

## Appendix E

# Subregional Groundwater Model

## Appendix E Subregional Groundwater Model

Malbec Properties Pty Ltd



Sub-regional Groundwater Model:

Proposed Residential Subdivision  
South West Rocks, NSW

P0802023JR04\_v2  
July 2010

ENVIRONMENTAL



WATER



WASTEWATER



GEOTECHNICAL



CIVIL



PROJECT  
MANAGEMENT



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# 1 Overview

## 1.1 Background and Scope

This report documents the formation and results of a sub-regional numerical groundwater model. The model was developed to assess groundwater related impacts associated with a proposed residential sub-division at Belle O'Connor Street, South West Rocks, NSW. The model was developed in response to requests for further information that were outlined by the NSW Department of Planning (DoP) following GHD's review of Martens and Associates (2009) Engineering Services and Stormwater Management Report (report # P0802023JR02\_v7).

## 1.2 Objectives

Primary objectives of this investigation are to:

1. Assess the existing groundwater regime.
2. Determine site aquifer properties.
3. Develop calibrated finite-difference groundwater flow models of steady-state and transient groundwater levels for both existing and developed-conditions.
4. Assess changes (if any) to groundwater levels which arise due to the proposed-development.

## 1.3 Previous Investigations

This investigation builds on the hydrogeological content within following:

- o Martens and Associates (P0802023JR02\_v7, March 2009), *Engineering Services and Stormwater Management Report*.
- o Douglas Partners (October 2007), *Report on Hydrogeological Assessment: Proposed Residential Subdivision off Phillip Drive, South West Rocks*.

## **2 Site Description**

### **2.1 Location and Setting**

The site is located at Belle O'Connor Street, South West Rocks, NSW; is shown on the site plan in Attachment A; and has an area of approximately 25.94 ha.

The site is predominantly undeveloped and occupied by heath and grassland. Two residential dwellings are shown on site aerial photography.

### **2.2 Geology**

Site geology is summarised in Section 3.2 and detailed in borehole logs which are provided within Attachment B. Refer to Attachment A for borehole locations.

### **2.3 Drainage**

The site has low grades of approximately 0.5 – 1% which generally fall to the north. A ridge exists in the centre of the site and is orientated south to north.

An existing man-made drainage channel has been excavated on the western portion of the site. This channel is approximately 0.5 m deep x 2 m wide and drains to a creek which exists approximately 100 m north of the proposed area of site development.

The creek is approximately 5 m wide and flows towards the east into Saltwater Lagoon. Flow from Saltwater Lagoon exits to Saltwater Creek which flows to the ocean.

### **2.4 Rainfall**

#### *2.4.1 Overview*

Mean monthly/annual rainfall at Smoky Cape Lighthouse BOM station, South West Rocks, NSW (approximately 4 km from site) is summarised in Table 1.

Table 1: Mean monthly/annual rainfall at Smoky Cape Lighthouse BOM station, South West Rocks, NSW.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rain (mm)	147.8	169.5	183.6	169.9	135.6	131.7	78.5	81.1	56.2	92.4	113.1	119.2	1486.8

#### 2.4.2 Site Data

For the purpose of examining data trends in continual groundwater monitoring data (23.02.2010 to 24.05.2010 inclusive) obtained from site groundwater monitoring bores (GMB's) and providing a basis for estimation of recharge for the groundwater model, rainfall was derived from two sources: namely:

1. Smoky Cape Lighthouse BOM Station – daily observations were used to provide an estimate of site rainfall between 23.02.2010 and 25.03.2010.
2. Site Rain Gauge – an on-site rain gauge was used to provide an estimate of site rainfall between 26.03.2010 and 24.05.2010. The gauge was set to measure rainfall at a 15 minute frequency (same frequency as data loggers within site GMB's). The rain gauge was not utilised throughout the length of the continual groundwater monitoring period due to availability.

An analysis was undertaken to compare daily rain observed by the above two sources over the same time period (26.03.2010 to 24.05.2010). This was undertaken to assess the degree of difference between the two locations as it was intended to use rain observations from Location 1 to estimate recharge for the first third of the transient calibration model.

Total rain observed at Location 1 was 152 mm with total rain over the same time period being 97 mm at Location 2. This represents a 36% reduction in rainfall and is thought to be attributable due to a localised rain shadow affect. Review of topography suggests that there would be a rain shadow affect for rain clouds propelled by all winds except those from the west or north.

Rain data at Location 1 (x axis) and 2 (y axis) is plotted in Figure 1. The plot indicates that there is a correlation between observations from the two locations; however, the plot also shows rainfall being markedly different between each location for some days. The plots shows that Location 1 normally receives more rain than Location 2, however there are exceptions to this.

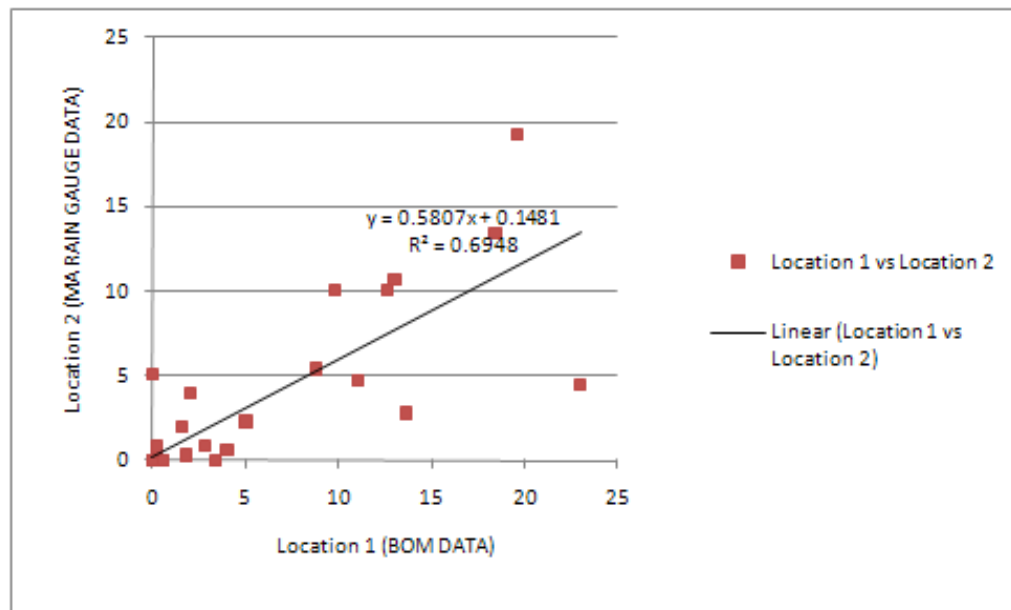


Figure 1: Rain data (Location 1 vs Location 2).

#### 2.4.3 Residual Rain Analysis

Manual and continual groundwater level measurements taken to date are summarised in Table 3 within 3.6.

In light of the annual residual rain mass (Figure 2), the time of the Douglas Partners groundwater level measurements coincides with a period of low rainfall and therefore these measurements are considered to be unrepresentative of typical levels.

In light of the monthly residual rain mass (Figure 3), the time of the Martens and Associates groundwater level measurements coincides with near monthly average rainfall for February and March. Lower than average rainfall occurred towards the end of the monitoring period for the months of April and May. This suggests that observed groundwater levels are likely to be representative for February and March (high rainfall months) and lower than usual for the months of April and May. The Martens and Associates levels are considered as the preferred benchmark for assessment and model calibration purposes given the increased frequency of observations and the observed rainfall at/near the time of observations.

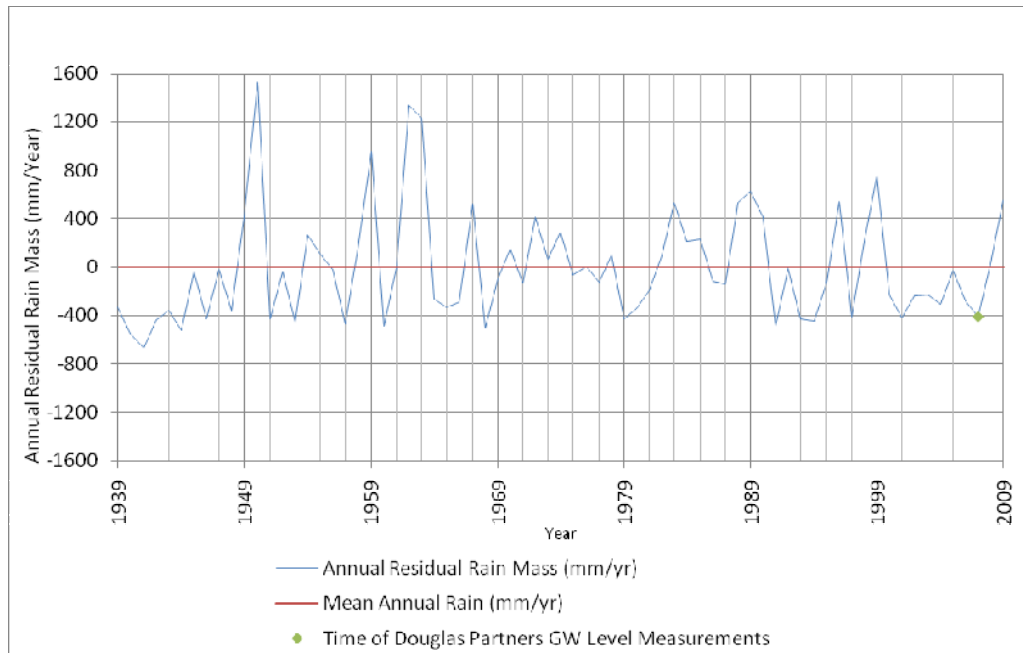


Figure 2: Annual residual rain mass (observed annual rain – mean annual rain) with plot identifying time of Douglas Partners groundwater level measurements.

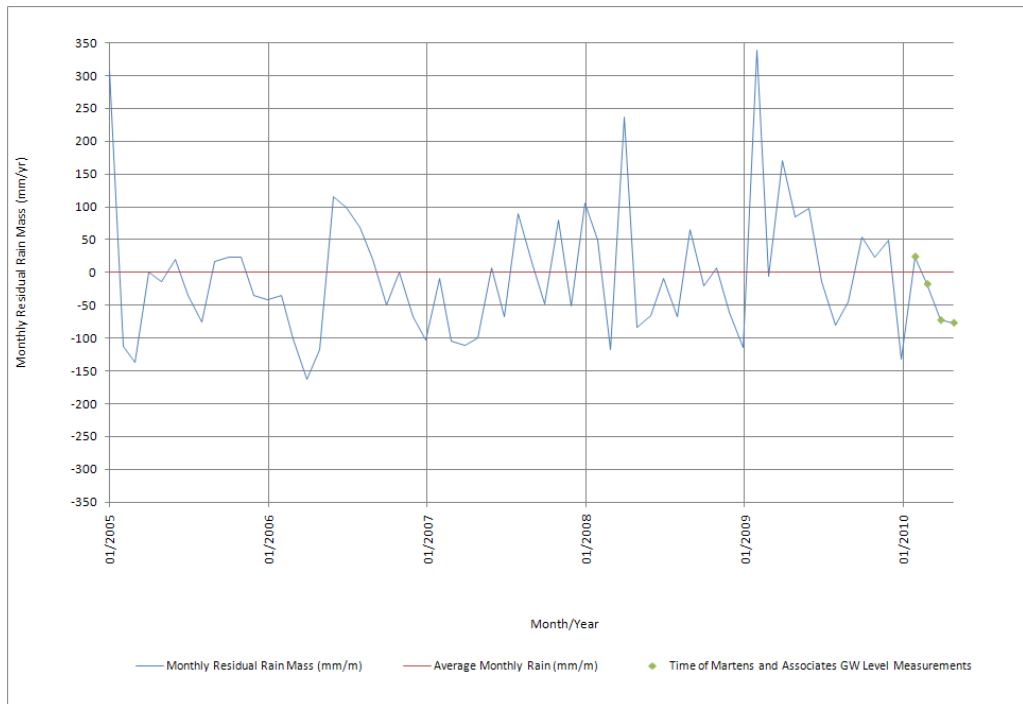


Figure 3: Monthly residual rain mass (observed monthly rain – mean monthly rain) with markers identifying time of Martens and Associates groundwater level measurements (22.02.2010, 26.03.2010 and 24.05.2010). It is noted that the dates of 23.02.2010 and 24.05.2010 mark the start and end of the continuous monitoring period (GMB's 201, 205, 209, 210 and 3).

## 3 Hydrogeology

### 3.1 Resource Use

The Macleay Alluvium and Coastal Sand's groundwater resource occupies an area of 492 km<sup>2</sup>, has an average salinity of 100 mg/L, annual water use of 775 ML and is shallow with a general depth to the top of the aquifer of 3 m (Australian Natural Resource Atlas, 2009).

### 3.2 Water Bearing Strata

Based on review of site borehole data, site inspection observations, aerial photographs, topography, 1:250,000 geological mapping (Geological Survey of NSW, 1971) and 1:25,000 lower Macleay quaternary geological mapping (Geological Survey of NSW, 2005), the aquifer in the vicinity of the site consists of 2 layers, namely:

1. Quaternary sand – comprised of fine to medium grained quaternary sand that extends from natural surface level to depths of approximately 1.5 – 3.5 m. This layer occupies in-filled areas either side of the ridge that extends through the site.
2. Residual/Quaternary clay - comprised of clay and exists below the sand layer or below natural surface level (in areas where there is no sand layer). This clay layer is comprised of either residual clays or quaternary clays in-filled either side of the site's ridge (beneath the sand deposits). This layer has variable depths and is considered to range in thickness from 1 to 10 m with the bulk of the layer being of the order of 10 m thick.

A third geological unit comprised of quartz coastal sand comprises the depth of the aquifer in the coastal dune area to the north of the site. This area extends from the coast to approximately 600 m inland based on quaternary geological mapping (Geological Survey of NSW, 2005).

Bedrock comprised of New England granites and Permian Basins underlies the clay layer and the quartz coastal sand unit and therefore forms the aquifers base.

### 3.3 Hydraulic Conductivity (K)

K testing to date is summarised in Table 2. Testing comprised rising head tests within site Groundwater Monitoring Bores (GMB's). K estimates vary considerably; however, this is expected giving the site's hydrogeological setting. K estimates compare well between bores in

cases where estimates are provided by two sources and also compare well with typical ranges cited in the literature.

Results indicate that the sand layer ranges from low to moderate permeability in the area of the site. K estimates associated with the clay layer are indicative of low permeability. No spatial trends are observed within the data. Refer to the site plan for the location of GMB's numbered 2##. Refer to Douglas Partners (October, 2007) for the location of GMB's numbered #.

Table 2: Summary of aquifer K testing results.

