Cardno
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Estuarine Planning Levels Study

Foreshore Region of Leichhardt Local Government Area

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Prepared for Leichhardt Municipal Council

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1 Introduction

Leichhardt Municipal Council (LMC) is responsible for local planning and land management for some 17km of foreshore land along Sydney Harbour.

As part of its Open Space Strategy (1993), and in line with a number of key State Government strategies, Council is continually seeking opportunities to establish and/or extend the open space linkages around the entire foreshore area. To achieve these outcomes, Council often needs to assess the feasibility of land for this purpose, or is undertaking construction or reconstruction of seawalls, walkways or boardwalks along the foreshore area.

Council also has the responsibility to ensure that the risks associated with wave action and storm tide inundation from the harbour are properly considered for all development applications.

To establish and maintain a consistent approach to the management of these areas, Council has commissioned a study to establish Estuary Planning Levels that can be readily applied to any section of the foreshore.

LMC engaged Cardno Lawson Treloar to undertake this investigation and this report describes the data available to the study, the range of investigations undertaken and the outcomes.

Generally, all results are in terms of Australian Height Datum (AHD).

The study area comprises the entire foreshore connection of the Leichhardt Council Local Government Area (LGA) to Sydney Harbour and the Parramatta River, extending from Iron Cove to Rozelle Bay. The LGA is shown high-lighted on Figure 1.1.

2 Objectives

The primary objective of the study was to define storm tide, wave run-up and overtopping impact effects on water level for the foreshore areas of the Leichhardt Council LGA, so that consistent and informed development decisions can be made for the management of these areas.

Specifically, the study has produced information on water levels (designated as a still water level) and wave impacts (a short term process) as may be generated by a range of storm events, including the 5, 10, 20, 50, 100 and 200-years average recurrence interval (ARI) design conditions.

The study provides a maximum level at each property, with simple adjustments to wave run-up that can be applied, depending on typical shoreline treatments, such as sloping embankments, beaches or vertical walls, and has been presented on a GIS layer for inclusion in Council's cadastral system.

Also incorporated into the study is a review of the practices and policies of other government bodies that manage development and works along estuarine foreshore areas in the Sydney metropolitan region (Section 3). These bodies include the Sydney Harbour Foreshore Authority and NSW Maritime.

3 Review of Current Practices

A number of Councils and Government Agencies were contacted with the purpose of inquiring about their existing policies, procedures and development controls that are applied to manage development and works with direct foreshore access to Sydney Harbour and/or the Parramatta River. The purpose of this assessment is to be able to determine where Council's estuarine planning policy sits relative to those of other local government bodies.

In the first instance a letter was sent to a number of Councils, together with the Sydney Harbour Foreshore Authority (SHFA) and NSW Maritime Authority. Those letters were followed by telephone requests for information and interviews with planning, environmental and engineering staff - as nominated by each body.

Generally, none of the groups contacted has undertaken a detailed study to prepare development controls of this nature. The closest any party has to such a planning control is the Department of Planning (DoP) who have prepared a Development Control Plan for Sydney Harbour, published in 2005 and available at www.planning.nsw.gov.au under Plans for Action and then Foreshores and Waterways Areas.

It appeared as though, apart from DoP themselves, only some of the Groups contacted were aware of this control plan. However, it provides little information of use to Leichhardt Council, or other government bodies. For example, boat shed floor levels are to be set at 1.6m AHD, tops of seawalls and reclamation areas are to be at 1.7m AHD. There is no floor level information for residential properties or set-back restrictions, for example.

NSW Maritime tend to assess each application individually. Although they have an Engineering Standards and Guidelines for Maritime Structures plan; it advises development proponents that they need to assess:-

- wind climate
- wave climate
- currents
- water levels (tidal range, storm surge, flood levels, seiching)
- coastal processes (accretion, erosion), and
- services (available, such as electricity and water).

Generally, they advise also that development proponents follow various maritime structures codes such as AS4997-2005.

Manly Council has completed a number of Coastline Hazard Definition Studies. A copy of one such report "Davis Marina to Manly Point" was provided. Although that document addresses the Coastal Inundation Hazard, it does so by referring to Manly Cove, for example, showing an historical photograph of one such event and then advising that the potential for overtopping needs to be assessed from time-to-time, but mainly for drainage system assessment. Floor levels are not mentioned specifically.

On the other hand, Ashfield Council advised that the Haberfield Rowing Club was the only site that had direct water front property. All other properties stood landward of park areas such as Timbrell Park or across major roadways such as Dobroyd Parade. Hence there was no need for such a development control in their local government area. Lane Cove Council has a policy of not permitting new development closer than 15m from the foreshore. "Low-lying" areas require a flood study to define floor levels based on the 100-years flood level +0.5m freeboard – no marine-based conditions.

Sydney City Council advises that it defers to the Department of Planning, see above, which document provides virtually no guidance, and does not intend to undertake work of this type at present.

Woollahra Council doesn't have any specific development controls, but is aware of the DoP plan - only an LEP setting building standards has been prepared. They advised also that the Sydney Coastal Councils Group is working with CSIRO and has engaged Macquarie University to investigate a range of shoreline risk issues.

The Sydney Coastal Council's group has plans and projects in place, mainly to examine the risks of climate change. A description of some of their current work is provided in Appendix A. One would consider that part of such a process would be to establish present inundation levels, but that appears not to be the case.

Amongst the Council's contacted, Pittwater has the most developed policy, which was adopted in 2004 (Pittwater Council 2004b). Pittwater Council also has a related coastline risk management policy (Pittwater Council 2004a), but no development control plans as such. Areas of application are identified on Pittwater Council's Estuarine Hazard and Coastline Hazard maps, respectively. The Estuarine policy advises that all floor levels shall be at or above the Estuarine Planning Level, excluding only open decks and open balconies, jetties, ramps and pontoons. However, variations are allowed in the cases of boat-sheds and constrained or heritage sites, where consideration may be given to a lower floor level for non-residential areas, subject to demonstration through an Estuarine Risk Management Report that all precautions have been taken to minimise risk from the effects of tidaloceanic inundation and wave action for the 100-years ARI conditions. Furthermore, on-site mitigation works are allowed, provided that the works do not affect neighbouring properties adversely and protection at 100-years ARI is achieved. Also, a Section 88B notation may be required under the Conveyancing Act 1919 describing the location and type of wave action or inundation works with a requirement for their retention and maintenance. Where subdivision might be sought, each additional created lot must be at or above the Estuarine Planning Level.

The Pittwater policy document also advises that redevelopment proponents may seek independent advice as an alternative. That advice must include a site survey and be prepared by a Coastal Engineer.

A range of forms is included in the policy document that allows redevelopment proponents to determine the relevant Estuarine Planning Level for their sites from Pittwater Council's web site, depending on the existing or proposed edge treatment.

Great Lakes Council was contacted also – Mr Gerard Tuckerman of the Natural Systems Branch. He advised that Council was investigating water levels in Smiths and Wallis Lakes. More information was obtained from Mr Richard Dewar of Webb, McKeown and

Associates who is undertaking the work for them. Generally, for Smiths Lake, the main issue is entrance berm management. In Wallis Lake they have undertaken a range of joint ocean and catchment flooding simulations, taken the envelope of water level results and added in wave run-up based on MHL (2001) for eight locations. The work is in draft form. It is noted that that study has not set out to be as flexible in terms of edge treatment types, or as spatially detailed as the present study for the Leichhardt LGA.

Appendix B provides a summary of these inquiries and the outcomes.

4 Physical Processes

The purpose of this section is to describe the physical processes that are important to the overall physiography of Port Jackson/Parramatta River in the Leichhardt Council LGA. These processes are: -

- Waves
- Currents
- Water Levels
- Winds

A glossary of terms is presented in Appendix C.

4.1 Waves

Waves that occur in estuarine areas may have energy in three distinct frequency bands. These are principally related to the generation and propagation of ocean swell (wave periods 7 to 20 seconds) and local sea (less than 7 seconds, typically even shorter at this site). Large waves generated by a storm are generally categorised as sea because wind energy is still being transferred to the ocean. Long waves (wave periods greater than 25 seconds) occur during storms and are caused by wave grouping. However, swell and long period waves are not important to this study because the site is too far from the coast.

Natural water waves are irregular in height and period and so it is necessary to describe wave conditions using a range of statistical parameters. In this study the following have been used:-

- H_s significant wave height - either H_{mo} or $H_{1/3}$, which is the average of the highest 1/3 of waves in a record
- H_{mo} significant wave height (H_s) based on $4\sqrt{M_o}$ where M_o is the zeroth moment of the wave energy spectrum (rather than the time domain $H_{1/3}$ parameter).
- H_{max} maximum wave height in a specified time period
- T_p wave energy spectral peak period, that is, the wave period related to the highest ordinate in the wave energy spectrum
- T_z average zero crossing period based on upward zero crossings of the still water line. An alternative definition is based on the zeroth and second spectral moments

Wave heights defined by zero upcrossings of the still water line fulfil the Rayleigh Distribution in deep water and thereby provide a basis for estimating other wave height parameters from H_s. In shallow water, that is, depths less than half a wave length or 3 to 5m at this site, significant wave height defined from the wave spectrum, H_{mo}, is normally larger (typically 5% to 8%) than $H_{1/3}$ defined from a time series analysis.

Water waves also have a dominant direction of wave propagation and directional spread about that direction that can be defined by a Gaussian or generalised cosine ($\cos^n$) distribution (amongst others), and a wave grouping tendency. Directional spread is reduced by refraction as waves propagate into the shallow, nearshore regions and the wave crests become more parallel with each other and the seabed contours. Although neither of these characteristics is addressed explicitly in this study, directional spreading was included in the numerical wave modelling work. Directional spreading causes the sea surface to have a more short-crested wave structure in deep water.

Waves propagating into shallow water may undergo changes caused by refraction, shoaling, bed friction, wave breaking and, to some extent, diffraction.

Wave refraction is caused by differential wave propagation speeds. That part of the shoreward propagating wave which is in the more shallow water has a lower speed than those parts in deeper water. When waves approach a coastline obliquely these speed differences cause the wave fronts to turn and become more coast parallel. Associated with this directional change there are changes in wave heights. On irregular seabeds wave refraction becomes a very complex process. Waves propagating over a steep sided trench at a small angle to the trench alignment undergo a spatially rapid refraction process.

Waves propagating shoreward develop reduced speeds in shallow water. In order to maintain constancy of wave energy flux (ignoring energy dissipation processes) their heights must increase. This phenomenon is termed shoaling and leads to a significant increase in wave height near the shoreline.

A turbulent boundary layer forms above the seabed with associated wave energy losses that are manifested as a continual reduction in wave height in the direction of wave propagation - leaving aside further wind input, refraction, shoaling and wave breaking. The rate of energy dissipation increases with greater wave height and reducing depth.

Wave breaking occurs in shallow water when the wave crest speed becomes greater than the wave phase speed. For irregular waves this breaking occurs in different depths so that there is a breaker zone rather than a breaker line. Seabed slope, wave period and water depth are important parameters affecting the wave breaking phenomenon. As a consequence of this energy dissipation, wave set-up (a rise in still water level caused by wave breaking), develops shoreward from the breaker zone in order to maintain conservation of momentum flux. This rise in water level increases non-linearly in the shoreward direction and allows larger waves to propagate shoreward before breaking. Field measurements have shown that the slope of the water surface is normally concave upward. Wave set-up at the shoreline can be in the order of 15% of the equivalent deep-water significant wave height. Lower set-up occurs in estuarine entrances, but the momentum flux remains the same. Wave set-up is smaller where waves approach a beach obliquely, but then a longshore current can be developed. Wave grouping and the consequent surf beats also cause fluctuations in the still water level. Wave set-up is also smaller for local sea where the wave periods are relatively short.

Wave diffraction will not be particularly important for this study because there will be no real obstructions near the shoreline.

In a random wave field each wave may be considered to have a period different from its predecessors and successors and the distribution of wave energy is often described by a wave energy spectrum. In fact, the whole wave train structure changes continuously and individual waves appear and disappear until quite shallow water is reached and dispersive processes are reduced. In developed sea states, that is swell, the Bretschneider modified Pierson-Moskowitz spectral form has generally been found to provide a realistic wave energy description. For developing sea states the JONSWAP spectral form, which is generally more 'peaky', has been found to provide a better spectral description. Long waves have very irregular spectral forms.

For structural design in the marine environment it is necessary to define the H_{max} parameter related to storms having average recurrence intervals (ARI) of a pre-determined number of years. However, the expected H_{max}, relative to H_s in statistically stationary wave conditions, increases as storm/sea state duration increases. Based on the Rayleigh Distribution the usual relationship is:-

$$H_{max}=H_s\sqrt{(0.5\,\ell n Nz)}$$

where Nz is the number of waves occurring during the time period being considered, where individual waves are defined by Tz.

ℓn is the natural logarithm

This relationship has been found to overestimate H_{max} by about 10% in severe ocean storms. In shallow water the relationship is not fulfilled. In very shallow water H_{max} is replaced by the breaking wave height, H_b.

Waves propagating through an area affected by a current field are caused to turn in the direction of the current. The extent of this direction change depends on wave celerity, current speed and relative directions. Wave height is also changed. Opposing currents cause wave lengths to shorten and wave heights to increase and may lead to wave breaking. When the current speed is greater than one quarter of the phase speed, the waves are blocked. Conversely, a following current reduces wave heights and extends wave lengths.

Within Port Jackson, flood and ebb tidal currents will move wave energy focal points. However, strong winds may occur on flood and ebb currents and this issue was not considered.

4.2 Currents

Currents within Port Jackson are caused by a range of phenomena, including: -

- Astronomical Tides
- Winds
- River Discharges
- Coastal Trapped Waves and Other Tasman Sea Processes
- Nearshore Wave Processes
- Density Flows

The astronomical tides are caused by the relative motions of the Earth, Moon and Sun, see Section 6.3. The regular rise and fall of the tide level in the sea causes a periodic inflow (flood tide) and outflow (ebb tide) of oceanic water to the Harbour and mixed oceanic and oceanic/river water from the harbour to the sea. A consequence of this process is the generation of tidal currents. The volume of sea water that enters the Harbour or leaves the Harbour on flood and ebb tides, respectively, is termed the tidal prism; which parameter varies due to the inequality between tidal ranges. The tidal prism is affected by changes in inter-tidal areas, such reclamations, but not by dredged areas below low tide, such as navigation channels and trenches.

Wind forcing is applied to the water surface as interfacial shear, the drag coefficient and consequent drag force varying with wind speed. Momentum from the wind is gradually transferred down through the water column by vorticity, the maximum depth of this effect being termed the Ekman depth. At the surface, wind caused currents are in the direction of the wind, but in the southern hemisphere they gradually turn to the left of the wind direction until they flow in the opposite direction at the Ekman depth. Port Jackson is too shallow for this condition to develop fully and wind driven currents are affected by the seabed boundary layer. Wind driven currents diminish with depth. Because wind forcing is applied at the water surface, the relative effect is greater in shallow water where there is less water column volume per unit plan area. Therefore wind driven currents are greater in more shallow areas. Maximum surface current speed is in the order of 1% to 3% of the wind speed, depending on water depth. Where water is piled up against a coastline by wind forcing a reverse flow develops near the seabed.

Density currents may be caused by freshwater inflows, for example, when the Lane Cove River is in flood. The freshwater is more buoyant and tends to spread across the surface until mixing with the ambient seawater occurs.

Coastal Trapped Waves (CTW) are long period wave phenomena that propagate northward along the continental shelf, Freeland et al, 1986. Their origin is not fully understood, but they are believed to originate from the passage of successive high and low pressure meteorological systems across southern Australia. These systems have inter-arrival times varying from 3 to 7 days, typically, and these are the periods of the observed CTW. These waves are irregular and cause approximate coast parallel currents and variations in water levels. They are trapped on the continental shelf by refraction and the Coriolis force. CTW are known to occur on the continental shelf of NSW and will affect observed water levels in Port Jackson.

In terms of this water levels study, tidal currents may influence the development of wind set-up and hence, along with processed discharge information, were addressed in model calibration.

4.3 Water Levels

Water level variations in Port Jackson result from one or more of the following natural causes:-

- Eustatic and Tectonic Changes
- Tides

- Wind Set-up and the Inverse Barometer Effect
- Wave Set-up
- Wave Run-up
- Fresh Water Flow
- Tsunamis
- Greenhouse Effect
- Global Changes in Meteorological Conditions

Eustatic sea level changes are long term world wide changes in sea level relative to the land mass and are generally caused by changes to the polar ice caps. No rapid changes are believed to be occurring at present and this aspect has not been addressed in this study. Nevertheless, a minimum rise of 1mm per annum is now generally accepted. Tectonic changes are caused by movement of the Earth's crust; they may be vertical and/or horizontal

Tides are caused by the relative motions of the Earth, Moon and Sun and their gravitational attractions. While the vertical tidal fluctuations are generated as a result of these forces, the distribution of land masses, bathymetric variation and the Coriolis force determine the local tidal characteristics.

Wind setup and the inverse barometer effect are caused by regional meteorological conditions. When the wind blows over an open body of water, drag forces develop between the air and the water surface. These drag forces are proportional to the square of the wind speed. The result is that a wind drift current is generated. This current may transport water towards the coast upon which it piles up causing wind set-up. Wind set-up is inversely proportional to depth.

In addition, the drop in atmospheric pressure, which accompanies severe meteorological events, causes water to flow from high pressure areas on the periphery of the meteorological formation to the low pressure area. This is called the 'inverse barometer effect' and results in water level increases up to 1cm for each hecta-Pascal (hPa) drop in central pressure below the average sea level atmospheric pressure in the area for the particular time of year, typically about 1010 hPa. The actual increase depends on the speed of the meteorological system and 1cm is only achieved if it is moving slowly. The phenomenon causes daily variations from predicted tide levels up to 0.05m. The combined result of wind set-up and the inverse barometer effect is called storm surge.

Wave run-up is the vertical distance between the maximum height a wave runs up the beach or a coastal structure and the still water level, comprising tide plus storm surge. Additionally, run-up level varies with surf-beat, which arises from wave grouping effects. Wave set-up is included implicitly in wave run-up.

Tsunamis are caused by sudden crustal movements of the earth and are commonly, but incorrectly, called 'tidal waves'. They are very infrequent and unlikely to occur during a storm and so have not been included in this study. Nevertheless, in the context of events having recurrence intervals in the order of 100 years, one should keep this point in mind. The highest tsunami observed in the Sydney region was about 0.8m (crest to trough) at Fort Denison caused by an earthquake in Chile in 1960, Bureau of Meteorology (1998).

Global meteorological and oceanographic changes, such as the El Nino Southern Oscillation phenomenon in the eastern southern Pacific Ocean, and continental shelf waves, cause medium term variations in mean sea level. The former phenomenon may persist for a year or more. The causes are not properly understood, but analyses of long term data from Australian tide gauges indicate that annual mean sea level may vary up to 0.1m from the long term trend, whilst mean sea level may vary by more than 0.2m over the time scale of weeks as a result of coastal trapped wave activity.

Many scientists believe that global warming of the Earth's atmosphere will lead to a rise in mean sea level. Predictions of global sea level rise due to this Greenhouse effect vary considerably. It is impossible to state conclusively by how much the sea may rise, and no policy yet exists regarding the appropriate provision that should be made in the design of new coastal developments.

4.4 Winds

Wind affects the wave, current and water level climates in Sydney Harbour, as discussed in Sections 4.1 to 4.3 above. Data was obtained from a site at Sydney Airport. Discussion of the wind climate is provided in Section 6.2. This site provides reliable long-term data appropriate for use in design event assessment.

