6.4 a Coastal Inundation Study WBM

BMT WBM Pty Ltd
Level 8, 200 Creek Street
Brisbane 4000
Queensland Australia
PO Box 203 Spring Hill 4004

Tel: +61 7 3831 6744
Fax: + 61 7 3832 3627

ABN 54 010 830 421

www.bmtwbm.com.au

Our Ref: MJA: L.B16650.002.docx

26 September 2012

Ella Bay
PO Box 5766
West End Qld 4101

Attention: Rod Lamb

Dear Rod

RE: ELLA BAY EROSION PRONE AREA RE-ASSESSMENT

I refer to our recent discussions regarding the previous WBM assessment of the erosion prone area at Ella Bay and the comments received from the Department of Environment and Heritage Protection (DEHP).

Since the previous assessment in 2007 there have been two major changes in the legislative guidelines relating to these assessments. Firstly, DEHP now adopts a sea level rise (SLR) prediction of 0.8m (previously 0.3m). Secondly, erosion prone assessments (EPAs) are now required to include the impact of SLR both on inundation and its effect on morphological processes. These components are covered in this updated assessment.

In relation to the higher SLR value consideration has been given to the geography of the area, existing beach profiles and sediment characteristics. It is evident that beach ridges in the area are predominantly wave formed with the coarser particles being moved onshore to the upper beach face/dune and the finer particles remaining in the nearshore zone. This has resulted in beach profiles with two distinct slopes; a steep upper beach face with coarse sand and a flat nearshore zone with fine sand.

The standard method of Bruun (refer Figure 1) for predicting beach response to sea level rise is based on the upper beach/dune sand eroding and depositing in the nearshore zone to maintain the same depths below mean sea level. This rule is not applicable in north Queensland where the beach sand is sorted as described above. Therefore an alternative assessment using recession at the existing beach slope is also used and a nominal value selected based on the two analyses.

The potential impacts of climate change on the extreme sea water level (i.e. storm surge levels) are investigated in the James Cook University Ocean Hazard Assessment Stage 3 report. For example at Flying Fish Point, the 1 in 100year ARI storm tide level with green house allowance is 2.27mAHD (an increase of 0.33m compared to present 1 in 100 year ARI levels). The components of this are 0.3m SLR (the adopted value at the time of the study) and a further 10% (0.03m) for increased storm intensity. Applying the same principal for the current SLR estimate (0.8m) will result in an overall increase of 0.88m including increased storm intensity.

As indicated above the Bruun rule is not an appropriate method for predicting shoreline recession due to sea level rise where the sand profile across the beach is distinctly sorted as in north Queensland. Therefore, calculations are made with both the Bruun and beach slope methods to derive a representative recession value.

For the Bruun method it has been assumed that the depth of closure is 7m and the intertidal beach slope is 1:12 (from survey) and the dune height is 3.0m.

Therefore, the predicted recession = 0.88 * 7 * 12 / (7 + 3) = 7.4m.

For the beach slope method sea level rise of 0.8m at an upper beach slope of 1:12 (from survey) gives a recession of 10.6m.

The above analysis gives an average calculated value of around 10m. However, due to the lack of recent research relating to a shoreline's response to SLR then it is considered appropriate to conservatively allow 30 metres for the future impacts of the predicted Greenhouse induced sea level rise.

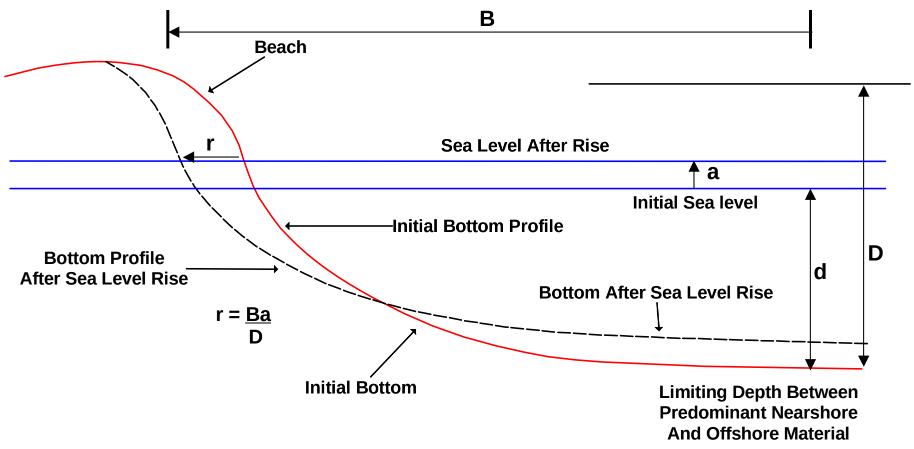

Figure 1: Bruun Rule for Shoreline Response to Rising Sea Level

EPA Width Calculation

On the basis of the components and the factor of safety as discussed in the previous report (WBM 2007) and the updated SLR as above, the erosion prone area width has been determined as follows:

E = [(N x R) + C + G] x (1 + F) + D

where

E = (N x R)	=	20m
C	=	25m
G	=	30m
F	=	0.4
D	=	6m
E	=	111m

It is therefore recommended that an erosion prone area width of 110 metres be adopted for the open beach area. The EPA width is measured from the seaward toe of the frontal dune, which is usually approximated by the vegetation line.

The area around the creek entrance has a higher potential for erosion and therefore the current DEHP width of 165m is considered appropriate.

Inundation Extent

The 100 year ARI storm tide mean water surface level at the shoreline is has been given by DEHP as 2.1mAHD (from Cassowary Coast Storm Tide Study). Therefore, the 100 year ARI design storm tide inundation level at the shoreline is expected to be 2.98mAHD (offshore storm tide level at 2.1mAHD + SLR of 0.8m + storm intensity component of 0.08m).

The predicted 100 year ARI storm tide mean water surface levels are still lower than the dune top height of approx. 3.1m (refer Figure 2 below). Therefore inundation does not impact on the erosion prone area assessment as erosion will continue to act on the face of the frontal dune.

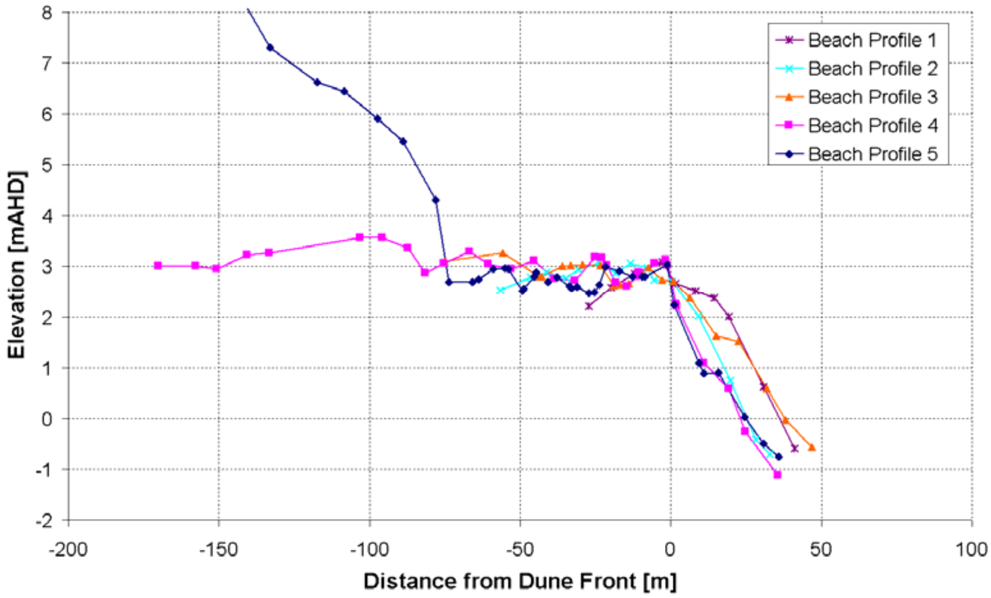

Figure 2: Beach Profiles at Ella Bay

Recommended EPA Widths

Therefore, it is recommended that the EPA widths of 110m for the southern shoreline and 165m for the area surrounding the Creek apply (refer Figure 3).

Figure 3: Recommended EPA widths at Ella Bay

I hope this assessment is sufficient for your current needs. Please do not hesitate to contact me if you require further information.

