6A Market Street East
NAREMBURN NSW 2065
AUSTRALIA

P O Box 572
CAMMERAY NSW 2062

fax 02 9460 7664
ph 02 9460 7663
mobile 0416 037 336
E -mail gba@tpg.com.au

gpb:gpb/09-41/lr897

21 March, 2010

Walker Corporation
Level 50 Governor Phillip Tower
1 Farrer Place
Sydney NSW 2000

Attention: Mr Stuart Gander

Dear Stuart

BARLINGS BEACH COASTAL ENGINEERING ADVICE
COASTAL ENGINEERING ADVICE
MAPPING OF YR 2050 AND YR 2100 COASTAL HAZARD LINES

We refer to recent discussions between Mr Gary Blumberg of gbaCOASTAL *(GBAC)* and Mr Stuart Gander of Walker Corporation *(WC)* regarding the above. GBAC is pleased to report in this matter under the following main headings:

- Background
- Site Inspection
- General Response to Council Comments on CES (2005)
- Preliminary Conservative Assessment of Yr 2100 LRFC
- Refined Assessment of Hazards contributing to Coastal Hazard Lines
- Mapping of 2050 and 2100 Coastal Hazard Lines
- Summary
- References

All reference to Relative Level *(RL)* in this report is to Australian Height Datum *(AHD)*. AHD is approximately mean sea level along the Australian coastline.

1 BACKGROUND

WC is developing *Reflections*, a residential subdivision at Barlings Beach, Batemans Bay on the NSW South Coast. Thirty five lots are proposed for Stage 1, some 17 of which are sold. The location of Barlings Beach showing the subdivision is presented in **Figure 1**.

Coastal Engineering Solutions *(CES)* has prepared two reports to describe the coastal hazard for the subdivision *(May 2005 and Nov 2009)*. Council has requested further information relating to the 2005 advice *(E09.3154; 00.4935.D; 00.4035.B; 9/12/09)*.

Mr Gary Blumberg joined WC at a meeting with Council officers on 19/1/10. Mr Blumberg canvassed the various issues raised by Council in regard to the existing coastal assessments. The primary consideration was the position of the Year 2100 Line of Reduced Foundation Capacity *(LRFC)*.

On the basis of this discussion, Council officers indicated to WC that they would be prepared to start processing individual DA's within the Barlings Beach *Reflections* development, subject to GBAC preparing a note confirming the discussions *(GBAC lr896v2, 28/1/10).*

This letter formalises WC's response to Council's request for further information relating to the CES studies, and develops and presents refined and definitive coastal hazard lines for the site.

2 SITE INSPECTION

A site inspection was made of the central and western area of Barlings Beach by Mr Gary Blumberg on 19/1/10 between 11.30 am and 12.30 pm. Weather during the inspection was fine, wind moderate to fresh from the S to SE, and wave heights were 2 m breaking across the beach compartment. We understand that the wave conditions on the beach were unusually large on the day of the inspection. No rain had fallen in the previous 2 to 3 days. The tide was just on a spring high at RL 0.7 *(predicted)* with the high water mark some 5 to 10 m seaward of the back-beach escarpment. Selected photos taken during the inspection are presented below.

Barlings Beach forms a narrow approximately 1 km long pocket beach aligned E-W *(beach facing south)*. The beach is afforded some protection by Browlee Headland and its reefs further to the south (**Figure 1** and **4**).

The dunal profile is well vegetated (**Photos 2**, **4** and **5**). We observed a zonation comprising spinifex, marram *(W end)*, saltmarsh, pigface, lomandra, teatree and banksia. This was interspersed from the N by terrestrial grasses. In the centre of the beach, a former scarp is evident in the seaward margin of the dune, now well stabilised with vegetation. This feature, which measures some 10 to 15 m in cross-shore profile, was probably formed in the severe storms of the mid-1970's. A transverse, lower-height dune field feature, also vegetated, appears to cross the main dune. The alignment of this secondary feature suggests it has developed in response to SW winds.

Seaward of the eastern end of the current subdivision *(centre of the beach)*, the back-beach escarpment was measured at approximately 18 m from the mean water line

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

(midday). This distance increases westward. The back-beach erosion escarpment was measured at approximately 0.5 to 1.0 m in height over the inspected length of beach. This is low and indicative of relative coastal protection.

It appeared that the western end of the beach was more exposed to coastal processes than areas further to the east. This was evident by a generally larger beach width and slightly higher dune crest. At the western end there was evidence of recent beach recovery seaward of a former back-beach scarp. Spinifex had taken in the incipient foredune, although this had been exposed to recent runup.

No stormwater outlets are located along the beach opposite the subdivision.

3 GENERAL RESPONSE TO COUNCIL COMMENTS ON CES (2005)

GBAC has reviewed the ESC letter to President Property Group dated 9/12/09. Our main thoughts in this matter were conveyed at the meeting with Council officers on 19/1/10 which we understand went some way to addressing Council's concerns (**Section 4**).

We confirm here our opinion related to seven main points raised in Council's letter:

(i) Lack of on-site investigations and concern with proxy reference to Currarong Beach
(ii) Need to incorporate a 1% AEP storm event
(iii) No consideration of local wave climate
(iv) No consideration of impact of storm waves on sand movement
(v) Need to consider increased wave energy at the beach as a consequence of climate change
(vi) Clarification on beach profile for application of Bruun Rule
(vii) Clarification on relationship between hazard line and zone of stable foundations and building setbacks

3.1 Lack of On-Site Investigations and Concern with Proxy Reference to Currarong Beach

Council is concerned that no on-site investigations were completed as part of the 2005 assessment. As discussed at the meeting with Council, GBAC believes that the aerial photogrammetry negates the need for additional on-site investigations. This dataset provides the main parameters to permit a description of the coastal hazard lines (refer **Section 5**).

There is also a concern that Currarong was used as a proxy or reference site to examine the behaviour of Barlings Beach. While it is always a good idea to ground truth coastal behaviour with other locations, we don't believe that a focus on Currarong is necessary here. Given that photogrammetry is available, we have all the information we need to make a site specific assessment, including an assessment of dune slumping and extent of zones of reduced foundation capacity (**Section 5.4** and **5.5**). Photogrammetry is an exceptionally robust tool as it provides the direct response of the beach system to the coastal processes and hazards – to describe beach erosion and recession there is no need to investigate wave climate, wave energy transfer, sediment transport etc. The photogrammetry depicts the morphological response of the prototype, avoiding the need to analyse or model.

3.2 Need to Incorporate a 1% AEP Storm Event

Council reiterates that the hazard lines must be developed for a 1% AEP *(annual exceedance probability)* event. This is appropriate. However, they point out that no 1% AEP ocean inundation event is recorded over the 39 year period of the photogrammetry *(1964 to 2003)*. Council quotes CES (2005) in which it is reported "it is believed that the 1974 storms correspond to a 50 year return period event".

In GBAC's experience there is little to distinguish between a 50 year storm and a 100 year storm. The two are often interchanged to the extent that some studies simply refer to an extreme storm. Data prepared from Port Kembala waverider show that predicted offshore significant wave heights are some 7% larger for a 100 year ARI event compared to a 50 year ARI event (**Figure 3**).

There is a another compelling argument to adopt the May-June 1974 storms as the design event for assessing coastal hazard at Barlings Beach. In accordance with the recommendation in AS4997- Guidelines for the Design of Maritime Structures *(AS,2005)*, SMEC (2008) adopted a storm event having a 5% probability of being exceeded over a 50 year period for their full coastal risk analysis for the Shoalhaven Coastline Management Study. From the analysis of wave statistics at Port Kembla, SMEC found that the May-June 1974 storm event had such a probability of exceedance *(5% in 50 years)*. Accordingly they adopted the storms of May-June 1974 as their design storm event.

Based on standard risk evaluation techniques, it can be shown that a storm with a 5% probability of being exceeded over a period of 50 years correlates with a 0.1%AEP event. It follows that this event should conservatively represent Council's requirement that a 1% AEP event be considered.

3.3 No Consideration of Local Wave Climate

Council is concerned that no consideration was given to local wave climate in reaching conclusions relating to shoreline recession and storm bite.

As noted above, in GBAC's opinion this is not important since the shoreline recession and storm bite are derived from the photogrammetry for Barlings Beach. The photogrammetry provides the exact signature of the impact of the local wave climate.

3.4 No Consideration of Impact of Storm Waves on Sand Movement

Our response here would be the same as that above. The sand movement on the beach of consequence to the matter of coastal hazard lines relates exclusively to long-term sand losses from the beach *(shoreline recession)* and storm bite. These are suitably described by the photogrammetry, and a separate assessment of the contribution of sea level rise to shoreline recession (**Section 5.2.1**).

3.5 Need to Consider Increased Wave Energy at the Beach as a Consequence of Climate Change

Council here makes reference to advice included in CES (2009). While CES (2009) refers to McInnes et al (2007), Council is concerned about the conclusions reached regarding no increased wave energy to the beach as a consequence of climate change.

As GBAC reads McInnes et al (2007), there is a need to account for a 32% increase in offshore storm wave heights. This will lead to larger storm bite (**Section 5.1**).

3.6 Clarification on Beach Profile for Application of Bruun Rule

Council has requested that profile data be provided to support establishment of the RL 0 bench mark and the application of the Bruun Rule. This is addressed in **Section 5.2.1**.

3.7 Clarification on Relationship between Hazard Line and Zone of Stable Foundations and Building Setbacks

The various dune stability zones which apply at the back of a beach are fully described in Nielsen et al (1992). This methodology is currently adopted by DECCW in the application of coastal hazard lines in NSW, including the description of Zone of Slope Adjustment *(ZSA)* and Zone of Reduced Foundation Capacity *(ZRFC).*

In the absence of site specific information, it is common practice in NSW *(and suitably conservative)* to assume an internal angle of friction *(Ø)* equal to 30 degrees for dune sand. This has now been done for Barlings Beach and directly applied to the Nielsen model to define the ZSA and ZRFC (**Sections 5.4**, **5.5** and **6**).

There is no need nor value to be drawing on similar results for Currarong or any other beach for that matter.

4 PRELIMINARY CONSERVATIVE ASSESSMENT OF YR 2100 LINE OF REDUCED FOUNDATION CAPACITY (LRFC)

Mr Gary Blumberg joined WC at a meeting with Council officers on 19/1/10. Mr Blumberg canvassed the various issues raised by Council in regard to the existing coastal assessments. The primary consideration was the position of the Year 2100 Line of Reduced Foundation Capacity *(LRFC)*. On the basis of this discussion, the Council officers indicated to WC that they would be prepared to start processing individual DA's within the Barlings Beach *Reflections* development, subject to GBAC preparing a note confirming the discussions *(GBAC lr896v2, 28/1/10).*

The preliminary conservative assessment allocated a setback value to seven components to develop a Line of Reduced Foundation Capacity *(LRFC)* for the year 2100, summarised in **Table 1**. On this basis it was confirmed that the line would be located no further than 183 m from the current RL 0 line along Barlings Beach *(Mean Tide Mark).*

TABLE 1 PRELIMINARY CONSERVATIVE ASSESSMENT OF YR 2100 LINE OF REDUCED FOUNDATION CAPACITY

	Component	**Value for Planning Date 2100**
1	Long-term shoreline recession excluding the effects of SLR	14.6 m
2	Sea level rise *(SLR)* recession	84 m
3	SLR recession offset	-13.6 m
4	Storm bite	62 m
5	Beach rotation	8.7 m
6	Width of Zone of Slope Adjustment *(ZSA)*	6.1 m
7	Width of Zone of Reduced Foundation Capacity *(ZRFC)*	20.8 m
Total		**182.6 m**

GBAC discussed the matter of the SLR recession offset with DECCW on 11/2/10 *(Mr Phil Watson, pers comm)*. It was agreed that this offset should reasonably apply, however Mr Watson suggested that a value of 1 mm/yr rather than 1.7 mm/yr more accurately represents the annual SLR over the recent past *(period of photogrammetry)*. Also, it was agreed that a more accurate description of this offset is achieved if the long-term recession value is modified *(reduced)* rather than the introduction of a separate SLR recession offset component.

The preliminary conservative assessment confirmed that the released blocks within the *Reflections* development, landward of the Boulevard, were well removed from the Yr 2100 LRFC and this permitted Council to start processing individual DA's. The preliminary assessment is refined in this advice.

5 REFINED ASSESSMENT OF HAZARDS CONTRIBUTING TO COASTAL HAZARD LINES

The following component hazards have been reviewed to develop our refined assessment of erosion and recession hazards:

- Storm bite
- Shoreline recession
- Beach Rotation
- Width of Zone of Slope Adjustment *(ZSA)*
- Width of Zone Reduced Foundation Capacity *(ZRFC)*

To assist develop the hazard lines it is useful to divide the beach into three areas or precincts: west, central and east. These broadly occupy tracts of beach which share alignment and relative coastal exposure. Each measures 300 m in length. Note that the photogrammetry distinguishes three blocks for the beach which broadly follow the selected precincts.

On the basis of the above we then develop our refined assessment of year 2050 and 2100 coastal hazard lines for the site (**Section 6**).

5.1 Storm Bite

Storm bite *(or beach erosion)* refers to the loss of beach and dune sand in a storm or closely-linked series of storms.

DIPNR provided historical aerial photogrammetry to CES to enable the assessment of storm bite and shoreline recession *(sediment budget component,* **Section 5.2.2***)* This included a tabulation of beach volumes *(m3/m)* for the following seven dates of photography covering a total of 20 shore-normal profiles spread along Barlings Beach *(Mr Phil Watson, DIPNR, 1/4/05)*:

(i) Feb 1964
(ii) Jun 1972
(iii) Sep 1975
(iv) May 1980
(v) Apr 1984
(vi) Apr 1993
(vii) Feb 2003

GBAC has separately sourced the photogrammetric CAD plots from DECCW *(Mr Bob Clout, 27/1/10).* A copy of the beach volumes and photogrammetric plots provided by DECCW is attached in **Appendix A**.

CES considered the average beach volume reduction between the Jun 1972 and Sep 1975 photogrammetry as representative of design storm bite attributed to the storms of May-Jun 1974. CES increased these erosion volumes by 25% to allow for beach recovery that would have occurred between the May-Jun 1974 storms and Sep 1975. GBAC believes that the CES approach is reasonable and has adopted the same for this assessment, summarised in **Table 2**. Note that these data exclude the effects of climate change.

Gordon (1987) used all available data for the NSW coast to consider the relationship between storm demand and recurrence interval. This was based on ten years of profiles at 19 beaches, 35 to 40 years of NSW coastal air photography and 14 years detail study of Sydney beach cuts. A key plot from Gordon presenting this information is reproduced in **Figure 2**. It is clear from **Table 2** and **Figure 2** and that Barlings Beach would be regarded as less than a “low demand open coast beach”.

TABLE 2 DESIGN STORM BITE
1% AEP STORM EXCLUDING EFFECTS OF CLIMATE CHANGE

Area of Barlings Beach	**Approx Chainage from Western Headland**	**Photogrammetry**		**Average Storm Bite from Photogrammetry (m^3/m)**	**Adopted 1% AEP Design Storm Bite (m^3/m)**
		Block	**Profiles**		
West	0 – 300 m	1	1 to 6	59.7	75
Central	300 - 600 m	2	1 to 7	31.5	39
East	600 – 900 m	2	8 -10	5.8	7
		3	1 - 4		
Source	DIPNR (2005). Refer **Appendix A**				

McInnes et al (2007) reports that for storms from the S to SE directions at Batemans Bay *(135 to 180° from N)*, maximum Hs is predicted to increase by up to 11% by 2030 and up to 32% by 2070. Having regard to the broad trends indicated for these results and for the purposes of this advice, we have assumed increases in storm Hs of 20% by 2050 and 50% by 2100.

To gauge the influence of increased storm Hs as a consequence of climate change on design erosion, it would seem reasonable to correlate the change in predicted storm recurrence based on a valid and current dataset *(say Hs vs ARI for Port Kembla which is well established in the literature),* and apply this to the erosion demand trends developed in Gordon (1987). This methodology is presented in **Figure 3**. Our assessment of future storm erosion demand taking in account the predicted influence of climate change as described in **Figure 3**, is summarised in **Table 3**.

TABLE 3 DESIGN STORM BITE
1% AEP STORM INCLUDING EFFECTS OF CLIMATE CHANGE

Area of Barlings Beach	**Approx Chainage from Western Headland**	**Adopted 1% AEP Design Storm Bite excluding the effects of Climate Change (m^3/m)** [Table 2]	**Design Storm Bite including the Effects of Climate Change (m^3/m) (1)**	
			2050	**2100**
West	0 – 300 m	75	119	161
Central	300 - 600 m	39	46	64
East	600 – 900 m	7	13	19
Notes	(1)	Derivation shown in **Figure 3**		
Source	DIPNR (2005)			

5.2 Shoreline Recession

Shoreline recession is the long-term retreat of the shoreline manifest as incomplete beach recovery following erosion events *(budget losses)*. Sea level rise *(SLR)* due to climate change also contributes to shoreline recession.

While storm bite is assessed above in volumetric terms *(to be deducted from the coastal profiles in accordance with the Nielsen Model,* **Sections 5.4** and **6***)*, recession is addressed as a lateral retreat in the shoreline profile.

We consider “SLR recession” first as it influences the calculation of “sediment budget recession”. As there are components that add to and subtract from the total shoreline recession, the convention applied in this section is to treat recession as a negative distance and accretion as a positive distance.

