had appeared; and

- In 2002, the Bay and Basin Leisure Centre building, oval and dams had been constructed adjacent to the northeastern corner of the site. The sewer main easement track had also developed near the northern boundary of Lot 801.

### 2.4.2 *Literature Review*

A review of existing literature held on public file was undertaken to attempt to identify any previous hydrogeologic studies in the vicinity of the subject property. Existing environmental reports were provided by Shoalhaven City Council via a Freedom of Information Act search for the following properties:

- Lots 801 and 802, DP 1022286, Vincentia, NSW;

- Lots 72, 73, 74, 75; DP 874040, Vincentia, NSW;

- Lot 1, DP866983, Vincentia, NSW;

- Lot 51 DP 862697, Vincentia, NSW; and

- Lot 1 DP550361, Vincentia, NSW.

A total of five reports were provided, of which only one had a cursory mention of groundwater conditions. The reports included:

- Allen Price & Associates (August 2000) *Report on the Flooding Levels on an Existing Watercourse Within the Subdivision of Lot 791 DP 877477, The Wool Road – Vincentia (for Wollongong Pty Ltd);*

- Allen Price & Associates (June 2000) *Report on the 1:100 Year Flooding Levels on an Existing Watercourse Within the Subdivision of Lot 791 DP 877477, The Wool Road – Vincentia (for Irrayadda Pty Ltd);*

- Lyall & Macoun Consulting Engineers (June 1998) *Bay & Basin Leisure Centre Water Quality Management Strategy;*

- Cowman Stoddart Pty Ltd (June 1998) *Bay and Basin Leisure Centre Town Planning Report and Statement of Environmental Effects;* and
- Coffey & Partners Pty Ltd (undated) *Geotechnical Investigation, Northern Area, Vincentia Environmental Study, N.S.W.*

The only mention of hydrogeology in these reports was in the Coffey Report, in which observations of groundwater inflows into testpits were described. In general, groundwater was described as being encountered in the low-lying topographic areas, with little or no groundwater encountered in testpits on the ridge crests. Groundwater inflow was generally described as slow to extremely slow, and appeared to be associated with the contact between overlying sediments and weathered bedrock. The one exception was in a testpit in the estuarine sediments close to the wetlands, where an 'extremely high flow' was observed into the test pit. It was suggested that groundwater at this location may have been confined, and rapidly flooded the testpit once the confining layer was breached.

# 3 *REGIONAL GEOLOGY AND HYDROGEOLOGY*

According to the Australia 1:250,000 Geological Series Sheet S1 56-13 (Ulladulla, New South Wales) the site is underlain by rocks from the Wandrawandian Siltstone and possibly the Conjola Formation, part of the Permian Shoalhaven Group. The Wandrawandian Siltstone comprises siltstone and silty sandstone which is pebbly in part, while the Conjola Formation consists of conglomerate sandstone and silty sandstone.

Folding of the sedimentary units in the vicinity of Jervis Bay is indicated by a series of roughly NNW-SSE trending anticlines and synclines. The subject property is located close to the fold axis of the Bherwherre Anticline, with the surficial sedimentary units on either side dipping east towards Jervis Bay, or west towards St. Georges Basin. While the plot location of the anticline axis is approximate, it appears that the subject property lies on the eastern side of the fold axis, and is associated with the sedimentary units that dip towards Jervis Bay.

## 3.1 *FIELD INVESTIGATIONS*

A field investigation was undertaken by Network Geotechnics Pty Ltd, comprising installation of piezometers, collection and analysis of soil samples, water level measurement, hydraulic conductivity testing and groundwater quality assessment (electrical conductivity [EC]).

A total of nine monitoring wells were installed (BHF9, BHI1, BHI3, BHJ1, TH17, BH2, BH3, BH4 and BH5) to depths ranging from 2.7 to 9.6m below ground level (bgl) within the proposed commercial precinct (*Figure 3, Annex A*). Ongoing weekly groundwater level measurements were obtained from 7 January 2004 to 9 March 2004. Water level sampling intensity was then reduced to 6 monthly intervals with the most recent water level sample round obtained on 28 November 2005. An assessment of the results from January 2004 to March 2004 is provided in the following sections.

## 3.2 *LOCAL GEOLOGY*

A review of previous site investigation reports indicated that the site had been divided into several geotechnical units based on geology, landform characteristics and typical soil associations. Five geotechnical units were described at the investigation site, with details of each of these geotechnical units summarised in *Table 3.1* below.

*Table 3.1 Geotechnical classification of soils present at the investigation site (Coffey, 1988)*

| Geotechnical Unit | Depth | Geology | Groundwater Characteristics |
|---|---|---|---|
| A – Residual Soil and Weathered Sandstone Bedrock | 0.0 – 0.6 m Slope-wash Soil | Grey-brown, grey, brown and yellow-brown, moist, medium dense clayey sand, silty sand, clayey silty sand and sandy gravel. | Very limited groundwater inflow occurred at 1.6 m to 2.5 m depth. Groundwater inflow tends to be concentrated approximately along the interface between the residual soil and weathered rock. |
| | 0.7-2.15 m Residual Soil | Yellow-brown, orange-brown, red-brown, grey, moist, medium dense and medium dense to dense clay sand, gravelly clayey sand and very stiff to hard sandy clay of medium plasticity. | |
| | Sandstone | Fine to coarse grained, red brown, yellow brown, grey, massive, extremely and highly weathered, extremely low to low strength. | |
| B - Weathered thinly laminated siltstone | 0.0 – 0.3 m Slope-wash Soil | Brown, yellow-brown and grey, dry and moist, medium dense clayey sand and clayey silty sand. | No groundwater encountered. |
| | 0.8-1.9 m Residual Soil | Grey, yellow-brown, red-brown, orange brown, moist, hard and hard to friable silty clay of medium to high plasticity, sandy clay and sandy silty clay of medium to medium to high plasticity and clay of medium to high and high plasticity. | |
| | Siltstone | Grey, yellow, orange-brown, red-brown, very thinly laminated, extremely to moderately weathered, very low to high strength. | |
| C - Residual soil greater than 2.5m deep developed on sedimentary rock. | 0.2-0.85 m Slope-wash Soil | Grey, brown, dry and moist, loose to medium dense and medium dense sand, silty sand and clayey sand. | Very limited groundwater inflows at depths ranging between 1.8 m and 3.0 m below ground surface within the clay residual soils. |
| | Residual soil | Grey, orange-brown, red-brown, yellow-brown, moist, very stiff, hard and friable clay of high plasticity, sandy clay and sandy-silty clay of medium plasticity and silty clay and sandy silty gravelly clay of medium to high plasticity. | |
| D – Estuarine sediments greater than 2.5m thick. | To greater than 2.65 m | Interbedded brown and grey, moist, medium dense clayey sand and silty sand of low plasticity and grey, red-brown, yellow-brown, moist, moist to wet, stiff, very stiff and very stiff to hard clay, silty clay and sandy-silty clay of medium to high plasticity of low plasticity. | Extremely high flow below 2.0 m depth. Groundwater was probably under confining pressure, possibly linked to the wetlands groundwater system. |
| E – Swamp sediments overlaying residual and/or estuarine sediments. | 1.7 m Swamp sediments | Dark brown to black and grey, moist to wet, firm and stiff clay of high plasticity. The upper 0.4m of the swamp sediments is partly organic with a pungent odour. | Very low groundwater flows occurred at about 1.5 m depth immediately above the residual soil and swamp sediment boundary. |
| | To greater than 2.65 m Residual Soil | Grey, moist to wet, hard silty clay of medium to high plasticity. | |

Recent geotechnical investigations indicated that the site contains several distinct soil horizons. The A1 (topsoil) layer ranged from 0.1 to 0.6 m bgl, and comprised silty sand and silty clay. This layer overlays an A2 horizon described as silty to clayey sand slopewash that is characteristic of side slopes and valley floors. The A2 horizon overlays the B horizon, described as clays derived from in-situ weathering of the underlying siltstone and sandstone bedrock. The B horizon is subdivided into a B1 and B2 horizon, based on textural and colour differences.

