Port Macquarie-Hastings Council

martens consulting engineers

Area 14 Stage 1B Groundwater Study, Lake Cathie, NSW
Amendment 1

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT
MANAGEMENT

P0601504JR02-V03
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All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Overview

1.1 Background

Hastings Urban Growth Strategy (2001) identifies land between Lake Cathie and Bonny Hills (know as Area 14) as one of the major urban growth areas in the Hastings Valley. As a consequence, Council has co-ordinated the preparation of an Urban Design Master Plan for Area 14 (adopted in February, 2004).

Further to the above, we understand that Council is now proceeding with amendments to the LEP for Area 14, including changes to zoning to enable development to proceed in accordance with the Master Plan. An independent review of the Local Environmental Study (LES) for Area 14 by GHD (2006), which included the stormwater quality report prepared by Jelliffe Environmental (2002), has concluded by recommending that further groundwater assessment is required to more fully consider the issue of determining a suitable 'set-back' to the littoral rainforest (ie. the 'buffer design').

This reports updates and amends a previous report dated 9th July, 2007 (reference P0601504JR01-V03) and has been provided in response to further issues raised by Hastings Council. The report amendments are primarily concerned with:

1. Providing further clarity in terms of groundwater impacts and management requirements.

2. Providing supplementary information in relation to stormwater management adjacent to the SEPP 26 rainforest and integrating stormwater management systems with groundwater management systems.

1.2 SEPP 26 – Littoral Rainforests

SEPP 26 Littoral Rainforests aims to provide a mechanism for the consideration of applications for development that potentially damage or destroy littoral rainforest areas with a view to the preservation of those areas in a natural state. The SEPP controls development both within a littoral rainforest and within 100 m from the mapped rainforest area, by requiring the concurrence of the NSW Director of Planning.

The subject land contains SEPP 26 – Littoral Rainforest No. 116 and therefore the provisions of the policy apply. The purpose of this investigation is to examine the impact of the proposed rezoning and preliminary buffer recommendations provided by King and Campbell. Specifically, this report assesses the impact in terms of hydrogeological consequences.

1.3 Project Scope

This report has been prepared to assist with the rezoning process and address matters raised by the GHD (2006) LES review. Primary objectives of the work include:

1. To more fully document the existing groundwater regime.

2. Assess in detail, the likely impacts of the proposed rezoning for Area 14, on local groundwater regimes, which come about principally through modifications to the local water cycle (ie. surface runoff and infiltration changes).

3. Assess the requirements for a suitable buffer design. This incudes not only set-back distance, but also any compensatory measures which would need to be included in the buffer design (eg. planting, stormwater management and infiltration, environmental monitoring *etc*).

4. Determine any initial and on-going site and buffer management requirements to ensure that the current groundwater conditions are maintained or modified as required.

1.4 Rezoning Proposal

The rezoning proposal included an indicative structure plan which was would be subject to the DCP process. This is provided in Attachment A and is summarised as follows:

- Preservation of the existing SEPP 26 land.

- Establishment of a 40-60 m wide vegetation buffer planted with species compatible with those found in the SEPP 26 land. This would be comprised of both existing vegetation as well as new regeneration areas.

- Provision of a 30 m wide asset protection zone (APZ) which include an internal access road running parallel with the vegetation buffer.

- Residential land to the west of the APZ. This would be of varying density, with impervious area coverage, based on Councils advice, likely to range between say 50 – 70 % and include roofs, roads, driveways and other pavements. The approximate location of the residential land to the west of the vegetation buffer is provided in Attachment A and B.

1.5 Previous Investigations

1.5.1 Hackett Laboratory Services Pty Ltd (February, 2001)

Hackett Laboratory Services undertook preliminary geotechnical investigations throughout the study area during 2001. Locations of soil test pits are provided in Attachment B of this report. 7 test pits were excavated throughout the study area ranging in depth between 300 and 1500 mm. Investigations indicated that aside from test pit 1, which revealed a generally sandy profile, all other test pits revealed silty loam topsoils overlying medium to heavy clay sub-soils.

Groundwater was only observed at test-pit 6. Unfortunately surface levels for the investigation pits was not provided as part of the Hackett Laboratories report. Based on the presently available survey data, test-pit 6 is situated at approximately 11 – 11.5 mAHD. It is not possible from the report data to determine whether the observed groundwater represented a likely groundwater level or a temporary level associated with saturated surface soils.

1.5.2 Jelliffe Environmental Pty Ltd (June 2002)

This report provided advice and recommendations in relation to stormwater quality management requirements for the subject land. Relevant comments provided in the report are as follows:

- An unconfined aquifer is likely to be present under the sandy soils of the SEPP 26 forest to the east and also in the sandy soils at the southern end of the site.

- The mean dry season water level in the unconfined aquifer underlying the SEPP 26 forest will be determined by mean sea level. However, the extent and depth of the freshwater lens and the incursion of the saline 'wedge' will depend on the volume of fresh water in the lens above sea level. Sources of freshwater for the lens are: a) rain falling directly onto the SEPP 26 forest; b) runoff fro the predominantly clay catchment to the west which infiltrates into the sandy soil at the base of the slope; and c) groundwater infiltration from higher ground.

- To avoid the risk of reducing recharge to the aquifer below the SEPP 26 area, it was recommended that runoff collected on the eastern side of the site discharge to seepage lines constructed into the sandy soil along the western edge of the SEPP 26 forest.

- No evidence of a water table was observed for elevations > 9 mAHD.

- Peak water tables in the SEPP 26 area will potentially fluctuate by > 1 m due to runoff and infiltration fro the clay based catchment to the west.

- Infiltration into the clayey soils to the west is likely to be low and therefore runoff to the low lying SEPP 26 areas would dominate in the local hydrological cycle.

- Use of rainwater tanks to allow for OSD and therefore slow release of water into the water table at the allotment level.

1.5.3 Storm Consulting Pty Ltd (April 2006)

This report provided an integrated water cycle management plan for Area 14. The following comments summarise relevant aspects of the study:

- A vegetated buffer strip to the SEPP 26 land was recommended.

- Stormwater treatment from the rezoned land was to be by CDS unit and sand filtration.

- A recycled water main was recommended to provide recycled water to the subject land

2 Existing Environmental Setting

2.1 Topography

Site 0.5 contours were provided by Hastings Council and are relied upon for the purposes of this investigation. Further to this, surface levels at each of the installed piezometers were surveyed by King and Campbell Pty Ltd. Site survey data are provided in Attachment B and indicate that the western portion of the site is generally dominated by a relatively steep north-south aligned ridge with grade ranging between 10-20 %. To the east of the ridge, the site is relatively flat with grades of < 10 % grading towards the beach (see Figure 1).

Figure 1: View towards north of sub-catchments C3 and C4 indicating low gentle gradients at lower portions of the site.

2.2 Geology

No rock outcropping was observed at within the study area although a small outcrop occurs at the beach in the north east portion of the study area. Rock cores were not collected from the beach outcrop as part of this investigation. Review of local 1:250 000 geological series mapping (Hasting Sheet 5614, 1968) indicates that local bedrock is formed from the Myrabed formation including schist, phyllite greywacke and slate. Low lying areas are composed of various with Quaternary and Holocene silts, muds, sands and gravels.

2.3 Surface Drainage and Existing Hydrology

No defined water courses occur within the immediate study area which is dominated by a series of concave drainage depressions draining towards the SEPP 26 forest. We have separated the site into 4 primary coastal sub-catchments which are provided in Attachment B. Catchment areas are summarised below in Table 1. We note that a small farm dam was located within catchment C2 between elevations of approximately 12.0 – 12.5 mAHD (see Figure 2).

Table 1: Coastal sub-catchment areas (ha).

Catchment	Area (ha)
C1	5.172
C2	5.959
C3	7.066
C4	3.367

Figure 2: View towards south of sub-catchment C2 (delineated with dashed line) with existing farm dam located at middle foreground.

Our observations of surface water hydrology are as follows. These generally accord with the findings of Jelliffe Environmental (2001).

- Soil profiles within the elevated portions of the site (say > 8m AHD) are generally very high in clay content which, together with the relatively steep gradient, indicates that much rainfall is transmitted downslope as surface runoff.

- Surface runoff collected at the base of north-south aligned ridge line predominantly infiltrates to both recharge local groundwater, but also to provide soil moisture to surface soil layers.

- Some 60 mm of rain fell within the study area in the week prior to installation of the piezometers. During the field investigations, we noted that the low lying northern and eastern portions of the site were water logged to the point that it was difficult, notably at the north of the site, to navigate a 4WD through the terrain.

  The field observations support the contention that low lying areas of the site have the propensity to become water logged for some periods after rainfall as water pools at the slope base and then recharges local groundwater. Temporary perched water tables in the low lying areas therefore form a part of the local hydrogeological cycle and supply water to deeper groundwater.

- Further to the above, we note that surface runoff coefficients on the north-south aligned grass covered ridge are likely to be higher than in the past when the site was more heavily vegetated. This has probably led to an increase in surface soil moisture (wetter and more frequently wet) along the eastern edge of the ridge.

2.4 Soil Profile

Soil profiles were investigated during site borehole drilling and soil sample retrieval. Detailed borehole logs provided in Attachment C.

Generally, soil profiles are characterised by low permeability topsoil of loams, clay loams and light clays to a varying depths of approximately 0.5 – 0.7 m. Below this, sub-soils grade from medium to heavy clay, with minimal sand content.

The exceptions to this were BH3 and BH4 which revealed clays to approximately 2.5 m depth, overlying clayey sands to at least 6 m depth.

2.5 Climate and Antecedent Rainfall

Local climate is summarised in Table 2 indicating that the site receives moderate to high annual rainfall which is higher in the first 6 months of the year. Mean annual rainfall is approximately 1539.5 mm/year. Mean minimum temperatures range between 7.2 °C in July, through to 18.4 °C in February. Mean maximum temperatures range between 17.9 °C in July, through to 25.9 °C in February.

Table 2: Local climate summary (rainfall and temperature – Port Macquarie data, Class A pan evaporation – Taree data).

	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Σ / Avg.**
Mean Rain (mm)	153.3	177.4	176.4	167.7	147.3	131.5	97.8	82.6	82.1	94.1	102.4	126.9	1539.5
Median Rain (mm)	113.4	159.1	157.9	131.2	114.7	99.8	76.2	53.5	63.7	72.1	85	110	1424.5
Rain days	12.4	13.3	14.3	12.7	11.4	10.0	9.2	8.6	8.9	10.6	10.9	11.2	133.5
Class A Evap (mm)	180.0	148.0	136.0	102.0	68.0	57.0	63.0	87.0	117.0	149.0	159.0	195.0	1461.0
Max T (°C)	25.7	25.9	25.1	23.1	20.7	18.5	17.9	18.8	20.4	21.8	23.2	24.7	265.8
Min T (°C)	18.3	18.4	17.1	14.1	10.9	8.5	7.2	7.7	9.9	12.8	15.1	17.1	157.1

In terms of the 6 months prior to the start of the primary groundwater monitoring period, Table 3 indicates that rainfall was approximately similar to the long-term average climatic conditions. On this matter we note that 'average' conditions are rarely achieved in the natural environment. However, the data support the view that at the time of the on-set of monitoring, groundwater levels are likely to have represented 'typical' conditions for an average rainfall year.

Further to the above, we note that during the December – January primary monitoring period, rainfall was considerably lower than the long-term average for the area with a deficit of approximately 104 mm over the two months. This represents some 37 % lower than average rainfall. During this period, groundwater recharge rates are expected to have been reduced and evapotranspiration losses are expected to be more 'observable' than would otherwise be the case for an 'average' rainfall condition.

Table 3: Estimate of site antecedent rainfall conditions for February 2007at the time of field investigations (15.2.2007).

Month - Year	Average Rainfall (mm)	Actual Rainfall (mm)	Difference (mm)
May – 2006	147.3	4.6	-142.7
Jun – 2006	131.5	138.8	7.3
Jul – 2006	97.8	227.4	129.6
Aug – 2006	82.6	166.4	83.8
Sep – 2006	82.1	88.8	6.7
Oct – 2006	94.1	45	-49.1
Nov – 2006	102.4	155.6	53.2
Dec – 2006	126.9	67.2	-59.7
Jan – 2006	153.3	108.8	-44.5
Total	1018	1002.6	-15.4

3 Existing Groundwater Conditions

3.1 Field Investigations

Field investigations and groundwater level observations were undertaken during November 2006 to February 2007. Whilst this is a relatively brief period, it is considered adequate to determine groundwater trends and investigate the relationship between antecedent climatic conditions and groundwater level. Investigations and observations included the following works:

- Excavation during 9-10/11/2006 of 6 sub-surface boreholes by truck mounted drill rig in accordance with AS 1796 (1993) to determine soil profile conditions (see Attachment C for borehole logs). Installed piezometers locations are given in Attachment B.

- Installation of 6 piezometers during 9-10/11/2006 for monitoring of *in-situ* groundwater level. Piezometer construction methodology consisted of the following:

    - Construction from 50 mm threaded UPVC tubing, fitted with UPVC end cap and covered with geotextile cloth prior to installation. A minimum of 3 m of well screen was included at each piezometer site.

    - Piezometers were backfilled with clean washed fine gravel and capped with a layer of bentonite pellets and sealed with rapid set concrete.

    - All piezometers were fitted with lockable galvanised iron monuments and padlocked after site works to ensure security of the well.

    - All piezometers were fully purged following installation.

- Groundwater levels were monitored manually at each location using ‘dip metering’. Manual monitoring times included 9/11/2006, 23/11/2006 and 4/2/2007.

- Field measurement of aquifer hydraulic conductivity was undertaken using the Hvorslev (1951) method at BH2, BH3, BH5 and BH6. Detailed measurements of storativity and specific yield were beyond the scope of this investigation.

- Installation of groundwater high resolution monitoring 'Divers' at boreholes BH2, BH3, BH5 and BH6. Initially BH4 was also instrumented (between 10-22/11/2006) but the well was predominantly dry and monitoring was subsequently abandoned.

  Diver data were initially downloaded after the 'trial' period between 11/11/2006 and 22/11/2006. Following this, final Diver locations and levels were determined with comprehensive groundwater level monitoring occurring between 23/11/2006 and 4/2/2007.

- Collection of groundwater samples from each of the piezometers. Each piezometer was purged twice before collection of groundwater samples. We note that following well purging, it was not possible to collect sufficient sample volume from BH1 (which was dry), BH4 (insufficient volume) and BH6 (insufficient volume).

3.2 Piezometer Installation Summary

Piezometers were installed to varying depths depending on ground conditions at the time of installation and groundwater conditions encountered during drilling. We note that low strength bedrock was not encountered at any of the boreholes. A summary of each piezometer installation is provided in Table 4. Penetration depths of installed piezometers were generally > 3.0 m.

We note due to extremely wet ground conditions at the time of installation, some borehole collapse occurred at BH1, BH3 and BH4. This meant that piezometer penetration was somewhat less than the full extent of the borehole depth.

Table 4: Summary of piezometer installations.

	BH1	**BH2**	**BH3**	**BH4**	**BH5**	**Bh6**
Surface level (mAHD)	12.815	12.13	8.380	8.310	15.730	13.800
Well invert (mAHD)	9.810	5.210	4.860	4.160	6.880	9.280
Penetration depth (m)	3.005	6.920	3.520	4.150	8.850	4.520

3.3 Groundwater Water Quality

Groundwater data were collected from piezometers with sufficient sample available. Sampling was not possible from BH1, BH4 and BH6. A summary of the groundwater quality testing is as follows with details provided in Table 5 and Table 6. Attachment D provides full results.

- pH indicates acidic conditions. This occurs both in groundwater contained within residual soil as well as that contained within the Quaternary and Holocene deposits.

- Electrical conductivity (EC) for BH2 was typical of freshwater (see Table 7) whereas BH3 and BH5 maintained EC levels which were in the saline range generally unsuitable for rainforest species. Data suggest local geology may be high in salt content, resulting groundwater within the north-south aligned ridge-line being generally saline and not particularly suited to terrestrial plant growth. Contrasting this, BH2 was fresh suggesting that water collected from this piezometer was being actively recharged by infiltrating surface waters (perched water table). Groundwater mounding at BH2 supports this contention.

Table 5: Groundwater quality monitoring results (23/11/2006).

Parameter	BH1	BH2	BH3	BH4	BH5	BH6
pH	-	5.00	5.80	-	5.70	-
Electrical Conductivity (µS/cm)	-	583	6640	-	6470	-
Nitrate-N (mg/L)	-	0.01	0.02	-	0.02	-
Nitrite-N (mg/L)	-	0.20	0.90	-	0.30	-
TKN-N (mg/L)	-	0.02	0.01	-	0.01	-
Ammonia-N (mg/L)	-	0.20	0.90	-	0.30	-
TN-N (mg/L)	-	0.23	0.93	-	0.33	-
TP-P (mg/L)	-	0.35	0.60	-	0.33	-
BOD_5 (mg/L)	-	< 1.00	< 1.00	-	< 1.00	-
TSS (mg/L)	-	600	1900	-	2700	-

- Nitrogen species including nitrate and Kjeldahl nitrogen were near to or below detection levels. However, nitrite and ammonia levels were moderate in all boreholes, with total nitrogen in groundwater ranging between 0.23 - 0.93 mg/L.

- Total phosphorus levels in groundwater were higher than expected given the high clay content of local catchment soils. We note that all groundwater samples collected contained relatively high levels of suspended solids despite purging of each piezometer. It is possible that elevated phosphorus is partly attributable to sediment sorption related processes.

Further testing would be required to estimate the fraction of bound and unbound phosphorus in groundwater samples.

Table 6: Average groundwater quality conditions (23/11/2006).

Parameter	Site Average
pH	5.50
EC (µS/cm)	4564
Nitrate-N (mg/L)	0.02
Nitrite-N (mg/L)	0.47
TKN-N (mg/L)	0.01
Ammonia-N (mg/L)	0.47
TN-N (mg/L)	0.50
TP-P (mg/L)	0.43
BOD_5 (mg/L)	< 1.00
TSS (mg/L)	1733

Table 7: Typical electrical conductivity ranges (µS/cm).

Water type	Electrical conductivity (µS/cm)
Deionised water	0.5-3
Pure rainwater	<15
Freshwater rivers	0-800
Marginal river water	800-1600
Brackish water	1600-4800
Saline water	>4800
Seawater	51 500

- 5 day biochemical oxygen demand (BOD_5) levels were all below detection limits (< 1 mg/L). This indicates that local groundwater resources have not been significantly impacted by groundwater pollution events and that the local aquifer is relatively low in organic materials.

- In summary, local groundwater is brackish to saline but generally maintains low pollutant levels. Salinity is noticeably lower in higher aquifer levels. This concurs with the recommendations made by Jelliffe Environmental, who suggested that the freshwater lens would sit above saline water.

3.4 Hydraulic Conductivity

Hydraulic conductivity (K_{sat}) of the sites aquifer was determined at four locations including BH2, BH3, BH5 nd BH6. Detailed pump-test data and analysis reports are provided in Attachment E. The following matters are noted:

- K_{sat} generally increases with proximity to the ocean. This is expected given that sub-soil sand content increases and clay content decreases with proximity to the ocean.

- There is a considerable difference in aquifer K_{sat} between the hillslope, which maintains K_{sat} of 1.2 – 5.8 x 10^{-8} m/s, and the lower slopes, notably where sand occurs, which reach up to 5.8 x 10^{-6} m/s. BH2 appears to mark a transition between the hillslope and the lower sand plain / back barrier dune areas.

- We expect that K_{sat} would increase further towards the ocean given increasing sand content.

Table 8: Hydraulic conductivity test results.

Date	K_{sat} (m/d)
BH2	0.180
BH3	0.505
BH5	0.005
BH6	0.001

For the purposes of groundwater modelling, adopted K_{sat} for the clay and lower silty sand units were 0.10 and 2.5 m/d respectively.

3.5 Groundwater Levels

3.5.1 Hydro-geological Model

A hydro-geological model has been prepared for the study area based on available field testing information and previous test pit data provided by Hackett Laboratories. A stylised section of the model is provided in Attachment B and is described as follows:

- Relatively high groundwater tables with steep gradients are found within the extremely weathered soil mantle of the north-south aligned ridge.
- Water table position within the ridge appears to be dependent on local topographic catchment area. For example, BH1 maintains little to no catchment area and maintained no permanent water table < 3 m below ground level during the primary observation period. However, BH2 which is situated at a similar surface level but resides within a considerably larger topographic catchment, maintained water levels near to the surface. We note that it is possible that borehole smearing could have occurred during the installation of BH1 due to the excessively wet conditions during field works. If this were the case, then results for BH1 should be viewed with caution
- It therefore follows that variable topography along the edge of the SEPP 26 forest will result in variable recharge from upslope freshwater runoff.
- Freshwater within the SEPP 26 forest soils is recharged either by direct incident rainfall or by surface runoff from upslope areas.
- Groundwater recharge from 'pooled' upslope runoff is considerably fresher than deeper groundwater. During or after periods of extended or intense rainfall, runoff will saturate the upper clay layers of the sites low lying areas. This may at times result in a temporary perched groundwater body overlying the more permanent groundwater body some metres below.
- Sea water intrusion occurs into the study area. This occurs as a denser 'wedge' of water at approximately 0 m AHD and underlies the entire study area. Brackish and saline groundwater conditions observed above this level at the site are likely to be a function of inherent salinity of local rock formations, inclusion of salt spray into the drainage water, and may be the result of some diffusion between saline and fresh water bodies.

3.5.2 Manual Level Observations

Manual groundwater level observations were made during each site inspection. Levels are provided in Table 9 and accord with the results of detailed 'Diver' monitoring.

Table 9: Summary of manual GW level measurements (mAHD).

Date	BH1	BH2	BH3	BH4	BH5	Bh6
10/11/2006	10.32	11.53	5.36	5.87	12.18	Dry
23/11/2006	Dry	12.09	5.68	4.29	13.12	10.78
4/02/2007	Dry	11.50	4.97	Dry	12.17	10.89
Average	na	11.71	5.34	5.075	12.49	10.83

3.5.3 Barometric Pressure

Barometric pressure has the capacity to affect pressure readings at the 'Diver' locations by up to 20-35 cm on a weekly basis. Barometric pressure was monitored at the site using a 'BaroDiver' installed above the water table at BH6. This allowed for continuous monitoring of barometric pressure in order that groundwater levels could be calibrated to a normalised pressure of 1000 hPa.

Measurement frequency was set to 5 minutes with a summary of results provided in Figure 3. All water level compensation was undertaken through software provided with the 'Divers'. Barometric pressure varied considerably during the primary observation period, fluctuating about a mean of approximately 1015 hPa.

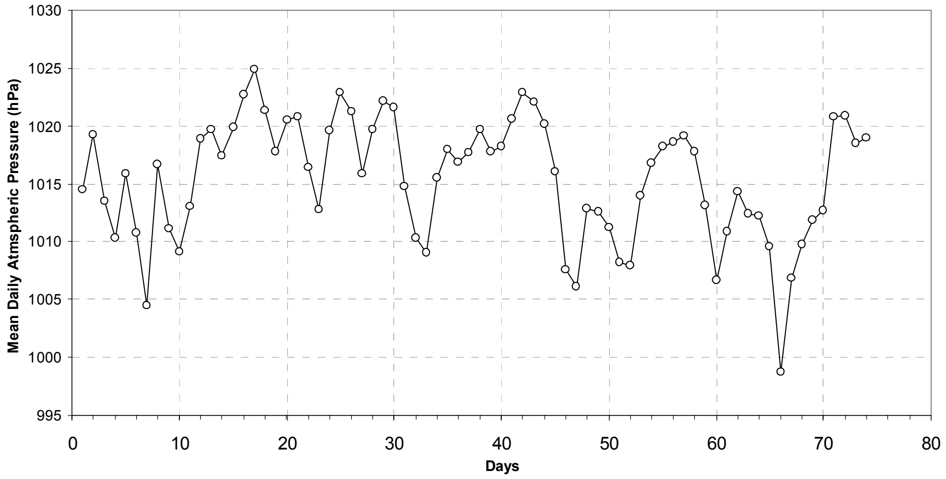


Figure 3: Variation in barometric pressure during primary monitoring period (day 0 = 23/11/2006, day 74 = 4/2/2007).

3.5.4 Daily Monitoring Results

Daily groundwater level records were compiled from 10 minute sampling data collected at each 'Diver' installation. Results are provided in Attachment F, with a summary plot provided in Figure 4. The following is noted:

- Water levels at BH2, BH3 and BH5 show a steady decline during the primary monitoring period.

- Water levels at BH2, BH3 and BH5 tend to show similar peaks and troughs.

- Water levels at BH6 increase for approximately 2 weeks, before levelling and then very slowly decreasing. The initial increase period is attributed to the bore being purged and recovery-tested prior to 'Diver' installation. Monitoring results during the initial 2 weeks therefore reflect the 'tail' of recovery testing undertaken on 23/11/2006.

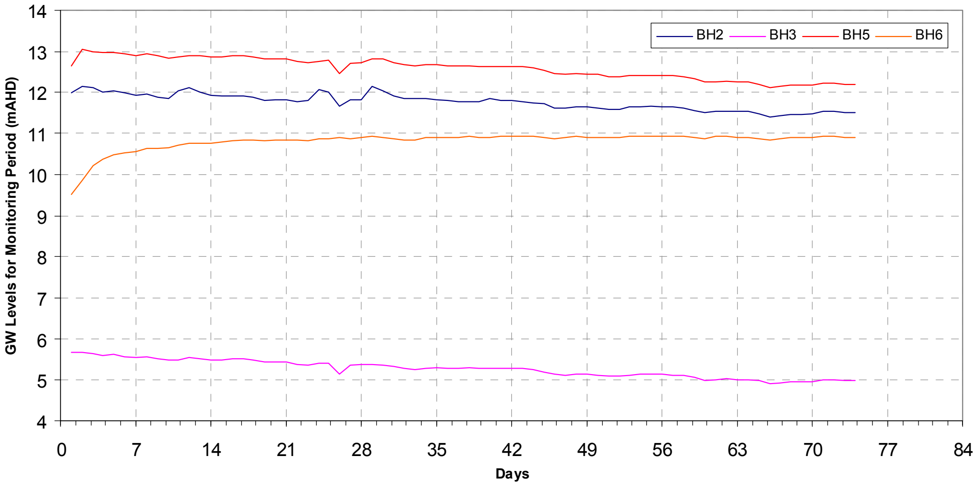


Figure 4: Variation in groundwater level during primary monitoring period (day 0 = 23/11/2006, day 74 = 4/2/2007).

In order that monitoring results could be compared between piezometers, daily data were 'normalised' by dividing the daily observation by the mean of the observation period, and expressing this as a percentage deviation from the mean. Results are provided in Figure 5 and show that for all piezometers, including the later period for BH6, there is a similar gradual decline in water level. This suggests that local groundwater levels, whilst varying in height and absolute level variations, respond in a similar way to local environmental conditions.

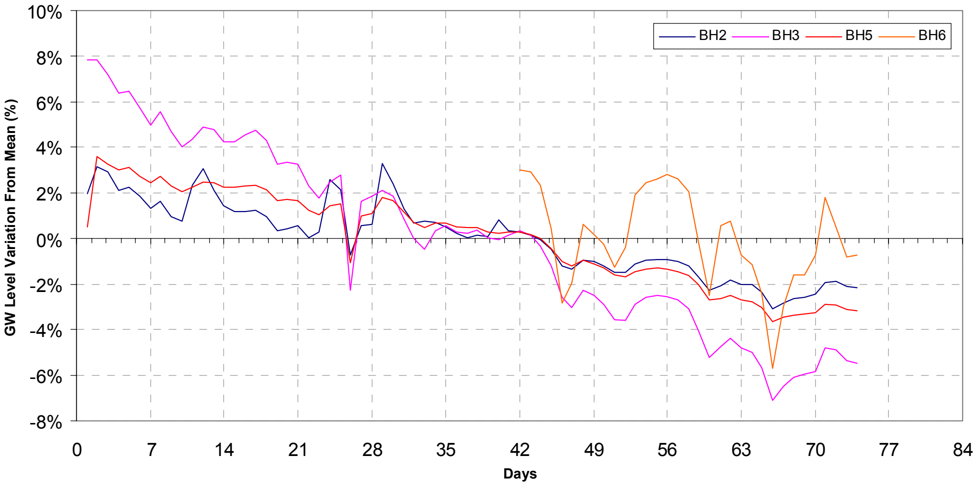


Figure 5: Variation in relative groundwater level (with respect to mean level observed at each piezometer) during primary monitoring period (day 0 = 23/11/2006, day 74 = 4/2/2007).

3.5.5 *Tidal Influence*

Detailed monitoring data (10 minute intervals) showed that small daily groundwater level fluctuations occurred at all observation sites. Figure 6 and Figure 7 provide plots of relative groundwater levels expressed as deviations from daily means for 12/12/206 and 13/01/2007. In both cases, two peaks and two troughs are apparent.