Yours faithfully
BMT WBM Pty Ltd

Malcolm Andrews

Associate

A part of BMT in Energy and Environment

Ella Bay Integrated Resort

Coastal Inundation Study

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May 2008

Ella Bay Integrated Resort

Coastal Inundation Study

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Prepared For:	Satori Resorts Pty Ltd
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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BMT WBM Pty Ltd BMT WBM Pty Ltd Level 11, 490 Upper Edward Street Brisbane 4000 Queensland Australia PO Box 203 Spring Hill 4004 Tel: +61 7 3831 6744 Fax: + 61 7 3832 3627 ABN 54 010 830 421 002 www.wbmpl.com.au	***Document :*** R.B16650.002.01.doc ***Project Manager :*** Malcolm Andrews ***Client :*** Satori Resorts Pty Ltd ***Client Contact:*** Paul Sparshott ***Client Reference***

Title :	Ella Bay Integrated Resort - Coastal Inundation Study
Author :	Joris Jorissen, Malcolm Andrews
Synopsis :	This report describes the assessments undertaken to determine the storm tide inundation potential of a proposed development site at Ella Bay.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	14 March 2007	MJA		JGJ	
1	19 May 2007	MJA		JGJ	

DISTRIBUTION

DESTINATION	REVISION										
	0		2	3	4	5	6	7	8	9	10
Satori Resorts	PDF	PDF									
EPA	-	-									
WBM File	1	1									
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1 INTRODUCTION

1.1 Background

A residential development is planned over Lot 320 on N157629 at Ella Bay in Johnstone Shire (see Figure 1-1 for locality). The development adjoins the beach area and therefore the identification of coastal hazards of the site is essential. In particular, this will help defining the inundation risks to fauna, flora, humans and property and assist with developing strategies to manage the storm tide inundation risk of the development.

1.2 Study Area

The regional setting for Ella Bay is that it is located to the southern end of a beach about 10km long with substantial headlands of Heath Point immediately to the south and Cooper Point about 6 km to the north. Ella Bay Swamp, a National Park, is situated between the proposed development site and Cooper’s Point. At the mid-point of the bay (at approximately 2.5 km to the north of the site), there is also a small rocky point seaward of Ella Bay Swamp. Cooper Creek flows out into the Coral Sea in the vicinity of Cooper Point. The locality of the development site is presented in Figure 1-1.

To the south Heath Point connects to Flying Fish Point. Immediately to the south of Flying Fish Point is the mouth of the Johnstone River. The Johnstone River supplies substantial amounts of sediment to the beach system to the north including Ella Bay during flood events. The Great Barrier Reef is located approximately 36 kilometres offshore.

The site is within the Wet Tropics Coast Regional Coastal Management Plan.

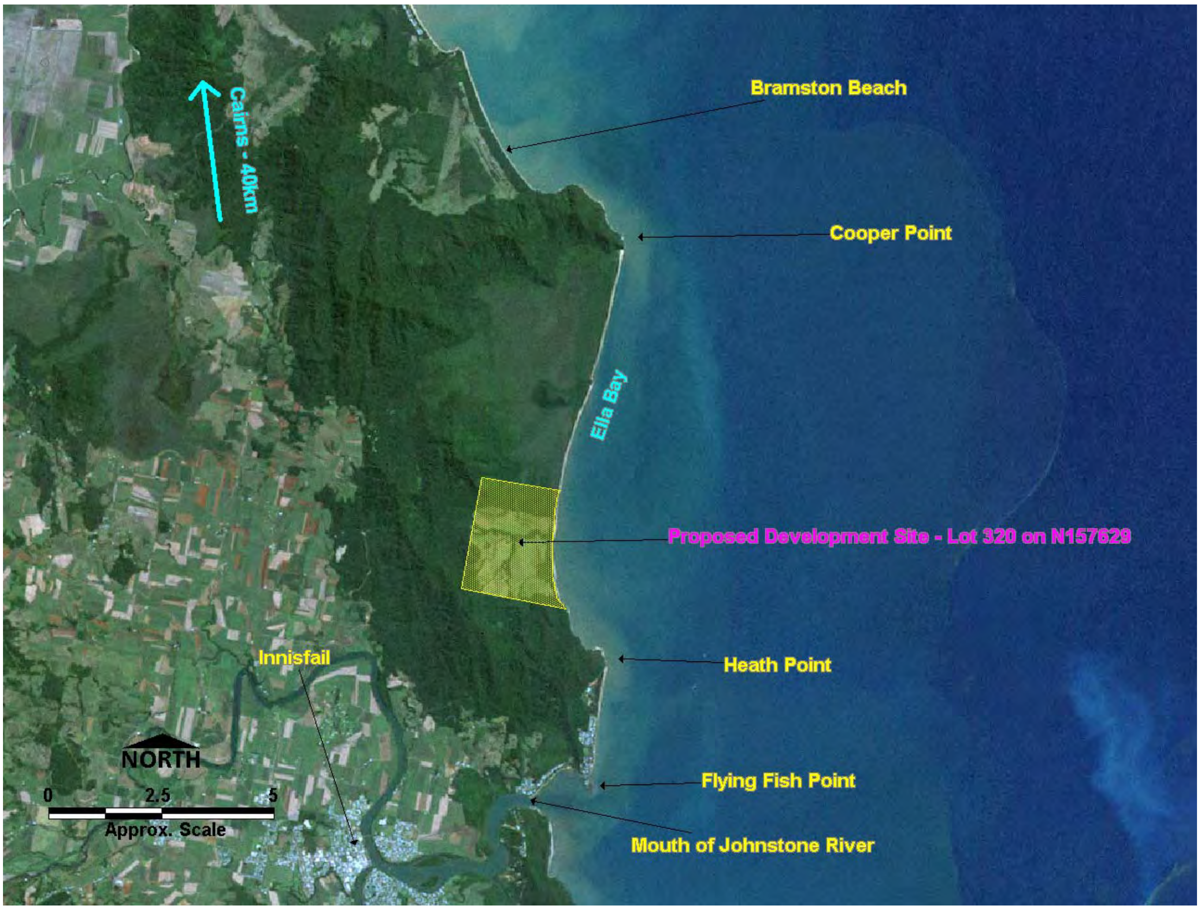

Figure 1-1 Locality Plan

1.3 Site Description

The proposed Ella Bay Integrated Resort site is located immediately behind the beaches of Ella Bay. Most of the site is currently being used as cattle farming land. Most of the surroundings is rainforest and wetland, although there is some development to the south east of the site (The Little Cove Development).

The main creek system on the site is Farm Creek, which comprises the majority of the site's surface water flow. Farm Creek has a number of branches on site. The two main branches join near the centre of the Site. From there, the creek runs across the site eastwards and flows out into sea at the beach on site. In addition to the Farm Creek system, there are a number of smaller watercourses and low-lying wetlands.

Both on the northern bank and southern bank of Farm Creek, there is a wetland swale behind the coastal dunes.

The mouth of the Farm Creek is morphological dynamic and its location varies from year to year [Refer to (WBM,2007A)]. Near the beach, the creek is relatively small, with a width of approximately 30 to 40 m near the beach.

Selected photographs of the beach at Ella Bay are included in Appendix C. The beach is exposed to day to day winds and waves from the southeast to northeast with the south and southeast direction being predominant on average. However, the fetch distances are relatively short because of the proliferation of offshore islands and shoals. There may be some penetration of longer period waves from the Northeast and South (associated with channels and gaps between the islands and shoals) however these will lose a large proportion of their energy due to diffraction, refraction and bottom friction before reaching the site.

The coastal inundation risk of the site is dominated by cyclone-induced storm tide events. During cyclonic conditions, the shoreline may be exposed to the existence simultaneously of high winds, large waves and elevated water levels.

1.4 Proposed Development

The proposed development is known as Ella Bay Integrated Resort and is located on a freehold property. The Master Plan for the proposed development is shown in Appendix A and includes the following key features:

- Low to medium density resorts, units and a day spa located along the eastern boundary of the site over a distance of approximately 1.7 km (near the beach);
- A community centre, sport academy and international school;
- An 18-hole golf course surrounded by residential housing lots; and
- An on-site sewerage treatment plant.