5 Study Approach Methodology

Definition of planning levels along the Leichhardt foreshore area involves the quantification of a range of coastal processes as well as consideration of their interaction and any joint occurrence potential. This section outlines the methodology employed to complete this planning levels assessment.

5.1 Water Levels

Design water levels are formed from a number of increments that are described in detail in Section 4.3. The extreme water levels described in Section 6.3 are basically applicable also to the shorelines of the Leichhardt LGA, albeit with some small location specific changes.

In calculating a design still water level for planning level estimations, extremal analysis of the Fort Denison tide gauge has been applied, see Section 6.3. Included in this analysis are the effects of wind set-up that were implicitly measured at the Fort Denison site. This level is therefore applicable to the Leichardt Foreshore when wind-setup differences between the two locations are considered. To this end wind set-up values around the Leichhardt foreshore were calculated from numerical model simulations as the difference from the Fort Denison level and applied as a correction to the design storm level at Fort Denison so as to not overestimate the still water level by accounting for the wind set-up component twice. For this task the Delft3D hydrodynamic model was utilised and is described in Section 7.1.

Design levels at Fort Denison, for ARI's greater than 10-years, typically occur as a result of East Coast Low (ECL) events and probably an associated coastal trapped wave. In line with the dominant East Coast Low forcing, consideration of wind set-up from easterly winds was given, as these winds in combination with design levels at Fort Denison provide greater levels than a potential westerly wind combined with a spring high tide condition. That is, the 100-yearsARI level at Fort Denison is 1.45mAHD, some 0.35m above HAT, which is substantially higher than the MHWS level. Associated wave parameters were also chosen along similar lines. That is, joint occurrence issues were considered.

Wind set-up values were determined by simulating a suite of average recurrence interval wind speeds for eight directional sectors; although only easterly conditions were finally considered, see above. Extremal analysis of Sydney airport wind data, see Section 6.2, provided wind speeds for six recurrence intervals from 5-years ARI to 200-years ARI. Each simulation was completed over a 12-hours period with a spring tidal range boundary condition, peaking at 0.94mAHD (approximately the 1% exceedance level at Leichhardt), to provide a realistic estimation of the dynamic wind/tide effects over a non-stationary high water level surface. Wind speeds peaked for a 6-hours period to coincide with the peak water level around the Leichhardt foreshore. This has been found to provide a slightly lower wind set-up than simulations undertaken with static water levels in other project sites, including large estuary areas such as Brisbane Water.

Wind duration is important to the development of water level set-up. In reality, the critical wind duration that causes the maximum wind set-up at a given location would change in line with the variation of fetch lengths and depths in the individual directions. When the matter of actual wind speed and direction duration is considered this combination is unlikely to persist for more than six hours in any one combined condition. To this end, a six-hour peak wind duration was employed, which is likely to allow the maximum wind set-up to occur while also ensuring that phasing with the high tide is incorporated.

Model input is typically based on the 10-minutes average wind speed and direction parameters as they may vary with time. The SWAN wave model has been verified in Botany Bay using 10-minute average wind data and indeed both the Delft3D and SWAN models specify this wind parameter for model input. Comparison of Tables 6.1 and 6.2, in Section 6.2, shows that the 10-minute average data is slightly higher than the 3-hour duration data. Adopting the 10-minute average data along with a six-hour peak duration therefore provides a conservative outcome, which for the definition of planning levels is an appropriate position.

5.2 Local Sea

The SWAN wave model was used to develop the wave 'climate' at foreshore locations along the Leichhardt LGA study area. Virtually no swell will penetrate to the area therefore only local sea conditions were considered. This task required the SWAN wave propagation model to be applied to a large range of offshore wind directions from north through south to north-west at 22.5o increments around the clock. Additionally, a range of wind speeds from 2.5 to 25m/s were included, leading to 176 wave modelling cases at a water level of +1.3mAHD – a rare high water level, but not unknown. This level relative to MHWS, for example, does not have a significant effect on wave generation, but prevented wave breaking in front of the foreshore structures. The results of this wave modelling provided a basis for developing 59 years of time series wave data at the foreshore locations from the observed wind data.

This model output provided a long-term time series of wave parameters at each of the foreshore locations in terms of Hs, Tz and direction, together with wind speed and direction. These results were then examined to identify peak storm wave heights, which were then analyzed using the Extreme Value Type 1 distribution and applying the method of moments. Jointly occurring wave period parameters were then determined by correlation analysis.

5.3 Joint Occurrence

Wind set-up and local wave set-up were separated because wave set-up calculations based on different foreshore edge treatments were required. This calculation utilised the wave on the foreshore location that was derived from the design directional wind conditions. Furthermore, the small, local wave set-up was not included in the EPL calculations because the calculation of wave run-up implicitly includes the wave set-up component. Therefore, the EPL was based on wave and wind set-up values derived from the same wind parameters and although not concurrently selected it provided a slightly conservative result.

Design water levels for properties located along the foreshore of the Leichhardt Local Government Area will be affected by elevated water levels in Port Jackson that occur during severe ocean storms, generally from the east-north-east to south-south-east sector, not from westerly winds. Those high water levels may be accompanied by local sea wave activity that then causes wave set-up and run-up; though wave set-up will be minimal because wave periods will be very short. However, the highest storm tide levels in the Leichhardt area will occur during storms that have north-east to south-west sector winds - not northerly or westerly winds. Therefore, the joint occurrence of the highest water levels and highest local wind-generated waves will be very rare on the westward and northward facing shorelines of the study area. Hence, the following joint occurrence relationship between waves and the 100-years ARI design storm tide level has been adopted: -

- adjusted Fort Denison 100-years ARI storm tide and the highest 100-years ARI local sea from the northeast to southwest sector at each foreshore location.

5.4 Wave Set-up/Run-up

Wave run-up and wave overtopping height computations have been based on formulations presented in Coastal Engineering Manual (2002), Shoreline Protection Manual (1984) and a Public Works Department study (1992). They provide combined wave set-up and run-up heights, without providing a breakdown of these two water level components. None of these publications addresses wave run-up relationships for all shoreline case types that may be encountered in the Leichhardt LGA.

Wave run-up depends upon edge treatment and surface roughness and is irregular in its character. Five idealised edge treatment cases have been addressed in this study. They are described below:-

- 1 in 20 natural slope
- 1 in 10 beach face
- 1 in 5 embankment
- 1 in 2 seawall
- Vertical wall

For the first four cases, run-up is in terms of the 2% exceedence run-up height. That is, only 2% of run-up heights will be greater.

Generally, these edge treatment conditions refer to the shoreline form near the level of the 100-years ARI storm tide, that is, 1.45m AHD.

5.5 Inland Attenuation

Where a block slopes steeply back from the shoreline edge structure, the EPL may affect only a small part of the block. However, where a block is relatively flat, wave run-up may penetrate some distance inland, but is attenuated by percolation and friction. This landward reduction of wave inundation can not be estimated with great confidence, and has been based on observational experience. It is assumed that wave run-up diminishes to zero at a point 20m inland from the edge structure – local sea has less overland penetration capacity than swell. Nevertheless, the wave set-up component remains.

This issue also affects a parameter that may be termed a set-back limit. Figure 5.1 shows local sea wave-overtopping at the Gosford waterfront during the severe storms of June

2007. For these short period waves, with some freeboard between the SWL and wall crest, there is virtually no 'green-water' overtopping of the wall. Hence all redevelopments where the land may be inundated by wave over-topping should have some freeboard of this type (as distinct from the freeboard parameter discussed below). In that case set-back distances may be selected as:-

- Public walkway - 5m
- Playground - 10m
- Boating facilities - 0m
- Residence - 5m
- Industrial building – 2.5m

for public safety reasons.

5.6 Mean Sea Level Rise

In acknowledgement of the fact that sea level rise (SLR) will have significant economic, social and environmental impacts on the coastal zone, the NSW Government released a Draft Sea Level Rise Policy in 2009 outlining their objectives and commitments to communities affected by SLR. The primary objective of the Policy statement is to minimise the cost of climate change by:

- Promoting an adaptive, risk-based approach to managing SLR impacts,
- Providing guidance to local Councils to support their SLR adaptation planning,
- Encouraging appropriate development on land projected to be at risk from SLR,
- Continuing to provide emergency management support to coastal communities during times of floods and storms,
- Continue to provide updated information to the public about SLR and its impacts.

In support of this policy statement, the NSW Government has adopted a SLR planning benchmark. The NSW SLR planning benchmark is for an increase above 1990 mean sea levels of 40 cm by 2050 and 90 cm by 2100. These values were established through careful consideration of available SLR projections and takes into account the uncertainty associated with these projections. Full details are provided in Section 6.3.

5.7 Freeboard

The estimation of all of the components that make up the EPL at each selected location includes some uncertainty, and the degree of uncertainty varies with each water level component. It is greatest for wave run-up; and wave run-up is normally the largest water level component, other than astronomical tide.

It is common practice to take some precaution over this uncertainty. In this case, where wave run-up height is greater than or equal to 1.3m, no freeboard allowance has been adopted – as advised to Pittwater Council. Where it is equal to or less than 1m, a freeboard allowance of 0.3m is advised; with varying freeboard magnitude adopted for run-up heights between these delimiting magnitudes in order to provide consistent outcomes in EPL. Discussions with Sue Ribbons, Project Leader, Flood Plain Management Group at

Pittwater Council have informed us that they have adopted a MSL rise of 0.2m and a freeboard of up to 0.3m, as described above.

In terms of freeboard, Pittwater Council's Flood Risk DCP No. 30 (Pittwater Council 2002) advises a value of 0.5m be added to the 100-years ARI flood level; and advises further that this freeboard includes 'greenhouse and climate change' amongst other uncertainties. This includes 0.2m MSL rise, as implied in Department of Planning documents, see Section 6.1. Note though that the basic 100-years ARI ocean level was taken to be 1.5m AHD – rather than 1.45m AHD, hence effectively a MSL rise of 0.25m was adopted.

Within Brisbane Water, Gosford City Council presently, and for decades have, advise a freeboard of 0.5m be added to a water level 'observed' during the May 1974 severe ocean storm. It is understood that this includes about 0.2m MSL rise and 0.3m for uncertainty.

It would be possible to adopt different freeboard allowances for different types of property, but Council is advised to adopt Pittwater Council's approach, see Section 4.

5.8 Average Recurrence Interval

Design criteria are generally determined on the basis of an average recurrence interval (ARI). In this instance an ARI of 100-years has been adopted. This is a common design risk position for public and private property that is not of a critical nature – such as hospitals and ambulance stations.

Adopting this design ARI leads to the risk levels presented in Table 5.1.

Table 5.1 Risk Levels Associated with the 100-Years ARI

Planning Period or Property Life (years)	Probability (%) of Equalling or Exceeding the 100-Years ARI Level
25	22
50	39
75	53

These encounter probabilities indicate that there is a risk of the design water levels being exceeded during a planned functional life of a property that is less than 100 years, even though the 100-years ARI level has been adopted.

Department of Planning (2007) advises that for flood prone land 'unless there are exceptional circumstances, councils should adopt the 100-year flood as the FPL for residential development.' Department of Planning also define flood prone land as 'the area inundated by the probable maximum flood.' and 'that FPLs for typical residential development would generally be based around the 100-year flood plus an appropriate freeboard (typically 0.5m)'. It is noted though, that this study is not in fact investigating flood prone land in terms of the Floodplain Development Manual. Nevertheless, the adoption of the 100-years ARI conditions is also adopted commonly for coastal developments, but there is no probable maximum flood in coastal process terms, albeit the 10,000-years ARI parameters can be used in lieu.

Hence it is a reasonable design position to adopt 100-years ARI estuarine planning levels.

5.9 Discussion

The definition of planning levels along the Leichhardt Foreshore area were then made up of:-

- Design Still Water Level at the 100-years ARI
  - Storm Tide Level at Fort Denison
  - Wind Set-up Adjustment at Each Site
  - Wave Set-up at Each Site, a function of edge treatment and incident waves
- MSL Rise
- Local Design Wave Parameters
- Wave Run-up, a function of edge treatment type and roughness
- Freeboard

Results for each of these components were defined for a range of specified design cases from 5-years ARI to 200-years ARI.

The adopted study methodology provides a robust and physically realistic description of potential flooding along the Leichhardt foreshore. Where required, the study has taken a conservative position which provides confidence that planning levels are appropriately set, in terms of risk to Council and the Public.

6 Data

Data for this investigation was required to describe the physical processes of the Port Jackson region and to set up, calibrate and operate numerical models that were required for this study.

Wave climate and wind set-up parameters are caused by the local wind conditions and controlled by the regional physiographic setting, that is, fetch lengths and water depths. Hence a range of data items were required for these investigations to describe those phenomena.

6.1 LMC Information

A number of data items were provided by LMC. They related mainly to previous reports (WMA, 2001) and cadastral plans in electronic form. The WMA (2001) reports provided pictorial information describing the general forms of edge treatment along the LGA shoreline. That data has been used in formulating wave run-up height estimates.

6.2 Meteorological Data

Wind affects both the wave and current climates in Port Jackson. Wind data has been recorded at Sydney Airport since 1939, Moneypenny et al (1997). This is the closest reliable long-term wind recording site to Port Jackson. The location and impact of airport development have changed since then. From 1939 to 16 August, 1994, a Dines anemometer was used to record 10-minute averages of wind speed and direction. Since the early 1960’s, at least, this anemometer was located on a 10m mast near the intersection of the east-west and north-south runways. Recommended WMO clearances from buildings and other obstructions were maintained. During its period of service, the Dines anemometer was maintained well.

Since 16 August, 1994, wind data at the airport has been recorded using a Synchrotec anemometer installed on a 10m mast near the threshold of the main north-south runway, which is more exposed than the previous Dines anemometer site.

Analyses of these wind records, (Monypenny and Middleton, 1997), showed that there had been a gradual error (reduction) in wind speed recorded by the Dines anemometer. This reduction amounted to 2.6m/s by August, 1994. Monypenny and Middleton (1997) advise that a simplified linear adjustment be made to Sydney airport wind speeds up to 16 August, 1994 and this adjustment was made for this study. Data to 31 December, 2000 was obtained from the Bureau of Meteorology.

Appendix D presents a description of wind speed and direction joint occurrence at Mascot. Note that calms occur for about 17% of the time.

The long term Sydney Airport anemometer data introduced above has been analysed in terms of peak event wind speeds using the Extreme Value Type 1 distribution. Only independent (>24 hours apart) records were included in that analysis. Results are presented in Tables 6.1 and 6.2. Those wind speeds were used to undertake local wind set-up analyses, see Section 8.1 and local sea wave analyses, see Section 8.2.

Table 6.1 Wind Speeds (m/s) by Octant

Octant	Gust Speeds		10 min Average Speeds		3 hour Average Speeds	
	100 yr ARI	20 yr ARI	100 yr ARI	20 yr ARI	100 yr ARI	20 yr ARI
N	28.4	26.1	19.3	17.8	18.5	17.0
NE	23.8	22.9	18.3	17.6	17.6	16.9
E	25.7	22.8	19.8	17.5	19.0	16.8
SE	28.2	25.6	21.7	19.7	20.8	18.9
S	42.1	38.3	31.7	28.8	30.4	27.6
SW	35.1	31.9	25.6	23.3	24.6	22.4
W	38.3	35.0	26.6	24.3	25.5	23.3
NW	33.9	31.3	21.3	20.3	22.1	20.4

Table 6.1 also includes wind gust speed - generally 2-second gusts. These results are general and do not include any shoreline terrain correction factors. Additional information is presented in Table 6.2.

Table 6.2 Wind Speeds (m/s) at Selected ARI - 10 minute Average Speeds

Octant	Average Recurrence Interval (years)					
	5	10	20	50	100	1000
N	16.4	17.1	17.8	18.7	19.3	23.5
NE	17.0	17.3	17.6	18.0	18.3	20.3
E	15.4	16.5	17.5	18.8	19.8	26.3
SE	17.9	18.8	19.7	20.8	21.7	27.4
S	26.2	27.5	28.8	30.5	31.7	39.9
SW	21.2	22.3	23.3	24.6	25.6	32.1
W	22.2	23.3	24.3	25.6	26.6	33.1
NW	19.4	19.9	20.3	20.9	21.3	24.1

6.3 Water Level Data

Basic astronomical tide and storm tide data for Port Jackson is presented below. It is based on Fort Denison, but is realistic for the Leichhardt LGA, once other local area aspects have been included. The highest recorded 'still water level' was 1.43m AHD (at

Fort Denison) in May 1974. Some shoreline areas would have been affected by local sea wave run-up at the same time, and possibly by local wind set-up higher than that at Fort Denison, which is in the central area of the waterway.

Tidal planes derived from long term records at Fort Denison, Sydney Harbour are shown in Table 6.3, (Manly Hydraulics Laboratory, 1992). Tides in Port Jackson are semi-diurnal, that is, there are two high and two low tides each day, normally. On rare occasions there may be only one high or low tide because the lunar tidal constituents have a period of about 25 hours. There may also be a significant diurnal difference, that is, a significant difference between successive high tides and successive low tides.

Table 6.3 Tidal Planes for Port Jackson - Fort Denison

Tidal Plane	Water Level	
	m LAT	m AHD
Mean High Water Springs (MHWS)	1.61	0.69
Mean High Water Mark (MHWM)	1.48	0.56
Mean High Water Neaps (MHWN)	1.36	0.44
Mean Sea Level (MSL)	0.93	0.01
Mean Low Water Neaps (MLWN)	0.54	-0.39
Mean Low Water Springs (MLWS)	0.29	-0.64

Table 6.4 presents extreme water levels for typical Average Recurrence Intervals (ARI), also derived from the Fort Denison water level records (Manly Hydraulics Laboratory, 1992). These levels exclude wave set-up and relate to locations seaward of the wave breaking zone.

Table 6.4 Extreme Water Levels in Port Jackson – Fort Denison

Average Recurrence Interval (years)	Water Level	
	m LAT	m AHD
5	2.16	1.24
10	2.21	1.29
20	2.26	1.34
50	2.35	1.43
100	2.37	1.45
200	2.42	1.50

Although tidal planes in the reach of Port Jackson near the Leichhardt Council LGA will be similar to those at Fort Denison, the extreme water levels may be a little different. Hence a calibrated hydrodynamic model of Port Jackson was used to investigate water level differences between Fort Denison and the study sites in storm tide conditions.

At the regional scale, sea levels can be influenced by variations in ocean currents and in the atmosphere due to different wind regimes (McInnes *et al*., 1998). Coastal responses to SLR can be highly variable and often unpredictable, and are greatly influenced by the local geomorphology. Temporary flooding associated with storms and cyclones are generally short duration, infrequent and large-magnitude events. Cumulative erosion and inundation associated with global SLR or land subsidence processes, on the other hand, are typical of longer duration, low-magnitude events. Although the magnitude of future SLR may be relatively small in isolation, where severe storms coincide with elevated sea levels, wave attack and storm surge will result in significant impacts on vulnerable coastal areas.

Research into the long term SLR estimates for Australia indicate that the rate of SLR is slightly less than the global average. Church *et al.* (2006) analysed two of Australia's longest tide gauge records: Fort Denison, Sydney, and Fremantle, in Western Australia. That study determined that the global SLR from 1950 to 2000 was 1.3 (± 0.5) mm/yr, compared with a global average 1.8mm/yr. The difference is primarily thought to be due to the more frequent and intense El Niño events since the mid-1970's, which cause lower sea-levels around Australia (Holper *et al*., 2005).