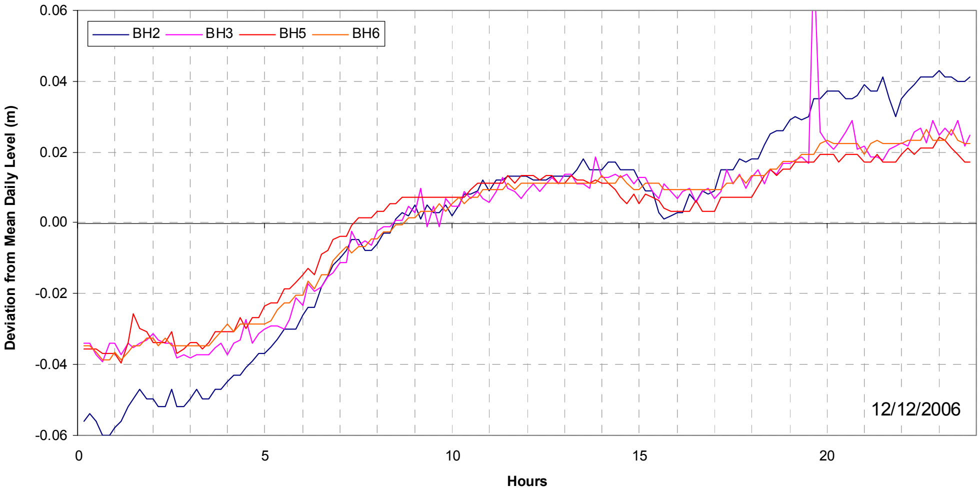


Figure 6: Relative groundwater level (as deviation from daily mean) for 12/12/2006.

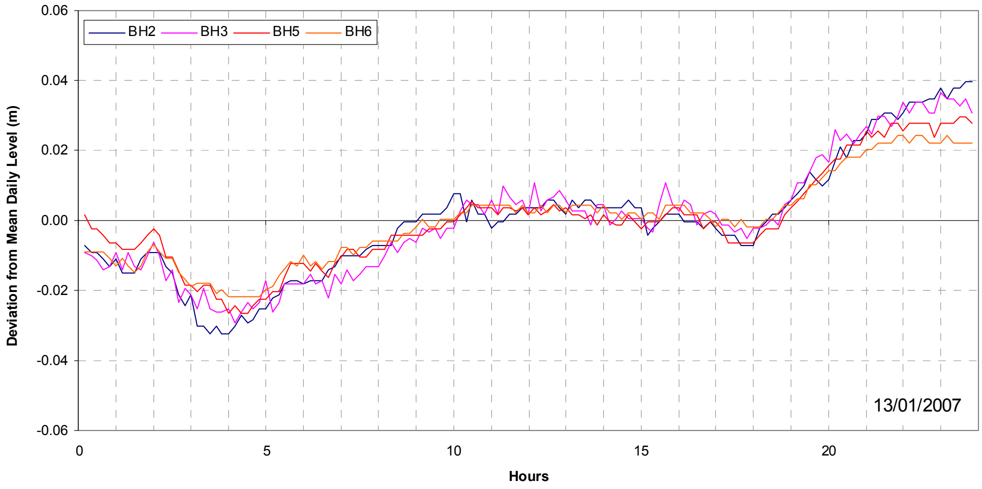


Figure 7: Relative groundwater level (as deviation from daily mean) for 13/01/2007.

An assessment of groundwater response times, or lags, to tidal incursions is provided in Table 10. The following comments are provided in relation to the influence of tide on local groundwater regime:

- Tide appears to influence all piezometers causing relative water level / pressure fluctuations of 2-3 cm above those caused by other environmental parameters. Tidal influence appears strongest at BH2 and BH3 which are located closer ocean.
- The mechanism by which the tide intrudes and acts on local groundwater is not fully understood. However, given that fluctuations are minor, the effect of tide can be generally discounted.
- Time lags in groundwater response appear to differ both between high and low tides, but also between monitoring days. Longer lags were noted where differences between low and high tide were greatest (eg. 12/12/2007).

Table 10: Assessment of groundwater response times (lags) to tidal incursions.

	Time (Hrs:Min)	**Tidal Height (m)**	**Corresponding GW Level (Hrs:Min)**	**GW Lag (Hrs:Min)**
		12/12/2006		
High Tide	2:32	1.18	12:00	9:28
	14:15	1.29	23:00	8:45
Low Tide	8:13	0.72	16:00	7:47
	20:53	0.51	4:00	7:07
		13/01/2007		

High Tide	8:19	1.7	12:00	3:41
	21:00	1.2	0:00	3:00
Low Tide	1:49	0.5	4:00	2:11
	15:49	0.3	18:00	2:11

3.5.6 Rainfall Influence

Historical daily rainfall data for the monitoring period were obtained from the Bureau of Meteorology's Port Macquarie climate monitoring station. Figure 8 provides a plot of mean 'normalised' groundwater level (ie. daily percent variation from observation period mean) variations across the site against daily rainfall. No apparent direct relation exists between rainfall and immediate site groundwater level fluctuations.

Further to the above, a lagged correlation function was prepared for the monitoring period extending some 7 weeks prior to the start of monitoring. To explain this procedure, for example, groundwater on day 'n' is correlated to rainfall on day 'n_{-t}' where 't' is the lag period in days. Results are provided in Figure 9 and suggest that there is no link between daily rainfall totals and daily groundwater level fluctuations.

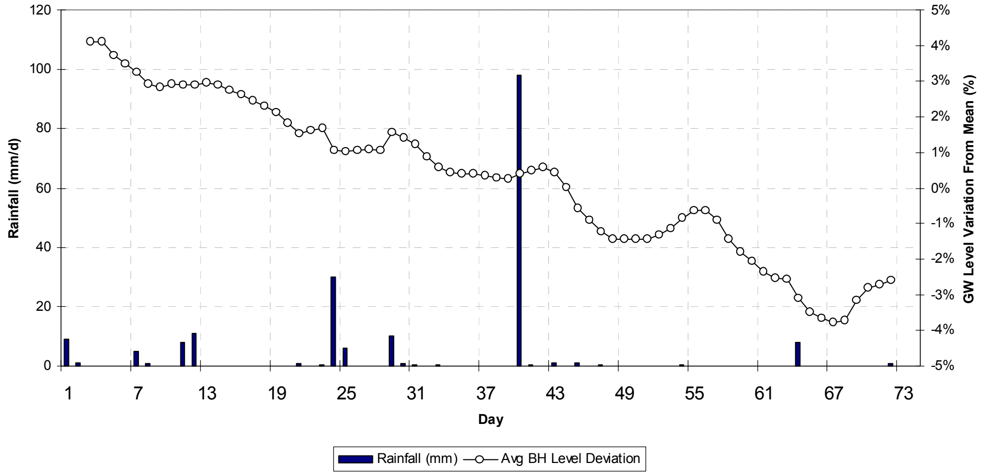


Figure 8: Site mean 'normalised' groundwater level variation (expressed as a 5 day running average) plotted in relation to rainfall during the primary monitoring period.

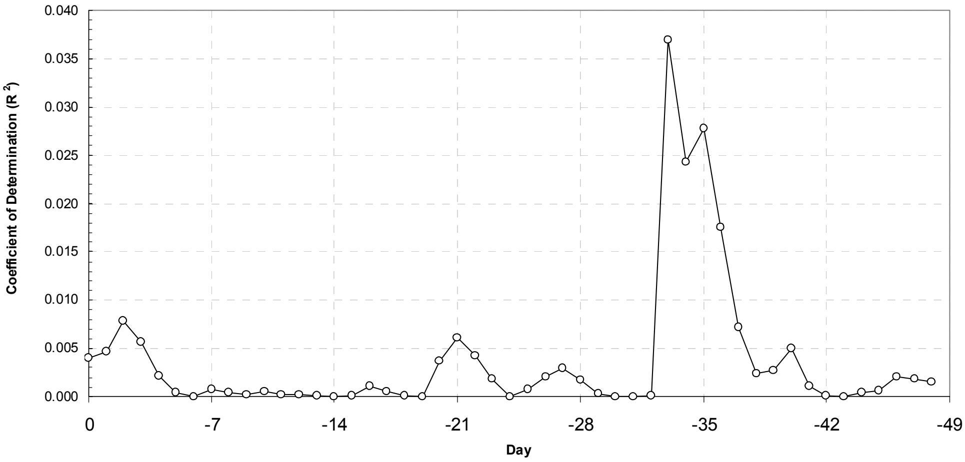


Figure 9: Lagged correlation function between site mean 'normalised' groundwater level variation (expressed as a 5 day running average) and antecedent rainfall.

In addition to the above analysis, lagged correlation functions between antecedent rainfall and groundwater level fluctuations were prepared for rainfall running totals of 7, 14, 21 and 28 day time 'blocks' (see Figure 10, Figure 11, Figure 12 and Figure 13). To explain this procedure, for example, groundwater level on day 'n' is correlated to the total rainfall falling during the period '$n_{-t \text{ to } -(t-P)}$' where 't' is the lag period in days prior to monitoring and 'P' is the period over which rainfall is totalled. This approach allows the effects of slower responses to rainfall totals over the historical record to be investigated.

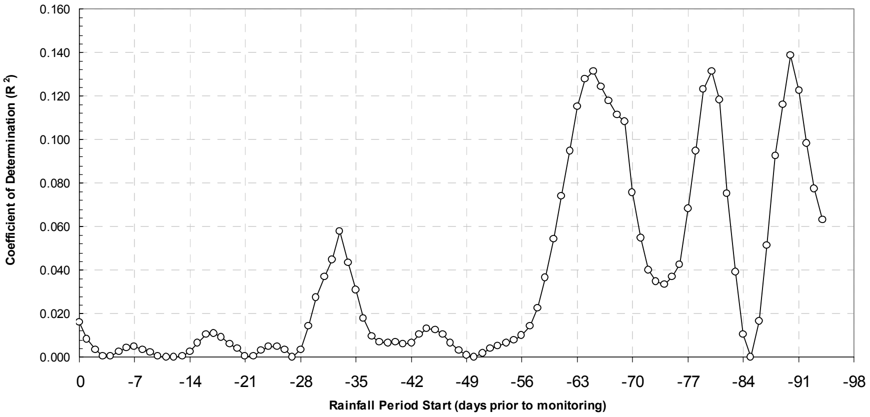


Figure 10: Lagged correlation function between site mean 'normalised' groundwater level variation (expressed as a 5 day running average) and antecedent rainfall total over 7 day block.

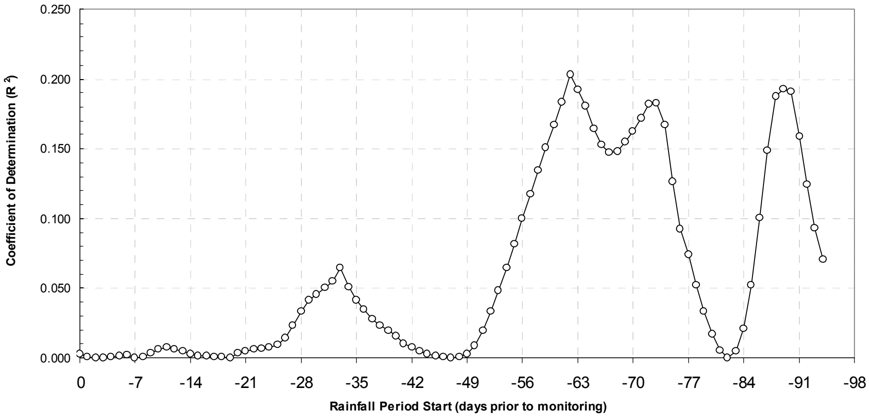


Figure 11: Lagged correlation function between site mean 'normalised' groundwater level variation (expressed as a 5 day running average) and antecedent rainfall total over 14 day block.

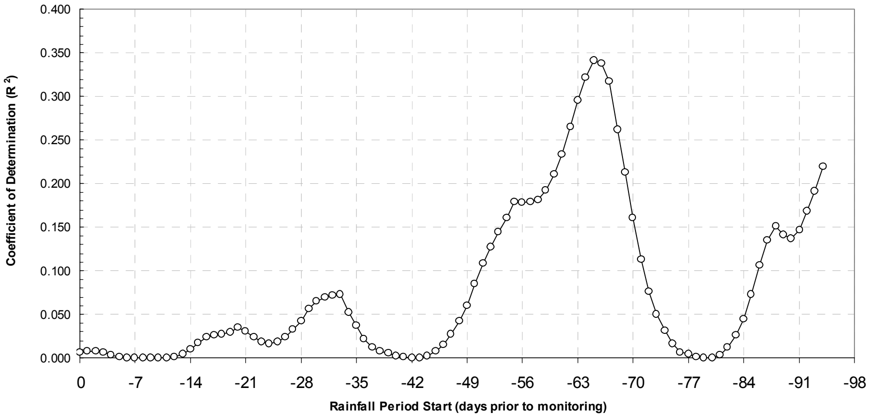


Figure 12: Lagged correlation function between site mean 'normalised' groundwater level variation (expressed as a 5 day running average) and antecedent rainfall total over 21 day block.

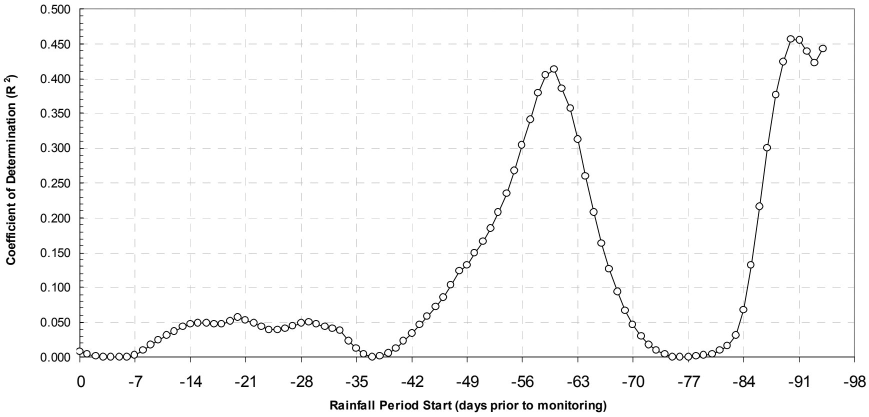


Figure 13: Lagged correlation function between site mean 'normalised' groundwater level variation (expressed as a 5 day running average) and antecedent rainfall total over 28 day block.

Results provided in the above charts suggest the following:

- Daily rainfall does not directly influence daily groundwater levels at the site. Rather, some period of time is required before groundwater levels respond to rainfall.

- Groundwater levels do not appear to be particularly influenced by any single rainfall event occurring on a particular day. Rather, the effect of accumulated rainfall appears more important.

- The lagged correlation analysis showed the strongest relation between a 4 week rainfall total occurring some 2 months (60 days) prior to monitoring.

- The lagged response to rainfall probably also reflects changing Class A Pan evaporation and therefore evapotranspiration rates (which were increasing during the monitoring period and increasing during the 2 months prior to monitoring). It is beyond the scope of this study to separate further the effects of rainfall and evapotranspiration rates on groundwater level.

- We note that for the purposes of this assessment, the lagged correlation analysis was undertaken for the site as a whole rather than for each individual piezometer. A more detailed analysis is beyond the scope of this study. However, we are of the view that groundwater below the sandier soil profiles is likely to show a faster response to antecedent weather conditions.

3.5.7 Long-term Level Fluctuations

On the basis of the previous results and discussions, it is clear that local groundwater levels at the study site appear to respond to seasonal climatic fluctuations. In crude terms and for the purposes of this assessment, this can be expressed as the difference between monthly rainfall and monthly evaporation.

By extrapolating the relation between moisture deficit (162 mm in the monitoring period) and consistent water tables drops, it was possible to estimate seasonal water table positions. Results are provided in Figure 14 and indicate that groundwater levels may fluctuate by approximately 1.0 – 1.5 m, reaching a peak during winter (or late winter / early spring). This is generally in agreement with previous estimates made by Jelliffe Environmental.

We note that this analysis is preliminary only and does not take account of lagged responses discussed earlier. This is expected to 'shift' the estimated levels by approximately 2 months forward in time.

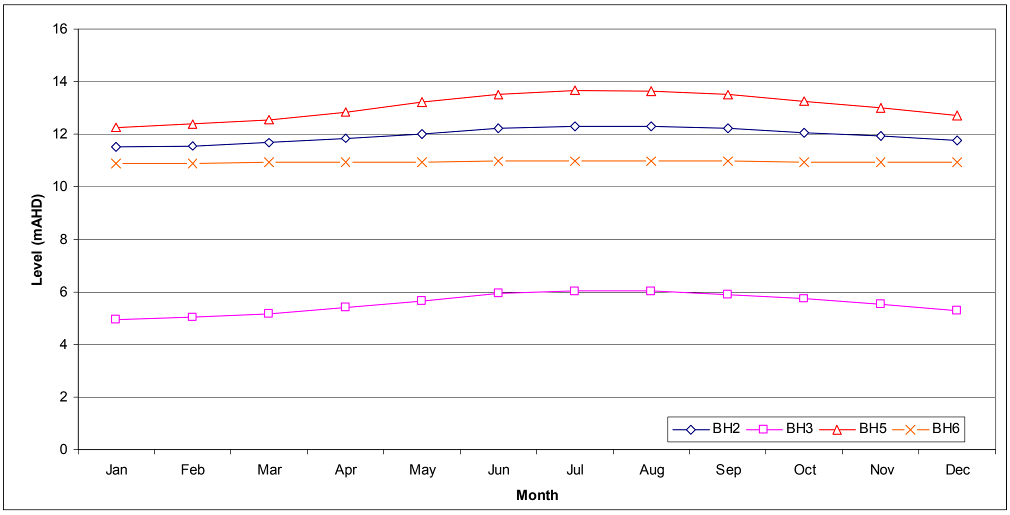


Figure 14: Estimate of seasonal groundwater level fluctuations for each instrumented piezometer site.

4 Groundwater Impact Assessment

4.1 Overview of Risks

Urban development has the capacity to alter both surface water regimes as well as local hydro-geology at the development site. This may come about through one of the following mechanisms:

- Impervious surfaces, such as roofs, pavements and roads, prevent direct infiltration. This may result in lowered soil moisture, less groundwater recharge below the impervious surfaces, reduced evapotranspiration rates, and increased runoff volumes.

- Increased runoff volumes, as well as increased runoff peak flow rates can occur as a part of urbanisation. In the case of this site, increase surface water flows would be generally received at the western 'edge' of the SEPP 26 forest.

- Sub-surface structures may deflect soil moisture and groundwater flows leaving 'shadow' immediately downslope where soil moisture and groundwater levels are depressed for some distance.

- Sub-surface drainage structures, such as drains behind retaining structures or roads, may lower groundwater tables both upslope and downslope of the drain.

4.2 Modelling

4.2.1 Method

The modelling approach undertaken included the following primary steps.

- Establishment of ModFlow Version 4.2 model of the study area. Surface terrain data were interpolated by 'Kriging' using 0.5 m contour data provided by Council's GIS and amended using field survey data for each piezometer provided by King & Campbell.

- Calibration of the pre-development groundwater model using monitored groundwater data and estimated long-term mean levels derived as a part of this study. Boundary conditions assumed in the model were:

  - The north-south aligned ridge line acted as a groundwater divide. Surface and groundwater water to the west of the divide were assumed to flow to water courses located either to the south west or north west of the study area.

  - A constant head boundary condition of 1 mAHD was assumed at the upper beach face.

  - North and south flow boundary conditions were set near to the topographic sub-catchments depicted in Attachment B (ie. C1 and C4).

  - No water courses were included as part of the model set-up.

  - The monitoring 'boundary', or point at which measureable change was assessed, was taken as the western edge of the SEPP 26 forest.

  - Pre-development evapotranspiration and recharge boundary conditions were based on existing catchment conditions which included primarily pasture grasses and some regenerated and replanted forest areas.

- A post-development model was created. This was essentially assumed to change the surface runoff rates and evapotranspiration boundary condition within the study area.

- Post-development conditions were modelled for impervious areas of 50%, 60 % and 70 %. These were based on advice provided by Council for likely ranges within any future development.

4.2.2 Evapotranspiration (ET) Rates and Crop Factors

Evapotranspiration rates are a key factor in estimating the likely recharge to groundwater and hence determining changes to groundwater level as a result of the proposed rezoning.

Annual average crop coefficients are frequently used to estimate the annual evapotranspiration rate. This is done by assuming that ET = E x CF where ET is the evapotranspiration rate, E is Class A Pan Evaporation, and CF is the Crop Factor. CF typically varies between plants as well as from month to month. In some cases, CF values are low to zero during winter periods when plant growth slows or stops (eg. deciduous trees).

Limited ET data are available for local rainforests. However, Myers *et al* (1999) have, based on a number of climatic investigations and ET modelling, presented some data for the local area. This is summarised in Table 11 and provides the following relevant information:

- Mean annual ET rates are approximately 5.38 mm/d or 1963.7 mm/year.
- ET rates are highest during late spring and summer, and lowest during June and July.
- ET rates during winter months, whilst approximately 50 % of those occurring in summer, are nevertheless still substantial.

Table 11: Evapotranspiration rates for forests within Bioclimatic Region 6 - warm tropical / temperate coastal (Myers *et al*, 1999).

Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
ET (mm/d)	6.8	6.3	5.5	4.5	3.4	3.4	3.8	4.9	6.1	6.3	6.6	6.9

The above data, together with local class A pan evaporation rates from Taree, can be used to estimate local CF values for each month. Estimates are provided in Table 12 and compared to values provided by NSW DEC (2004) for pasture.

Table 12: Crop factors (CF) for pasture and SEPP 26 forests.

Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Pasture	0.70	0.70	0.70	0.60	0.50	0.45	0.40	0.45	0.55	0.65	0.70	0.70
SEPP26	1.13	1.16	1.19	1.25	1.39	1.59	1.65	1.59	1.43	1.23	1.19	1.10

On the basis of the above estimates, annual average CF's were taken to be 0.59 for pasture and 1.32 for the SEPP 26 forest. For the urban areas, gardens and other pervious areas were considered to comprise of mixture of grasses (such as Kikuyu) and evergreen shrubs (typical of the local area). An average annual value of 0.80 was therefore used for pervious urban areas. These were further reduced as a function of impervious urban percentage for each modelling scenario.

The above data were used to derive broad average land-use groundwater recharge rate estimates which were iteratively adjusted in order that modelled heads closely matched observed observation well heads (Table 13).

Table 13: Recharge rates assumed for Modflow 4.2 modelling.

Area	Recharge (mm/d)
Pasture	0.71
Lower Forest	1.64
Upper Beach Face	3.84

Importantly, the seasonal data show that ET rates are considerably higher for forested areas than for the pasture covered sites. This confirms the contention that the present pasture is likely to have significantly increased the water surplus, delivered as runoff and groundwater recharge / drainage, to the SEPP 26 land, from that of the sites previous vegetation cover.

This would be particularly the case during the winter months, when pasture growth rates are substantially reduced. For example, ET during June and July for pasture are approximately 24 and 25 mm respectively, while ET for the SEPP 26 land are approximately 102 and 118 mm respectively. During summer months, differences between pasture and forest ET are not as pronounced as for winter.

From the above discussion, it is clear that the proposed revegetated buffer put forward by King & Campbell will have the effect of reducing groundwater recharge through increased evapotranspiration rates. Also, effective crop factors for urban areas will vary with percent catchment impervious percentage as indicated in Table 14.

Table 14: Effective crop factors (CF) for urban areas.

Percent Impervious (%)	Effective CF
50	0.40
60	0.32
70	0.24

4.2.3 Varying Urban Areas

An assessment of the potential impact on groundwater level was undertaken for various urban densities. Scenarios included in the modelling exercise (based on advice from Council) were as follows:

1. Vegetated buffer with 50 % impervious area
2. Vegetated buffer with 60 % impervious area
3. Vegetated buffer with 70 % impervious area

The impact of urbanisation in the local catchments, in terms of water budget is illustrated by the concept model provided in Figure 15. This illustrates that surface runoff from Zone A to Zone B will increase with urbanisation and recharge from Zone A to Zone B will decrease with urbanisation. Additional surface runoff flows from Zone A to Zone B will become increased Zone B recharge, subject to any changes in evapotranspiration brought about by the revegetation process. We note that for modelling purposes, Zones A and B were further separated, depending on the characteristics of each sub-catchment and locations / areas of final land-uses.

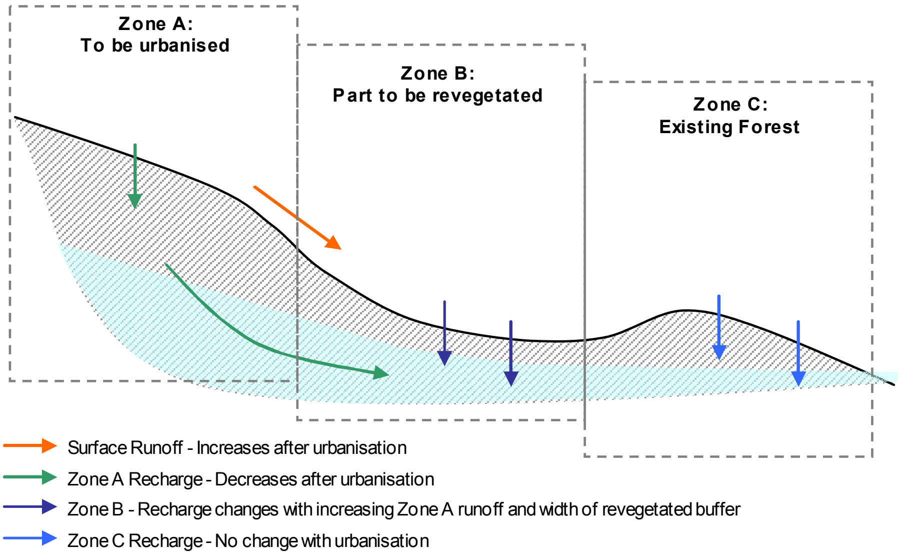


Figure 15: Concept model for impact of catchment urbanisation on coastal recharge rates.

For each development scenario, the effect on net water deficit / surplus on the SEPP 26 forest community was evaluated, together with an estimate of change in long-term groundwater level.

In terms of each sub-catchment affected by the proposal, effective buffer lengths, residual grass APZ and vegetated buffer zones were estimated using the draft structure plan. Given that a detailed CAD version of the plan was not available at the time of preparing this report, some variation in aerial estimates is expected.

A summary of buffer proposal based on the master plan is provided in Table 15. It is worth noting that effective buffer lengths are estimated based on the sub-catchments provided in Attachment B and are taken approximately centrally through the revegetation areas. These are not linear and it therefore follows that the calculated effective buffer width does not strictly accord with the minimum of 40 m drawn on the King & Campbell preliminary structure plan.

Table 15: Proposed master plan buffer estimates.

Sub-Catchment	Effective Buffer Length (m)	Estimate of Grass APZ (m^2)	Estimate of Vegetated Buffer (m^2)	Approx. Urban (m^2)	Mean Effective Buffer Width (m)
C1	272	3034	10160	4550	37.4
C2	263	3289	6155	27515	23.4
C3	289	3133	14634	24845	50.6
C4	104	600	3114	0	29.9

Results of the recharge analysis within Zone B and Zone C are summarised in Table 16. A summary of groundwater impact (worst case for each sub-catchment) modelling is provided in Table 17 and illustrated on a sub-catchment basis in Sheet 6 of Attachment B which shows drawdown (+ = lowering and - = raising of existing groundwater tables). Modelling shows varying responses to the proposed structure plan depending on sub-catchment. The following comments are provided:

- Groundwater response to land-use changes in the 4 sub-catchments is spatially variable and leads to both minor reductions and minor increases in groundwater level along the western SEPP26 boundary edge.

- The 50 % impervious area assessment could result in a net minor decrease in recharge to the SEPP 26 forest under the proposed buffer planting outlined in the structure plan. This is particularly the case for sub-catchment C1.

- Existing recharge from the buffer to the rainforest area is best approximated by the 60 % impervious urban area development scenario.

- In both the 60 and 70 % impervious urban area scenarios, localised elevation of the groundwater table occurs in response to urban runoff being discharged at the urban stormwater discharge points. The effect is most pronounced under the 70 % impervious urban area scenario in catchment C2 which indicates localised groundwater mounding within the revegetation area of the order of 1.0 – 1.2 m. In catchment C3, mounding reaches 0.5 – 0.6 m in the buffer area.

- Sub-catchment C1 shows reduced recharge for all urban development scenarios. This suggests that the proposed buffer is possibly too wide and will result in reduced frequency of occurrence of perched groundwater tables resulting from extended or intense rainfall events.

- The levels of modelled groundwater mounding are within the expected ranges of seasonal fluctuations.

Table 16: Modelled changes in groundwater recharge rate within the revegetation areas (Zone B) according to sub-catchment.

Inter-Zone Area	**Existing (ML/year)**	**50% Impervious Urban Area (ML/year)**	**60% Impervious Urban Area (ML/year)**	**70% Impervious Urban Area (ML/year)**
Buffer to Forest	44.26	41.35	43.95	46.25
Forest to Ocean	64.31	60.67	63.18	65.34

Table 17: Modelled maximum localised changes in groundwater level at the western edge of the SEPP26 forest (mm change).

Catchment	**50 % Impervious**	**60 % Impervious**	**70 % Impervious**
C1	-1800	-1700	-1600
C2	100	300	500
C3	200	300	600
C4	200	400	600

Our general comments in relation to these results are as follows:

- In areas where groundwater levels rise, these rises are considered insignificant given the depth of groundwater (> 3.0 m depth) within the SEPP 26 forest.

- Further to the above, we note that permanent groundwater below the SEPP 26 forest is generally saline or near saline. The addition of an additional thin layer of mounded fresh water to this aquifer is expected to have a negligible impact on existing groundwater chemistry below the SEPP 26 forest. Our view is that temporarily perched [near surface] groundwater table which occurs during and after extended or intense rainfall events is more significant to forest ecology than the permanent deeper groundwater table.

- In areas where there is groundwater lowering (ie. sub-catchment C1), the impact of this is not considered significant given that groundwater is moderately saline and not expected to sustain the rainforest. More important in these situations is the maintenance of surface water flow regimes to the rainforest.