1.5 Previous Studies

In September 2007, BMT WBM undertook an assessment of the erosion potential of the Ella Bay Integrated Resort site (WBM, 2007). As part of this study, beach profiles at the site were surveyed and available coastal studies were reviewed. The coastal studies that were reviewed included Ocean Hazard Assessment report (JCU, 2004), EPA wave data (EPA, 2005) and the Cardwell Inundation Study (BMT WBM, 2007). Further, a surface water and groundwater study for the Ella Bay Integrated Resort site was undertaken by Golder Associates in July 2007 (Golder, 2007).

A summary of the above studies is provided in section 2.

1.6 Scope of Study

The purpose of the study is to assess the coastal inundation risk in accordance with EPA guidelines for "Mitigating the Adverse Impacts of Storm Tide Inundation" (EPA, 2006).

The scope of works for the Ella Bay Integrated Resort Coastal Inundation Study comprised:

- Determine the 100 year ARI design storm tide level at the beach front and in the creek
- Assess the dune overtopping potential
- Determine the coastal hazard level of the proposed development

2 DATA COLLECTION

2.1 Tides Tables

The Maritime Safety Queensland tide station that is closest to the site is Flying Fish Point. Flying Fish Point is listed as a Secondary Place in relation to the Standard Port of Mourilyan Harbour in the 2008 Queensland Official Tide Tables and Boating Guide (Maritime Safety Queensland, 2007). For Flying Fish Point, the Tide Tables report the tidal information shown in Table 2-1.

Table 2-1 Tide levels for Flying Fish Point - From Maritime Safety Queensland (2006)

	Level [m+LAT]	Level [mAHD]
Highest Astronomical Tide (HAT)	3.35	1.72
Mean High Water Spring (MHWS)	2.53	0.9
Mean High Water Neap (MHWN)	1.87	0.24
Mean Sea Level (MSL)	1.69	0.06
Mean Low Water Neap (MLWN)	1.38	-0.25
Mean Low Water Spring (MLWS)	0.72	-0.91
Lowest Astronomical Tide (LAT)	0.00	-1.63

2.2 Previous Studies

Previous studies were reviewed. These studies are listed below and a summary of significant findings is detailed after:

- James Cook University – Ocean Hazard Assessment – Stage 3 report (JCU, 2004)
- EPA - Wave data recording program, Dunk Island, 1998–2002 (EPA, 2005)
- BMT WBM – Cardwell Inundation Study – Cardwell Shire Council (BMT WBM, 2007B)
- Golder - Conceptual Surface Water and Groundwater Hydrology models (Golder, 2007)

2.2.1 Ocean Hazard Assessment (JCU, 2004)

The Ocean Hazard Assessment – Stage 3 report (JCU, 2004) is the third in a series of studies to investigate the community vulnerability in Queensland to tropical cyclones and climate change and is part of the “Queensland Climate Change and Community Vulnerability to Tropical Cyclones” project. The project was completed through the combined efforts of the Queensland Environmental Protection Agency, Department of Natural Resources and Mines, Department of Emergency Services, and the Australian Bureau of Meteorology (Queensland) with much of the numerical modelling completed by the James Cook University.

The Ocean Hazard Assessment – Stage 3 report looked at storm surge levels during tropical cyclones at various locations along the coast of Queensland and the potential impacts of climate change on the storm surge levels.

The report contained the following findings for Flying Fish Point:

- The 100yr ARI storm tide level is 1.94mAHD
- The 100yr ARI storm tide level with green house allowance is 2.27mAHD
- The 500yr ARI storm tide level is 2.19mAHD
- The 500yr ARI storm tide level with green house allowance is 2.64mAHD

The levels above exclude wave setup or wave runup.

2.2.2 Wave data recording program, Dunk Island (EPA, 2005)

This report provides summaries of wave data analysis of wave measurements recorded 12.7km north of Dunk Island and 8km northeast of Clump Point during the period from December 1998 to November 2002. The Dunk Island wave recording station was commissioned as a project to study cyclonic wave conditions by EPA.

The Dunk Island wave station is located approximately 60 km to the south of Ella Bay.

The wave records are based on spectral analysis of Waverider Buoy measurements on a nominal recording interval of 1 hour. The greatest significant wave height recorded at Dunk Island during the period from 1998 to 2002 is 3-3.2m. A wave height exceedance chart based on the wave records is presented in Figure 2-1. No estimations of wave direction data have been provided.

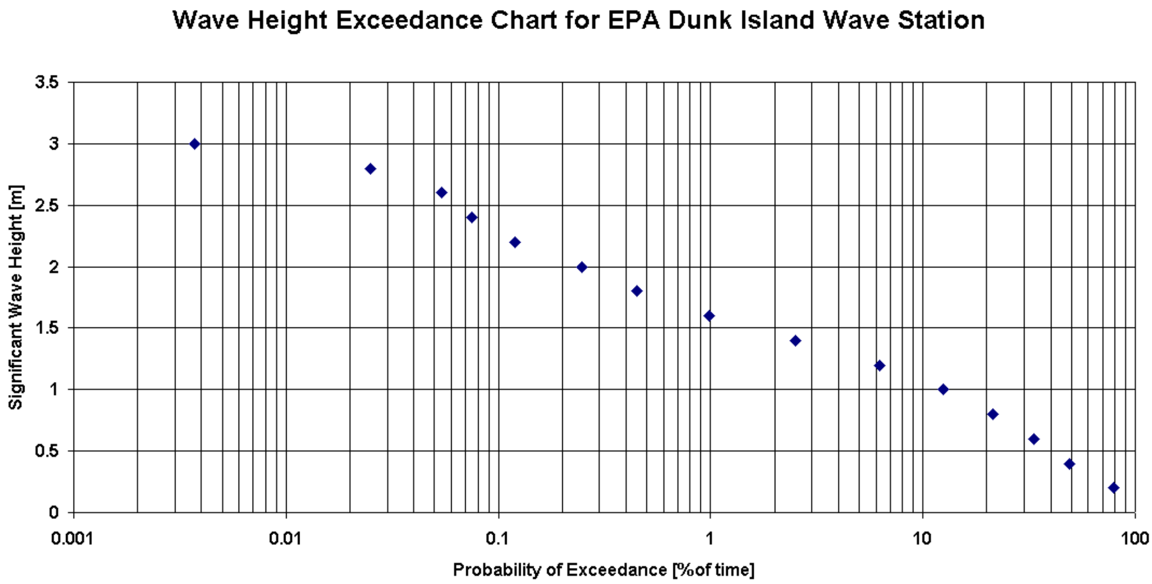

Figure 2-1 Wave Height Exceedance Chart – EPA's Dunk Island Wave Station

For extreme cyclonic conditions, the waves near the proposed development site are likely to be influenced by the limited fetch due to the presence of the Reef. This affects the suitability of the wave records for extreme storm conditions.

2.2.3 Cardwell Inundation Study (WBM, 2007B)

This study investigates the risk for Cardwell Shire Council to coastal and fluvial inundation. The coastal inundation potential is analysed by simulating synthesised tropical cyclone events using a numerical storm surge model.

As part of the study, cyclonic wave conditions were analysed at various locations along the Cardwell Shire coastline using SWAN wave models. The extreme wave conditions were derived from 50,000 years of parameterised tropical cyclone events.

For Wongaling Beach, the most northern location considered by the Cardwell Inundation Study, the 1:100 year maximum significant cyclonic wave height is predicted to be 3.82 m. Wongaling Beach is located 45 km to the south of Ella Bay.

2.2.4 Conceptual Surface Water and Groundwater Hydrology models (Golder, 2007)

This study, prepared by Golder & Associates, discussed the surface water hydrology and groundwater hydrology of the Ella Bay Integrated Resort site and surrounding areas. The report provides information on the topography of the site and the surface water drainage paths. The regional geology was also investigated as part of the study.

The geology of the development site is in the report described as basement rock that is generally overlain by quarternary-aged swamp and lacustrine deposits of silt, mud, clay and sand. The coastal frontage of the site is classed as quarternary-aged sand dune and beach ridge deposits. The quoted width of the sand dune and beach ridge deposits is 25m to 50m.

2.3 Beach Profiles

Surveys across the frontal dune, beach face and intertidal flats were carried in August 2007 at five sections across the site on a vertical datum of AHD. The survey plan is shown in Appendix D.

The five surveyed beach profiles are shown in Figure 2-2. The surveyed beach profiles indicate that the dune crest is typically at approximately 3.1mAHD. The average beach slope is approximately 1 in 10.6.