The borehole locations from the recent investigation are all associated with the C and D units as described in *Table 3.1*, and the lithological descriptions of the A1 and A2 horizons from these boreholes are consistent with the unit descriptions in *Table 3.1*.

Two geologic cross-sections through the study area are presented in *Figures 4* and *5* (*Annex A*), demonstrating the vertical relationships between the various units identified in the recent geotechnical investigation, as well as the relationship between the water table and the various lithologic units.

## *3.3 REVIEW OF GEOTECHNICAL INVESTIGATION*

The recent soil investigation comprised the collection of soil samples from the A1, A2, B1, B2 horizons and the regolith. These soil samples were tested for electrical conductivity (EC), pH, cation exchange capacity (CEC), $SO_4$ concentration and Chromium Reducible Sulphur (CRS) content.

The topsoil or A1 horizon was found to be slightly acidic, and non-saline. The A2 horizon samples were generally observed to be slightly acidic, non- to slightly saline, and marginally sodic. The B1 horizon was more variable with soil samples characterised as slightly acidic, non- to moderately saline, and non- to highly sodic. The B2 horizon soils were found to be slightly acidic, non- to moderately saline, and non- to marginally sodic. Samples taken from the siltstone and sandstone units were observed to be slightly acidic, non- to moderately saline, and non-sodic. None of the samples collected from the various horizons were found to present an acid sulfate soil hazard.

## *3.4 LOCAL HYDROGEOLOGY*

The network of monitoring wells was installed to assess the depth to groundwater and direction of groundwater flow in the vicinity of the investigation site. Initial measurement of water levels in the monitoring wells on 27 October 2003 indicated that the depth to groundwater ranged from 0.45 (BHI1) to 3.4 (BH3) metres bgl, as detailed in *Table 3.2*. In general, the water levels appear to indicate a zone of perched groundwater within the B2 horizon, and deeper water levels for the wells screened within bedrock. Whilst screened primarily within the B2 horizon, well BHJ1 also intercepts bedrock, which may account for the greater depth to water in this well.

*Table 3.2 Well Construction Details and initial water level measurements: October 27, 2003.*

| Well ID | Total Depth | Screened Interval | Screened | Depth to Water | Reduced Level (m) | |
|---|---|---|---|---|---|---|
| | (m, bgs) | (m, bgs) | Lithology | (m, bgs) | Ground Surface | Water Level |
| BHF9 | 3.0 | 0.5 – 3.0 | Estuarine (A2) | 2.3 | 16.95 | 14.65 |
| BHI1 | 3.0 | 0.5 – 3.0 | Sandy clay (B2) | 0.45 | 20.55 | 20.1 |
| BHI3 | 3.0 | 0.5 – 3.0 | Sandy clay (B1) | 1.4 | 28.00 | 26.6 |
| BHJ1 | 2.7 | 0.5 – 2.7 | Sandy clay (B2) | 2.25 | 24.55 | 22.3 |
| TH17 | 4.6 | 1.6 – 4.6 | Sandy clay (B2) | 0.95 | 22.70 | 21.75 |
| BH2 | 9.6 | 6.6 – 9.6 | Sandy clay (B2) | 1.15 | 27.96 | 26.81 |
| BH3 | 4.1 | 1.1 – 4.1 | Bedrock | 3.4 | 25.99 | 22.59 |
| BH4 | 6.0 | 3.0 – 6.0 | Bedrock | 3.05 | 28.07 | 25.02 |
| BH5 | 8.7 | 5.7 – 8.7 | Bedrock | 2.2 | 30.21 | 28.01 |

1. Data collection performed by Network Geotechnics.

Water levels were subsequently recorded on a weekly basis from 7 January 2004 to 9 March 2004, reducing to a six-monthly basis starting from 28 November 2005, to assess the long-term water table fluctuations and aquifer response to rainfall events. The results of nine rounds of water level measurements in piezometers throughout the site is presented in *Table 3.3*. Measurements of water levels in the monitoring wells on 9 March 2004 indicated that the depth to groundwater ranged from 1.23 (BHI1) to 4.69 (BH3) metres bgl, which indicates an overall decrease in water levels over the study period in all monitoring wells with the exception of BHF9 which indicated an increase in water level of 0.48. The water level in BHF9 is likely to be influenced by the surface water fluctuations in the adjacent wetland, and as such would behave differently from the rest of the wells.

*Table 3.3 Results of Water Level Measurements: 27th October 2003 to 9th March 2004 .*

| Well ID | 27-10-03 | 07-01-04 | 15-01-04 | 22-01-04 | 28-01-04 | 04-02-04 | 11-02-04 | 19-02-04 | 27-02-04 | 09-03-04 |
|---|---|---|---|---|---|---|---|---|---|---|
| **BHF9** | 2.30 | 1.00 | 2.00 | 2.37 | 1.45 | 2.20 | 2.03 | 1.20 | 2.14 | 1.82 |
| **BHI1** | 0.45 | 1.00 | 1.12 | 1.25 | 1.10 | 1.19 | 1.45 | 1.36 | 1.45 | 1.23 |
| **TH17** | 0.95 | 1.32 | 1.58 | 1.60 | 1.36 | 1.65 | 1.57 | 1.67 | 1.81 | 1.54 |
| **BH2** | 1.15 | 1.62 | 1.90 | 1.93 | 1.75 | 1.75 | 1.91 | 2.10 | 2.08 | 1.83 |
| **BHJ1** | 2.25 | 2.15 | 2.55[1] | 2.55[1] | 2.55[1] | 2.55[1] | 2.55[1] | 2.55[1] | 2.55[1] | 2.55[1] |
| **BH3** | 3.40 | 3.40 | 3.86 | 3.95 | 3.98 | 4.23 | 4.28 | 4.44 | 4.59 | 4.66 |
| **BH4** | 3.05 | 3.35 | 3.85 | 4.10 | 4.10 | 4.25 | 4.37 | 4.47 | 4.59 | 4.69 |
| **BHI3** | 1.40 | 1.50 | 1.80 | 1.92 | 2.05 | 2.50 | 3.10 | 3.35 | 3.37 | 3.04 |
| **BH5** | 2.20 | 2.23 | 2.80 | 3.00 | 2.94 | 3.05 | 2.75 | 2.93 | 3.33 | 3.11[2] |

1. Indicates the bottom of the piezometer (dry).
2. Indicates blockage in piezometer.

Data collection performed and provided by Network Geotechnics.