DECCW (formerly known as DECC), in planning for climate change, have produced a Sea Level Rise Policy Statement (DECCW, 2009a) that sets SLR planning benchmarks of 40 cm by 2050 and 90 cm by 2100 (relative to 1990 mean sea levels). These benchmarks are derived from both IPCC projections and CSIRO research. The manner in which they were calculated incorporates a range of variables, as shown in Table 5.2. The SLR component is derived from the IPCC SRES A1F1 climate change scenario (Table 5.1) due to the fact that, in the last decade, the observed global average of sea level from tide gauges and satellites is tracking along the upper bound of the IPCC projections.

Table 5.2: Components of Sea Level Rise Planning Benchmarks (after DECC, 2009a and b)

Component	2050	2100
SLR	30 cm	59 cm
Accelerated ice melt	(included above)	20 cm
Regional SLR variation	10 cm	14 cm
Rounding*	-	-3 cm
Total	***40 cm***	***90 cm***

DECCW's SLR Policy will be given statutory effect through State Environmental Planning Policy 71 – Coastal Protection and through a Ministerial Direction to local councils under Section 117 of the Environmental Planning and Assessment Act 1979. The Sea Level Rise Policy Statement (DECCW, 2009a) supersedes the 1988 NSW Coastline Hazard Policy. Most of objectives from that policy have been included in the NSW Coastal Policy 1997, which remains current. Other objectives from the 1988 NSW Coastline Hazard Policy are updated by the Sea Level Rise Policy Statement.

The Federal Department of Climate Change also undertook a so called first pass assessment of Climate Change Risks to Australia's Coastline (DCC, 2009). Within this it is stated that significant research since the release of the latest IPCC projection suggests that processes may lead to more rapid loss (i.e. melting) of ice and that upper range projections are more likely to be encountered by 2100. It finds that more recent analysis demonstrates that sea-level rise of up to a metre or more this century is plausible. Further, nearly all of the uncertainties in sea-level rise projections operate to increase rather than lower estimates of sea-level rise. A sea level rise of 1.1m by 2100 is considered a plausible upper range estimate.

As such LMC has adopted a range sea level rise values to undertake the assessment of estuarine planning levels; being 0.4m, 0.9m and 1.1m.

6.4 Wave Data

There is no measured wave data at this site. Hence local sea wave conditions were developed using available wind data, see Section 6.2, and a numerical wave model, see Section 7.2. In some cases, the shoreline of the study area will be sheltered from local sea waves during the severe ocean storms that cause elevated water levels in the Leichhardt LGA.

6.5 Discharge and Current Data

Discharge data (along with water level data) recorded for Sydney Water (Lawson and Treloar, 1992) on the 19th March 1992 was utilised for model calibration tasks. Locations where data was collected and made available can be seen in Figure 6.1. Available data over this period included reported water level and discharge rates only as no raw ADCP data was obtainable.

Subsequent to the completion of this draft report, Cardno Lawson Treloar obtained further ADCP transect data through the University of Sydney, School of Geosciences. This was made available for five transects within the study area, see Figure 6.1. At two locations the data included a number of passes over a single day at each transect during a spring tide cycle, from the 17th – 19th of February 2007. The other three transects contained sporadic data of variable quality. This data was provided as raw ADCP information and hence velocities across the transects could be investigated.

In both cases the field data used for calibration was recorded over a large area and hence transects were taken intermittently at intervals of about 1.5 hours or more. Furthermore, the accuracy of this data cannot be confirmed.

6.6 Bathymetric Data

A calibrated hydrodynamic model of Sydney Harbour was developed for this study. The bathymetric information was derived mainly from AUS Charts 201, 202 and 203, together with some other information provided by the University of Sydney.

7 Numerical Model Development

Numerical modelling was applied to the investigation of local area wind set up and to local area wave hindcasting. These models are described below.

7.1 Hydrodynamic Wind Set up Model

Wind set-up investigations required application of a high level model capable of simulating a range of processes – wind field and tidal forcing. These simulations were undertaken using the Delft3D modelling system.

The Delft3D modelling system has been applied to current and wave investigations at many international locations, as well as within Australia by Cardno Lawson Treloar – Port Botany (Sydney), Cairns Navy Base (Queensland), Brisbane Water, New Caledonia and Exmouth Gulf in Western Australia, for example.

The Delft3D modelling system includes wind, pressure, tide and wave forcing, three-dimensional currents, stratification, sediment transport and water quality descriptions and is capable of using irregular rectilinear or curvilinear coordinates.

Delft3D is comprised of several modules that provide the facility to undertake a range of studies. All studies generally begin with the Delft3D-FLOW module. From Delft3D-FLOW, details such as velocities, water levels, density, salinity, vertical eddy viscosity and vertical eddy diffusivity can be provided as inputs to the other modules. The wave and sediment transport modules work interactively with the FLOW module through a common communications file.

7.1.1 Hydrodynamic Numerical Scheme

The Delft3D FLOW module is based on the robust numerical finite-difference scheme developed by G. S. Stelling (1984) of the Delft Technical University in The Netherlands. Since its inception the Stelling Scheme has undergone considerable development and review by Stelling and others.

The Delft3D Stelling Scheme arranges modelled variables on a horizontal staggered Arakawa C-grid. The water level points (pressure points) are designated in the centre of a continuity cell and the velocity components are perpendicular to the grid cell faces. Finite difference staggered grids have several advantages including:-

- Boundary conditions can be implemented in the scheme in a rather simple way
- It is possible to use a smaller number of discrete state variables, in comparison with discretisations on non-staggered grids, to obtain the same accuracy
- Staggered grids minimise spatial oscillations in the water levels.

Delft3D can be operated in 2D (vertically averaged) or 3D mode. In 3D mode, the model uses the σ-coordinate system first introduced by N. Phillips in 1957 for atmospheric models. The σ-coordinate system is a variable layer-thickness modelling system, meaning that over the entire computational area, irrespective of the local water depth, the number of layers is constant. As a result, a smooth representation of the bathymetry is obtained.

Also, as opposed to fixed vertical grid size 3D models, the full definition of the 3D layering system is maintained into the shallow waters and until the computational point is dried.

Horizontal solution is undertaken using the Alternating Direction Implicit (ADI) method of Leendertse for shallow water equations. In the vertical direction (in 3D mode) a fully implicit time integration method is also applied.

Vertical turbulence closure in Delft3D is based on the eddy viscosity concept.

Wetting and Drying of Intertidal Flats

Many nearshore areas include shallow intertidal areas; consequently Delft3D includes a robust and efficient wetting and drying algorithm for handling this process.

Conservation of Mass

Problems with conservation of mass, such as a 'leaking mesh' do not occur within the Delft3D system.

However, whilst the Delft3D scheme is unconditionally stable, inexperienced use of Delft3D, as with most modelling packages, can result in potential mass imbalances.

Potential causes of mass imbalance and other inaccuracies include:-

- Inappropriately large setting of the wetting/drying parameter and unrefined inter-tidal grid definition
- Inappropriate bathymetric and boundary definition causing steep gradients
- Inappropriate time step selection (i.e. lack of observation of the scheme's allowable Courant Number condition) for simulation.

7.1.2 Model Setup

A 2-Dimensional Delft3D model of Port Jackson was created using a curvilinear grid with resolution along the Leichhardt foreshore areas of approximately 25m, see Figure 7.1.

In the absence of any other reliable long term offshore data, the model was forced at the ocean boundary with an adjusted Fort Denison tidal signal derived from tidal constants. While not exact, a comparison between the model boundary tidal signal and resulting model signal at Fort Denison shows that there is insignificant difference in amplitudes and minimal phase difference, see Figure 7.2. A small correction based on this comparison was therefore made and this amended signal applied to the model boundary.

Local atmospheric set-up/set-down is implicitly included in the Fort Denison water level records and there would be no discernible difference in that parameter between Fort Denison and Leichhardt. Furthermore the model is being used to derive a difference between Fort Denison and Leichhardt foreshore areas and hence boundary effects will have negligible influence on these results.

Wind coefficient parameters were based on values prescribed in Bowden (1983) as well as previous modelling exercises where calibration data was available for both calm and strong wind conditions. Calibration of wind set-up simulations was unable to be completed due to a lack of task specific water level and wind data. However, the adoption of physically realistic wind friction parameters is appropriate. Furthermore, modelled wind set-up values are provided as a difference from the Fort Denison level, which inherently includes measured wind set-up in its records. As such the wind setup difference values are relatively small in magnitude when considering the determination of the design still water level, see Section 8.1.

A constant roughness value was applied over the entire grid domain set at Chezy 65. No information was available on seagrass beds and other submarine areas that may act to impose areas of even higher friction around the study area, say Chezy 35, and as such this could not be investigated.

The model was initially calibrated using water level and discharge data recorded for Sydney Water (Lawson and Treloar, 1992) on the 19th March 1992 as described in Section 6.5.

Comparisons of discharge rates between recorded data and model output at the eight ADCP sections can be seen in Figures 7.3 to 7.5. Of the three cross-sections along the Leichhardt foreshore, XS4, XS7 and XS8, results show that the model performs well in the area of interest, providing good agreement with the measured data. The phasing of the model discharge signals represents the measured data well with some underestimation of the peak flows at cross-section 8. Such discrepancies can be attributed to the representation by the model of the local bathymetry or the inherent uncertainties in the collection of discharge data using ADCP instrumentation.

The discrepancy in the calibration at XS8 within Iron Cove can not be fully resolved. The Dobroyd and Hawthorn canals were not schematised in the model although their tidal prism is about 6% of that in Iron Cove, which does not fully account for the difference. Note though that there is no bias in the results. Comparison of water level recordings with the model output at three sites, see Figure 7.6, demonstrates that the model simulates the hydraulic regime within Sydney Harbour extremely well.

Further verification was sought using more recent data collected by the University of Sydney, see Section 6.5. This data was made available for five transects within the study area, with two transects providing greater temporal resolution – one from Manns Point to Robinsons Point on the northern foreshore and one under Iron Cove Bridge, within Iron Cove. Data at these locations included a number of passes over a single day at each transect during a spring tide cycle, from the 17th – 19th of February 2007. The Delft3D model was re-run over this period using the original model parameters to verify its performance. This included a spatially constant wind time-series. Comparison of the measured and modelled discharge at these two locations is provided in Figure 7.7 showing good agreement across the entire tidal period.

While water level and discharge comparisons are important for model verification, it is also necessary to verify the performance of the model in a 2D sense. That is, to compare spatial velocity distributions along the acquired ADCP transects. Tidal velocities will influence the development of wind set-up and hence the ability of the model to correctly describe the velocity distribution around the Leichhardt foreshore will be important for this study. Figure 6.1 describes the locations of the available ADCP cross sections. At three cross sections (Iron Cove Bridge, Manns Point and Balls Head) velocity profiles at two transect times were extracted and compared to the model output and are presented in Figures 7.8 to 7.10. Small differences are found between the measured and modelled results mainly due to the variability in field measurements when compared to the idealised model output. However, the general shape of the distribution and magnitudes are considered to be an excellent match.

A further two velocity profiles were extracted, one each at the remaining two transects, being Rodd Island and Cockatoo Island, and compared to the ADCP data. Figure 7.11 presents these comparisons and shows that, although velocities are low, the model replicates the measured data well, even describing the dual direction flow at Cockatoo Island.

In summary, the model verification task shows that the model describes the hydrodynamics within the study area extremely well and provides confidence in the results.

Model sensitivity to bed friction was investigated for two other friction values over the calibration period, one higher and one lower. Physically realistic Chezy parameters of 55 and 75 were modelled. Discharge and water levels results are presented against the original friction value of Chezy 65 in Figure 7.12 at an output location in Iron Cove. The results show that there is minimal effect on the water levels, the parameter of interest for planning levels, as a result of the varying friction values. Furthermore, model agreement with discharge and velocity profiles at a number of cross sections was observed and hence no further sensitivity tests were carried out.

The close comparison of the model to observed data provides confidence that the model adequately represents the hydrodynamics of Port Jackson for the purposes of this study.

7.2 Numerical Wave Model

The SWAN wave model was used to investigate the development of local sea in Port Jackson. This model system was developed at the Delft Technical University and includes wind input, (local sea cases), combined sea and swell, offshore wave parameters (swell cases), refraction, shoaling, non-linear wave-wave interaction, a full directional spectral description of wave propagation, bed friction, white capping, currents and wave breaking. It can include nesting of finer grid areas within an overall coarser grid model. For this study a constant grid size of 50m was used covering the region of Port Jackson shown in Figure 7.13, incorporating all relevant fetch lengths associated with the Leichhardt foreshore.

All model simulations were undertaken at a level of 1.3m AHD, this being a common high water level. It is likely that local sea wave generation and propagation to the shoreline is not particularly sensitive to the specific water level adopted, provided that it is a ‘high water level’. Note that water levels of 1.0 to 1.1m AHD occur a few times each year because of meteorological and open sea phenomena.

A large number of locations along the Leichhardt LGA shoreline of Port Jackson were selected for model output. Shoreline locations were generally in a depth of 1m CD, typically. Because local sea periods are relatively short, typically 1 to 3 seconds (Tz), bed friction, does not affect wave propagation to these locations. Wave breaking was important only at the shoreline structures themselves.

7.2.1 SWAN Model Calibration

Wave model calibration provides confidence that the model system applied to this investigation will reproduce wave conditions in Port Jackson reliably. The model has been calibrated for local sea in Botany Bay using the same Sydney airport wind as that used for this study, see Lawson and Treloar (2003). No site specific characteristics required changing and so the SWAN model can be used at this site also with confidence.

8 Numerical Model Results

Results of the numerical modelling were extracted from the wave and wind set-up simulations at 105 locations along the Leichhardt LGA foreshore. The locations of these output points can be seen in Figure 8.1.

8.1 Wind Set-Up

The maximum wind set-up result for each foreshore location is presented in Table E.1 of Appendix E for each adopted ARI. This wind set-up value was taken from the eastern directional sectors, because the occurrence of extreme water levels are a result of south-easterly coastal weather systems. Adopting the maximum value from these sectors, only, ensures that appropriate joint occurrence relationships, that is, extreme still water level and wind set-up, are preserved. That is, it is unlikely that extreme winds from the west would coincide with elevated estuary water levels that result from an offshore storm system.

Local wind set-up effects were calculated for the full range of directional-wind sectors, with easterly sectors being incorporated into the derivation of the planning levels on the rationale outlined above and in Section 5.1. The results show that a set-down occurs along the western shoreline with westerly winds and associated high tide, see Figure 8.2. This is due to the interaction between the flood tide signal and the opposing wind forcing. Wind set-up due to westerly winds would likely occur over an ebb/low tide period, however, which in terms of peak levels (or planning levels) would not be critical. On this basis consideration of easterly sector conditions was appropriate.

8.2 Local Sea Waves

The transfer of a long-term (59-years) wind time-series to a local sea wave time-series was achieved through a suite of 176 wave model cases run over 16 directional sectors, as discussed in Section 5.2. Extremal analysis was then undertaken to determine the design wave conditions at the 105 foreshore locations,

The results are presented in Appendix E for selected average recurrence intervals (ARI) from 5 to 200 years.

8.3 Swell Waves

Due to the position of the Leichhardt LGA within Port Jackson, little to no swell energy is able to penetrate to the Leichhardt foreshore. Hence assessment of swell waves was unnecessary and not included in the estimation of design foreshore levels.

9 Design Planning Levels

The estimation of design planning levels includes a number of components, which are:-

- Design Still Water Level
  - Storm Tide Level at Fort Denison
  - Wind Set-up Adjustment at Each Site
  - Wave Set-up at Each Site, a function of edge treatment and incident waves
- MSL Rise
- Local Design Wave Parameters
- Wave Run-up, a function of edge treatment type and roughness
- Freeboard

Results for each of these components are presented in Tables F.1 to F.4 of Appendix F specifically for the 100-years ARI design case; however wave and water level parameters are detailed for a range design cases from 5-years ARI to 200-years ARI in Table E.1.

9.1 Storm Tide Level

Storm tide level was based on extremal analysis of the long-term Fort Denison water level records, see Section 6.3.

9.2 Local Wind Set-up

Wind set-up at each location was derived as a difference from the Fort Denison design levels, which implicitly included wind set-up effects at the Fort Denison site. This was undertaken by numerical modelling and has been presented in Section 8.1.

9.3 Wave Set-up

The process of wave set-up refers to the deviation of the mean water level as a result of wave shoaling, breaking and momentum flux conservation as waves progress shoreward across the surf zone. Goda (2000) provides an approximation of this set-up based on the significant wave height (H_s) or the breaking wave height (H_b) near the shoreline, whichever is smaller. The calculation of wave set-up was implicitly included in the calculation of the wave run-up heights.

9.4 Local Design Wave

Discussion of the derivation of design waves at the 105 foreshore model output locations can be found in Section 8.2 and results are presented in Table 8.1. In defining the planning level, these design wave heights are to be used, generally. However, consideration of possible boat waves that may approach the shore when design water levels are present needs attention. Review of the NSW Maritime (2007) area map shows the presence of 8 knots speed restriction and no-wash zones along Leichhardt's western shoreline from Iron Cove to Snapper Island and along the eastern shoreline all the way from Rozelle Bay to Ballast Point at the north of Mort Bay. Along these shorelines consideration of boat waves can therefore be ignored. However, outside these areas, predominantly along the northern shoreline, the foreshore may be subject to wash of larger boats, like the State Transit ferry and jet-cat services. It is estimated that boat wash from these types of vessels could reach a height of 0.5m with a wave period in the order of 5 seconds.

It is believed, however, that most boating activity would not occur during severe storm conditions and therefore boat wave effects can be excluded when extreme water levels occur. It is also assumed that foreshore levels under the combination of high tides and possible boat waves would be far less than that under storm conditions.

On this basis, the wave run-up assessment was undertaken for the local design wind wave from the east-north-east to south directional sector. This provides consistency in the joint occurrence relationships between wave height and water level. That is, as for wind setup, extreme estuary water levels are a result of south-easterly ocean storms and the resulting wave conditions would be limited in direction. Adoption of waves from a directional sector between east-north-east to south is though to be slightly conservative from the point of view of joint occurrence. Furthermore, the ARI conditions for both wave and water level parameters are considered to occur together, again a conservative position.

9.5 Wave Run-up

Wave run-up calculations were developed for a range of edge treatments that best describe those found along the Leichhardt LGA foreshore. They included:-

- 1 in 20 natural slope
- 1 in 10 beach face
- 1 in 5 embankment
- 1 in 2 seawall
- Vertical wall

Calculations were undertaken for four edge treatment crest levels, being 1.5mAHD, 2mAHD, 2.5mAHD and 3mAHD, for each edge treatment type. The four selected crest levels are considered to cover the vast majority of foreshore levels around the Leichhardt LGA foreshore.

In defining the run-up level, three mechanisms of wave run-up were identified. They included wave run-up without overtopping of the edge treatment crest, wave run-up rising above the edge treatment crest, thereby resulting in wave overtopping, and wave overtopping when the design still water level is above the edge treatment crest; the last case not being a desirable condition.

9.5.1 Wave Run-up with No Overtopping

Run-up algorithms on smooth slopes can be found in many published articles and manuals. For the purposes of this study, the de Waal and van der Meer (1992) wave run-up algorithm for smooth slopes, as specified in the Coastal Engineering Manual (2002) has been adopted. The equation for this calculation is presented in Appendix G. It is described as a robust approximation developed using extensive measurements of model run-up data (CEM, 2002). Should the run-up level not exceed the defined crest level, then the planning level is considered to simply be the run-up height on top of the SWL (+freeboard+MSL rise).