- Ultimately, the final locations and extents of groundwater mounds or depressions will be dependent on the design of the stormwater system and location of stormwater discharge points. These are not available for the present study but will need to be considered in the design of the stormwater system when a development application is lodged for the site.

Finally, a preliminary analysis was undertaken to determine the required average planted buffer widths to estimate a 'no net change' in groundwater recharge at the study area. Water balance modelling was undertaken iteratively by adjustment of urban planted buffer areas. Results are provided in Table 18 with comments as follows:

- These results should be considered as conservative and viewed within the context of the potential groundwater rises or falls previously described.

- For the 50 % impervious development scenario, mean set-back distances would need to be marginally reduced in order to achieve no net change in groundwater recharge to the SEPP 26 area.

- In the case of the 60 % and 70 % impervious areas, mean set-back distances would need to be slightly increased (by 2 and 6 m respectively) in order to achieve no net change in groundwater recharge to the SEPP 26 area. The impact of climate change is considered later in this report in addition to this.

- In general our view is that the average 40 m set-back for revegetation proposed by the King & Campbell structure plan would lead to no significant changes to groundwater conditions provided that excess runoff from the catchment can be ensured to be delivered to the groundwater regime at the base of the north-south aligned slope. This could be achieved in principle through the use of deep stormwater infiltration trenches constructed within the planted buffer zone (discussed later in this report).

- The proposed 40 m set-back for revegetation appears to meet the objectives of SEPP 26 in that it guards against significant loss or deterioration of the forest community. Revegetation, subject to the other recommendations of this report, should be undertaken as soon as possible so as to ensure that maximum evapotranspiration rates can be achieved as early a possible in the development process.

- Several alternatives exist for managing the future urban areas to ensure that there will be no net change to existing recharge characteristics (should this be required). Such matters, which can be addressed at the development application stage, will include varying the mixture of impervious percentage and set-back distance between each of the sub-catchments.

  It is beyond the scope of this report to make final recommendations in relation to matters relating to urban density and set-back distance according to each sub-catchment. However, given the significantly higher aquifer permeability below the SEPP 26 forest and proximity to the ocean, we do not see that varying set-back distance in accordance with sub-catchment as strictly necessary.

Table 18: Effective[1] buffer widths required to ensure no net change in groundwater recharge.

Urban Catchment		50 % Impervious	60 % Impervious	70 % Impervious
Catchment	**Proposed Effective[1] Buffer (m)**	**Required Effective[1] Buffer (m)**	**Required Effective[1] Buffer m)**	**Required Effective[1] Buffer (m)**
Actual Mean Setback (m)	40	39[2]	42[2]	46[2]

[1] Effective buffer width refers to total planted buffer area divided by buffer length.

[2] This is the average or 'mean' buffer required for no net change, excluding the effects of climate change.

4.2.4 Impact of OSD Structures

One of the key hydrological issues for the development will be to ensure that surface runoff from urban areas is passed efficiently to the groundwater table at the base of the north-south aligned ridge. Our view is that on-site stormwater detention (OSD) will play an important role in the final urban hydrological cycle. OSD structures, including domestic rainwater tanks and other surface storages could be used to ensure that post-development flow rates approximate as close as possible pre-development flows. This means that recharge to groundwater will be at approximately the same rate as the present.

Some form of groundwater recharge within the catchment would be preferable, however, on the basis of our geotechnical investigations, our view is that will probably not be realistic or efficient given the very low permeability of surface clay soils.

4.2.5 Extreme Rainfall Events

Modelling of extreme rainfall events was not undertaken as part of this investigation. However, we note that during intense rainfall events, hill-slope runoff coefficients approach or reach 100 %. During these situations, a perched water table will occur above the lower permanent water table.

Following site development, extreme rainfall events will result in similar hydrological process, in that the majority of rainfall will be delivered to downslope areas and may result in a temporary perched water table. We note that the ultimate design of the sites stormwater management system should ensure that this process is not interrupted.

4.2.6 Climate Change

Comments in relation to climate change are provided in Table 19.

Table 19: Comments in relation to climate change matters.

Catchment	**Comments**
Rainfall Regime	The IGPCC (2006) indicates that there may be a reduction in local rainfall of the order of 400-500 mm in this next 100 years. This could reduce recharge to the western SEPP26 forest boundary from 44 to 11 ML/year based on water balance modelling. The could be higher with increased ET rates as a result of a mean surface temperature increase of say 1°C. Over the next 20 years, the recharge reduction would be approximately 6 ML, which is more than the increase in recharge resulting from the 70 % impervious urban area development scenario. Our view is that the proposed urban area could provide a valuable water resource for the SEPP 26 forest against the backdrop of potential climate change.
Sea Level Rise	Expected sea level rise in the next 100 years, and therefore rise in local coastal interface groundwater levels, is 0.18-0.91 m (DECC, 2007). Current DECC (2009) policy is that a 0.90 m sea level rise should be

	adopted for planning purposes for the year 2100. In the case of the modelling undertaken, a 1 m AHD fixed head boundary condition was assumed at the upper beach face to accommodate the effect of a 0.9 m sea level rise. Further to the above, we note that under the 70 % impervious area scenario within the development, this may lead to a localised median rise of approximately 1 m in catchment C2. This level would therefore still remain reasonably separated from the upper rainforest root zone and a significant impact is not expected. A more detailed sea level rise groundwater model should be developed at the project application stage of the development which would take into account of any effects of coastal recession. This would enable 'fine tuning' of the design of the groundwater recharge system(s).
Coastal Recession	Coastal recession could lead to partial removal of the SEPP 26 forest or westerly translation. These aspects are outside the project scope but should probably be considered in terms of long-term site management.

5 Concept Stormwater Management Requirements

5.1 Objectives

On the basis of investigations and findings presented in this study, the following drainage quantity and quality objectives are recommended. These should be in addition to any of Council's standard controls and are specific to the requirements for long-term management of the SEPP26 lands.

Water Quantity Management

The following water quantity design objectives are recommended for all development:

1. On-site stormwater detention (OSD) shall be provided for the site to ensure that pre-development flows are maintained up to the 1 in 100 year ARI storm event.

2. OSD volumes shall be determined on a individual sub-catchment basis and shall not be based on the aggregated total site discharge.

3. The following specific controls are required for each sub-catchment:

    a. A single OSD structure shall be provided at the lowest point possible in the catchment receiving urban drainage. This shall manage water from the entire sub-catchment.

    b. Each OSD shall be provided with an outlet structure(s) that allows flows to be spread such that they mimic current undeveloped surface flows arriving at the SEPP 26 rainforest.

    c. Each OSD shall where possible, be integrated with any end-of-line water quality management structure.

    d. Each OSD shall be provided with a temporary storage volume in addition to the OSD volume which can be directed to groundwater for recharge after treatment. Temporary storage volumes shall be sized on a sub-catchment basis to ensure that surplus water (ie. increased runoff received less increased evapotranspiration lost) within the revegetation area is passed to the groundwater system.

e. Each OSD shall be provided with variable outlet control to enable maximum temporary ponded water storage levels and therefore recharge rates to groundwater to be controlled.

Water Quality

The following water quality design objectives are recommended met for all development:

1. All urban stormwater released to the SEPP 26 wetland should retain similar nutrient and suspended sediment concentrations to those being delivered under undeveloped conditions. These concentrations shall be based on representative surface and groundwater sampling prior to design of any water quality management system.

2. The following specific controls are recommended for each sub-catchment:

    a. All surface water used to recharge groundwater shall be treated prior to recharge occurring such that similar nutrient concentrations to existing groundwater conditions are maintained.

    b. Any stormwater treatment device shall be designed such that it will have the capacity to receive and treat up to an additional 30 % water volume annually in the event that groundwater recharge rates need to be increased in the future in response to climate change.

5.2 Quality Management

5.2.1 Overview

The MUSIC water quality model was used to determine preliminary water treatment requirements. Whilst this is not a precise engineering design tool, it does provide a means by which pre- and post-development stormwater quality can be assessed and determine preliminary sizes of any stormwater treatment structures.

5.2.2 Set-up and Assumptions

MUSIC model set-up and assumptions are summarised in Table 20. Model layout for pre- and post-development scenarios (with treatment) are provided in Attachment B. Given that at the time of document preparation, urban design layouts were in concept stages only, analyses were detailed to the sub-catchment level.

Table 20: MUSIC model sub-catchment areas for existing conditions (ha).

Catchment	Area (ha)
C1 - Rural	1.213
C1 - Vegetation Regeneration Area	0.560
C2 - Rural	3.704
C3 - Rural	3.285
C3 - Vegetation Regeneration Area	0.969
C4 - Rural	0.106
C4 - Vegetation Regeneration Area	0.246

Table 21: MUSIC model sub-catchment areas for existing conditions (ha).

CATCHMENTS	AREA (ha)
C1 - Vegetation Regeneration Area	0.560
C1 - 40 m Vegetation Buffer	0.566
C1 - Urban Roads	0.184
C1 - All Urban	0.463
C2 - Vegetation Regeneration Area	0.000
C2 - 40 m Vegetation Buffer	1.107
C2 - Urban Roads	0.923
C2 - All Urban	1.674
C3 - Vegetation Regeneration Area	0.926
C3 -40 m Vegetation Buffer	0.374
C3 - Urban Roads	0.858
C3 - All Urban	2.096
C4 - Vegetation Regeneration Area	0.240
C4 - 40 m Vegetation Buffer	0.100
C4 - Urban Roads	0.000
C4 - All Urban	0.011

Table 22: Preliminary water quality modelling targets based on existing groundwater quality (mg/L).

Parameter	Target
Total Nitrogen (mg/L)	< 1.0
Total Phosphorus (mg/L)	< 0.6
Suspended Solids (mg/L)	< 50

Table 23: MUSIC model event mean concentrations (EMCs) and dry weather flow concentrations (DWC) (mg/L).

Type	Parameter	Concentration (mg/L)
Urban Roads	TN	2.100
	TP	0.260
	SS	260
All Urban	TN	2.700
	TP	0.340
	SS	150
Rural	TN	2.050
	TP	0.210
	SS	105
Forest	TN	0.850
	TP	0.075
	SS	80

5.2.3 Preliminary Structure Specifications

The following comments are made in relation:

1. Vegetation buffer plantings were included as part of the treatment train. Areas were based on existing aerial photography and the concept development layout (Attachment A).

2. Bio-filtration beds were used to treat urban runoff prior to release to the SEPP 26 lands. A single bed was used as an 'end-of-the-line' treatment system. Preliminary design parameters included:

Extended detention depth	0.5 m
Seepage loss	5.0 mm/hour
Filter depth	0.9 m
Filter median particle diameter	1.1 mm
Filter K_{sat}	40 mm/hour

We note that these parameters are preliminary and subject to modification and more detailed design at the development application stage of documentation. However, the preliminary specifications enabled preliminary estimates of bio-filtration unit areas to be estimated.

Preliminary bio-filtration surface areas are provided in Table 24.

Table 24: Preliminary estimates of bio-filtration unit surface areas (m^2).

Catchment	Area (m^2)
C1	210
C2	560
C3	750

5.2.4 Results

Results of MUSIC modelling are provided Table 25. These indicate that water quality targets (in terms of concentration, see Table 22) and discharge load targets (post-development ≤ pre-development load) to the SEPP26 land are achieved by the proposed treatment train. We note that gross pollutants have not been included in the modelling but we will need to be included as part of any future treatment train.

Table 25: MUSIC modelling results.

Existing Site Conditions						
	Concentration			**Load**		
Catchment	**TSS (mg/L)**	**TP (mg/L)**	**TN (mg/L)**	**TSS (kg/yr)**	**TP (kg/yr)**	**TN (kg/yr)**
C1	43.6	0.07	0.86	972.0	1.7	13.9
C2	51.5	0.10	0.91	2370.0	4.8	36.9
C3	46.3	0.08	0.88	2500.0	4.0	37.1
C4	33.0	0.05	0.80	133.0	0.2	1.92
Net / Total	47.3	0.08	0.88	5970.0	10.7	89.9
Post-development Site Conditions						
C1	23.5	0.04	0.83	332.0	0.7	10.4
C2	22.4	0.04	0.85	515.0	2.1	34.6
C3	23.0	0.04	0.86	593.0	2.3	37.2
C4	52.9	0.09	1.07	113.0	0.1	1.6
Net / Total	28.7	0.06	0.92	1550.0	5.3	83.9
Post-development Load Change (kg/year)				-4820.0	-5.4	-6.0

5.3 Quantity Management

5.3.1 Recharge Requirements

In accordance with the water quantity management objectives, there will be some requirement to enable excess surface water to adjacent to and within the revegetation area to be pass directly to groundwater after treatment in the bio-filtration units.

Preliminary estimates of annual recharge volumes are provided in Table 26. These will need to be refined through more detailed modelling (such as daily water balance modelling) as part of development application design and documentation. On the basis that vertical K_{sat} will be of the order of 4-5 m/d for recharge pits penetrating to the basal aquifer sands, our preliminary water balance modelling indicates that between 1 – 4 recharge pits will be required for catchments C1-C3.

Table 26: Preliminary design specifications for groundwater recharge pits.

Catchment	Estimate of Annual Surplus Runoff to go to Groundwater (ML/year)	Mean Design Recharge Rate for Infiltration Systems (m^3/d)	Total Recharge Well(s) Surface Area (m^2)	Number of 1.5x1.5 m Recharge Pits
C1	2.50	6.8	1.4	1
C2	15.12	41.4	8.3	4
C3	13.65	37.4	7.5	3
C4	0.00	0.0	0.0	0

5.3.2 *Stormwater Detention*

The DRAINS model was used to provide preliminary estimates of pre- and post-development sub-catchment flows to the SEPP26 lands. 70 % impervious area was assumed for the developed urban area. Preliminary on-site stormwater detention (OSD) specifications were determined on the following basis:

Available head and ground levels	Council survey data
Type	Dry surface depression
Minimum Surface Area	Based on bio-filtration

DRAINS model set-up, layout and detailed results are provided in Attachment B. A summary of OSD specifications is provided in Table 27.

Table 27: Preliminary design specifications for groundwater recharge pits.

Catchment	Storage Volume (m^3)	Surface Area (m^2)	Outlet Number & Size (mm)	Existing 100 Year ARI (m^3/s)	Developed 100 Year ARI (m^3/s)
C1	126	210	6 x 225	0.434	0.420
C2	476	560	5 x 450	1.610	1.610
C3	450	750	7 X 450	1.840	1.820
C4	na	na	na	0.259	0.259

5.4 Concept Designs

A concept design for the end-of-line stormwater management structures has been prepared and is provided in Attachment B. The following comments are made in respect of the concept design:

1. OSD and bio-filtration units are integrated into a single stormwater improvement device (SID).

2. SID unit locations are flexible.

3. Each catchment may contain one or more SIDs, although the preference is for a single unit in order to reduce maintenance requirements.

4. A single SID could be used to manage stormwater from 2 adjoining sub-catchments, providing that suitable fall can be achieved and the impacts on groundwater level have been fully determined.

5. SID outlet structures incorporate a water level control device which controls the bio-filtration unit invert and therefore the volume of water which is annually passed to groundwater.

6. The bio-filtration unit under-drain shall be directed to groundwater recharge. Recharge shall be undertaken by 1 or more pits in each sub-catchment. The recharge pits can be separated from the bio-filtration invert level control device. This will depend on final detailed design specifications and layout of the urban area.

7. SIDs will need to be provided with adequate access for on-going maintenance. The concept design provides for a wide bund to enable access to all areas of the SID. Where steeper side batters are required, a vehicular access ramp should be provided to enable bed maintenance.

5.5 Excavation Management

The recharge pits shall be excavated to penetrate into the medium – coarse sand beds beneath the upper clayey soil horizons. Pits should generally not be excavated below the water table. This will ensure that pit excavation can be shored by standard methods without significant risk of excavation collapse.

In the event that excavation into the permanent water table is required (to reach the more permeable underlying sand layers), permanent shoring by way of contiguous or secant piles should be investigated prior to excavation commencing.

5.6 Maintenance

We expect the following will be required in terms of SID maintenance:

1. Gross pollutants should not be allowed to enter the SID units. Gross pollutant traps should be installed upstream of SID units to prevent ingress of these materials into the SID.

2. If the SID units are vegetated with grasses, these may need to be mown in accordance with normal maintenance regime. As an alternative, grass and other vegetative species could be selected which do not require regular mowing to reduce the need for this type of routine maintenance.

3. Geotextile covered litter baskets within the recharge pits should be routinely inspected to assess accumulation of fines. We do not expect any significant carry through of fines from the bio-filtration unit to the recharge pit on the basis that most fines should be removed within the upper bio-filter media layers.

4. The bio-filtration units should be relatively free draining with surface water ponding for no more than 1 day. Annual inspections following extended wet-weather should preferably be undertaken to confirm that the bio-filtration units continue to drain adequately.

   In the event that bio-filtration units do not adequately drain, then the top 100 mm of media may need to be removed and replaced. On the basis of our experience with similar bio-filtration units, careful design and construction should ensure that 're-dressing' the bio-filtration units should not be required for at least 15 years.

6 Summary

6.1 Conclusions and Recommendations

The following comments are provided in terms of summarising the study outcomes and providing recommended management measures which will mitigate any potential impacts on groundwater conditions within or near to the SEPP 26 forest.

1. We broadly concur with the vegetated set-back or buffer approach provided by King & Campbell in the draft LES structure plan. On the basis of a proposed average 40 m planted distance, there are unlikely to be significant impacts on groundwater conditions below the SEPP 26 forest community.

2. With consideration to the potential impacts of climate change on local hydrogeology, it is likely that groundwater re-charge and surface soil moisture conditions will be considerably reduced from existing conditions over the next 20-100 years. This being the case, we see that controlled urban runoff will provide a possible mechanism to supply additional water to the SEPP26 forest otherwise lost through reduced annual rainfall and increased evaporation.

   On this basis, we recommend that stormwater discharge control structures are fitted with variable or exchangeable orifice or weir plates that can be used to adjust flow rates to the recharge pits.

3. Deep stormwater infiltration pits (or trenches depending on final designs) should be constructed within or to the west of the planted buffer zone. These should be excavated so that they extend through the surface clay layer and intersect the lower sand aquifer. There should be good connectivity between the infiltration trench bed and the underlying permeable aquifer.

   The effect of this will be to ensure that surface water is allowed to rapidly enter the local groundwater table without excessively saturating surface soils except during extreme rainfall conditions. This mechanism will have the additional benefit of reducing some of the edge effects of the existing pasture which is likely to have raised surface soil moisture conditions adjacent to the SEPP 26 forest.

4. We recommend that water which does not infiltrate to the deeper groundwater system [ie. surcharges from the bio-filtration units], is evenly distributed as it is released into the planted vegetated buffer area. Further to this, ground within the buffer area should be prepared in such a way so as to ensure maximum infiltration. This can be achieved by way of ground 'riffling' or minor contouring.

5. The buffer revegetation programme should be undertaken as soon as possible so as to ensure that maximum evapotranspiration rates can be achieved as early a possible in the development process.

6. Other than the deep infiltration pits / trenches, care should be taken within the development areas that groundwater is not significantly intersected and hence groundwater flow impeded or redirected. On the hillslopes, we suggest that excavations should preferably not exceed 2.5 m below ground level. If deeper excavations are required, then suitable mitigation measures should be included to ensure that groundwater flow is not redirected or permanently lowered. We do not believe that this will compromise future development, particularly given the likely lowering of groundwater tables in the urban zone.

   On the lower slopes, say below 12.5 mAHD (which excludes the majority of the residential development area), excavations > 1 m in depth (other than for the deep infiltration pits) should be plastic lined and backfilled with low permeability materials. This will minimise the impact of trenching for services and the stormwater system on groundwater recharge and flow directions.

7. For roads in low lying areas (say below 12.5 mAHD, we recommend that these should either be constructed to enable sufficient durability and bearing pressure under the assumption that the groundwater table may be close to or within the sub-grade materials, or be designed somewhat elevated to sure that pavement and upper sub-grade materials do not become water logged.

8. OSD structures, including domestic rainwater tanks (where these are installed within the catchments) and other surface storages should be used to ensure that post-development flow rates approximate as close as possible pre-development flow rates.

6.2 Additional Works for Future Project Applications

This study has identified a number of key management principles that will require further documentation and design at the project application stage, with further detailed design occurring prior to issuing of any construction certificate. We recommend the following additional information be collected to support any future application for residential development in the catchments.

1. More rigorous geotechnical investigations and design will be required for the design of the recharge pits. As a minimum, the following is recommended:

    a. A series of 4 groundwater bores should be established along the SEPP 26 zone within the proposed revegetated buffer zone to document sub-surface conditions.

    b. At each bore, further testing of saturated hydraulic conductivity in the underlying sand aquifer should be undertaken.

    c. Measurements of storativity / specific yield should be made in order that the groundwater mounding from recharge pits can be minimised.

    d. Each bore should be instrumented for a period of 6 months in order that long-term groundwater level fluctuations can be validated and incorporated into the design of recharge pits.

    e. 2 of the existing bores at higher elevations should be instrumented for the same 6 month period.

2. We recommend the establishment of at least 2 further monitoring bores within the SEPP 26 area (if this is possible) so that the current groundwater model for the study area can be extended to the coast as far as practical. Recommendations are:

    a. Bores should be located in either sub-catchments C2 or C3 and shall be suitable licensed by the relevant consent authority.

    b. Bores should be instrumented for the same 6 month period as noted above in item 1. Bores with the SEPP 26 area may need to be installed by hand or water jetting given the site sensitivity and difficulty of site access.

3. Further groundwater quality monitoring (notably nutrients) is recommended to provide better base-line groundwater quality data. This will assist with design of the bio-filtration units. In addition to those parameters already covered by this study, bound and unbound phosphorus levels should be determined in any future sampling. This will enable improved design of bio-filtration units. We recommend at least 2 further rounds of water quality sampling being spaces 3-6 months apart from all established bores.

4. Groundwater salinity measurements should be further documented. We recommend continuous monitoring for the 6 month period noted in item 1 at three locations:

    a. Within the SEPP 26 forest.
    b. Within the revegetation area
    c. An existing bore location further upslope.

5. Surface water sampling will be required to determine existing surface water nutrient concentrations. A minimum of 3 rounds of sampling during and following rainfall runoff periods is recommended. This will assist with design of the bio-filtration units.

6. A report will need to be prepared at the project application stage that provides the following:

    a. An updated groundwater model for the area incorporating the findings of past and on-going groundwater investigations and monitoring. The model should demonstrate that post-development drawdown (-ve or +ve) is minimised or avoided altogether within the SEPP26 rainforest area.

    b. A more detailed sea level rise groundwater model should be developed which would take into account of any effects of coastal recession. This would enable 'fine tuning' of the design of the groundwater recharge system(s).

    c. Confirmation of the design of end-of-line stormwater structures. This should include on a sub-catchment basis, revised OSD requirements and a daily water balance modelling demonstrating that surface moisture conditions within the SEPP 26 rainforest will not be affected by the proposed stormwater management infrastructure.

d. Updated and appropriately supported designs of the stormwater recharge pit system.

7 References

Australian Standard 1796 (1993) *Geotechnical Site Investigations*

DECC (2007) Practical Consideration of Climate Change

DECC (2009) Draft NSW Sea Level Rise Policy Statement

GHD (May 2006) Rezoning Application for Lot 4 DP 615261 and Lot 1 DP 374315, Ocean Drive, Lake Cathie

Hvorslev, M. J. (1951) *Time Lag and Soil Permeability in Ground Water)bservations*, Bulletin No. 36, U. S. Army Corps of Engineers, 50p

Intergovernmental Panel on Climate Change (IGPCC) (2006) Greenhouse Effects and Climate Change, Australian Commonwealth Government

Jelliffe Environmental Pty Ltd (June 2002) Stormwater Quality Management Report, Ocean Drive, Lake Cathie

Hazelton, P. A, Murphy, B. W. (eds, 1992) *What Do All The Numbers Mean ?*, NSW Department of Conservation and Land Management

Myers, B. J., Bond, W. J., Benyon, R. G., Falkiner, R. A., Polglase, P. J., Smith, C. J., Snow, V. O. and Theiveyanathan, S. (1999) Sustainable Effluent Irrigated Plantations: An Australian Guideline, CSIRO Forestry and Forestry Products, CSIRO Land and Water, Canberra, Australia

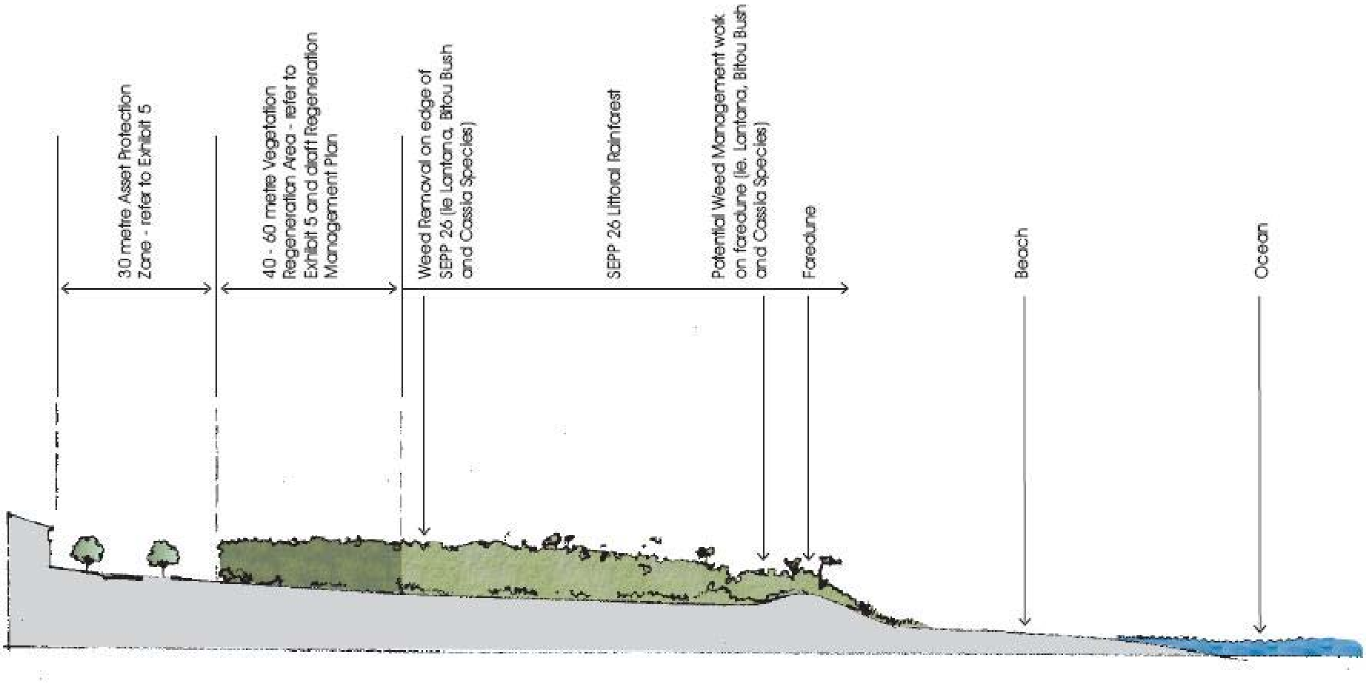
NSW Department of Environment and Conservation (2004) Use of Effluent by Irrigation

Storm Consulting (April 2006) Area 14 Integrated Water Cycle Management Plan

8 Attachment A – Development Proposal


Existing vegetation regeneration area to be retained
SEPP 26
Site boundary
Existing SEPP 26 littoral rainforest
30m Asset Protection Zone
Edge of SEPP 26 vegetation
New vegetation regeneration area. Refer to Draft Revegetation Management Plan
Extent of buffer to SEPP 26
Existing vegetation regeneration area to be retained
Residential
Building setback line
LEGEND
Edge of SEPP 26
Existing vegetation regeneration area
New vegetation regeneration area. Refer to Draft Revegetation Management Plan
SEPP 26 buffer area
Development Envelope
N
GENERAL NOTE
This plan has been prepared with regard to the Greater Lake Cathie and Bonny Hills Urban Design Master Plan
King & Campbell
Scale 1:2000 @ A1
Datum AHD
0
150
Project Number 13921 / 13974
Drawing Number Ex04
Exhibit 4: Indicative Structure Plan (subject to DCP process)
Lot 4, DP 615261 & Lot 1, DP 374315
Lake Cathie

Proposed typical section littoral rainforest



9 Attachment B – Plan Set

AREA 14 STAGE 1B GROUNDWATER STUDY
LAKE CATHIE, NSW

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DRAWN/REVIEWED: BR
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PAPER SIZE: A1/A3
VERTICAL RATIO: NA

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PROJECT MANAGER: DR D. MARTENS

DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 1 OF 12 SHEETS

◐ HACKETT LABORATORIES TEST PIT LOCATION (FEBRUARY 2001)

◐ MARTENS BOREHOLE / PIEZOMETER LOCATION (NOVEMBER 2006)

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STUDY AREA AND SAMPLING LOCATIONS