5.2.1 SLR Recession

The Bruun Rule is the accepted method for assessing the impact of sea level rise *(SLR)* on shoreline recession. It depends on the amount of sea level rise *(SLR)* and the slope of the active coastal profile. While the SLR values for the design dates 2050 and 2100 are now prescribed by DECCW benchmarks, the slope of the active beach profile is a second variable to be determined.

SLR Benchmarks

DECCW (2009b) recommends SLR benchmarks for the NSW coast. ESC requires that these be used for assessment of coastal hazards at Barlings Beach. The SLR benchmarks are summarised in **Table 4**.

TABLE 4 SLR BENCHMARKS APPLIED AT BARLINGS BEACH

Planning Dates	**Projected Rise in Mean Sea Level relative to 1990 Mean Sea Level**
2050	0.4 m
2100	0.9 m
Source DECCW (2009b)	

Slope of Active Coastal Profile

In order to calculate SLR recession, the slope of the active coastal profile must be established. Two separate investigations have been made to identify this parameter:

(i) seabed survey
(ii) analytical procedure after Hallermeier (1978)

<u>Seabed Survey</u>

The active coastal profile is formed in response to coastal processes, in particular wave action. It is well known that the seaward limit of the active coastal profile is typically characterised by a slope discontinuity. WC has undertaken seabed profile surveys over three shore-normal transects in order to investigate the location and depth of this discontinuity.

A seabed survey was undertaken Bullock & Walters Surveyors in February 2010. The results of the survey have been processed by GBAC and are presented in **Figure 4**. The bed survey shows a clear slope discontinuity for the three survey transects as summarised in **Table 5**. Included in the table is the nominal average dune crest level interpreted from land survey undertaken in Jan 2010. A copy of the land survey is included in **Appendix B**.

GBAC has adopted the nominal average dune crest level as a conservative boundary condition to calculate the slope of the active coastal profile.

TABLE 5 SLOPE OF ACTIVE COASTAL PROFILE BASED ON SLOPE DISCONTINUITY FROM SEABED SURVEY

Area of Barlings Beach	Bed Level at Slope Discontinuity (m AHD) (1)	Nominal Average Dune Crest Level (m AHD) (2)	Separation Distance (m)	Slope of Active Coastal Profile
West	RL -5.0	RL 6.5	300	1:26
Central	RL -7.2	RL 5.3	340	1:26
East	RL -8.5	RL 3.8	320	1:26
Notes	(1)	Interpreted from Bullock & Walters Surveyors seabed survey presented in **Figure 4**		
	(2)	Interpreted from Bullock and Walters Surveyors foreshore survey presented in **Appendix B**		

<u>Analytical Procedure after Hallermeier (1978)</u>

The “depth of closure” demarcates the seaward limit of sediment movement by waves. Hallermeier (1978) as reported in Coastal Engineering Manual *(USACE, 2002)* suggested an analytical approximation, using linear wave theory for shoaling waves, to estimate the depth of closure.

$d_L = 2.28H_e – 68.5 (H_e^2/gT_e^2)$

d_L annual depth of closure below mean low water
H_e non-breaking significant wave height exceeded 12 hours per year
T_e associated wave period
g acceleration due to gravity

NSW Department of Commerce Manly Hydraulics Laboratory has processed 20 years of wave data from the Batemans Bay offshore waverider buoy to derive the significant wave height and associated period exceeded 12 hours per year *(H_e, T_e)*. This data is presented in **Table 6** together with the calculated value for d_L and the associated closure bed level.

TABLE 6 ASSESSMENT OF HALLERMEIER CLOSURE DEPTH

Non-Breaking Significant Wave Height exceeded 12 hours per year (H_e) [(1)]	Associated Wave Period (T_e) [(1)]	Annual Depth of Closure below MLW (d_L)	Closure Bed Level (m AHD)
4.7 m	12.7 s	9.8 m	RL -10.2
Notes (1)	Data collected and processed by MHL *(Mr Mark Kulmar, MHL, 9/2/10 pers comm)*		

The approximate distance between a bed level of RL -10.2 and the dune crest as determined from the seabed survey profiles varies between 820 m and 1,250 m depending on beach area and location on the dune crest. Adopting nominal average dune crest levels as assessed from recent land survey, active profile slopes using the Hallermeier method are calculated at between 1:53 and 1:86 as detailed in **Table 7**.

TABLE 7 SLOPE OF ACTIVE COASTAL PROFILE BASED ON HALLERMEIER METHOD

Area of Barlings Beach	Closure Bed Level (m AHD) [(1)]	Nominal Average Dune Crest Level (m AHD) [(2)]	Separation Distance (m)	Slope of Active Coastal Profile
West	RL -10.2	RL 6.5	893	1:53
Central	RL -10.2	RL 5.3	843	1:54
East	RL -10.2	RL 3.8	1,210	1:86
Notes	(1)	From **Table 6**		
	(2)	As per **Table 5**		

Selection of Slope of Active Coastal Profile

CES (2005, 2009) have adopted 1:50 without justification. Ranasinghe et al (2007) indicate typical slopes of 1:50 and 1:100 for the NSW open coast. The Batemans Bay Vulnerability Study *(DLWC, 1996)* adopts slopes between 1:20 and 1:50 for beaches within Batemans Bay and these same slopes are used to calculate SLR recession in the Batemans Bay Coastline Hazard Management Plan *(Webb McKeown, 2001)*.

The seabed profile and Hallermeier assessments presented above indicate a range of active profile slopes which may apply to Barlings Beach. GBAC would expect site specific surveyed slopes to be more definitive than Hallermeier. For the purposes of this investigation and having regard to the broad ranges of slopes described for NSW generally and for Batemans Bay in particular, GBAC has elected to average the two procedures to develop prudent active profile slopes for assessment of SLR recession. The adopted slopes are summarised in **Table 8**.

TABLE 8 ADOPTED SLOPES OF ACTIVE PROFILE FOR BARLINGS BEACH

Area of Barlings Beach	**Slope from Seabed Survey** [Table 5]	**Slope from Hallermeier** [Table 7]	**Adopted Slope of Active Profile** (1)
West	1:26	1:53	1:40
Central	1:26	1:54	1:40
East	1:26	1:86	1:56
Notes	(1)	Average of slopes from seabed survey and Hallermeier	

SLR Recession

The SLR benchmarks and slopes of the active coastal profile can now be combined using the Bruun Rule to develop the design SLR recession values for the beach, presented below in **Table 9**.

TABLE 9 SLR RECESSION FOR BARLINGS BEACH

Area of Barlings Beach	**Adopted Slope of Active Profile** [Table 8]	**SLR increment from 1990 (m)** [Table 4]	**SLR Recession from 1990 (m)**	**SLR Recession from 2010 (m)**
Planning Date 2050				
West	1:40	0.4	-16.0	-15.2
Central	1:40	0.4	-16.0	-15.2
East	1:56	0.4	-22.4	-21.6
Planning Date 2100				
West	1:40	0.9	-36.0	-35.2
Central	1:40	0.9	-36.0	-35.2
East	1:56	0.9	-50.4	-49.3

The base date for the hazard line assessment developed in this advice is 2010. It follows therefore that the design SLR recession values relative to 1990 must be reduced to account for the SLR that has taken place over the last 20 years. As a conservative measure of this SLR, we apply the 1 mm/yr established for NSW over the past century and make the necessary adjustment (**Section 4**).

It follows from this table that the western and central areas of Barlings Beach, which front those areas forming the *Reflections* subdivision, are predicted to recede due to SLR processes by 15.2 m by 2050 and 35.2 m by 2100, compared to the current shoreline position *(2010)*.

5.2.2 Sediment Budget Recession

Sediment budget recession is defined using the available photogrammetry. For the three areas distinguished for Barlings Beach, GBAC has interrogated the photogrammetry and found long-term recession applying at the west and central areas, but long-term accretion at the eastern area. The volumetric analysis, as provided by DIPNR in 2005, has been interrogated to derive linear trendlines for the volume changes over the period of the photogrammetry (**Appendix A**).

The results are presented in **Table 10** and selected data in **Figure 5**. Incorporating all trend lines in **Figure 5** would over clutter the figure. Note that these are results must still be corrected to account for SLR recession over the period of the photogrammetry (**Section 4**), assessed below.

The recession fluctuations between profiles are due to natural and survey variability. To filter out this variability, we characterise the average recession across the profiles within each of the three designated beach areas. This varies between -0.21 m^3/m/yr *(recession)* in the central area of the beach, to +0.16 m^3/m/yr *(accretion)* in the eastern area of the beach (**Table 10**).

When applying sediment budget recession going forward to generate future hazard lines, it is appropriate to make a correction to account for the contribution of SLR recession over the period of the photogrammetry. If this were not done, then the SLR recession would in effect be double-counted into the future. For this reason the SLR recession parameters set out in **Table 10** are referred to as “uncorrected”.

DECCW (2009a) reports that SLR has been occurring over the past century at 1.7 mm/yr +/-0.3 mm. A detailed assessment of the tide gauge record for Sydney Harbour shows a mean relative sea level rise of approximately 1 mm/yr over this period *(You et al, 2009)*. GBAC has discussed this aspect with DECCW and elected to apply 1 mm/yr to make the sediment budget recession correction *(Mr Phil Watson, DECCW, 11/2/10)*.

For the adopted active profile slopes in **Table 8** and applying a 1 mm/yr SLR over the period of photogrammetry, the corrected sediment budget recession parameters for Barlings Beach are presented in **Table 11**.

It follows from the above that Barlings Beach is in fact not undergoing sediment budget recession but rather is stable or accreting. This outcome is reasonably common for compartmentalised NSW beachs.

TABLE 10 UNCORRECTED SEDIMENT BUDGET RECESSION 1964 - 2003

Area of Barlings Beach and Approx Chainage	Photogrammetry		Recession of Profile (m^3/m per year) (1)	Nominal Average Dune Crest Level (m AHD) (2)	Uncorrected Sediment Budget Recession (m/yr)
	Block	Profiles			
West	1	1	-0.26	6.5	-0.04
0-300 m	1	2	0.26	7.0	+0.04
	1	3	0.40	6.0	+0.07
	1	4	-0.22	7.0	-0.03
	1	5	-0.44	6.1	-0.07
	1	6	-0.37	6.4	-0.06
		Average	**-0.10**	**6.5**	**-0.02**
Central	2	1	-0.58	6.0	-0.10
300 - 600 m	2	2	-0.26	5.7	-0.04
	2	3	-0.33	5.6	-0.06
	2	4	-0.47	5.3	-0.09
	2	5	-0.40	5.1	-0.08
	2	6	-0.02	4.7	0.00
	2	7	0.22	4.8	+0.05
		Average	**-0.21**	**5.3**	**-0.04**
East	2	8	0.66	4.6	0.14
600 – 900 m	2	9	0.58	3.1	+0.19
	2	10	0.11	3.9	+0.03
	3	1	0.22	4.4	+0.05
	3	2	0.11	3.7	+0.03
	3	3	0.15	3.9	+0.04
	3	4	-0.22	2.7	-0.08
		Average	**+0.16**	**3.8**	**+0.04**
Notes	(1)	Based on linear trendline plotted in EXCEL through the volumetric data. Negative refers to recession, positive refers to accretion (**Figure 5**).			
	(2)	Nominal average crest level through the dune between the beach and the subdivision boundary.			
Source	DIPNR (2005)				

TABLE 11 CORRECTED SEDIMENT BUDGET RECESSION 1964 - 2003

Area of Barlings Beach	**Adopted Coastal Profile Slope** [Table 8]	**Correction to Budget Recession (m/yr)** [(1)]	**Uncorrected Sediment Budget Recession (m/yr)** [Table 10]	**Corrected Sediment Budget Recession (m/yr)**
West	1:40	+0.040	-0.02	+0.02
Central	1:40	+0.040	-0.04	0.00
East	1:56	+0.056	+0.04	+0.10
Notes	(1)	Based on 1 mm/yr x slope of active profile		

5.2.3 Total Shoreline Recession

The total shoreline recession for planning dates 2050 and 2100 is simply the sum of the SLR recession and the corrected sediment budget recession. This is summarised in **Table 12**.

5.3 Beach Rotation

Ranasinghe et al (2004), and Short and Trembanis (2004) report on a decadal scale pattern in beach rotation correlated to the Southern Oscillation Index *(SOI)*. In simple terms, the beach alignment pendulates in response to slight changes in wave direction as a consequence of SOI shifts in the location of weather systems. Beach rotation manifests in alternating and opposite erosion / accretion cycles at the ends of the beach, with the centre of the beach acting as the fulcrum and stable.

Collaroy Narrabeen beach has been investigated for beach rotation which has been found to be approximately +/-0.5 degree based on a similar change in average wave direction observed within an El Nino and La Nina cycle of nominal period 3 to 7 years.

Approximately 9 m represents a 0.5 degree swing in Barlings Beach over a beach length of 1 km *(tan 0.5 x 1000 = 8.7)*. The applicability of SOI rotation to Barlings which faces approx SSE is uncertain but has been included in this assessment as a precaution. It may be that because the beach is shielded from the ENE to NE waves that drive the El Nino component of the process, beach rotation is largely irrelevant. This could be investigated further if the coastal hazard lines developed for the beach require refinement.

This assessment incorporates a beach rotation hazard as summarised below in **Table 13**. These would apply for both planning dates 2050 and 2100.

TABLE 12 TOTAL SHORELINE RECESSION FOR BARLINGS BEACH

Area of Barlings Beach	**SLR Recession from 2010 (m)** [Table 9]	**Corrected Sediment Budget Recession from 2010 (m)** [developed from Table 11]	**Total Shoreline Recession from 2010 (m)**
Planning Date 2050			
West	-15.2	+0.8	-14.4
Central	-15.2	0.0	-15.2
East	-21.6	+4.0	-17.6
Planning Date 2100			
West	-35.2	+1.8	-33.4
Central	-35.2	0.0	-35.2
East	-49.3	+9.0	-40.3

TABLE 13 BEACH ROTATION HAZARD ADOPTED FOR BARLINGS BEACH

Area of Barlings Beach	**Beach Rotation Hazard (m)**
West	-9
Central	0
East	-9

5.4 Width of Zone of Slope Adjustment *(ZSA)*

As noted above in **Section 3.7**, the various dune stability zones which apply at the back of a beach are fully described in **Figure 6** developed by Nielsen et al (1992). This methodology, currently adopted by DECCW in the application of coastal hazard lines in NSW, includes a description of Zone of Slope Adjustment *(ZSA)* and Zone of Reduced Foundation Capacity *(ZRFC)* (**Section 5.5**).

In the absence of site specific information and as is common practice in NSW, the internal angle of friction *(Ø)* for dune sand has been conservatively assumed as 30 degrees. The top of swash has been defined as RL 2 as adopted by Nielsen et al (**Figure 6**).

5.5 Width of Zone Reduced Foundation Capacity *(ZRFC)*

The Nielsen Model defines the ZRFC as separating the Stable Foundation Zone *(SFZ)* immediately landward, and the ZSA immediately seaward. A safe angle of repose for the dune sand, calculated at 21 degrees, assumes a Factor of Safety *(FOS)* of 1.5. This line coincides with a back-beach scour level of RL -1.0 and is used to define the ZRFC (**Figure 6**).

GBAC assesses the ZRFC to range up to 12 m wide for the western area of Barlings Beach, increasing up to 15 m wide for the central area of Barlings Beach. The shape and elevation of the dune surface results in the differences between these beach areas.

6 MAPPING OF 2050 AND 2100 COASTAL HAZARD LINES

The above assessments have been combined and mapped onto four suitably spaced shoreline profiles to describe the year 2050 and 2100 coastal hazard lines for the west and central areas of Barlings Beach. Since the subdivision does not extend to the eastern area of the beach, the assessment has not been extended into this area.

DECCW photogrammetric profiles numbers 2 and 5 in Block 1 have been selected to represent the west area of Barlings Beach. Profiles 3 and 6 in Block 2 have been selected to represent the central area of Barlings Beach. The profile layout as shown in DECCW's photogrammetric base layout is reproduced in **Figure 7**.

A survey of the beach and dune was undertaken by Bullock & Walters Surveyors in Jan 2010 (**Appendix B**). This survey has been mapped at 10 m chainages onto the four selected beach profiles as shown in **Figure 8**. It can be seen from the figure that the 2010 survey is little changed from the 2003 survey, the most recent date included in the photogrammetry. GBAC assumes the 2010 profiles to reasonably represent long-term beach full beach profiles which are appropriate to use as the base profiles for the assessment of the 2050 and 2100 coastal hazard lines.

The parameters applied to generate the 2050 and 2100 coastal hazard lines are derived in **Section 5** and summarised in **Table 14.** Included in the table are the chainages defining the landward limit of the ZSA, and the boundary between the SFZ and the ZRFC. These chainages are all graphically determined in AUTOCAD as shown in **Figures 9** and **10**. The final predicted 2050 and 2010 coastal hazard lines are mapped at **Figures 11** and **12**.

The alignment and position of the photogrammetric profiles in Block 1 do not permit the analysis to extend up to the headland at the west end of Barlings Beach. In this zone, GBAC believes that it is reasonable to extend the hazard lines parallel to the back-beach erosion escarpment. This is shown in **Figure 11**.

It is clear from the assessment that the seaward boundary of the *Reflections* subdivision is well landward of the 2100 ZRFC. At its most critical location, GBAC assesses the subdivision to encroach no closer than 27 m from the 2100 ZRFC *(Lot 81, Stage 2)*.