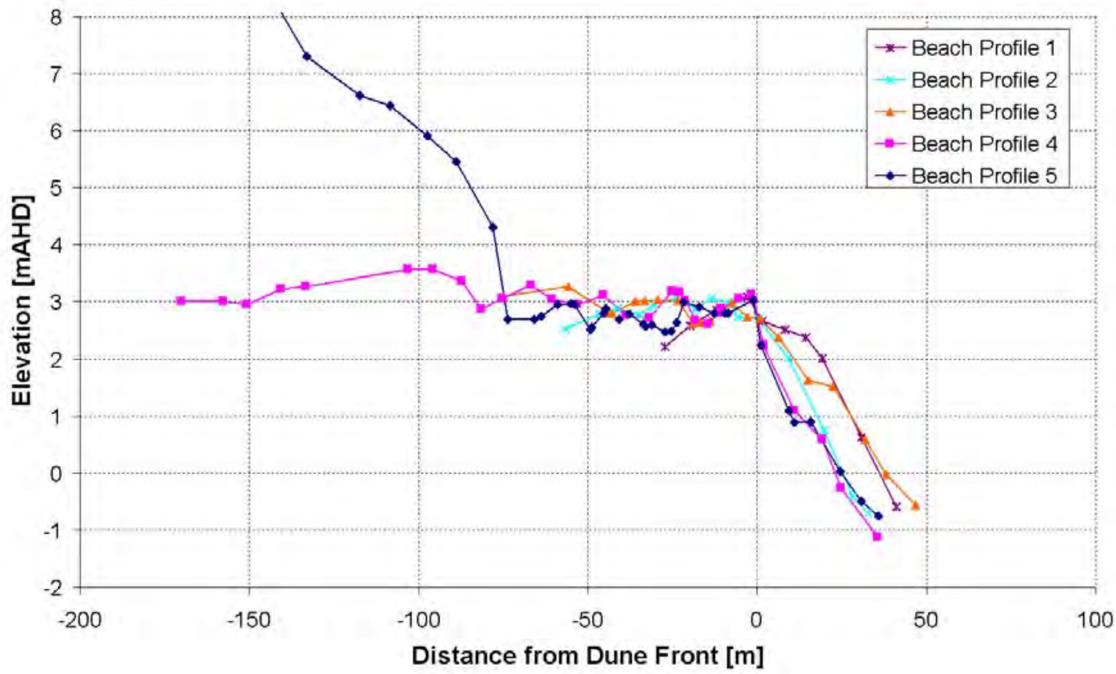

Figure 2-2 Beach Profiles at Ella Bay

2.4 Topographical surveys

A detailed ground survey of a part of the proposed development site was undertaken by C&B Surveyors in December 2007. The ground survey is included in Appendix E. In addition, contour lines by C&B surveyors were made available. These contours are also included in Appendix E. It is noted that the ground surveys do not cover the entire extend of the proposed development site, partly due to the restricted accessibility of areas of the site.

Assessing the ground elevations, it can be noted that the site generally slopes up towards the west with fairly mild slopes. The ground levels in the areas west of the main access road on site (approximately 500m from the shoreline) are generally higher than 5mAHD.

Further, the surveys indicate that there is a low-lying area behind the dunes with ground elevations below the height of the dunes. This zone is typically situated at about 50 to 100 metres from the dune front and consists of densely vegetated wetlands/swales.

In some areas of this low-lying land the ground elevation is below 2.0mAHD. It should however be noted that the topographical information at the low-lying areas behind the dune is limited. This is partially due to restricted accessibility of these locations. No development or land use changes are planned in these wetland/swale areas.

3 ASSESSMENT OF DESIGN STORM TIDE LEVELS

In order to determine the storm tide levels for the site, it is necessary to consider all the scenarios that may cause elevated water levels. At Ella Bay, the extreme storm tide levels are dominated by elevated water levels associated with cyclonic events.

Extreme storm tide levels in the region were investigated in (JCU, 2004). The storm tide level predictions in (JCU, 2006) represent still water level predictions and exclude wave setup and wave runup. In order to determine the coastal inundation level at the proposed development site, it is required to consider the combined effects of atmospheric tide, storm surge, wave setup and runup effects of waves.

In this section, the design storm tide levels for the site including wave setup and wave runup are discussed.

3.1 Storm Tides

Extreme storm tide levels in the region were investigated in (JCU, 2004). For Ella Bay, (JCU, 2004) predicts the following peak storm tide levels:

- The 1 in 100 year ARI storm tide level in 2008: 1.94mAHD
- The 1 in 100 year ARI storm tide level in 2058 (with green house allowance): 2.27mAHD

The storm tide levels above represent still water level and include possible wind setup, barometric setup and impacts of climate change (mean sea level rise plus expected changes due to changes in storm magnitude and frequency). However, the levels do not include the contribution of waves (wave setup and runup).

3.2 Wave Setup and Wave Runup

Wave setup is an elevation of the mean (time-averaged) water surface due to the pumping effect of waves and wave runup is the intermittent process of advancement and retreat of the instantaneous shoreline on a time-scale that is of the order of the incoming wave period (~10s).

Along the wave exposed shoreline wave setup and wave runup can be a significant contributor to the peak inundation levels. Furthermore the large quantity of energy contained in individual wave runup or swash events can pose a serious risk to any structures within the wave runup zone.

The wave setup and setup in coastal inlets differs significantly from the wave setup and runup at the beach. Therefore, the wave setup and runup in the creek on site was calculated separately from the remaining shoreline.

3.2.1 Extreme Waves at Ella Bay

Extreme cyclone-induced wave conditions in the nearby beaches in the Cardwell Shire were investigated in “Cardwell Inundation Study” (WBM, 2006). For Wongaling Beach, a beach that is located about 45km to the south of Ella Bay, the predicted 1 in 100 year ARI significant wave height is 3.82m and a typical peak wave period of about 10 s.

Given the proximity of Wongaling Beach (45 km to the south of the site) and the degree of similarity of the coastline configuration, the wave conditions at Ella Bay are expected to be similar to the wave conditions at Wongaling Beach.

For extreme cyclonic conditions, the waves at both Wongaling Beach and Ella Bay are likely to be influenced by the limited fetch due to the presence of the Great Barrier Reef. Because the Great Barrier Reef at Wongaling Beach is located further offshore than at Ella Bay, the extreme wave heights at Ella Bay may be marginally smaller than at Wongaling Beach.

Nevertheless, it was therefore considered appropriate to use the extreme offshore wave predictions of Wongaling Beach for the Ella Bay beaches. The 100 year ARI offshore wave condition at the site is a significant wave height of 3.82m and a peak wave period of 10 s.

3.2.2 Wave setup and Wave Runup at Shoreline

Wave setup is a phenomenon that can be understood by observation of the shore-normal momentum balance in the surf zone. Due to wave breaking, the radiation stress decrease rapidly towards the shore. This results in a residual force towards the shore, which generates a positive mean water surface gradient to the shore. Over the last decades, several empirical parameterisation studies have been undertaken to estimate wave setup and runup.

For this study, the wave setup and runup on the ocean facing shoreline was calculated using the empirical wave setup model of Stockdon et al. (2006). In Stockdon model both the wave setup and runup are a function of foreshore beach slope, wave height and peak wave period.

Wave setup by Stockdon et al. (2006):.

$$s_{shoreline} = 0.35 \cdot \beta_f \sqrt{H_{s,0} \cdot L_0}$$ **Equation 1**

with:

$s_{shoreline} =$ Wave setup at the shoreline [m]

$\beta_f =$ Foreshore beach slope = 1 in 10.6 [-]

$H_{s,0} =$ Offshore significant wave height [m]

$L_0 = \dfrac{gT^2}{2\pi}$ = Deepwater wave length [m]

Wave runup by Stockdon et al. (2006):.

$$R_{2\%} = s_{shoreline} + \frac{\sqrt{S_{inc}^2 + S_{IG}^2}}{2}$$ **Equation 2**

with:

$R_{2\%}$ = Wave runup exceeded by 2% of the waves [m]

$s_{shoreline}$ = Wave setup at the shoreline [m]

S_{inc} = Runup for incident swash = $0.75 \cdot \beta_f \sqrt{H_{s,0} \cdot L_0}$ [m]

S_{IG} = Runup for infragravity swash = $0.06\sqrt{H_{s,0} \cdot L_0}$ [m]

Using the 100 year ARI design wave conditions of Wongaling Beach (H_s of 3.82m and T_p of 10 s), the calculated wave setup at the Ella Bay shoreline is 0.81m and the calculated 2% wave runup is 1.94m.