The definition of run-up on a vertical wall is quite different, however. For a smooth impermeable, continuous wall the run-up level can be approximated as the wave height above the still water level (SWL), or approximately two times the crest level above the SWL. This is derived from linear wave theory – suitable for short period waves.

9.5.2 Wave Run-up with Overtopping

Once the crest level is reached, the mechanism of run-up is no longer applicable because there is no edge treatment slope to allow the run-up process to continue. In this case overtopping of the crest occurs and a wave is transmitted onto the foreshore area. This transmitted wave can be defined using an algorithm developed by Seelig (1980) as defined in the Shoreline Protection Manual (1984). The equation is presented in Appendix G. The run-up level can then simply be defined as the height of the transmitted wave added to the crest level (+freeboard+MSL rise). Note though, that local wind wave propagation over land is much less than it is for swell.

9.5.3 Overtopping when SWL is above the Crest

Should the design SWL be above the foreshore crest level, then waves are able to directly surge over the foreshore crest and onto the foreshore areas, albeit with some attenuation. Studies undertaken by the Public Works Department (1990) define the depth of this surge as half the approaching wave height above the design SWL. This is thought to be a realistic approximation of the wave dynamics and from this the planning level can be defined as the height of the penetrated wave over the crest plus the storm tide level. Again, this approximation is defined in Appendix G.

9.6 Estuarine Planning Levels

The definition of estuarine planning levels can therefore be undertaken using the following calculation:-

$$PL = DWL + WRH \qquad (9.1)$$

where:-

PL - Planning Level

DWL - Design Water Level = Design Level at Fort Denison + Local Wind Setup (relative to Fort Denison) + 0.4m Mean Sea Level rise.

WRH - Wave Run-up Height - based on edge treatment type

Both the design water level and wave run-up level are presented in Tables F.1 to F.4 of Appendix F for the 100-years design return periods – a freeboard of 0.3m is included. Calculation of run-up height, in order to undertake the above calculation, requires use of the run-up equations presented in Appendix G.

Table F.5 of Appendix F presents the preliminary Estuary Planning Level for the 100-years ARI parameters. The maximum calculated value for all foreshore edge treatment combinations (being type and crest level) has been adopted as the preliminary Estuary Planning Level at each site. It is envisaged that, should further clarification of the planning level be required, consideration of the type of edge treatment and specific crest level could be undertaken using Tables F.1 to F.4. An example of this is provided in Section 9.7.

Note that a freeboard of 0.3m is included in these planning levels.

Figure 9.1 presents the various definitions of the Estuary Planning Level.

9.6.1 Foreshore Finishes

The magnitude of wave run-up is also dependant on the finish material of the foreshore edge treatment. Generally, the higher the porosity or roughness of the edge treatment, the lower the run-up height is. The algorithms adopted for run-up calculations were for smooth impermeable slopes, an upper limit case. As a basic guide, reduction coefficients are provided, in line with published literature (CEM, 2002) and based on a variety of possible edge treatment types. They are presented in Table 9.1.

Table 9.1 Surface Roughness Reduction Factors

Type of Edge Treatment Surface	Reduction Factor for $R_{u2\%}$
Smooth, concrete, asphalt, sand and block/brick revetment	1.0
Grass/vegetated bank	0.90
Modular permeable wall	0.80
Rock structure (1 layer)	0.60
Rock structure (2 layer)	0.55

It should be noted that these factors are applicable to the run-up height component only, not the combined planning level. Therefore, should such reduction factors be incorporated into the assessment of the EPL, they must be applied to the wave run-up height only using equation 9.1 together with the values from Table F.2 (for the 100-years ARI case). The revised formula for calculating the EPL is now:-

PL = DWL + (WRH x RR) (9.2)

where:-

RR = Surface Reduction Factor - from Table 9.1

9.6.2 Inland Reduction in Estuarine Planning Levels

As discussed in Section 5.5, the inland extent of the wave inundation is assumed to be 20m from the edge treatment crest. The EPL should therefore be applied over this 20m wide area of the foreshore. Landward of this area, the planning level should be based on the calculated design water level (DWL) for the appropriate foreshore location (+MSL rise +freeboard).

9.6.3 Further Considerations

The definition of the EPL above has included a freeboard allowance of 0.3m. It is thought prudent that such an allowance be applied to account for uncertainty in the predictions of storm tide and sea level rise.

Should a particular property lie between two of the reported foreshore locations, linear interpolation between the reported location results should be undertaken. This has been pre-prepared for council and overlayed on the cadastral layer of councils GIS database. Hence each cadastral property under 5mAHD has a set of water level, wave and planning level values pre-calculated.

Calculation of planning levels along the Leichhardt foreshore area shows that some overtopping under design conditions may occur. Should the land level behind a foreshore structure be at a lower level than the crest then it can be expected that some ponding of estuarine waters will occur. Hence drainage of such areas should be considered.

9.7 Application of the Estuarine Planning Level

A preliminary Estuarine Planning Level has been calculated for all foreshore areas, based on the 100-years ARI event, and is presented in Appendix F, Table F.5. This level has been defined as the maximum level derived from the range of possible foreshore types under the adopted 0.9m sea level rise scenario (see Tables F.1 to 4) and includes a freeboard amount of 0.3m. Depending on the foreshore crest level this preliminary planning level will govern development on a given site. These levels are also used to define flood affected lots under the council's planning instruments.

For example, a hypothetical site (location near Location 50) would define the base planning level as follows:

- The existing edge treatment is a vertical wall with a 2.6m AHD crest level.
- From Table F.5 the preliminary Estuarine Planning Level can be calculated by interpolation between the levels defined for a crest level of 2.5mAHD (EPL=3.04m) and 3mAHD (EPL = 3.46mAHD).
- The preliminary Estuarine Planning Level is therefore defined as 3.12mAHD.

However, a more refined definition of the planning level is sought by the owner due to the fact that the foreshore edge is a vertical wall.

- From Tables F.3 and F.4 the Estuarine Planning Level can be calculated by interpolating between the levels defined for a crest level of 2.5mAHD (EPL = 3.0m – Table F.3) and 3mAHD (EPL = 3.2mAHD – Table F.4) based on a sea level rise of 0.9m.
- The refined Estuarine Planning Level is therefore defined as 3.04mAHD.

The owner now wishes to redevelop the site; replacing the existing vertical wall with a 1:2 sloped seawall of crest level 2.8mAHD. In doing so, a small studio is to be built close to the foreshore edge and it is considered that this is to have a design life of 50-years (approximately). A sea level rise of 0.4m would then be adopted for this dwelling based on this design life.

- From Tables F.3 and F.4 the Estuarine Planning Level can be calculated by interpolating between the levels defined for a crest level of 2.5mAHD (EPL= 2.96m – Table F.3) and 3mAHD (EPL = 3.38mAHD – Table F.4)
- The Estuarine Planning level is therefore defined as 3.21mAHD.

10 Concluding Remarks

This report has been prepared for Leichhardt Municipal Council to provide a basis for physically reliable and consistent planning level definition in line with the Government of New South Wales planning policy.

It describes the status of similar planning procedures in other local government areas of NSW and then discusses the physical processes that must be considered for the development of this level parameter.

The basic storm tide parameter component was taken from Fort Denison. A calibrated numerical hydraulic model was used to determine wind set-up changes from those at Fort Denison to 105 locations in the Leichhardt LGA. Additionally, a verified numerical wave model was applied together with long term wind data to the definition of wind wave information at the same locations.

All of these parameters were defined in terms of selected ARI between 5 and 200 years.

Wave run-up heights have been determined for five types of edge treatment, each with two crest levels. Run-up reduction factors for a range of revetment roughness types have been determined, from smooth to two layers of rock protection.

The results have been presented in a tabular form and as a GIS layer Council's application.

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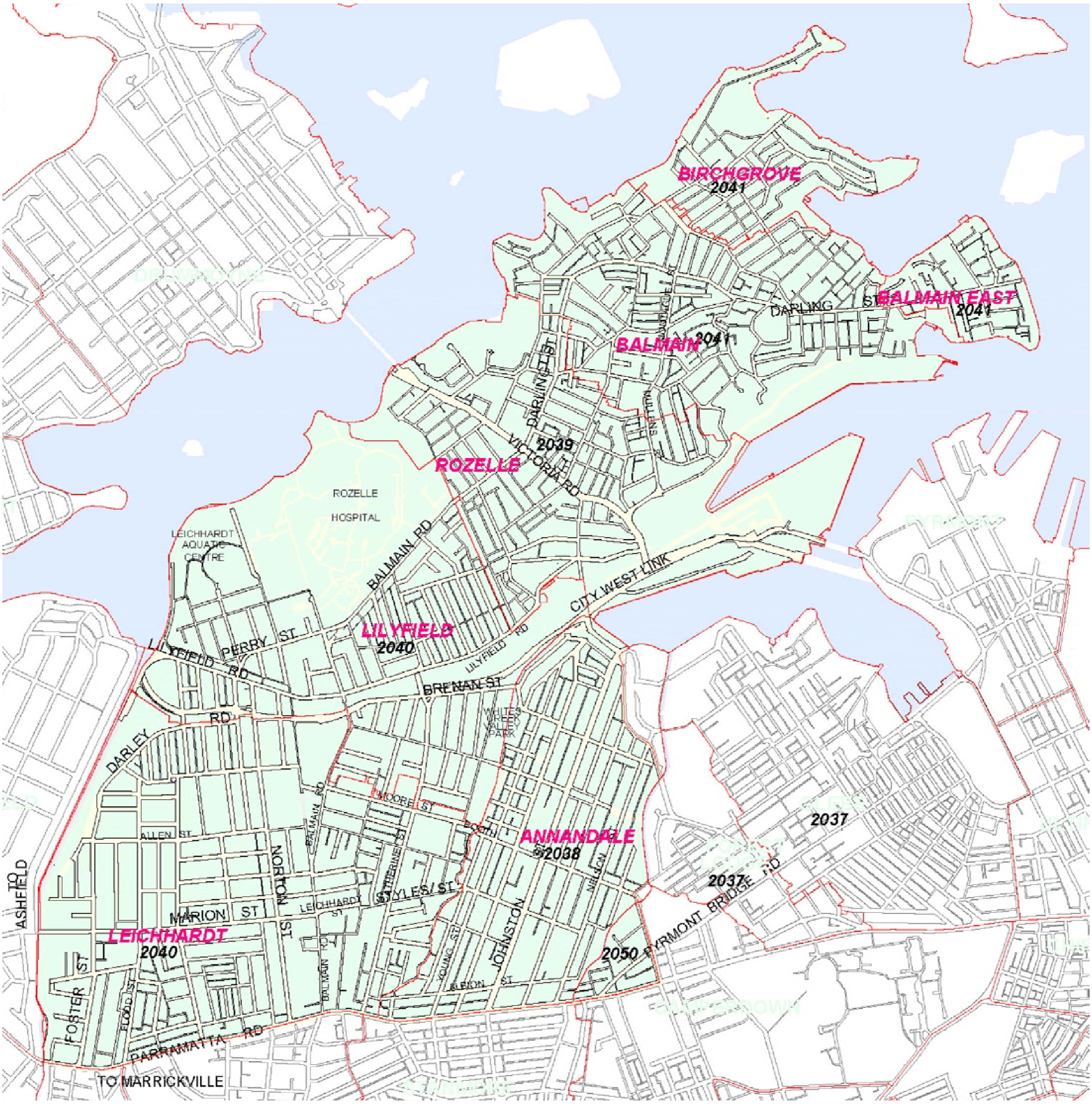
Figures



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Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

LEICHHARDT LOCAL GOVERNMENT AREA

LJ2611/R2358v5 April 2010

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Figure 1.1

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

WAVE OVERTOPPING OF SEAWALL
BRISBANE WATER, GOSFORD

Figure 5.1

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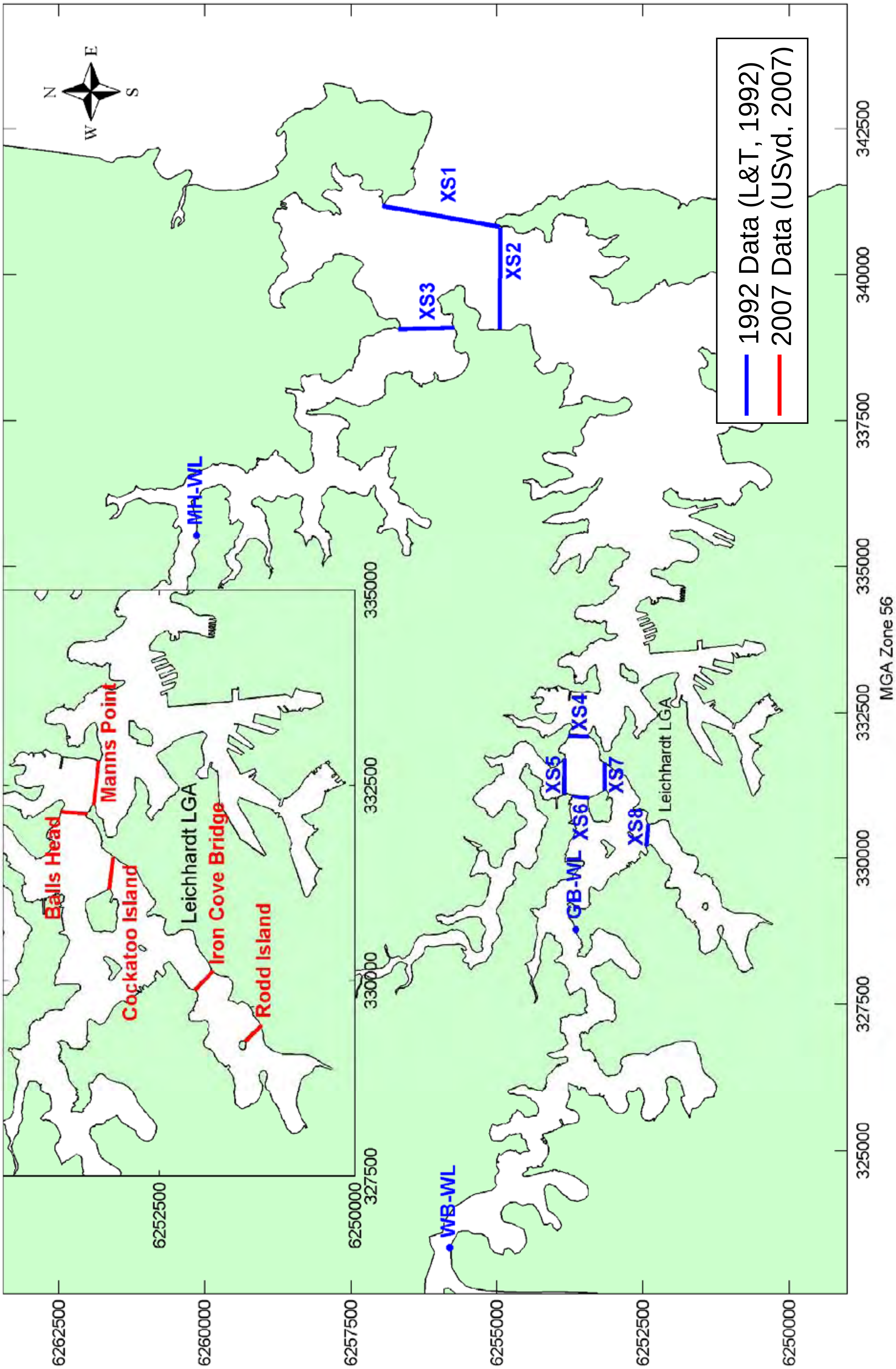
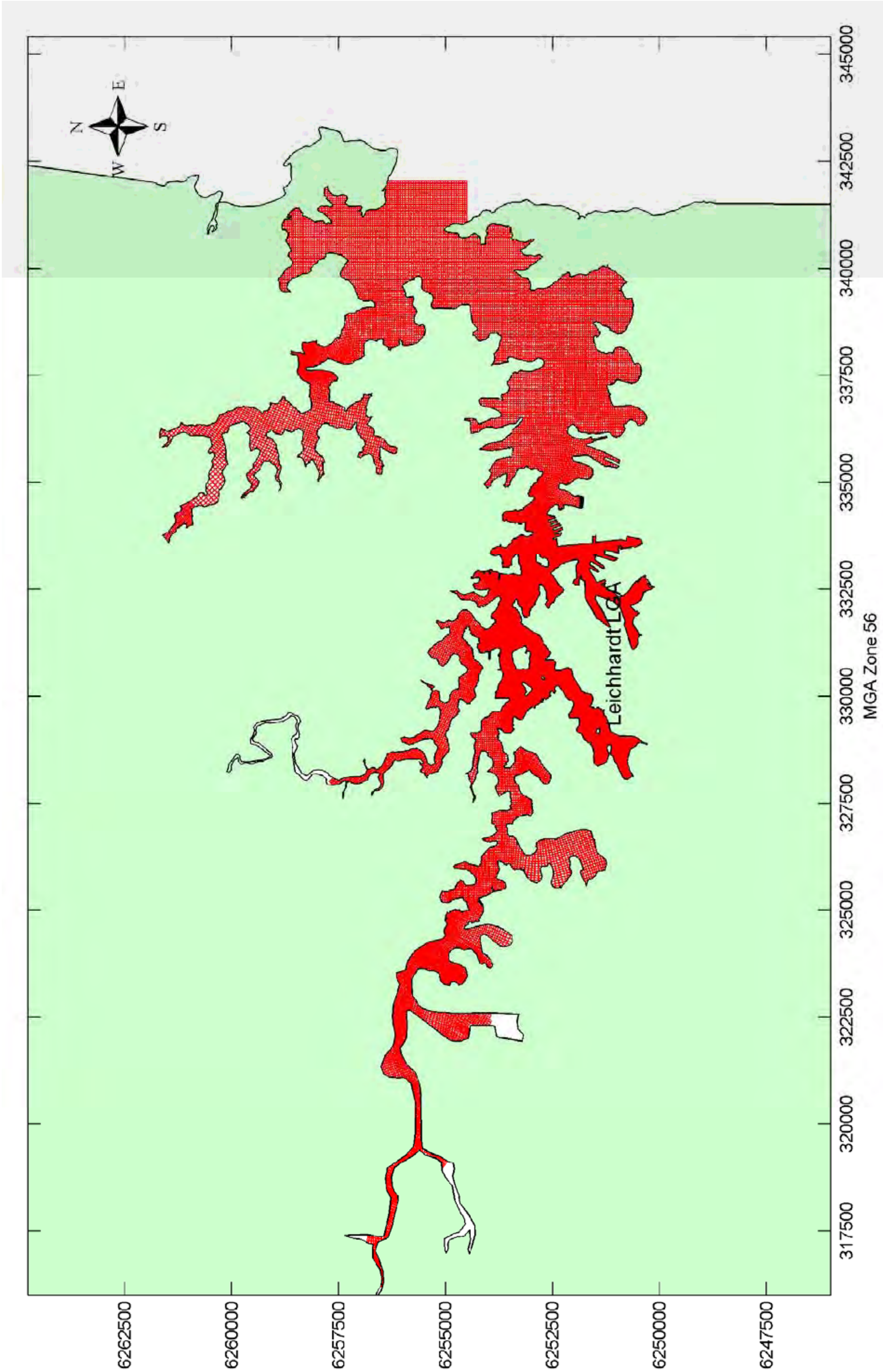


Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

CALIBRATION DATA LOCATIONS

Figure 6.1



Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL GRID SYSTEM

Figure 7.1

LJ2611/R2358v5 April 2010

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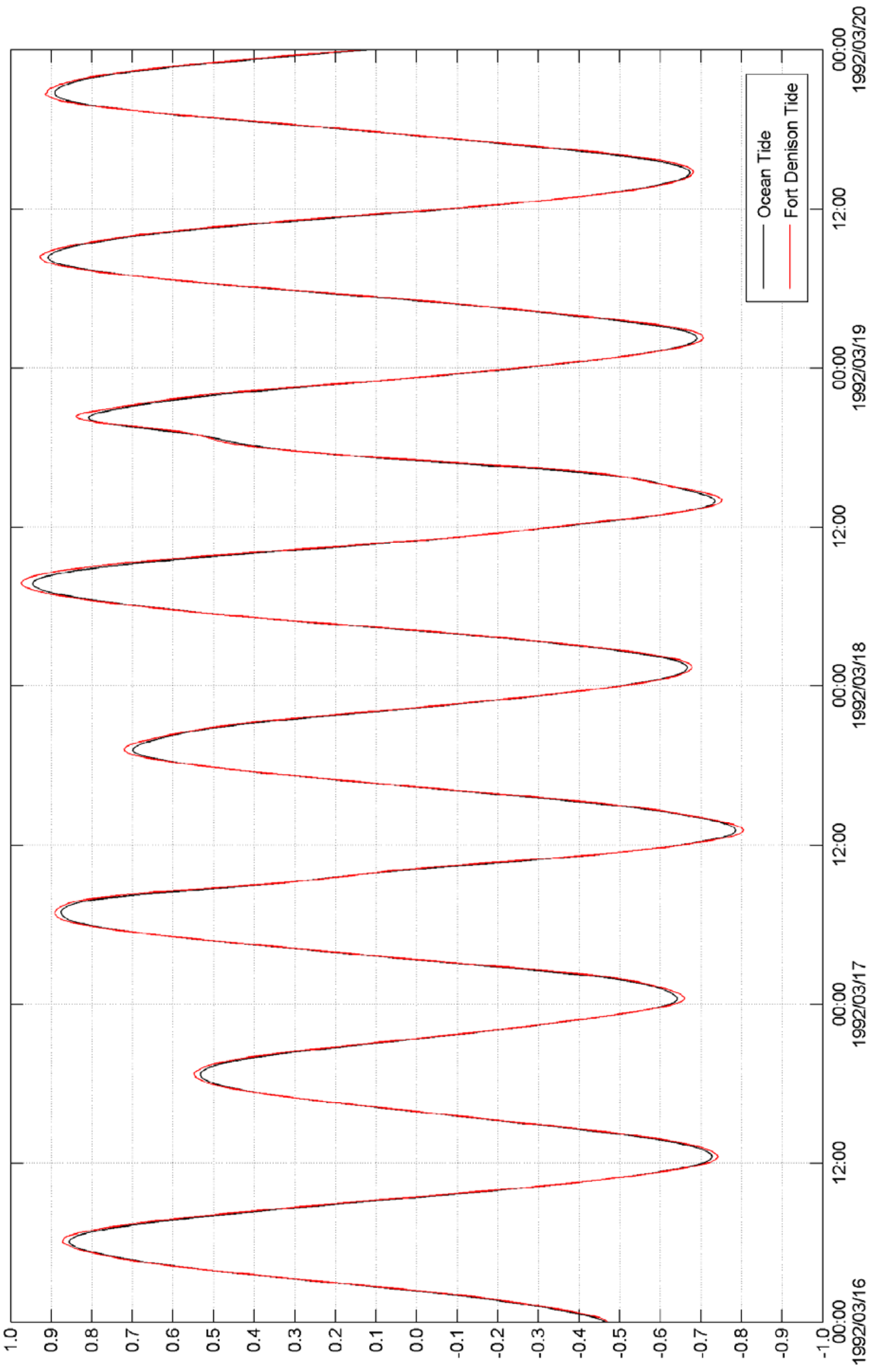

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

COMPARISON OF OFFSHORE BOUNDARY AND FORT DENISON TIDES

Figure 7.2

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LJ2611/R2358v5 April 2010

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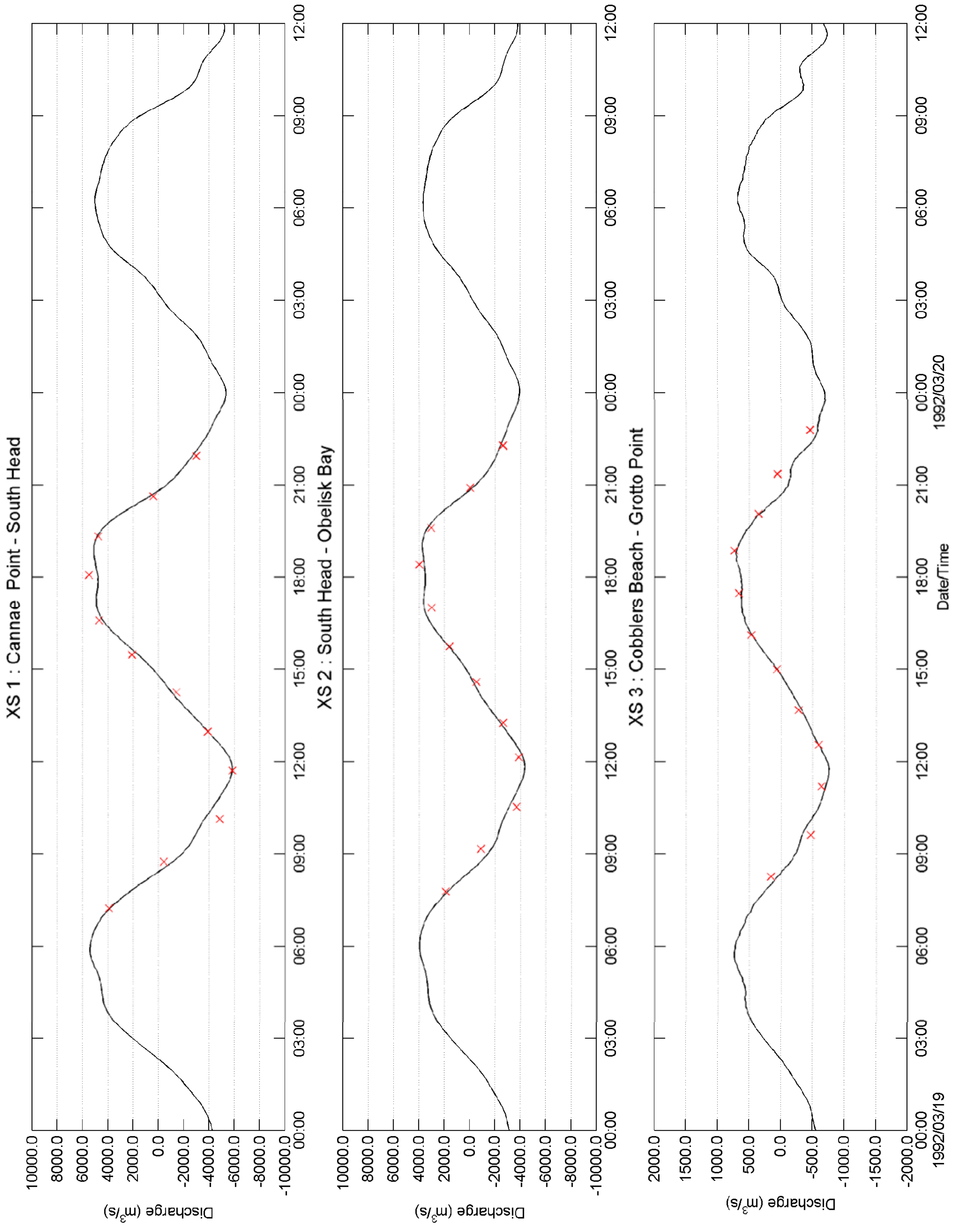

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL CALIBRATION
DISCHARGE CALIBRATION – MAY 1992
Figure 7.3

LJ2611/R2358v5 April 2010

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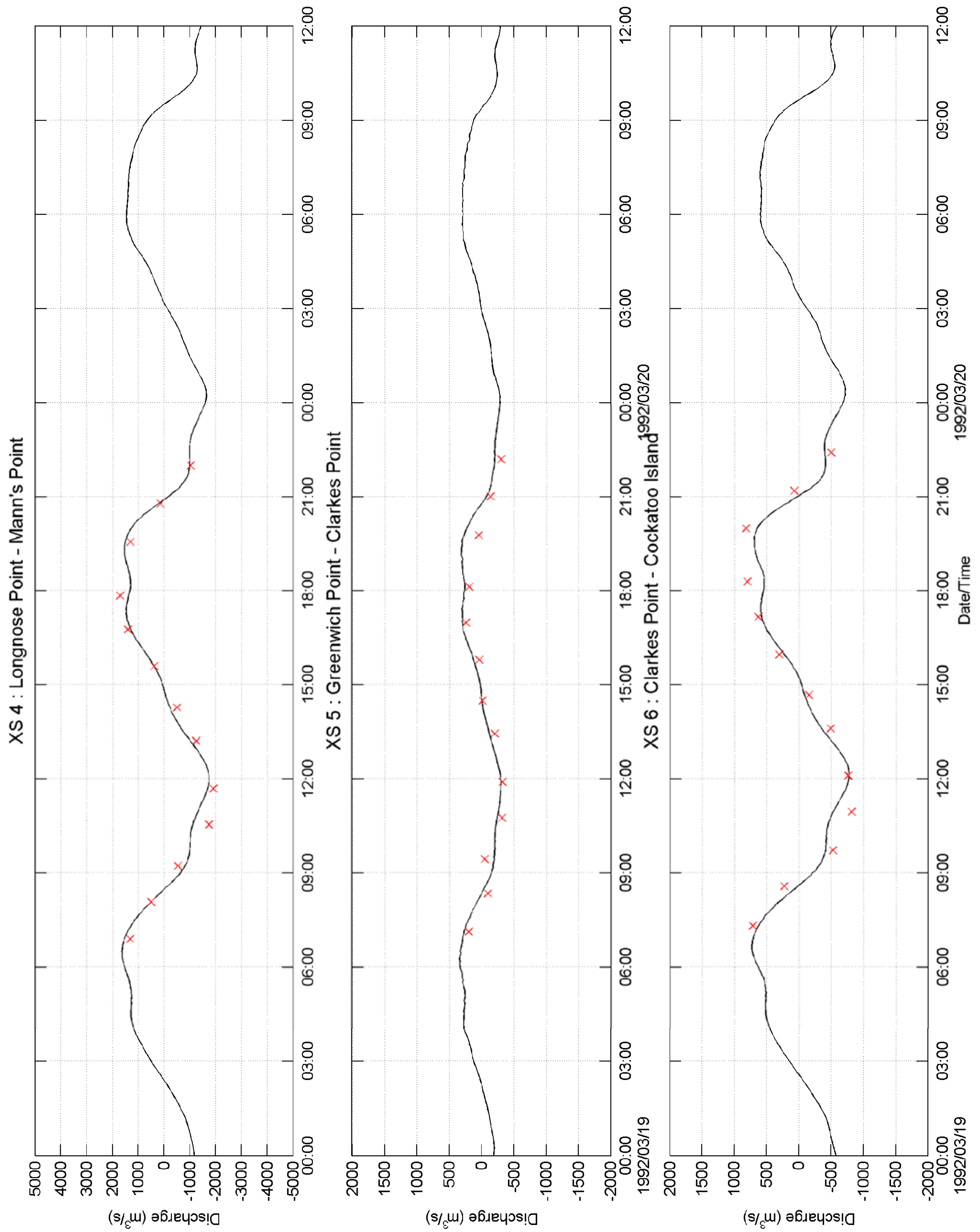

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL CALIBRATION
DISCHARGE CALIBRATION – MAY 1992
Figure 7.4

Cardno Lawson Treloar

LJ2611/R2358v5 April 2010

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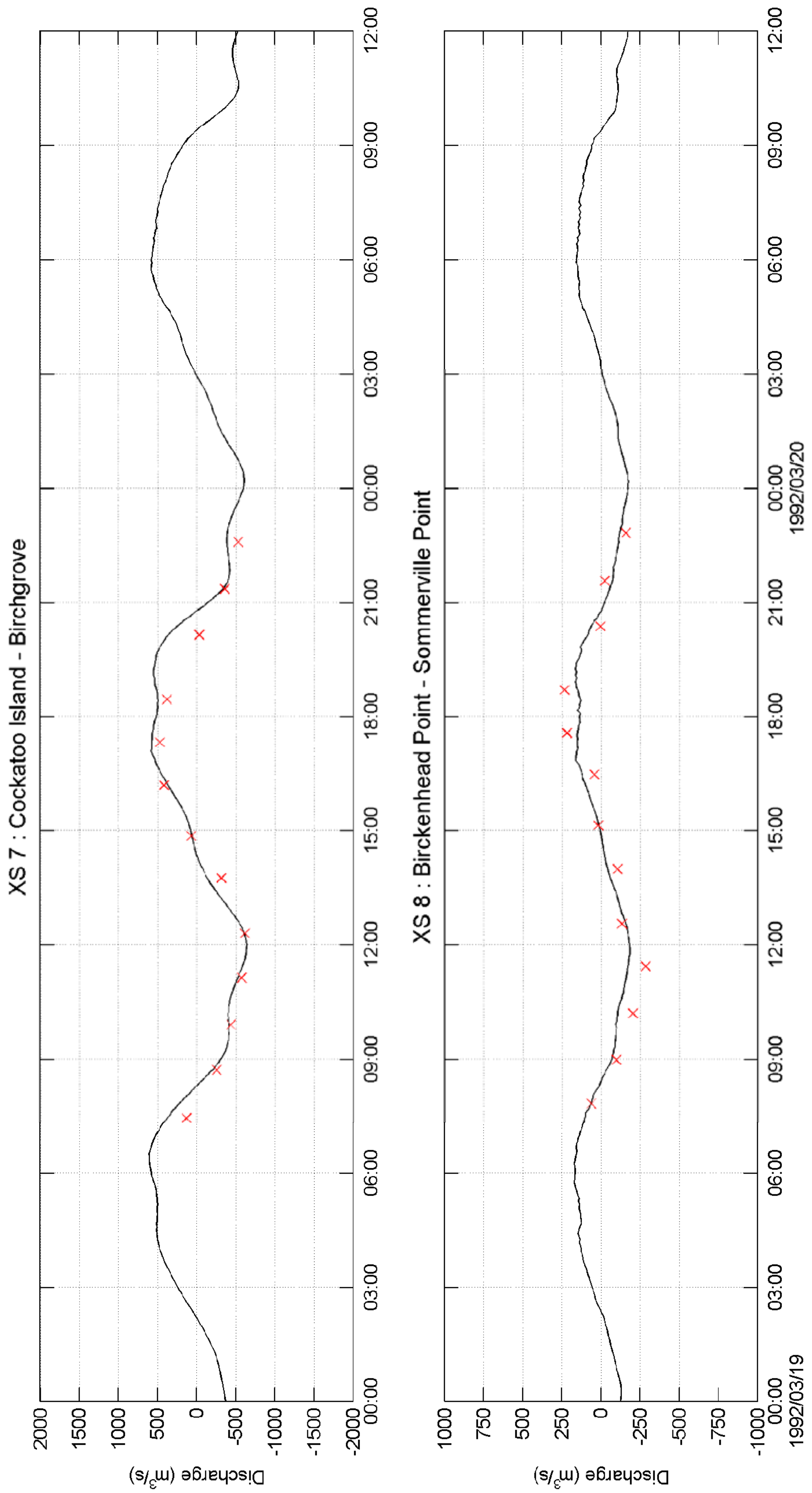

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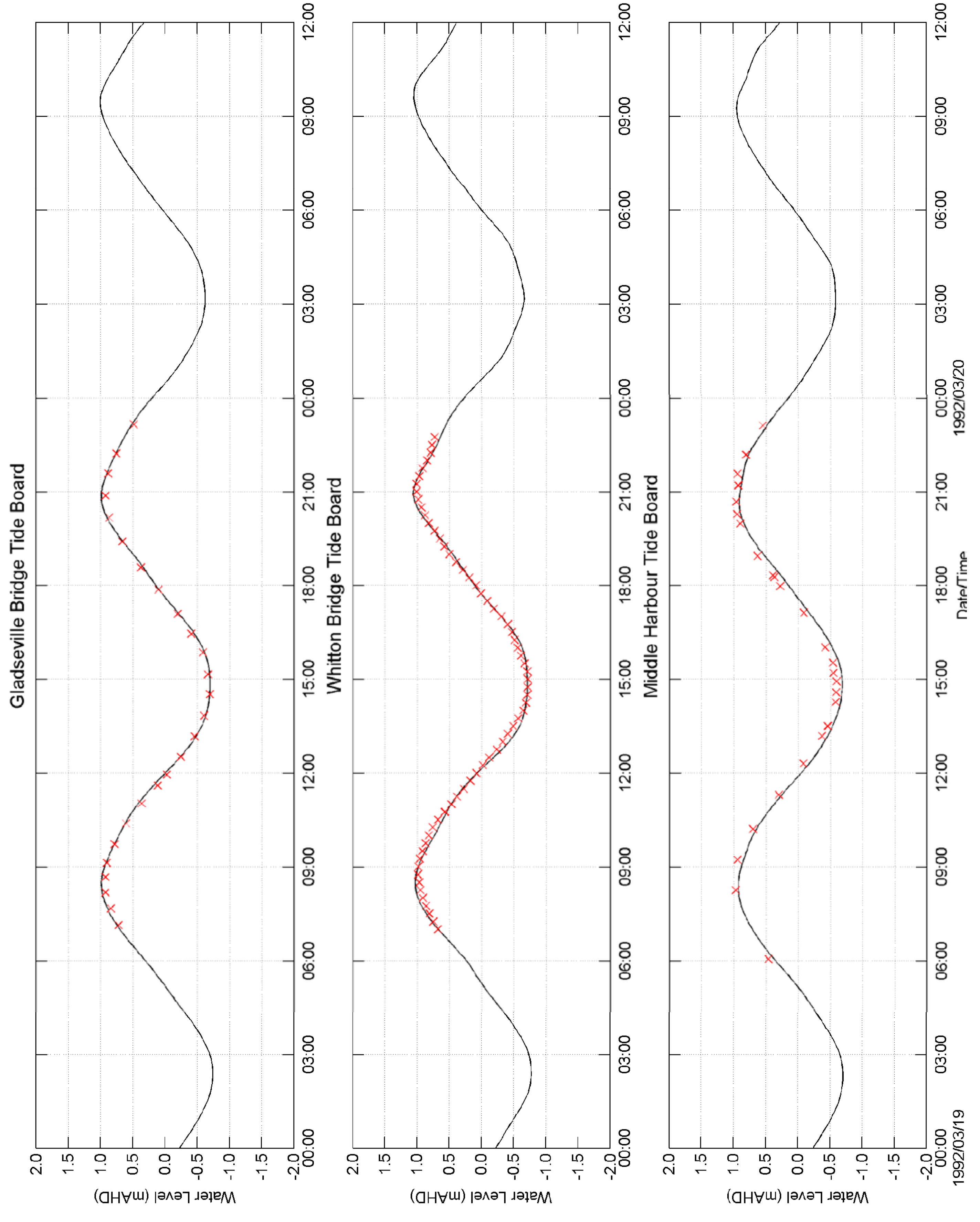
Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL CALIBRATION
DISCHARGE CALIBRATION – MAY 1992
Figure 7.5