It follows that the subdivision would be protected from erosion and recession hazard to Year 2100 and beyond and that no special provisions need apply to the foundations of buildings located in the subdivision.

7 SUMMARY

Walker Corporation *(WC)* is developing *Reflections*, a residential subdivision at Barlings Beach, Batemans Bay on the NSW South Coast. Thirty five lots are proposed for Stage 1, some 17 of which are sold. Coastal Engineering Solutions *(CES)* has prepared two reports to describe the coastal hazard for the subdivision *(May 2005 and Nov 2009)*. Council has requested further information relating to the 2005 advice. WC retained gbaCOASTAL Pty Ltd *(GBAC)*, Coastal Engineering Specialists, to address the outstanding requirements and develop refined maps of the 2050 and 2100 coastal hazard lines for the site which are acceptable to Council.

Mr Gary Blumberg from GBAC joined WC at a meeting with Council officers on 19/1/10. On the basis of this discussion, Council officers indicated to WC that they would be prepared to start processing individual DA's within the Barlings Beach *Reflections* development, subject to GBAC preparing a note confirming the discussions. GBAC letter lr896v2 dated 28/1/10 presented this "preliminary advice". This follow up letter formalises WC's response to Council's request for further information relating to the CES studies, and develops and presents refined and definitive coastal hazard lines for the site.

A site inspection was made by Mr Blumberg of the central and western area of Barlings Beach on 19/1/10. The dunal profile was found top be well vegetated. A zonation mainly comprising spinifex, marram *(W end)*, saltmarsh, pigface, lomandra, teatree and banksia was observed. It appeared that the western end of the beach was more exposed to

TABLE 14 2050 AND 2100 COASTAL HAZARD LINES FOR WEST AND CENTRAL AREAS OF BARLINGS BEACH

Area of Barlings Beach	**Representative Profile Locations adopted from Photogrammetry**		**Shoreline Recession (m)** [Table 12]	**Beach Rotation (m)** [Table 13]	**Design Storm Bite including the Effects of Climate Change (m^3/m)** [Table 3]	**Position of Coastal Hazard Lines – Chainage along DECCW Photogrammetric Profile (m)** [Figure 8 and 9]	
	Block	**Profile**				**Landward Boundary ZSA (1)**	**Landward Boundary ZRFC (2)**
Planning Date 2050							
West	1	2	-14.4	-9	119	103	93
	1	5	-14.4	-9	119	88	80
Central	2	3	-15.2	0	46	101	90
	2	6	-15.2	0	46	90	75
Planning Date 2100							
West	1	2	-33.4	-9	161	76	66
	1	5	-33.4	-9	161	62	53
Central	2	3	-35.2	0	64	76	63
	2	6	-35.2	0	64	63	48
Notes	(1)	Assumes angle of friction for dune sand of 30 degrees					
	(2)	Based on FOS=1.5 and back-beach scour level of RL -1.0					

coastal processes than areas further to the east. No stormwater outlets were encountered along the beach opposite the subdivision. GBAC prepared preliminary advice confirming discussions from the meeting on 19/1/10. *(GBAC lr896v2, 28/1/10)*. The key finding was that the released blocks within the *Reflections* development, landward of the Boulevard, were well removed from the year 2100 Line of Reduced Foundation Capacity *(LRFC)*. This permitted Council to start processing individual DA's within the subdivision.

GBAC's preliminary advice refined in this letter. The component hazards reviewed to develop the refined assessment of year 2050 and 2100 coastal hazard lines for the site comprise storm bite, shoreline recession, beach rotation, width of Zone of Slope Adjustment *(ZSA)*, and width of Zone Reduced Foundation Capacity *(ZRFC)*.

Storm bite refers to the loss of beach and dune sand in a storm or closely-linked series of storms. To gauge the influence of increased storm waves as a consequence of climate change on design erosion, GBAC has correlated the change in predicted storm recurrence and applied this to extrapolated, generalised erosion demand trends developed by others for the NSW coast. Storm bite is assessed in volumetric terms.

Shoreline recession is the long-term retreat of the shoreline manifest as incomplete beach recovery following erosion events *(budget losses)*. Sea level rise *(SLR)* due to climate change also contributes to shoreline recession. Unlike storm bite, recession is addressed as a lateral retreat in the shoreline profile. "SLR recession" is distinguished from "sediment budget recession". GBAC applies currently adopted DECCW SLR benchmarks, and a combination of seabed profile survey and well accepted analytical techniques to select a closure depth in order to apply the Bruun Rule. A precautionary allowance for beach rotation is also adopted.

The various dune stability zones which apply at the back of a beach are fully described by the Nielsen Model. This methodology, currently adopted by DECCW in the application of coastal hazard lines in NSW, is applied here at Barlings Beach.

The above assessments are combined and mapped onto four suitably spaced shoreline profiles to describe the year 2050 and 2100 coastal hazard lines for the west and central areas of Barlings Beach. A summary is presented in **Table 14** and the mapped lines shown in **Figures 11** and **12**. Since the subdivision does not extend to the eastern area of the beach, the assessment has not been extended into this area.

The refined assessment confirms and that the seaward boundary of the *Reflections* subdivision is well landward of the 2100 ZRFC. At its most critical location, GBAC assesses the subdivision to encroach no closer than 27 m from the 2100 ZRFC *(Lot 81, Stage 2)*.

It follows that the subdivision would be protected from erosion and recession hazard to Year 2100 and beyond and that no special provisions need apply to the foundations of buildings located in the subdivision.

8 REFERENCES

CERC (2002)
Coastal Engineering Manual
US Army Corps of Engineers

Coastal Engineering Solutions (2005)
Barlings Beach Coastal Hazard Assessment
Prepared for Barlings Beach Community Pty Ltd, May 2005

Coastal Engineering Solutions (2009)
Barlings Beach, NSW
Coastal Hazard Assessment Update 2009
Prepared for Barlings Beach Community Pty Ltd, November 2009

DECCW (2009b)
NSW Sea Level Rise Policy Statement
ISBN 978-1-74232-464-7, DECCW 2009/708, October 2009

DECCW (2009a)
Derivation of the NSW Government's Sea Level Rise Planning Benchmarks
Technical Note
ISBN 978 1 74232 465 4, October 2009

DIPNR (2005)
Barlings Beach Photogrammetry Volumes
Courtesy P Watson, 1/4/2005 pers com

DLWC (1996)
Batemans Bay Vulnerability Study
Coastal and Riverine Management Directorate
October 1996

Gordon AD (1987)
Beach Fluctuations and Shoreline Change – 1987
8 th Australian Conference on Coastal and Ocean Engineering, Nov 1987

Hallermeier RJ (1978)
Uses for a Calculated Limit Depth to Beach Erosion
Proceedings of the 16th Coastal Engineering Conference
American Society of Civil Engineers, New York, pp 1493-1512.

Lord D and Kulmar M (2003)
The 1974 Storms Revisited: 25 Years Experience in Ocean Wave Measurement along the South-East Australian Coast
Paper No 163, 27th International Conference on Coastal Engineering, Sydney, July 2000

McInnes KL, Abbs DJ, O'Farrell SP, Macadam I, O'Grady J and Ranasinghe R (2007),
Projected Changes in Climatological Forcing for Coastal Erosion in NSW
A Project Undertaken by CSIRO for the NSW Department of Environment and Climate Change, August 2007

Nielsen AF, Lord DB, Poulos HG (1992)
Dune Stability Considerations for Building Foundations
Aust. Civ. Eng. Trans., IEAust., Vol. CE 34, 2

NSW Government (1990)
Coastline Management Manual
ISBN 0730575063, September 1990

Public Works (1989)
Batemans Bay Oceanic Inundation Study
Report 89012 prepared for ESC
ISBN 0730551679, May 1989

Ranasinghe R, Watson P, Lord D, Hanslow D and Cowell P (2007)
Sea Level Rise, Coastal Recession and the Bruun Rule
Coasts and Ports 2007, Melbourne

Ranasinghe R, McLoughlin R, Short A and Symonds G (2004)
The Southern Oscillation Index, Wave Climate and Beach Rotation
Marine Geology 204 (2004) 273 - 287

Short AD and Trembanis AC (2004)
Decadal Scale Patterns in Beach Oscillation and Rotation, Narrabeen Beach, Australia – Time Series, PCA and Wavelet Analysis
Journal of Coastal Research, 20, 2, 523 – 532, Spring 2004

SMEC (2008)
Shoalhaven Coastal Zone Management Plan
Coastal Hazard Summary Report
Project No 3001209, for Shoalhaven City Council, 31/01/08

Standards Australia (2005)
AS 4997 - Guidelines for the Design of Maritime Structures

Webb McKeown & Associates (2001)
Batemans Bay Coastline Hazard Management Plan
Adopted by ESC November 2001

You Z, Lord D and Watson P (2009)
Estimation of Relative Mean Sea Level Rise from Fort Denison Tide Gauge Data
Coastal Unit, DECCW
Coasts and Ports 2009, Aukland

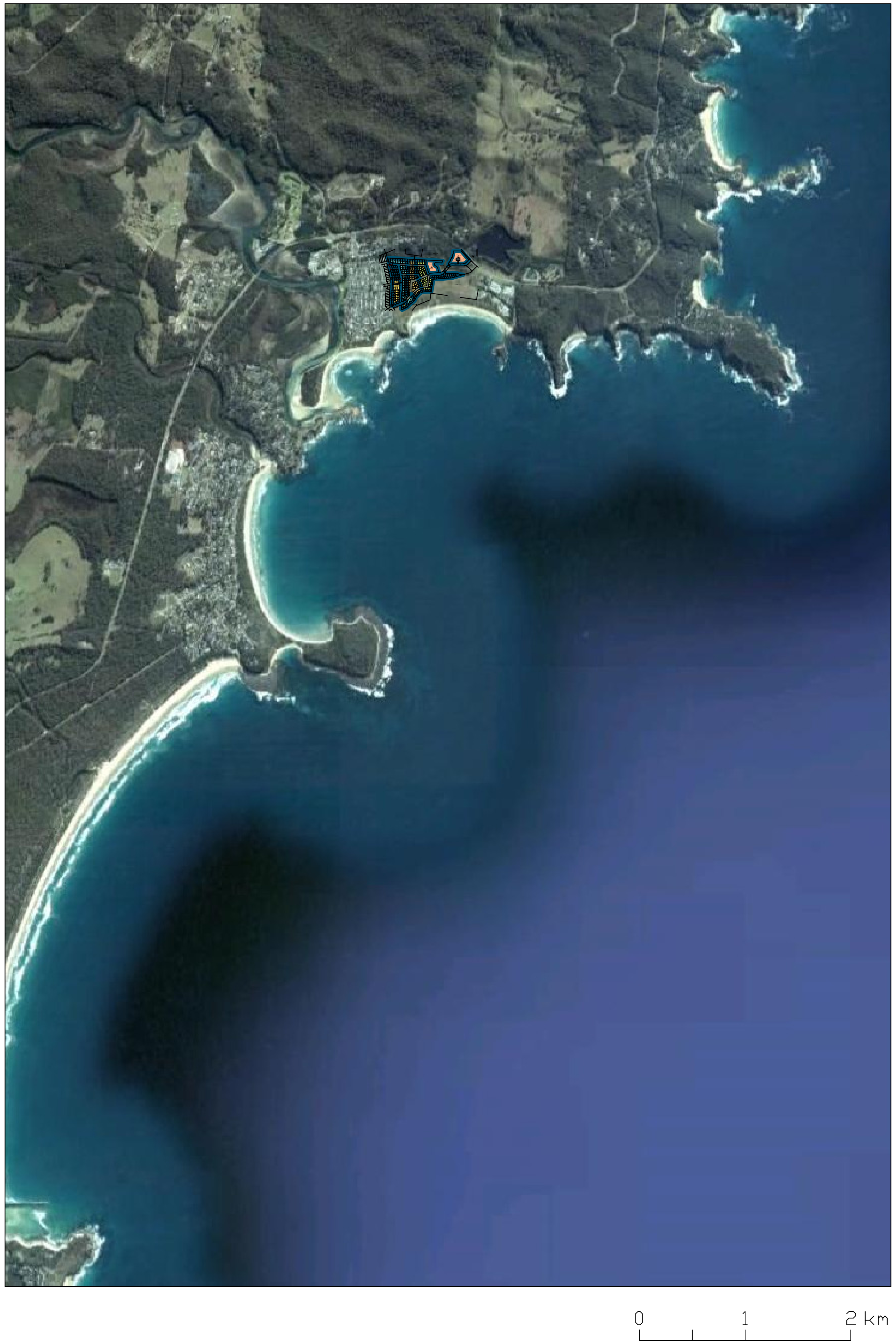
We trust that the above meets your immediate requirements. Should you wish to discuss or clarify any aspects, please do not hesitate to call the undersigned.

Yours faithfully
gbaCOASTAL Pty Ltd

G P Blumberg
Principal

LIST OF FIGURES

FIGURE 1

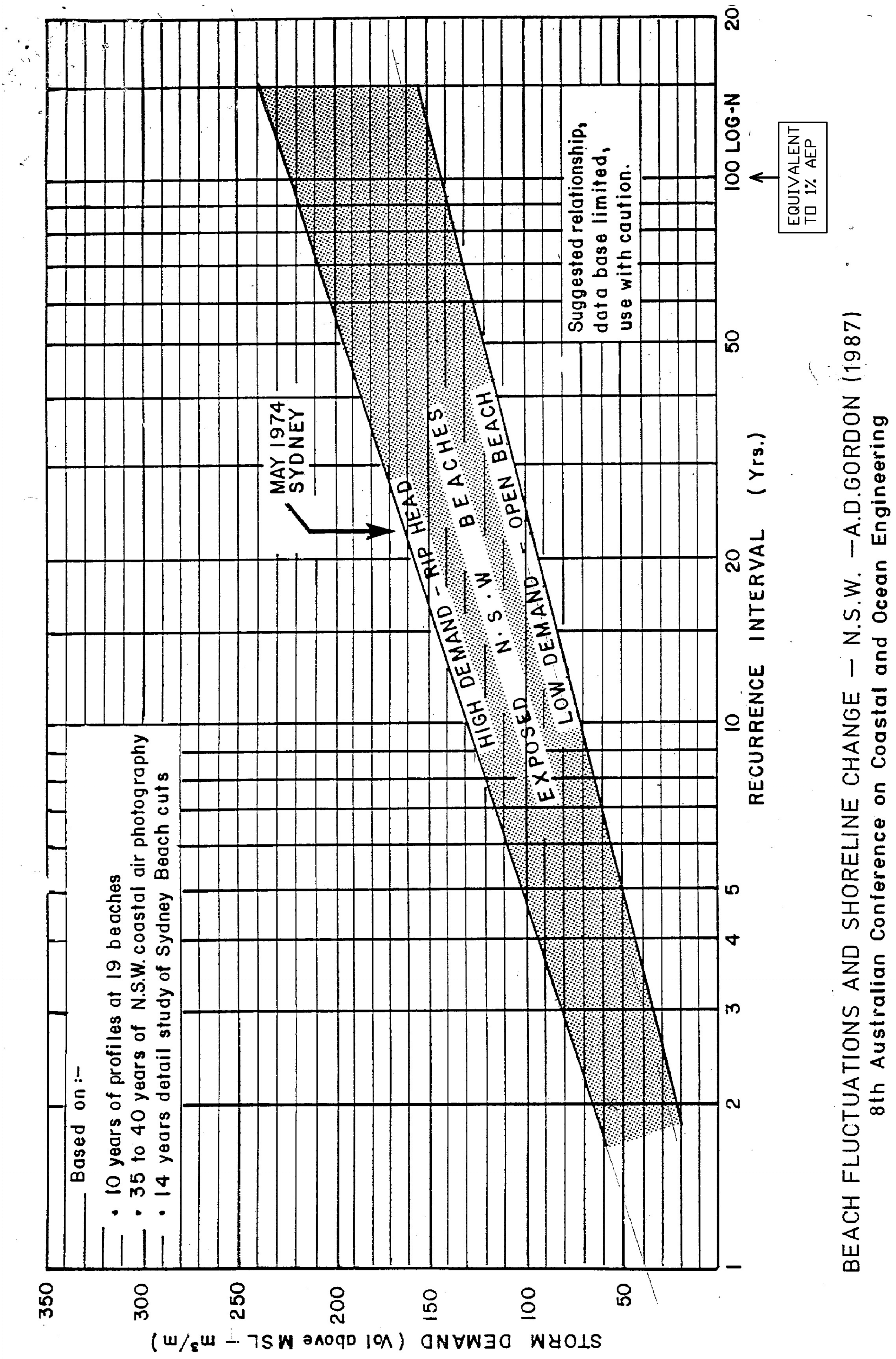


SOURCE: GOOGLE EARTH PRO 15/3/10

SUBDIVISION LAYOUT FROM WC 15/3/10
(STAGES 1 TO 5 SHOWN)