It is noted that for situations where the foredune is overtopped by the combination of storm tide and wave runup, the wave runup height will be lower as there is then no slope to runup on.

3.2.3 Wave Setup in Farm Creek

It is important to note that water levels created by wave setup will not translate far into tidal inlets and wave setup may be significantly smaller within inlets and creeks. The wave setup formula presented in section 3.2.2 is therefore only applicable to the shoreline that is under direct attack of waves (i.e the beach of Ella Bay). Within Farm Creek, the creek that runs across the site, the wave-generated water level setup will be less.

Field measurements of Nielsen et al. (1989) and Hanslow et al. (1996) show that in a trained river (like the Brunswick River) waves generate no measurable wave setup (at least up to 4m H_s).

Nevertheless, the wave setup contribution to the storm tide levels in the creek was calculated using empirical formulae by Hanslow and Nielsen (1993). In Hanslow and Nielsen (1993), the mean water surface setup across the surf zone is a function of the relative water depth.

The wave setup across the surfzone, according to Hanslow and Nielsen (1993), is shown in equation 3.

$$\eta(h) = \frac{0.048\sqrt{H_{0,rms} L_0}}{1 + 10\dfrac{h}{H_{0,rms}}}$$

Equation 3

with:

$\eta(h) =$ Local wave setup [m]

$h =$ Local water depth [m]

$H_{0,rms} =$ Offshore root-mean square wave height [m]

$L_0 = \dfrac{gT^2}{2\pi} =$ Deepwater wave length [m]

With the creek bed level at the creek mouth at about LAT (-1.63mAHD), the calculated wave setup in the creek is about 0.07m.

As a conservative approach, an allowance of 0.3m is recommended for wave setup in Farm Creek.

3.3 Climate Change Impacts

There is a generally consensus that changes in atmospheric concentrations of the so-called greenhouse gasses will change climate patterns. Research on likely climate change impacts indicates that two fundamental impacts may affect the shoreline, namely:

- Mean sea level rise; and
- Changes to frequency and magnitude of Tropical Cyclones.

The following sections discuss the two possible impacts

3.3.1 Mean Sea Level Rise

Although, to date there have been no conclusive studies that quantify future sea level rise, sea level has been rising at about 1.0-1.5 mm/year for many years and it is expected that this rate of rise will accelerate in the future due to the effects of climate change.

There are uncertainties as to the actual magnitude and rate of future sea level rise. This has lead to various scenarios being adopted by the Intergovernmental Panel on Climate Change (IPCC), based on the range of model results available and dependent upon the amount of future emissions assumed. Based on the IPCC 2001 upper bound of the 50-year sea level rise, an allowance of 0.3 m for global warming induced sea level rise is recommended for developments with a planning horizon of 50 years. This allowance is consistent with recommendations of The Institution of Engineers, Australia, National Committee on Coastal and Ocean Engineering and EPA recommendations for shoreline erosion assessments. A Mean Sea Level Rise of 0.3 m was also assumed in Ocean Hazard Assessment (JCU, 2004)

3.3.2 Changes to storm magnitude and frequency

Both magnitude and frequency of waves and storm tides may be affected by changes in the frequency and magnitude of tropical cyclones. The affect of the possible changes on extreme storm tide levels was investigated in the Ocean Hazard Assessment; refer to (JCU, 2004).

According to (JCU, 2004), the 100 year ARI storm surge level near the site (without wave setup) is set to increase by 0.33m over the coming 50 years (0.03m or 10% more than the expected mean sea level rise).

3.4 Conclusions on Storm Tide Levels

In order to determine design storm tide levels for the site, it is necessary to consider all the scenarios that may cause elevated water levels. At Ella Bay, the extreme storm tide levels are dominated by elevated water levels associated with cyclonic events.

The design wave runup level for the Ella Bay shoreline is defined by the 1 in 100 year ARI design storm tide level plus 2% wave runup and is estimated to be 4.21mAHD (offshore storm tide level at 2.27mAHD + wave runup of 1.94m). It is noted that the calculated wave runup height is greater than the dune crest height at the site. As a result, significant dune overtopping may be expected during 100 year ARI design conditions (Refer to section 4.2).

The 100 year ARI storm tide mean water surface level at the shoreline is estimated to be 3.08mAHD (offshore storm tide level at 2.27mAHD + wave setup of 0.81m). The predicted 100 year ARI storm tide mean water surface level is similar to the dune top height.

The 100 year ARI design storm tide inundation level in the mouth of Farm Creek (inland of the beach) is estimated to be 2.57mAHD (offshore storm tide level at 2.27mAHD + wave setup of 0.3m).

The storm tide levels above include possible impacts of climate change over the planning period of the development (50 years).

4 ASSESSMENT OF COASTAL INUNDATION HAZARD

The State Coastal Management Plan defines Natural Hazard Management Areas (storm tide) by land inundated by HAT plus a nominal 1.5m (based on state-wide storm tide statistics). The definition of the Natural Hazard Management Areas (Storm Tide) may be refined by site-specific coastal inundation study. This section details the site-specific coastal inundation assessment that was undertaken for the Ella Bay Integrated Resort site.

The coastal inundation levels across the site were assessed by analysing the main inundation mechanisms that cause flooding on the site. During storm tide events, seawater may inundate the developed site through two inundation mechanisms, namely:

- Wave overtopping of the dune front; and
- Backwater flooding into creek entrance of Farm Creek

The assessment of the 100 year ARI flood conditions as a result of these coastal inundation mechanisms is discussed below.

4.1 Wave Overtopping

4.1.1 Waver Overtopping Discharges

The assessment of the storm tide levels has indicated that the mean water surface level at the shoreline during 100 year ARI design conditions is similar to the dune top height (3.08mAHD vs. 3.1mAHD). Due to wave oscillation (advancement and retreat of the instantaneous waterline on a time-scale of a wave period), seawater may overtop the dune front.

To estimate the volume of seawater that potentially overtops the dune front, the methodology described in Eurotop “Wave Overtopping of Sea Defences and Related Structures: Assessment Manual” (EA/ENW/KFKI, 2007) was used.

Schüttrumpf (2001) performed model tests for different straight seadikes with smooth slopes between 1:3 and 1:6 to investigate wave overtopping for zero freeboard. On the basis of these model tests, he derived formulae to predict the wave overtopping discharge.

For a breaker parameter of smaller than 2.0 ($\xi_{,m-1,0}$), Schüttrumpf (2001) suggests the following mean overtopping discharge:

$$q = 0.0537\xi_{m-1,0}\sqrt{gH_{m,0}{}^{3}} \qquad \textbf{Equation 4}$$

with:

$q =$ Mean overtopping discharge per linear metre shoreline [m3/s/m]

$\xi_{m-1,0} = \dfrac{\tan\alpha}{H_{m,teo}/L_{toe}}$ = Breaker parameter; f(beach slope, wave steepness at toe) [-]

$H_{m,toe} =$	RMS wave height at toe	[m]
$L_{toe} =$	Mean wave length at toe	[m]

In equation 4, it can be seen that the wave overtopping discharge in the Schüttrumpf model is a function of the wave condition at the toe of the seadike. For the situation in Ella Bay, where the location of a toe is less defined, the wave conditions in the nearshore zone near the beach have been used.

Given that the nearshore zone in front of the beach is relatively shallow, wave breaking will be experienced during design wave conditions (depth-limited breaking). Using a breaker index of 0.55 (natural dissipative beach), the Schüttrumpf model predicts a mean dune front overtopping discharge of 0.20m^3/s per linear metre of shoreline.

Although the wave overtopping discharge is expressed as a mean discharge, in reality, there is no constant discharge over the crest of a structure during overtopping. The process of wave overtopping is very random in time and volume. The highest waves will push a large amount of water over the crest in a short period of time, less than a wave period. Lower waves may not produce any overtopping.