GMB	Test Type/Consultant	Test Medium	Estimated K (m/d)	Source
202		Sand	2.31	
205		Sand	1.97	
208		Sand	1.17	
209	Rising Head/Martens and Associates	Sand	0.04	This report
210		Sand	0.39	
3		Clay/siltstone	0.002	
4		Claystone	0.003	
201		Clay	0.05	
2 <sup>4</sup>		Sand	25.92	
5		Sand	0.08	
6		Sand <sup>1</sup>	15.12	
8 <sup>4</sup>		Sand <sup>1</sup>	21.6	
9 <sup>4</sup>	Rising Head/Douglas Partners	Silty Sand <sup>1</sup>	1.21	Douglas Partners (2007)
10 <sup>4</sup>		Sand	25.92	
1 <sup>4</sup>		Interbedded indurated sand/silty sand	0.86	
3		Clay/claystone	0.0009	
4		Claystone	0.002	
Geometric mean			1.84	
Median		Sand	1.59	
Mean			8.05	
Geometric mean			0.004	
Median		Clay/claystone/siltstone	0.002	
Mean			0.012	

Notes: <sup>1</sup> Reported value equals the average of two test results. <sup>2</sup> Martens and Associates results taken on 21/02/2010 and 22/02/2010. <sup>3</sup> Douglas Partners results taken between July and August, 2007. <sup>4</sup> Bore located north of creek which traverses west to east north of proposed-development area.

### **3.4 Recharge**

The Australian Natural Resource Atlas (2009) indicates that recharge as a proportion of annual rainfall is approximately 3% for the alluvial deposits, 2% for the estuarine flats and 30% for coastal dunes. These values are within the expected range for the site given a shallow groundwater regime which is likely to be strongly influenced by evapotranspiration (ET). No further background research with regards to recharge was undertaken as this parameter is calibrated in the sub-regional groundwater model(s).

### **3.5 Storage**

Both aquifer layers are considered to be predominantly unconfined although semi-confined conditions may occur in isolated areas.

No attempt has been made to estimate Specific Yield ( $S_y$ ) based on pump test data. Based on cited representative  $S_y$  values for fine sand/silt and clay, the  $S_y$  is likely to be of the order of 0.1 and 0.025 for the sand and clay layers respectively (Bair and Lahm, 2006). The expected lower and upper bounds for  $S_y$  are between 0.075 and 0.2 for the sand layer and between 0.01 and 0.05 for the clay layer.

### **3.6 Water Level Measurements**

#### *3.6.1 Manual Groundwater Measurements*

Manual groundwater level measurements taken to date are summarised in Table 3.

Table 3: Manual groundwater level measurements.

Groundwater Levels Recorded by Martens and Associates						
GMB ID	GMB Surface Level	22.02.2010	26.03.2010	24.05.2010	24.07.2007	
		mAHD	mAHD	mAHD	mAHD	
201	5.4	3.45	3.93	3.22	-	
205	3.45	2.75	3.21	2.55	-	
209	3.85	3.23	3.21	3.06	-	
210	3.59	3.32	3.17	2.99	-	
3	3.35	2.17	2.95	2.61	-	
202	3.6	2.57	2.95	2.50	-	
208	3.59	2.94	-	-	-	
Groundwater Levels Recorded by Douglas Partners						
3	3.35	-	-	-	0.97	
4	5.14	-	-	-	2.71	
5	4.35	-	-	-	3.65	
6	3.25	-	-	-	2.17	
10	3.12	-	-	-	2.09	
CPTu103	3.10	-	-	-	2.30	
CPTu105	3.00	-	-	-	2.30	
CPTu106	3.40	-	-	-	2.70	

Notes: <sup>1</sup>CPTu### denotes a groundwater level determined based on piezo cone penetration test result.

### 3.6.2 Continuous Groundwater Measurements

Groundwater levels were continually monitored (15 minute frequency) within GMB's 201, 3, 205, 209, 210 and at an upstream and downstream location within the creek which transverses west to east through the site using data loggers. Barometric pressure was recorded at the same frequency to allow atmospheric compensation of logger data. A plot of groundwater levels within monitored GMB's is provided in Figure 4 with a statistical summary of continual groundwater levels provided in Table 4.

Data indicates that groundwater exists at shallow depths beneath the site (typically 0.35 to 1.70 mBGL). Groundwater reaches ground level at some locations during high rainfall. Groundwater appears to be controlled by direct rainfall and ET.

Residual analysis (Figure 5) indicates that site GMB's respond in a similar manner to stresses with the exception of GMB 3 whose response is very different. This difference is not well understood but may be attributable to either local lower permeability material, due to clogging of the well screen; or due to installation (this well was not installed by Martens so details are limited). It is noted that GMB 3 was installed in 2007 whilst the other GMB's were installed in 2010 and therefore the bores performance may have deteriorated. GMB 201 is also screened within clay but exhibits a hydrograph similar to the other bores and markedly different to GMB 3. Based on the above groundwater level data obtained from within GMB 3 was excluded from the model calibration process.

Table 4: Statistical summary of recorded water levels (mAHD) for monitoring period (23/02/2010 to 24/05/2010).

	201	3	205	209	210	CK US	CK DS
Minimum	3.22	2.61	2.53	3.03	2.93	0.93	0.96
10th%ile	3.30	2.64	2.58	3.07	2.99	0.72	0.75
25th%ile	3.45	2.75	2.70	3.17	3.09	0.82	0.85
Median	3.61	2.80	2.83	3.21	3.19	0.88	0.92
Mean	3.67	2.81	2.88	3.21	3.25	0.90	0.93
75th%ile	3.87	2.93	3.04	3.26	3.42	0.96	1.00
90th%ile	4.11	2.95	3.19	3.34	3.63	1.06	1.09
Maximum	4.41	3.15	3.43	3.71	3.70	1.37	1.41
Range	1.19	0.55	0.90	0.68	0.76	0.44	0.45
Minimum Depth to GW	0.99	0.20	0.02	0.14	-0.11	-	-
Ground Level	5.40	3.35	3.45	3.85	3.59	-	-

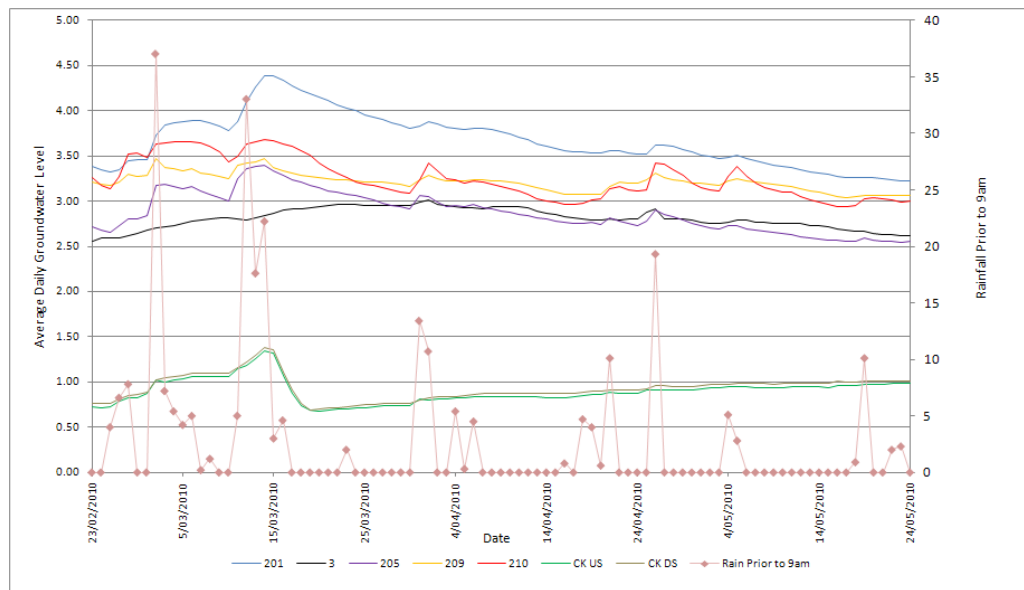


Figure 4: GMB hydrographs and observed daily rainfall prior to 9am (rain data from 23.02.2010 to 25.03.2010 based on daily BOM observations at Smoky Cape Lighthouse, rain data from 26.03.2010 to 24.05.2010 based on site rain gauge data).

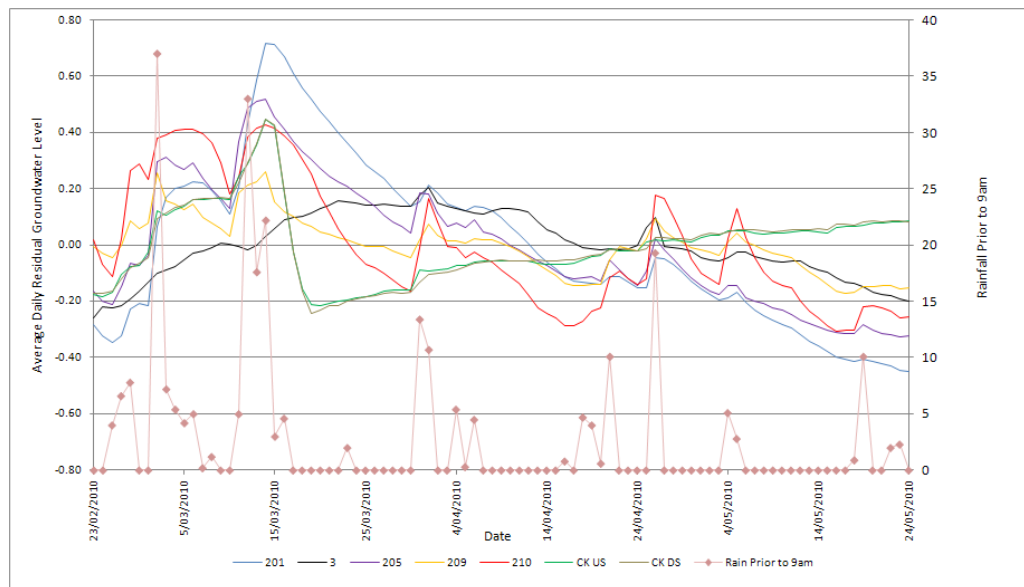


Figure 5: GMB residual groundwater level plot (observed average daily level – average level for whole of monitoring period).

### 3.6.3 Continuous Creek Measurements

Continual logging of creek water levels indicates that the creek drains to a background level of approximately 0.68 mAHD with a mean level of approximately 0.9 mAHD. No obvious tidal signals exist in the data. It is noted that levels for the downstream creek location are slightly higher (~0.02 m) than those for the upstream creek location. This is considered to be attributable to survey error – the level at the top of a

stake at each location was measured by a registered surveyor to provide a basis for level correction.

## 4 Model Development

### 4.1 Conceptual Model

The conceptual model is based on information detailed in Sections 2 to 3 and is summarised as a schematic section below (Figure 6).

Inflow to the system consists of infiltrated rainfall resulting in recharge. System outflow consists of ET and discharge to surface water features (drains).

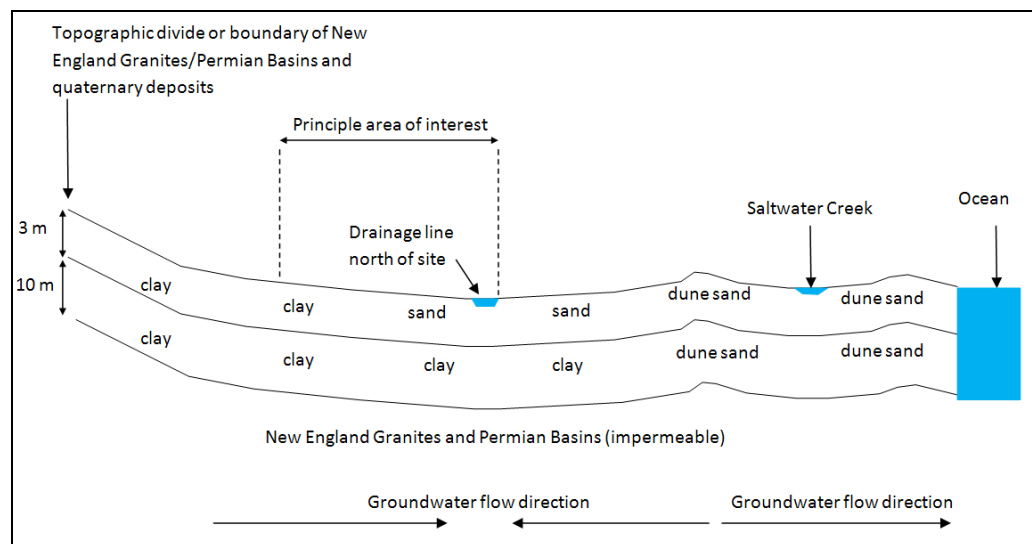


Figure 6: Conceptual model section schematic (south - north) through aquifer.

### 4.2 Model Discretisation

Model discretisation is summarised in Table 5. The model's exterior grid along with the active domain boundary and other features is shown in Attachment A. The rationale for the active domain boundaries is summarised in Table 6. It is noted that this active domain boundary was developed in consultation with GHD (Stuart Grey). It is also noted that a small grid size of 20 m x 20 m was applied in order to respect cell aspect ratios since the model's top layer is only 3 m thick (variation between the cell length, width and depth should typically not exceed tenfold).

Final models employ a grid with increased resolution over the site (cells of 5 x 5 m) to allow proposed stormwater swales to be modelled accurately.

It is noted that the southern active domain boundary required relocation further to the north to permit convergence in transient simulations. This is documented in further detail within Marten and Associates letter (P0802023JC13V1, 13.05.2010) to GHD and was accepted by GHD.

Table 5: Model grid discretisation

Origin easting, northing	504300, 6580200
Upper right easting, northing	506800, 6583200
Grid cell size	20 m x 20 m (uniform) initially with final models employing increased grid resolution over site
Layers	2
Columns	125
Rows	150
Model dimensions (active + inactive cells)	2.5 km x 3.0 km

Table 6: Active model domain rationale.

Boundary	Justification
Northern	Assigned based on constant head used to represent the ocean.
Eastern	Assigned based on interface between quaternary deposits and New England Granites and Permian Basins.
Southern	Assigned as per eastern boundary with certain portions also assigned based on a groundwater divide (at a topographic divide).
Western	Pathline boundary (i.e normal to flow contours).

### 4.3 Layer Topography

Ground surface (Figure 7) was developed based on interpolation of x,y,z points from 0.5 m contours which were provided by the client. Interpolation was completed within Surfer to produce a 20 m x 20 m gridfile. This gridfile was then imported to the groundwater model.

In general terms layer terrain is as follows:

- The bottom of Layer 1 is a reproduction of the surface terrain at a level 3 m lower.

- The bottom of Layer 2 is a reproduction of the surface terrain at a level 10 m lower.

The exception to the above occurs in areas where layer properties are identical for both layers 1 and 2. In these areas the bottom elevation of layer 1 was decreased to increase layer thickness and increase model stability by reducing the potential for dry cells. The assumed bedrock elevation (bottom of layer 2) was also modified to be flat in the areas north of the creek that traverses west-east through the site. The bottom of Layer 1 was set at -0.5 mAHD north of the creek. These layers are considered adequate to reflect site geology.