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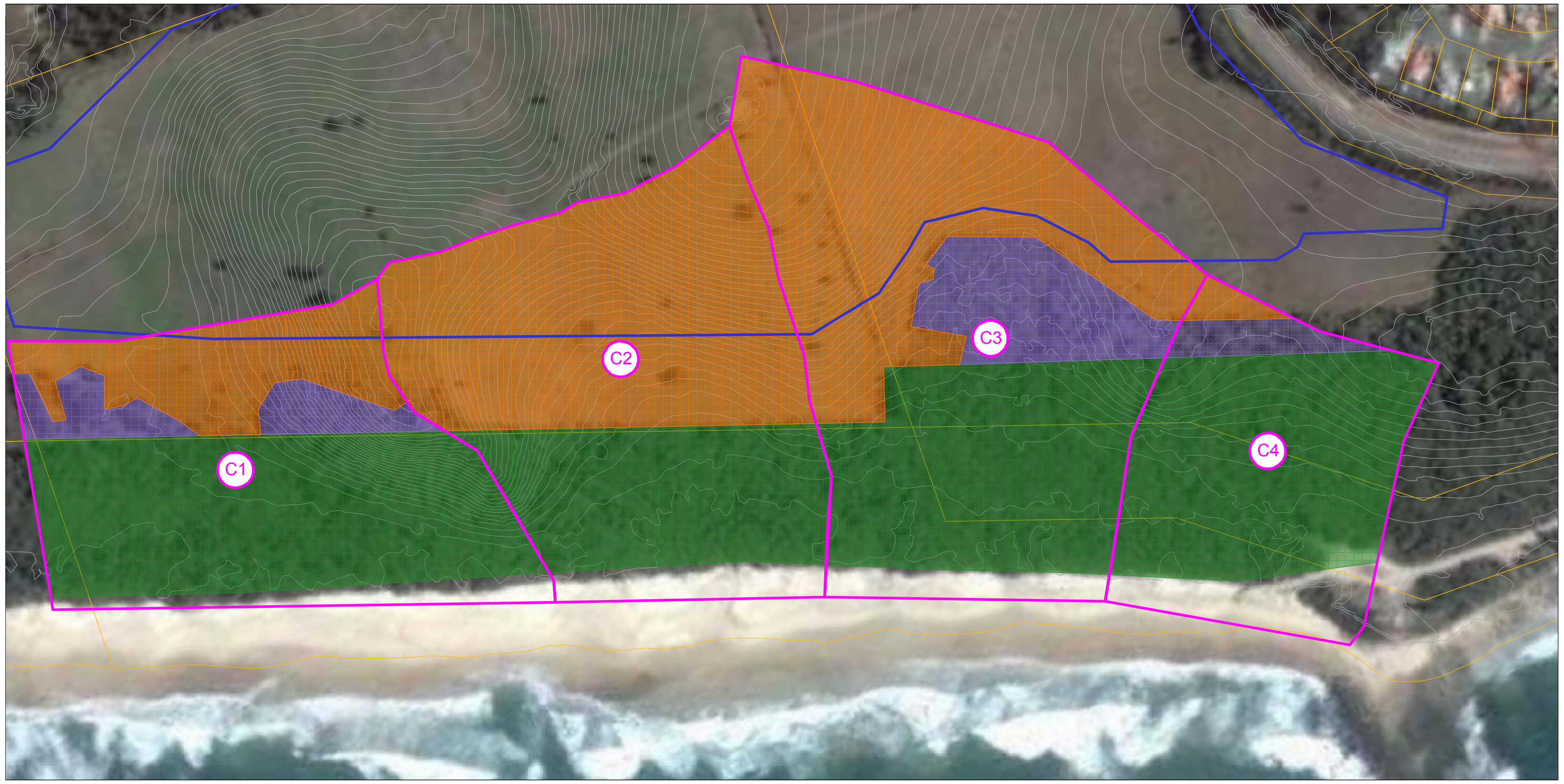
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 2 OF 12 SHEETS



- ☐ STRUCTURE PLAN DEVELOPMENT AREA
- 🟩 EXISTING SEPP 26 FOREST
- ▨ EXISTING VEGETATION REGENERATION AREA
- 🟧 EXISTING PASTURE
- ☐ SUB-CATCHMENT BOUNDARY

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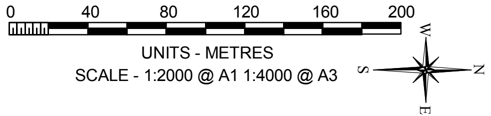

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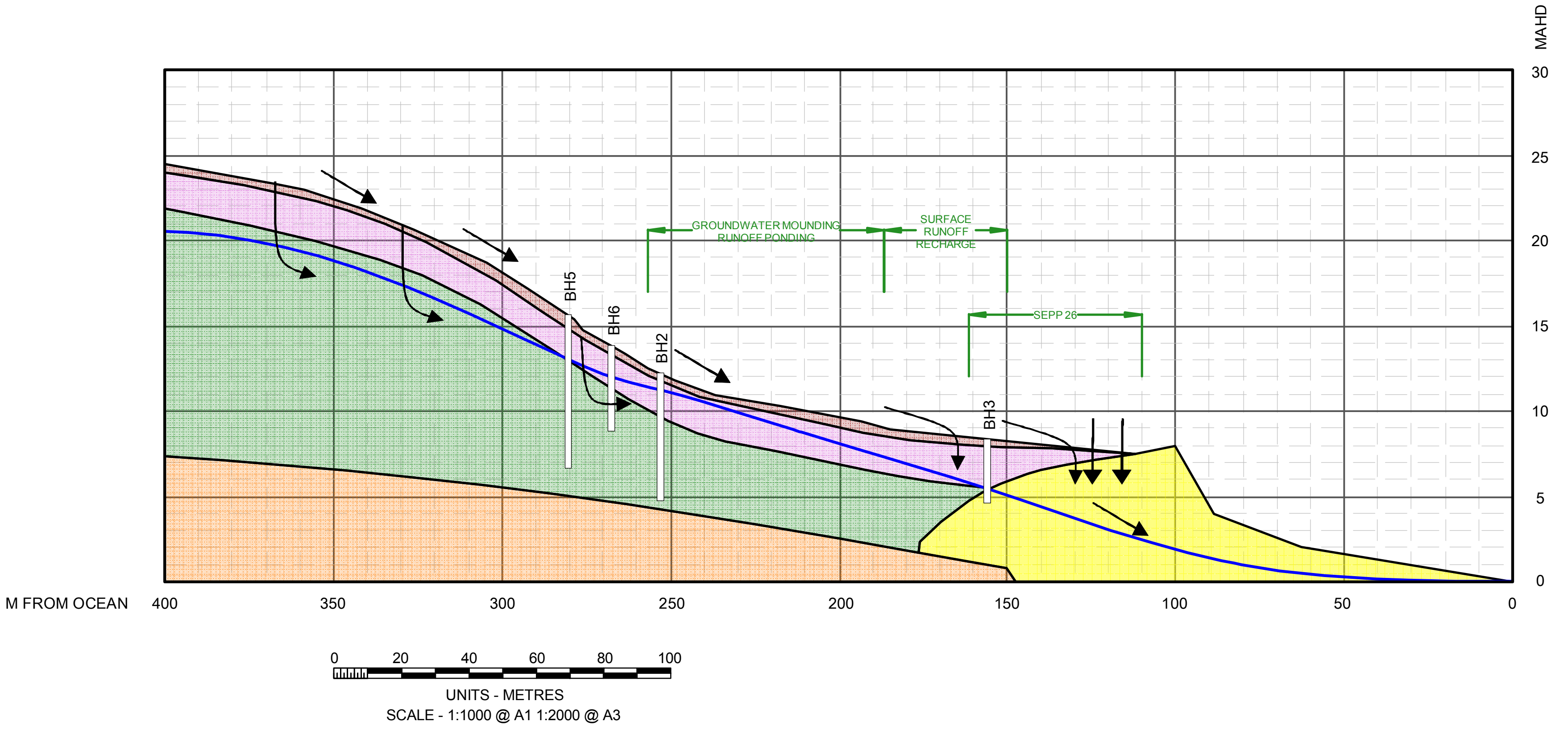
TITLE:
COASTAL SUB-CATCHMENTS, EXISTING LAND-USE
AND EXTENT OF URBAN AREAS
AS DEFINED IN STRUCTURE PLAN

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 3 OF 12 SHEETS



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🟨 FORESHORE SANDS AND DUNES

🟧 BEDROCK (EST.)

🟩 EXTREMELY WEATHERED MANTLE / HEAVY CLAYS

🟪 SUB-SOIL LIGHT TO MEDIUM CLAYS

🟫 TOPSOIL LOAMS, CLAY LOAMS

MEAN WATER TABLE POSITION

↘ SURFACE AND GROUNDWATER FLOWS

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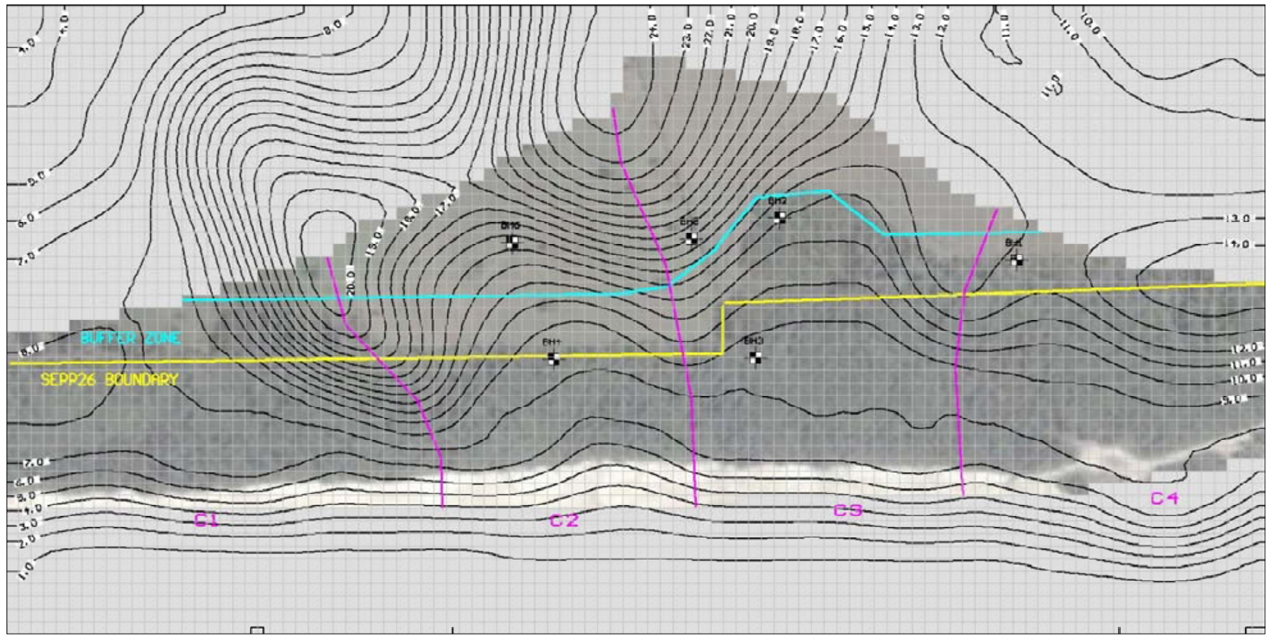

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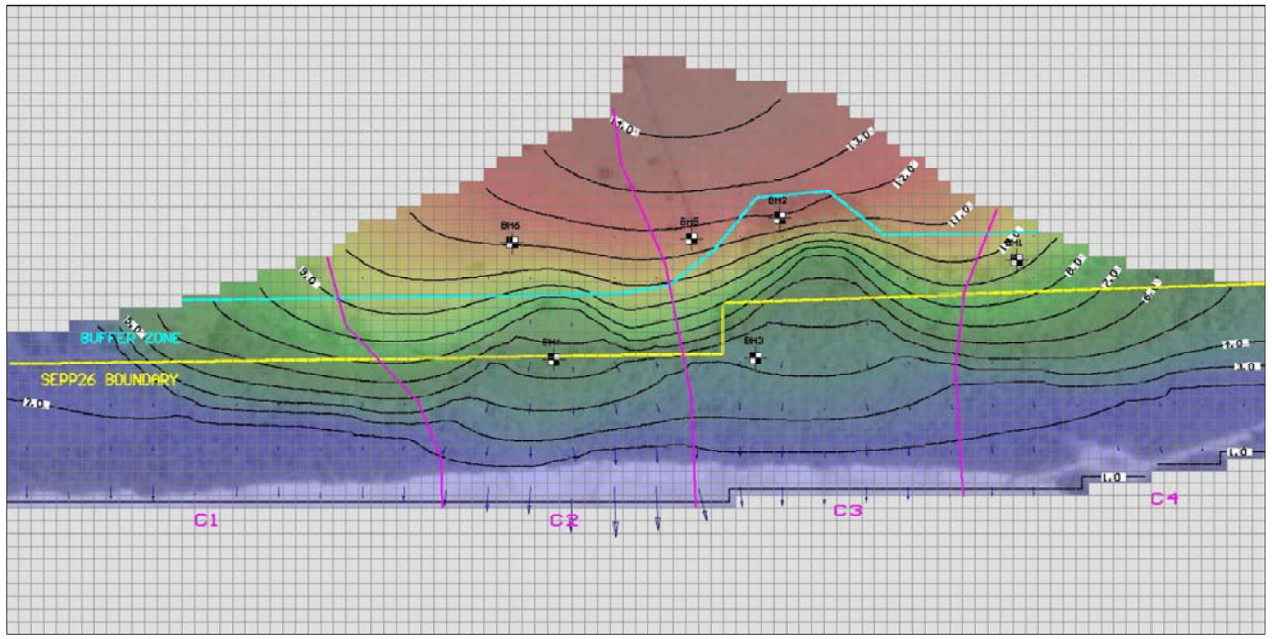

(B) EXISTING WATER TABLE CONDITIONS AND FLOW VECTORS

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MODFLOW MODEL SET-UP

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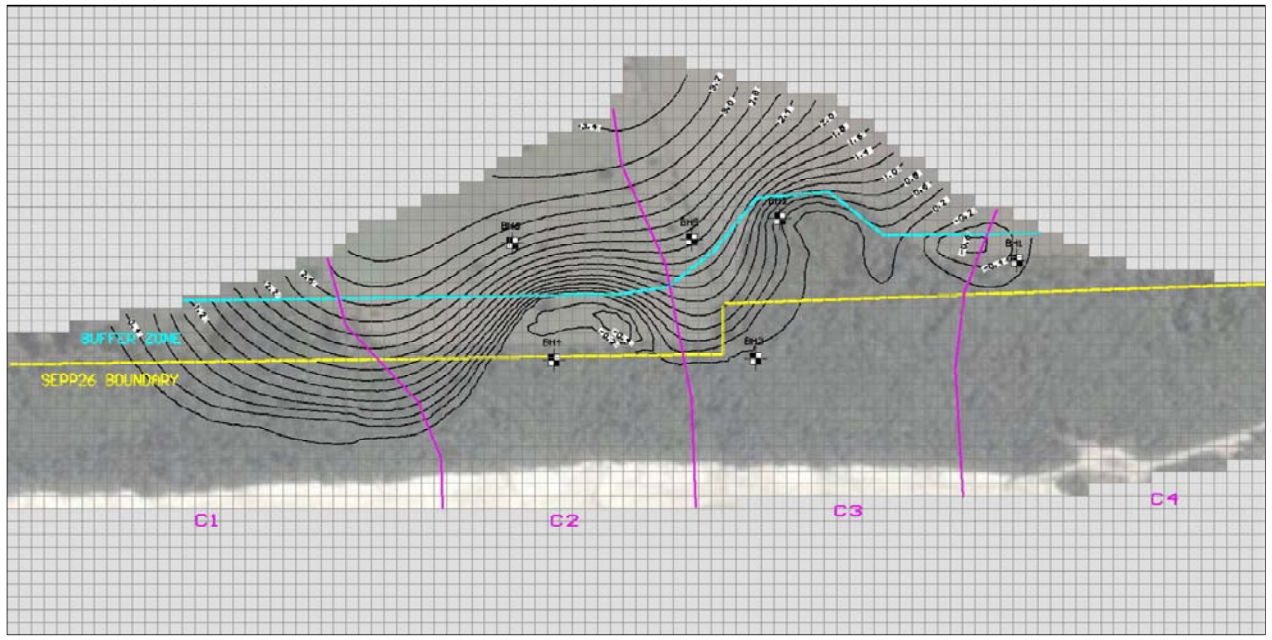
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 5 OF 12 SHEETS



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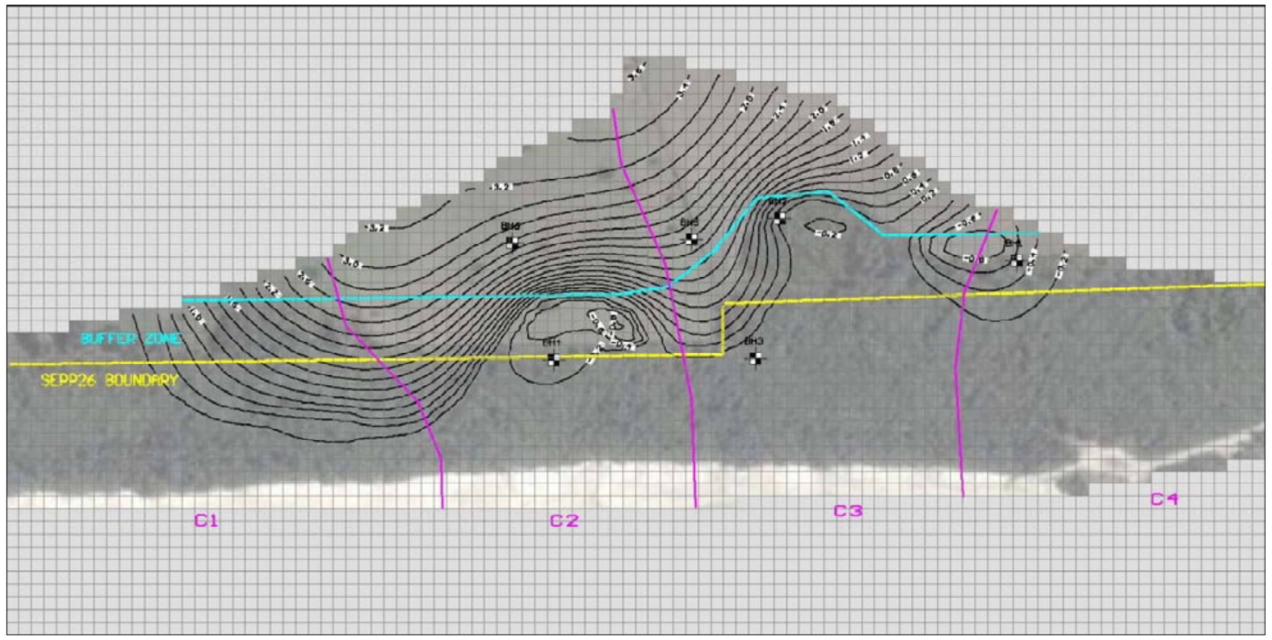

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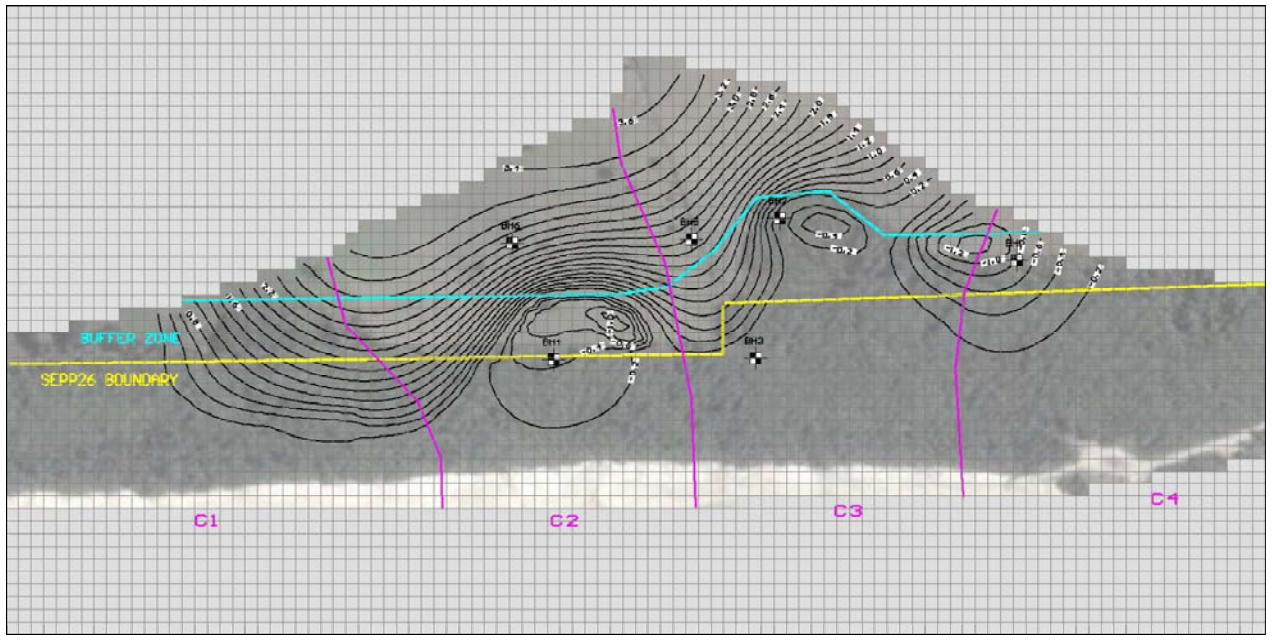

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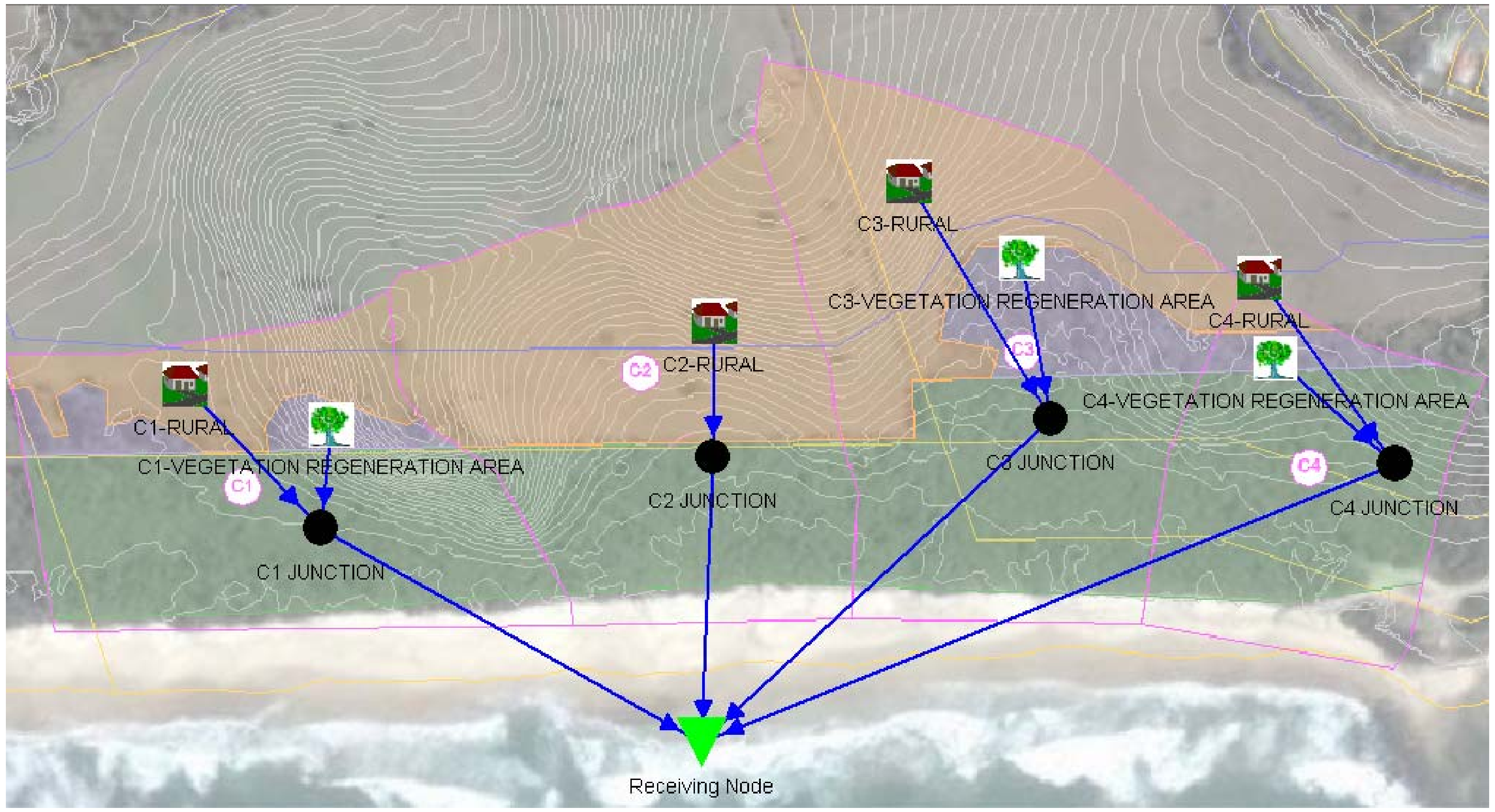
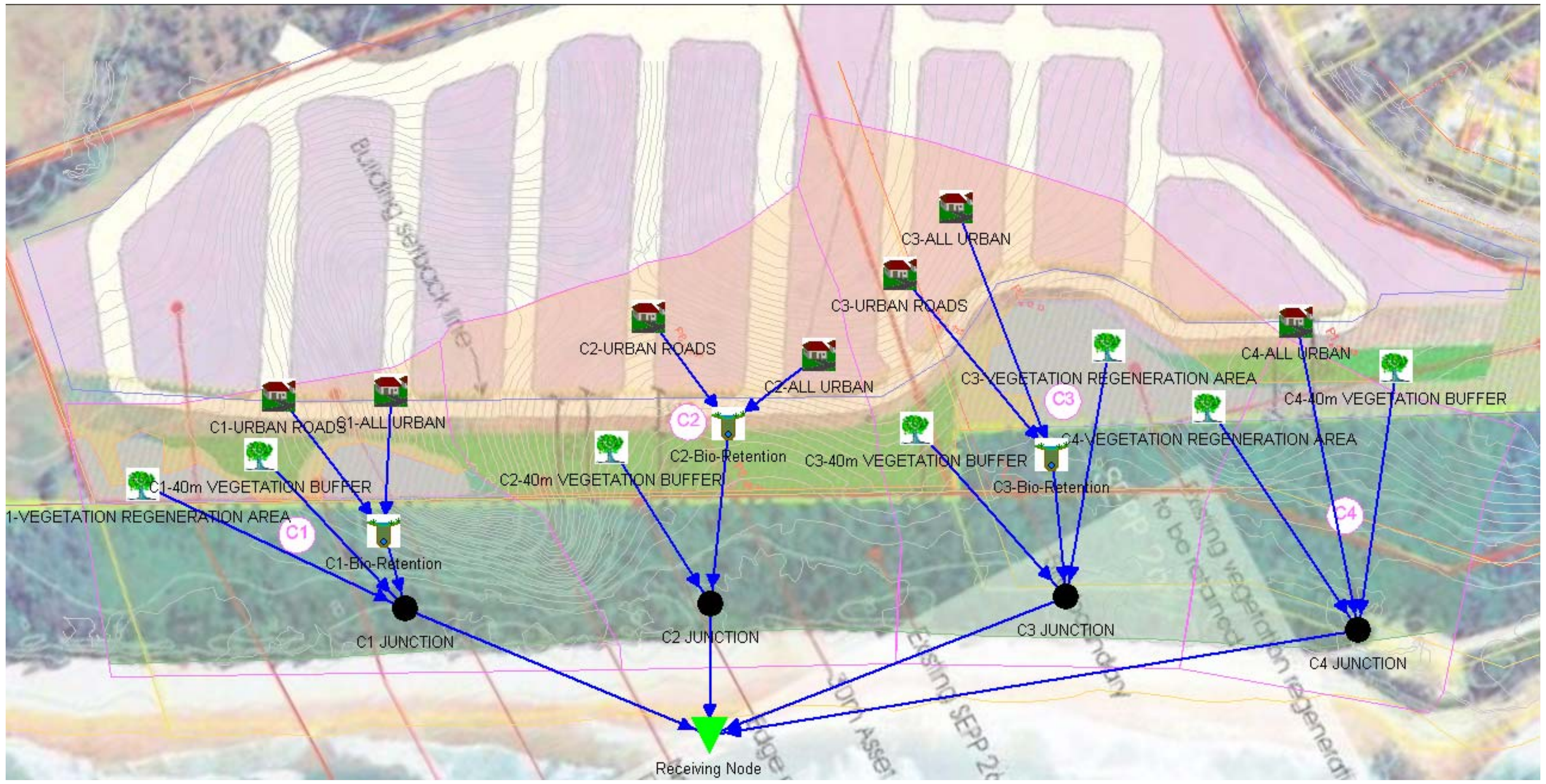
TITLE:
MODFLOW MODEL DRAWDOWN RESULTS

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 6 OF 12 SHEETS





REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	26.06.09	DMM

BAR SCALE
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UNITS - METRES
SCALE - 1:2000 @ A1 1:4000 @ A3
W N E S

DESIGNED: DMM
DRAWN/REVIEWED: BR
PAPER SIZE: A1/A3
DATUM: NA
HORIZONTAL RATIO: 1:4000 @A3 1:2000 @ A1
VERTICAL RATIO: 1:4000 @A3 1:2000 @ A1