It is noted that the tests by Schüttrumpf were undertaken for seadikes, where the overtopping rate is unaffected by the geometry and roughness of the hinterland (no flow obstruction), whereas the wave overtopping rate at this site would be significantly reduced due to substantial friction caused by the dense vegetation fronting the site. Experimental research on the impacts of Vetiver grass on wave overtopping discharge (Vu Minh Anth, 2007) suggests that medium dense Vetiver grass can reduce the wave overtopping discharge by approximately 55%, while for dense Vetiver grass reductions up to 70% were found.

Furthermore, the beach slope at Ella Bay is significantly milder than slopes tested by Schüttrumpf. Milder slopes generally result in smaller overtopping rates.

To account for the factors above, it is considered appropriate to apply reduction factors. To account for the obstruction effect of the dense vegetation on the dune top a reduction of 55% is considered to be appropriate and for the milder slope a reduction of 20% is applied.

Applying these reduction factors, the mean overtopping discharge at the dune front would be 0.05 m^3/s per linear metre shoreline or 50 l/s/m.

The majority of the wave overtopping volume will be attenuated in the dunes adjacent to the beach and will directly flow back into sea when the instantaneous waterline has retreated (during wave troughs). However, a proportion may penetrate into the wide zone of dense vegetation that is located between the beach and the proposed developments of the Resort. The zone of dense vegetation, which will remain as part of the development, is typically about 100m wide.

Allowing for an equal distribution between the discharge that directly flows back into sea when the instantaneous waterline has retreated and the discharge that penetrates into the densely vegetated zone, the 100 year ARI design mean overtopping discharge behind the dune front would be 25 l/s per linear metre shoreline. This flow may run landwards through the vegetated zone, where a portion may infiltrate into the soil.

4.1.2 Wave Overtopping Volume Losses to Soil Infiltration

A portion of the seawater that overtops the dune front may infiltrate into the soil. Based on the geology as described in the (Golder, 2007) report, the area on site were significant infiltration of overtopped seawater can occur is limited to the 25m to 50m wide zone directly behind the beach (coastal sand dunes and beach ridges). The remaining parts of the site are either swamps or consist of mostly silt, mud or clay deposits. Silt, mud or clay soils have a relative small hydraulic conductivity.

4.1.2.1 Infiltration capacity

Until specific measurement and tests are performed for the sand dunes on site, a precise estimate of the soil infiltration capacity and/or groundwater hydraulic conductivity is not possible.

Nevertheless, an estimate of the soil infiltration capacity of the dunes was made. Based on a literature review on the hydraulic conductivity of sandy soils, the infiltration capacity of the dunes is estimated to be in the range between 180 to 600mm/hour.

4.1.2.2 Groundwater Table during Design Storm Conditions

Although the horizontal hydraulic conductivity of the dunes is expected to be high and therefore the groundwater table in the dunes will be influenced by the prevailing seawater levels, the groundwater table is expected to be substantial lower than the peak storm tide level at the shoreline due to relative short duration of the storm surge in relation to the response time of the groundwater levels in the dunes.

In this assessment, it is assumed that the groundwater table remains below the ground surface during the period that wave overtopping is experienced in a design storm tide event.

4.1.2.3 Resulting Soil Infiltration Losses

A portion of the seawater that overtops the dune front will infiltrate into the soil as seepage.

Using a typical hydraulic conductivity for dunes, the potential infiltration rate of overtopped seawater that infiltrates into the dunes may be about 2 to 6 l/s per linear metre of shoreline. This is equivalent to about 8 to 24% of the wave overtopping discharge that potentially penetrates onto the site.

It is noted that in order for soil infiltration to be able to occur, it is necessary that the groundwater table is below the ground surface and infiltration of overtopped seawater may increase the local groundwater table. This potentially may lead to a reduction in the infiltration rate.

4.2 Backwater flooding via Farm Creek

An important flooding mechanism due to storm tide events is elevated seawater levels backing into Farm Creek and inundating low-lying areas around the creek. The 100 year ARI peak flood level in the creek is estimated to be 2.57mAHD (storm tide level plus climate change allowance and wave setup).

With the exception of the area around the mouth of the creek, the flow velocities as a result of elevated seawater levels backing into the creek are expected to be low.

4.3 Assessment of Coastal Inundation Level

The two main mechanisms of coastal inundation, which can cause flooding on the development site, are wave overtopping of the dunes and backwater flooding into the creek mouth of Farm Creek. These flooding mechanisms, if experienced, are likely to occur simultaneously.

During the 100 year ARI design storm tide event, elevated seawater levels will back into Farm Creek, with a flood level of 2.57 mAHD at the creek mouth as a result.

At the same moment, wave overtopping may be experienced at the dunes. A portion of the wave overtopping volume has the potential to penetrate through the densely vegetated area and flow into the low-lying wetland swales, which are located behind the dunes. The wave overtopping discharge that flows onto the development site (behind the dunes) is estimated to be around 19 to 23 l/s per linear metre shoreline.

As a result of wave overtopping, the peak flood levels around the swales may be greater than peak flood level in creek mouth (2.57mAHD), but are unlikely to be greater than the mean dune top height, which is estimated to be at 3.1mAHD.

Without further investigations (eg. hydraulic modelling), the recommended coastal inundation design level for proposed developments that are located east of the main road reserve is 3.1mAHD (Refer to Masterplan). For proposed developments that are located west of the main road reserve, the recommended coastal inundation design level is 2.57mAHD.

4.4 Coastal Inundation Hazard

The suitability of developments in coastal regions is dependent on the coastal hazard level of the existing land and the compatibility of the development to that hazard level. Residential developments are incompatible with a “high” coastal inundation hazard level. In “low” coastal hazard areas, residential developments may be considered provided that suitable measures are implemented to mitigate the adverse affects of coastal inundation.

In Guideline of State Coastal Management Plan (EPA, 2006), areas are classed as “high” coastal inundation hazard zones if prior to development one of the following criteria is met:

- Inundation depth equal or greater than 1m;
- Wave heights equal or greater than 0.9m;
- Depth x Velocity Product is equal or greater than 0.3 m^2/s.

4.4.1 Coastal Hazard - Inundation Depth

The recommended coastal inundation design level for proposed developments that are located east of the main road reserve is 3.1mAHD and 2.57mAHD for proposed developments that are located west of the main road reserve.

Based on these levels, land that is located east of the main road reserve and has an existing ground level of 2.1mAHD or less is according to the Guidelines of State Coastal Management Plan classed as a high coastal hazard zone. For the areas west of the road reserve, land with an existing ground elevation of 1.57mAHD or less is according to these guidelines classed as a high coastal hazard zone.

4.4.2 Coastal Hazard – Wave Height

Given the height of the dunes and the width of the dense vegetation fronting the site, the wave action resulting from waves overtopping the dunes is expected to be negligible. In addition, the wave action on site as a result of waves propagating into the creek entrance of Farm Creek is considered to be small (narrow creek opening and angled to the shoreline).

4.4.3 Coastal Hazard – Depth Velocity Products

Generally the flow velocities in the areas west of the main road reserve are expected to be low during design storm tide events as these areas are inundated by seawater backing into Farm Creek. In the low-lying areas behind the dunes (around the swales), there is a potential for a flow to develop in order to drain the seawater that is entering the site by overtopping of the dunes. The depth velocity products associated with this flow could not be assessed on the basis of the available information.

5 CONCLUSIONS

A residential development is planned over Lot 320 on N157629 at Ella Bay in Johnstone Shire (see Figure 1-1 for locality). The Master Plan for the proposed development is shown in Appendix A. The development adjoins the beach area and therefore the identification of the coastal inundation hazard of the site is essential.

In order to identify the coastal hazard inundation levels of the site the extreme storm tide levels at Ella Bay and inundation levels on the proposed development site have been assessed. This report presents the outcomes of this assessment.