In general, shallow groundwater flow in the vicinity of the subject property would be expected to follow topography, flowing downslope from the ridgelines towards local drainage features and ultimately towards the low-lying wetland to the northeast of the property. This is supported by the observed hydraulic head distribution, which indicates that shallow groundwater flows downslope (approximately northward) from the ridgeline that forms the southeastern boundary of Lot 801, following topography. Groundwater flow appears to be towards the drainage channel along the northwestern boundary of Lot 801 and presumably on towards the low-lying wetland area north of the site (*Figure 6, Annex A*). The water table gradient also mimics the surface topography, with a steeper gradient observed close to the ridgeline, becoming flatter towards the wetland.

In the mid to lower slope regions where the Jervis Bay Leek Orchid and Leafless Tongue Orchid are encountered, the water table appeared to be located approximately between 3 – 3.5 m bgl. However, the depth to groundwater was observed to fluctuate across the duration of the investigation period in accordance with local rainfall patterns, and extended water level monitoring would be required to establish the seasonal range of water table fluctuation.

### 3.4.1 *Analysis Of Hydraulic Head Fluctuations*

The results of water level measurements during the study period from 27 October 2003 to 9 March 2004 are presented in *Figure 3.1*, indicating a general decline in water levels during the study period. The greatest water level variation was observed in monitoring well BHI3, which was installed to 3 m bgl and is located at the top of the surface water drainage running through Lot 801 (*Figure 3, Annex A*). Depth to water in BHI3 ranged from 1.4 m bgl in October 2003 to 3.37 m bgl in February 2004 (a decline of approximately 2 metres). The smallest variation was observed in TH17, which was installed to a depth of 4.6 m bgl (*Figure 3, Annex A*). Depth to water in TH17 ranged from 0.95 m bgl in October 2003 to 1.81 m in February 2004, a total decline of 0.86 m. The average water level fluctuation observed in the monitoring well network between October 2003 to March 2004 was 1.43 m.

The depth to water was generally greatest in bores BH3 and BH4, located in the vicinity of the orchids, with water levels of 4.66 m bgl and 4.69 m bgl, respectively, observed during the 9 March 2004 monitoring event. These wells are screened in bedrock, and therefore are not representative of perched groundwater as most of the other wells are. Monitoring well BH5 was installed on the upper ridge slope along the southern boundary of the site to a depth of 8.5 m bgl. Depth to water in this well is generally 1.5 to 2 metres shallower than in BH3 and BH4, which are also screened within bedrock, but the greater depth of installation may have penetrated confined aquifer zones within the bedrock. Wells BH2, TH17 and BHI1 are all screened within the same sandy clay unit (B2), and exhibit very similar water level trends across the study period. BHF9 is located closest to the wetland to the north of the site, and exhibits a more dynamic response to rainfall events than in other locations.

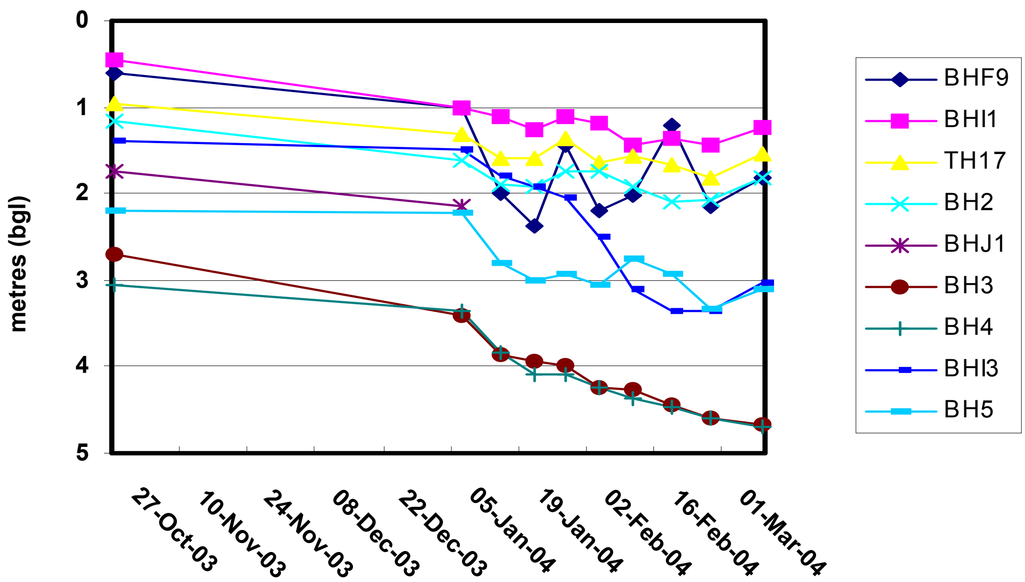


***Figure 3.1*** ***Hydrograph of water levels from 27 October 2003 to 1 March 2004.***

The correlation between water level readings and rainfall from 7 January 2004 to 9 March 2004 is presented in *Figure 3.2*. A comparison of the rainfall data for this period with the average historical rainfall values indicates below average rainfall conditions for the duration of the study period, which is reflected in the general decline in water levels throughout the study period. In addition, storm events have not produced a significant response in most of the monitoring wells, with the possible exception of a subtle decrease in the rate of water level following the storm event in late January.

The more dynamic response to storm events observed in monitoring well BHF9 may be due to a strong hydraulic response to surface water fluctuations in the adjacent wetland, or perhaps differences in the estuarine sediments in which it is screened. Monitoring well BH3, screened in the shallow sediments adjacent to the orchid colonies, exhibits a consistent decline in water levels regardless of storm events, suggesting that the relatively minor rainfall volumes during these storm events are not significantly contributing to groundwater recharge.