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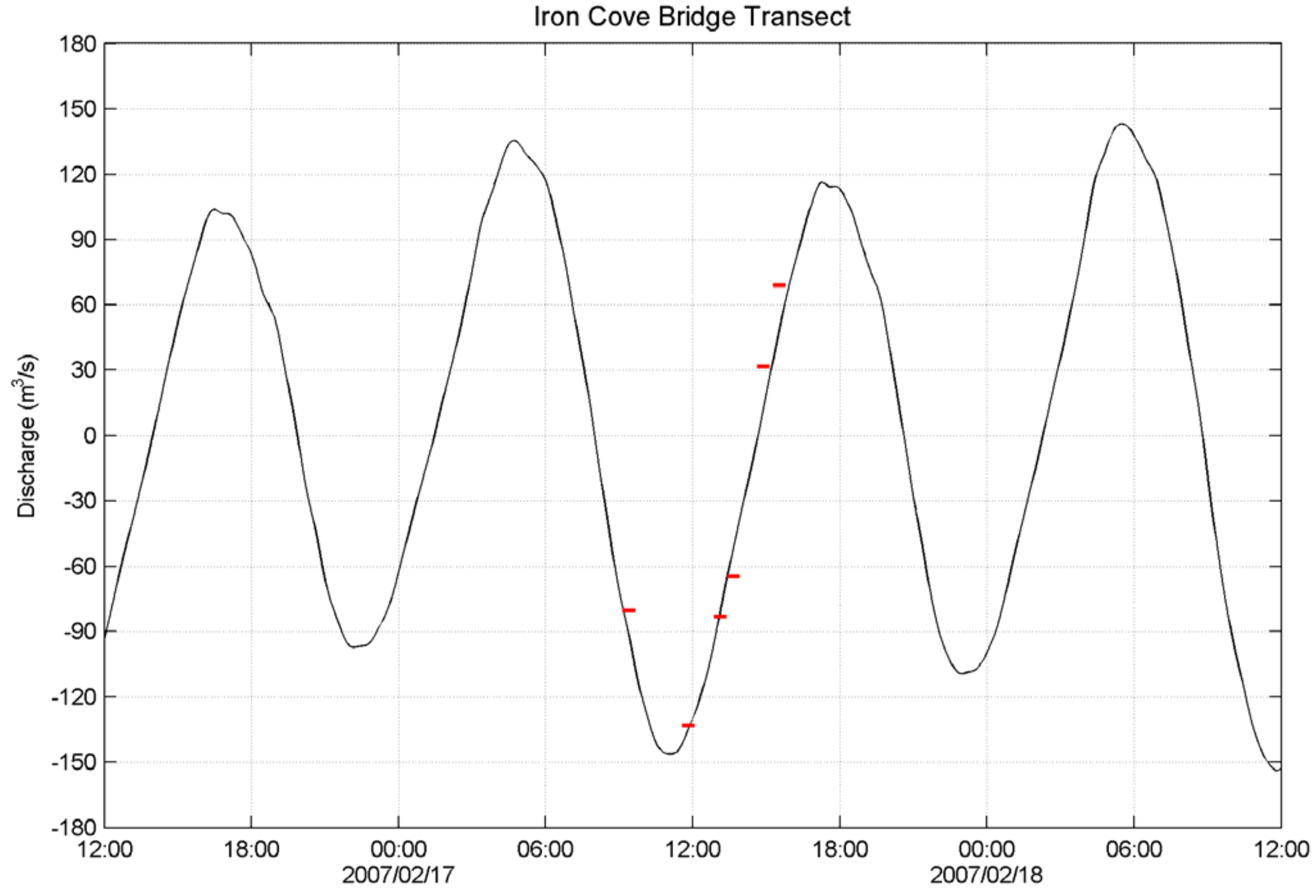
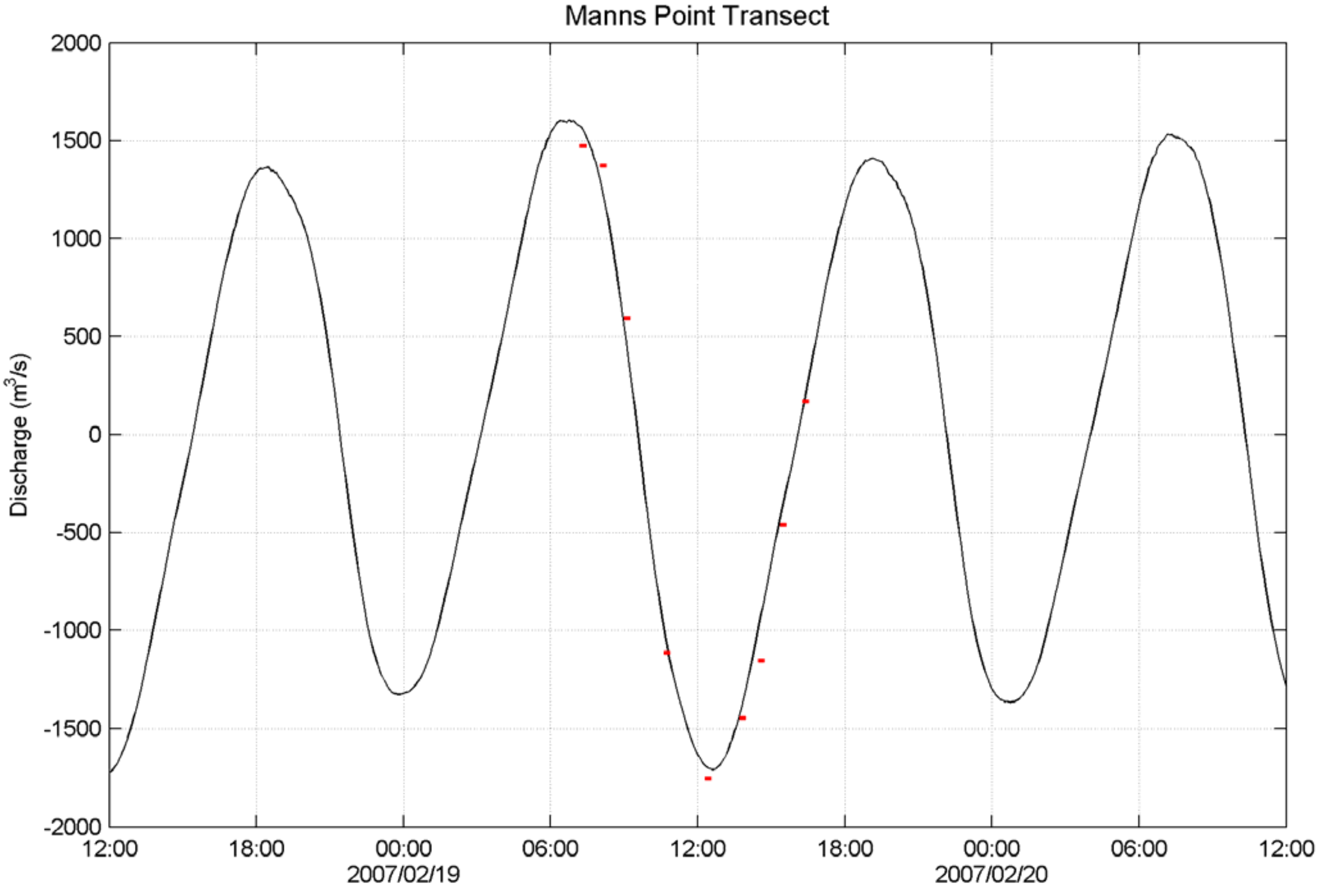
Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL CALIBRATION
WATER LEVEL CALIBRATION – MAY 1992

Figure 7.6





Data Source: University of Sydney, School of Geosciences

Cardno Lawson Treloar

LJ2611/R2358v5 April 2010

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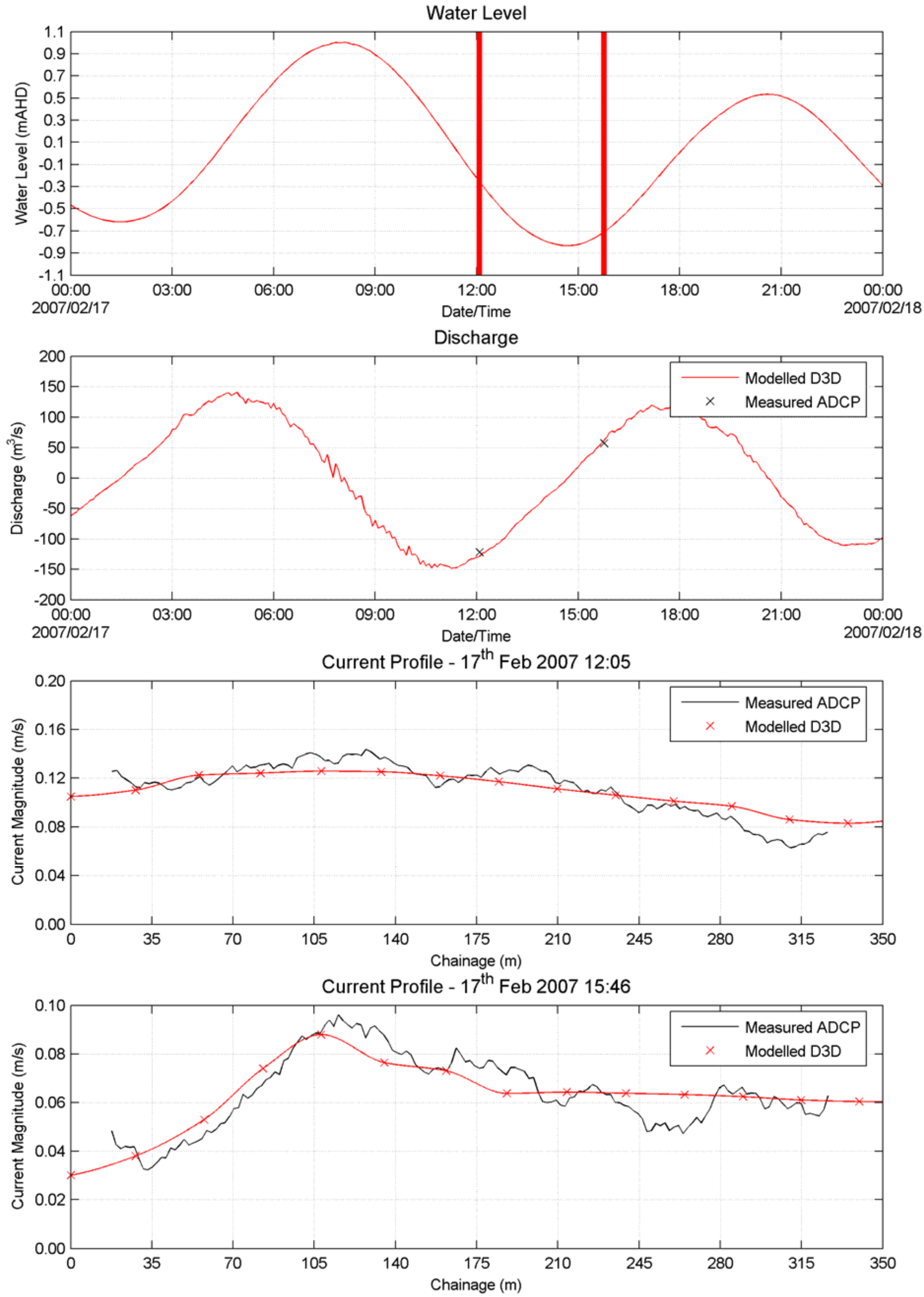
Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL VERIFICATION
DISCHARGE CALIBRATION – FEBRUARY 2007
Figure 7.7



Data Source: University of Sydney, School of Geosciences

Cardno Lawson Treloar

LJ2611/R2358v5 April 2010

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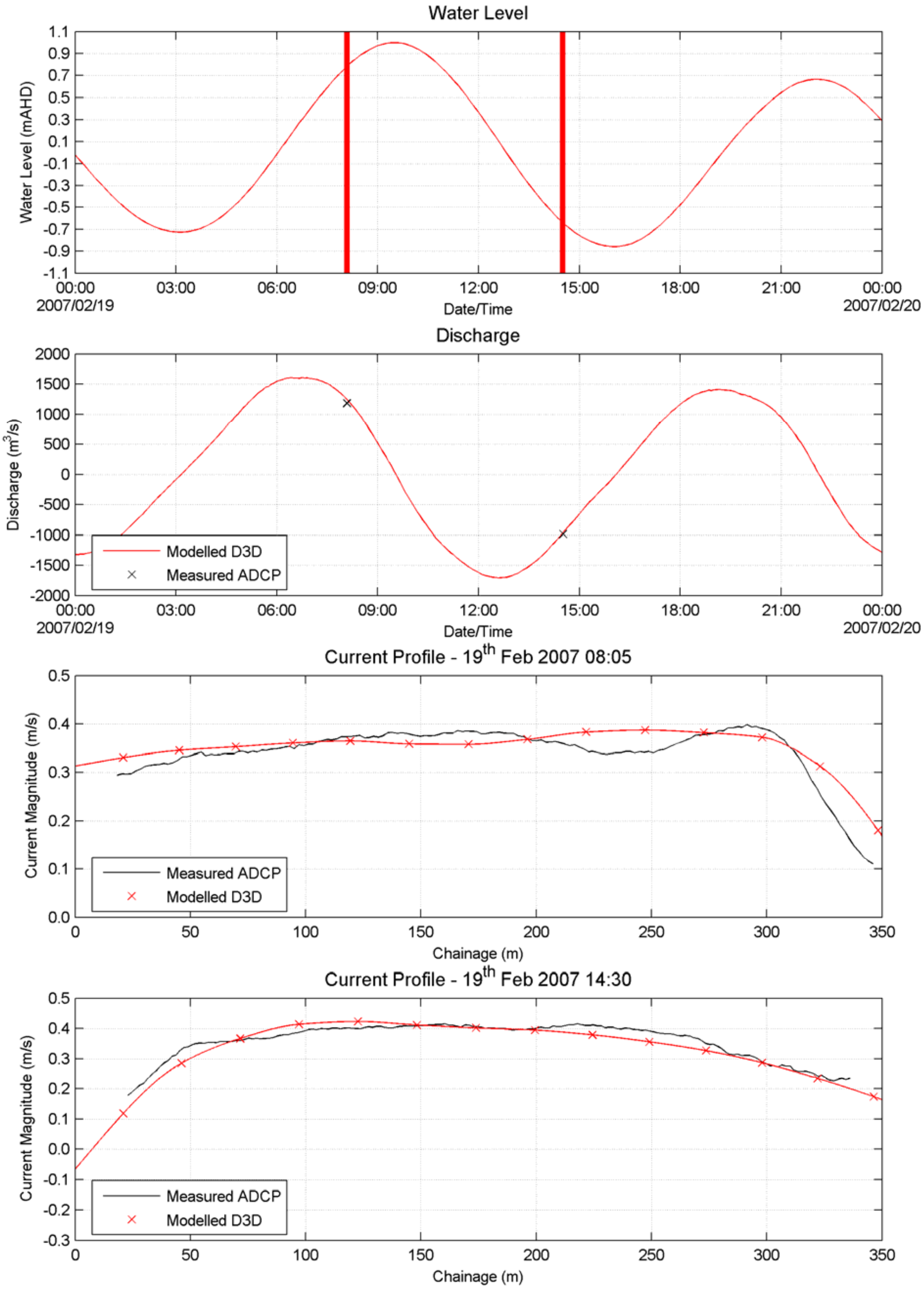
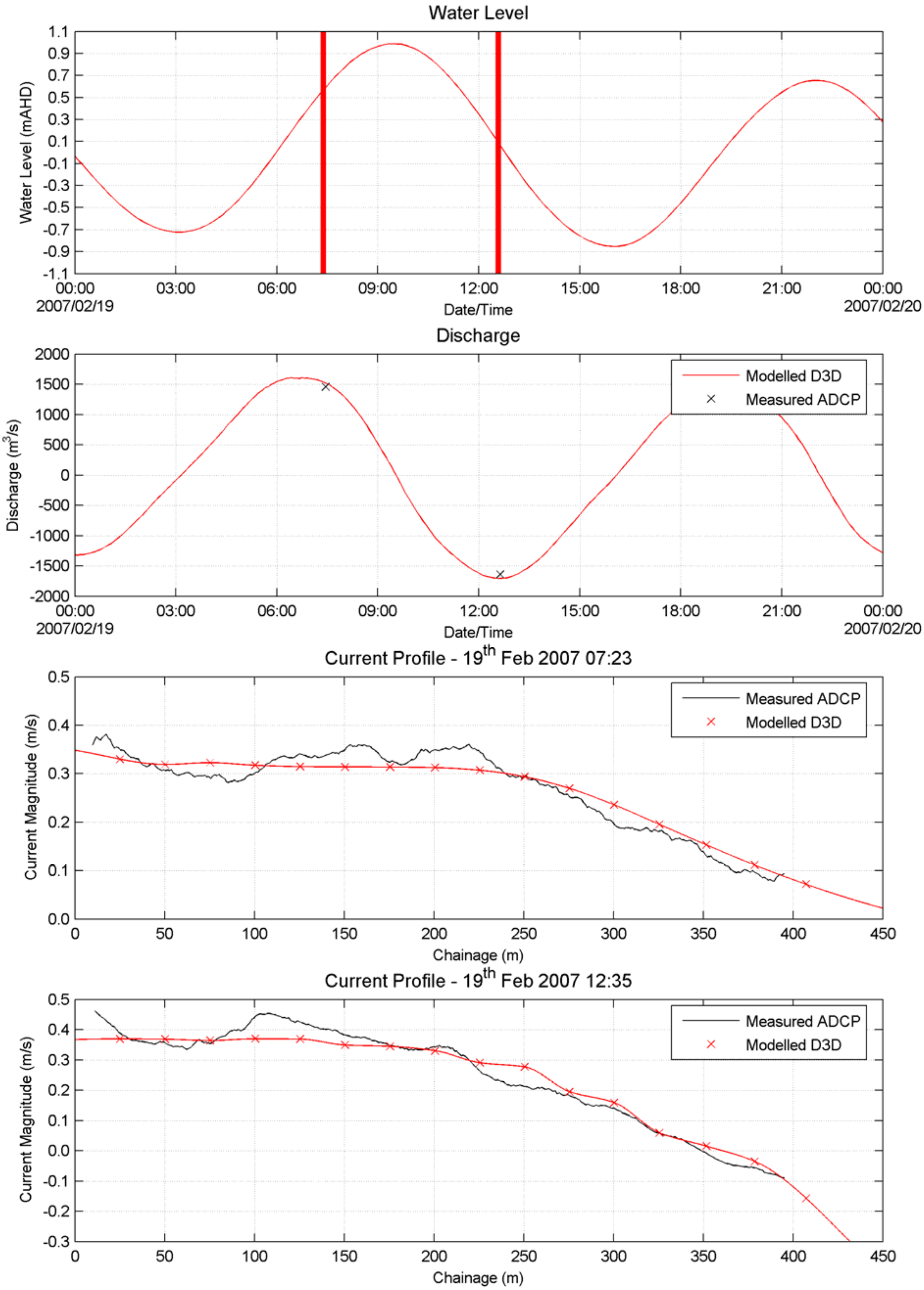
Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL VERIFICATION
FEBRUARY 2007 – IRON COVE BRIDGE
Figure 7.8



Data Source: University of Sydney, School of Geosciences

DELFT3D MODEL VERIFICATION
FEBRUARY 2007 – MANNS POINT
Figure 7.9



Data Source: University of Sydney, School of Geosciences

Cardno Lawson Treloar

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL VERIFICATION
FEBRUARY 2007 – BALLS HEAD
Figure 7.10