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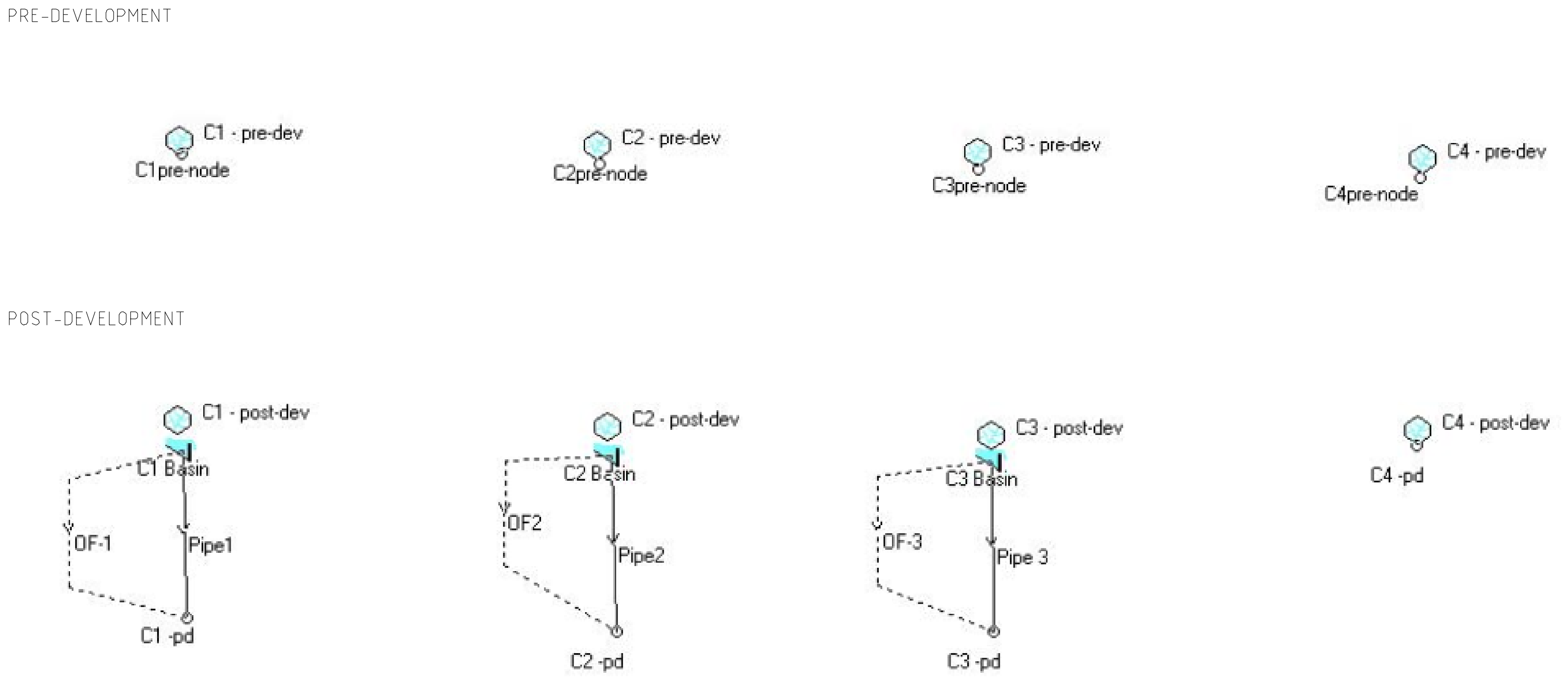
Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE:
MUSIC MODEL SET-UP
TOP - PRE-DEVELOPMENT
BOTTOM - DEVELOPED WITH TREATMENT

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 7 OF 12 SHEETS



REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	26.06.09	DMM

BAR SCALE

DESIGNED: DMM
DATUM: NA
DRAWN/REVIEWED: BR
HORIZONTAL RATIO: NA
PAPER SIZE: A1/A3
VERTICAL RATIO: NA

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TITLE:
DRAINS MODEL SET-UP

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 8 OF 12 SHEETS

DRAINS PRE-DEVELOPMENT MODEL INPUT DETAILS

PIT / NODE DETAILS			Version 9										
Name	Type	Family	Size	Ponding	Pressure	Surface	Max Pond	Base	Blocking	x	y	Bolt-down	id
				Volume	Change	Elev (m)	Depth (m)	Inflow	Factor			lid	
				(cu.m)	Coeff. Ku			(cu.m/s)					
C1pre-node	Node					NA		0		60.671	93.454		53061608
C2pre-node	Node					NA		0		132.57	91.736		53061856
C3pre-node	Node					NA		0		198.089	91		53061857
C4pre-node	Node					NA		0		274.405	89.527		53061858
DETENTION BASIN DETAILS													
Name	Elev	Surf. Area	Init Vol. (cu.m)	Outlet Type	K	Dia(mm)	Centre RL	Pit Family	Pit Type	x	y	HED	Crest RL
SUB-CATCHMENT DETAILS													
Name	Pit or	Total	Paved	Grass	Supp	Paved	Grass	Supp	Paved	Grass	Supp	Paved	Grass
	Node	Area	Area	Area	Area	Time	Time	Time	Length	Length	Length	Slope(%)	Slope
		(ha)	%	%	%	(min)	(min)	(min)	(m)	(m)	(m)	%	%
C1 - pre-dev	C1pre-noc	0.647	0	100	0	0	10	0					
C2 - pre-dev	C2pre-noc	2.597	0	100	0	0	10	0					
C3 - pre-dev	C3pre-noc	2.954	0	100	0	0	10	0					
C4 - pre-dev	C4pre-noc	0.352	0	100	0	0	10	0					
PIPE DETAILS													
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	I.D.	Rough	Pipe Is	No. Pipes	Chg From
			(m)	(m)	(m)	(%)		(mm)	(mm)				
DETAILS of SERVICES CROSSING PIPES													
Pipe	Chg	Bottom	Height of Service	Chg	Bottom	Height of	Chg	Bottom	Height of Service	etc			
	(m)	Elev (m)	(m)	(m)	Elev (m)	(m)	(m)	Elev (m)	(m)	etc			
CHANNEL DETAILS													
Name	From	To	Type	Length	U/S IL	D/S IL	Slope	Base Width	L.B. Slope	R.B. Slope	Manning	Depth	Roofed
				(m)	(m)	(m)	(%)	(m)	(1:?)	(1:?)	n	(m)	

DRAINS RESULTS FOR 1 IN 100 YR ARI STORM (PRE-DEVELOPMENT)

DRAINS results prepared 07 July, 2010 from Version 2010.04						
PIT / NODE DETAILS				Version 8		
Name	Max HGL	Max Pond	Max Surface	Max Pond	Min	Overflow
		HGL	Flow Arriving	Volume	Freeboard	(cu.m/s)
			(cu.m/s)	(cu.m)	(m)	
SUB-CATCHMENT DETAILS						
Name	Max	Paved	Grassed	Paved	Grassed	Supp.
	Flow Q	Max Q	Max Q	Tc	Tc	Tc
	(cu.m/s)	(cu.m/s)	(cu.m/s)	(min)	(min)	(min)
C1 - pre-dev	0.434	0	0.434	0	10	0
C2 - pre-dev	1.741	0	1.741	0	10	0
C3 - pre-dev	1.98	0	1.98	0	10	0
C4 - pre-dev	0.236	0	0.236	0	10	0
Outflow Volumes for Total Catchment (0.00 impervious + 6.55 pervious = 6.55 total ha)						
Storm	Total Rainfall	Total Runoff	Impervious Runoff	Pervious Runoff		
	cu.m	cu.m (Runoff %)	cu.m (Runoff %)	cu.m (Runoff %)		
AR&R 100 year, 15 minutes storm, average 200 mm/h, Zone 1	3275	2810.23 (85.8%)	0.00 (0.0%)	2810.23 (85.8%)		
AR&R 100 year, 20 minutes storm, average 177 mm/h, Zone 1	3864.5	3365.36 (87.1%)	0.00 (0.0%)	3365.36 (87.1%)		
AR&R 100 year, 25 minutes storm, average 161 mm/h, Zone 1	4393.96	3860.71 (87.9%)	0.00 (0.0%)	3860.71 (87.9%)		
AR&R 100 year, 30 minutes storm, average 148 mm/h, Zone 1	4847	4279.84 (88.3%)	0.00 (0.0%)	4279.84 (88.3%)		
PIPE DETAILS						
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm	
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)		
CHANNEL DETAILS						
Name	Max Q	Max V	Chainage	Max	Due to Storm	
	(cu.m/s)	(m/s)	(m)	HGL (m)		
DETENTION BASIN DETAILS						
Name	Max WL	MaxVol	Max Q	Max Q	Max Q	
			Total	Low Level	High Level	
CONTINUITY CHECK for AR&R 100 year, 20 minutes storm, average 177 mm/h, Zone 1						
Node	Inflow	Outflow	Storage Change	Difference		
	(cu.m)	(cu.m)	(cu.m)	%		
C1pre-node	332.43	332.43	0	0		
C2pre-node	1334.33	1334.33	0	0		
C3pre-node	1517.75	1517.75	0	0		
C4pre-node	180.86	180.86	0	0		

REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	07.07.10	DMM

BAR SCALE

DESIGNED: DMM
DATUM: NA
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HORIZONTAL RATIO: NA
PAPER SIZE: A1/A3
VERTICAL RATIO: NA

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TITLE:
DRAINS MODEL
PRE-DEVELOPMENT INPUTS AND OUTPUT

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V2.TCW

SHEET 9 OF 12 SHEETS

DRAINS POST-DEVELOPMENT MODEL INPUT DETAILS

PIT / NODE DETAILS			Version 9								
Name	Type	Family	Size	Ponding	Pressure	Surface	Max Pond	Base	Blocking	x	y
				Volume	Change	Elev (m)	Depth (m)	Inflow	Factor		
				(cu.m)	Coeff. Ku			(cu.m/s)			
C1 -pd	Node					10		0		61.309	13.604
C3 -pd	Node					10		0		200.592	10.954
C2 -pd	Node					10		0		135.514	10.954
DETENTION BASIN DETAILS											
Name	Elev	Surf. Area	Init Vol. (cu.m)	Outlet Typ	K	Dia(mm)	Centre RL	Pit Family	Pit Type	x	y
C1 Basin	10	210	0	Culvert	0.5					60.671	42.413
	10.6	210									
C3 Basin	10	750	0	Culvert	0.5					200.297	40.695
	10.6	750									
C2 Basin	10	560	0	Culvert	0.5					134.213	43.803
	10.85	560									
SUB-CATCHMENT DETAILS											
Name	Pit or	Total	Paved	Grass	Supp	Paved	Grass	Supp	Paved	Grass	Supp
	Node	Area	Area	Area	Area	Time	Time	Time	Length	Length	Length
		(ha)	%	%	%	(min)	(min)	(min)	(m)	(m)	(m)
C1 - post-dev	C1 Basin	0.647	79	21	0	5	10	0			
C3 - post-dev	C3 Basin	2.954	79	21	0	5	10	0			
C2-post-dev	C2 Basin	2.597	81	19	0	5	10	0			
PIPE DETAILS											
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	I.D.	Rough	Pipe Is
			(m)	(m)	(m)	(%)		(mm)	(mm)		
Pipe1	C1 Basin	C1 -pd	10	10	9.5	5	Concrete, not under roads	225	225	0.3	NewFixed
Pipe 3	C3 Basin	C3 -pd	10	10	9.5	5	Concrete, not under roads	450	450	0.3	NewFixed
Pipe 2	C2 Basin	C2 -pd	10	10	9.5	5	Concrete, not under roads	450	450	0.3	NewFixed
DETAILS of SERVICES CROSSING PIPES											
Pipe	Chg	Bottom	Height of Service	Chg	Bottom	Height of	Chg	Bottom	Height of	etc	
	(m)	Elev (m)	(m)	(m)	Elev (m)	(m)	(m)	Elev (m)	(m)	etc	
CHANNEL DETAILS											
Name	From	To	Type	Length	U/S IL	D/S IL	Slope	Base Width	L.B. Slope	R.B. Slope	Manning
				(m)	(m)	(m)	(%)	(m)	(1:?)	(1:?)	n
OVERFLOW ROUTE DETAILS											
Name	From	To	Travel	Spill	Crest	Weir	Cross	Safe Depth	SafeDeptl	Safe	Bed
			Time	Level	Length	Coeff. C	Section	Major Storms	Minor Sto	DxV	Slope
			(min)	(m)	(m)			(m)	(m)	(sq.m/sec	(%)
OF-1	C1 Basin	C1 -pd	1	10.6	5	1.7	Grassed swale with 1:4 sideslopes	0.5	0.4	1	5
OF-3	C3 Basin	C3 -pd	1	10.6	5	1.7	Grassed swale with 1:4 sideslopes	0.5	0.4	1	5
OF-2	C2 Basin	C2 -pd	1	10.85	5	1.7	Grassed swale with 1:4 sideslopes	0.5	0.4	1	5

DRAINS RESULTS FOR 1 IN 100 YR ARI STORM (POST-DEVELOPMENT)

DRAINS results prepared 07 July, 2010 from Version 2010.04							
PIT / NODE DETAILS				Version 8			
Name	Max HGL	Max Pond	Max Surface	Max Pond	Min	Overflow	Constraint
		HGL	Flow Arriving	Volume	Freeboarc	(cu.m/s)	
			(cu.m/s)	(cu.m)	(m)		
C1 -pd	9.61		0				
C3 -pd	9.68		0.013				
C2 -pd	9.7		0				
SUB-CATCHMENT DETAILS							
Name	Max	Paved	Grassed	Paved	Grassed	Supp.	Due to Sto
	Flow Q	Max Q	Max Q	Tc	Tc	Tc	
	(cu.m/s)	(cu.m/s)	(cu.m/s)	(min)	(min)	(min)	
C1 - post-dev	0.487	0.4	0.087	5	10	0	AR&R 100
C3 - post-dev	2.224	1.826	0.398	5	10	0	AR&R 100
C2-post-dev	1.963	1.646	0.316	5	10	0	AR&R 100
Outflow Volumes for Total Catchment (4.95 impervious + 1.25 pervious = 6.20 total ha)							
Storm	Total Rainfall	Total Runoff	Impervious Runoff	Pervious Runoff			
	cu.m	cu.m (Runoff %)	cu.m (Runoff %)	cu.m (Runoff %)			
AR&R 100 year, 15 minutes storm, average 200 mm/h, Zone 1	3099	2927.42 (94.5%)	2424.70 (98.0%)	502.72 (80.5%)			
AR&R 100 year, 20 minutes storm, average 177 mm/h, Zone 1	3656.82	3472.67 (95.0%)	2870.05 (98.3%)	602.62 (81.7%)			
AR&R 100 year, 25 minutes storm, average 161 mm/h, Zone 1	4157.83	3960.35 (95.3%)	3270.04 (98.5%)	690.30 (82.3%)			
AR&R 100 year, 30 minutes storm, average 148 mm/h, Zone 1	4586.52	4376.73 (95.4%)	3612.30 (98.6%)	764.43 (82.7%)			
PIPE DETAILS							
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm		
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)			
Pipe1	0.373	3.2	10.111	9.611	AR&R 100 year, 25 minutes stor		
Pipe 3	1.872	4.4	10.182	9.682	AR&R 100 year, 25 minutes stor		
Pipe 2	1.529	4.6	10.195	9.695	AR&R 100 year, 25 minutes stor		
CHANNEL DETAILS							
Name	Max Q	Max V	Chainage	Max	Due to Storm		
	(cu.m/s)	(m/s)	(m)	HGL (m)			
OVERFLOW ROUTE DETAILS							
Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV	Max Widtl	Max V
OF-1	0	0	1.262	0	0	0	0
OF-3	0.013	0.013	1.262	0.057	0.06	0.45	1.02
OF-2	0	0	1.262	0	0	0	0
DETENTION BASIN DETAILS							
Name	Max WL	MaxVol	Max Q	Max Q	Max Q		
			Total	Low Level	High Level		
C1 Basin	10.47	100.4	0.373	0.373	0		
C3 Basin	10.61	465.4	1.885	1.872	0.013		
C2 Basin	10.76	429.8	1.529	1.529	0		
CONTINUITY CHECK for AR&R 100 year, 25 minutes storm, average 161 mm/h, Zone 1							
Node	Inflow	Outflow	Storage Change	Difference			
	(cu.m)	(cu.m)	(cu.m)	%			
C1 Basin	412.83	410.52	2.31	0			
C1 -pd	410.52	410.52	0	0			
C3 Basin	1884.84	1867.21	17.63	0			
C3 -pd	1867.21	1867.21	0	0			
C2 Basin	1662.68	1648.77	13.91	0			
C2 -pd	1648.77	1648.77	0	0			

REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	07.07.10	DMM

BAR SCALE

DESIGNED: DMM
DATUM: NA
DRAWN/REVIEWED: BR
HORIZONTAL RATIO: NA
PAPER SIZE: A1/A3
VERTICAL RATIO: NA

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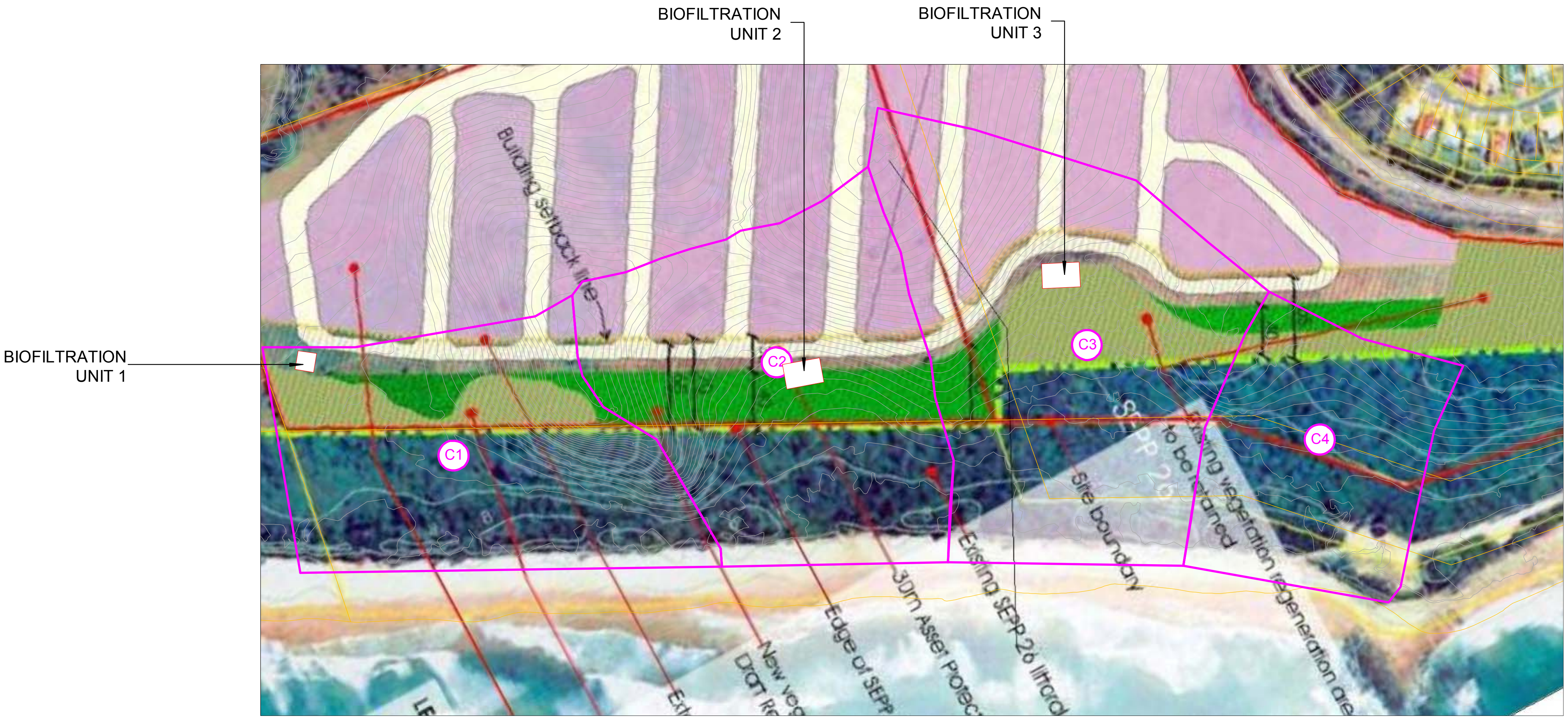
TITLE:
DRAINS MODEL
POST-DEVELOPMENT INPUTS AND 100YR OUTPUT

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V2.TCW

SHEET 10 OF 12 SHEETS



▢ STRUCTURE PLAN DEVELOPMENT AREA

▦ EXISTING SEPP 26 FOREST

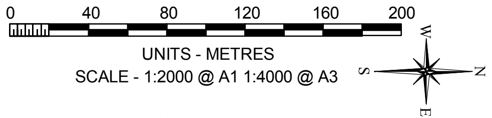
▦ EXISTING VEGETATION REGENERATION AREA

▦ EXISTING PASTURE

▢ SUB-CATCHMENT BOUNDARY

REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	26.06.09	DMM

BAR SCALE



UNITS - METRES
SCALE - 1:2000 @ A1 1:4000 @ A3

DESIGNED: DMM
DRAWN/REVIEWED: BR
PAPER SIZE: A1/A3
DATUM: NA
HORIZONTAL RATIO: 1:4000 @A3 1:2000 @ A1
VERTICAL RATIO: 1:4000 @A3 1:2000 @ A1

CLIENT/ PROJECT: HASTINGS COUNCIL

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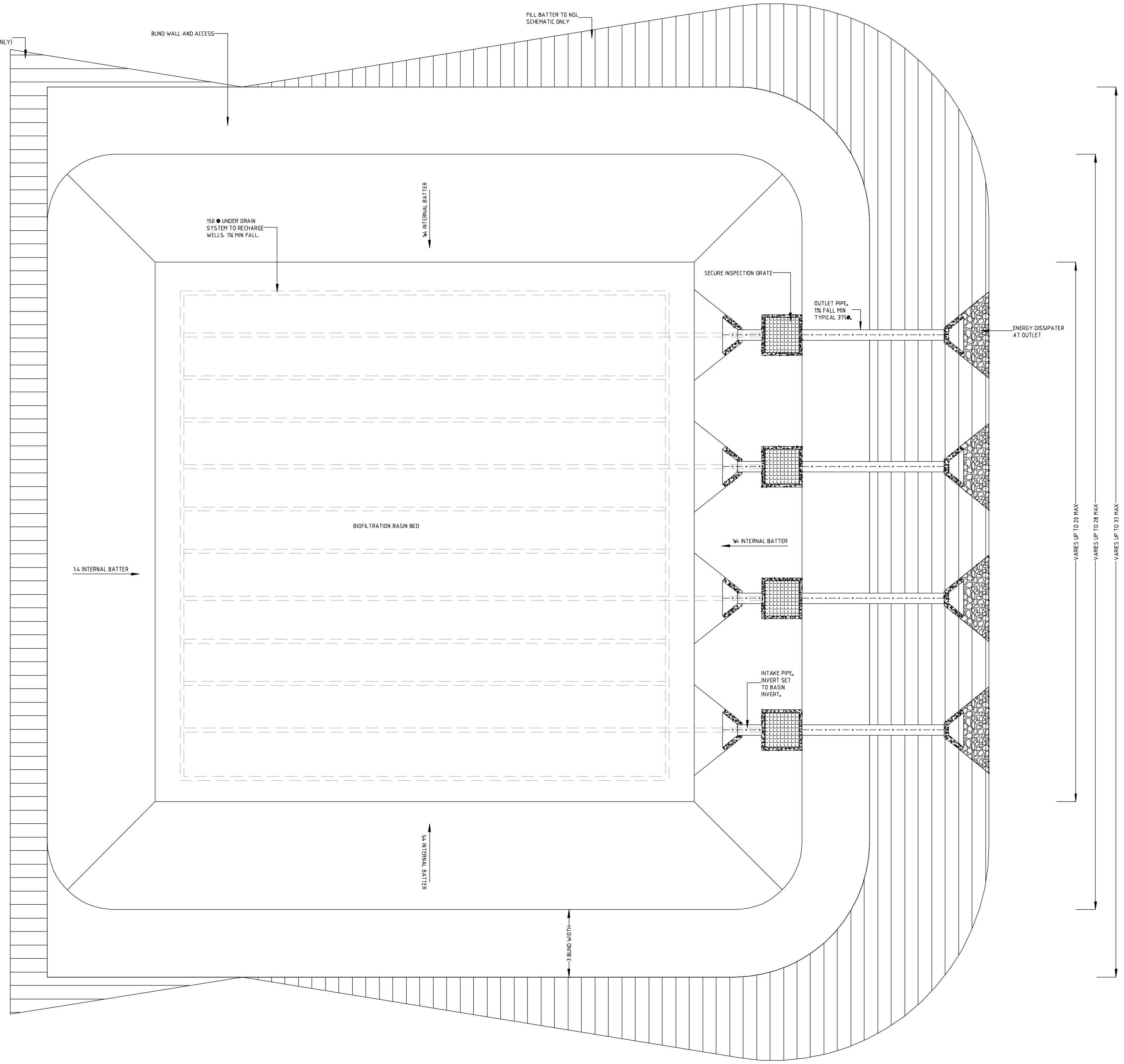
Email: mail@martens.com.au Internet: http://www.martens.com.au

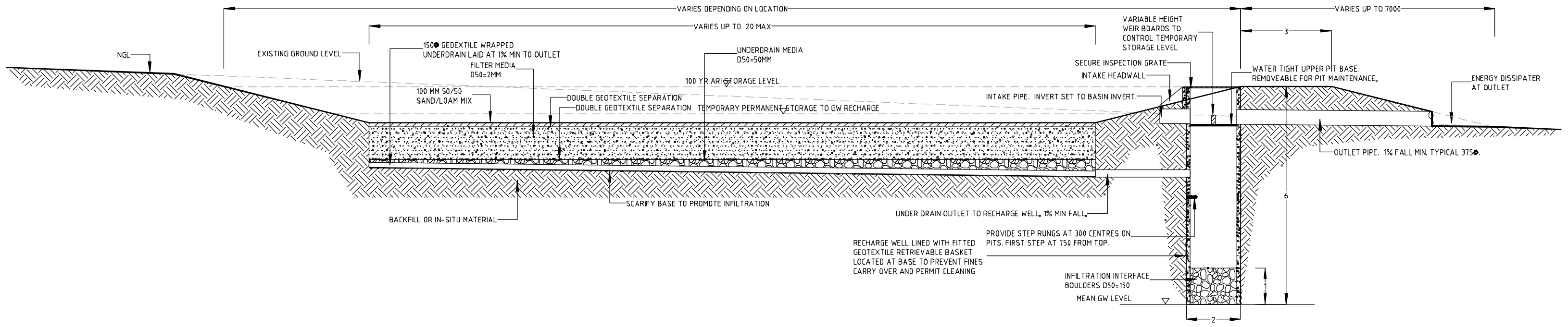
TITLE: PRELIMINARY BIO-FILTRATION UNIT LOCATIONS

PROJECT MANAGER: DR D. MARTENS

DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 11 OF 12 SHEETS





REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	04.06.09	DMM

BAR SCALE

0 2 4 6 8 10

UNITS - METRES
SCALE - 1:100 @ A1 1:200 @ A3

DESIGNED: DMM
DRAWN/REVIEWED: BR
PAPER SIZE: A1/A3
DATUM: NA
HORIZONTAL RATIO: 1:200 @A3 1:100 @ A1
VERTICAL RATIO: 1:200 @A3 1:100 @ A1

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Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE:
CONCEPT STORMWATER MANAGEMENT STRUCTURE

PROJECT MANAGER: DR D. MARTENS
DRAWING NUMBER: P0601504JD04-V1.TCW

SHEET 12 OF 12 SHEETS

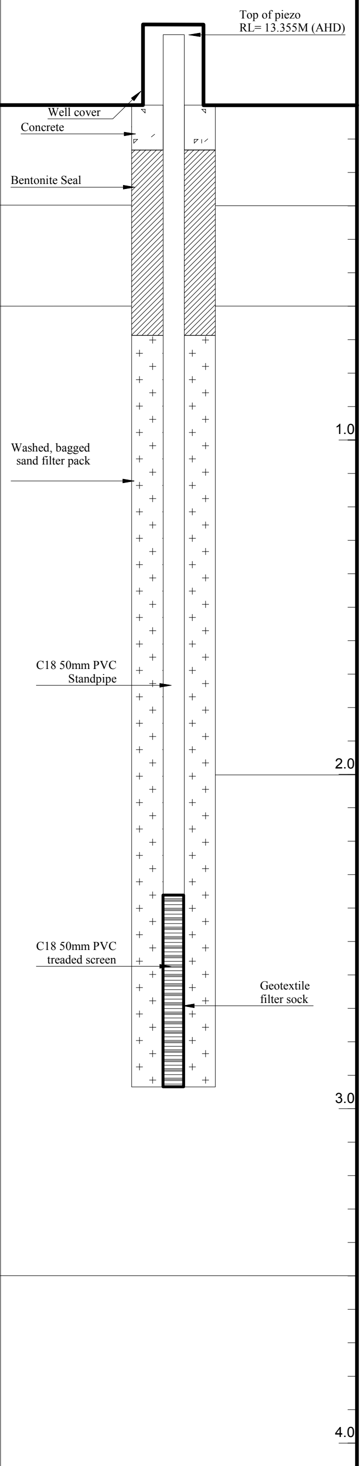
10 Attachment C – Borehole Logs

CLIENT	**HASTINGS COUNCIL**	**COMMENCED** 9/11/06	**COMPLETED** 9/11/06	**REF** **BH1**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED** GH	**CHECKED** GT	**Sheet** 1 **of** 2
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY** SANDSTONE	**VEGETATION** PASTURE	**PROJECT NO.** P0601504
EQUIPMENT	AUGER	**EASTING** NA	**RL SURFACE** 12.815M (AHD)	
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 7.5M	**NORTHING** NA	**ASPECT** EAST	**SLOPE** 0-5%