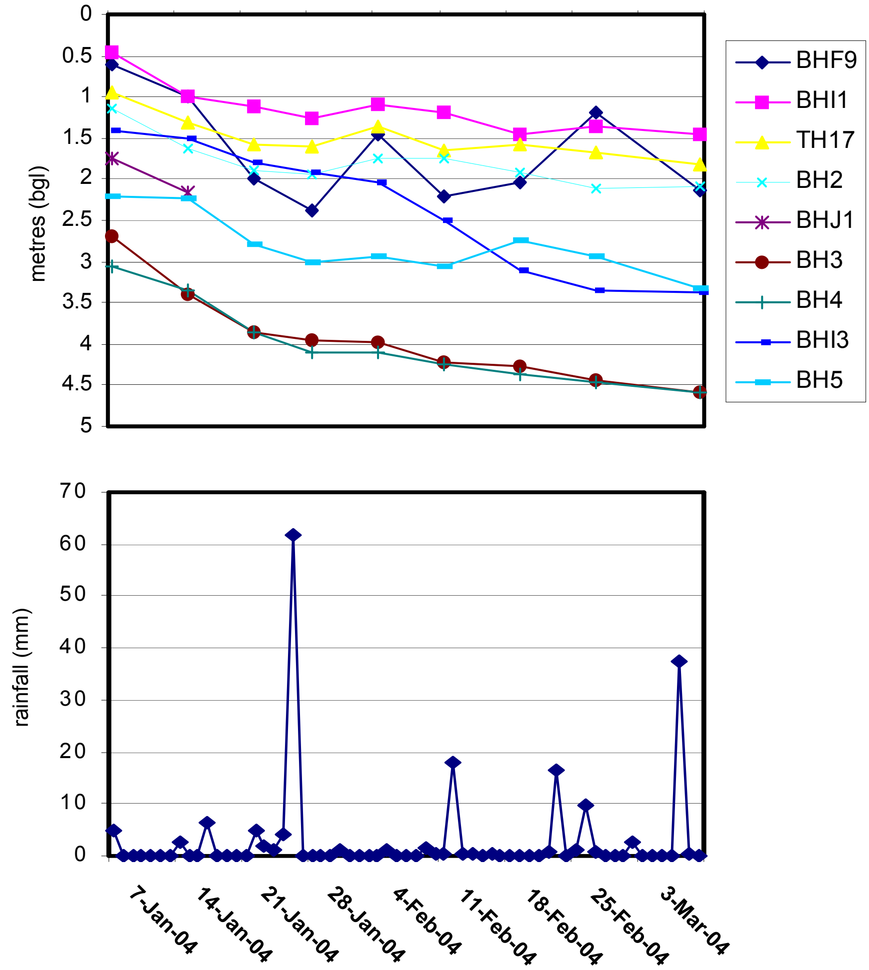


*Figure 3.2* ***Rainfall and hydrograph from 7 January 2004 to 9 March 2004***

### 3.4.2 *Analysis Of Aquifer Response According To Lithologic Units*

Hydrographs from 7 January 2004 to 9 March 2004 are presented in *Figures 3.3 to 3.5*. The data was analysed to assess the differences in aquifer response to rainfall events within the perched groundwater and bedrock aquifers.

*Hydraulic Response in the B2 Horizon*

A hydrograph of piezometers screened within the sandy clays of the B2 horizon is presented in *Figure 3.2* below. Despite the significant difference in the depth of installation of well BH2, the similarities in both the depth to water and the trend in water level fluctuation suggest that the hydrogeologic properties of the B2 horizon are relatively uniform at the three well locations. A subtle response to the storm event in late January is evident in the three trends, suggesting that this perched aquifer zone is likely to be relatively responsive to rainfall recharge with only a short time lag between the storm event and the observed response in the water levels.

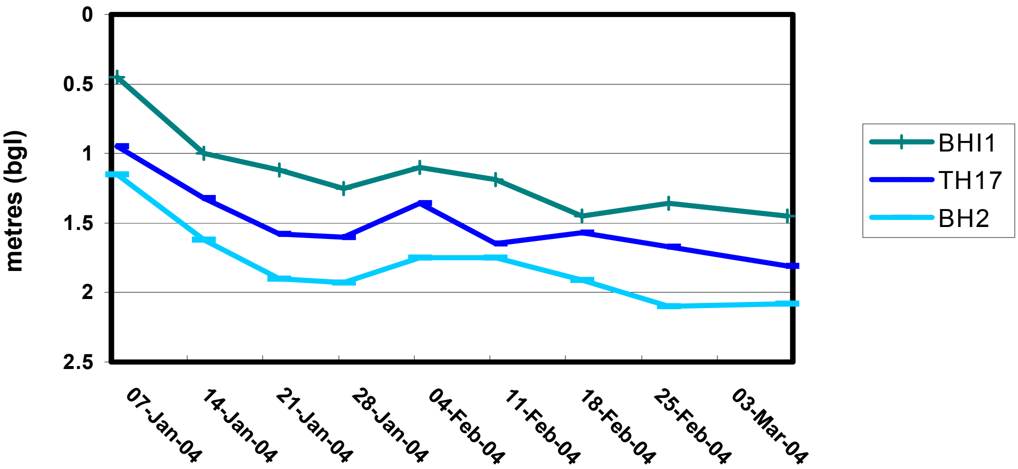


*Figure 3.3* ***Hydrograph of water levels from monitoring wells screened within the B2 horizon (7 January 2004 to 9 March 2004): BHI1 (3 m depth), TH17 (4.6 m depth) and BH2 (9.6 m depth).***

*Hydraulic Response in Fractured Bedrock*

A hydrograph of piezometers screened within bedrock is presented in *Figure 3.4*. BH3 and BH4 were installed at similar depths in the upper bedrock profile, whilst BH5 was installed to a slightly greater depth. The water levels in BH4 and BH5 are nearly identical, suggesting that a uniform aquifer zone exists in the upper weathered bedrock profile. The depth to water was somewhat shallower at BH5, which may suggest that the deeper installation depth at this location resulted in penetration of confined aquifer zones in the bedrock that were not encountered at BH3 and BH5. There appears to be no significant response to the rainfall events in wells BH3 and BH4, although BH5 does exhibit a slight response to the slightly increased rainfall in February. It is likely that the low permeability of the clay material overlaying the bedrock inhibits the vertical infiltration of rainfall recharge from isolated storm events, and that significant recharge to this zone is dependent upon a sustained period of rainfall.

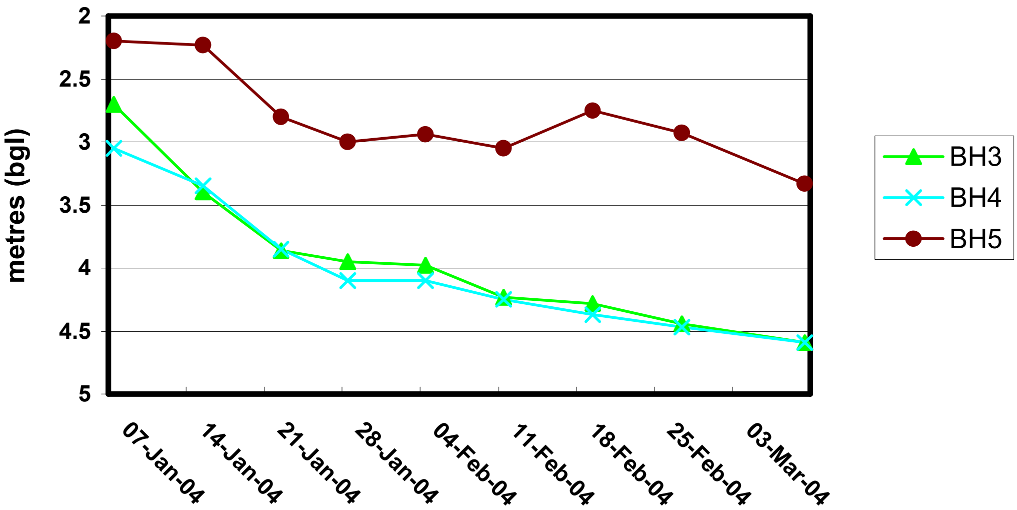


*Figure 3.4* ***Hydrograph of water levels from monitoring wells screened in bedrock (7 January 2004 to 9 March 2004): BH3 (4.1 m depth), BH4 (6.0 m depth) and BH5 (8.7 m depth).***