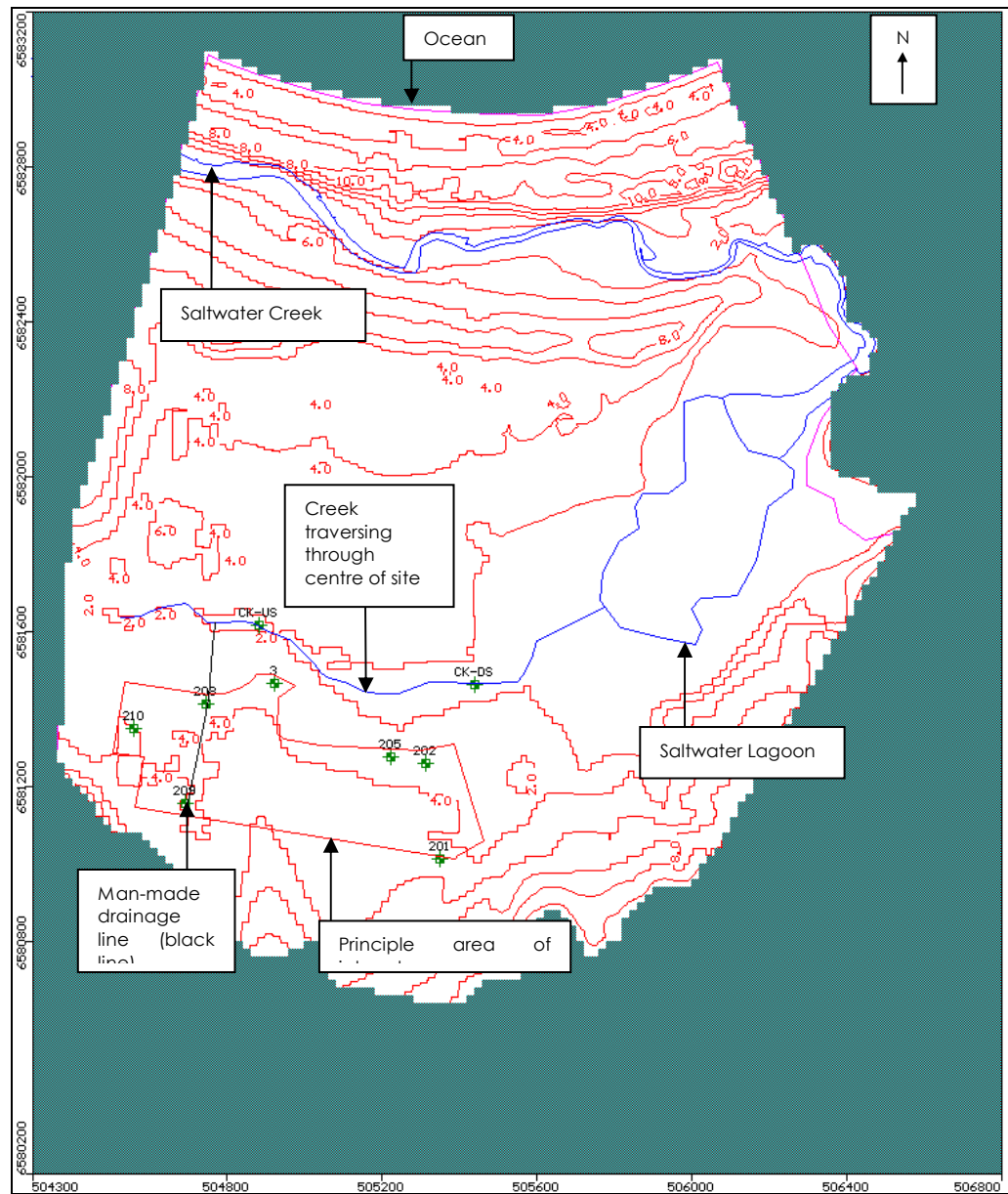


Figure 7: Model grid showing surface contours, inactive areas of the model (green), surface water features and the principle area of interest. Refer to model coordinates (which are in m) for scaling purposes if required.

**4.4 Boundary Conditions**

With respect to Figure 8 boundary conditions for existing-development steady-state and transient models were applied as follows:

## Drain

A DRAIN was applied to simulate the following:

- Central man-made drainage line which runs south-north through the site (assumed width – 2 m). Denoted by DRAIN reach (silver line) between B and C in Figure 8.
- Creek which runs west-east north of the proposed-development site (assumed width – 5 m). Denoted by DRAIN reach (silver line) between A and D in Figure 8.
- Saltwater Lagoon (whole cell coverage). Denoted by silver polygon near D in Figure 8.
- Saltwater Creek (assumed width – 10 m). Denoted by DRAIN reach (silver line) between G and E in Figure 8.

With the exception of the creek which traverses west-east through the site, DRAIN conductance values were assigned based on a DRAIN K value of 0.775 m/d, drain bed thickness of 0.5 m and were calculated based on the area that the surface water body occupied within each cell multiplied by the DRAIN K value divided by the DRAIN thickness. The DRAIN conductance of the creek which traverses west-east through the site was assigned based on a DRAIN K value of 0.31 m/d and bed thickness of 0.5 m. Conductance was determined through calibration.

With the exception of the site drain, the level for the DRAINS was set at 0.68 mAHD (background level of lagoon based on diver monitoring). The site man-made drain was assigned a drain elevation of 0.5 m below the top of the cell.

It is noted that DRAIN reaches visible in Figure 8 that are not mentioned above are associated with developed-condition modelling and were used to represent proposed stormwater drainage swales.

## Ocean Constant Head Boundary

A constant head of 0 mAHD was applied at the ocean boundary denoted by the red line near F in Figure 8.

## Additional Boundary Conditions and Parameters

Parameters such as K, recharge, ET and storage were interrogated through the process of model calibration and are therefore discussed in Section 4.5.

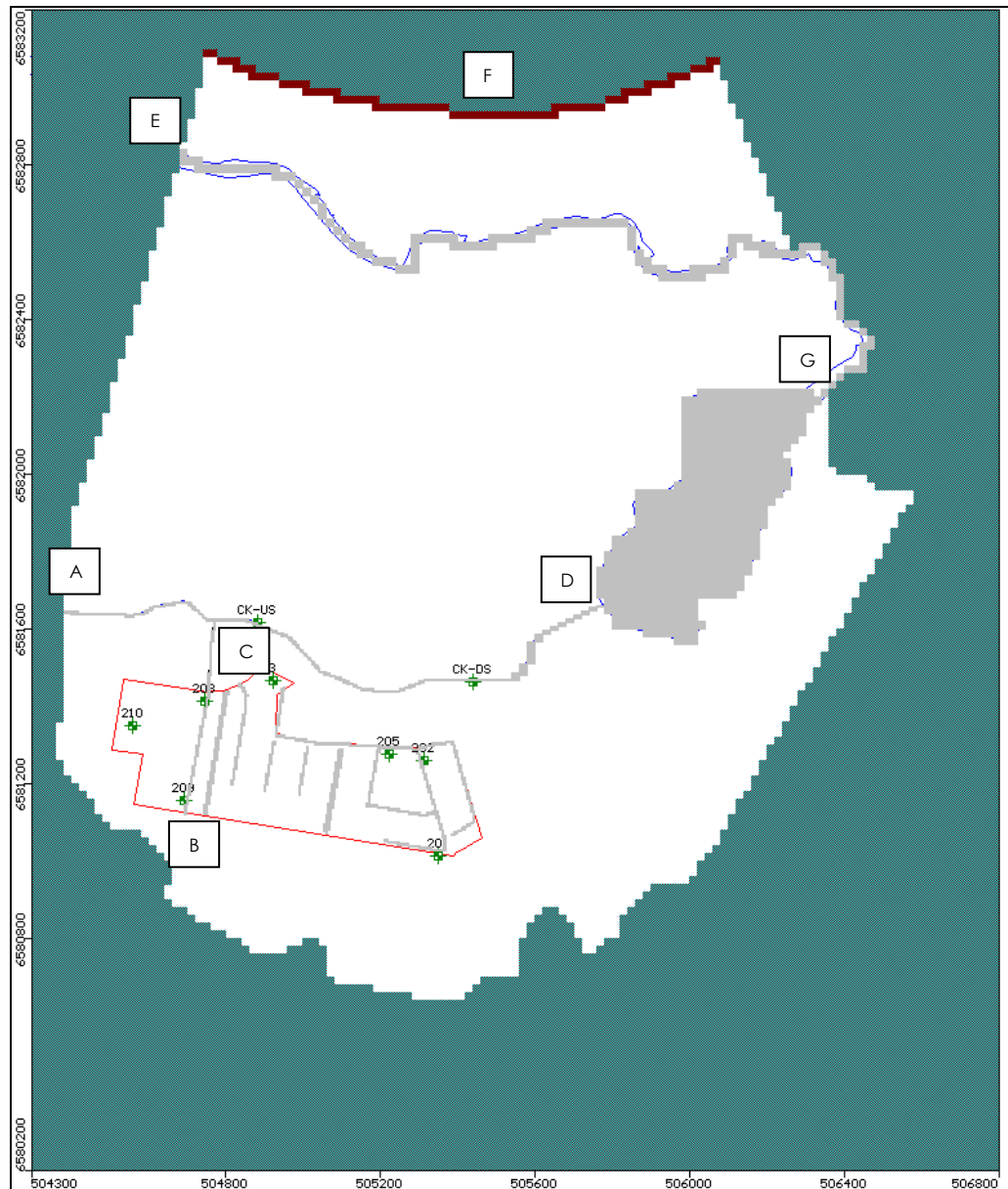


Figure 8: Boundary conditions used in groundwater model.

## 4.5 Calibration

### 4.5.1 Method

Final model calibration was achieved through adoption of the method outlined in the flow chart within Attachment C.

#### 4.5.2 Steady-state (Attachment C – step 1)

The steady-state calibration model (C1) was developed and calibrated to groundwater level measurements taken by Martens and Associates on 22th February, 2010. These measurements were elected as the calibration data because based on historical residual rain mass analysis (Section 3.6.1); they are more likely to be representative of typical groundwater levels as opposed to the Douglas Partner's measurements which were taken in 2007 after a dry period. Furthermore this data marks the start of the continuous groundwater level monitoring period and therefore the calibrated model output provides an appropriate initial heads surface for subsequent transient model runs which correspond to the period of continuous groundwater level monitoring.

Steady-state calibration results are provided in Attachment D (sheet 1). Results indicate that the model is reasonably calibrated in the vicinity of the site. The model is not as well calibrated in the immediate vicinity of GMB 201 which exhibits the maximum residual of +0.69 m.

Rather than over-parametise the model in an attempt to force improved calibration at GMB 201 it was decided to maintain initial parametisation and concede that the model is not well calibrated in the vicinity of GMB 201.

With GMB 201 excluded from calibration results indicate that the maximum residual is +0.31 m and the absolute residual mean is 0.16 m. The residual mean is 0.02 m which indicates that the model is slightly over-predicting head at site GMB's. The normalised RMS is 16%.

Calibration results indicate that the steady-state model is sufficiently calibrated to allow its use for impact assessment.

#### 4.5.3 Transient (Attachment C – step 2)

Using the steady-state model (C1) as the calibrated basis for transient modelling, model C2 was developed to facilitate transient model calibration. The intent of this model was to provide verification that the model responds in-sync with temporal groundwater level observations. The same assumptions that were applied in C1 were applied to C2. The model was calibrated to average monthly head observations at site GMB's based on the continual groundwater level monitoring which spanned 3 months (23.02.2010 to 24.05.2010). The model was comprised of monthly stress periods which resulted in 3 periods and 12 data points for calibration.

Transient calibration results are provided in Attachment D (sheet 2) and indicate that the model is reasonably well calibrated except in the

vicinity of GMB 201 which exhibits the maximum residual of 0.8 m. The absolute residual mean is 0.26 m which indicates that the model has an average error of 0.26 m over the calibration data points. It is noted that GMB 3 was excluded from model calibration due to potential data inaccuracies (see Section 3.6.2).

In light of the above the transient model is considered to be calibrated satisfactorily and therefore application of its parameters and assumptions to a long-term simulation model is appropriate.

#### 4.5.4 Existing-development Transient Simulation (Attachment C – step 3)

To further validate the site groundwater models a long-term transient model (M2) was developed based on the same assumptions that were applied in C1 and C2. The model spanned 220 months at monthly stress periods. Recharge for the model was derived from BOM monthly rain observations at Smoky Cape Lighthouse from January, 1992 to April, 2010 (inclusive). Whilst there is no available calibration data to validate the model the model results were assessed in light of the available site data to ensure that the model was outputting reasonable simulation results.

In light of available site data simulation results were deemed reasonable and therefore it was concluded that steady-state and transient model calibration was adequate.

#### 4.5.5 Recharge Values and Zones

Three recharge zones were applied to the calibration models (Figure 9). A high recharge zone (white zone) was applied to represent an area of sand dunes, the low recharge zone (green/teal blue zone) was applied to represent the majority of the model area and the area with extremely low recharge (dark blue) is representative of lower permeability clayey soil material on relatively higher slopes.

The applied recharge rates as a percentage of annual rain was 30%, 2% and 0.5% for the white, green/teal blue and dark blue zones respectively. Consequently, recharge for C2 and M2 was based on application of these percentages to monthly rainfall. For the steady-state calibration model (C1) recharge was applied based on application of these percentages to the rainfall considered responsible for the steady-state head observations. The month of rainfall (173 mm) prior to steady-state head observations was considered to be responsible for the steady-state head observations.

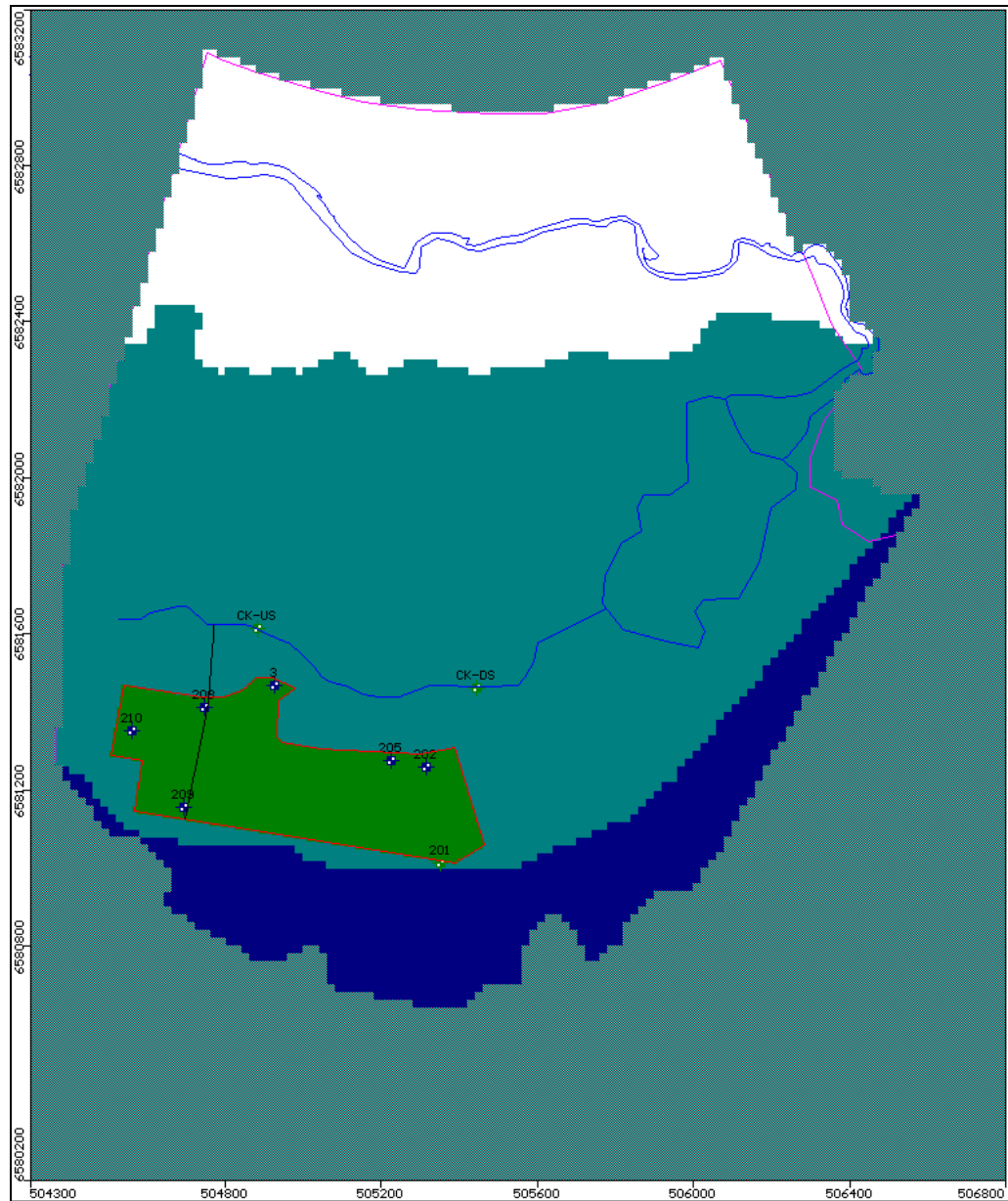


Figure 9: Recharge zones as a percentage of rainfall: white = 30%, green = 2%, blue = 0.5%.