On the basis of the assessments undertaken, the following is noted:

- Extreme elevated seawater levels at Ella Bay are dictated by storm tide events associated with cyclonic events.
- The storm tide levels for the site are based on offshore storm tide levels predicted by the Ocean Hazard Assessment (JCU, 2004) with inclusion of applicable wave setup.
- Wave setup and wave overtopping calculations were undertaken with a conservative estimate of the 100 year ARI wave height at the site. The adopted 100 year ARI offshore significant wave height was 3.82m. The calculated wave setup on the shoreline is 0.81m and 0.07m in the mouth of Farm Creek. Although the calculated wave setup in the mouth of Farm Creek is only 0.07m, nevertheless a wave setup allowance of 0.3m was adopted for the assessment of the 100 year ARI storm tide level in the mouth of Farm Creek. This is a precautious approach.
- The 100 year ARI storm tide mean water surface level at the shoreline is 3.08mAHD and 2.57mAHD in the mouth of Farm Creek. These levels include allowance for possible climate change impacts over the planning period of the development (50 years).
- The beach profile surveys of the site show that the crest level of the dunes is typically at approximately 3.1mAHD, which is a similar level as the 100 year ARI storm tide mean water surface level at the shoreline.
- Due to the fact that the dune front is at a similar level as the 100 year ARI storm tide mean water surface level at the shoreline, significant wave overtopping will be experienced at the dune front during design storm conditions. Although, the majority of the wave overtopping volume will directly flow back into sea when the instantaneous waterline has retreated (during wave troughs), a portion may penetrate through the dense vegetated zone that is fronting the site.
- The wave overtopping discharge that flows onto the development site (through the dense vegetated zone) is estimated to be around 19 to 23 l/s per linear metre shoreline.
- The wave overtopping volume, which enters the site, will generally flow into the low-lying swales that are located behind the coastal dunes. During severe wave overtopping events, there is a potential that a flow towards Farm Creek develops in order to drain the area behind the dunes. It was not possible to assess the flow conditions of this possible flow in this study.
- The recommended coastal inundation design level for proposed developments that are located east of the main road reserve is 3.1mAHD and 2.57mAHD for proposed developments that are located west of the main road reserve.

- Land that is located east of the main road reserve and has an existing ground level of 2.1mAHD or less is according to the guidelines of State Coastal Management Plan classed as a zone of high coastal hazard. For areas to the west of the main road reserve, land with an existing ground elevation of 1.57mAHD or less is according to the guidelines classed as a zone of high coastal hazard.
- In areas that are inundated by the 100 year ARI design storm tide event but not classed as "high coastal hazard" zones, residential developments may be considered provided that suitable measures are implemented to mitigate the adverse impacts of coastal inundation.
- Where drainage paths are not significantly obstructed, filling of allotments is considered to be a suitable mitigation measure. For residential allotments that are located to the east of the main road reserve, a minimum fill level of 3.1 mAHD is recommended.

6 REFERENCES

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APPENDIX A: MASTER PLAN OF ELLA BAY INTEGRATED RESORT

Figure A-1 Master Plan Layout of Ella Bay Integrated Resort

APPENDIX B: GROUND PHOTOGRAPHS – JUNE 2007

Figure B-1 Ella Bay From Heath Point

Figure B-2 Beach of the Proposed Development Site, Looking North

Figure B-3 Dune Scarps near Site

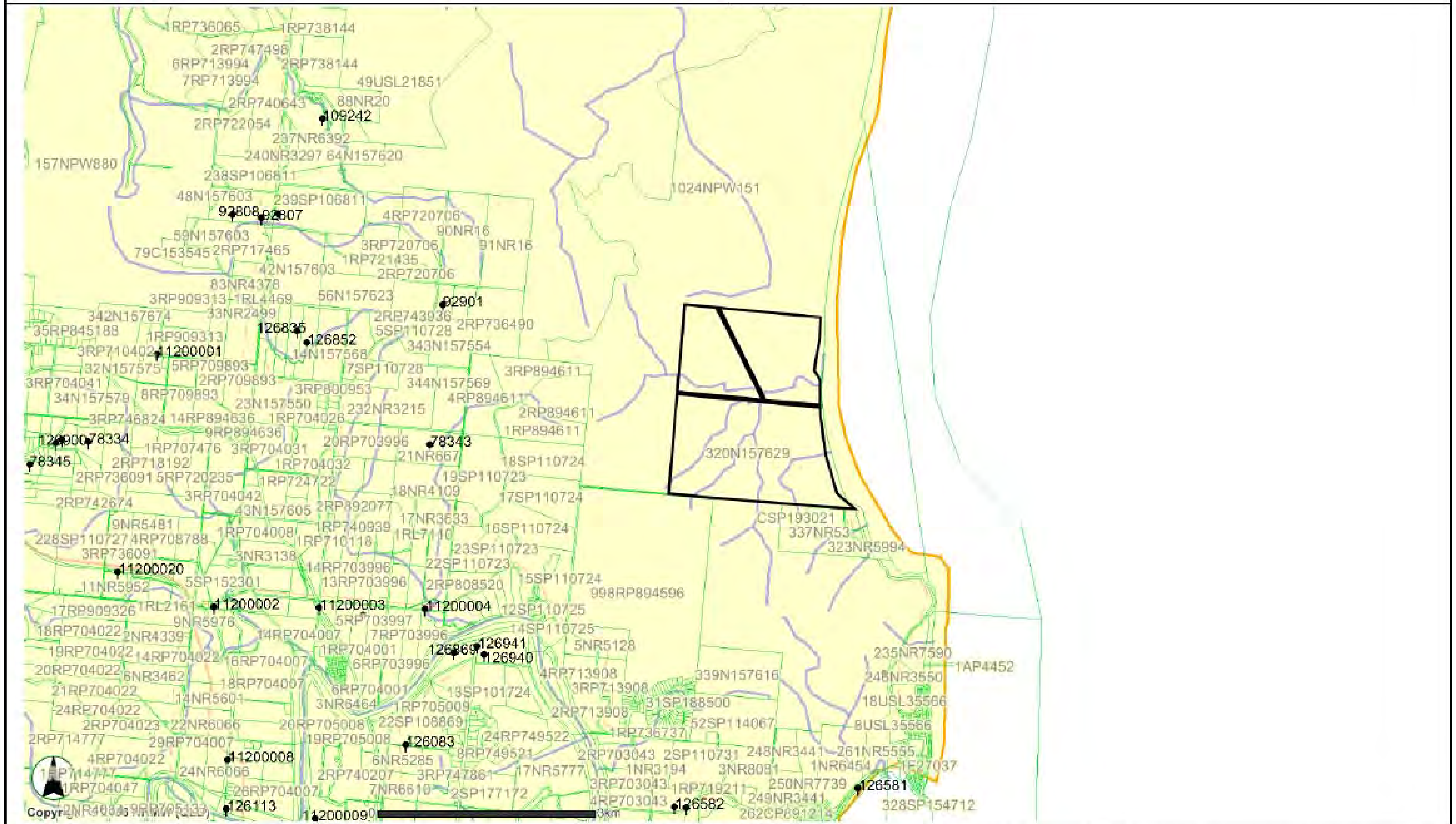
Figure B-4 Pioneer Vegetation on Beach Dune near Site

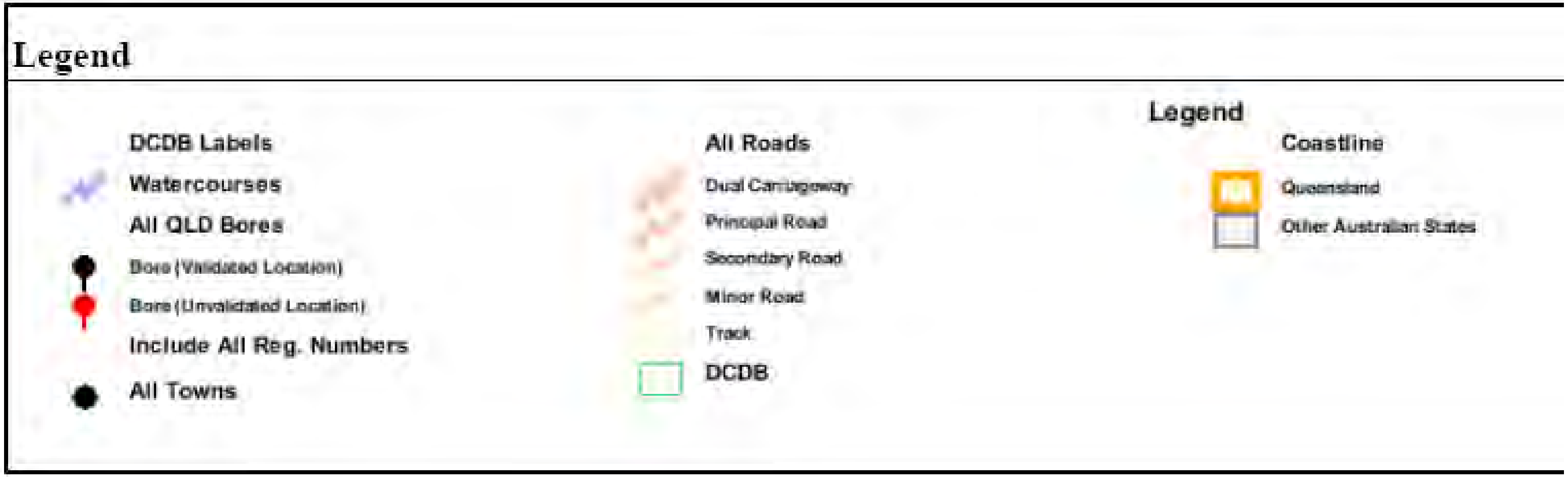
Figure B-5 Location where Creek approaches the Beach