EXCAVATION DATA — MATERIAL DATA — SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)
A	Nil	N	W	0.3			L	LOAM - Brown, moderately structured.	S		A 1331/	0.2 1/0.2
A	Nil	N	W	0.6			LC	LIGHT CLAY - Browny yellow, massive, weakly structured.	S			
A	Nil	N ▽	M W	1.0 2.0 3.0 3.5			MC	MEDIUM CLAY - Orange with minor grey mottling, firm, well structured.	F			
A	Nil	Y	W	4.0			MC	CLAY- Dark grey, 15% gravels (1-5mm).	F			

WELL CONSTRUCTION DETAILS



EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

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Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	9/11/06	**COMPLETED**	9/11/06	**REF**	**BH1**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 2 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	12.815M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 7.5M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	0-5%

EXCAVATION DATA						MATERIAL DATA					SAMPLING & TESTING		
METHOD	**SUPPORT**	**WATER**	**MOISTURE**	**DEPTH (M)**	**PENETRATION RESISTANCE** L M H R	**GRAPHIC LOG**	**CLASSIFICATION**	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	**CONSISTENCY**	**DENSITY INDEX**	**TYPE**	**DEPTH (M)**	**WELL CONSTRUCTION DETAILS**
A	Nil	Y	W	5.0			MC	CLAY- Dark grey, 15% gravels (1-5mm).	F				5.0
				6.0				Borehole terminated at 6.0m on clays.					6.0
				7.0									7.0
				8.0									8.0

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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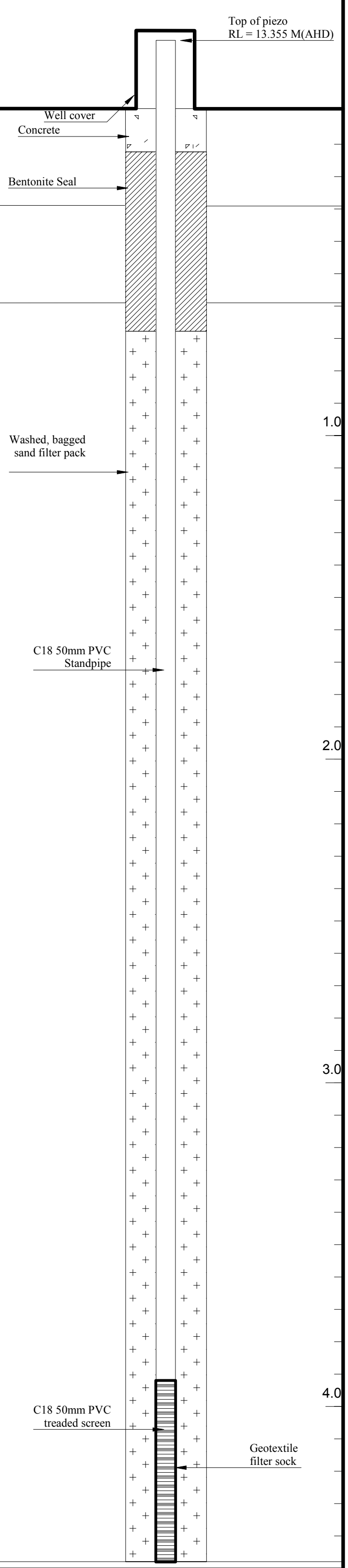
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	9/11/06	**COMPLETED**	9/11/06	**REF**	**BH2**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet 1 of 2**	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	12.13M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 7.5M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	0-5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)
A	Nil	N	W	0.3			L	LOAM - Brown, moderately structured.	S		A 1331/1/0.2	0.2
A	Nil	N	W	0.6			LC	LIGHT CLAY - Browny yellow, massive, weakly structured.	S			
A	Nil	N	M	1.0 2.0 3.0 4.0 4.5			HC	HEAVY CLAY - Red and white mottled, plastic.	S			

WELL CONSTRUCTION DETAILS



EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
⊻ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

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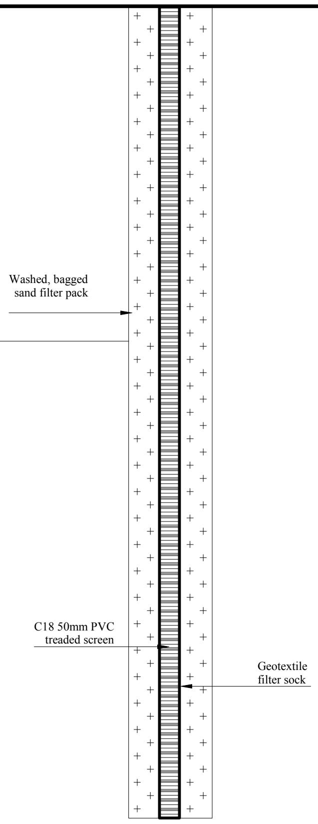
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	9/11/06	**COMPLETED**	9/11/06	**REF**	**BH2**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 2 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	12.13M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 7.5M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	0-5%

EXCAVATION DATA						MATERIAL DATA					SAMPLING & TESTING		
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	WELL CONSTRUCTION DETAILS
A	Nil	N	M	5.0 5.5			C	CLAY- With 10-15% sharp edged gravels (0-10mm).	F		A 1331/1/0.2	0.2	
A	Nil	N	W	6.0 7.0 7.5			C	CLAY - Pink and orange, saturated, soft, with 10-15% sharp edged gravels (0-10mm).	St				
				8.0				Borehole terminated at 7.5m on clay.					



EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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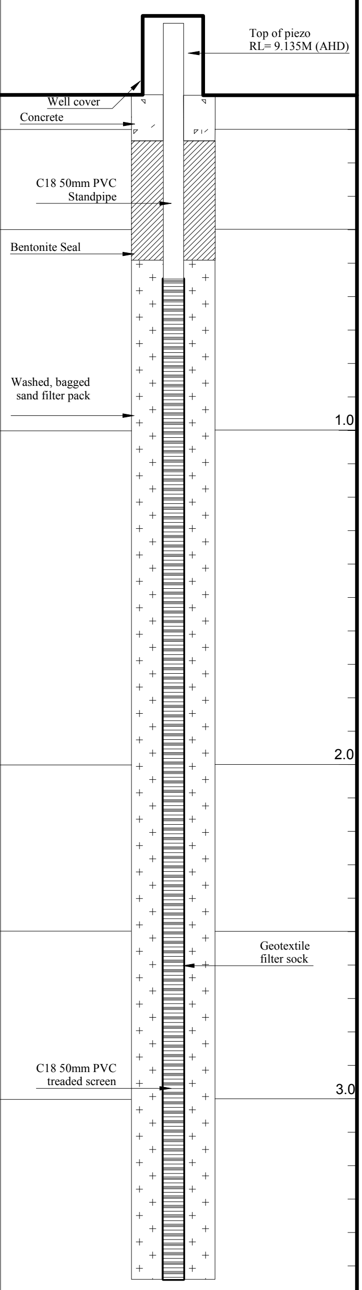
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	9/11/06	**COMPLETED**	9/11/06	**REF**	**BH3**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 1 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	RAINFOREST	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	8.375M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 6.0M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	0-5%

EXCAVATION DATA					MATERIAL DATA						SAMPLING & TESTING	
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)
A	Nil	N	W	0.1			SiC	SILTY CLAY - Brown.	S			
A	Nil	N	W	0.4			LC	LIGHT CLAY - Browny yellow, massive, weakly structured.	S		A 1331/1/0.2	0.2
A	Nil	N	M	1.0			C	MEDIUM TO HEAVY CLAY - Red and orange mottled.	F			
A	Nil	N	M	2.0			C	MEDIUM TO HEAVY CLAY - Orange and white mottled.	F			
A	Nil	N ∇	M	2.5			SC	SANDY CLAY - Orange.	F			
A	Nil	N	W	3.0			CS	CLAYEY SAND - Orange.		MD		
A	Nil	N	W	4.0			CS	CLAYEY SAND - Orange.		MD		

WELL CONSTRUCTION DETAILS



EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
∇ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	9/11/06	**COMPLETED**	9/11/06	**REF**	**BH3**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 2 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	RAINFOREST	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	8.375M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 6.0M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	0-5%

EXCAVATION DATA						**MATERIAL DATA**					**SAMPLING & TESTING**		
METHOD	**SUPPORT**	**WATER**	**MOISTURE**	**DEPTH (M)**	**PENETRATION RESISTANCE** L M H R	**GRAPHIC LOG**	**CLASSIFICATION**	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	**CONSISTENCY**	**DENSITY INDEX**	**TYPE**	**DEPTH (M)**	**WELL CONSTRUCTION DETAILS**
											A	0.2	1331/1/0.2
A	Nil	N	W	5.0			CS	CLAYEY SAND - Orange.		D			5.0
				6.0									6.0
								Borehole terminated at 6.0m on clayey sand.					
				7.0									7.0
				8.0									8.0

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

Quality Sheet No. 4

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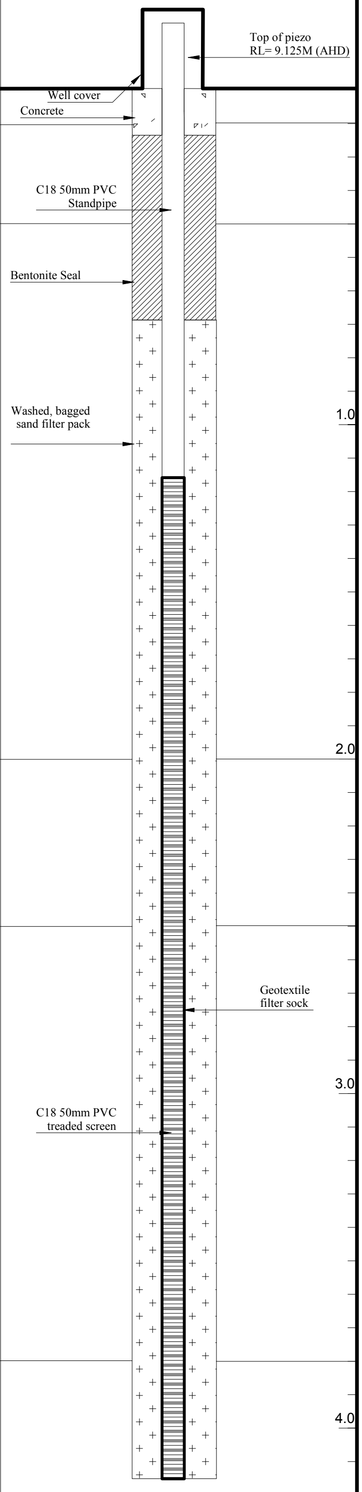
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	10/11/06	**COMPLETED**	10/11/06	**REF** **BH4**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 1 **of** 2
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.** P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	8.31M (AHD)	
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 6.0M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE** 0-5%

EXCAVATION DATA						**MATERIAL DATA**					**SAMPLING & TESTING**		
METHOD	**SUPPORT**	**WATER**	**MOISTURE**	**DEPTH (M)**	**PENETRATION RESISTANCE** L M H R	**GRAPHIC LOG**	**CLASSIFICATION**	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	**CONSISTENCY**	**DENSITY INDEX**	**TYPE**	**DEPTH (M)**	**WELL CONSTRUCTION DETAILS**
A	Nil	N	W	0.1			SiC	SILTY CLAY - Brown.	S				
A	Nil	N	W	0.4			LC	LIGHT CLAY - Browny yellow, massive, weakly structured.	S		A 1331/1/0.2	0.2	
A	Nil	N	M	1.0 2.0			MC	MEDIUM CLAY - Orange with minor grey mottling, firm, well structured.	F				
A	Nil	N	W	2.5			SC	LIGHT SANDY CLAY - Orange.	F				
A	Nil	N	Wp	3.0 3.8			CS	CLAYEY SAND - Orange.		MD			
A	Nil	N	Wl	4.0			CS	FINE CLAYEY SAND - Pinky orange, totally structured. Rounded pebbles hit with auger, <20mm with possible larger stones in profile.		MD			



EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
∇ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	10/11/06	**COMPLETED**	10/11/06	**REF**	**BH4**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 2 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	8.31M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 6.0M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	0.5%

EXCAVATION DATA | MATERIAL DATA | SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	WELL CONSTRUCTION DETAILS
A	Nil	N	Wl	5.0 6.0			CS	FINE CLAYEY SAND - Pinky orange, totally structured. Rounded pebbles hit with auger, <20mm with possible larger stones in profile.		D			5.0 6.0
				7.0 8.0				Borehole terminated at 6.0m on clayey sand.					7.0 8.0

EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING		CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure	SH Shoring	N None observed	D Dry	L Low	VS Very Soft	VL Very Loose	A Auger sample	pp Pocket penetrometer	Y USCS
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test	N Agricultural
BH Backhoe bucket	RB Rock Bolts	▽ Water level	W Wet	H High	F Firm	MD Medium Dense	U Undisturbed sample	VS Vane shear	
E Excavator	Nil No support	◁ Water outflow	Wp Plastic limit	R Refusal	St Stiff	D Dense	D Disturbed sample	DCP Dynamic cone penetrometer	
HA Hand auger		▷ Water inflow	Wl Liquid limit		VSt Very Stiff	VD Very Dense	M Moisture content	FD Field density	
S Hand spade					H Hard		Ux Tube sample (x mm)	WS Water sample	
PT Push tube					F Friable				
A Auger									

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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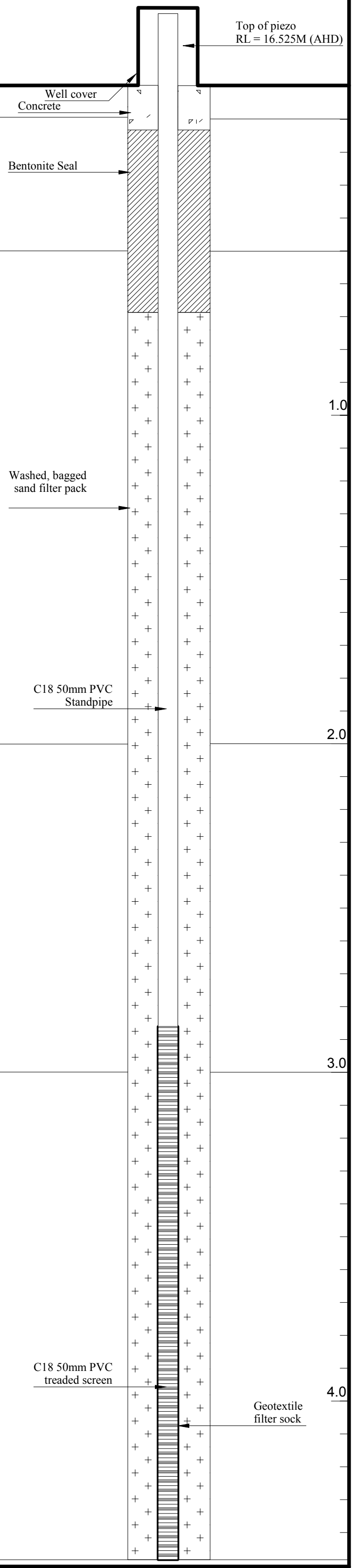
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	10/11/06	**COMPLETED**	10/11/06	**REF**	**BH5**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GT	**CHECKED**	GH	**Sheet** 1 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	15.725M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 9.0M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	5-10%

EXCAVATION DATA						MATERIAL DATA					SAMPLING & TESTING		
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	WELL CONSTRUCTION DETAILS
A	Nil	N	M	0.1			SiC	SILTY CLAY - Dark brown.	S				
A	Nil	N	M	0.5			C	CLAY - Orange/brown (no sands).	F		A 1331/1	0.2 0.2	
A	Nil	N	M	1.0 2.0			C	CLAY - White/light grey with red mottling.	F				
A	Nil	N	M	3.0			C	CLAY - White with pink/red mottling with 10% gravels (1-10mm).	F				
A	Nil	N	M	4.0 4.5			C	CLAY - White with pink/red mottling with 5% gravels (1-5mm).	F				



EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

Quality Sheet No. 4

martens

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6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
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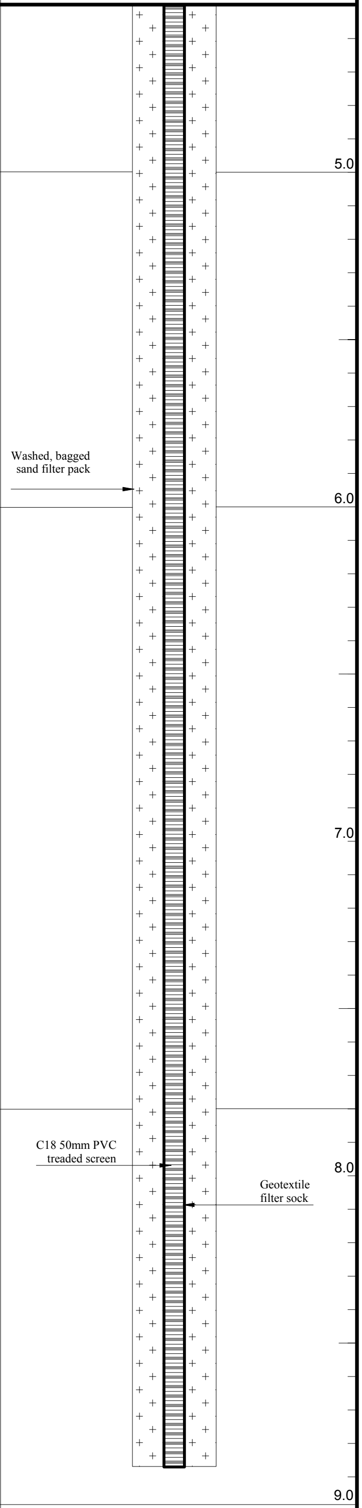
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	10/11/06	**COMPLETED**	10/11/06	**REF**	**BH5**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GT	**CHECKED**	GH	**Sheet**	2 of 2
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	15.725M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 9.0M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	5-10%

EXCAVATION DATA						MATERIAL DATA					SAMPLING & TESTING		
METHOD	**SUPPORT**	**WATER**	**MOISTURE**	**DEPTH (M)**	**PENETRATION RESISTANCE** L M H R	**GRAPHIC LOG**	**CLASSIFICATION**	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	**CONSISTENCY**	**DENSITY INDEX**	**TYPE**	**DEPTH (M)**	**WELL CONSTRUCTION DETAILS**
A	Nil	N	M	5.0			C	CLAY - White with pink/red mottling with 5% gravels (1-5mm).	F				
A	Nil	N	M	6.0			C	CLAY - White with pink/red mottling with 5% gravels (1-5mm).	St				
A	Nil	N	M	7.0 7.8			C	CLAY - Orange, clean.	St				
A	Nil	N	W	8.0 9.0			C	CLAY - Orange, clean. Borehole terminated at 9.0m on clay.	St				



EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING		CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure	SH Shoring	N None observed	D Dry	L Low	VS Very Soft	VL Very Loose	A Auger sample	pp Pocket penetrometer	Y USCS
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test	N Agricultural
BH Backhoe bucket	RB Rock Bolts	▽ Water level	W Wet	H High	F Firm	MD Medium Dense	U Undisturbed sample	VS Vane shear	
E Excavator	Nil No support	◁ Water outflow	Wp Plastic limit	R Refusal	St Stiff	D Dense	D Disturbed sample	DCP Dynamic cone penetrometer	
HA Hand auger		▷ Water inflow	WI Liquid limit		VSt Very Stiff	VD Very Dense	M Moisture content	FD Field density	
S Hand spade					H Hard		Ux Tube sample (x mm)	WS Water sample	
PT Push tube					F Friable				
A Auger									

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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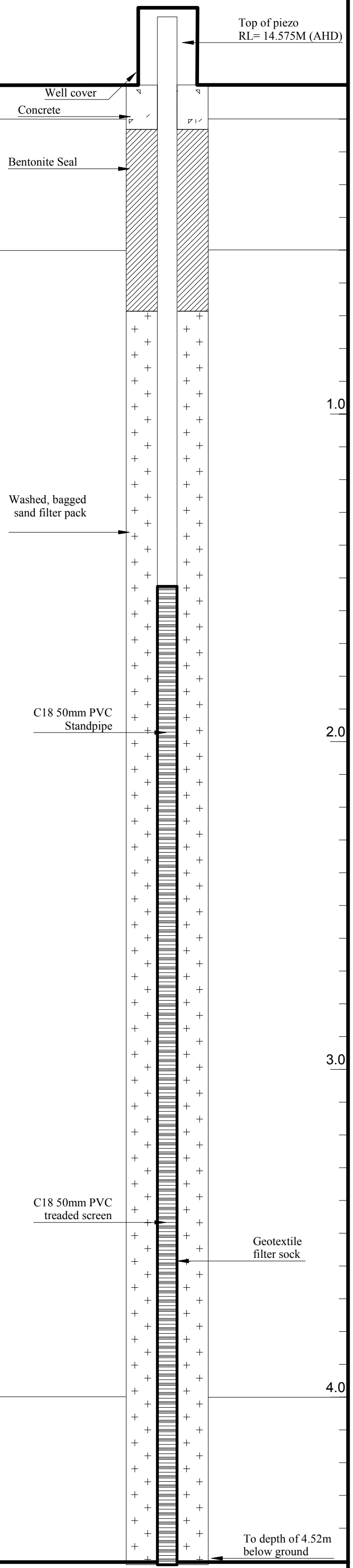
Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	10/11/06	**COMPLETED**	10/11/06	**REF**	**BH6**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet** 1 **of** 2	
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.**	P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	13.80M (AHD)		
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 5.5M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE**	5-10%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)
A	Nil	N	M	0.1			SiL	SILTY LOAM - Brown, organic.	S			
A	Nil	N	M	0.5			LC	LIGHT CLAY - Browny yellow, massive, weakly structured.	F			
A	Nil	N	D-M	1.0 2.0 3.0 4.0			SC	LIGHT SANDY CLAY - Brownish yellow with 15% small angular gravels (<10mm) throughout.	F			
A	Nil	N	M				SC	LIGHT SANDY CLAY - Light brown with 15% small angular gravels (<10mm) throughout.	St			

WELL CONSTRUCTION DETAILS



EQUIPMENT / METHOD
- N Natural exposure
- X Existing excavation
- BH Backhoe bucket
- E Excavator
- HA Hand auger
- S Hand spade
- PT Push tube
- A Auger

SUPPORT
- SH Shoring
- SC Shotcrete
- RB Rock Bolts
- Nil No support

WATER
- N None observed
- X Not measured
- ▽ Water level
- ◁ Water outflow
- ▷ Water inflow

MOISTURE
- D Dry
- M Moist
- W Wet
- Wp Plastic limit
- Wl Liquid limit

PENETRATION
- L Low
- M Moderate
- H High
- R Refusal

CONSISTENCY
- VS Very Soft
- S Soft
- F Firm
- St Stiff
- VSt Very Stiff
- H Hard
- F Friable

DENSITY
- VL Very Loose
- L Loose
- MD Medium Dense
- D Dense
- VD Very Dense

SAMPLING & TESTING
- A Auger sample
- B Bulk sample
- U Undisturbed sample
- D Disturbed sample
- M Moisture content
- Ux Tube sample (x mm)
- pp Pocket penetrometer
- S Standard penetration test
- VS Vane shear
- DCP Dynamic cone penetrometer
- FD Field density
- WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
- Y USCS
- N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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Engineering Log - Borehole

CLIENT	**HASTINGS COUNCIL**	**COMMENCED**	10/11/06	**COMPLETED**	10/11/06	**REF** **BH6**
PROJECT	**GROUNDWATER INVESTIGATIONS**	**LOGGED**	GH	**CHECKED**	GT	**Sheet 2 of 2**
SITE	**AREA 14, LAKE CATHIE**	**GEOLOGY**	SANDSTONE	**VEGETATION**	PASTURE	**PROJECT NO.** P0601504
EQUIPMENT	AUGER	**EASTING**	NA	**RL SURFACE**	13.80M (AHD)	
EXCAVATION DIMENSIONS	DIA: 100MM DEPTH: 5.5M	**NORTHING**	NA	**ASPECT**	EAST	**SLOPE** 5-10%

EXCAVATION DATA						**MATERIAL DATA**					**SAMPLING & TESTING**		
METHOD	**SUPPORT**	**WATER**	**MOISTURE**	**DEPTH (M)**	**PENETRATION RESISTANCE** L M H R	**GRAPHIC LOG**	**CLASSIFICATION**	**DESCRIPTION OF STRATA** Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	**CONSISTENCY**	**DENSITY INDEX**	**TYPE**	**DEPTH (M)**	**WELL CONSTRUCTION DETAILS**
A	Nil	N	M	5.0 5.5			SC	LIGHT SANDY CLAY - Light brown with 15% small angular gravels (<10mm) throughout.	St				5.0
				6.0 7.0 8.0				Borehole terminated at 5.5m on redrock.					6.0 7.0 8.0

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

PENETRATION
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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Engineering Log - Borehole

11 Attachment D – Laboratory Results

CUSTOMER CENTRIC - ANALYTICAL CHEMISTS

No. 13542.

Accredited for compliance with ISO/IEC 17025. The results of tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. NATA is a signatory to the APLAC mutual recognition arrangement for the mutual recognition of the equivalence of testing, calibration and inspection reports.

AQIS

AUSTRALIAN QUARANTINE
AND INSPECTION SERVICE

SYDNEY License No. N0356.

Quarantine Approved Premises criteria 5.1 for quarantine containment level 1 (QCI) facilities. Class five criteria cover premises utilised for research, analysis and testing of biological material, soil, animal, plant and human products.

FINAL CERTIFICATE OF ANALYSIS - ENVIRONMENTAL DIVISION

Laboratory Report No:	E029326	Cover Page 1 of 4 plus Sample Results
Client Name:	Martens Consulting Engineers	
Client Reference:	Area 14 Lake Cathie	
Contact Name:	Grant Harlow	
Chain of Custody No:	na	Date Received: 24/11/2006
Sample Matrix:	WATER	Date Reported: 06/12/2006

This Final Certificate of Analysis consists of sample results, DQI's, method descriptions, laboratory definitions, and internationally recognised NATA accreditation and endorsement. The DQO compliance relates specifically to QA/QC results as performed as part of the sample analysis, and may provide an indication of sample result quality. Transfer of report ownership from Labmark to the client shall only occur once full & final payment has been settled and verified. All report copies may be retracted where full payment has not occured within the agreed settlement period.

QUALITY ASSURANCE CRITERIA

Accuracy:	matrix spike:	1 in first 5-20, then 1 every 20 samples
	lcs, crm, method:	1 per analytical batch
	surrogate spike:	addition per target organic method
Precision:	laboratory duplicate:	1 in first 5-10, then 1 every 10 samples
	laboratory triplicate:	re-extracted & reported when duplicate RPD values exceed acceptance criteria
Holding Times:	soils, waters:	Refer to LabMark Preservation & THT table VOC's 14 days water / soil VAC's 7 days water or 14 days acidified VAC's 14 days soil SVOC's 7 days water, 14 days soil Pesticides 7 days water, 14 days soil Metals 6 months general elements Mercury 28 days
Confirmation:	target organic analysis:	GC/MS, or confirmatory column
Sensitivity:	EQL:	Typically 2-5 x Method Detection Limit (MDL)

QUALITY CONTROL GLOBAL ACCEPTANCE CRITERIA (GAC)

Accuracy:	spike, lcs, crm surrogate:	general analytes 70% - 130% recovery phenol analytes 50% - 130% recovery organophosphorous pesticide analytes 60% - 130% recovery phenoxy acid herbicides 50% - 130% recovery
	anion/cation bal:	+/- 10% (0-3 meq/l), +/- 5% (>3 meq/l)
Precision:	method blank:	not detected >95% of the reported EQL
	duplicate lab RPD (metals):	0-30% (>10xEQL), 0-75% (5-10xEQL) 0-100% (<5xEQL)
	duplicate lab RPD:	0-50% (>10xEQL), 0-75% (5-10xEQL) 0-100% (<5xEQL)

QUALITY CONTROL ANALYTE SPECIFIC ACCEPTANCE CRITERIA (ASAC)

Accuracy:	spike, lcs, crm surrogate:	analyte specific recovery data <3xsd of historical mean
Uncertainty:	spike, lcs:	measurement calculated from historical analyte specific control charts

RESULT ANNOTATION

DQO:	Data Quality Objective	s:	matrix spike recovery	p:	pending
DQI:	Data Quality Indicator	d:	laboratory duplicate	lcs:	laboratory control sample
EQL:	Estimated Quantitation Limit	t:	laboratory triplicate	crm:	certified reference material
- - :	not applicable	r:	RPD relative % difference	mb:	method blank

David Burns
Quality Control (Report signatory)
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Geoff Weir
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Simon Mills
Authorising Chemist (NATA signatory)
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This document is issued in accordance with NATA's accreditation requirements.

Laboratory Report: E029326

Cover Page 2 of 4

NEPC GUIDELINE COMPLIANCE - DQO

1. GENERAL

A. Results relate specifically to samples as received. Sample results are not corrected for matrix spike, lcs, or surrogate recovery data.

B. EQL's are matrix dependant and may be increased due to sample dilution or matrix interference.

C. Laboratory QA/QC samples are specific to this project.

D. Inter-laboratory proficiency results are available upon request. NATA accreditation details available at www.nata.asn.au.

E. VOC spikes & surrogates added to samples during extraction, SVOC spikes & surrogates added prior to extraction.

F. Recovery data outside GAC limits shall be investigated and compared to ASAC (historical mean +/- 3sd). If recovery data <20%, then the relevant results for that compound are considered not reliable.

G. Recovery data (ms, surrogate, crm, lcs) outside ASAC limits shall initiate an investigative action. Anomolous QC data is examined in conjunction with other QC samples and a final decision whether to accept or reject results is provided by the professional judgement of the senior analyst. The USEPA-CLP National Functional Guidelines are referred to for specific recommendations.