#### 4.5.6 ET Values and Zones

An ET zone was applied to the flat portion of land which surrounds Saltwater Lagoon at a rate of 100 mm/yr with an extinction depth of 1.5 m. This zone was applied to simulate an area which is considered to be controlled by deficit net recharge due to a shallow water table and a water balance regime dominated by ET.

#### 4.5.7 K Values and Zones

Conductivity values and zones that produced final model calibration are in Figure 10 and Figure 11. Adopted K values compare well with site data (Table 2).

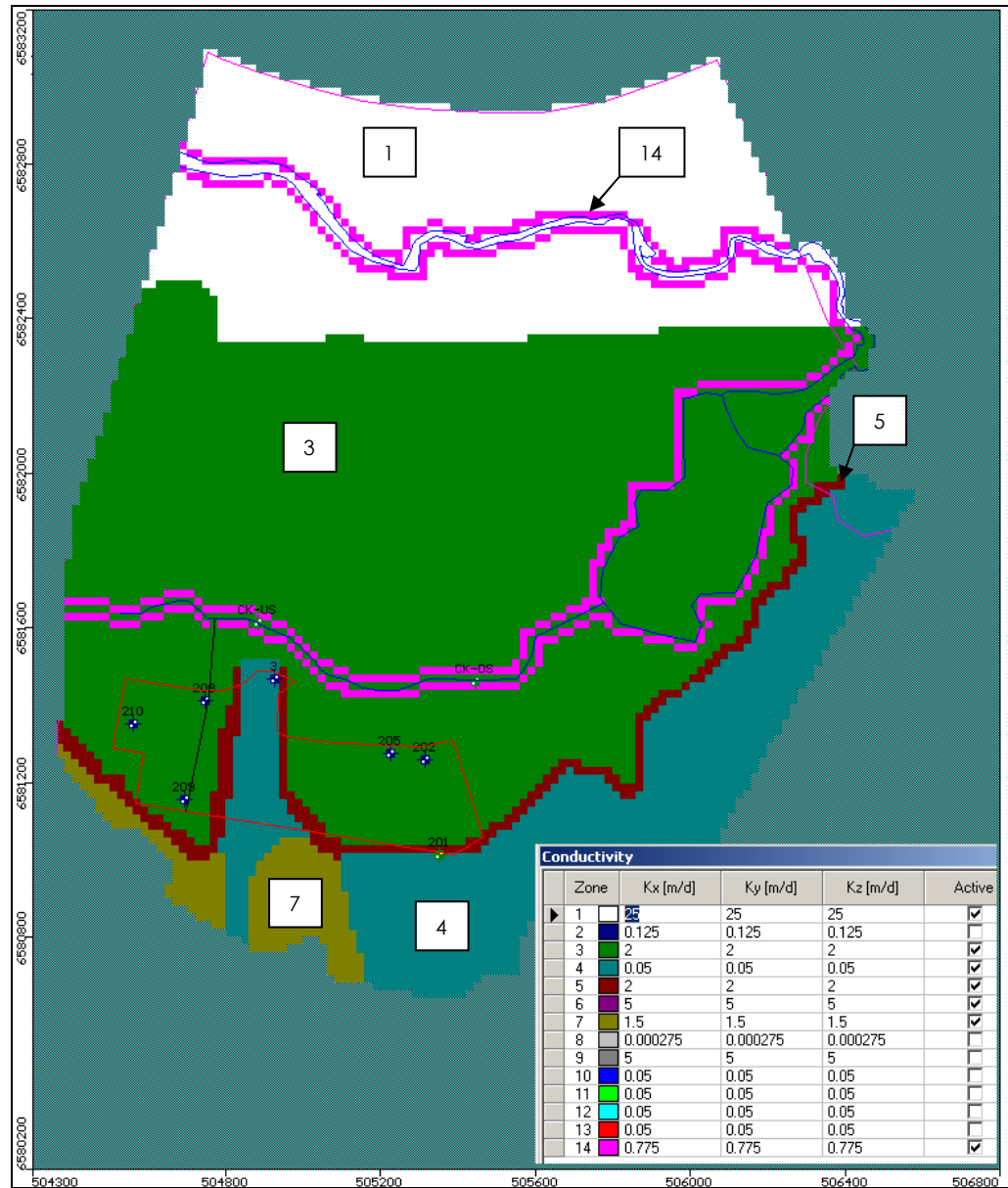


Figure 10: Layer 1 K values/zones.

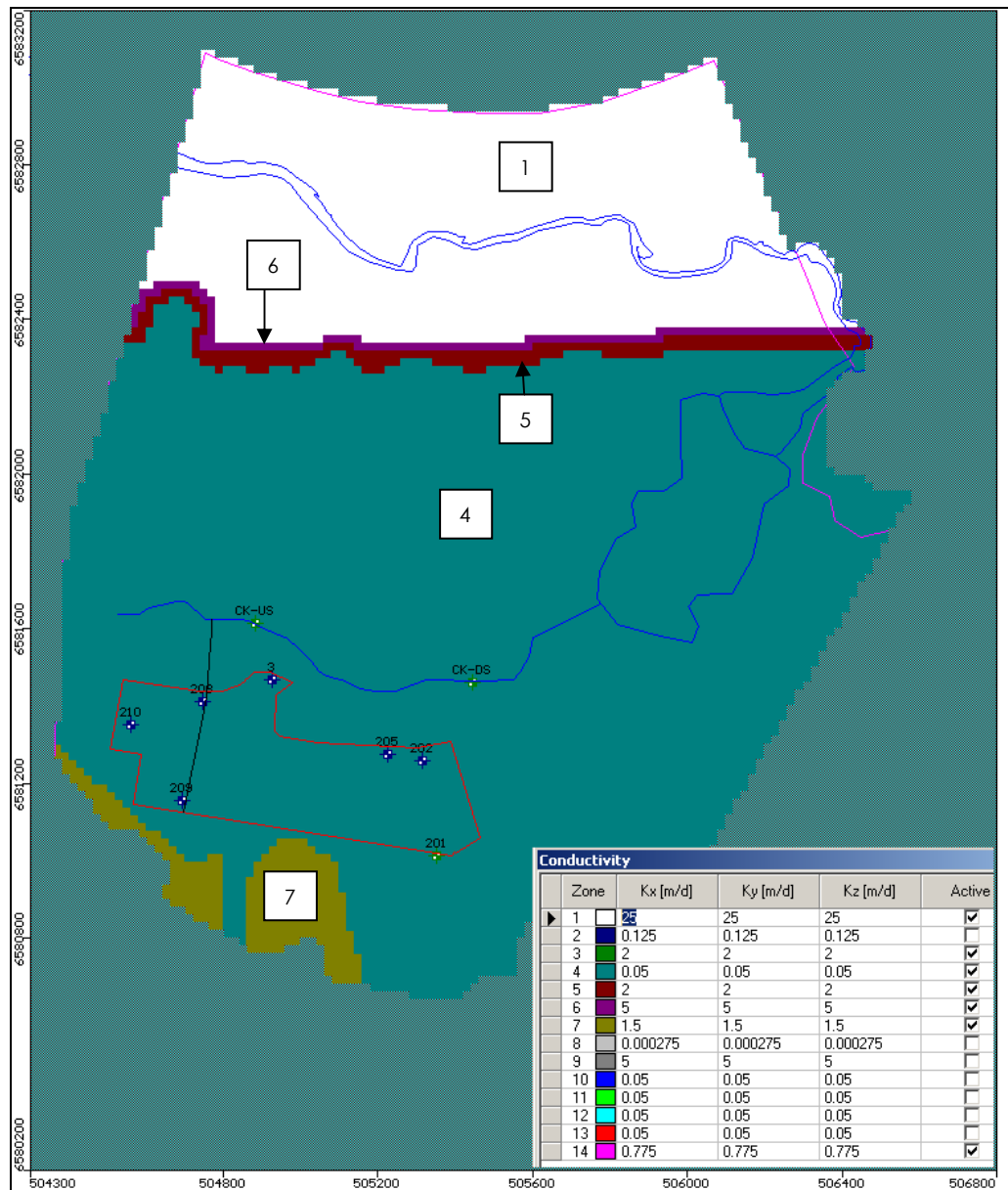


Figure 11: Layer 2 K values/zones.

#### 4.5.8 Storage Values and Zones

Specific Yield ( $S_y$ ) was assigned a value of 0.1 and 0.03 for the sand and clay layers respectively. Specific Storage ( $S_s$ ) was assigned the default value of  $1 \times 10^{-5}$  for both layers.

## 5 Simulations

### 5.1 Overview

The following conditions were simulated in separate models.

Model 1 (M1): Existing Conditions (steady-state model)

This model is the same as the steady-state calibration model (C1) with the exception of recharge which is applied based on average annual rainfall.

Model 2 (M2): Existing Conditions (transient)

This model is based on the same assumptions that were applied in M1, however, the model is transient. The model spans for 220 months at monthly stress periods. Recharge for the model was derived from BOM monthly rain observations at Smoky Cape Lighthouse from January, 1992 to April, 2010 (inclusive).

Model 3 (M3): Developed Conditions (steady-state)

This model was developed to simulate developed-conditions.

Model 4 (M4): Developed Conditions (transient)

This model was developed to simulate developed-conditions and is based on the same transient time scale as M2.

### 5.2 Model Condition Changes

To assess models M3 and M4 parameters were changed as follows.

Recharge

Recharge was decreased by 50% over the area of the site to simulate decreased recharge due to increased impervious areas.

Increases to impervious areas were also expected to increase run-off conveyed by site swales. This was expected to cause a higher zone of recharge immediately downslope of the site. To model this the volume by which recharge was reduced was attributed to "run-off"; 30% of this was applied to a zone of higher recharge (15 m wide strip) immediately downslope of the site. The zone of higher recharge is considered adequate to model the infiltration of water at the site swale points.

### Drains

Proposed stormwater swales were modelled within the developed condition groundwater models using the DRAIN boundary condition. The elevation, area and length for each drain was specified based on proposed swale design levels. A high conductance value was used for these drains as the swales are intended to be efficient drainage structures.

### Sea Level Rise

To assess sea level rise the constant head boundary at the ocean interface was raised from a level of 0 mAHD to 0.9 mAHD. DRAIN levels for the creek/lagoon were raised from 0.68 mAHD to 1.58 mAHD. The 1.58 mAHD level was arrived at to respect the same head differential as is currently observed between the ocean and the creek/lagoon background level.

## **5.3 Results**

### *5.3.1 Steady-state (M1 and M3)*

Existing-development groundwater head contours are in Attachment E (sheet 1). Developed condition groundwater head contours are in Attachment E (sheet 2). Drawdown plots between the two simulations are within Attachment E (sheet 3). An additional drawdown plot (Attachment E, sheet 3) provides results with sea level of 0.9 mAHD (i.e. climate change induced sea level rise) for developed conditions. This plot was included for completeness and to show that climate change induced sea level rise has a negligible impact on the developed site's hydrogeological condition.

Interpretation of the developments impacts on groundwater levels in the area of vegetated lands between the development site and the creek which transverses west to east are assessed using four "Observation Bores" (OB1-OB4) which are theoretical bores within the model. The location of these points is provided in Attachment E. Model results for the 4 observations points are summarised in Table 7.

Table 7: Steady-state groundwater levels for existing conditions and developed conditions at OB1-OB4.

Observation Point	Steady-state Groundwater Level (mAHD)						
	M1	M1a	M3	M3a	Difference (M1 – M3)	Difference (M1 – M1a)	Difference (M1 – M3a)
OB1	1.63	1.96	1.54	1.93	0.09	-0.33	-0.30
OB2	1.04	1.76	0.97	1.73	0.07	-0.72	-0.69
OB3	1.72	2.34	1.56	2.15	0.16	-0.62	-0.43
OB4	1.31	2.08	1.24	1.97	0.07	-0.77	-0.66

Notes:

M1 = existing conditions.

M1a = existing conditions with sea level rise of 0.9 mAHD.

M3 = developed conditions.

M3a = developed conditions with sea level rise.

(M1 – M3) = change in levels due to developed conditions.

(M1 – M1a) = change in levels due to sea level rise to 0.9 mAHD (existing conditions).

(M1 – M3a) = change in levels due to sea level rise to 0.9 mAHD (developed conditions).

Negative change = increase in water table from initial level, positive change = decrease in water table from initial level.

### 5.3.2 Transient (M2 and M4)

A summary of M2 and M4 groundwater levels is provided in Table 8. This summary shows a statistical analysis of modelled groundwater levels from the 220 stress periods.

Table 8: Summary of groundwater levels from M2 and M4.

Existing Conditions (M2)													
GMB	OB4	OB3	OB2	OB1	CK-US	CK-DS	3	210	209	208	205	202	201
Ground Level	1.44 <sup>1</sup>	2.41 <sup>1</sup>	2.97 <sup>1</sup>	2.82 <sup>1</sup>	NA	NA	3.35	3.59	3.85	3.59	3.45	3.60	5.40
Minimum	1.18	1.52	0.96	1.50	0.71	0.73	1.56	2.80	3.30	2.44	2.13	2.19	3.21
Median	1.25	1.62	1.01	1.58	0.71	0.75	1.68	2.91	3.34	2.54	2.28	2.34	3.41
Mean	1.26	1.63	1.01	1.59	0.71	0.75	1.70	2.92	3.34	2.56	2.28	2.34	3.42
Maximum	1.39	1.79	1.14	1.75	0.73	0.77	1.99	3.11	3.39	2.76	2.50	2.56	3.70
Developed Conditions (M4)													
Minimum	1.12	1.42	0.93	1.44	0.71	0.73	1.46	2.64	3.14	2.28	1.96	2.02	3.00
Median	1.21	1.54	0.98	1.53	0.71	0.74	1.58	2.77	3.28	2.41	2.12	2.18	3.23
Mean	1.21	1.55	0.99	1.54	0.71	0.74	1.58	2.78	3.26	2.41	2.13	2.19	3.23
Maximum	1.38	1.80	1.10	1.71	0.73	0.77	1.83	3.03	3.36	2.64	2.48	2.52	3.65

Notes: <sup>1</sup> Surface level in groundwater model. Remaining levels are surveyed.