LJ2611/R2358v5 April 2010
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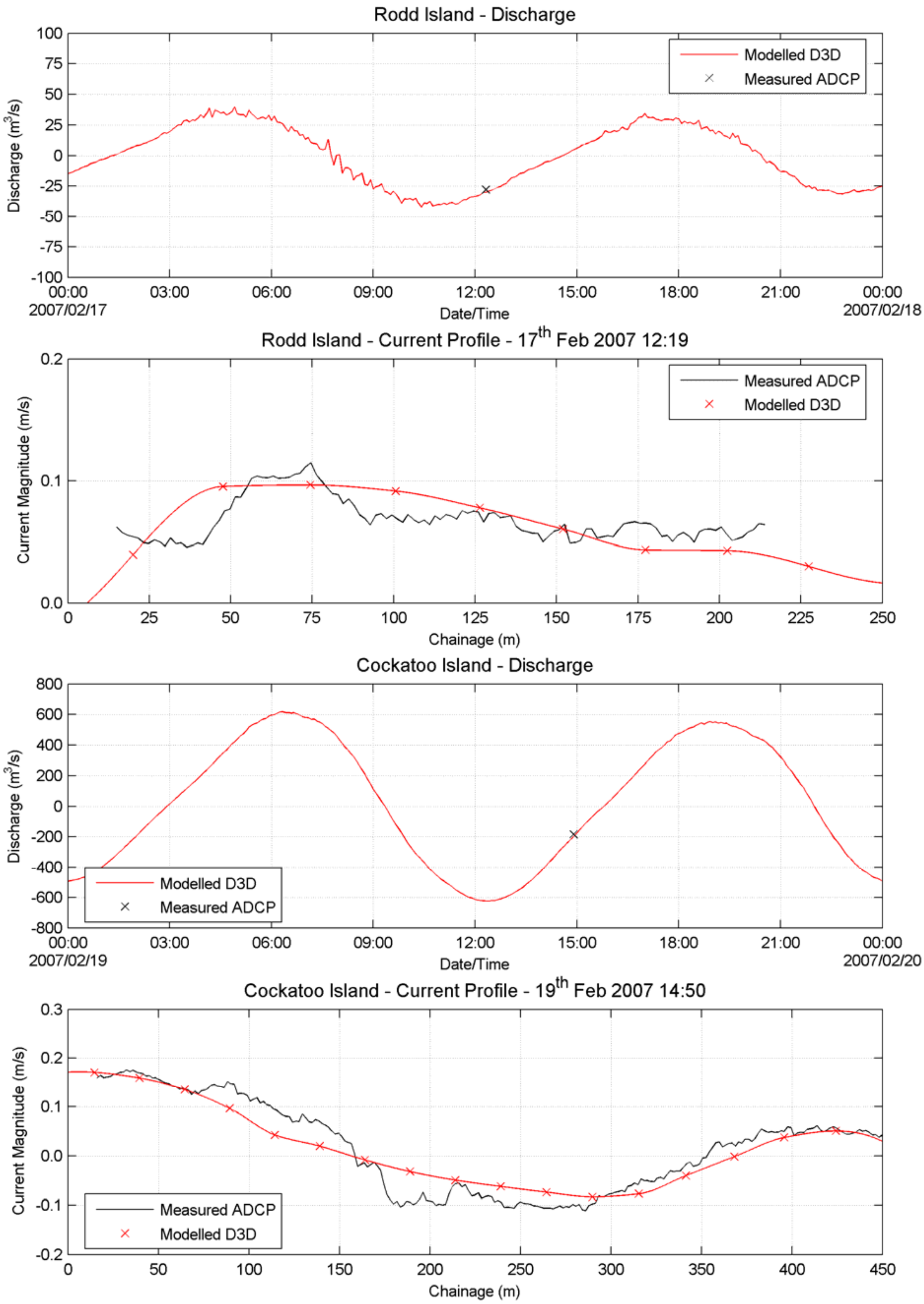

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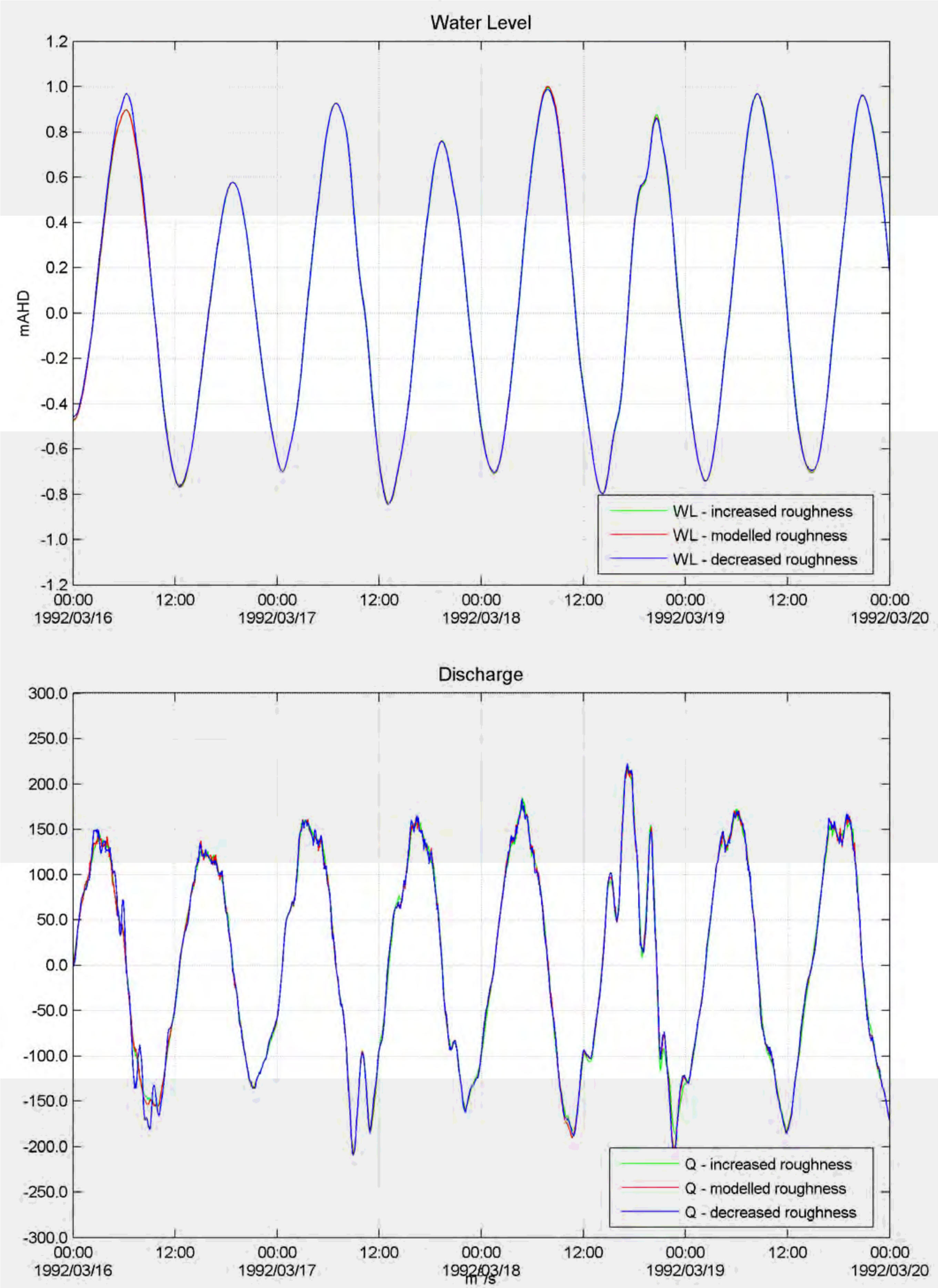
DELFT3D MODEL VERIFICATION
FEBRUARY 2007 – RODD AND COCKATOO ISLANDS
Figure 7.11



Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

DELFT3D MODEL SENSITIVITY TO BED ROUGHNESS

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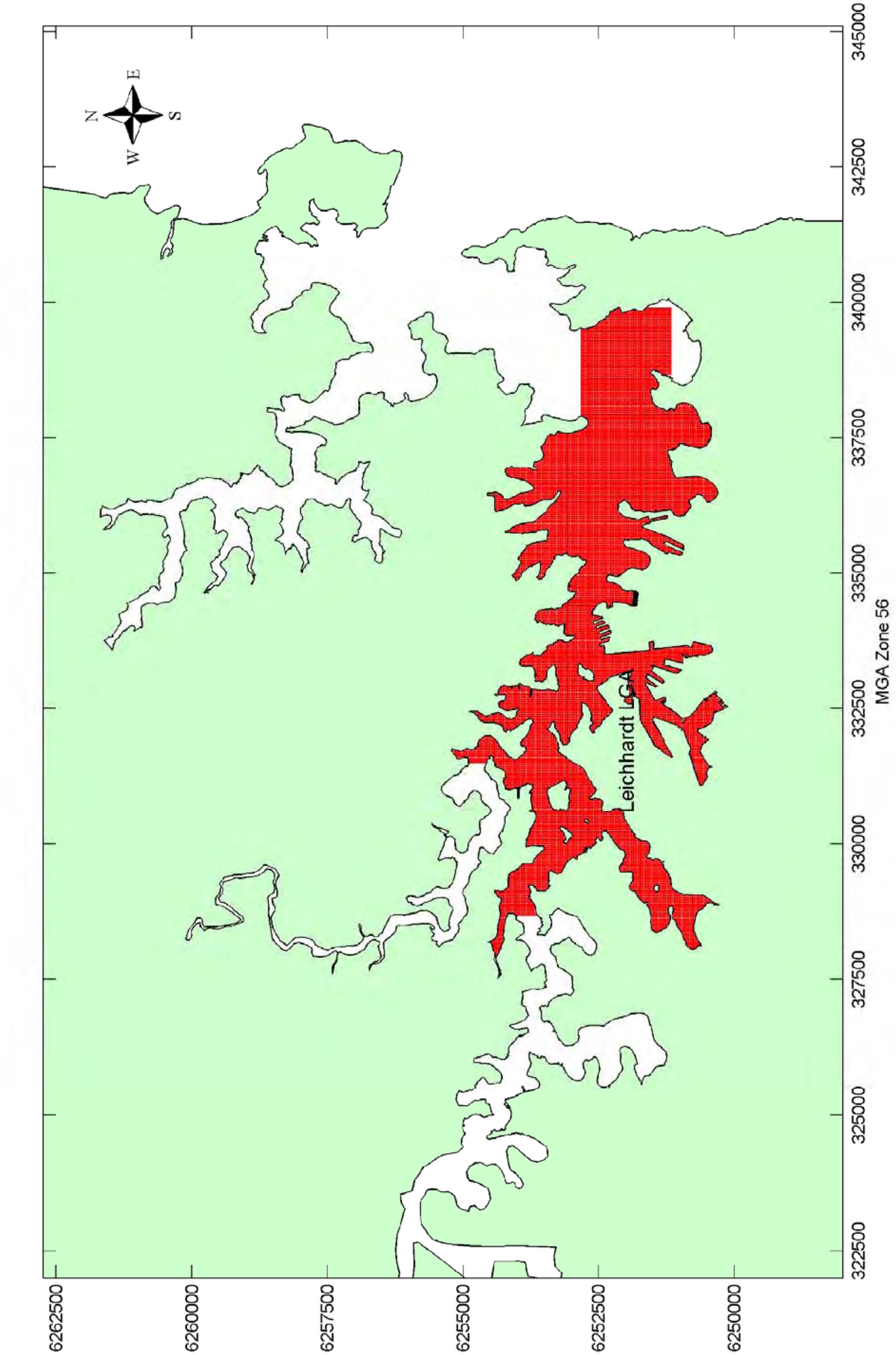
Figure 7.12



Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

SWAN MODEL GRID SYSTEM

Figure 7.13

Cardno Lawson Treloar

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Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

FORESHORE OUTPUT LOCATIONS

Figure 8.1

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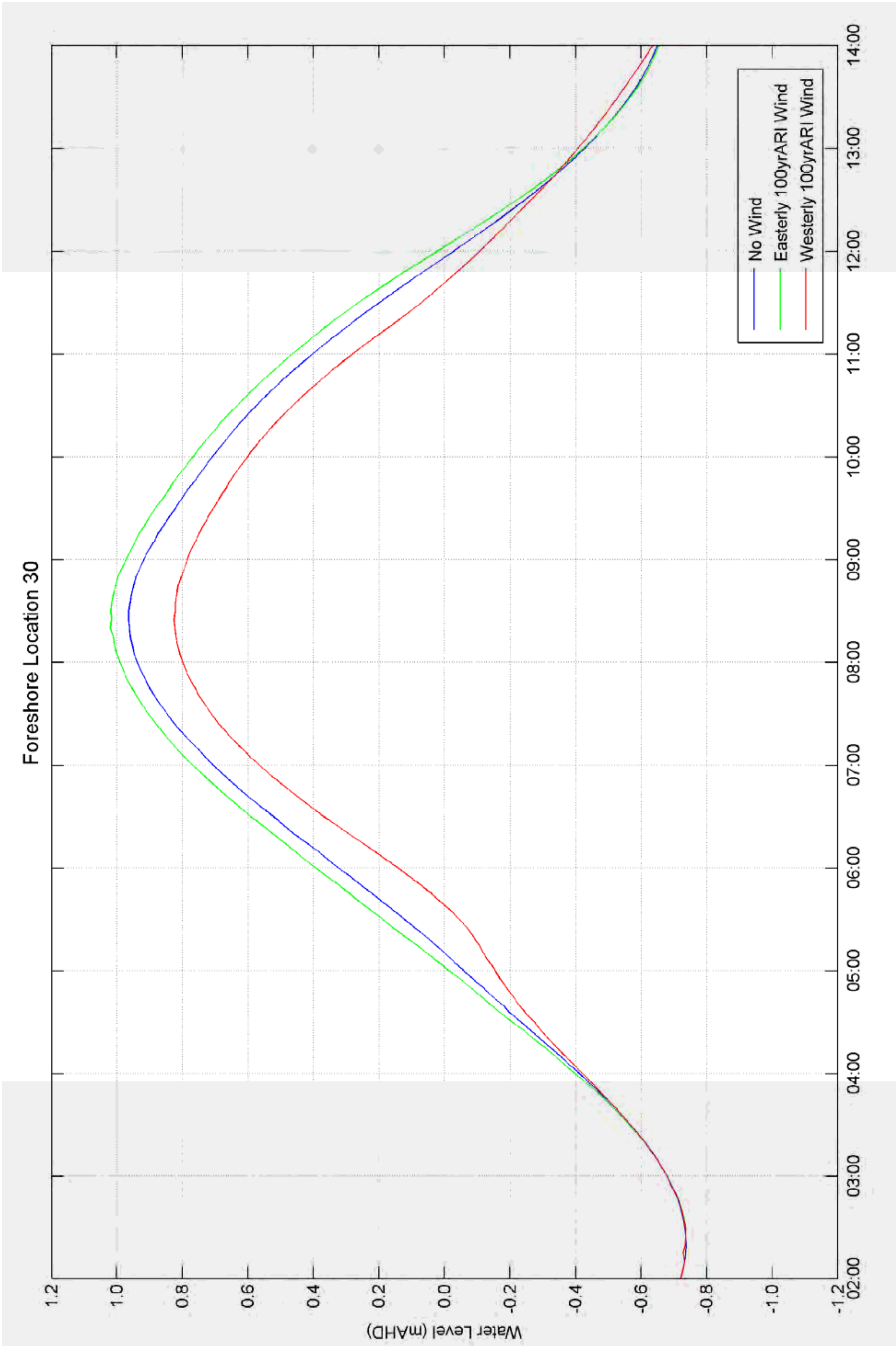

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

COMPARISON OF WIND SETUP RESPONSE
UNDER 100-YEARS ARI WIND CONDITION

Figure 8.2

LJ2611/R2358v5 April 2010

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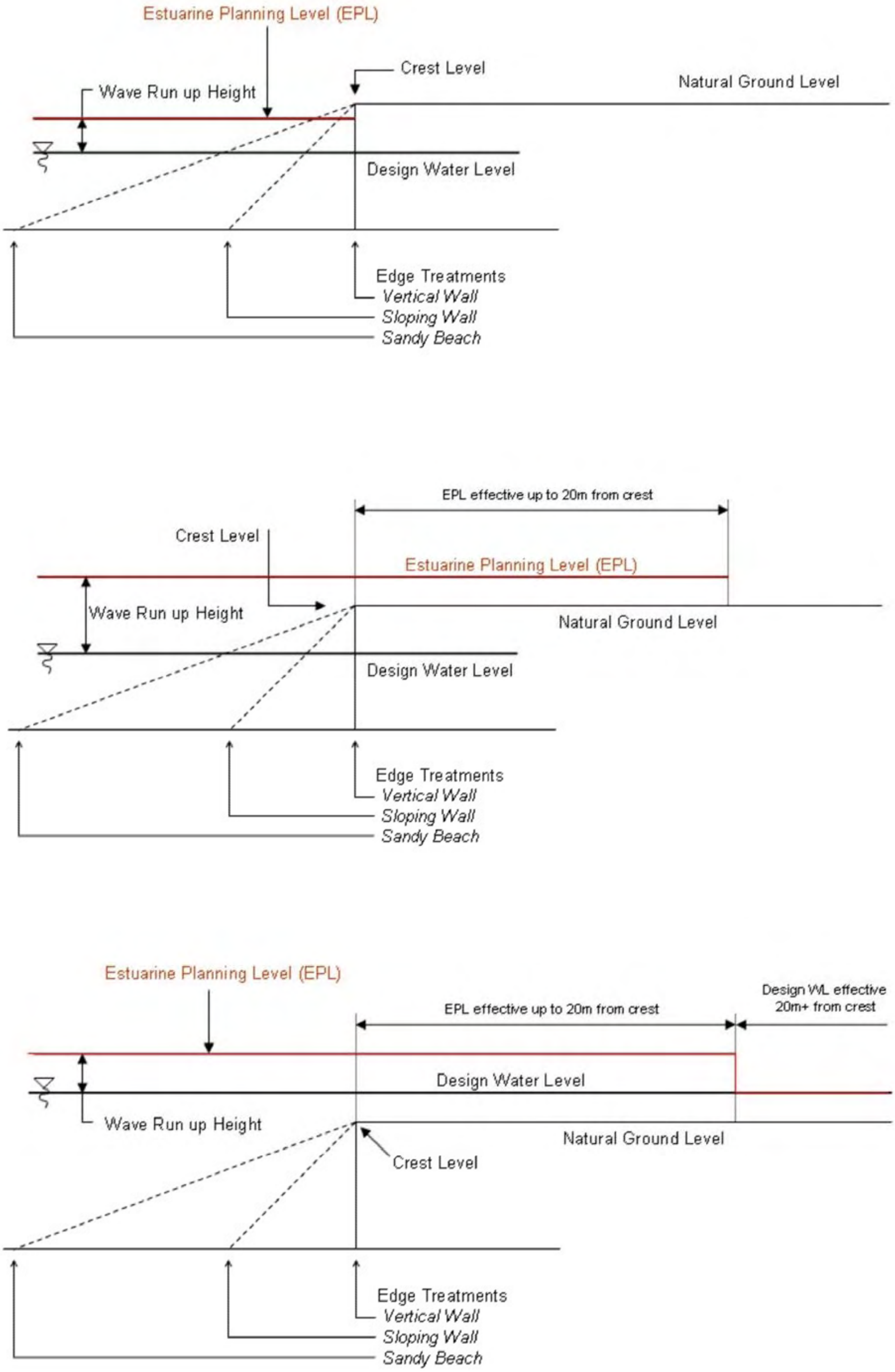

Estuary Planning Levels Study - Foreshore Regions of Leichhardt LGA

ESTUARY PLANNING LEVEL DEFINITIONS

Figure 9.1

Appendix A

Sydney Coastal Councils Plans

SYDNEY BEACH VALUATION PROJECT
SUMMARY REPORT – APRIL 2007

The Sydney Coastal Councils Group (SCCG) has engaged Macquarie University to undertake a valuation of Sydney beaches, and develop a process to assist Local and State Governments to make more informed decisions on how to protect coastal property, infrastructure, beach environments and amenity at threat of coastal erosion due to enhanced climate change impacts.