H. Extraction (preparation) date refers to the date that sample preparation was initiated. Note that certain methods not requiring sample preparation (eg. VOCs in water, etc) may report a common extraction and analysis date.

I. LabMark shall maintain an official copy of this Certificate of Analysis for all tracable reference purposes.

2. CHAIN OF CUSTODY (COC) & SAMPLE RECEIPT NOTICE (SRN) REQUIREMENTS

A. SRN issued to client upon sample receipt & login verification.

B. Preservation & sampling date details specified on COC and SRN, unless noted.

C. Sample Integrity & Validated Time of Sample Receipt (VTSR) Holding Times verified (preservation may extend holding time, refer to preservation chart).

3. NATA ACCREDITED METHODS

A. NATA accreditation held for each in-house method and sample matrix type reported, unless noted below (Refer to subcontracted test reports for NATA accreditation status).

B. NATA accredited in-house laboratory methods are referenced from NEPC, ASTM, modified USEPA / APHA documents. Corporate Accreditation No. 13542.

C. Subcontracted analyses: Refer to Sample Receipt Notice and additional DQO comments.

Reported by Sydney Analytical Laboratories, NATA accreditation No.1884.

Environmental Laboratory Industry Group
Foundation Member

Laboratory Report: E029326

4. QA/QC FREQUENCY COMPLIANCE TABLE SPECIFIC TO THIS REPORT

Matrix: **WATER**

Page:	Method:	Totals:	#d	%d-ratio	#t	#s	%s-ratio
1	pH in water	3	0	0%	0	0	0%
2	Electrical conductivity (EC)	3	0	0%	0	0	0%
3	Nitrate as N	3	0	0%	0	0	0%
3	Nitrite as N	3	0	0%	0	0	0%
4	TKN (as N)	3	0	0%	0	0	0%
5	Ammonia as N	3	0	0%	0	0	0%
6	Total Nitrogen (as N)	3	0	0%	0	0	0%
7	Total Phosphorus (as P)	3	0	0%	0	0	0%
8	BOD	3	1	33%	0	0	0%
9	Suspended Solids (TSS)	3	1	33%	0	0	0%

GLOSSARY:

#d	number of discrete duplicate extractions/analyses performed.
%d-ratio	NEPC guideline for laboratory duplicates is 1 in 10 samples (min 10%).
#t	number of triplicate extractions/analyses performed.
#s	number of spiked samples analysed.
%s-ratio	USEPA guideline for laboratory matrix spikes is 1 in 20 samples (min 5%).

5. ADDITIONAL COMMENTS SPECIFIC TO THIS REPORT

A. All tests were conducted by LabMark Environmental Sydney, NATA accreditation No. 13542, Corporate Site No. 13535, unless indicated below.
B. The following test was conducted by Sydney Analytical Laboratories, NATA accreditation No.1884. :-SAL18500. Results for TSS and BOD issued on 06/12/06.

This document is issued in accordance with NATA's accreditation requirements.

Foundation
Member

Laboratory Report: E029326

Cover Page 4 of 4

Laboratory QA/QC data shall relate specifically to this report, and may provide an indication of site specific sample result quality. LabMark DOES NOT report NON-RELEVANT BATCH QA/QC data. Acceptance of this self assessment certificate does not preclude any requirement for a QA/QC review by a accredited contaminated site EPA auditor, when and wherever necessary. Laboratory QA/QC self assessment references available upon request.

Laboratory Report No: E029326

Client Name: Martens Consulting Engineers

Contact Name: Grant Harlow

Client Reference Area 14 Lake Cathie P0601504

Page: 1 of 9
plus cover page

Date: 06/12/06

This report supercedes reports issued on: N/A

Final
Certificate
of Analysis

Laboratory Identification		**56960**	**56961**	**56962**							
Sample Identification		BH2	BH3	BH5							
Depth (m)		--	--	--							
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06							
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06							
Laboratory Analysis Date		24/11/06	24/11/06	24/11/06							
Method : E018.1											
pH in water	**EQL**										
pH (pH units)	0.1	5.0	5.8	5.7							

Results expressed in pH units unless otherwise specified

Comments:

E018.1: Direct measurement by pH ion selective electrode.

Laboratory Identification		**56960**	**56961**	**56962**	**mb**						
Sample Identification		BH2	BH3	BH5	QC						
Depth (m)		--	--	--	--						
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--						
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06						
Laboratory Analysis Date		24/11/06	24/11/06	24/11/06	24/11/06						
Method : E032.1 **Electrical conductivity (EC)**	**EQL**										
Electric conductivity (uS/cm)	1	583	6640	6470	1						

Results expressed in uS/cm unless otherwise specified

Comments:

E032.1: Measurement by EC probe. Results expressed in uS/cm.

Laboratory Report No: E029326
Client Name: Martens Consulting Engineers
Contact Name: Grant Harlow
Client Reference Area 14 Lake Cathie P0601504

Page: 3 of 9
plus cover page
Date: 06/12/06
This report supercedes reports issued on: N/A

Final
Certificate
of Analysis

Laboratory Identification		**56960**	**56961**	**56962**	**lcs**	**mb**					
Sample Identification		BH2	BH3	BH5	QC	QC					
Depth (m)		--	--	--	--	--					
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--					
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	24/11/06					
Laboratory Analysis Date		27/11/06	27/11/06	27/11/06	24/11/06	24/11/06					
Method : E037.1/E051.1 **Nitrite as N**	**EQL**										
NO2-N	0.01	0.01	0.01	0.01	99%	<0.01					
Method : E037.1/E051.1 **Nitrate as N**	**EQL**										
NO3-N	0.01	<0.01	0.02	<0.01	89%	<0.01					

Results expressed in mg/l unless otherwise specified

Comments:

E037.1/E051.1: Nitrate determined by colour. Sample filtered through 0.45um prior to analysis.
E037.1/E051.1: Nitrite determined by colour. Sample filtered through 0.45um prior to analysis.

Laboratory Report No: E029326

Client Name: Martens Consulting Engineers

Contact Name: Grant Harlow

Client Reference Area 14 Lake Cathie P0601504

Date: 06/12/06

This report supercedes reports issued on: N/A

Final
Certificate
of Analysis

Laboratory Identification		**56960**	**56961**	**56962**	**lcs**	**mb**					
Sample Identification		BH2	BH3	BH5	QC	QC					
Depth (m)		--	--	--	--	--					
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--					
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	24/11/06					
Laboratory Analysis Date		28/11/06	28/11/06	28/11/06	28/11/06	28/11/06					
Method : E039.1 **TKN (as N)**	**EQL**										
Total Kjeldahl Nitrogen	0.1	0.2	0.9	0.3	80%	<0.1					

Results expressed in mg/l unless otherwise specified

Comments:

E039.1: Sample filtered through 0.45um filter prior to analysis. Acidic digestion followed by determination by colour.

Laboratory Report No: E029326
Client Name: Martens Consulting Engineers
Contact Name: Grant Harlow
Client Reference Area 14 Lake Cathie P0601504

Date: 06/12/06
This report supercedes reports issued on: N/A

Final
Certificate
of Analysis

Laboratory Identification		**56960**	**56961**	**56962**	**lcs**	**mb**					
Sample Identification		BH2	BH3	BH5	QC	QC					
Depth (m)		--	--	--	--	--					
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--					
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	24/11/06					
Laboratory Analysis Date		24/11/06	24/11/06	24/11/06	24/11/06	24/11/06					
Method : E036.1/E050.1											
Ammonia as N	**EQL**										
Ammonia	0.01	0.02	<0.01	<0.01	97%	<0.01					

Results expressed in mg/l unless otherwise specified

Comments:

E036.1/E050.1: Determined by colour. Sample filtered through 0.45um prior to analysis.

Laboratory Identification		**56960**	**56961**	**56962**	**lcs**	**mb**					
Sample Identification		BH2	BH3	BH5	QC	QC					
Depth (m)		--	--	--	--	--					
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--					
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	24/11/06					
Laboratory Analysis Date		27/11/06	27/11/06	27/11/06	24/11/06	24/11/06					
Method : E038.1 **Total Nitrogen (as N)**	**EQL**										
Total Nitrogen (as N)	0.1	0.2	0.9	0.3	94%	<0.1					

Results expressed in mg/l unless otherwise specified

Comments:

E038.1: Total Nitrogen by calculation.

Laboratory Identification		**56960**	**56961**	**56962**	**lcs**	**mb**					
Sample Identification		BH2	BH3	BH5	QC	QC					
Depth (m)		--	--	--	--	--					
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--					
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	24/11/06					
Laboratory Analysis Date		28/11/06	28/11/06	28/11/06	28/11/06	28/11/06					
Method : E038.1											
Total Phosphorus (as P)	**EQL**										
Total Phosphorus (as P)	0.01	0.35	0.60	0.33	103%	<0.01					

Results expressed in mg/l unless otherwise specified

Comments:

E038.1: Alkaline persulphate digestion followed by colour determination.

Laboratory Report No: E029326
Client Name: Martens Consulting Engineers
Contact Name: Grant Harlow
Client Reference Area 14 Lake Cathie P0601504

Page: 8 of 9
plus cover page
Date: 06/12/06
This report supercedes reports issued on: N/A

Final
Certificate
of Analysis

Laboratory Identification		**56960**	**56961**	**56962**	**56960d**	**56960r**	**mb**				
Sample Identification		BH2	BH3	BH5	QC	QC	QC				
Depth (m)		--	--	--	--	--	--				
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--	--				
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	--	24/11/06				
Laboratory Analysis Date		29/11/06	29/11/06	29/11/06	29/11/06	--	29/11/06				
Method : 5210B											
BOD	**EQL**										
BOD	1	<1	<1	<1	<1	--	<1				

Results expressed in mg/l unless otherwise specified

Comments:

5210B: Five days incubation. Determined by oxygen electrode.

Laboratory Report No: E029326

Client Name: Martens Consulting Engineers

Contact Name: Grant Harlow

Client Reference Area 14 Lake Cathie P0601504

Date: 06/12/06

This report supercedes reports issued on: N/A

Final
Certificate
of Analysis

Laboratory Identification		**56960**	**56961**	**56962**	**56960d**	**56960r**	**mb**				
Sample Identification		BH2	BH3	BH5	QC	QC	QC				
Depth (m)		--	--	--	--	--	--				
Sampling Date recorded on COC		23/11/06	23/11/06	23/11/06	--	--	--				
Laboratory Extraction (Preparation) Date		24/11/06	24/11/06	24/11/06	24/11/06	--	24/11/06				
Laboratory Analysis Date		30/11/06	30/11/06	30/11/06	30/11/06	--	30/11/06				
Method : 2540D											
Suspended Solids (TSS)	**EQL**										
Total suspended solids	1	600	1900	2700	590	2%	<1				

Results expressed in mg/l unless otherwise specified

Comments:

2540D: Gravimetric test.

Report Date : 24/11/2006
Report Time : 1:00:26PM

Quality, Service, Support

Sample **Receipt** Notice (SRN) for **E029326**

Client Details

Client Name:	Martens Consulting Engineers
Client Phone:	02 9476 8777
Client Fax:	02 9476 8767
Contact Name:	Grant Harlow
Contact Email:	gharlow@martens.com.au
Client Address:	6/37 Leighton Pl Hornsby NSW 2077
Project Name:	Area 14 Lake Cathie
Project Number:	P0601504
CoC Number:	- Not provided -
Purchase Order:	- Not provided -
Surcharge:	COD, required
Sample Matrix:	WATER

Laboratory Reference Information

Please have this information ready when contacting Labmark.

Laboratory Report:	**E029326**
Quotation Number:	- Not provided, standard prices apply
Laboratory Address:	Unit 1, 8 Leighton Pl. Asquith NSW 2077
Phone:	61 2 9476 6533
Fax:	61 2 9476 8219
Sample Receipt Contact:	Jakleen El Galada
Email:	jakleen.galada@labmark.com.au
Reporting Contact:	Jyothi Lal
Email:	jyothi.lal@labmark.com.au

Date Sampled (earliest date):	23/11/2006
Date Samples Received:	24/11/2006
Date Sample Receipt Notice issued:	24/11/2006
Date Preliminary Report Due:	01/12/2006

NATA Accreditation:	13542
TGA GMP License:	185-336 (Sydney)
APVMA License:	6105 (Sydney)
AQIS Approval:	NO356 (Sydney)
AQIS Entry Permit:	200409998 (Sydney)

Sample Condition:
COC received with samples. Report number and lab ID's defined on COC.
Samples received in good order .
Samples received with cooling media: Crushed ice .
Samples received chilled.
Security seals not required. Direct Labmark's custody taken .
Sample container & sample integrity suitable .

Comments:
BOD and TSS subcontracted to SAL. Nutrients analysed on final day of THT.

Holding Times:
Date received allows for insufficient time to meet Technical Holding Times.
Note: Samples received 0 day(s) after Technical Holding Times expire. LabMark can not guarantee holding time compliance.

Preservation:
Chemical preservation of samples satisfactory for requested analytes.

Important Notes:
Sample disposal of environmental samples shall be 31 days (water) and 3 months (soil, HN03 preserved samples) after laboratory receipt, unless otherwise requested in writing by the client. Samples requested to be held in non-refrigerated storage shall incur $5.00/ sample/ 3 months. Additional refrigerated storage shall incur $20/ sample/ 3 months. Combination prices apply only if requested. Transfer of report ownership from LabMark to the client shall occur once full and final payment has been settled and verified. All report copies may be retracted where full payment does not occur within the agreed settlement period.

Analysis comments:

Subcontracted Analyses:
Reported by Sydney Analytical Laboratories, NATA accreditation No.1884.

Thank you for choosing Labmark to analyse your project samples.
Additional information on www.labmark.com.au

Report Date : 24/11/2006
Report Time : 1:00:26PM

Quality, Service, Support

Sample **Receipt** Notice (SRN) for **E029326**

The table below represents LabMark's understanding and interpretation of the customer supplied sample COC request. Please confirm that your COC request has been entered correctly. Due to THT and TAT requirements, testing shall commence immediately as per this table, unless the customer intervenes with a correction prior to testing.

GRID REVIEW TABLE

				Requested Analysis																			
No.	**Date**	**Depth**	**Client Sample ID**	Electrical conductivity (EC)	Ammonia as N	Nitrite as N	Nitrate as N	NOx (as N)	pH in water	PREP Not Reported	TKN (as N)	Total Nitrogen (as N)	Total Phosphorus (as P)	External BOD	External Suspended Solids (TSS)								
56960	23/11		BH2	●	●	●	●	●	●	●	●	●	●	●	●								
56961	23/11		BH3	●	●	●	●	●	●	●	●	●	●	●	●								
56962	23/11		BH5	●	●	●	●	●	●	●	●	●	●	●	●								
			Totals:	3	3	3	3	3	3	3	3	3	3	3	3								

Thank you for choosing Labmark to analyse your project samples.
Additional information on www.labmark.com.au

12 Attachment E – Pump-test Analysis Records

Single Bore Slug Test (Rising or Falling)

Method based on Hvorslev (1981)

Method ST-# Revised 7.3.2007

martens
consulting engineers since 1989

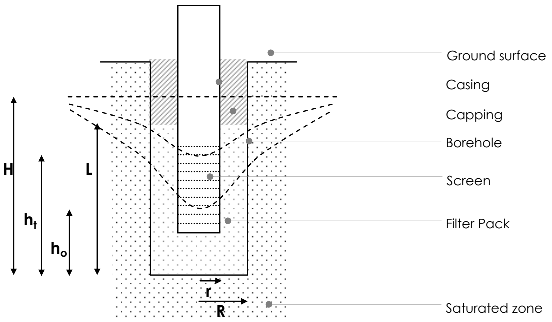
6/37 Leighton Place, Hornsby NSW 2077 Australia, Ph: (02) 9476 8777 Fax: (02) 9476 8767, mail@martens.com.au, www.martens.com.au

PROJECT DETAILS

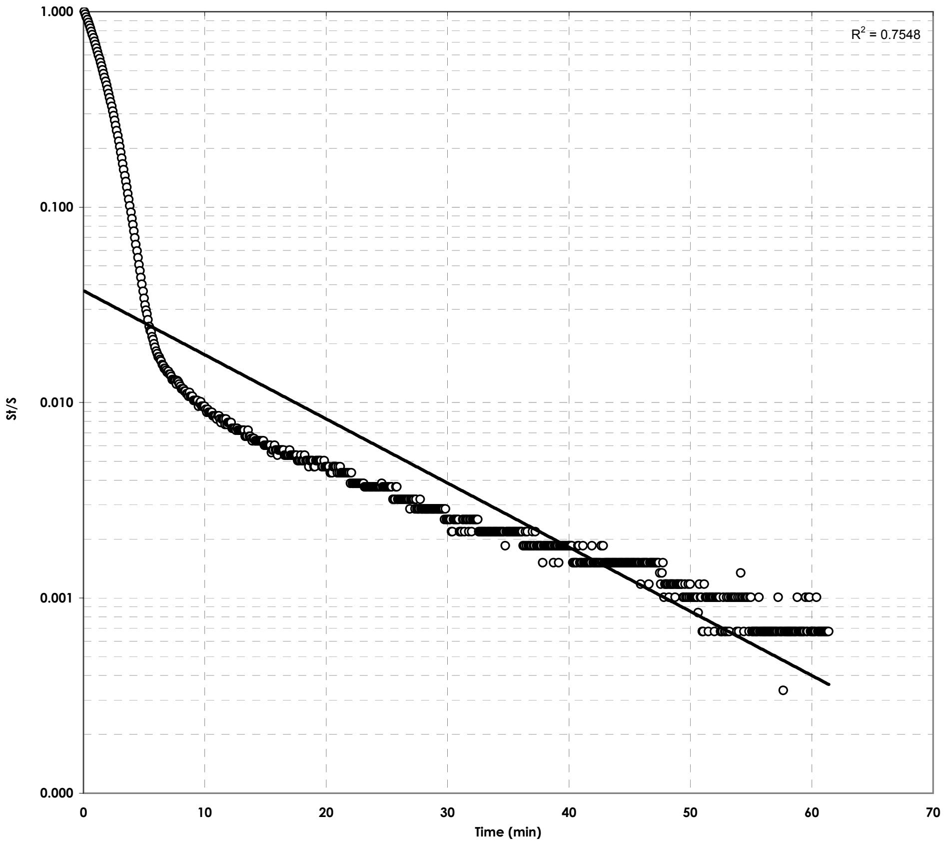
Project	**Area 14 Stage 1B Groundwater Study, Lake Cathie, NSW**			Ref. No.	**P0601504JS09 - BH2**
Author	**Dr D. Martens**	Reviewed	**Mr G. Taylor**	Date Created	**8.3.2007**

STEP 1 : ENTER BOREHOLE DATA

FACTOR	**Enter Data**	**Unit**
H - Initial water level reading (depth)	**12.032**	m
h_o - Water level reading at time = 0 (depth)	**6.067**	m
r - Casing radius	**0.025**	m
R - Bore radius	**0.050**	m
L - Length of open screen	**5.97**	m
T_o - Length of characteristic time	**2.00**	minutes
K_{sat} - Saturated hydraulic conductivity	**0.180**	m/d



STEP 2 : PLOT DATA



Single Bore Slug Test (Rising or Falling)

Method based on Hvorslev (1981)

Method ST-# Revised 7.3.2007

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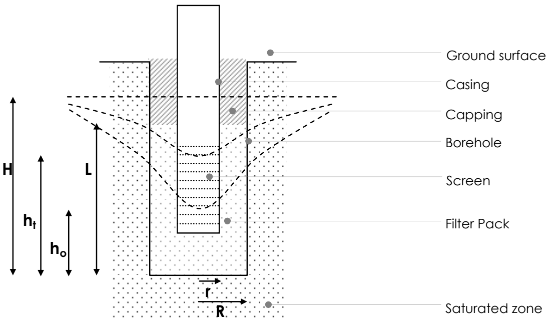
PROJECT DETAILS

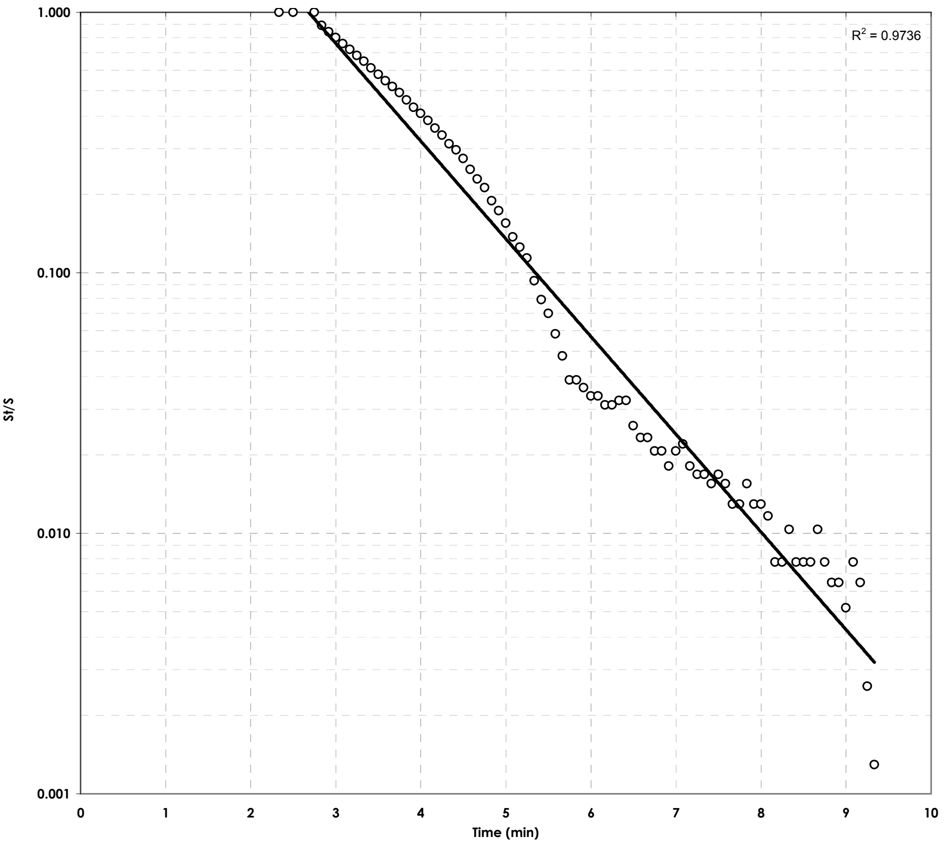
Project	Area 14 Stage 1B Groundwater Study, Lake Cathie, NSW			Ref. No.	P0601504JS09 - BH3
Author	Dr D. Martens	Reviewed	Mr G. Taylor	Date Created	8.3.2007

STEP 1 : ENTER BOREHOLE DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	5.667	m
h_o - Water level reading at time = 0 (depth)	4.894	m
r - Casing radius	0.025	m
R - Bore radius	0.050	m
L - Length of open screen	0.50	m
T_o - Length of characteristic time	4.10	minutes
K_{sat} - Saturated hydraulic conductivity	0.505	m/d



STEP 2 : PLOT DATA



Single Bore Slug Test (Rising or Falling)

Method based on Hvorslev (1981)

Method ST-# Revised 7.3.2007

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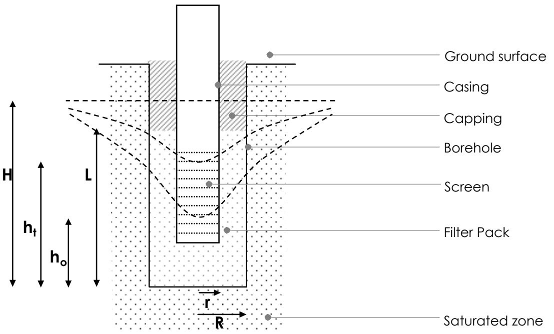
PROJECT DETAILS

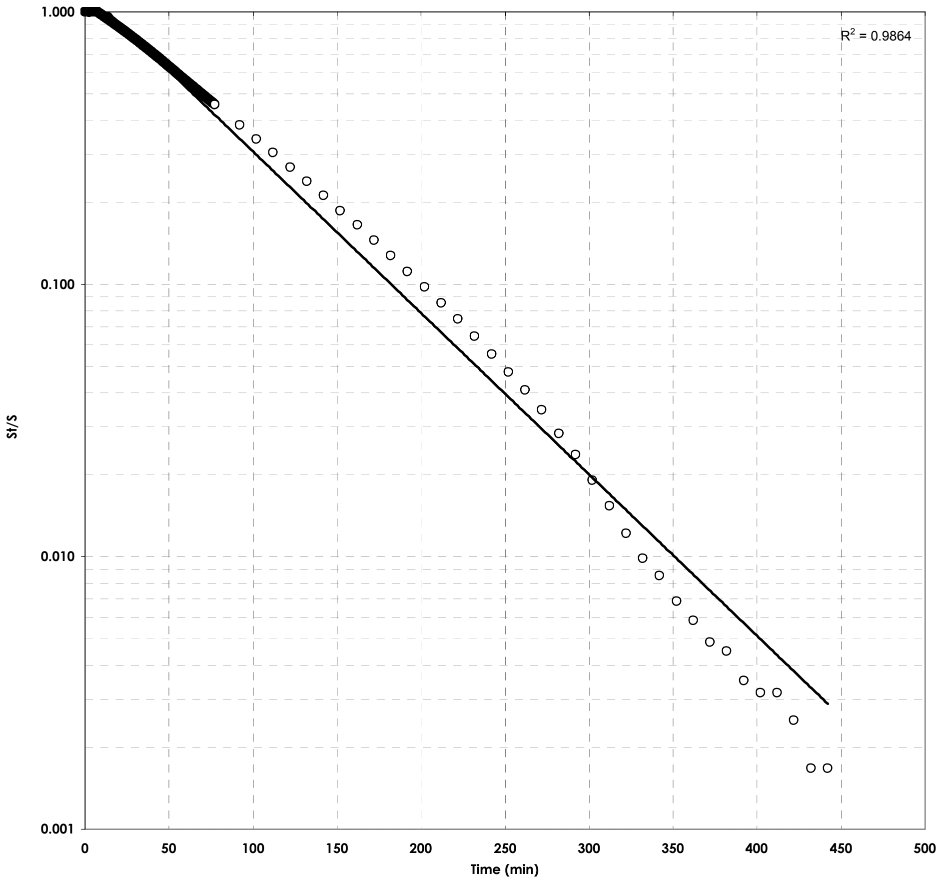
Project	**Area 14 Stage 1B Groundwater Study, Lake Cathie, NSW**			Ref. No.	**P0601504JS09 - BH5**
Author	**Dr D. Martens**	Reviewed	**Mr G. Taylor**	Date Created	**8.3.2007**

STEP 1 : ENTER BOREHOLE DATA

FACTOR	**Enter Data**	**Unit**
H - Initial water level reading (depth)	**13.0**	m
h_o - Water level reading at time = 0 (depth)	**7.0**	m
r - Casing radius	**0.025**	m
R - Bore radius	**0.050**	m
L - Length of open screen	**5.20**	m
T_o - Length of characteristic time	**86.3**	minutes
K_{sat} - Saturated hydraulic conductivity	**0.005**	m/d



STEP 2 : PLOT DATA



Single Bore Slug Test (Rising or Falling)

Method based on Hvorslev (1981)

Method ST-# Revised 7.3.2007

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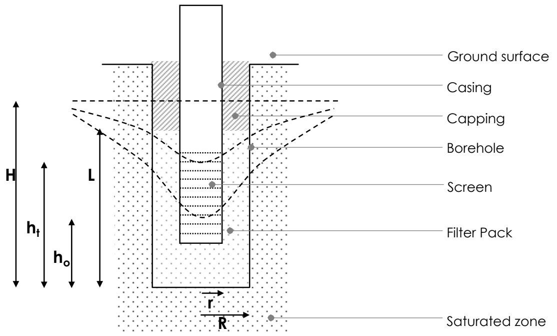
PROJECT DETAILS

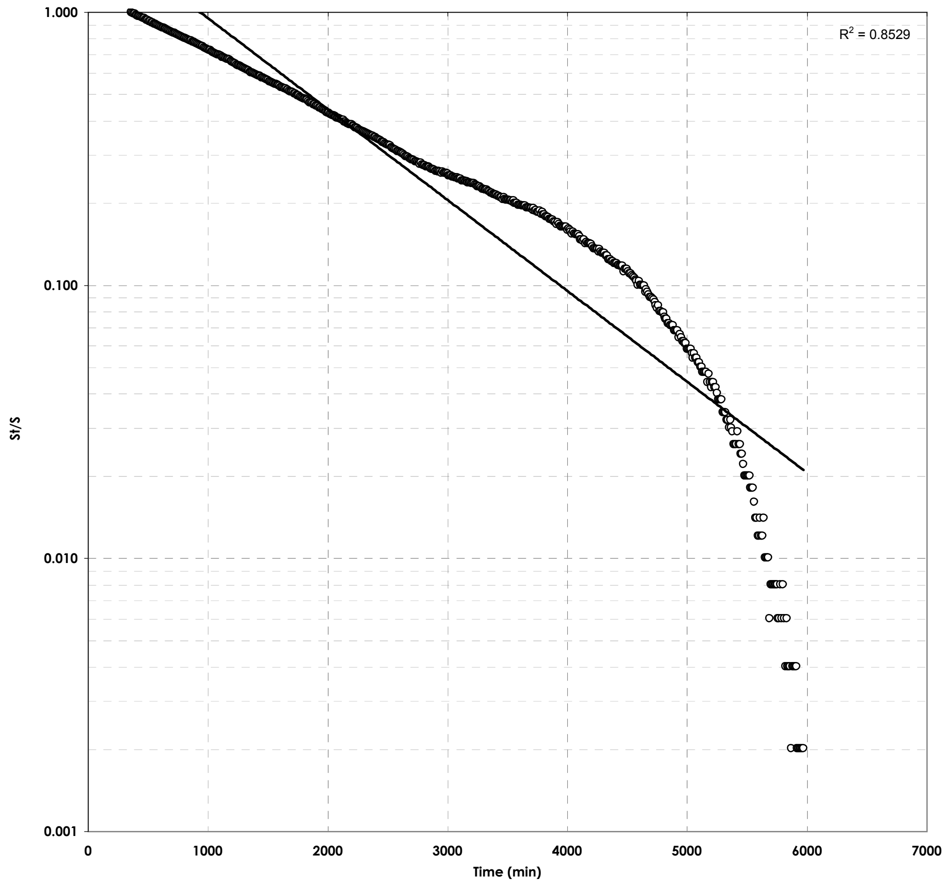
Project	Area 14 Stage 1B Groundwater Study, Lake Cathie, NSW			Ref. No.	P0601504JS09 - BH6
Author	Dr D. Martens	Reviewed	Mr G. Taylor	Date Created	8.3.2007