Figure B-6 Creek Meandering at Proposed Development Site

APPENDIX C: IDENTIFIED WATER COURSES BY DNR

Lot 320 N157629

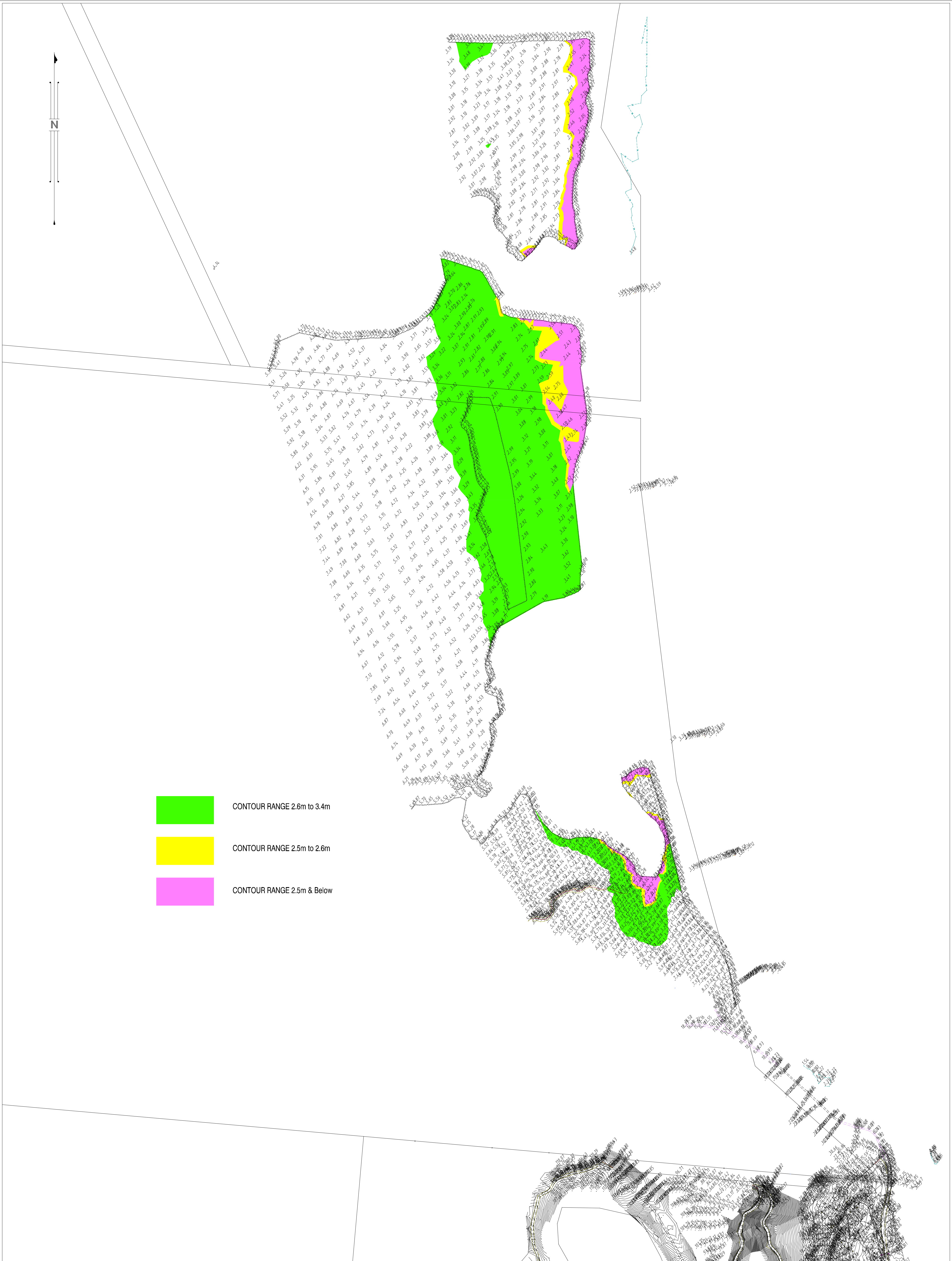



Legend
Legend
DCDB Labels
Watercourses
All QLD Bores
Bore (Validated Location)
Bore (Unvalidated Location)
Include All Reg. Numbers
All Towns
All Roads
Dual Carriageway
Principal Road
Secondary Road
Minor Road
Track
DCDB
Coastline
Queensland
Other Australian States

APPENDIX D: BEACH PROFILE SURVEYS

Figure D-1 Survey Plan of Surveyed Beach Profiles

APPENDIX E: TOPOGRAPHICAL SURVEYS



NOTES

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Origin of Levels: PM 21932
RL 3.672

Meridian: MGA Zone 55

Origin of Coordinates: PM 166747
E 400699.57
N 8068620.034
RL 4.069

Contour Interval:
Index:

Miscellaneous:

0 30 60 90 120 150
metres

SCALE 1:3000 IS APPLICABLE ONLY TO THE ORIGINAL SHEET SIZE. (A1)

PROJECT MANAGER/SURVEYOR RJB	DESIGNED		
CHECKED	SURVEYED		
DRAWN RJB 12/12/07	FIELD BK.	LEVEL DATUM AHD	
DRAFTING CHECKED	SHEET SIZE A1	SHEET 1 OF SHEETS 1	
CAD 30840-32.DWG 30840100.CIV	SCALE 1:3000		

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CONTOUR RANGE
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PO Box 59 INNISFAIL QLD 4860
Tel: (07) 4061 2211
Fax: (07) 4061 4631
innisfail@cbgroup.com.au
www.cbgroup.com.au

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AMENDED	ISSUE	DRAWING NO.
		30840/32


2.0
9.5
7.3
5.6
4.0
3.1
3.2
11.5
10.0
5.3
2.6
5.4
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9.9
15.4
9.9

BMT WBM Brisbane	Level 11, 490 Upper Edward Street Brisbane 4000 PO Box 203 Spring Hill QLD 4004 Tel +61 7 3831 6744 Fax +61 7 3832 3627 Email wbm@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Denver	14 Inverness Drive East, #B132 Englewood Denver Colorado 80112 USA Tel +1 303 792 9814 Fax +1 303 792 9742 Email wbmdenver@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Melbourne	Level 5, 99 King Street Melbourne 3000 PO Box 604 Collins Street West VIC 8007 Tel +61 3 9614 6400 Fax +61 3 9614 6966 Email wbmmelbourne@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Morwell	Cnr Hazelwood Drive & Miners Way Morwell 3840 PO Box 888 Morwell VIC 3840 Tel +61 3 5135 3400 Fax +61 3 5135 3444 Email wbmmorwell@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Newcastle	126 Belford Street Broadmeadow 2292 PO Box 266 Broadmeadow NSW 2292 Tel +61 2 4940 8882 Fax +61 2 4940 8887 Email wbmnewcastle@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Perth	1 Brodie Hall Drive Technology Park Bentley 6102 Tel +61 8 9328 2029 Fax +61 8 9486 7588 Email wbmperth@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Sydney	Suite 206, 118 Great North Road Five Dock 2046 PO Box 129 Five Dock NSW 2046 Tel +61 2 9713 4836 Fax +61 2 9713 4890 Email wbmsydney@wbmpl.com.au Web www.wbmpl.com.au
BMT WBM Vancouver	1190 Melville Street #700 Vancouver British Columbia V6E 3W1 Canada Tel +1 604 683 5777 Fax +1 604 608 3232 Email wbmvancouver@wbmpl.com.au Web www.wbmpl.com.au