## 5.4 Impact Analysis

### 5.4.1 Vegetated Lands North of Site

Steady-state results (Section 5.3.1) indicate that developed conditions with no sea level rise will lead to decreases in groundwater levels at OB1 to OB4 by depths ranging from 0.07 to 0.16 m with a median depth decrease of 0.08 m. Results for developed conditions with sea level rise indicate that groundwater levels will increase at OB1 to OB4 by a median depth of 0.55 m. Results indicate that existing conditions with sea level rise would lead to a median groundwater level increase of 0.67 m for OB1 to OB4.

Transient results (Section 5.3.2) for developed conditions with no sea level rise indicate that median groundwater levels at OB1 to OB4 will decrease by depths of 0.05 m, 0.03 m, 0.08 m and 0.04 m at OB1, OB2, OB3 and OB4 respectively.

Both steady-state and transient results indicate that groundwater levels will decrease slightly at OB1 to OB4 under developed conditions with no sea level rise. With developed conditions and an assumed sea level rise to 0.9 mAHD results indicate that groundwater levels will increase by a median depth of 0.55 m. This depth increase of 0.55 m is less than that which would occur without site development (median depth increase of 0.67 m at OB1 to OB4).

The modelled changes to groundwater levels within the vegetated lands north of the development site are best characterised as being minor. Total drawdown (i.e lowering) in the groundwater table is of the order of 30 to 160 mm. Such change is small compared to the existing water table range and is not expected to significantly affect vegetation.

#### 5.4.2 Site Groundwater Levels

Transient results (Section 5.3.2) indicate that developed conditions with no sea level rise will lead to minor decreases in site groundwater levels. Across GMB's 201, 202, 205, 208, 209, 210 and 3 the maximum decrease to median groundwater level is 0.18 m at GMB 201 with the minimum being 0.06 m at GMB 209.

Steady-state results (Attachment E) indicate that developed conditions with no sea level rise will decrease groundwater levels by a maximum depth of approximately 0.35 m in the centre of the site. Drawdown then decreases outwards toward site boundaries. Drawdown at the site boundaries is typically of the order of 0.1 to 0.2 m.

Steady-state results (Attachment E) indicate that developed conditions with sea level rise will lead to similar drawdown over the site but negative drawdown (i.e increases to groundwater levels) in the area of the creek located to the north of the site. The exception to this is the north eastern corner of the site as model results indicate that groundwater levels will rise in this area by a depth of the order of 0.2 m.

Modelled changes in groundwater levels beneath the developed site in response to sea level rise are not considered to be an impediment to the site's development.

#### 5.4.3 Conclusion

Changes to groundwater levels which arise due to site development are minor when considered in light of the shallow (~1 m) groundwater in these areas and likely natural level variation. These changes are not expected to have any adverse impacts on local vegetation associations to the north of the site. Changes in site groundwater regime in response to sea level rise are not significant and shall not pose a significant limitation to the site's development.

## 6 Conclusion

A sub-regional numerical groundwater model (MODFLOW) was developed and calibrated (steady-state and transient) to assess the impact of a proposed sub-division at Belle O'Connor Street, South West Rocks, NSW.

Results indicate that the proposed development shall result in the following hydrogeological changes at the site:

1. Reduced site recharge due to increased impervious area.
2. Increased discharge to surface water through the function of site road drainage swales as groundwater drains.
3. Drawdown in average water table levels beneath the site. Drawdown of the order of 0.35 m is anticipated at the centre of the site based on steady-state modelling. Drawdown decreases outwards from the centre of the site towards site boundaries. Drawdown at the site boundaries is typically of the order of 0.1 to 0.2 m.
4. Drawdown of the water table in the area of adjacent vegetated lands by depths of the order of 0.03 to 0.16 m (based on steady-state and transient modelling).

Analysis of climate change sea level rise impacts indicates that groundwater levels will increase by depths of the order of 0.1 to 0.3 m in the north eastern portion of the site. This is based on comparing existing conditions with sea level at 0 mAHD to developed conditions with sea level at 0.9 mAHD.

Modelling results indicate that the drawdown in groundwater levels in the area of vegetated lands will be minor when considered in light of the shallow (~1 m) groundwater in these areas. These changes are not expected to have any adverse impacts on local vegetation association.

## 7 References

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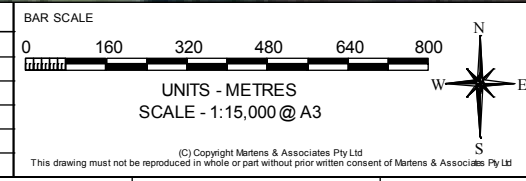
**8 Attachment A – Site Plan**



**KEY:**

- MAGENTA POLYLINE - ACTIVE GROUNDWATER MODEL DOMAIN BOUNDARY
- BLACK RECTANGLE - GROUNDWATER MODEL GRID EXTERIOR
- RED POLYLINE - AREA OF PROPOSED SITE DEVELOPMENT
- BH-P0802023-## - BOREHOLE ID WITH ACCOMPANYING BOREHOLE LOCATION MARKER  
(NOTE: GROUNDWATER MONITORING BORES EXIST AT 3, 201, 202, 205, 208, 209 AND 210)

REV.	DESCRIPTION	DATE	ISSUED
1	ATTACHMENT A	03.06.2010	BR



DESIGNED: BR	DATUM: mAHD	CLIENT/PROJECT MALBEC PROPERTIES/ GROUNDWATER ASSESSMENT
DRAWN/REVIEWED: BR/AN	HORIZONTAL RATIO: 1:15,000	THIS PLAN MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS APPROVED BY PRINCIPAL CERTIFYING AUTHORITY All measurements in m unless otherwise specified.
PAPER SIZE: A3	VERTICAL RATIO: 1:15,000	

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

TITLE: PROPOSED AREA OF SITE DEVELOPMENT, GROUNDWATER MODEL GRID EXTERIOR AND ACTIVE DOMAIN BOUNDARY AND GROUNDWATER MONITORING BORES		SHEET <b>1</b>
PROJECT MANAGER: ANDREW NORRIS	DRAWING NUMBER: P0802023JD11_V2_SH1	OF 1 SHEETS

## 9 Attachment B – Borehole Logs

CLIENT		Malbec Properties Pty Ltd		COMMENCED	20/2/10	COMPLETED	22/2/10	REF		BH201							
PROJECT		Geotechnical Investigations		LOGGED	JSF	CHECKED	ASN	Sheet 1 of 1									
SITE		South West Rocks		GEOLOGY	Quaternary/Claystone	VEGETATION	Grass	PROJECT NO. P0802023									
EQUIPMENT			4WD MOUNTED AUGER		EASTING	NA		RL SURFACE	6m AHD								
EXCAVATION DIMENSIONS			Ø 95mm X 8.5m depth		NORTHING	NA		ASPECT	North		SLOPE	<1°					
EXCAVATION DATA				MATERIAL DATA				SAMPLING & TESTING									
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA		CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	GROUNDWATER BORE CONSTRUCTION DETAILS			
								Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.									
A	Nil	N	M	0.25			CL	SILTY CLAY FILL - Light grey with orange mottles, moist.						Well Cover			
A	Nil	N	M	0.65			CL	SILTY/SANDY CLAY - Brown, moist, soft to firm.				A	0.5	Concrete			
A	Nil	N	M	1.0			CL	SILTY CLAY WITH MINOR SAND - Orange/brown mottles, moist, firm to stiff.				A	1.0	Bentonite Seal			
A	Nil	N	M	1.2			CL	SILTY CLAY - Grey and red mottled, moist, firm to stiff, minor sand.				A	1.5	Soil and Backfill.			
A	Nil	N	M	1.7			CL	SILTY CLAY - Grey and red mottled, moist, firm to stiff, minor sand.				A	1.8	UPVC Pipe.			
A	Nil	N	M	1.9			CL	SANDY CLAY - Brown, moist, with gravels (1-5mm, 10%).				A	2.0				
A	Nil	Y	W	2.4			CL	SILTY CLAY - Grey with minor orange mottles, moist, firm to stiff. Orange mottles disappear at depth.				A	2.0				
A	Nil	Y	W	3.0			CH	CLAY - Grey to dark grey, very stiff, moist.				A	4.0				
A	Nil	Y	W	4.0			CH	CLAY - Grey to dark grey, very stiff, moist.				A	5.2	5.4m bgl			
A	Nil	Y	W	6.0			CH	CLAY - Grey and purple mottles, grading to purple/red in colour, moist, stiff.				A	6.0	UPVC Screen			
A	Nil	Y	W	7.0			CH	CLAY - Grey and purple mottles, grading to purple/red in colour, moist, stiff.				A	7.0	Sand Pack.			
A	Nil	Y	W	8.0			CH	CLAY - Light red/purple, moist, very stiff.				A	8.0				
A	Nil	Y	W	8.5			CH	CLAY - Light red/purple, moist, very stiff.				A	8.5	8.4m bgl			
													Borehole terminated at 8.5m on clay.				
													9.0				
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		W Wet	H High	F Firm	MD Medium Dense	U Undisturbed sample	DCP Dynamic cone penetrometer								
E Excavator		Nil No support		Wp Plastic limit	R Refusal	St Stiff	D Dense	D Disturbed sample	M Moisture content								
HA Hand auger				WL Liquid limit		VSt Very Stiff	VD Very Dense	Mx Tube sample (x mm)	FD Field density								
S Hand spade						H Hard		WS Water sample									
PT Push tube						F Friable											
A Auger																	
CC Concrete Corer																	

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



CLIENT		Malbec Properties Pty Ltd		COMMENCED	21/2/10	COMPLETED	22/2/10	REF		BH203			
PROJECT		Geotechnical Investigations		LOGGED	JSF	CHECKED	ASN	Sheet 1 of 1					
SITE		South West Rocks		GEOLOGY	Quaternary	VEGETATION	Heath	PROJECT NO. P0802023					
EQUIPMENT		4WD MOUNTED AUGER		EASTING	NA	RL SURFACE	4.0m AHD						
EXCAVATION DIMENSIONS		Ø 95mm X 2.5m depth		NORTHING	NA	ASPECT	North	SLOPE	<1%				
EXCAVATION DATA				MATERIAL DATA				SAMPLING & TESTING					
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
								Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.					
A	Nil	N	M	0.5			SM	SILTY SAND - Grey brown, moist, medium grained.			A	0.5	2023/203/ 0.5
A	Nil	N	M	0.6			SP	SAND - Dark red brown, moist.			A	0.75	2023/203/ 0.75
A	Nil	Y	W	1.0			SP	SAND - Light brown, moist, grades to orange brown at 1.0m, wet below 1.1m, grades to light yellow at 1.6m.			A	1.0	2023/203/ 1.0
				1.5			SP		A			1.5	2023/203/ 1.5
				2.0			SP		A			2.0	2023/203/ 2.0
A	Nil	Y	W	2.5			CL	CLAY - Dark grey, stiff, moist.			A	2.5	2023/203/ 2.5
				3.0				Borehole terminated at 2.5m on stiff clay.					
				4.0									
				5.0									
				6.0									
				7.0									
				8.0									
				8.5									
				9.0									

EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	SH Shoring SC Shotcrete RB Rock Bolts Nil No support	N None observed X Not measured ▽ Water level △ Water outflow ▽ Water inflow	D Dry M Moist Wp Plastic limit Wl Liquid limit	L Low M Moderate H High R Refusal	VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	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  Y USCS N Agricultural

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

	MARTENS & ASSOCIATES PTY LTD 6/37 Leighton Place Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767 mail@martens.com.au WEB: http://www.martens.com.au	<b>Engineering Log - Borehole</b>
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Quality Sheet No. 4

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH204					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1							
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Heath		PROJECT NO. P0802023							
EQUIPMENT				4WD MOUNTED AUGER		EASTING		NA		RL SURFACE		4.5m AHD							
EXCAVATION DIMENSIONS				Ø 95mm X 2.5m depth		NORTHING		NA		ASPECT		North		SLOPE		<1%			
EXCAVATION DATA				MATERIAL DATA						SAMPLING & TESTING									
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA		CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS					
								Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.											
A	Nil	N	M	0.4			OL	ORGANIC SILTY CLAY - Dark brown, moist/wet, soft.				A	0.2	2023/203/ 0.2					
A	Nil	0.7	M	0.7			CL	SILTY CLAY - Brown, moist, soft.				A	0.5	2023/203/ 0.5					
A	Nil	Y	W	1.0			SP	SAND - Light grey/brown, wet, medium dense, dark brown from 2.0m.				A	0.75	2023/203/ 0.75					
				1.5						A	1.5	2023/203/ 1.5							
				2.0						A	2.0	2023/203/ 2.0							
				2.5				A	2.5	2023/203/ 2.5			Borehole terminated at 2.5m on wet sand.						
				3.0															
				4.0															
				5.0															
				6.0															
				7.0															
				8.0															
				8.5															
				9.0															

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
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test
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								
CC Concrete Corer								

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

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH205																					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1																							
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Grass		PROJECT NO. P0802023																							
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		3.5m AHD																					
EXCAVATION DIMENSIONS				Ø 95mm X 8.5m depth				NORTHING		NA		ASPECT		North		SLOPE		<1%																	
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING																							
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	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)	GROUNDWATER BORE CONSTRUCTION DETAILS																			
A	Nil	N	M	0.65			SM	SILTY SAND - Grey, moist, minor clay, medium grained.						A	0.5																				
A	Nil	Y	W	1.0			SP	SAND - Cream, medium grained, moist, minor clay, wet below 1.0m.						A	0.75	2023/205/ 0.75																			
A	Nil	Y	W	2.0			SP	SAND - Grey, wet, medium grained.						A	2.0	2023/205/ 2.0																			
A	Nil	Y	W	2.25			SP	SAND - Grey, wet, medium grained.						A	2.2	2023/205/ 2.2																			
A	Nil	Y	W	3.0			CL	CLAY - Grey, very stiff.						A	2.5	2023/205/ 2.5																			
A	Nil	Y	W	4.0			CL	CLAY - Grey, very stiff.						A	2.5	2023/205/ 2.5																			
A	Nil	Y	W	5.0			SP	SAND - Grey, with minor clay, wet, medium grained.						A	2.5	2023/205/ 2.5																			
A	Nil	Y	W	6.0			SP	SAND - Grey, with minor clay, wet, medium grained.						A	2.5	2023/205/ 2.5																			
A	Nil	Y	M	6.5			SP	SAND - Grey, with minor clay, wet, medium grained.						A	2.5	2023/205/ 2.5																			
A	Nil	Y	M	7.0			CL	CLAY - Grey, grading to grey and red/orange mottled, stiff to very stiff.						A	8.0	2023/205/ 8.0																			
A	Nil	Y	M	8.0			CL	CLAY - Grey, grading to grey and red/orange mottled, stiff to very stiff.						A	8.0	2023/205/ 8.0																			
A	Nil	Y	M	8.5			CL	CLAY - Grey, grading to grey and red/orange mottled, stiff to very stiff.						A	8.0	2023/205/ 8.0																			
Borehole terminated at 8.5m on stiff clay.																																			
EQUIPMENT / METHOD																																			
SUPPORT				WATER				MOISTURE				PENETRATION				CONSISTENCY				DENSITY				SAMPLING & TESTING				CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION							
N Natural exposure				N None observed				D Dry				L Low				VS Very Soft				VL Very Loose				A Auger sample				pp Pocket penetrometer				USCS			
X Existing excavation				X Not measured				M Moist				M Moderate				S Soft				L Loose				B Bulk sample				S Standard penetration test				Agricultural			
BH Backhoe bucket				RB Rock Bolts				W Wet				H High				F Firm				MD Medium Dense				U Undisturbed sample				VS Vane shear							
E Excavator				Nil No support				Wp Plastic limit				R Refusal				St Stiff				D Dense				D Disturbed sample				DCP Dynamic cone penetrometer							
HA Hand auger				Water outflow				WL Liquid limit				VSt Very Stiff				VD Very Dense				M Moisture content				FD Field density											
S Hand spade				Water inflow								H Hard								Ux Tube sample (x mm)				WS Water sample											
PT Push tube												F Friable																							
A Auger																																			
CC Concrete Corer																																			
EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS																																			
MARTENS & ASSOCIATES PTY LTD 6/37 Leighton Place Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767 mail@martens.com.au WEB: http://www.martens.com.au																																			
<b>Engineering Log - Borehole</b>																																			