STEP 1 : ENTER BOREHOLE DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	10.504	m
h_o - Water level reading at time = 0 (depth)	9.510	m
r - Casing radius	0.025	m
R - Bore radius	0.050	m
L - Length of open screen	0.99	m
T_o - Length of characteristic time	2000	minutes
K_{sat} - Saturated hydraulic conductivity	0.0007	m/d



STEP 2 : PLOT DATA



13 Attachment F – GW Level Summaries

Date	BH2 - Temp (°C)	BH2 - mAHD	BH3 - Temp (°C)	BH3 - mAHD	BH5 - Temp (°C)	BH5 - mAHD	BH6 - Temp (°C)	BH6 - mAHD
23/11/2006	18.85	11.99	17.27	5.68	19.56	12.65	19.18	9.51
24/11/2006	18.90	12.13	17.23	5.68	19.53	13.03	18.33	9.87
25/11/2006	18.92	12.11	17.24	5.64	19.54	12.99	18.34	10.21
26/11/2006	18.92	12.01	17.23	5.60	19.54	12.96	18.34	10.36
27/11/2006	18.92	12.03	17.24	5.61	19.54	12.97	18.34	10.49
28/11/2006	18.92	11.98	17.23	5.57	19.55	12.93	18.35	10.53
29/11/2006	18.92	11.92	17.24	5.53	19.55	12.89	18.36	10.55
30/11/2006	18.92	11.95	17.24	5.56	19.56	12.93	18.36	10.64
1/12/2006	18.92	11.88	17.26	5.52	19.56	12.88	18.36	10.64
2/12/2006	18.92	11.85	17.28	5.48	19.56	12.84	18.37	10.66
3/12/2006	18.92	12.04	17.29	5.50	19.56	12.87	18.38	10.71
4/12/2006	18.92	12.12	17.30	5.53	19.56	12.90	18.38	10.75
5/12/2006	18.92	12.01	17.33	5.52	19.56	12.89	18.40	10.77
6/12/2006	18.92	11.93	17.34	5.49	19.56	12.87	18.40	10.77
7/12/2006	18.92	11.90	17.36	5.49	19.57	12.86	18.41	10.80
8/12/2006	18.92	11.90	17.38	5.51	19.57	12.87	18.42	10.82
9/12/2006	18.92	11.91	17.39	5.52	19.57	12.88	18.42	10.84
10/12/2006	18.92	11.88	17.41	5.49	19.57	12.86	18.44	10.84
11/12/2006	18.92	11.80	17.43	5.44	19.57	12.80	18.44	10.82
12/12/2006	18.92	11.81	17.45	5.44	19.57	12.80	18.45	10.85
13/12/2006	18.91	11.83	17.47	5.44	19.57	12.79	18.46	10.85
14/12/2006	18.91	11.77	17.50	5.39	19.57	12.74	18.47	10.83
15/12/2006	18.91	11.80	17.52	5.36	19.58	12.72	18.48	10.83
16/12/2006	18.91	12.07	17.54	5.40	19.58	12.76	18.49	10.87
17/12/2006	18.91	12.02	17.56	5.41	19.58	12.78	18.50	10.88
18/12/2006	18.91	11.67	17.96	5.15	19.58	12.45	18.79	10.90
19/12/2006	18.91	11.83	17.60	5.35	19.58	12.71	18.52	10.86
20/12/2006	18.91	11.84	17.62	5.37	19.58	12.72	18.53	10.89
21/12/2006	18.91	12.15	17.64	5.38	19.58	12.81	18.54	10.92
22/12/2006	18.91	12.04	17.65	5.36	19.58	12.79	18.55	10.89
23/12/2006	18.91	11.91	17.66	5.31	19.58	12.73	18.56	10.87
24/12/2006	18.91	11.84	17.67	5.27	19.58	12.67	18.57	10.85
25/12/2006	18.91	11.85	17.69	5.24	19.58	12.64	18.58	10.85
26/12/2006	18.91	11.85	17.71	5.28	19.58	12.67	18.59	10.89
27/12/2006	18.91	11.82	17.72	5.30	19.58	12.67	18.60	10.90
28/12/2006	18.91	11.79	17.75	5.28	19.58	12.65	18.61	10.90
29/12/2006	18.91	11.77	17.76	5.28	19.58	12.65	18.62	10.90
30/12/2006	18.91	11.78	17.79	5.29	19.58	12.64	18.64	10.91
31/12/2006	18.91	11.77	17.80	5.27	19.58	12.62	18.64	10.89
1/01/2007	18.91	11.85	17.82	5.26	19.58	12.62	18.66	10.91
2/01/2007	18.91	11.80	17.84	5.27	19.58	12.62	18.67	10.92
3/01/2007	18.91	11.80	17.86	5.28	19.58	12.62	18.69	10.93
4/01/2007	18.91	11.78	17.87	5.27	19.58	12.61	18.69	10.93
5/01/2007	18.91	11.76	17.88	5.25	19.58	12.58	18.71	10.93
6/01/2007	18.91	11.71	17.89	5.20	19.58	12.53	18.72	10.91
7/01/2007	18.91	11.62	17.91	5.13	19.58	12.46	18.73	10.88
8/01/2007	18.91	11.61	17.91	5.11	19.58	12.43	18.75	10.89
9/01/2007	18.91	11.65	17.92	5.15	19.58	12.46	18.76	10.91
10/01/2007	18.91	11.64	17.93	5.14	19.58	12.45	18.77	10.91
11/01/2007	18.91	11.62	17.94	5.12	19.59	12.42	18.78	10.90
12/01/2007	18.91	11.59	17.96	5.08	19.59	12.39	18.79	10.89
13/01/2007	18.91	11.59	17.97	5.08	19.60	12.38	18.81	10.90
14/01/2007	18.91	11.63	17.98	5.12	19.59	12.41	18.82	10.92
15/01/2007	18.91	11.65	18.00	5.13	19.58	12.42	18.83	10.93
16/01/2007	18.91	11.66	18.02	5.13	19.58	12.42	18.85	10.93
17/01/2007	18.91	11.65	18.04	5.13	19.58	12.41	18.86	10.93
18/01/2007	18.91	11.64	18.06	5.13	19.58	12.40	18.87	10.93
19/01/2007	18.91	11.62	18.07	5.11	19.58	12.38	18.88	10.93
20/01/2007	18.91	11.57	18.09	5.06	19.58	12.33	18.90	10.90
21/01/2007	18.92	11.50	18.11	4.99	19.58	12.25	18.91	10.88
22/01/2007	18.92	11.52	18.13	5.02	19.58	12.26	18.92	10.91
23/01/2007	18.92	11.55	18.15	5.04	19.59	12.27	18.93	10.91
24/01/2007	18.92	11.53	18.17	5.02	19.58	12.25	18.95	10.90
25/01/2007	18.92	11.52	18.17	5.00	19.58	12.24	18.96	10.89
26/01/2007	18.92	11.48	18.19	4.97	19.58	12.20	18.97	10.88
27/01/2007	18.92	11.40	18.21	4.89	19.58	12.13	18.99	10.85
28/01/2007	18.92	11.43	18.22	4.93	19.59	12.15	19.00	10.87
29/01/2007	18.92	11.45	18.24	4.95	19.59	12.16	19.02	10.89
30/01/2007	18.92	11.46	18.27	4.95	19.59	12.17	19.03	10.89
31/01/2007	18.92	11.47	18.29	4.96	19.59	12.17	19.04	10.90
1/02/2007	18.92	11.54	18.32	5.01	19.59	12.22	19.06	10.92
2/02/2007	18.92	11.54	18.34	5.01	19.59	12.22	19.07	10.91
3/02/2007	18.93	11.51	18.36	4.98	19.59	12.19	19.08	10.90
4/02/2007	18.93	11.51	18.38	4.98	19.59	12.19	19.10	10.90
Mean	18.91	11.76	17.76	5.27	19.58	12.59	18.67	10.81
Start Dec	18.92	11.88	17.26	5.52	19.56	12.88	18.36	10.64
End Dec	18.91	11.77	17.80	5.27	19.58	12.62	18.64	10.89
End Jan	18.92	11.47	18.29	4.96	19.59	12.17	19.04	10.90

14 Attachment G – Notes About This Report

Important Information About Your Report

Subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all of course, are necessarily relevant to all reports, but are included as general reference.

Engineering Reports - Limitations

Geotechnical reports are based on information gained from limited sub-surface site testing and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Engineering Reports – Project Specific Criteria

Engineering reports are prepared by qualified personnel and are based on the information obtained, on current engineering standards of interpretation and analysis, and on the basis of your unique project specific requirements as understood by Martens. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the Client.

Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relative if the design proposal is changed (eg. to a twenty storey building). Your report should not be relied upon if there are changes to the project without first asking Martens to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Martens will not accept responsibility for problems that may occur due to design changes if they are not consulted.

Engineering Reports – Recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced and therefore your site investigation report recommendations should only be regarded as preliminary.

Only Martens, who prepared the report, are fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Martens cannot be held responsible for such misinterpretation.

Engineering Reports – Use For Tendering Purposes

Where information obtained from this investigation is provided for tendering purposes, Martens recommend that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. Attention is drawn to the document 'Guidelines for the Provision of Geotechnical Information in Tender Documents', published by the Institution of Engineers, Australia.

The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Engineering Reports – Data

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings *etc* are customarily included in a Martens report and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These data should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Engineering Reports – Other Projects

To avoid misuse of the information contained in your report it is recommended that you confer with Martens before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Subsurface Conditions - General

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects, relevant standards and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions - the potential for will depend partly on test point (eg. excavation or borehole) spacing and sampling frequency which are often limited by project imposed budgetary constraints.

- Changes in guidelines, standards and policy or interpretation of guidelines, standards and policy by statutory authorities.

- The actions of contractors responding to commercial pressures.

- Actual conditions differing somewhat from those inferred to exist, because no professional, no matter how qualified, can reveal precisely what is hidden by earth, rock and time.

  The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions

If these conditions occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Subsurface Conditions - Changes

Natural processes and the activity of man create subsurface conditions. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Reports are based on conditions which existed at the time of the subsurface exploration.

Decisions should not be based on a report whose adequacy may have been affected by time. If an extended period of time has elapsed since the report was prepared, consult Martens to be advised how time may have impacted on the project.

Subsurface Conditions - Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those that were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved at the time when conditions are exposed, rather than at some later stage well after the event.

Report Use By Other Design Professionals

To avoid potentially costly misinterpretations when other design professionals develop their plans based on a report, retain Martens to work with other project professionals who are affected by the report. This may involve Martens explaining the report design implications and then reviewing plans and specifications produced to see how they have incorporated the report findings.

Subsurface Conditions - Geoenvironmental Issues

Your report generally does not relate to any findings, conclusions, or recommendations about the potential for hazardous or contaminated materials existing at the site unless specifically required to do so as part of the Company's proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geoenvironmental or site contamination assessments. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Martens for information relating to such matters.

Responsibility

Geotechnical reporting relies on interpretation of factual information based on professional judgment and opinion and has an inherent level of uncertainty attached to it and is typically far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded.

To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Martens to other parties but are included to identify where Martens' responsibilities begin and end. Their use is intended to help all parties involved to recognize their individual responsibilities. Read all documents from Martens closely and do not hesitate to ask any questions you may have.

Site Inspections

Martens will always be pleased to provide engineering inspection services for aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site. Martens is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

Soil Data

Explanation of Terms (1 of 3)

Definitions

In engineering terms, soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material does not exhibit any visible rock properties and can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726 and the S.A.A Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

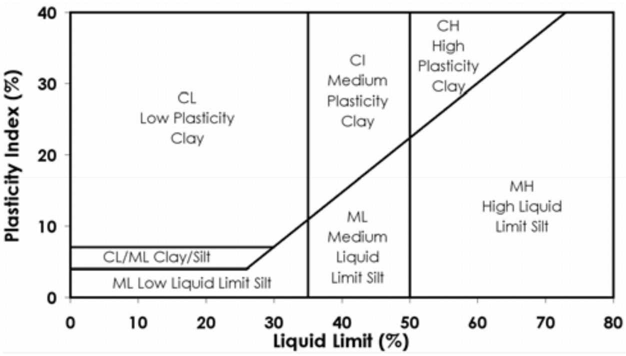
Particle Size

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay). Unless otherwise stated, particle size is described in accordance with the following table.

Division	Subdivision	Size
BOULDERS		>200 mm
COBBLES		60 to 200 mm
GRAVEL	Coarse	20 to 60 mm
	Medium	6 to 20 mm
	Fine	2 to 6 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties

Plasticity properties can be assessed either in the field by tactile properties, or by laboratory procedures.



Moisture Condition

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and damp and is darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

Term	C_u (kPa)	Approx SPT "N"	Field Guide
Very Soft	<12	2	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	2 to 4	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	4 – 8	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	8 – 15	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	15 – 30	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	> 200	> 30	The surface of the soil can be marked only with the thumbnail.
Friable	-		Crumbles or powders when scraped by thumbnail

Density of Granular Soils

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration test (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	%	SPT 'N' Value (blows/300mm)	CPT Cone Value (q_c Mpa)
Very loose	< 15	< 5	< 2
Loose	15 – 35	5 - 10	2 -5
Medium dense	35 – 65	10 - 30	5 - 15
Dense	65- 85	30 - 50	15 - 25
Very dense	> 85	> 50	> 25

Minor Components

Minor components in soils may be present and readily detectable, but have little bearing on general geotechnical classification. Terms include:

Term	Assessment	Proportion of Minor component In:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: < 5 % Fine grained soils: < 15 %
With some	Presence easily detectable by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 – 12 % Fine grained soils: 15 – 30 %

Soil Agricultural Classification Scheme

In some situations, such as where soils are to be used for effluent disposal purposes, soils are often more appropriately classified in terms of traditional agricultural classification schemes. Where a Martens report provides agricultural classifications, these are undertaken in accordance with descriptions by Northcote, K.H. (1979) *The factual key for the recognition of Australian Soils*, Rellim Technical Publications, NSW, p 26 - 28.

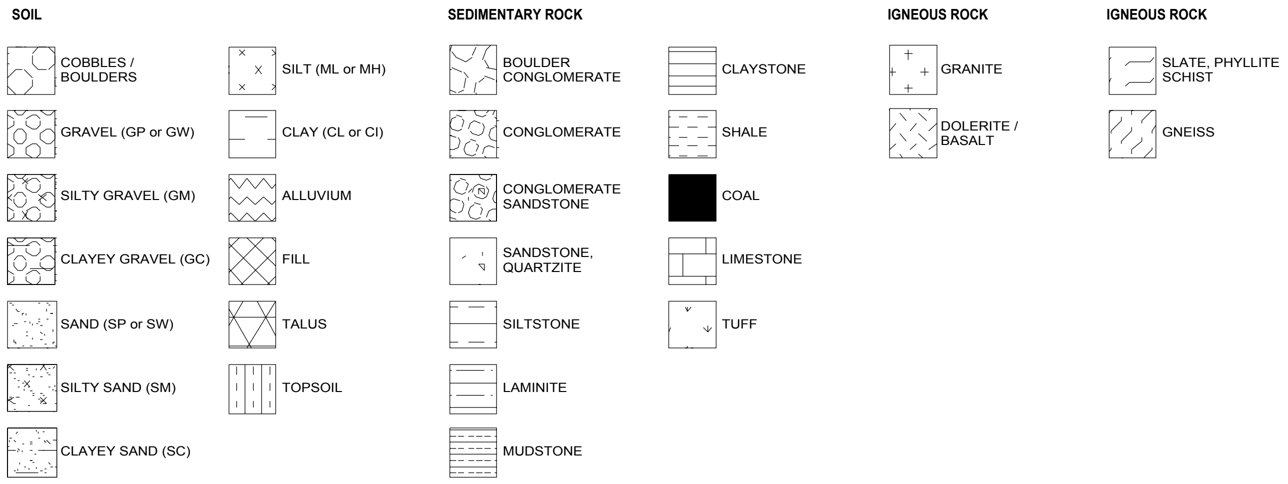
Symbol	Field Texture Grade	Behaviour of moist bolus	Ribbon length	Clay content (%)
S	Sand	Coherence nil to very slight; cannot be moulded; single grains adhere to fingers	0 mm	< 5
LS	Loamy sand	Slight coherence; discolours fingers with dark organic stain	6.35 mm	5
CLS	Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain	6.35mm - 1.3cm	5 - 10
SL	Sandy loam	Bolus just coherent but very sandy to touch; dominant sand grains are of medium size and are readily visible	1.3 - 2.5	10 - 15
FSL	Fine sandy loam	Bolus coherent; fine sand can be felt and heard	1.3 - 2.5	10 - 20
SCL$^-$	Light sandy clay loam	Bolus strongly coherent but sandy to touch, sand grains dominantly medium size and easily visible	2.0	15 - 20
L	Loam	Bolus coherent and rather spongy; smooth feel when manipulated but no obvious sandiness or silkiness; may be somewhat greasy to the touch if much organic matter present	2.5	25
Lfsy	Loam, fine sandy	Bolus coherent and slightly spongy; fine sand can be felt and heard when manipulated	2.5	25
SiL	Silt loam	Coherent bolus, very smooth to silky when manipulated	2.5	25 + > 25 silt
SCL	Sandy clay loam	Strongly coherent bolus sandy to touch; medium size sand grains visible in a finer matrix	2.5 - 3.8	20 - 30
CL	Clay loam	Coherent plastic bolus; smooth to manipulate	3.8 - 5.0	30 - 35
SiCL	Silty clay loam	Coherent smooth bolus; plastic and silky to touch	3.8 - 5.0	30- 35 + > 25 silt
FSCL	Fine sandy clay loam	Coherent bolus; fine sand can be felt and heard	3.8 - 5.0	30 - 35
SC	Sandy clay	Plastic bolus; fine to medium sized sands can be seen, felt or heard in a clayey matrix	5.0 - 7.5	35 - 40
SiC	Silty clay	Plastic bolus; smooth and silky	5.0 - 7.5	35 - 40 + > 25 silt
LC	Light clay	Plastic bolus; smooth to touch; slight resistance to shearing	5.0 - 7.5	35 - 40
LMC	Light medium clay	Plastic bolus; smooth to touch, slightly greater resistance to shearing than LC	7.5	40 - 45
MC	Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture, some resistance to shearing	> 7.5	45 - 55
HC	Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shearing	> 7.5	> 50

Soil Data

Explanation of Terms (3 of 3)

martens consulting engineers

Symbols for Soil and Rock



Unified Soil Classification Scheme (USCS)

<table>
<tr><td colspan="8">FIELD IDENTIFICATION PROCEDURES
(Excluding particles larger than 63 mm and basing fractions on estimated mass)</td><td>USCS</td><td>Primary Name</td></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS
More than 50 % of material less than 63 mm is larger than 0.075 mm</td><td rowspan="16">(A 0.075 mm particle is about the smallest particle visible to the naked eye)</td><td rowspan="4">GRAVELS
More than half of coarse fraction is larger than 2.0 mm.</td><td colspan="2" rowspan="2">CLEAN GRAVELS (Little or no fines)</td><td colspan="3">Wide range in grain size and substantial amounts of all intermediate particle sizes.</td><td>GW</td><td>Gravel</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with more intermediate sizes missing</td><td>GP</td><td>Gravel</td></tr>
<tr><td colspan="2" rowspan="2">GRAVELS WITH FINES (Appreciable amount of fines)</td><td colspan="3">Non-plastic fines (for identification procedures see ML below)</td><td>GM</td><td>Silty Gravel</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>GC</td><td>Clayey Gravel</td></tr>
<tr><td rowspan="4">SANDS
More than half of coarse fraction is smaller than 2.0 mm</td><td colspan="2" rowspan="2">CLEAN SANDS (Little or no fines)</td><td colspan="3">Wide range in grain sizes and substantial amounts of intermediate sizes missing.</td><td>SW</td><td>Sand</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>SP</td><td>Sand</td></tr>
<tr><td colspan="2" rowspan="2">SANDS WITH FINES (Appreciable amount of fines)</td><td colspan="3">Non-plastic fines (for identification procedures see ML below)</td><td>SM</td><td>Silty Sand</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>SC</td><td>Clayey Sand</td></tr>
<tr><td rowspan="8">FINE GRAINED SOILS
More than 50 % of material less than 63 mm is smaller than 0.075 mm</td><td colspan="8">IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM</td></tr>
<tr><td colspan="2">DRY STRENGTH (Crushing Characteristics)</td><td colspan="2">DILATANCY</td><td>TOUGHNESS</td><td>DESCRIPTION</td><td>USCS</td><td>Primary Name</td></tr>
<tr><td colspan="2">None to Low</td><td colspan="2">Quick to Slow</td><td>None</td><td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity</td><td>ML</td><td>Silt</td></tr>
<tr><td colspan="2">Medium to High</td><td colspan="2">None</td><td>Medium</td><td>Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays</td><td>CL</td><td>Clay</td></tr>
<tr><td colspan="2">Low to Medium</td><td colspan="2">Slow to Very Slow</td><td>Low</td><td>Organic slits and organic silty clays of low plasticity</td><td>OL</td><td>Organic Silt</td></tr>
<tr><td colspan="2">Low to Medium</td><td colspan="2">Slow to Very Slow</td><td>Low to Medium</td><td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td><td>MH</td><td>Silt</td></tr>
<tr><td colspan="2">High</td><td colspan="2">None</td><td>High</td><td>Inorganic clays of high plasticity, fat clays</td><td>CH</td><td>Clay</td></tr>
<tr><td colspan="2">Medium to High</td><td colspan="2">None</td><td>Low to Medium</td><td>Organic clays of medium to high plasticity</td><td>OH</td><td>Organic Silt</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td colspan="6">Readily identified by colour, odour, spongy feel and frequently by fibrous texture</td><td>Pt</td><td>Peat</td></tr>
<tr><td colspan="10">Low Plasticity – Liquid Limit W_L < 35 % Medium Plasticity – Liquid limit W_L 35 to 60 % High Plasticity - Liquid limit W_L > 60 %</td></tr>
</table>

Rock Data

Explanation of Terms (1 of 2)

Definitions

Descriptive terms used for Rock by Martens are given below and include rock substance, rock defects and rock mass.

Rock Substance	In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot, unless extremely weathered, be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Rock substance is effectively homogeneous and may be isotropic or anisotropic.
Rock Defect	Discontinuity or break in the continuity of a substance or substances.
Rock Mass	Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

Degree of Weathering

Rock weathering is defined as the degree in rock structure and grain property decline and can be readily determined in the field.

Term	Symbol	Definition
Residual Soil	Rs	Soil derived from the weathering of rock. The mass structure and substance fabric are no longer evident. There is a large change in volume but the soil has not been significantly transported.
Extremely weathered	EW	Rock substance affected by weathering to the extent that the rock exhibits soil properties - ie. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decrease compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original rock substance is no longer recognisable.
Moderately weathered	MW	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly weathered	SW	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance usually by limonite has taken place. The colour and texture of the fresh rock is recognisable.
Fresh	Fr	Rock substance unaffected by weathering

Rock Strength

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance is the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	Is (50) MPa	Field Guide	Symbol
Extremely weak	< 0.03	Easily remoulded by hand to a material with soil properties.	EW
Very weak	0.03 - 0.1	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VW
Weak	0.1 - 0.3	A piece of core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	W
Medium strong	0.3 - 1	A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	MS
Strong	1 - 3	A piece of core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife.	S
Very Strong	3 - 10	A piece of core 150mm long x 50mm diameter may be broken readily with hand held hammer. Cannot be scratched with pen knife.	VS
Extremely strong	> 10	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	ES

Rock Data

Explanation of Terms (2 of 2)

Degree of Fracturing

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but excludes fractures such as drilling breaks.

Term	Description
Fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than core diameter.
Highly fractured	Core lengths are generally less than 20mm-40mm with occasional fragments.
Fractured	Core lengths are mainly 30mm-100mm with occasional shorter and longer sections.
Slightly fractured	Core lengths are generally 300mm-1000mm with occasional longer sections and occasional sections of 100mm-300mm.
Unbroken	The core does not contain any fractures.

Rock Core Recovery

TCR = Total Core Recovery

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100\%$$

SCR = Solid Core Recovery

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100\%$$

RQD = Rock Quality Designation

$$= \frac{\sum \text{Axial lengths of core} > 100\,\text{mm long}}{\text{Length of core run}} \times 100\%$$

Rock Strength Tests

▼	Point load strength Index (Is50) - axial test (MPa)
▶	Point load strength Index (Is50) - diametrall test (MPa)
●	Unconfined compressive strength (UCS) (MPa)

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)

BP	Bedding plane parting
X	Foliation
L	Cleavage
JT	Joint
F	Fracture
SZ	Sheared zone (Fault)
CS	Crushed seam
DS	Decomposed seam
IS	Infilled seam
V	Vein

Coating or Filling

Cn	Clean
Sn	Stain
Ct	Coating
Fe	Iron Oxide

Roughness

Po	Polished
Ro	Rough
Sl	Slickensided
Sm	Smooth
Vr	Very rough

Planarity

Cu	Curved
Ir	Irregular
Pl	Planar
St	Stepped
Un	Undulating

Inclination

The inclination of defects are measured from perpendicular to the core axis.

Test Methods

Explanation of Terms (1 of 2)

Sampling

Sampling is carried out during drilling or excavation to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples may be taken by pushing a thin-walled sample tube into the soils and withdrawing a soil sample in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils. Other sampling methods may be used. Details of the type and method of sampling are given in the report.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Hand Excavation – in some situations, excavation using hand tools such as mattock and spade may be required due to limited site access or shallow soil profiles.

Hand Auger - the hole is advanced by pushing and rotating either a sand or clay auger generally 75-100mm in diameter into the ground. The depth of penetration is usually limited to the length of the auger pole, however extender pieces can be added to lengthen this.

Test Pits - these are excavated with a backhoe or a tracked excavator, allowing close examination of the *in-situ* soils if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) - the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling - the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength *etc.* is only marginally affected.

Continuous Spiral Flight Augers - the hole is advanced using 90 - 115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or *in-situ* testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface or, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling - similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling - a continuous core sample is obtained using a diamond tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in AS 1289 Methods of Testing Soils for Engineering Purposes - Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

(i) In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7 blows:

as 4, 6, 7
N = 13
(ii) In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm

as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

CONE PENETROMETER TESTING AND INTERPRETATION

Cone penetrometer testing (sometimes referred to as Dutch Cone - abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in AS 1289 - Test F4.1.

In the test, a 35mm diameter rod with a cone tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on separate 130mm long sleeve, immediately behind the cone. Tranducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records.

The information provided on the charts comprises:
Cone resistance - the actual end bearing force divided by the cross sectional area of the cone - expressed in MPA.
Sleeve friction - the frictional force of the sleeve divided by the surface area - expressed in kPa.
Friction ratio - the ratio of sleeve friction to cone resistance - expressed in percent.

There are two scales available for measurement of cone resistance. The lower (A) scale (0 - 5 Mpa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main (B) scale (0 - 50 Mpa) is less sensitive and is shown as a full line.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%-2% are commonly encountered in sands and very soft clays rising to 4%-10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:

q_c (Mpa) = (0.4 to 0.6) N (blows/300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:

q_c = (12 to 18) c_u

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes *etc.* This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

DYNAMIC CONE (HAND) PENETROMETERS
Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods. Two relatively similar tests are used.

Perth sand penetrometer - a 16 mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS 1289 - Test F 3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
Cone penetrometer (sometimes known as the Scala Penetrometer) - a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289 - Test F 3.2). The test was developed initially for pavement sub-grade investigations, with correlations of the test results with California bearing ratio published by various Road Authorities.

LABORATORY TESTING
Laboratory testing is carried out in accordance with AS 1289 Methods of Testing Soil for Engineering Purposes. Details of the test procedure used are given on the individual report forms.

TEST PIT / BORE LOGS
The test pit / bore log(s) presented herein are an engineering and/or geological interpretation of the sub-surface conditions and their reliability will depend to some extent on frequency of sampling and the method of excavation / drilling. Ideally, continuous undisturbed sampling or excavation / core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than ‘straight line’ variation between the boreholes.

GROUND WATER
Where ground water levels are measured in boreholes, there are several potential problems:

In low permeability soils, ground water although present, may enter the hole slowly, or perhaps not at all during the time it is left open.
A localised perched water table may lead to an erroneous indication of the true water table.
Water table levels will vary from time to time with seasons or recent prior weather changes. They may not be the same at the time of construction as are indicated in the report.
The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.