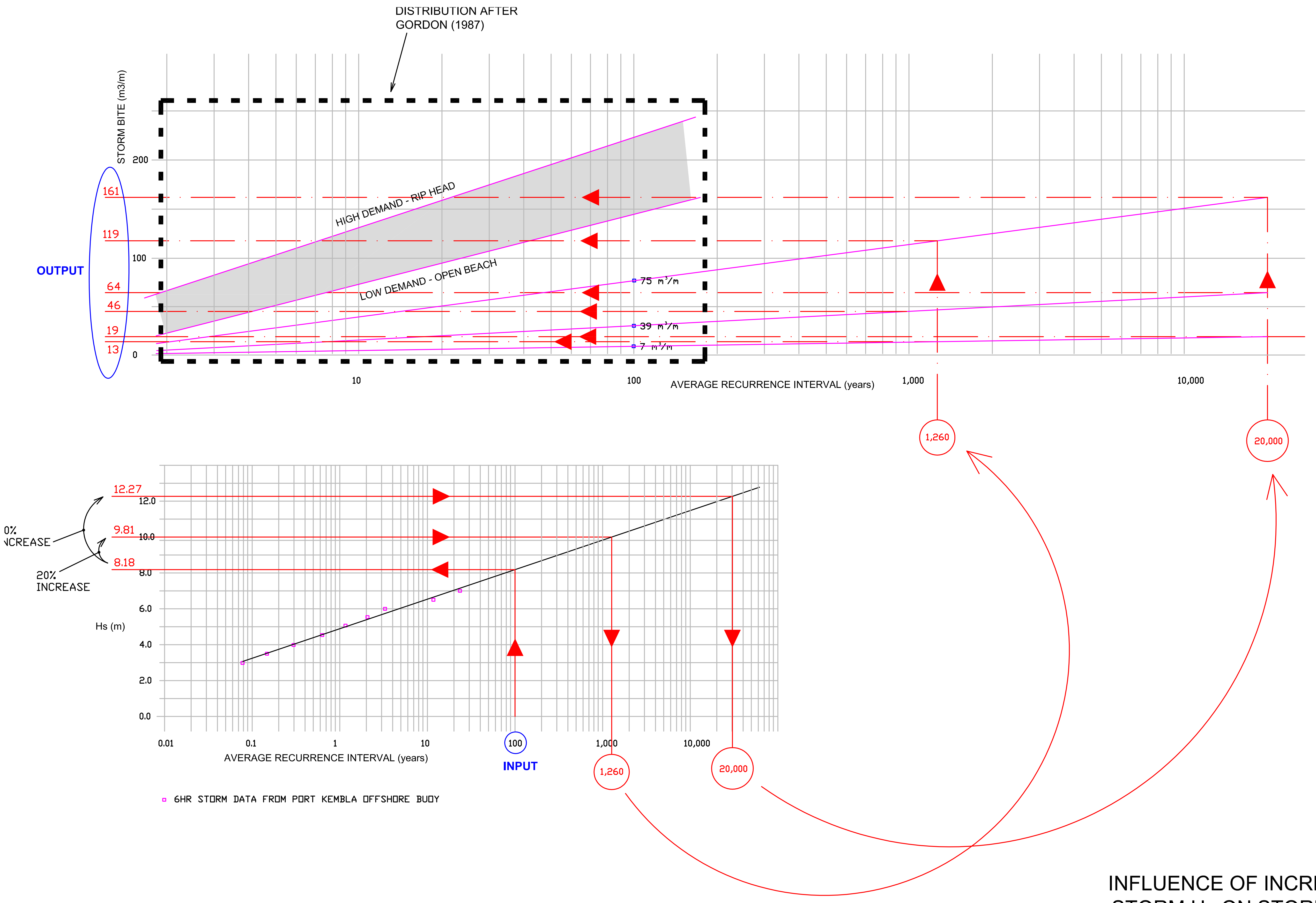
gbaCOASTAL
J09-41/lr897
Plot date 18/3/10

LOCATION OF BARLINGS
BEACH SHOWING
REFLECTIONS SUBDIVISION



gbaCOASTAL
J09-41/lr897
Plot date 18/3/10

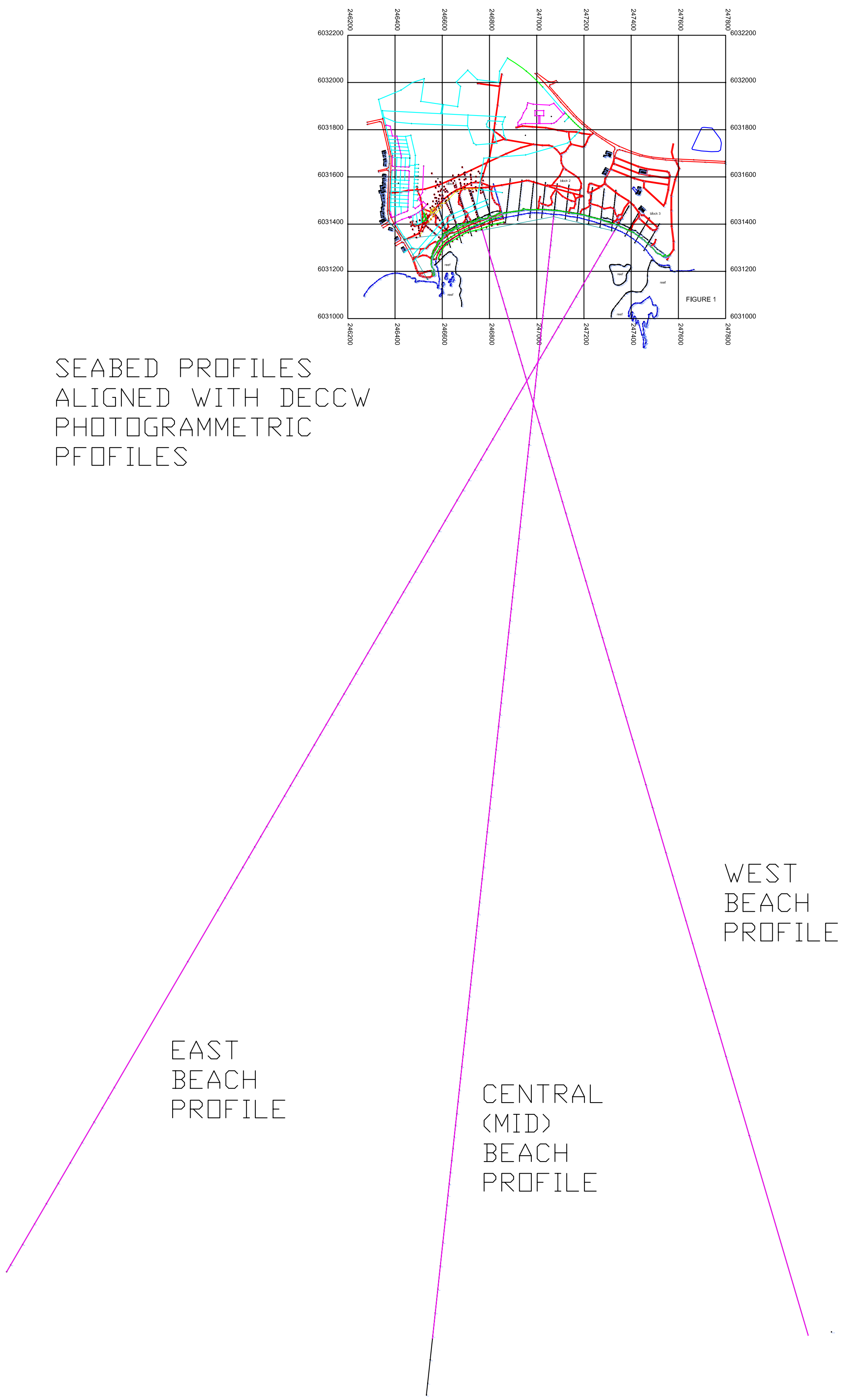
RELATIONSHIP BETWEEN STORM DEMAND AND RECURRENCE INTERVAL FOR NSW COAST

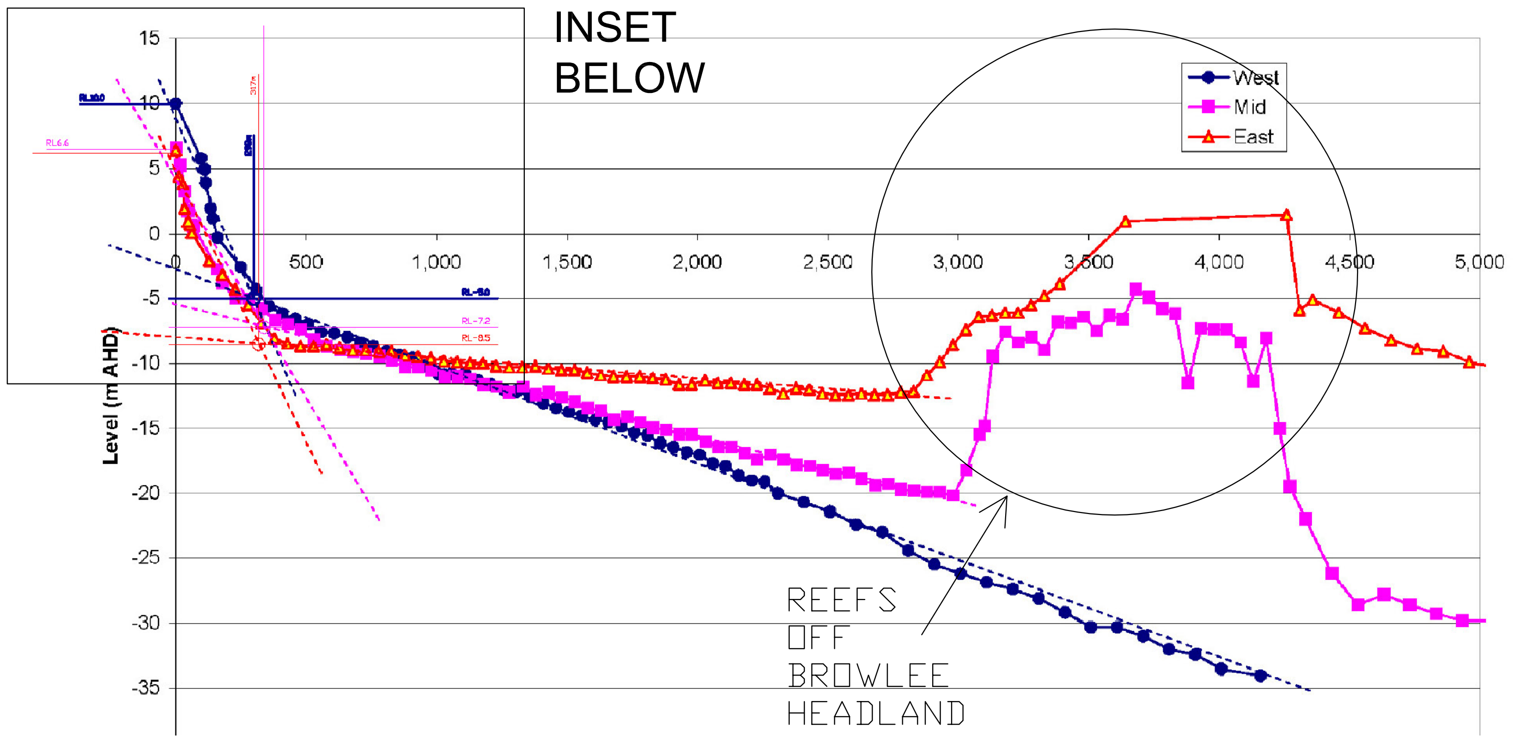


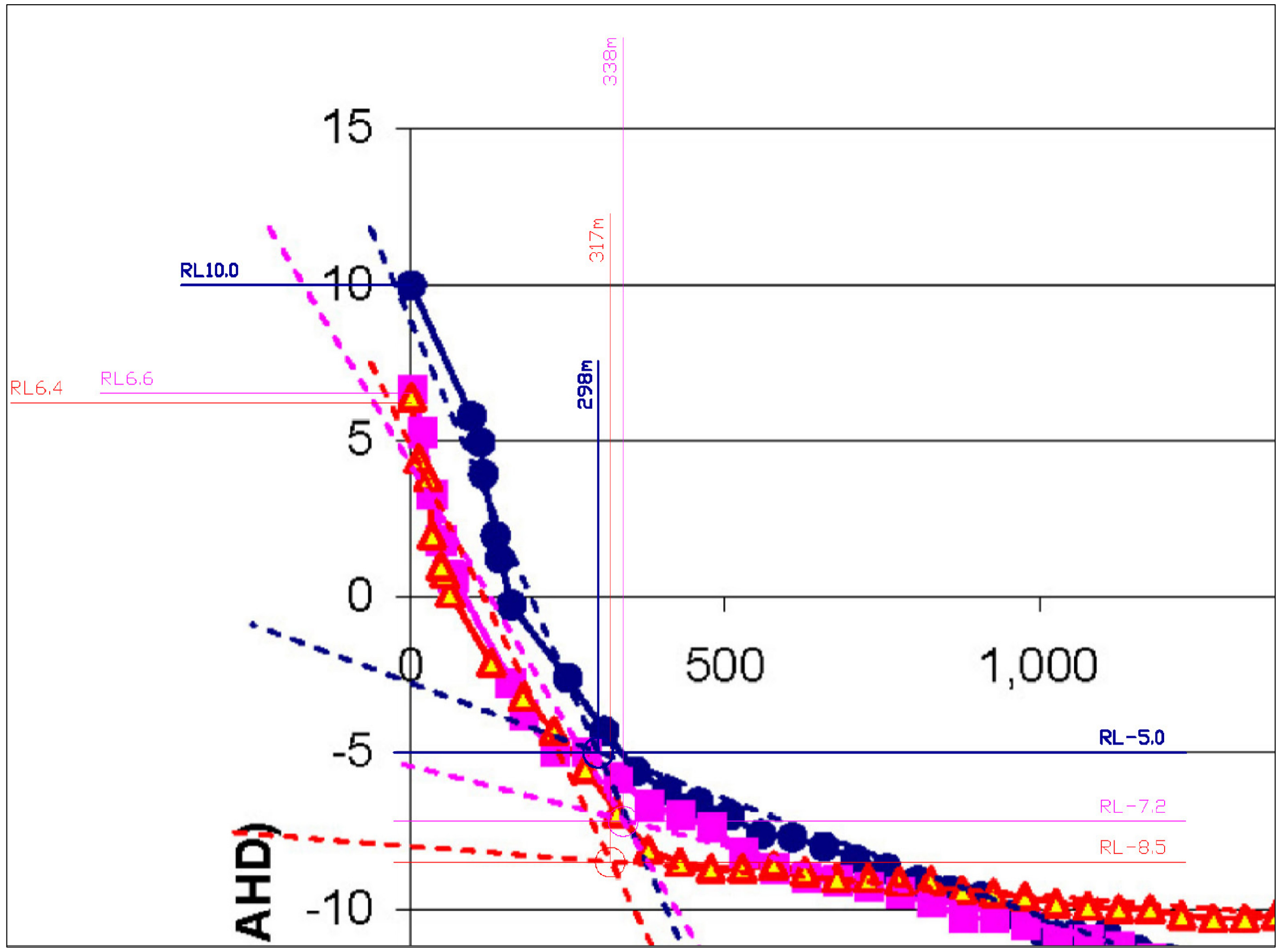
INFLUENCE OF INCREASED STORM Hs ON STORM BITE AS A CONSEQUENCE OF CLIMATE CHANGE

gbaCOASTAL
J09-41/lr897
Plot date 18/3/10

FIGURE 4







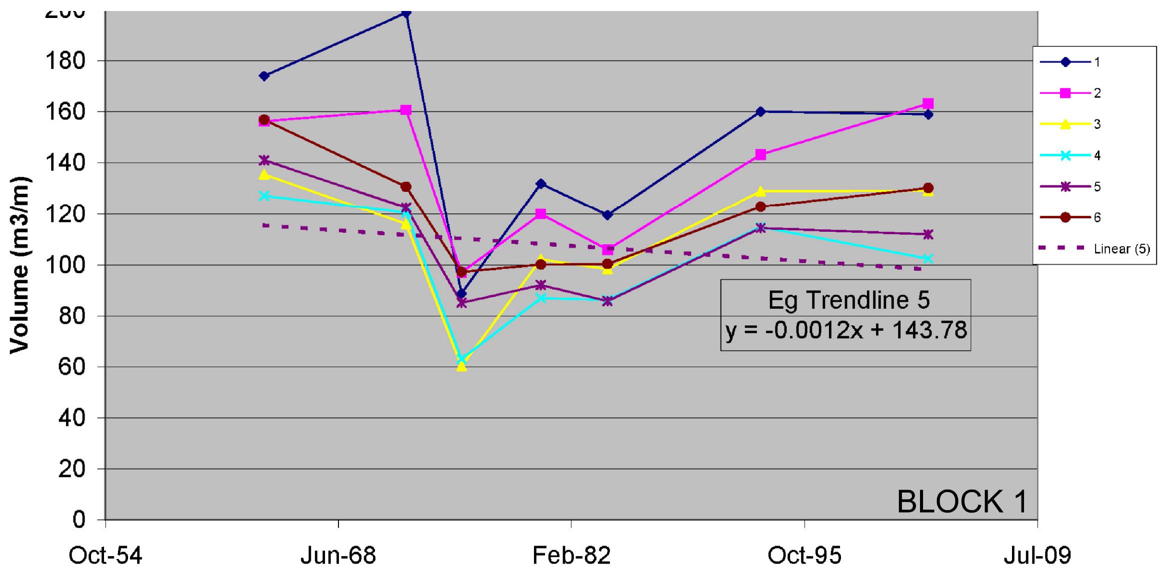
SOURCE:

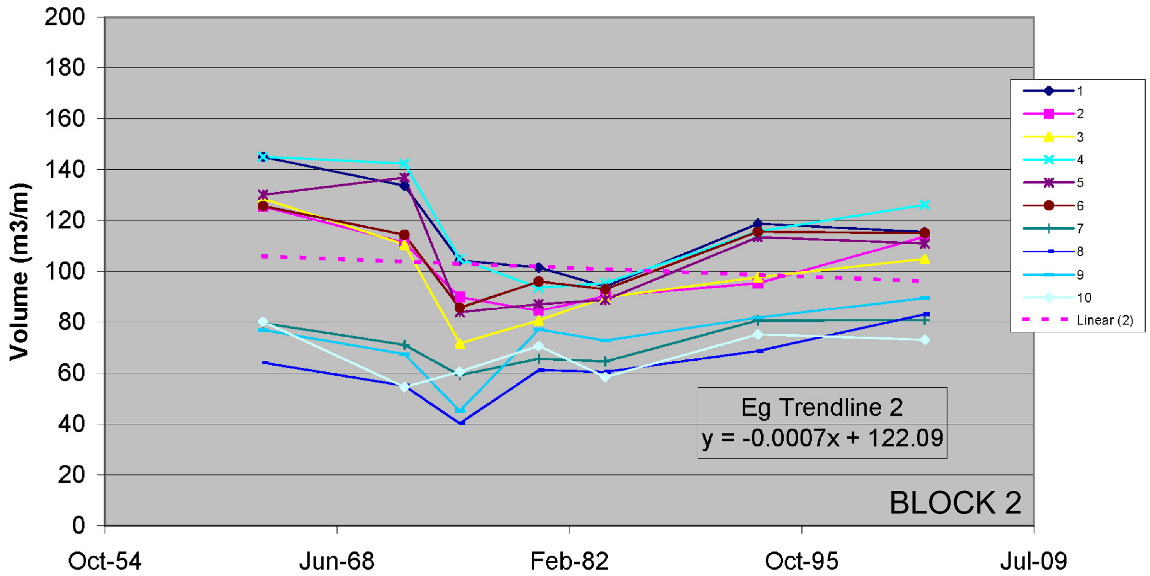
1 BULLOCK & WALTERS SURVEYORS SEABED PROFILE SURVEY FEB 2010

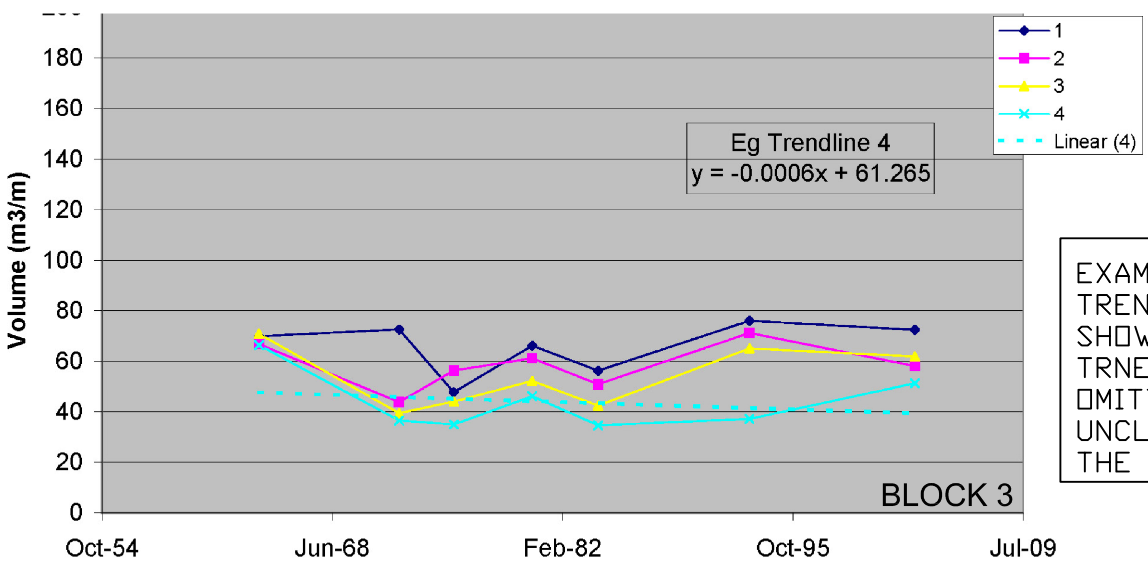
2. DECCW PHOTOGRAMMETRIC PROFILE BASE

gbaCOASTAL
J09-41/lr897
Plot date 18/3/10

FEBRUARY 2010 SEABED PROFILE SURVEY





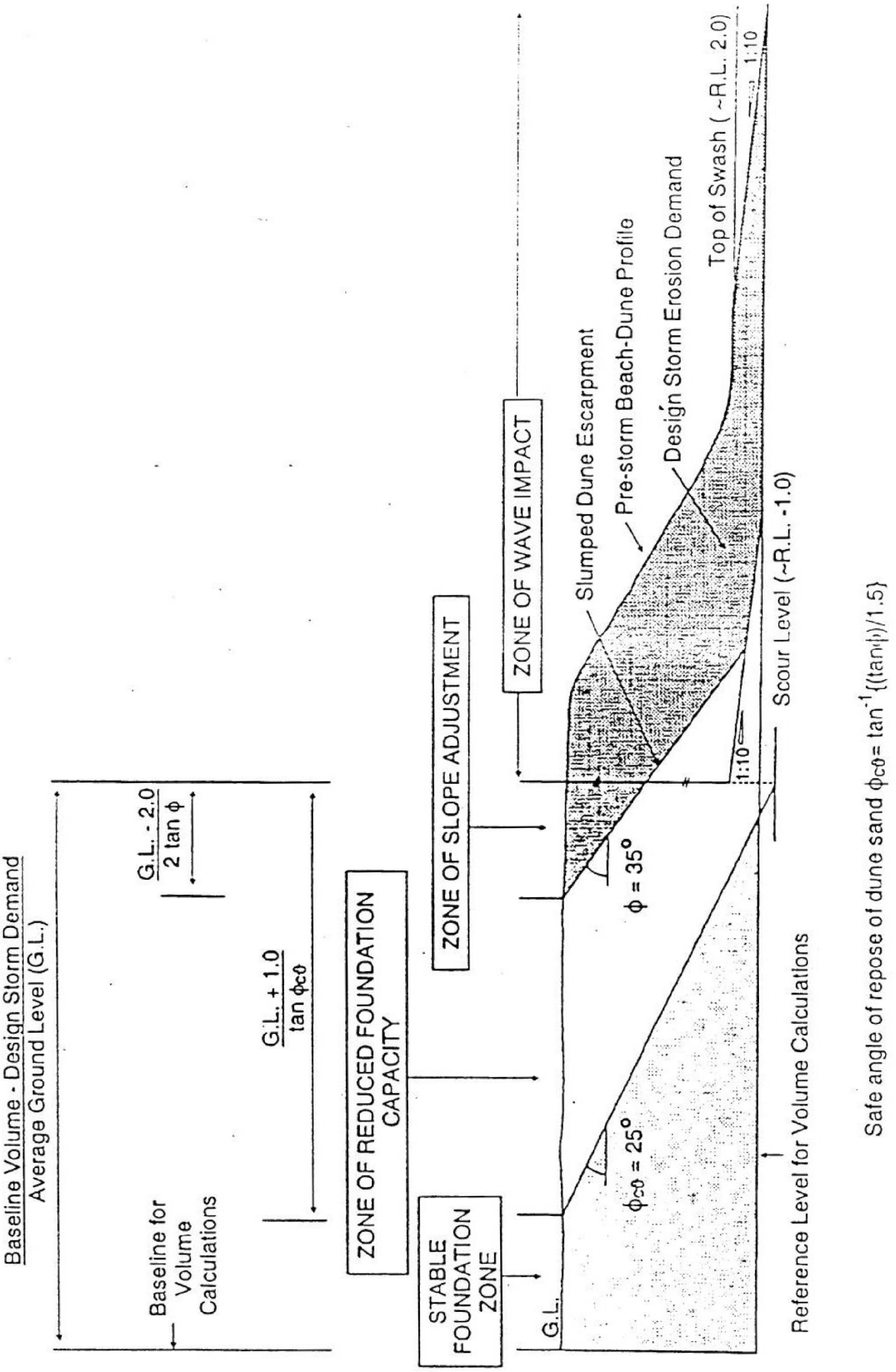


EXAMPLE TRENDLINES SHOWN. TRNEDLINES OMITTED TO UNCLUTTER THE FIGURE

SOURCE: PHOTOGRAMMETRIC VOLUMES BY DIPNR (2005)

PHOTOGRAMMETRIC VOLUMES SHOWING EXAMPLE TRENDLINE ASSESSMENT

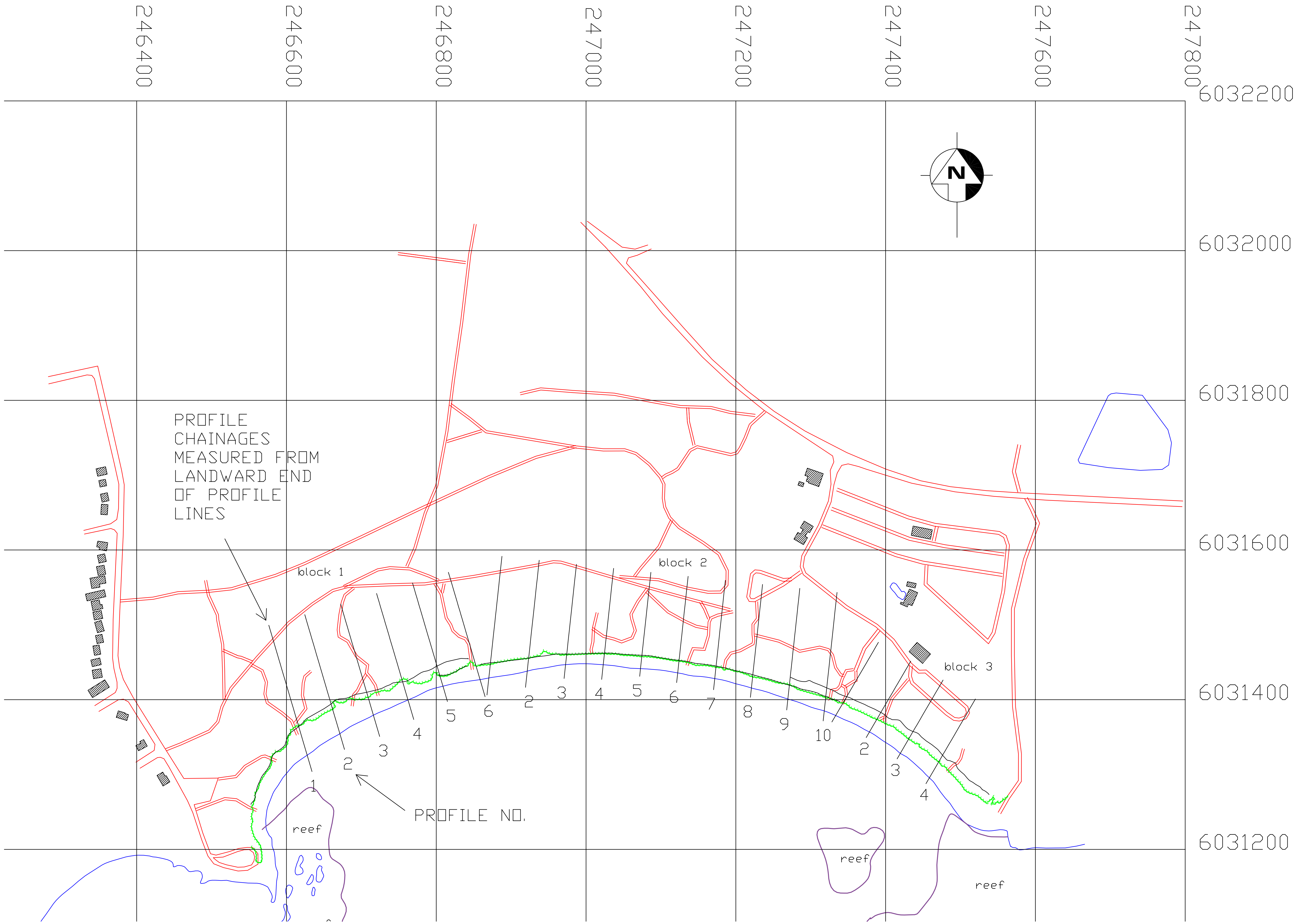
gbaCOASTAL
J09-41/lr897
Plot date 18/3/10



SOURCE: NIELSEN ET AL (1992)