*Hydraulic Response in the Estuarine Sediments (A2)*

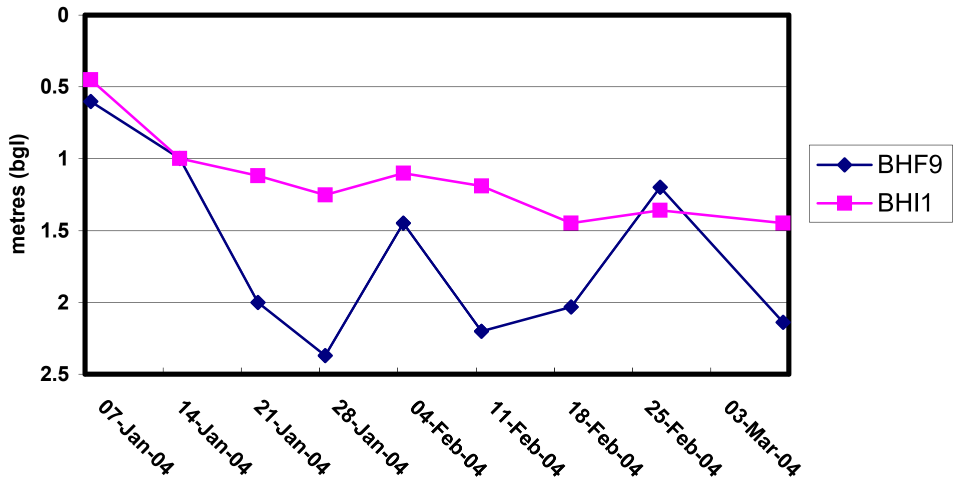


*Figure 3.5* ***Hydrograph of water levels from 7 January 2004 to 9 March 2004 located at the topographically low area of the site: BHF9 (3 m depth) and BHI1 (3 m depth).***

A hydrograph of monitoring wells located at the northern boundary of the site is presented in *Figure 3.5*. BHF9 is the northern–most monitoring well, installed within the estuarine deposits (A2) adjacent to the tidal wetland area. Water levels are dynamic and may be influenced by fluctuations in surface water levels within the adjacent wetland, thus producing a rapid response to storm events.

# 4 *DEVELOPMENT IMPACT ASSESSMENT*

### 4.1.1 *Hydrogeology and the Leek Orchids*

There appear to be two groundwater regimes present in the upper lithological profile at the site: a perched water table that occurs within the shallow unconsolidated sediments, and a deeper, confined/semi-confined aquifer system within the weathered bedrock profile. Analysis of hydrographs indicates that hydraulic head values in both systems have declined over the investigation period, presumably due to the below average rainfall conditions. The one significant storm event during the study period produced a minor response in water levels in the perched aquifer (B2 horizon), but did not appear to produce a response in the upper bedrock aquifer (as defined by wells BH3 and BH4).

Wells BH3 and BH4 are located closest to the Jervis Bay Leek Orchids observed on Lot 801. The soil profile in this location comprises less than 2 metres of clayey sand overlying sandstone bedrock. Water levels in BH3 and BH4 varied from approximately 3 to 4.5 m bgl throughout the study period, but these wells were installed and screened within the sandstone bedrock and are therefore not indicative of perched groundwater in the shallow soil profile. However, the shallow soil was reported as being moist to wet during drilling suggesting that it has a capacity to retain moisture even during periods of relatively low rainfall.

Orchids are characterised by shallow root systems, and therefore the shallow soil profile would be the primary consideration with regards to the presence of groundwater. The occurrence of perched groundwater in a thin, sandy soil profile overlying bedrock would be expected to be ephemeral, with the recharge mechanism comprising direct infiltration of rainfall. The clay content would promote moisture retention between rainfall events.

The observation that these orchids will lay dormant without blooming during drought years suggests that a certain degree of soil moisture is necessary to stimulate growth. It is unlikely that the shallow root system of the orchids requires direct hydraulic connection with the perched water table, and rainfall recharge in the immediate vicinity of the orchid colonies should provide sufficient moisture to stimulate growth.

Development at the site would potentially have the effect of decreasing recharge to groundwater, due to a combination of soil compaction, impermeable surfaces and stormwater drainage systems. However, it is expected that these impacts would be limited to the areas immediately beneath the development footprint, as rainfall recharge through unsealed surfaces would not be affected. In addition, the proposed water sensitive urban design measures such as on-site stormwater retention basins would provide additional recharge to the groundwater system to help alleviate the potential losses associated with development. It is also worthwhile noting that the orchid population located on the western side of the watercourse, opposite the proposed development area, is relatively remote from the proposed development area, and the groundwater regime in this area should not be affected by the development activities. Thus, in terms of potential impacts to local hydrogeology, it is considered unlikely that the proposed development would pose a threat to the health of the leek orchids.

It is recommended that monitoring of water levels continue during, and up to three months after, construction to assess whether the development has an impact on local groundwater conditions. Specifically, this will provide a record of the observed water level fluctuations at the site in its natural, pre-developed state, including the effects of drought conditions on local groundwater levels, which can then act as a basis for comparison to the potential influence of development. It will be important to record rainfall during the monitoring period, to assess the relative contribution of climatic conditions to variations in water levels.

#### *4.1.2 Salinity And Acid Sulphate Soils*

The analytical results for soil samples collected from the site suggest that there appears to be minimal risk of encountering acid sulphate soils in the area and minimal risk in developing salinity hazards. The B horizon and regolith are most susceptible to dispersion and salinity at the site.