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH206					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1							
SITE		South West Rocks		GEOLOGY		Claystone/Siltstone		VEGETATION		Grass		PROJECT NO. P0802023							
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		5.0m AHD					
EXCAVATION DIMENSIONS				Ø 95mm X 2.5m depth				NORTHING		NA		ASPECT		North		SLOPE		<1%	
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING							
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	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)	RESULTS AND ADDITIONAL OBSERVATIONS			
A	Nil	N	M	0.4			CL	SILTY/SANDY CLAY - Dark grey, moist, soft.						A	0.2	2023/206/ 0.2			
A	Nil	N	M	0.7			CL	CLAY - Yellow orange with grey mottles.						A	0.5	2023/206/ 0.5			
A	Nil	N	W	1.0			CL	CLAY - Grey with red mottles, gravels (5-20mm, 10-15%), grades to extremely weathered claystone from 1.4m.						A	1.0	2023/206/ 1.0			
				1.5												A	1.5	2023/206/ 1.5	
				2.5												A	2.5	2023/206/ 2.5	
				3.0				Borehole terminated at 2.5m on extremely weathered claystone/siltstone.											
				4.0															
				5.0															
				6.0															
				7.0															
				8.0															
				8.5															
				9.0															

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
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test
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								
CC Concrete Corer								

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



CLIENT		Malbec Properties Pty Ltd		COMMENCED	22/2/10	COMPLETED	22/2/10	REF		BH207			
PROJECT		Geotechnical Investigations		LOGGED	JSF	CHECKED	ASN	Sheet 1 of 1					
SITE		South West Rocks		GEOLOGY	Claystone/Siltstone	VEGETATION	Grass	PROJECT NO. P0802023					
EQUIPMENT		4WD MOUNTED AUGER		EASTING	NA	RL SURFACE	4.0m AHD						
EXCAVATION DIMENSIONS		Ø 95mm X 2.5m depth		NORTHING	NA	ASPECT	North	SLOPE	<1%				
EXCAVATION DATA				MATERIAL DATA				SAMPLING & TESTING					
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
A	Nil	N	M	0.35			SM	SILTY SAND - Light grey, wet, medium grained.					
A	Nil	N	M	1.0			CL	CLAY - Grey, moist, stiff, angular gravels (5-10mm, 5-10%), orange mottles from 0.8m, gravels increasing with depth.			A	0.5	2023/207/ 0.5
A	Nil	N	M	1.4			CL				A	1.0	2023/207/ 1.0
A	Nil	N	W	2.0			EW	EXTREMELY WEATHERED CLAYSTONE/SILTSTONE - Gravelly clay, orange with grey mottles, gravels (5-20mm, 20%).			A	1.5	2023/207/ 1.5
A	Nil	N	W	2.5			EW				A	2.5	2023/207/ 2.5
				3.0				Borehole terminated at 2.5m on extremely weathered claystone/siltstone.					No ground water observed after two hours.
				4.0									
				5.0									
				6.0									
				7.0									
				8.0									
				8.5									
				9.0									

EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	SH Shoring SC Shotcrete RB Rock Bolts Nil No support	N None observed X Not measured Water level Water outflow Water inflow	D Dry M Moist W Wet Wp Plastic limit Wl Liquid limit	L Low M Moderate H High R Refusal	VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	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 Y USCS N Agricultural

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

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CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH208					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1							
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Grass		PROJECT NO. P0802023							
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		4.0m AHD					
EXCAVATION DIMENSIONS				Ø 95mm X 5.5m depth				NORTHING		NA		ASPECT		North		SLOPE		<1%	
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING							
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	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)	GROUNDWATER BORE CONSTRUCTION DETAILS			
A	Nil	N	M	0.25			SM	ORGANIC SILTY SAND - Dark brown/black.						A	0.2	0.61m above gl 0.505m above gl Well Cover			
A	Nil	N	M	0.6			CL	SILTY CLAY - Orange brown and grey mottled, moist.						A	0.5	Concrete Bentonite Seal 0.4m bgl			
A	Nil	Y	W	1.0	0.9		SP	SAND - Orange, moist, medium dense, wet and light yellow/grey from 0.9m, yellow from 1.2m, grey from 1.5m.						A	1.0	Soil and Backfill UPVC Pipe 1.14m bgl			
A	Nil	Y	W	2.0			SP							A	1.5	UPVC Screen			
A	Nil	Y	W	2.4			SP							A	2.0	Sand Pack 2.64m bgl			
A	Nil	Y	W	4.0			CL	CLAY - Grey/dark grey, moist, stiff, grades to light grey (some angular gravels - 5-10mm, <5%) at 4.5-5.0m, light grey green from 5.2-5.5m.						A	2.5	2.64m bgl			
A	Nil	Y	W	5.0			CL							A	5.0	2023/208/ 5.0			
				5.5				Borehole terminated at 5.5m on clay.											
				6.0															
				7.0															
				8.0															
				8.5															
				9.0															
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		N Agricultural				
X Existing excavation		SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test										
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	DCP Dynamic cone penetrometer	D Disturbed sample										
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																			
CC Concrete Corer																			

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

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH209							
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1									
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Grass		PROJECT NO. P0802023									
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		4.0m AHD							
EXCAVATION DIMENSIONS				Ø 95mm X 5.5m depth				NORTHING		NA		ASPECT		North		SLOPE		1%			
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING									
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA <small>Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.</small>				CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	GROUNDWATER BORE CONSTRUCTION DETAILS					
A	Nil	N	M	0.05			OL	ORGANIC SILTY SAND - Dark brown/black.							0.2	0.54m above gl 0.46m above gl Well Cover					
A	Nil	N	M	-0.25			CL	CLAY - Brown, moist.						A	0.2	Concrete					
A	Nil	N	M	-0.35			CL	SILTY CLAY - Grey, moist.								Bentonite Seal					
				0.6				SAND - Light grey, moist, (wet below 1.1m), medium grained.						A	0.5	0.5m bgl					
				1.0												A	1.0	Soil and Backfill.			
				2.0												A	1.5	UPVC Pipe.			
				3.0												A	2.0	2.0m bgl			
				3.9												A	2.5	UPVC Screen.			
				4.0				CLAY - Grey to dark grey, moist, stiff.								Sand Pack.					
				5.0														3.5m bgl			
				5.5				Borehole terminated at 5.5m on clay.													
				6.0																	
				7.0																	
				8.0																	
				8.5																	
				9.0																	
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	DCP Dynamic cone penetrometer												
E Excavator		Nil No support	∇ Water outflow	Wp Plastic limit	R Refusal	St Stiff	D Dense	D Disturbed sample	M Moisture content												
HA Hand auger			∇ Water inflow	WL Liquid limit		VSt Very Stiff	VD Very Dense	Ux Tube sample (x mm)	FD Field density												
S Hand spade						H Hard			WS Water sample												
PT Push tube						F Friable															
A Auger																					
CC Concrete Corer																					

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

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH210					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1							
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Grass		PROJECT NO. P0802023							
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		3.5m AHD					
EXCAVATION DIMENSIONS				Ø 95mm X 4.2m depth				NORTHING		NA		ASPECT		North		SLOPE		<1%	
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING							
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	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)	GROUNDWATER BORE CONSTRUCTION DETAILS			
A	Nil	N	M	0.01			OL	ORGANIC SILTY CLAY - Dark brown/black, moist/wet, soft.								0.51m above gl Well Cover			
A	Nil	N	M	0.35			CL	SILTY CLAY - Brown orange and grey mottled, moist.								Concrete Bentonite Seal UPVC Pipe 0.5m bgl Soil and Backfill 0.72m bgl			
A	Nil	Y	W	2.0	0.75		SP	SAND - Brown/orange, moist, medium grained, wet below 0.75m, yellow from 1.0-1.4, grey from 1.4-1.7, brown from 1.7-2.2, minor clay content from 2.5 - increasing with depth.						A	0.5	2023/210/ 0.5			
A	Nil	Y	W	2.0			SP							A	1.0	2023/210/ 1.0			
A	Nil	Y	W	2.0			SP							A	1.5	2023/210/ 1.5			
A	Nil	Y	W	2.0			SP							A	2.0	2023/210/ 2.0			
A	Nil	Y	M	3.8			CL	CLAY - Grey, wet, very soft.								3.72m bgl			
A	Nil	Y	W	4.2			SP	SAND - Grey, medium grained, wet.											
				4.2				Borehole terminated at 4.2m on clay.											
				5.0															
				6.0															
				7.0															
				8.0															
				8.5															
				9.0															

EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	SH Shoring SC Shotcrete RB Rock Bolts Nil No support	N None observed X Not measured Water level Water outflow Water inflow	D Dry M Moist W Wet Wp Plastic limit Wl Liquid limit	L Low M Moderate H High R Refusal	VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	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

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

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH211		
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1				
SITE		South West Rocks		GEOLOGY		Claystone/Siltstone		VEGETATION		Grass		PROJECT NO. P0802023				
EQUIPMENT		4WD MOUNTED AUGER		EASTING		NA		RL SURFACE		4.5m AHD						
EXCAVATION DIMENSIONS		Ø 95mm X 2.5m depth		NORTHING		NA		ASPECT		North East		SLOPE		1-2%		
EXCAVATION DATA				MATERIAL DATA				SAMPLING & TESTING								
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS			
								Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.								
A	Nil	N	M	0.4			SM	SILTY SAND - Grey, moist, medium grained.								
A	Nil	N	M	0.9			SM	SILTY SAND - Brown, minor clay, increasing with depth, moist, medium grained.								
A	Nil	1.1 Y	W	1.0 1.3			SP	CLAYEY SAND - Red, grey, brown mottled, medium grained, moist.			A	1.0	2023/211/ 1.0		1.0	
A	Nil	Y	W	2.0 2.5			CL	CLAY - Grey, very stiff, grades to clay (extremely weathered claystone), grey with red mottles.			A	1.5	2023/211/ 1.5 Residual soil from 1.3m.		2.0	
								Borehole terminated at 2.5m on clay.								
				3.0												
				4.0												
				5.0												
				6.0												
				7.0												
				8.0												
				8.5												
				9.0												

<b>EQUIPMENT / METHOD</b> N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	<b>SUPPORT</b> SH Shoring SC Shotcrete RB Rock Bolts Nil No support	<b>WATER</b> N None observed X Not measured ▽ Water level △ Water outflow ▽ Water inflow	<b>MOISTURE</b> D Dry M Moist Wp Plastic limit Wl Liquid limit	<b>PENETRATION</b> L Low M Moderate H High R Refusal	<b>CONSISTENCY</b> VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	<b>DENSITY</b> VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	<b>SAMPLING &amp; TESTING</b> 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	<b>CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION</b> <table border="1"> <tr><td>Y</td><td>USCS</td></tr> <tr><td>N</td><td>Agricultural</td></tr> </table>	Y	USCS	N	Agricultural
Y	USCS												
N	Agricultural												

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

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH212					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1							
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Heath		PROJECT NO. P0802023							
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		4.0m AHD					
EXCAVATION DIMENSIONS				Ø 95mm X 5.5m depth				NORTHING		NA		ASPECT		North East		SLOPE		<1%	
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING							
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	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)	RESULTS AND ADDITIONAL OBSERVATIONS			
A	Nil	N	M	0.3			SM	ORGANIC CLAYEY/SILTY SAND - Dark brown, medium grained, moist.											
A	Nil	N	M	0.8			SM	SILTY SAND - Grey/brown, moist, minor clay content.											
A	Nil	Y	W	1.0			SP	SAND - Brown, moist, medium grained, wet below 1.1m.											
A	Nil	Y	W	2.0			SP												
A	Nil	Y	W	3.0			SP												
A	Nil	Y	W	3.1			SP												
A	Nil	Y	W	4.0			CL	CLAY - Light grey, stiff to very stiff, angular gravels (2-5mm, 10%) grades to CLAY - Grey and red/pink mottled, stiff, gravels (2-5mm, 10%).						A	3.5	2023/212/ 3.5	Residual soil from 3.1m.		
A	Nil	Y	W	5.0			CL												
A	Nil	Y	W	5.5			CL							A	5.5	2023/212/ 5.5			
				6.0				Borehole terminated at 5.5m on clay.											
				7.0															
				8.0															
				8.5															
				9.0															

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
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test
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								
CC Concrete Corer								

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

	MARTENS & ASSOCIATES PTY LTD 6/37 Leighton Place Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767 mail@martens.com.au WEB: http://www.martens.com.au	<b>Engineering Log - Borehole</b>
	(C) Copyright Martens & Associates Pty. Ltd. 2010	

CLIENT		Malbec Properties Pty Ltd		COMMENCED	22/2/10	COMPLETED	22/2/10	REF		BH213			
PROJECT		Geotechnical Investigations		LOGGED	JSF	CHECKED	ASN	Sheet 1 of 1					
SITE		South West Rocks		GEOLOGY	Quaternary	VEGETATION	Heath	PROJECT NO. P0802023					
EQUIPMENT		4WD MOUNTED AUGER		EASTING	NA	RL SURFACE	4.0m AHD						
EXCAVATION DIMENSIONS		Ø 95mm X 5.5m depth		NORTHING	NA	ASPECT	North East	SLOPE	<1%				
EXCAVATION DATA				MATERIAL DATA				SAMPLING & TESTING					
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
								Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.					
A	Nil	N	M	0.4			SM	ORGANIC CLAYEY/SILTY SAND - Dark brown, medium grained, moist.					
A	Nil	N	M	0.8			SM	SILTY SAND - Grey/brown, moist, minor clay content.					
		0.9		1.0									
A	Nil	Y	W	2.0			SP	SAND - Brown, moist, medium grained, wet from 0.9m.					
A	Nil	Y	W	3.5			CL	CLAY - Grey, moist, plastic, stiff (in fill).			A	3.5	2023/213/ 3.5
A	Nil	Y	W	4.5			SC	CLAYEY SAND - Grey, wet, medium dense.					
A	Nil	Y	W	5.5			SP	SAND - Grey, wet, medium dense, minor clay content.					
								Borehole terminated at 5.5m on clay.					

EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	SH Shoring SC Shotcrete RB Rock Bolts Nil No support	N None observed X Not measured ▽ Water level △ Water outflow ▽ Water inflow	D Dry M Moist W Wet Wp Plastic limit Wl Liquid limit	L Low M Moderate H High R Refusal	VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	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
								Y USCS N Agricultural

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

CLIENT		Malbec Properties Pty Ltd		COMMENCED	22/2/10	COMPLETED	22/2/10	REF		BH214			
PROJECT		Geotechnical Investigations		LOGGED	JSF	CHECKED	ASN	Sheet 1 of 1					
SITE		South West Rocks		GEOLOGY	Claystone/Siltstone	VEGETATION	Heath	PROJECT NO. P0802023					
EQUIPMENT		4WD MOUNTED AUGER		EASTING	NA	RL SURFACE	4.5m AHD						
EXCAVATION DIMENSIONS		Ø 95mm X 2.5m depth		NORTHING	NA	ASPECT	North West	SLOPE	<1%				
EXCAVATION DATA				MATERIAL DATA				SAMPLING & TESTING					
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
					L M H R			Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.					
A	Nil	N	M	0.5			OL/CL	ORGANIC CLAYEY SILT - Dark brown, moist, soft.					Residual soil profile.
A	Nil	N	M	0.75			CL	SANDY CLAY - Orange/brown, moist, firm.					
A	Nil	N	M	1.0 1.2			CL	CLAY - Grey with angular gravels (2-10mm, 10%), moist. Grades to				1.0	
A	Nil	N	M	1.8			CL	SANDY CLAY - Grey, with angular gravels (2-10mm, 5-10%).					
A	Nil	N	M	2.0 2.5			CL	CLAY - Grey, very stiff, red mottles, increasing with depth, gravels at 2.5m (5-20mm, 5%).				2.0	
				3.0 4.0 5.0 6.0 7.0 8.0 8.5 9.0				Borehole terminated at 2.5m on clay.					No ground water observed after one hour.

EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	SH Shoring SC Shotcrete RB Rock Bolts Nil No support	N None observed X Not measured ▽ Water level △ Water outflow ▽ Water inflow	D Dry M Moist W Wet Wp Plastic limit Wl Liquid limit	L Low M Moderate H High R Refusal	VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	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 Y USCS N Agricultural

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



MARTENS & ASSOCIATES PTY LTD  
6/37 Leighton Place  
Hornsby, NSW 2077 Australia  
Phone: (02) 9476 9999 Fax: (02) 9476 8767  
mail@martens.com.au WEB: http://www.martens.com.au

**Engineering Log -  
Borehole**

Quality Sheet No. 4

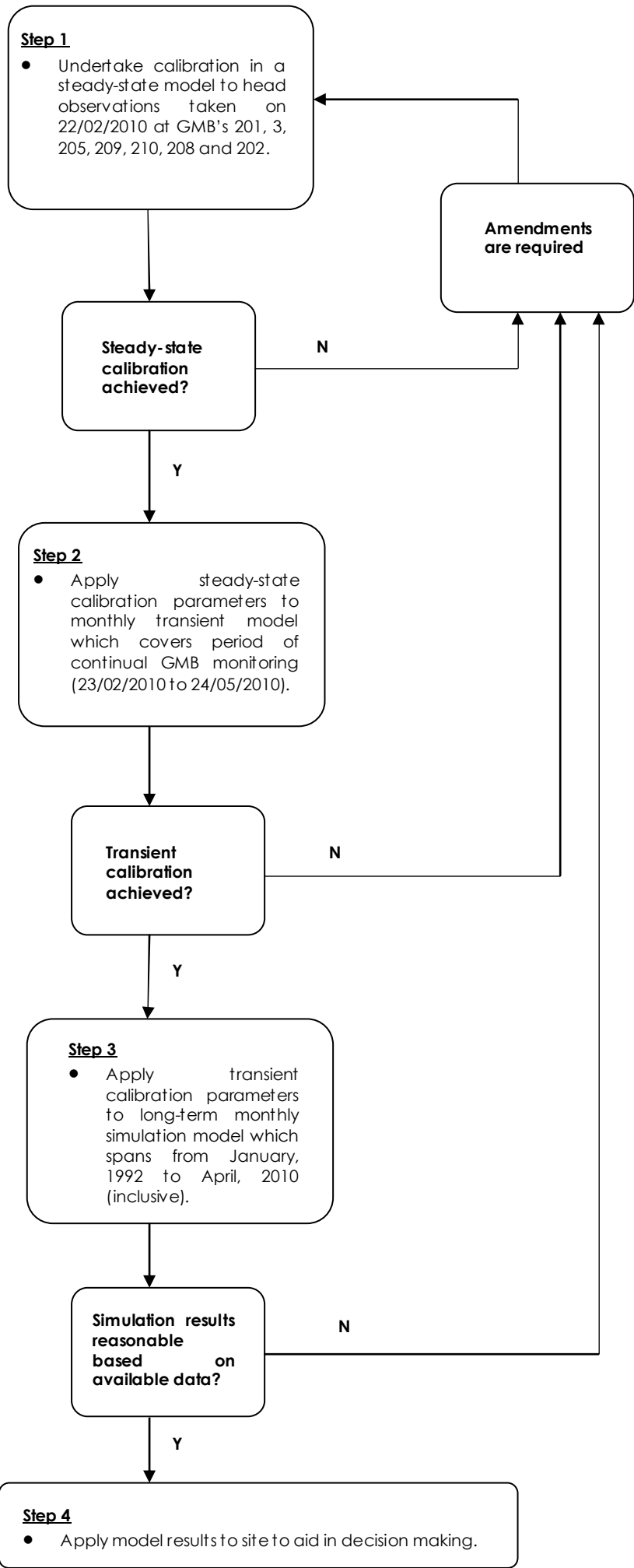
(C) Copyright Martens & Associates Pty. Ltd. 2010

CLIENT		Malbec Properties Pty Ltd		COMMENCED		22/2/10		COMPLETED		22/2/10		REF		BH215					
PROJECT		Geotechnical Investigations		LOGGED		JSF		CHECKED		ASN		Sheet 1 of 1							
SITE		South West Rocks		GEOLOGY		Quaternary		VEGETATION		Heath		PROJECT NO. P0802023							
EQUIPMENT				4WD MOUNTED AUGER				EASTING		NA		RL SURFACE		4.0m AHD					
EXCAVATION DIMENSIONS				Ø 95mm X 4.0m depth				NORTHING		NA		ASPECT		North East		SLOPE		<1%	
EXCAVATION DATA				MATERIAL DATA								SAMPLING & TESTING							
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE	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)	RESULTS AND ADDITIONAL OBSERVATIONS			
A	Nil	N	M	0.5			SM	SILTY SAND - Dark brown, moist, medium dense.											
A	Nil	N	M	0.85			SM	SILTY SAND - Brown, minor clay, increasing with depth, moist, medium grained.											
A	Nil	Y	W	1.0			SP	SAND - Brown, moist, medium grained, wet below 0.9m.									1.0		
A	Nil	Y	W	1.2			SP	SAND - Light grey, wet, medium grained, medium dense.											
A	Nil	Y	W	1.7			SP	SAND - Light grey, wet, medium grained, medium dense.											
A	Nil	Y	W	2.0			CL	CLAY - Grey, minor sand, moist, stiff, grades to dark grey then grades to grey/green below 2.5m.									2.0		
A	Nil	Y	W	2.7			CL	CLAY - Grey, minor sand, moist, stiff, grades to dark grey then grades to grey/green below 2.5m.											
A	Nil	Y	W	3.0			CL	CLAY - Brown, moist, stiff, gravels (5-20mm, 10%).											
A	Nil	Y	W	4.0			CL	CLAY - Brown, moist, stiff, gravels (5-20mm, 10%).											
				4.0				Borehole terminated at 4.0m on clay.						A	4.0	Residual soil from 3.7m. 2023/215/4.0			
				5.0				Borehole terminated at 4.0m on clay.											
				6.0				Borehole terminated at 4.0m on clay.											
				7.0				Borehole terminated at 4.0m on clay.											
				8.0				Borehole terminated at 4.0m on clay.											
				8.5				Borehole terminated at 4.0m on clay.											
				9.0				Borehole terminated at 4.0m on clay.											

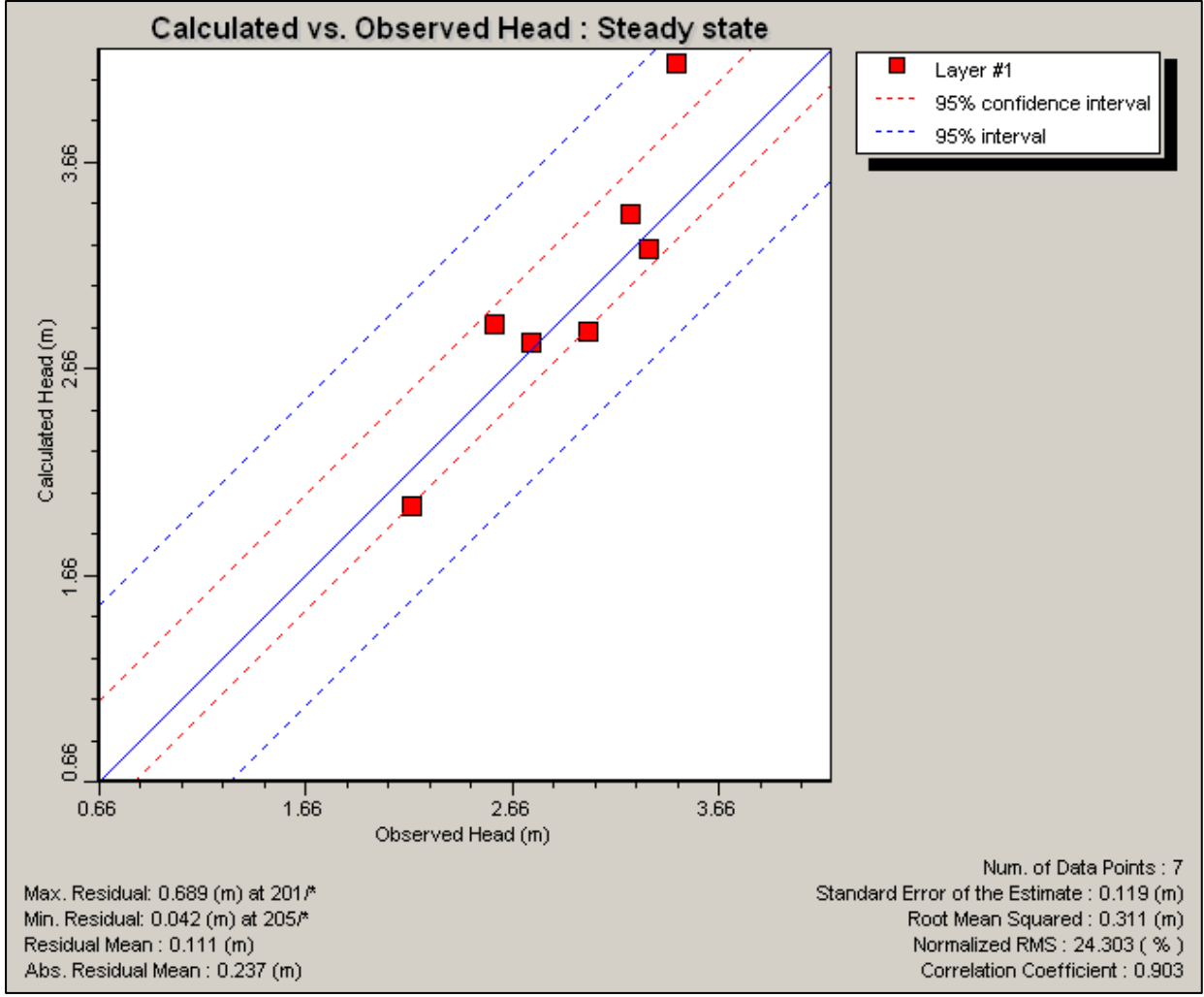
EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure X Existing excavation BH Backhoe bucket E Excavator HA Hand auger S Hand spade PT Push tube A Auger CC Concrete Corer	SH Shoring SC Shotcrete RB Rock Bolts Nil No support	N None observed X Not measured ▽ Water level △ Water outflow ▽ Water inflow	D Dry M Moist Wp Plastic limit Wl Liquid limit	L Low M Moderate H High R Refusal	VS Very Soft S Soft F Firm St Stiff VSt Very Stiff H Hard F Friable	VL Very Loose L Loose MD Medium Dense D Dense VD Very Dense	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 Y USCS N Agricultural

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

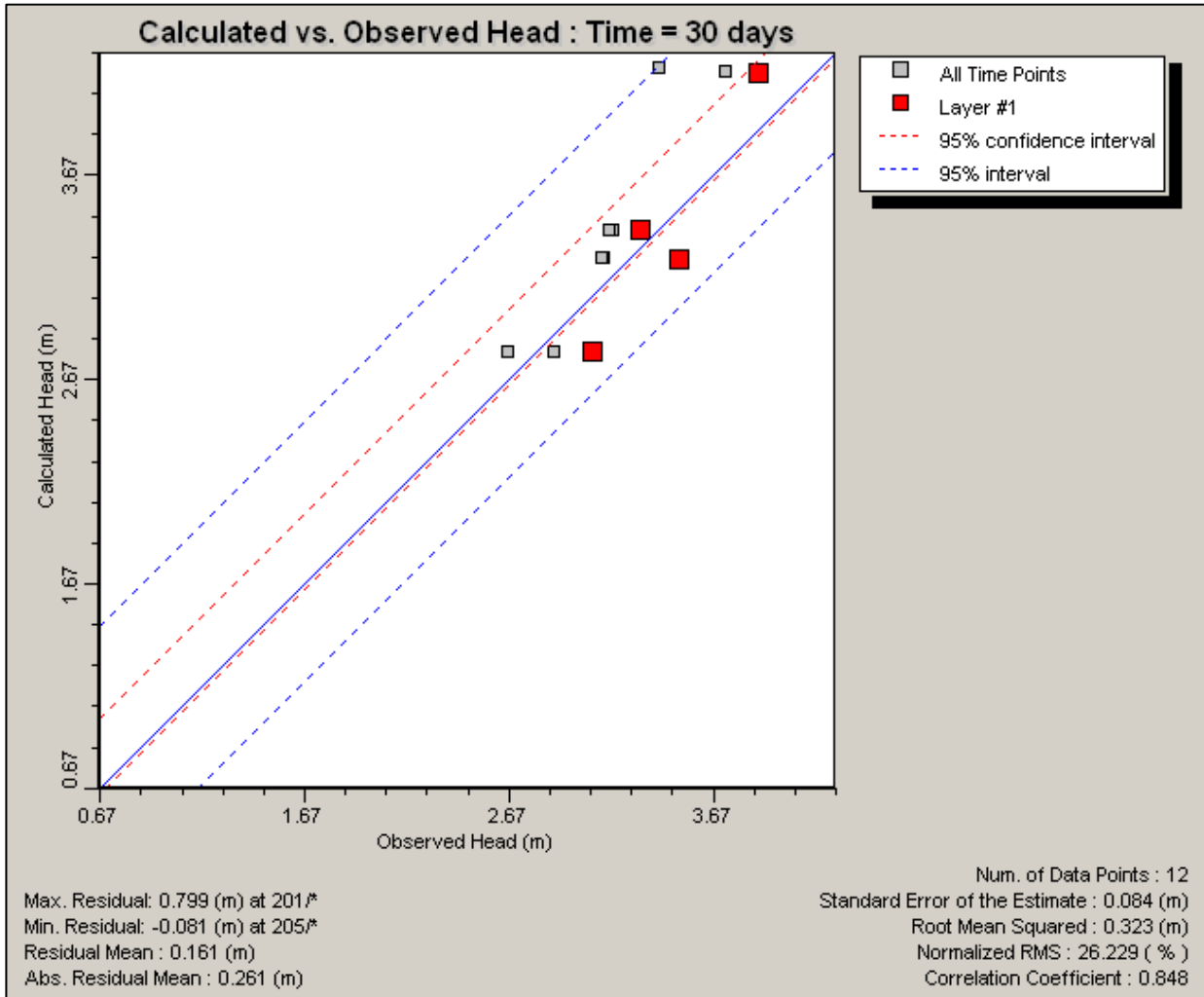
**10      Attachment C – Calibration Method Flow Chart**