NIELSEN MODEL FOR DUNE STABILITY ZONES

FIGURE 7

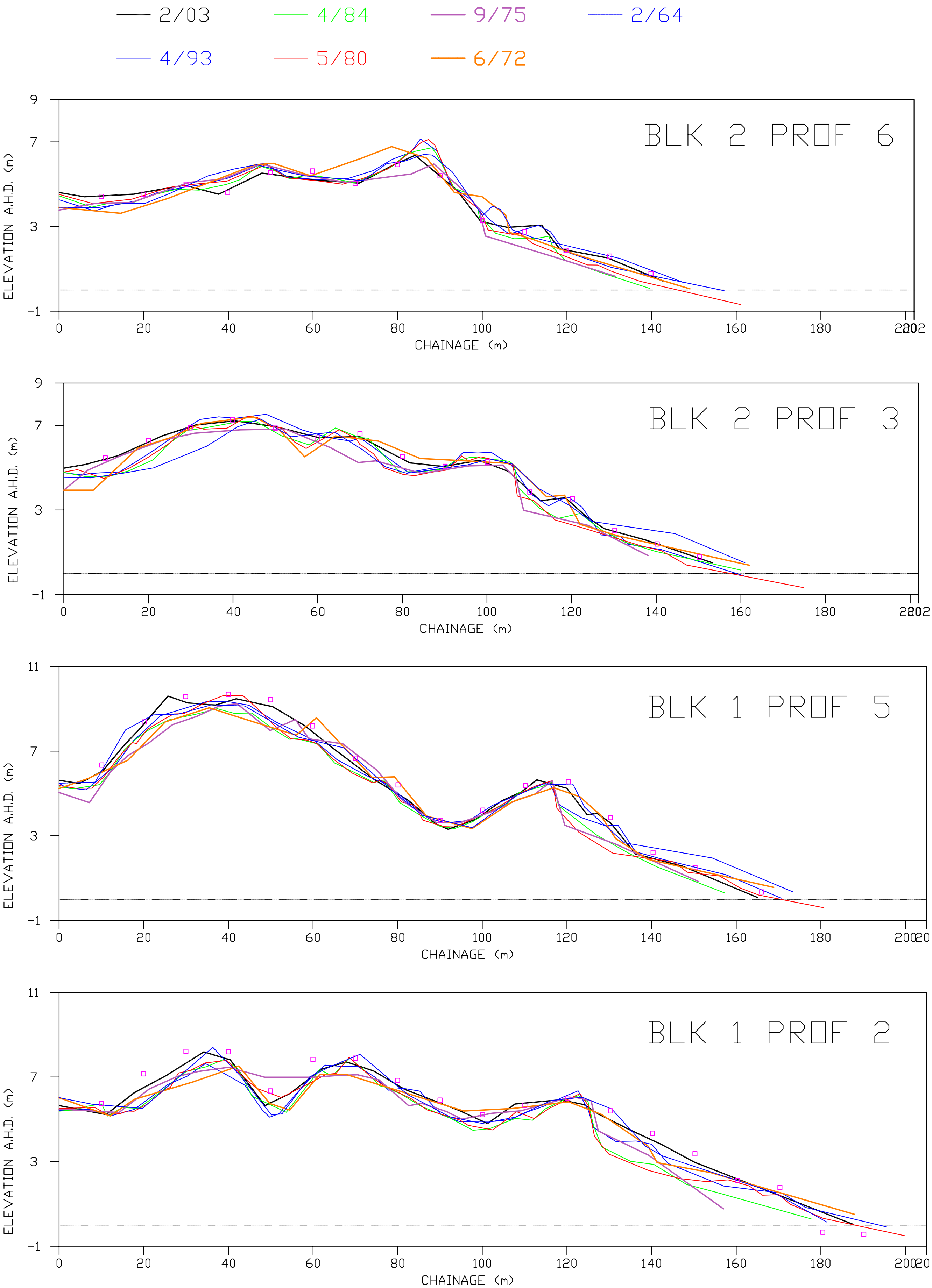


SOURCE: DECCW. BASE FROM 2003 AERIAL PHOTOGRAPHY. MGA GRID IN METRES

gbaCOASTAL
J09-41/lr897
Plot date 18/3/10

PHOTOGRAMMETRIC BASE LAYOUT FOR BARLINGS BEACH

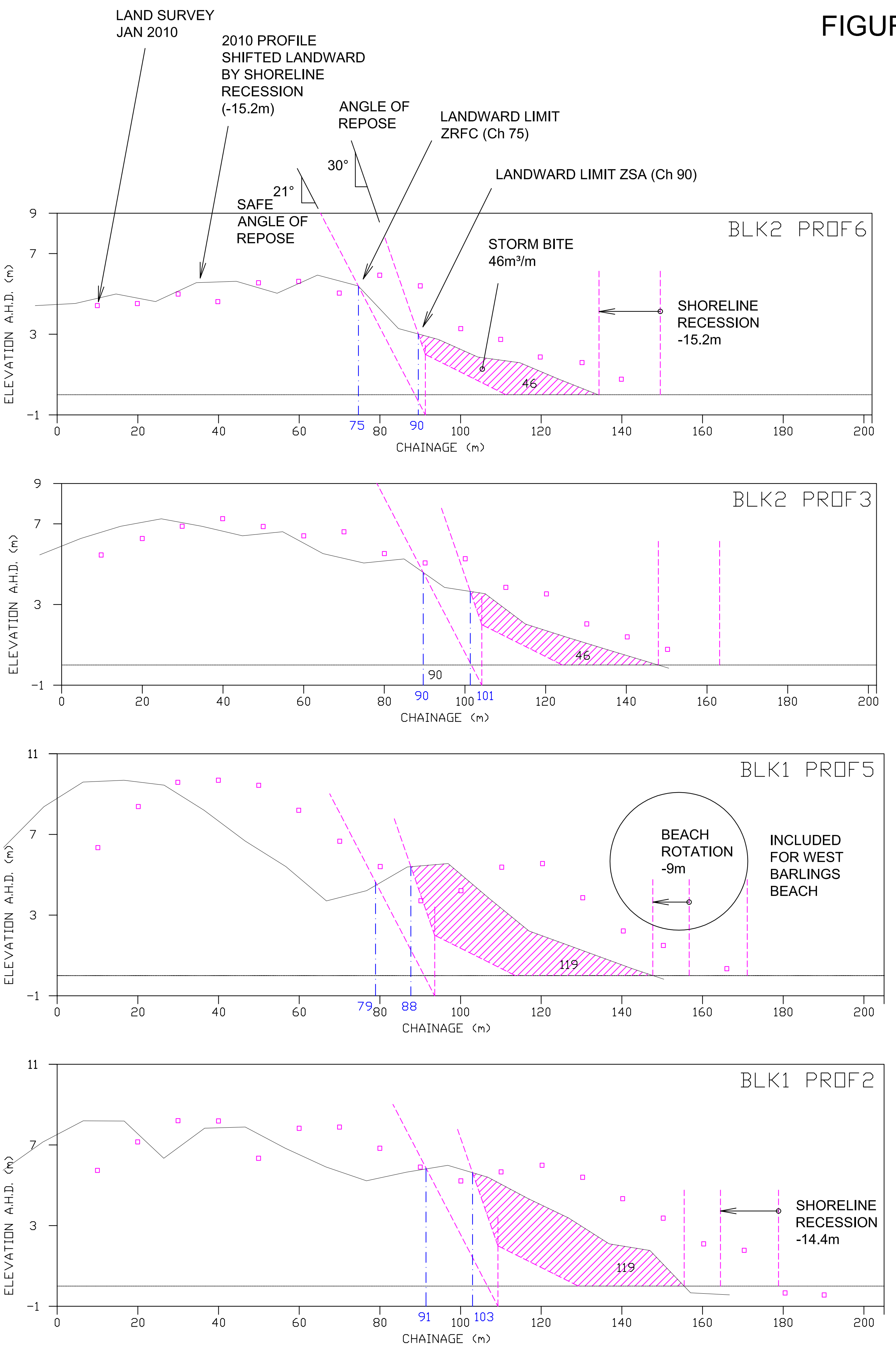
FIGURE 8



gbaCOASTAL
J09-41/lr897
Plot date 18-3-10

SELECTED PHOTOGRAMMETRIC PROFILES WITH 2010 SURVEY POINTS

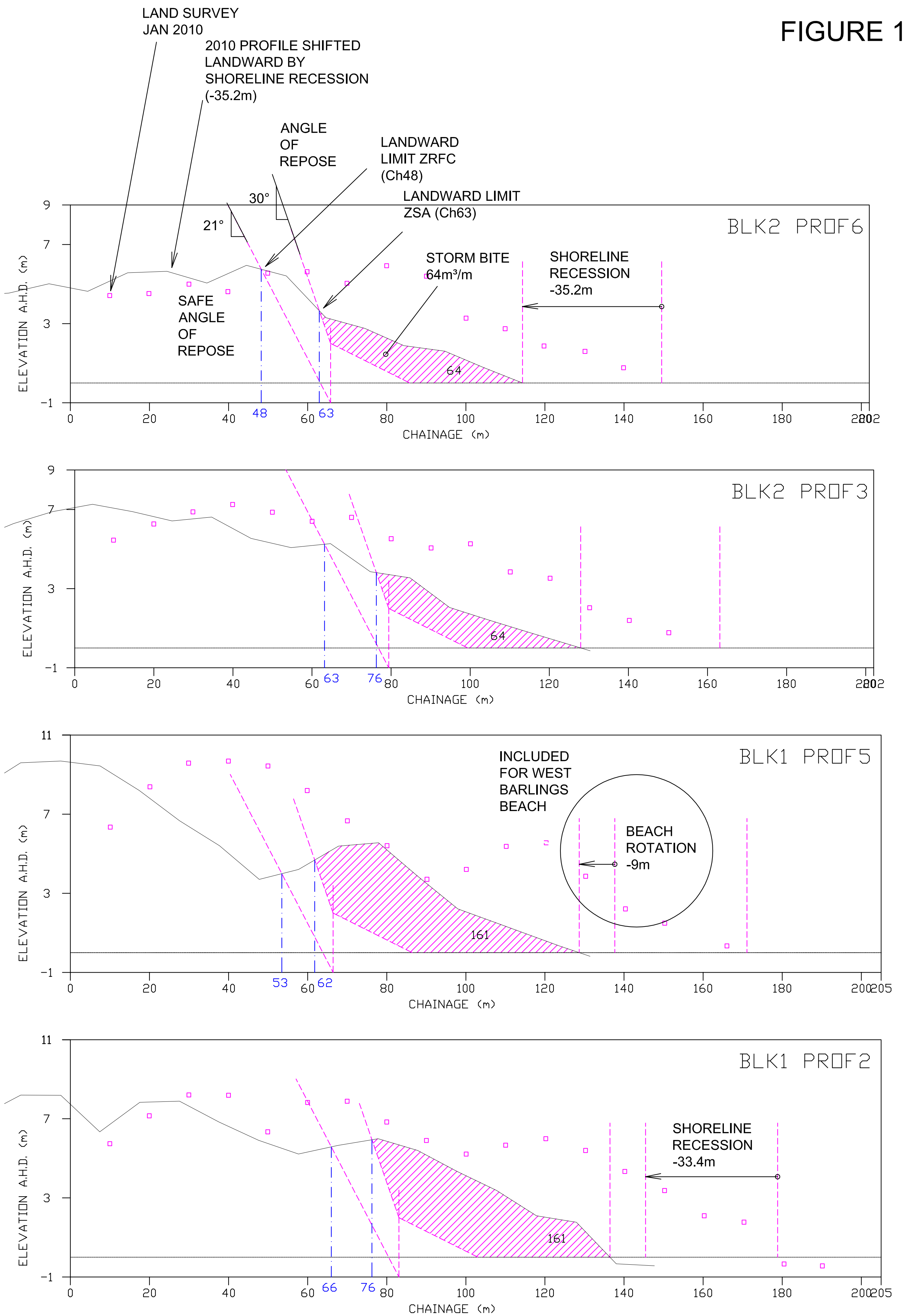
FIGURE 9



gbaCOASTAL
J09-41/lr897
Plot date 18-3-10

2050 HAZARD LINE ASSESSMENT

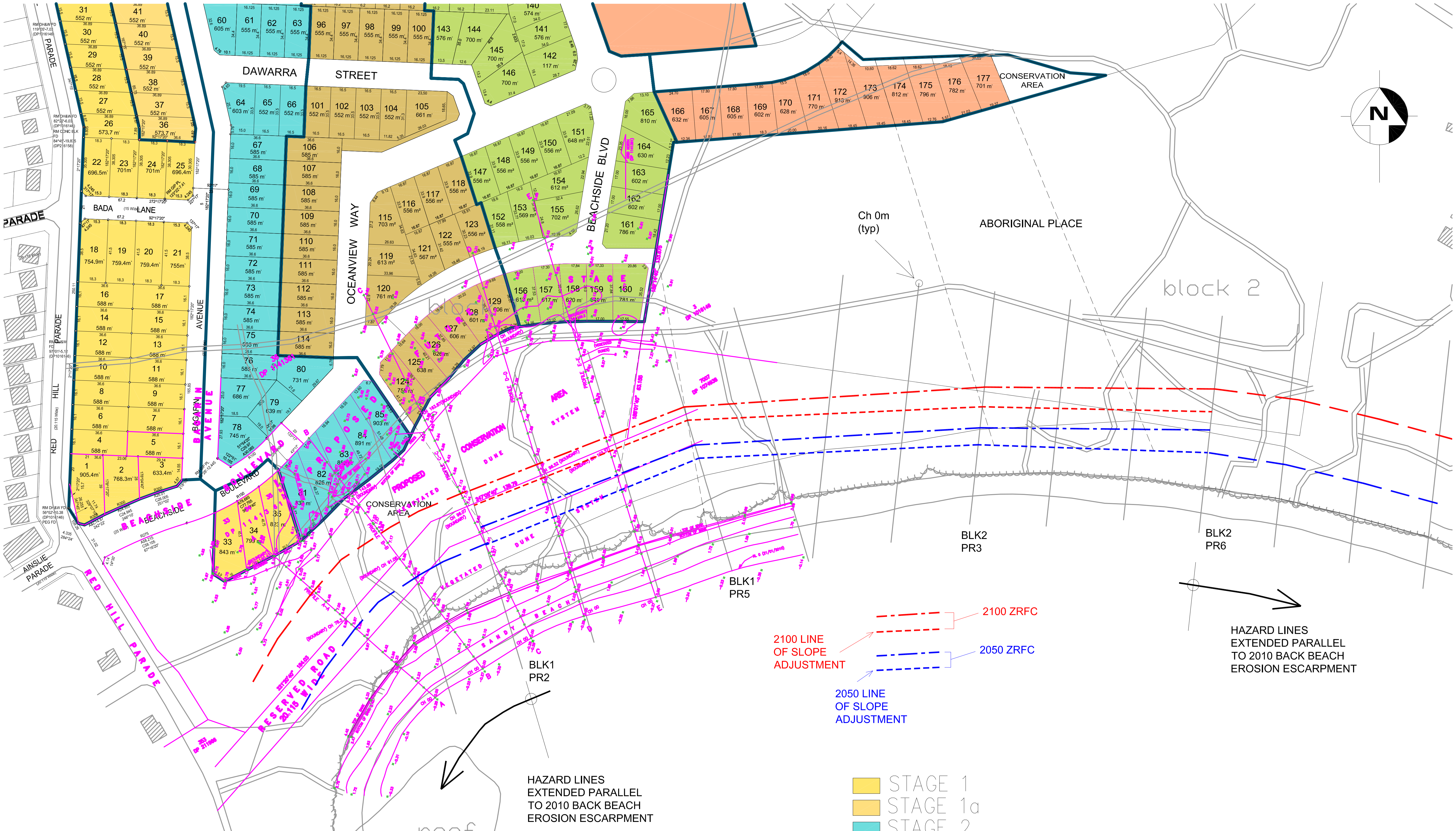
FIGURE 10



gbaCOASTAL
J09-41/lr897
Plot date 19-3-10

2100 HAZARD LINE ASSESSMENT

FIGURE 11



STAGE 1
STAGE 1a
STAGE 2
STAGE 3
STAGE 4
STAGE 5

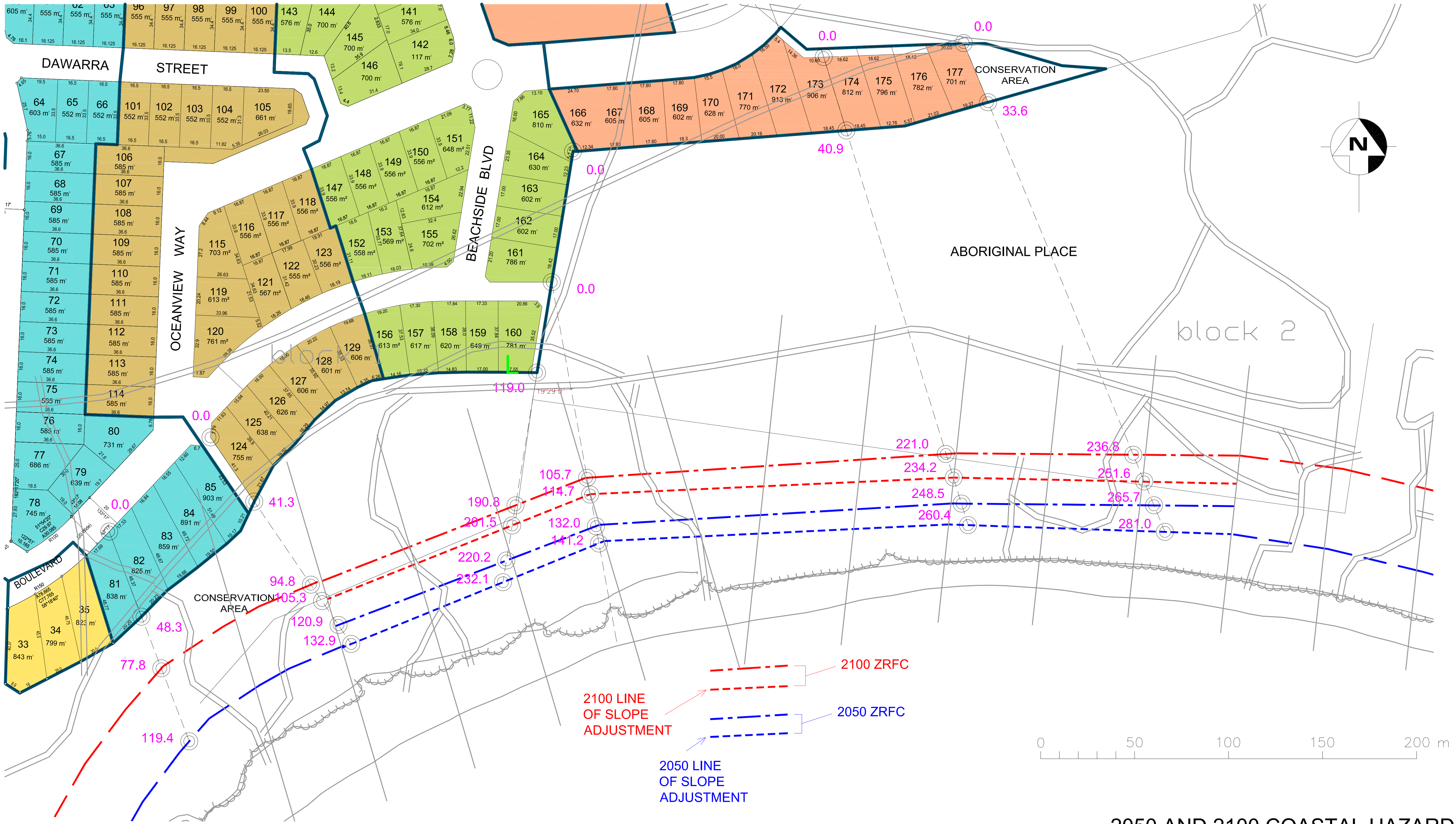
0 50 100 150 m

NOTES

1. ASSESSMENT OF HAZARD LINES ALLOWS FOR EROSION, RECESSION AND BEACH ROTATION, INCLUDING EFFECTS OF CLIMATE CHANGE ON SEA LEVEL RISE AND STORM WAVES
2. SUBDIVISION LAYOUT FROM WALKER CORP 15/3/10
3. PHOTOGRAMMETRIC BASE FROM DECCW
4. BEACH AND DUNE SURVEY BY BULLOCK & WALTERS SURVEYORS JAN 2010

gbaCOASTAL
J04-41/lr897
Plot date 18/3/10

2050 AND 2100 COASTAL HAZARD LINES SHOWING ZONE OF SLOPE ADJUSTMENT (ZSA) AND ZONE OF REDUCED FOUNDATION CAPACITY (ZRFC)



NOTES

1. ASSESSMENT OF HAZARD LINES ALLOWS FOR EROSION, RECESSION AND BEACH ROTATION, INCLUDING EFFECTS OF CLIMATE CHANGE ON SEA LEVEL RISE AND STORM WAVES
2. SUBDIVISION LAYOUT FROM WALKER CORP 15/3/10
3. PHOTOGRAMMETRIC BASE FROM DECCW
4. BEACH AND DUNE SURVEY BY BULLOCK & WALTERS SURVEYORS JAN 2010