Annex A

# Figures

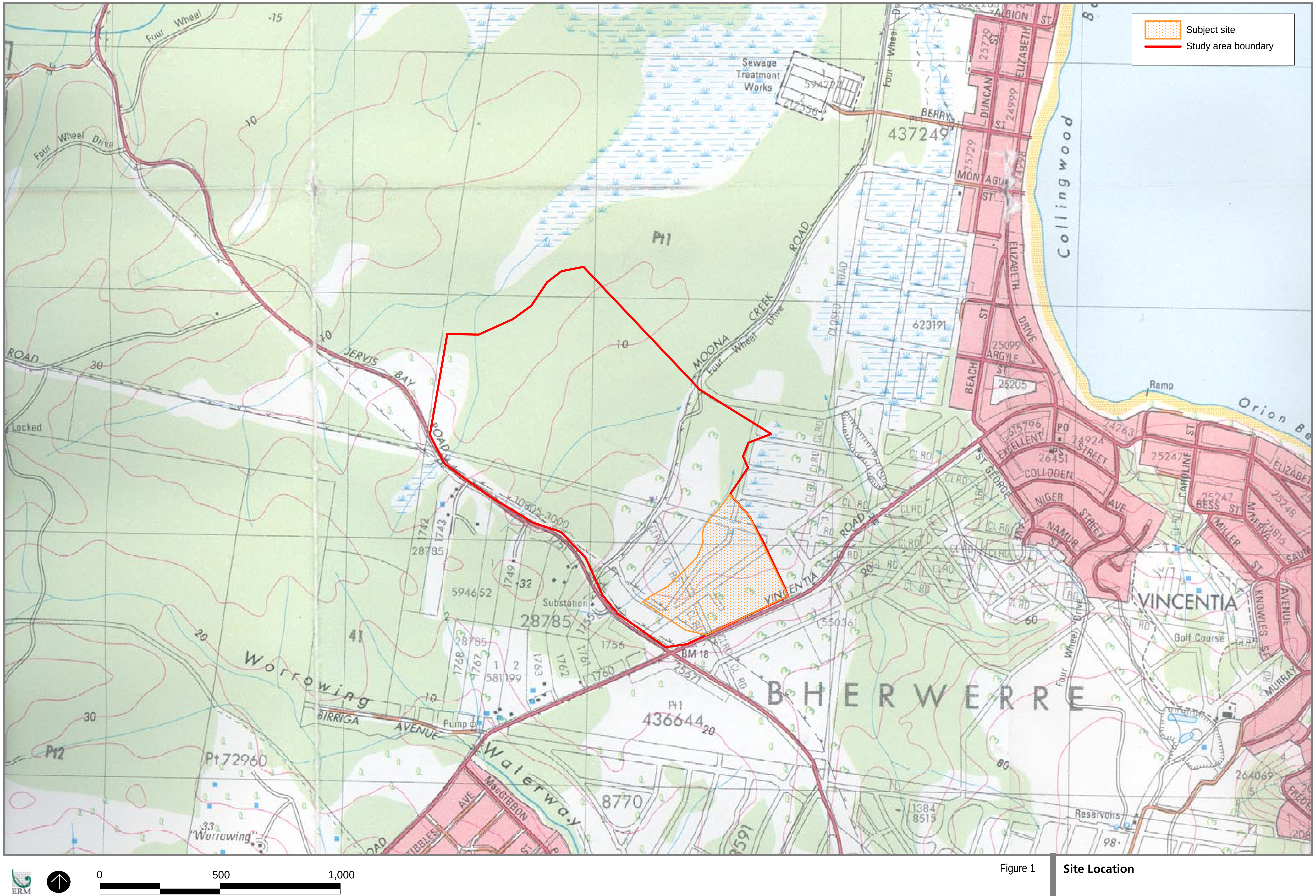


Figure 1 **Site Location**

Vincentia Hydrogeological Study

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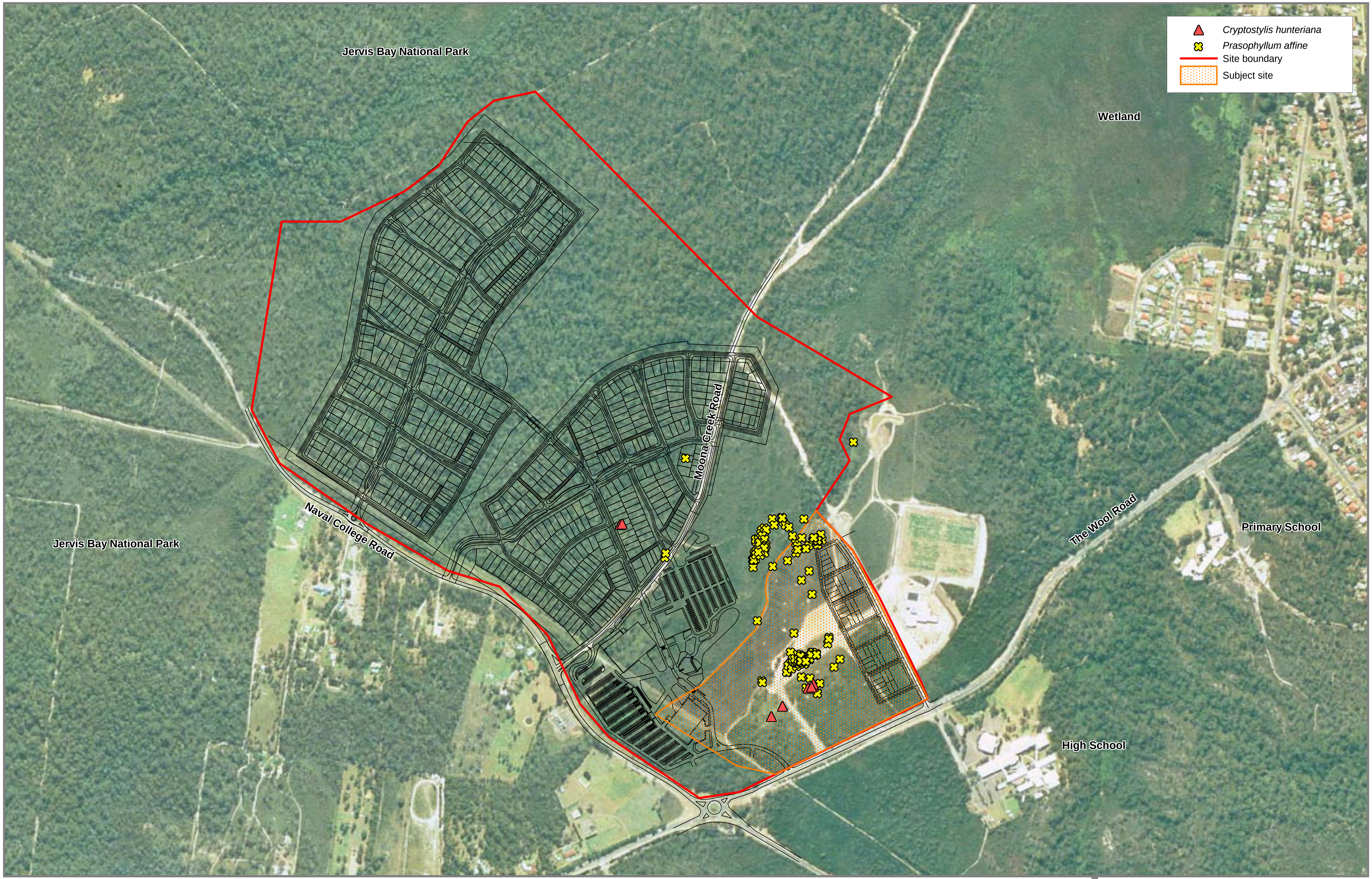