## 11 Attachment D – Calibration Results

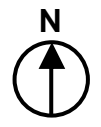
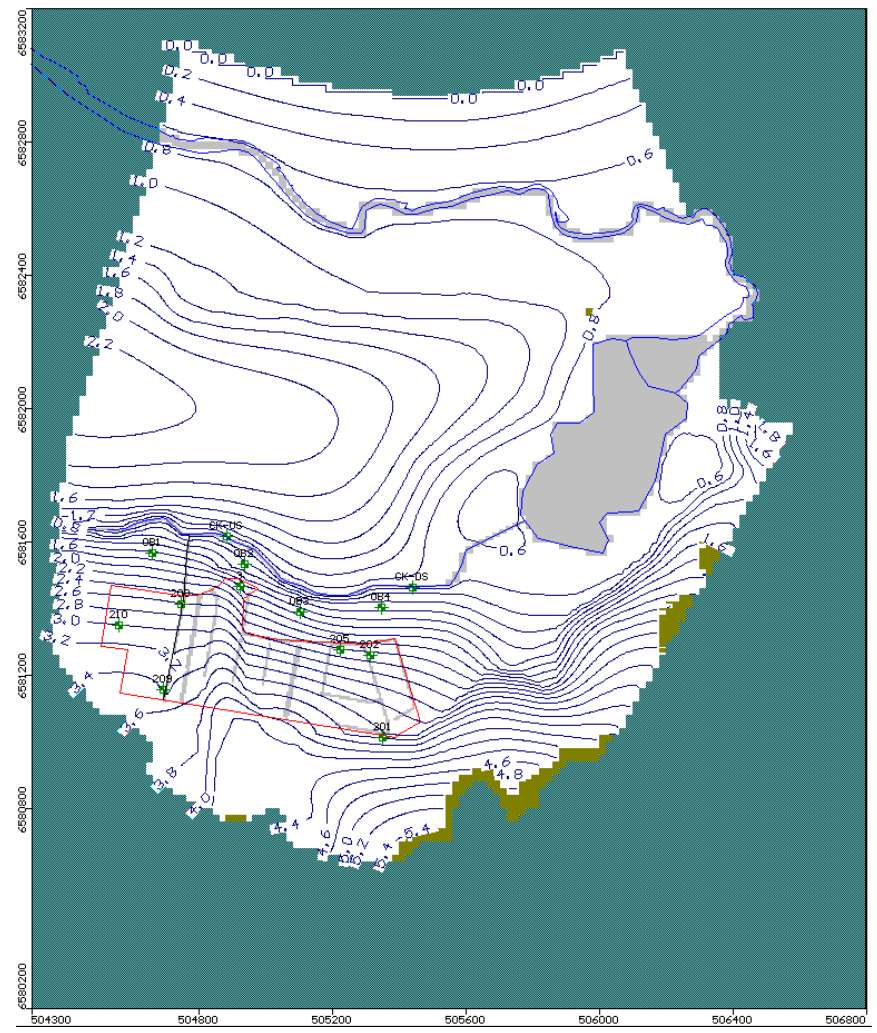
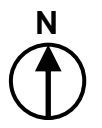


<b>Martens &amp; Associates Pty Ltd</b> ABN 85 070 240 890		<b>Environment   Water   Wastewater   Geotechnical   Civil   Management</b>	
Drawn:	BJR	<b>C1 OUTPUT (I.E STEADY-STATE CALIBRATION)</b>	Drawing No:
Approved:	ASN		<b>ATTACHMENT D - 1</b>
Date:	02.06.2010		Job No: P0802023
Scale:	NA		



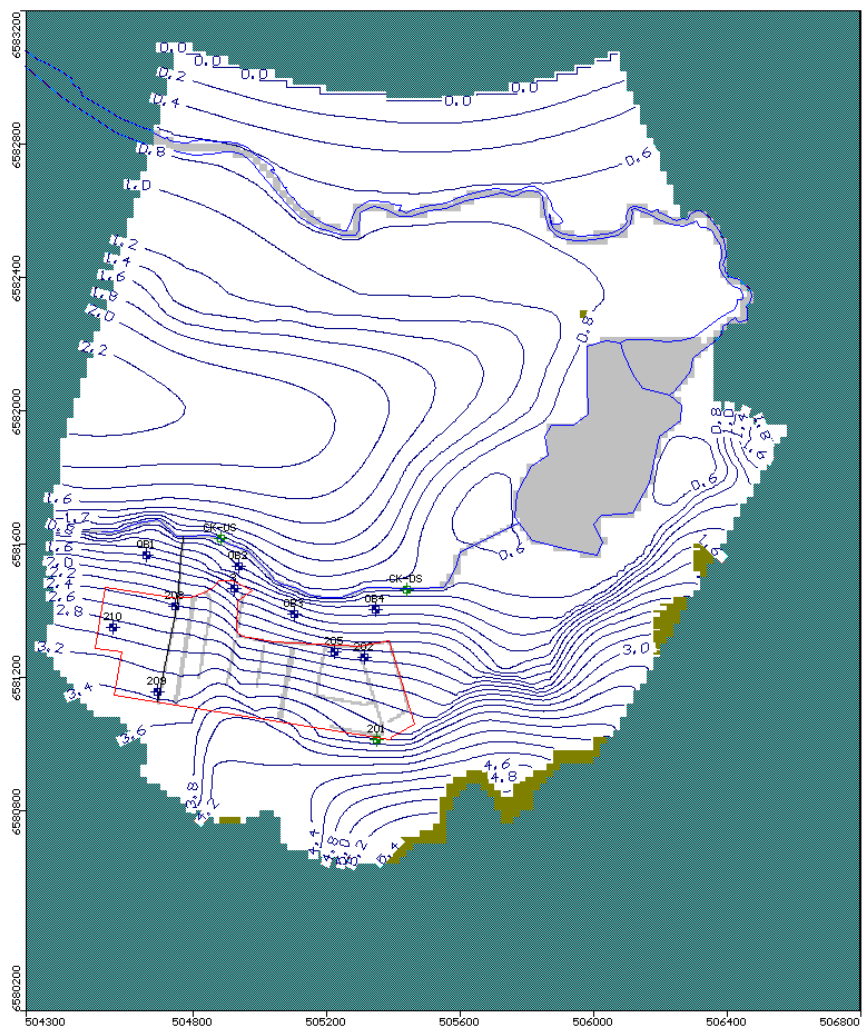
<b>Martens &amp; Associates Pty Ltd</b> ABN 85 070 240 890		Environment   Water   Wastewater   Geotechnical   Civil   Management	
Drawn:	BJR	<b>C2 OUTPUT (I.E TRANSIENT CALIBRATION)</b>	Drawing No:
Approved:	ASN		<b>ATTACHMENT D - 2</b>
Date:	02.06.2010		Job No: P0802023
Scale:	NA		

## 12 Attachment E – Model Results



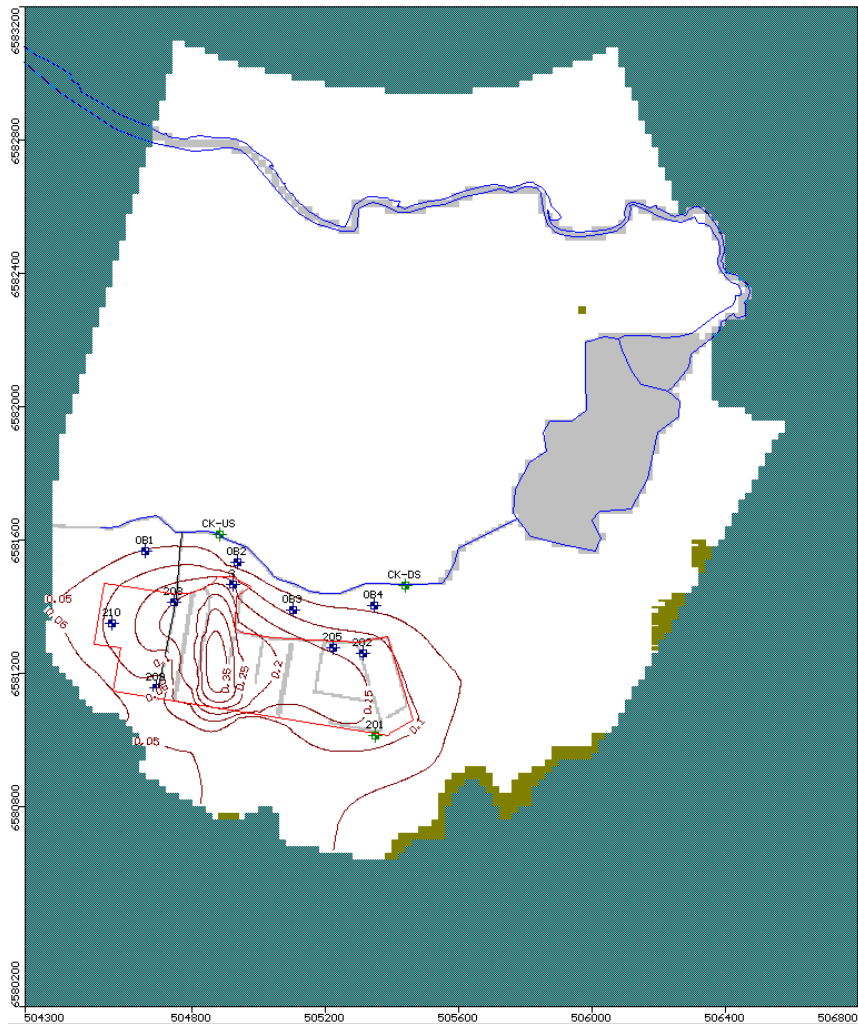
Key:  
 Blue lines – groundwater head contours (0.2 m interval)  
 Silver areas – drain boundary  
 Teal blue – inactive flow  
 Olive – dry cells

<b>Martens &amp; Associates Pty Ltd</b> ABN 85 070 240 890		<b>Environment   Water   Wastewater   Geotechnical   Civil   Management</b>	
Drawn:	BJR	<b>M1 (I.E EXISTING CONDITIONS – STEADY STATE)</b>	Drawing No:
Approved:	ASN		<b>ATTACHMENT E - 1</b>
Date:	02.06.2010		Job No: P0802023
Scale:	Refer to X,Y AXIS		

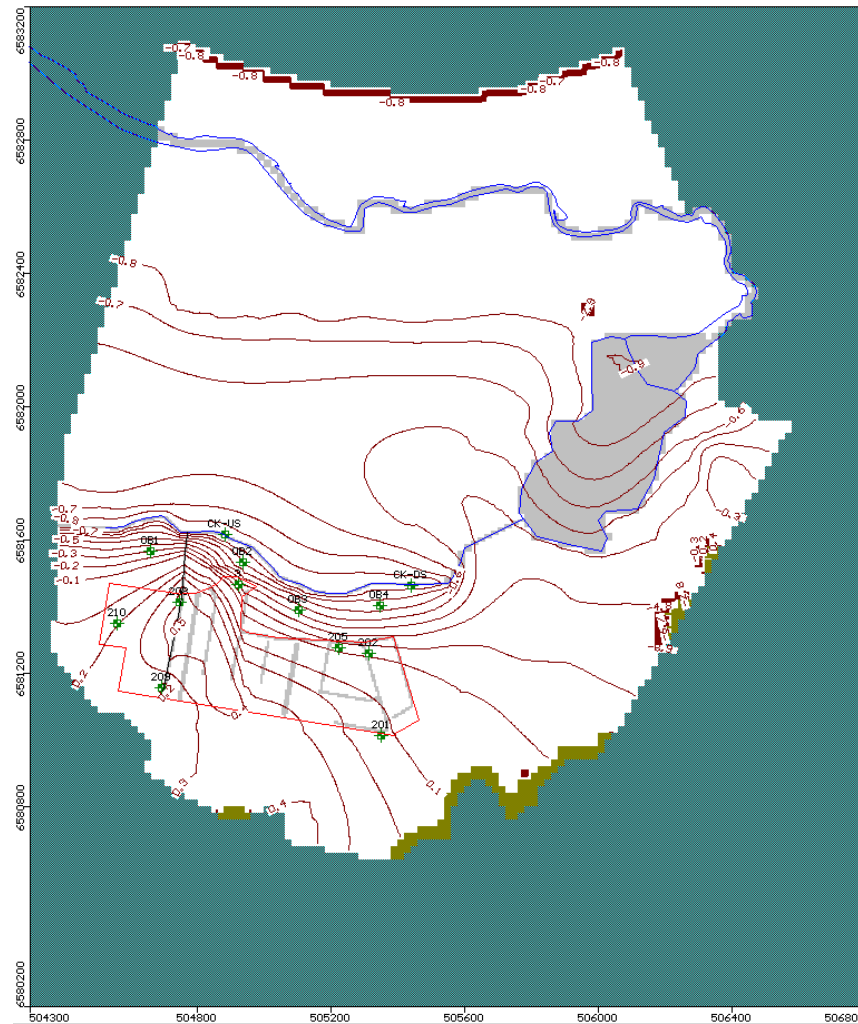


<b>Martens &amp; Associates Pty Ltd</b> ABN 85 070 240 890	
Drawn:	BJR
Approved:	ASN
Date:	02.06.2010
Scale:	Refer to X,Y AXIS

Environment   Water   Wastewater   Geotechnical   Civil   Management	
<b>M3 (I.E DEVELOPED CONDITIONS – STEADY STATE)</b>	Drawing No: <b>ATTACHMENT E - 2</b>
	Job No: P0802023



Drawdown plot with sea level for developed conditions at 0 mAHD.



Drawdown plot for developed conditions with sea level at 0.9 mAHD.

- Key:
- Blue lines – groundwater head contours (0.2 m interval)
  - Silver areas – drain boundary
  - Teal blue – inactive flow
  - Olive – drv cells

<b>Martens &amp; Associates Pty Ltd</b> ABN 85 070 240 890		<b>Environment   Water   Wastewater   Geotechnical   Civil   Management</b>	
Drawn:	BJR	<b>DRAWDOWN PLOT BETWEEN M1 AND M3</b>	Drawing No:
Approved:	ASN		<b>ATTACHMENT E - 3</b>
Date:	02.06.2010		Job No: P0802023
Scale:	Refer to X,Y AXIS		