STAGE 1
STAGE 1a
STAGE 2
STAGE 3
STAGE 4
STAGE 5

2050 AND 2100 COASTAL HAZARD LINES SHOWING ZONE OF SLOPE ADJUSTMENT (ZSA) AND ZONE OF REDUCED FOUNDATION CAPACITY (ZRFC)

SET OUT DIMENSIONS RELATIVE TO SUBDIVISION LAYOUT

gbaCOASTAL
J04-41/lr897
Plot date 18/3/10

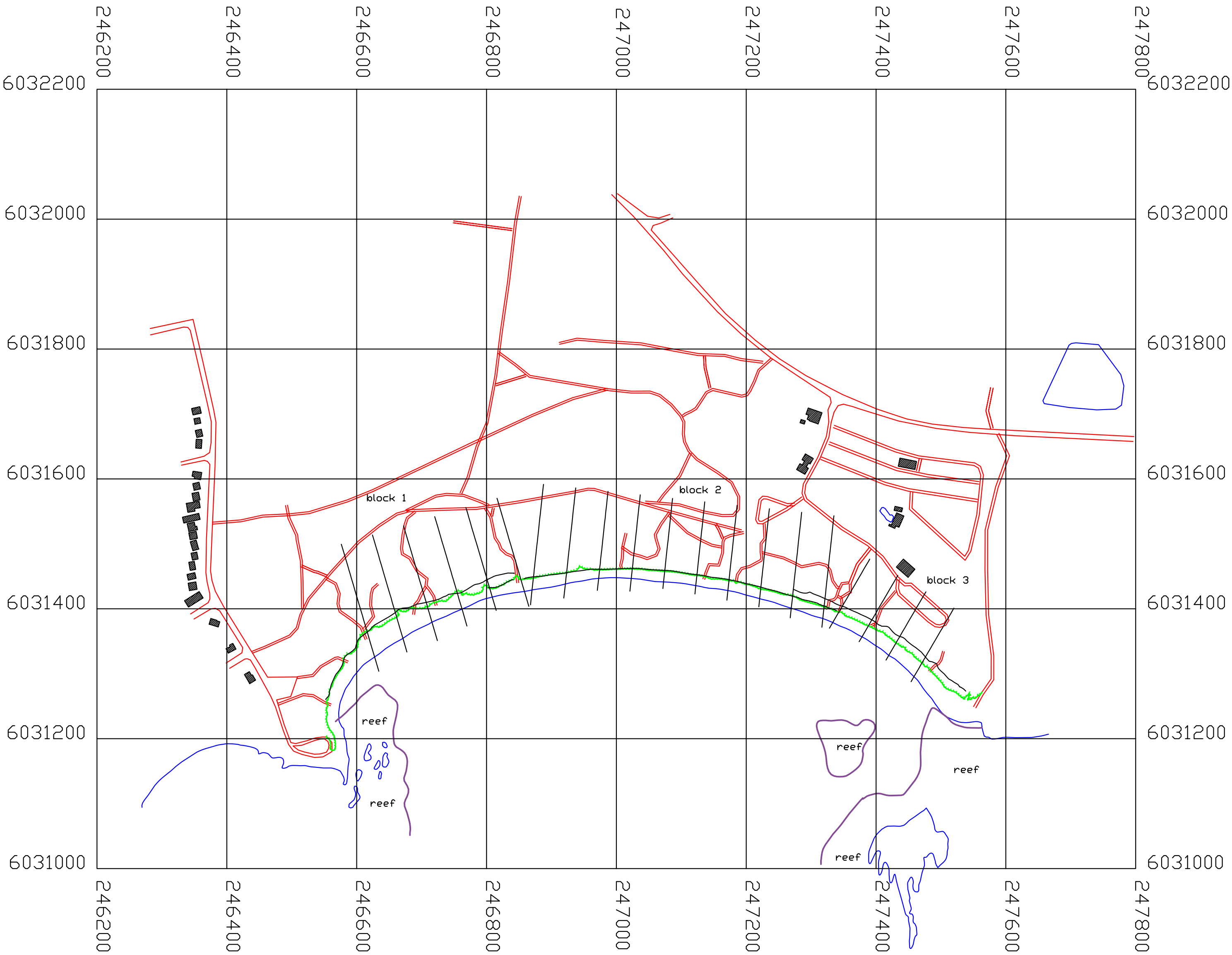
APPENDIX A

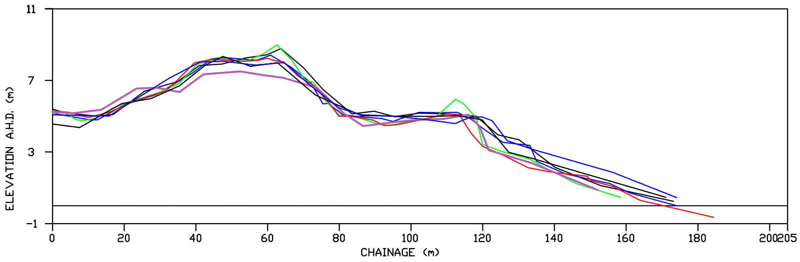
AERIAL PHOTOGRAMMETRY
PROVIDED BY DECCW
(REPRODUCED FROM CES, 2005)

			Area contained seaward of truncation point (m2)							Storm Bite
Block	**Profile No**	**Prof Trucation Chainage (m)**	Feb-64 1964	Jun-72 1972	Sep-75 1975	May-80 1980	Apr-84 1984	Apr-93 1993	Feb-03 2003	m3/m 72-75
1	1	135	174.1	198.9	88.8	131.9	119.5	160.1	159	110.1
	2	125	156.3	160.8	97	119.9	105.9	143.3	163.2	63.8
	3	123	135.5	116	60.2	102.1	98.3	128.9	129.1	55.8
	4	121	127.1	120.5	63.1	86.9	86.3	114.8	102.4	57.4
	5	117	141.1	122.5	85.1	92.1	85.8	114.4	111.9	37.4
	6	115	156.9	130.7	97.2	100.1	100.3	122.8	130.2	33.5
2	1	130	145	133.7	104.3	101.6	94.1	118.7	115.5	29.4
	2	119	125.5	111.3	90	84.5	90.4	95.4	113.7	21.3
	3	107	128.6	110.6	71.7	80.7	89.9	97.8	105	38.9
	4	97	145.1	142.4	105	93.7	95.5	115.7	126.2	37.4
	5	95	130.1	136.9	83.9	87.2	88.9	113.5	111	53
	6	93	125.7	114.4	85.8	96.1	93.1	115.6	115.1	28.6
	7	104	79.6	71.1	59.2	65.7	64.6	80.7	80.8	11.9
	8	112	64.1	55.1	40.3	61.2	60.5	68.7	83.1	14.8
	9	117	76.9	67.5	45.2	77.1	72.8	81.8	89.6	22.3
	10	130	80.2	54.6	60.6	70.7	58.5	75.2	73.1	-6
3	1	85	69.9	72.6	47.8	66.2	56.3	76	72.4	24.8
	2	81	66.8	43.9	56.4	61.2	51	71.2	58.1	-12.5
	3	81	70.9	39.5	44.1	52.3	42.5	65.1	61.9	-4.6
	4	89	66.4	36.6	35	46.2	34.7	37.2	51.4	1.6

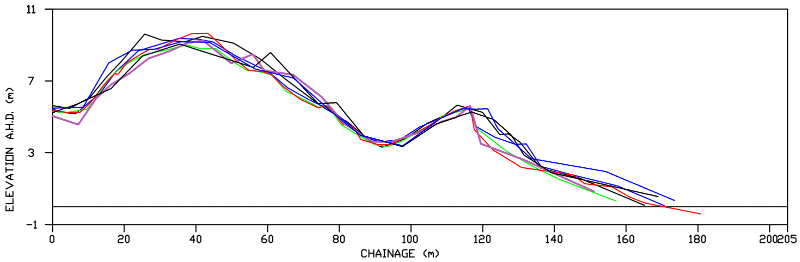
	Volume contained seaward of truncation point (m3)						
Block	1964.093 1964	1972.425 1972	1975.695 1975	1980.356 1980	1984.277 1984	1993.288 1993	2003.099 2003
1	36272	34233	19927	25851	24308	32141	32559
2	49415	45178	33181	36614	36599	43307	45941
3	10293	6901	7099	8489	6948	9648	9094
Total	**95980**	**86312**	**60207**	**70954**	**67855**	**85096**	**87594**

Table 2.1: Photogrammetry Volumes (Courtesy P. Watson (DIPNR) – 1st April 2005)

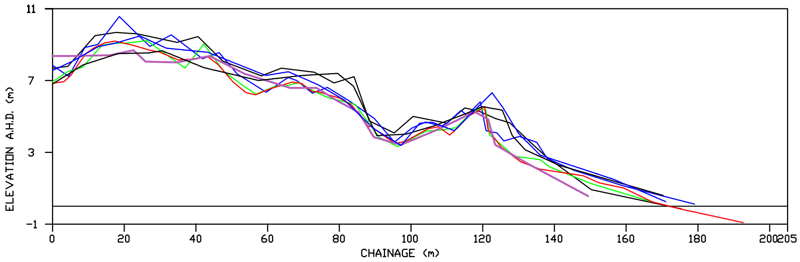

246200
246400
246600
246800
247000
247200
247400
247600
247800
6032200
6032000
6031800
6031600
6031400
6031200
6031000
block 1
block 2
block 3
reef
reef
reef
reef
reef



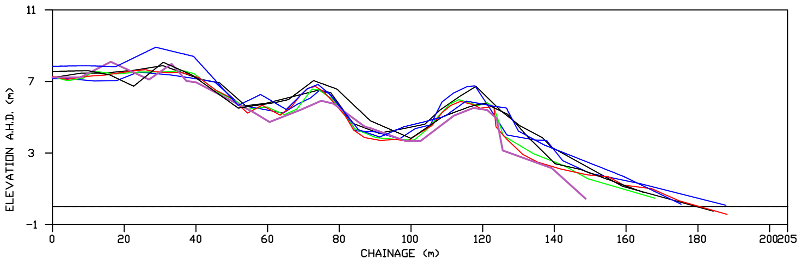
PROFILE 6



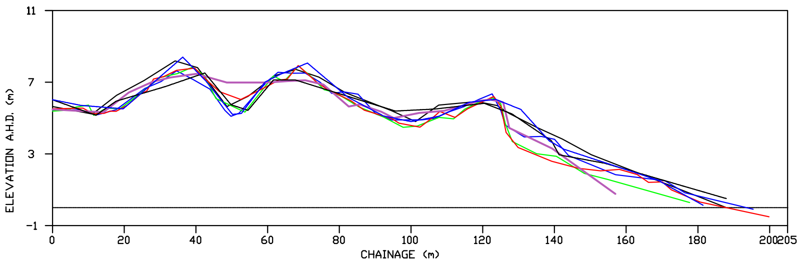
PROFILE 5



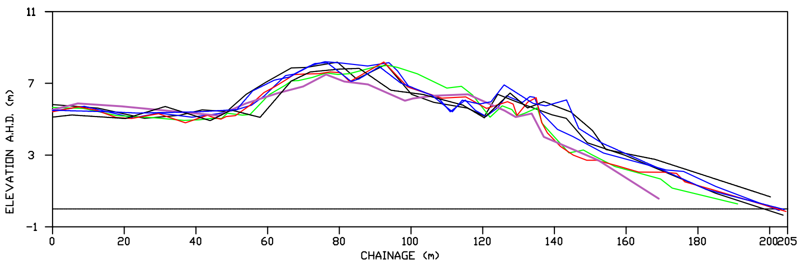
PROFILE 4



PROFILE 3



PROFILE 2



PROFILE 1

a:\b91031.dat (2003)

a:\b91931.dat

a:\b91841.dat

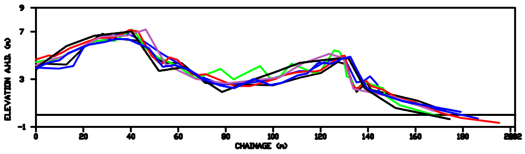
a:\b91801.dat

a:\b91751.dat

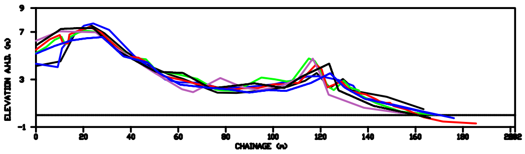
a:\b91721.dat

a:\b91641.dat (1964)

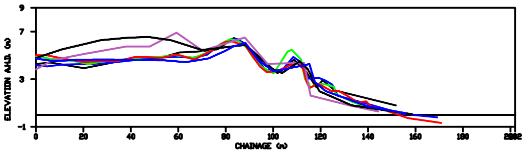
block 1



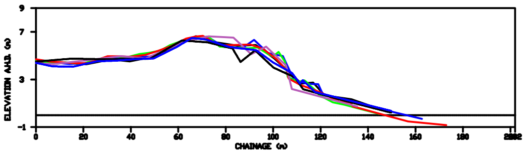
PROFILE 10



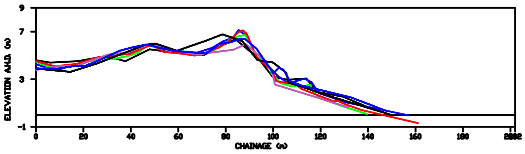
PROFILE 9



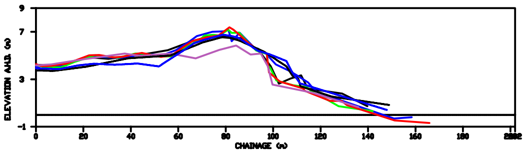
PROFILE 8



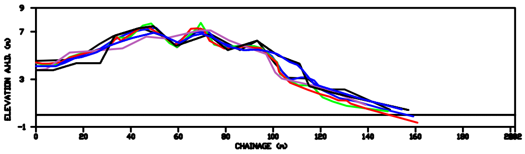
PROFILE 7



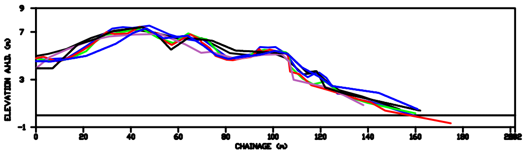
PROFILE 6



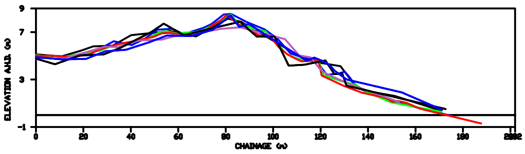
PROFILE 5



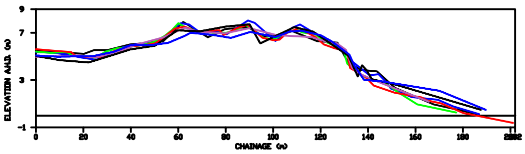
PROFILE 4



PROFILE 3



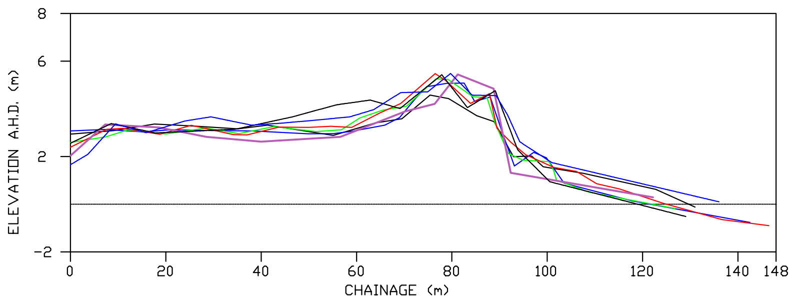
PROFILE 2



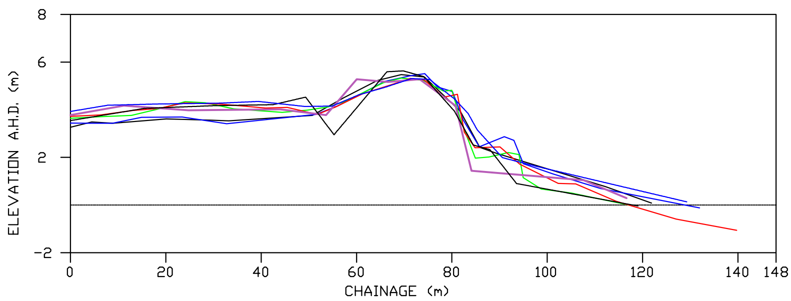
PROFILE 1

a:\b91032.dat
a:\b91932.dat
a:\b91842.dat
a:\b91802.dat
a:\b91752.dat
a:\b91722.dat
a:\b91642.dat