0 200 400
Metres

Figure 2

**Location of Subject Site and Study Area**

Vincentia Hydrogeological Study

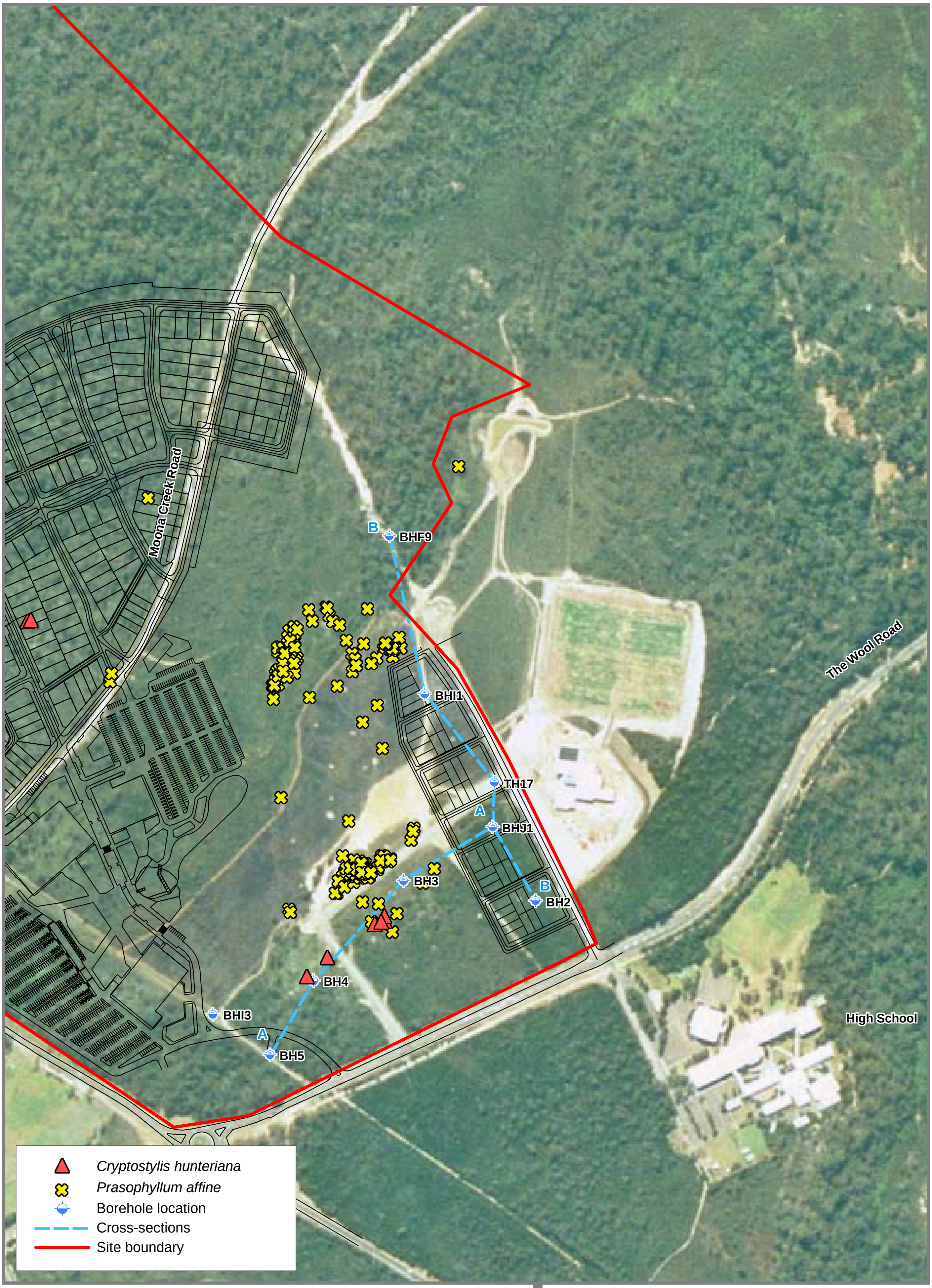


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Figure 3

**Bore Locations**

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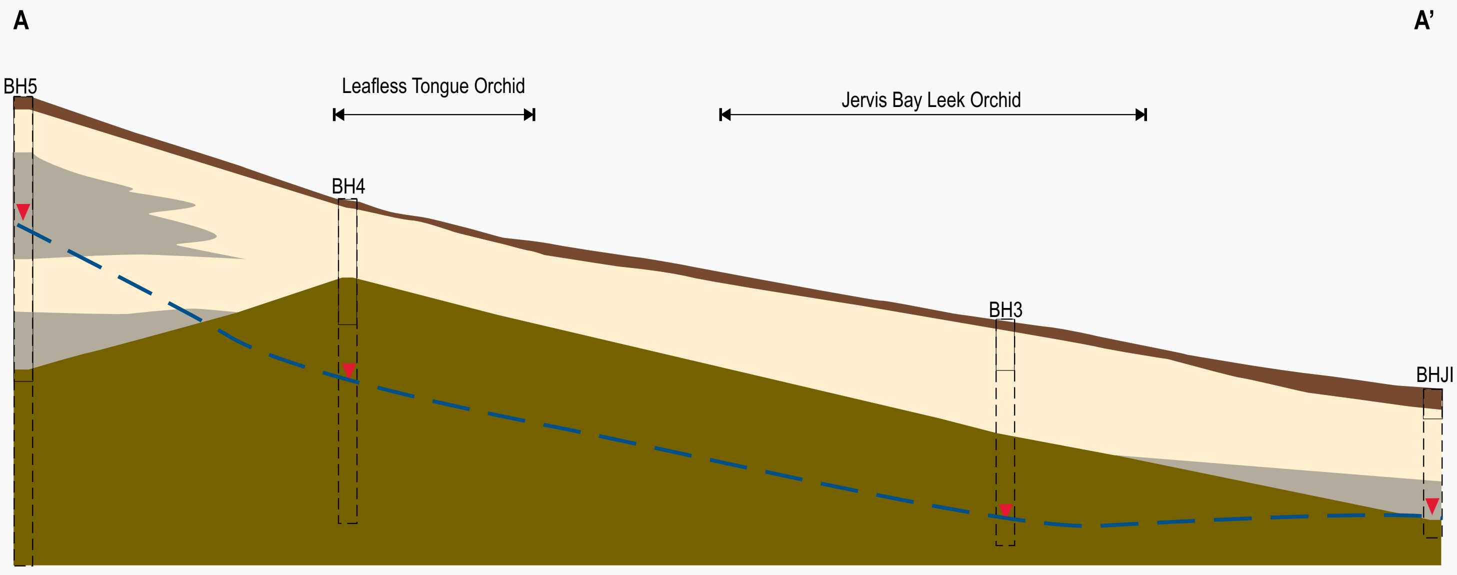