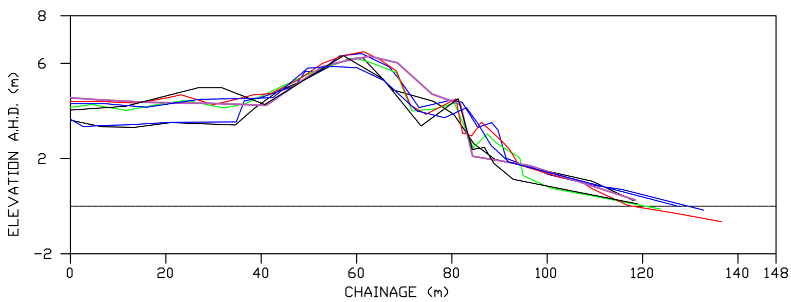
block 2



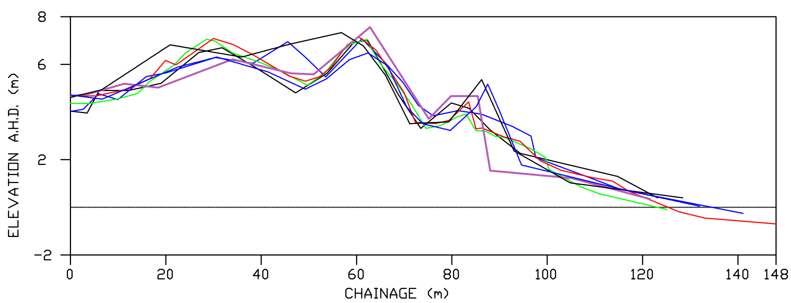
PROFILE 4



PROFILE 3



PROFILE 2



PROFILE 1

a:\b91033.dat

a:\b91933.dat

a:\b91843.dat

a:\b91803.dat

a:\b91753.dat

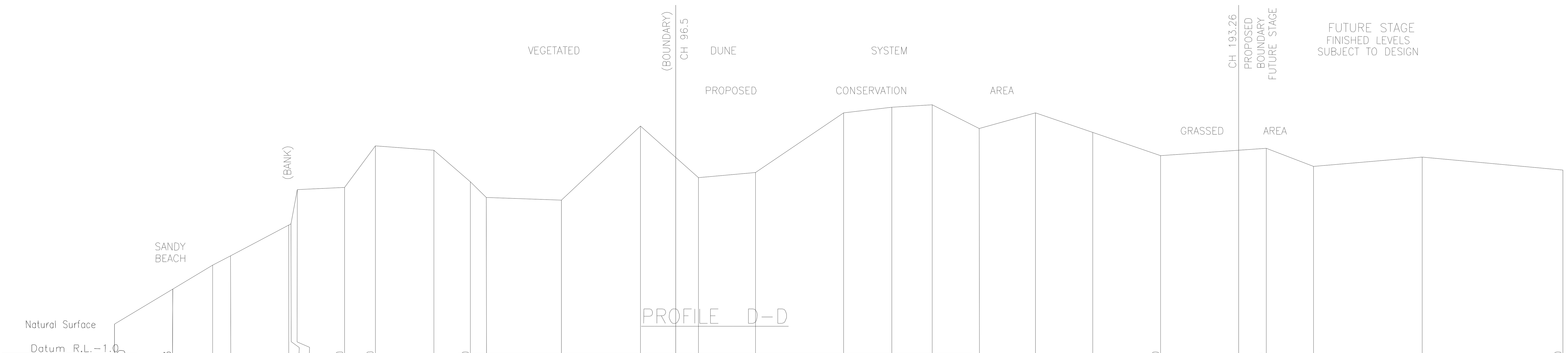
a:\b91723.dat

a:\b91643.dat

block 3

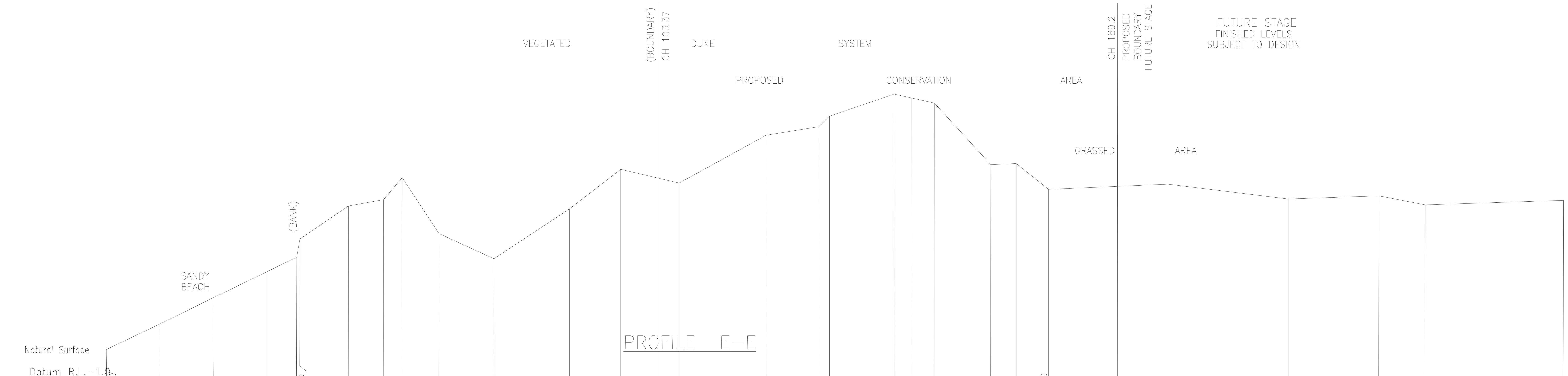
APPENDIX B

LAND SURVEY OF BEACH AND FORESHORE FRONTING REFLECTIONS SUBDIVISION (BULLOCK AND WALTERS SURVEYORS, JAN 2010)



CHAINAGE	Natural Surface
0.000	0.000
10.000	1.203
16.873	2.027
20.000	2.358
30.000	3.419
30.390	3.460
31.430	4.640
39.550	4.710
44.830	6.140
54.890	5.990
61.180	4.910
63.970	4.370
76.830	4.280
90.430	6.830
100.390	5.050
110.210	5.230
125.335	7.280
133.625	7.480
140.585	7.560
148.685	6.740
158.345	7.280
168.185	6.607
179.825	5.810
197.985	6.060
206.125	5.440
224.825	5.750
249.015	5.310

Scale Horizontal 1:500 Vertical 1:100

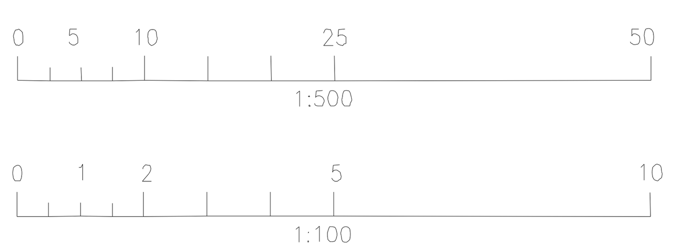


CHAINAGE	Natural Surface
0.000	0.000
10.000	0.967
20.000	1.933
30.000	2.920
35.587	3.470
36.207	4.150
45.337	5.380
51.837	5.620
55.337	6.445
62.227	4.350
72.537	3.400
86.617	5.280
96.237	6.760
107.167	6.240
123.437	8.040
133.334	8.360
135.337	8.750
147.394	9.580
150.594	9.436
154.934	9.240
165.484	6.930
170.224	6.980
176.294	6.010
198.634	6.200
221.154	5.650
238.114	5.760
246.774	5.430
272.664	5.600

Scale Horizontal 1:500 Vertical 1:100

AUSTRALIAN HEIGHT DATUM – ORIGIN PM 80971 3.618m

REFER TO DRAWING 12901-21A FOR PLAN



RL 0 SETBACK PROFILES

BARLINGS BEACH ESTATE
TOMAKIN
FOR PRESIDENT PROPERTY GROUP

G.A. BEASLEY PTY LIMITED TRADING AS
BULLOCK & WALTERS
ABN 56 056 675 355
Surveyors, Planners, Road and Drainage Engineers
Centrepoint, 13 Beach Rd. Batemans Bay 2536 (PO Box 346)
Ph (02) 44724750 Fax (02) 44727569

Surveyed: 21/01/10
Designed:
Drawn: 22/01/10
Approved:

Scale AS SHOWN
Drawing No. 12901-21C

AUSTRALIAN HEIGHT DATUM – ORIGIN PM 80971 3.618m
CONTOUR INTERVAL 1m

BEARINGS & DISTANCES SHOWN ARE BASED ON DEPOSITED PLAN 1141361

REFER TO DRAWING 12901-21B & C FOR PROFILES

FUTURE STAGE SHOWN AS PER ISSUED PLAN
(BARLINGS BEACH – REVISED SUBDIVISION MASTERPLAN SEPTEMBER 2009
DRAWING M-01-REVISION D)

LEVELS OF LOTS IN FUTURE STAGE SUBJECT TO DESIGN

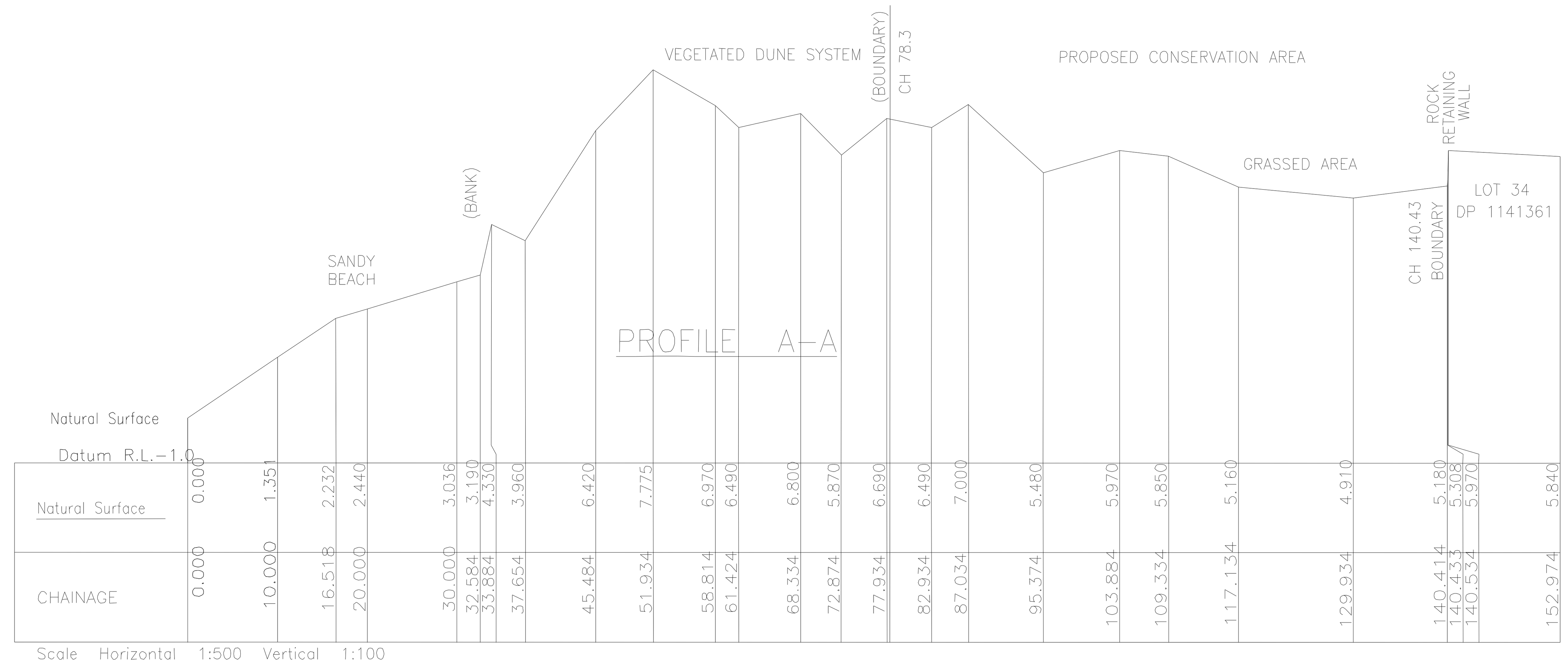
0 10 20 40 80
1:600

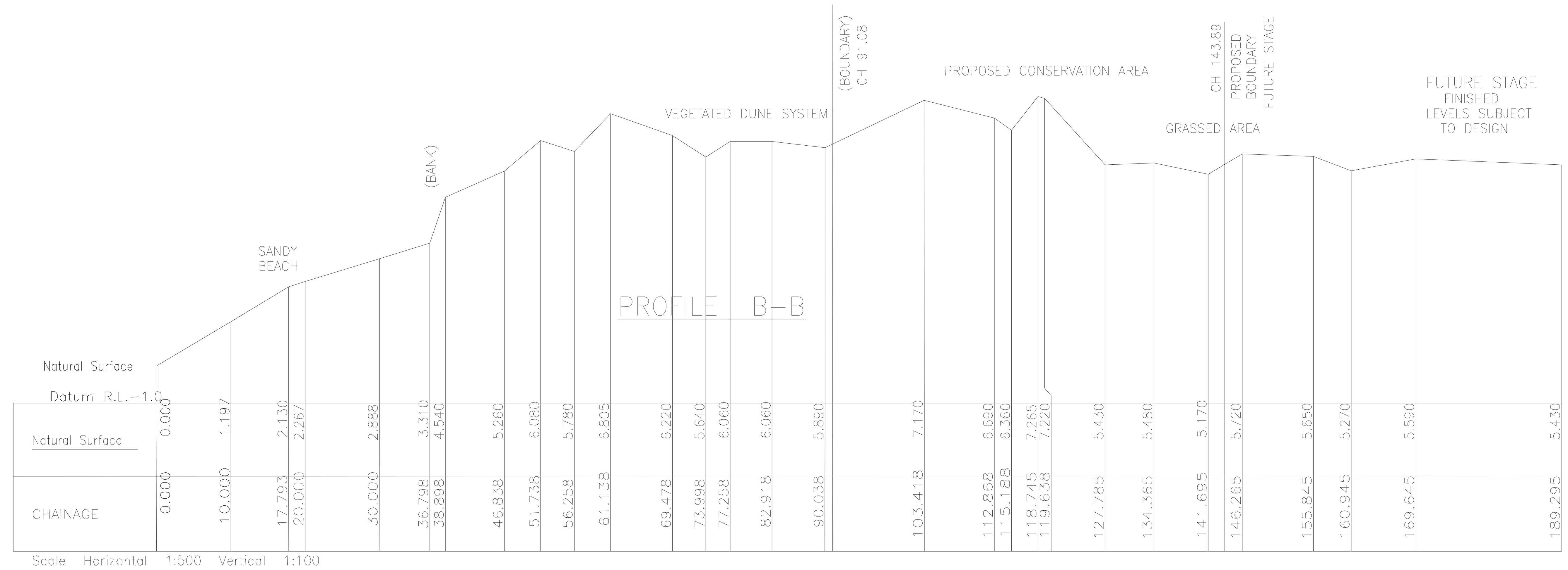
RL 0 SETBACK PLAN
BARLINGS BEACH ESTATE
TOMAKIN
FOR PRESIDENT PROPERTY GROUP

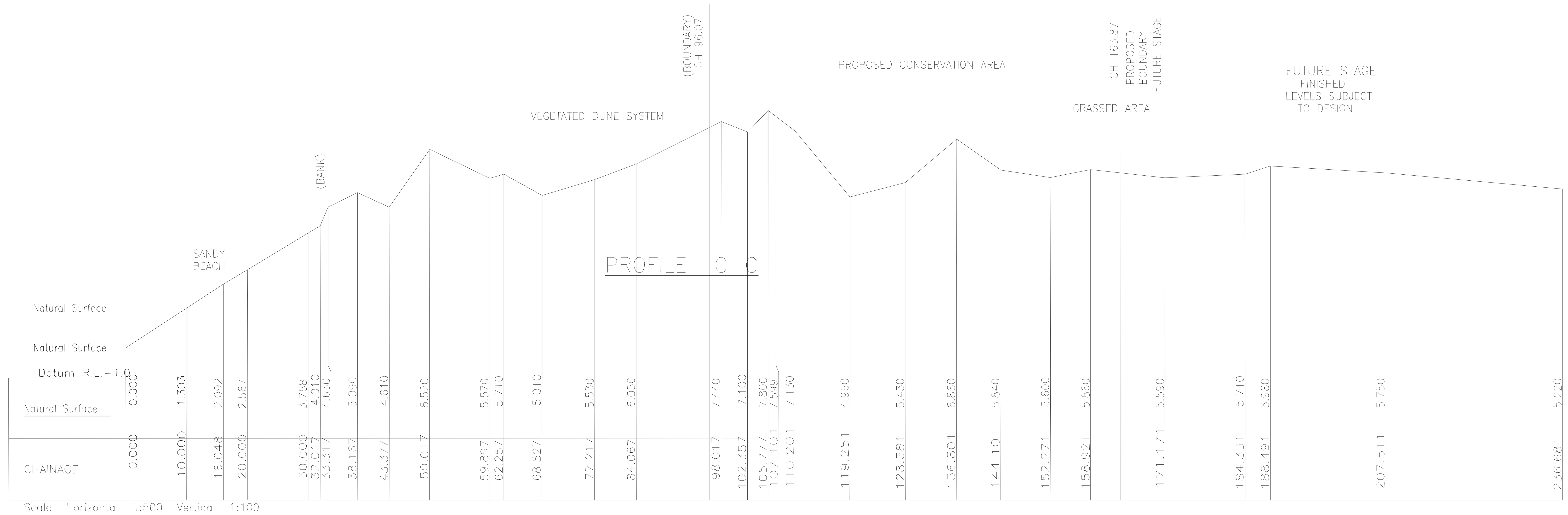
G.A. BEASLEY PTY LIMITED TRADING AS
BULLOCK & WALTERS
ABN 56 056 675 355
Surveyors, Planners, Road and Drainage Engineers
Centrepoint, 13 Beach Rd, Batemans Bay 2536 (PO Box 346)
Ph (02) 44724750 Fax (02) 44727569

Surveyed:	21/01/10
Designed:	
Drawn:	22/01/10
Approved:	

Scale 1:600
Drawing No. 12901-21A







AUSTRALIAN HEIGHT DATUM – ORIGIN PM 80971 3.618m

REFER TO DRAWING 12901–21A FOR PLAN

0 5 10 25 50
1:500

0 1 2 5 10
1:100

RL 0 SETBACK PROFILES

BARLINGS BEACH ESTATE
TOMAKIN
FOR PRESIDENT PROPERTY GROUP

G.A. BEASLEY PTY LIMITED TRADING AS
BULLOCK & WALTERS
ABN 56 056 675 355
Surveyors, Planners, Road and Drainage Engineers
Centrepoint, 13 Beach Rd. Batemans Bay 2536 (PO Box 346)
Ph (02) 44724750 Fax (02) 44727569

Surveyed:	21/01/10
Designed:	
Drawn:	22/01/10
Approved:	

Scale AS SHOWN

Drawing No. 12901–21A