Source: Geology based on logs provided by Network Geotechnics Pty Ltd

Horizontal = 0 50m Approximate only

Vertical = 0 2m Approximate only

- Topsoil
- Sand
- Clay
- Rock
- Standing water level
- Water line

Figure 4

## SW-NE Cross Section A - A'

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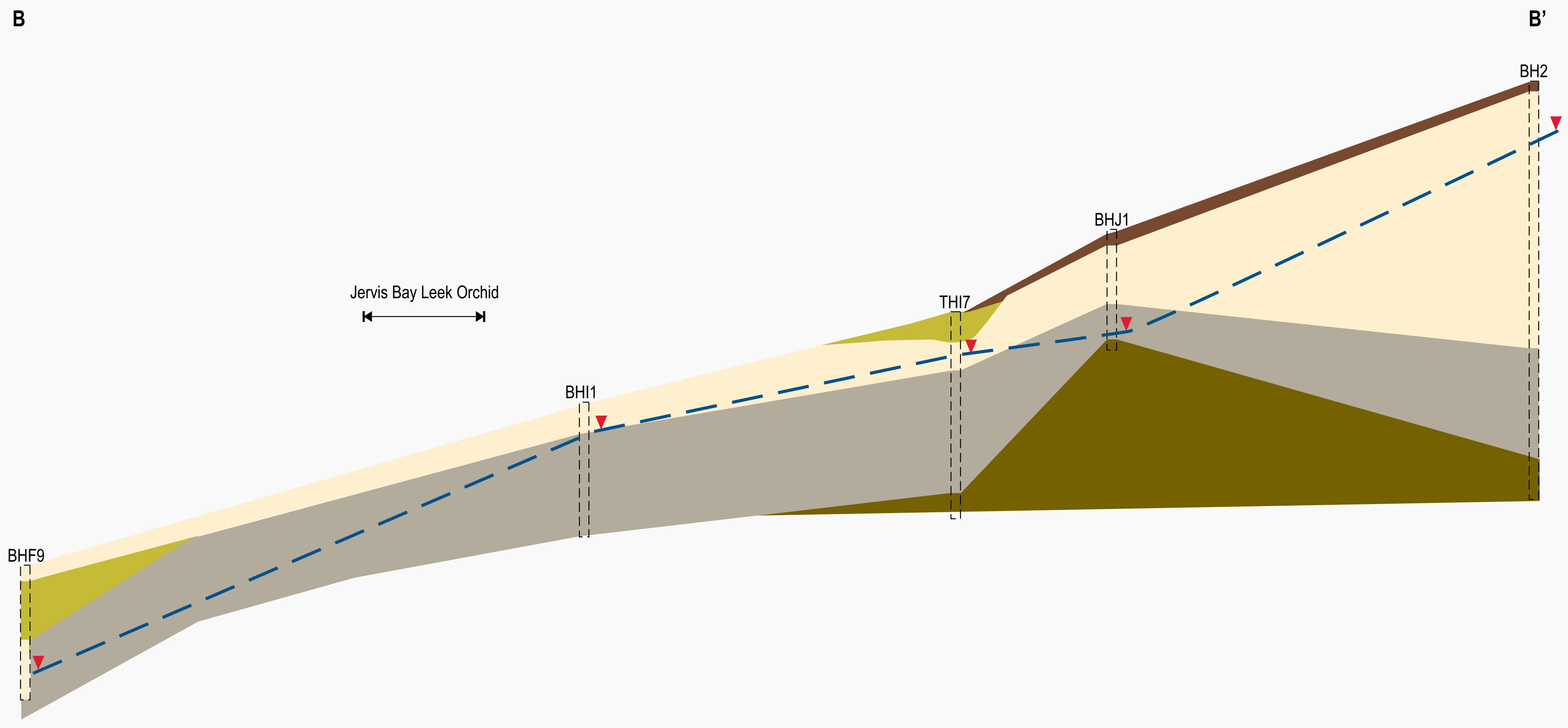


Source: Geology based on logs provided by Network Geotechnics Pty Ltd

Horizontal = 0 50m Approximate only

Vertical = 0 2m Approximate only

- Topsoil
- Silt
- Sand
- Clay
- Rock
- Standing water level
- Water level December 2003

Figure 5

**NW-SE Cross Section B - B'**

Vincentia Hydrogeology Study

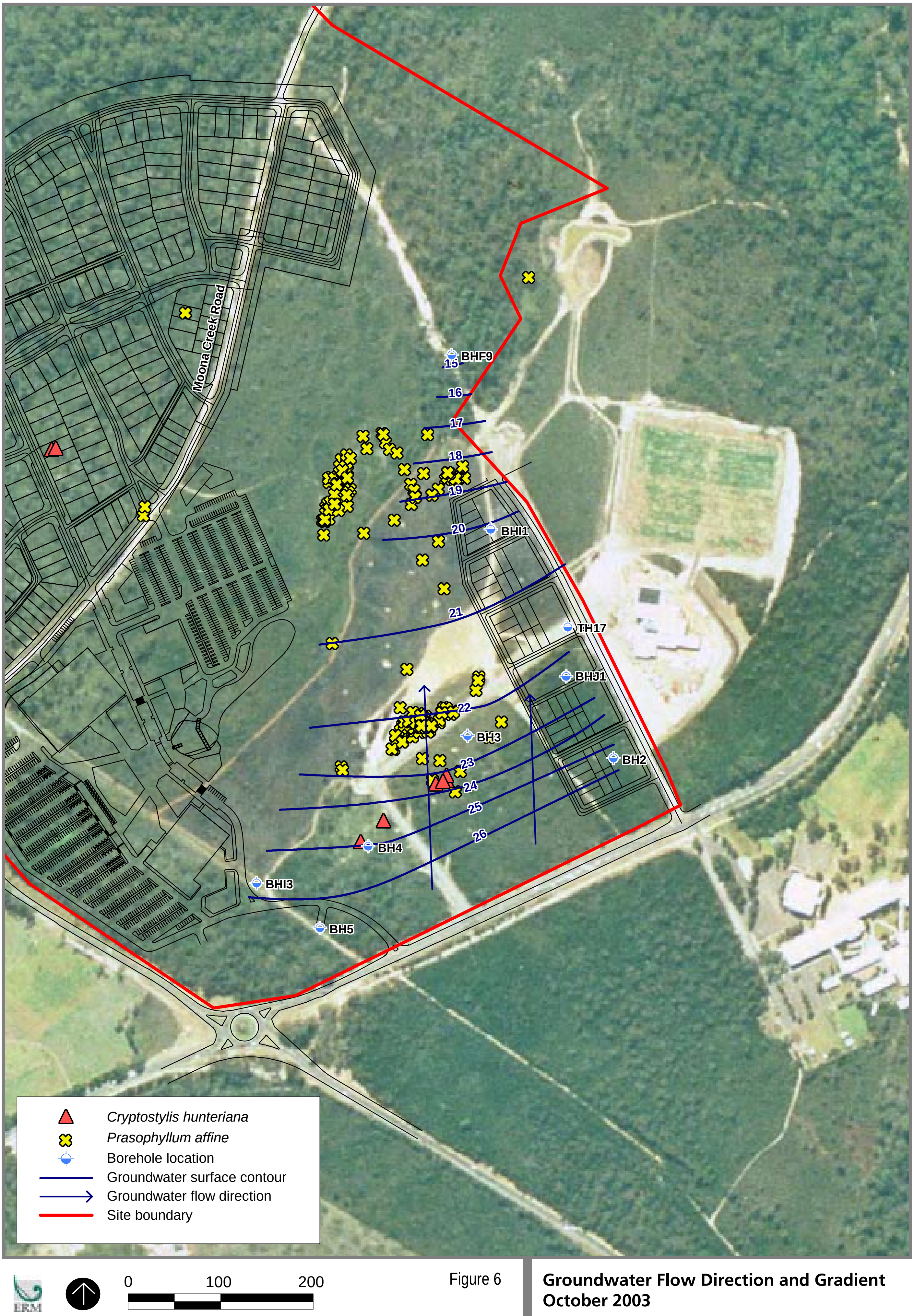


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Figure 6

**Groundwater Flow Direction and Gradient October 2003**

Vincentia Hydrogeological Study