This project is to be undertaken as a three-year PhD project, supported by a grant from the NSW Greenhouse Office Community Action Grants Program worth over $220,000. The project began in December 2006, following the appointment of the PhD candidate, David Anning. The working title of the project is: **"Quantifying the Value of Sydney (NSW) Beaches in order to assess cost / benefit of necessary coastal protection / abatement measures as a result of enhanced climate change impacts"**

Elements of the Research Project

Project Objectives:

This project will determine the total economic value of selected Sydney beaches, in three different local government areas. It is intended that they will also represent different biophysical environments: oceanic, estuarine and urbanised coastlines. This will provide a baseline value against which changes (natural or otherwise) may be tracked.

The result of the valuations, including stakeholder preferences for environmental attributes identified in the valuation process, will then be used in developing a process for assessing coastal protection measures against social, environmental and economic criteria. This will enable more efficient utilisation of available beach management resources at a state and regional level.

Key Project Components

Stage 1: Calculation of Total Economic Value of selected Sydney beaches

Calculation of value from existing data sets within Sydney and NSW

Existing proxy data sets from a number of key sectors (housing, tourism, fisheries etc.) will be identified, and partnership agreements with relevant data holders will be established. Marketed environmental values will then be calculated for the three study sites, and displayed graphically. The spatial distribution of values can be used to identify key privately and publicly owned coastal assets threatened by enhanced climate change impacts.

Calculation of the value of non-marketed coastal amenities

Existing preferences for environmental goods and services (amenities) will then be identified using a number of non-market environmental valuation methods. The method of coastal asset valuation, including identification of publicly available and controlled information sources, will be transferable between locations and at a number of spatial scales.

Estimation of willingness to pay (WTP) for coastal goods and services
Key stakeholder groups will be involved in the development and testing of a questionnaire to determine willingness to pay for coastal goods and services. Stakeholders will include: domestic and international tourists, residents of 'at risk' coastal locations, local business owners, and decision-makers in Local and State Governments. This questionnaire will be designed in such a way that it can be used at other sites in the Sydney region and elsewhere on the NSW coast.

Stage 2: Development of process for assessing coastal protection proposals

Analysis of existing coastal management framework and decision-making process
The next component of the project is to develop a decision-making process in partnership with the coastal councils that will allow them to prioritise beach protection works necessary to respond to enhanced climate change impacts.
A key objective is to identify a process that allows for rapid assessment of projects against a range of environmental, social and economic criteria, and is transferable between locations and at different spatial scales. This process will be informed by the values of coastal assets and social preferences identified during stakeholder consultation in the valuation process.

Write up of method, results, and transferability to other coastal locations
The findings will be presented in a final report to the SCCG and the NSW Greenhouse Office, will be broadly distributed in the wider media and made available to all interested stakeholders.

Project Outcomes:

The project will benefit stakeholders in the Sydney region through:
- Enhancing the understanding of the likely impacts of climate change and available coastal protection measures in the Sydney region
- Working with stakeholders (eg. SCCG member councils and other stakeholders) to improve the management of coastal assets in response to climate change impacts
- Developing a baseline value for coastal assets in three study sites to inform management actions, and against which management effectiveness can be assessed
- Identification of a process to value coastal assets, transferable between locations and at different spatial scales
- Developing an open and transparent decision making process to assess coastal protection options against social, environmental and economic criteria

Project Management

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This project has been assisted by the New South Wales Government,
through its Climate Action Grants Program

SYDNEY COASTAL COUNCILS

New South Wales Government

MACQUARIE UNIVERSITY ~ SYDNEY

SCCG Climate Change Projects

A Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises

Australian Greenhouse Office - Urban Integrated Assessment Programme

The SCCG in partnership with two CSIRO Divisions (Sustainable Ecosystems, and Marine and Atmospheric Research) has recently been successful in gaining significant grant funding from the Australian Greenhouse Office - Urban Integrated Assessment Programme grant application to undertake a project titled "A Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises".

The project aims to develop and trial a method for a systems approach to regional climate change adaptation strategies in large urban areas. The project aim directly addresses AGO priorities through:

- Developing and testing an integrated (systems) method to generate information about the likely impacts of climate change and feasible adaptation strategies in the Sydney region;
- Deepening the understanding of the likely impacts of climate change and resulting adaptation options in the Sydney region through integration of existing models, vulnerability mapping, and an analysis of adaptive capacity.

Through the project a template for vulnerability mapping in the SCCG will be created. This phase will also be to collate information on ongoing or planned studies and also identify possible impact models for application.

Issues workshops with local governments and other stakeholders will be undertaken to determine regional vulnerabilities and drivers. The basic vulnerability template will be enhanced with the addition of key issues, and quantitative data or qualitative risk assessments, depending on available information and interest. A range of different scenarios for future climate change will be used to simulate changes in climate hazards relevant to SCCG.

Workshops will be conducted for each LGA. These workshops will discuss the output of the regional vulnerability mapping process and use this as a tool to discuss individual priorities for adaptation and determine local contextual variables which may affect adaptation.

Local council adaptation strategies for key issues that emerge from the workshops will be chosen. Recommendations will be made to councils on how to improve their adaptation strategies. Local councils will also be provided with monitoring and evaluation frameworks to help benchmark and improve those strategies into the future.

Finally the project will be widely reported and prepared for transferability to other large urban regions.

This is a very exciting project for the SCCG and continues the work of the Group to promote and develop the resources, tools and frameworks Member Councils will require to address the impacts of climate change.

Quantifying the Value of Sydney's Beaches
NSW Greenhouse Office - Community Action Grants Program

Through this project funded by the NSW Greenhouse Office Community Action Grants Program the SCCG has formally engaged Macquarie University to undertake a PhD topic "Quantifying the Value of Sydney (NSW) Beaches in order to assess cost / benefit of necessary coastal protection / abatement measures as a result of enhanced climate change impacts" This program worth a total of $229,125 has recently comenced foolwng the apointment of a PhD canditate.

The project information will be presented in a final report and other useful 'media' and will assist Local and State Governments' make more informed decisions on how to protect coastal property, infrastructure, beach environments and amenity at threat of coastal erosion.

Sydney Coastal Councils Group - Macquarie University MOU

The SCCG formerly signed off on its second University MOU partnership program with the Department of Physical Geography at Macquarie University in December 2005.

The Partnership has been established to encourage academic cooperation through research and study in the furtherance of the advancement of learning and through the stated objectives outlined below:

The objectives of the program include:

1) To promote academic cooperation which enhances the above mentioned goals (and which relates to the items listed in the attached schedule).
2) To encourage visits by staff between our institutions for the purpose of engaging in research.
3) To foster the exchange of academic publications and scholarly information, and
4) Other forms of cooperation which the two institutions may jointly arrange.

Following on from the very successful SCCG / MU climate Change forum in July 2005 entitled: "*Climate Change in the Sydney Region*" the program partners have been busy developing and implementing identified priorities during the year.

Climate Change Fact Sheets for Local Government – are currently being finalised for SCCG Member Councils. The Secretariat has consulted with the Technical Committee and Macquarie University to set the following topics for briefing notes / fact sheets to be produced by 3rd year Environmental Science students. These are currently being prepared and will be available shortly. Topics include:

Sydney coastal landscapes in AD2050 and AD2100

1) - How might climate change affect the Sydney coastal region by AD2050 and AD2100? (focus biodiversity (marine and terrestrial), erosion and cliff retreat, a comparison of International, National and Regional climate change strategies

2) Possible sea level rise in the Sydney coastal region by AD2050 and AD2100?

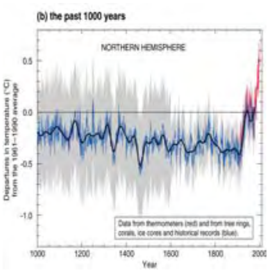
3) The frequency and intensity of climate related 'extreme events' in the Sydney coastal region by AD2050 and AD2100? (focus on storm events (such as 'east coast lows', river floods, bushfires)

4) Potential socio-economic impacts of climate change in the Sydney coastal region by AD2050 and AD2100? (focus on human health, recreational opportunities, housing, business and insurance)

5) What can individuals, households and communities do to respond / adapt to climate change?

Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises

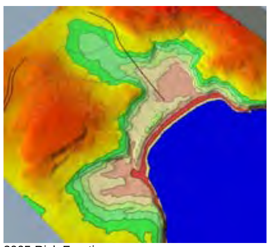
NATIONAL CLIMATE CHANGE ADAPATION PROGRAM
PROJECT SUMMARY REPORT



As part of the Australian Greenhouse Office (AGO) National Climate Change Adaptation Program, the Sydney Coastal Councils Group (SCCG) have partnered with two CSIRO Divisions (Sustainable Ecosystems, and Marine and Atmospheric Research) to undertake research on regional approaches to managing climate vulnerability in the Sydney region.

Elements of the Research Project

Project Objectives:


2005 Risk Frontiers

The aim of the project is to develop and trial a method for a systems approach to regional climate change adaptation strategies in large urban areas. The project aim directly addresses AGO priorities through:

- Developing and testing an integrated (systems) method to generate information about the likely impacts of climate change and feasible adaptation strategies in the Sydney region;
- Deepening the understanding of the likely impacts of climate change and resulting adaptation options in the Sydney region through integration of existing models, generation of new knowledge where there are significant gaps, scenario analysis, an analysis of adaptive capacity, and assessment of demonstration projects.
- Assessing the transferability of the integrated (systems) method to other large urban areas, with transfer to be facilitated through the project National Reference Group.

Key Project Components

Stage 1: Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises

Creation of a template for vulnerability mapping in the SCCG.

In order to provide an initial basis for awareness raising and discussion, a template for vulnerability mapping in the SCCG will be created. This template will utilise existing outputs from CSIRO and other relevant projects (e.g. UPRCT project) and present them as simple spatial overlays. A major aspect of this phase will also be to collate information on ongoing or planned studies and also identify possible impact models for application in stage 6 of the project, as well as local experts and potential partners.

Issues workshops with local governments and other stakeholders to determine regional vulnerabilities and drivers

The aim of the issues workshops would be to determine regional drivers. With input from stakeholders the basic vulnerability template would be enhanced with the addition of key issues, and either quantitative data or qualitative risk assessments, depending on available information and interest. A range of different scenarios for future climate change will be used to simulate changes in climate hazards relevant to SCCG, with priority hazards for vulnerability mapping identified by stakeholders.

LGA priorities and capacity for adaptation and determination of local contextual variables

Workshops will be conducted for each LGA represented by the SCCG (15 LGAs across Sydney, representing over 1.3 million people). These workshops will discuss the output of the regional vulnerability mapping process and use this as a tool to discuss individual priorities for adaptation and determine local contextual variables which may affect adaptation. The workshops will also highlight specific local strengths and weaknesses with regards to building future capacity for responding to climate change.

Analysis of existing adaptive measures and capacity

Three local councils will be chosen as case studies of local council adaptation strategies for key issues that emerged from the regional and local workshops (eg. water, infrastructure / asset protection, public health). The three case studies will include councils that have identified that they are either: (i) doing well in terms of implementing adaptation strategies; (ii) doing average in terms of implementing adaptation strategies; or (iii) doing poorly in terms of implementing adaptation strategies. Recommendations will be made to councils on how to improve their adaptation strategies. Local councils will also be provided with monitoring and evaluation frameworks to help benchmark and improve those strategies into the future. The analysis will also help select & design demonstration projects for the 2nd stage of the project (currently unfunded).

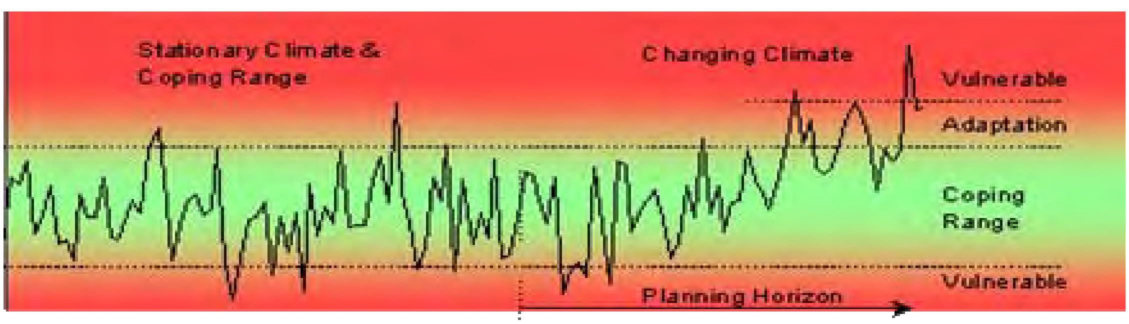
Write up of method, results, and transferability to other large urban regions

The write-up will include detailed discussion of the application of a systems method to understanding climate vulnerability and adaptation strategies. The major focus of the final report will be the discussion of the transferability of the method to other large urban regions.

Project Outcomes:

The project will benefit stakeholders in the Sydney region through:

- Generating information about the likely impacts of climate change (eg. flooding, coastal erosion and temperature) and feasible adaptation strategies (eg. capital works, education, and planning) in the Sydney region;
- Deepening the understanding of the likely impacts of climate change and resulting adaptation options in the Sydney region through integration of existing models, vulnerability mapping, and an analysis of adaptive capacity;
- Building the capacity of stakeholders in the Sydney region to implement, and monitor the success of, adaptation strategies (eg. for infrastructure, health, and biodiversity);
- Working with stakeholders (eg. SCCG member councils and other stakeholders) to build adaptation strategies into institutional structures and processes (eg. asset management plans, coastal management plans, estuary management plans, floodplain management plans, local environment plans, and regional environmental plans).



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Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

Appendix B

Responses to Inquiries about Similar DCP's – Other Councils/Government Agencies

Council/Government Agency	Contact Person(s)	Issues*				
		1	2	3	4	5
Ashfield Council	Janine Harris - Environment Officer	N	N.A.	None	None	5
Woollahra Council	Rebecca Peacock - Strategic Planning Section	N	N.A.	None	None	5
Sydney City Council	Andrew Thomas	N	N.A.	N.A	None	5
Canada Bay Council	Duty Planner	N	N.A.	N.A	None	5
Hunters Hill Council	Paul Murphy - Development Engineer	N	N.A.	N.A	N.A	5
Lane Cove Council	Killian Grenell - Engineer	Y	N.A.	>15m from Shoreline	Town Planning	5
North Sydney Council	Email	N	Not Done	Not Specified	N.A.	5
Mosman Municipal Council	Belinda Atkins - Environmental Co-ordinator	N	If < 6.5m AHD – Study Required	See 2	N.A.	5
Manly Council	Tim Macdonald - Team Leader, Coastal Management	Y	Project Specific	Not Specified	Coastal Hazard Studies	4
Pittwater Council	Sue Ribbons	Y	Detailed Modelling	Specific Controls/No DCP	Consistent Planning	2
NSW Maritime Authority	Dennis Buttigieg/Persephone Rougellis	N	DEP Plan + Site Specific Study	None	None	5
Sydney Coastal Councils	Geoff Withycombe	N	N.A.	N.A.	Mainly Climate Change	4
Sydney Harbour Foreshore Authority	Therese Hoy - Strategic Planning	N	DEP Plan	>2m AHD (Rocks & Darling Harbour Areas)	None	5
Great Lakes Council	Gerod Tuckerman – Natural Systems	Draft	Similar	Not Specified as Yet	Consistent Planning	3

1. Are there relevant policies and guiding documents?
2. How is the EPL or equivalent determined?
3. What restrictions or controls are applied in terms of planning levels?
4. What philosophies or objectives are the bases for the restrictions or controls, if any?
5. Evaluate the relevance of the policies and controls to the Leichhardt Council LGA. (1 to 5/High to Low)

This table is to be read in conjunction with Section 4 of this report.

Appendix C

Glossary

Glossary**

Advective Transport	The transport of dissolved material by water movement.
Australian Height Datum (AHD)	A common national plane of level corresponding approximately to mean sea level.
Amenity	Those features of an estuary/beach that foster its use for various purposes, eg. Clear water and sandy beaches make beach-side recreation attractive.
ARI	Average Recurrence Interval
Bed Load	That portion of the total sediment load that flowing water moves along the bed by the rolling or saltating of sediment particles.
Calibration	The process by which the results of a computer model are brought to agreement with observed data.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
CD	Chart Datum, common datum for navigation charts - 0.92m below AHD in the Sydney coastal region. Typically Lowest Astronomical Tide.

Discharge	The rate of flow of water measured in terms of volume per unit time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is flowing.
Dispersive Transport	The transport of dissolved matter through the estuary by vertical, lateral and longitudinal mixing associated with velocity shear.
Diurnal	A daily variation, as in day and night.
Ebb Tide	The outgoing tidal movement of water within an estuary.
Eddies	Large, approximately circular, swirling movements of water, often metres or tens of metres across. Eddies are caused by shear between the flow and a boundary or by flow separation from a boundary.
EIS	Environmental Impact Statement
Estuarine Processes	Those processes that affect the physical, chemical and biological behaviour of an estuary, eg. predation, water movement, sediment movement, water quality, etc.
Estuary	An enclosed or semi-enclosed body of water having an open or intermittently open connection to coastal waters and in which water levels vary in a periodic fashion in response to ocean tides.
Flocculate	The coalescence, through physical and chemical processes, of individual suspended particles into larger particles ('flocs').

Flood Tide	The incoming tidal movement of water within an estuary.
Fluvial	Relating to non-tidal flows.
Fluvial Processes	The erosive and transport processes that deliver terrestrial sediment to creeks, rivers, estuaries and coastal waters.
Fluvial Sediments	Land-based sediments carried to estuarine waters by rivers.
Foreshore	The area of shore between low and high tide marks and land adjacent thereto.
Fortnightly Tides	The variation in tide levels caused by the monthly variation of Spring and Neap Tides.
Geomorphology	The study of the origin, characteristics and development of land forms.
H_s (Significant Wave Height)	H_s may be defined as the average of the highest 1/3 of wave heights in a wave record ($H_{1/3}$), or from the zeroth spectral moment (H_{mo}), though there is a difference of about 5 to 8%.
Hydraulic Regime	The variation of estuarine discharges in response to seasonal freshwater inflows and tides.
Intertidal	Pertaining to those areas of land covered by water at high tide, but exposed at low tide, eg. intertidal habitat.
Isohaline	A line connecting those parts of a water mass having the same salinity, ie, a contour of equal salinity levels.

Littoral Zone	An area of the coastline in which sediment movement by wave, current and wind action is prevalent.
Littoral Drift Processes	Wave, current and wind processes that facilitate the transport of water and sediments along a shoreline.
Mangroves	An intertidal plant community dominated by trees.
Marine Sediments	Sediments in sea and estuarine areas that have a marine origin.
Mathematical/ Computer Models	The mathematical representation of the physical processes involved in runoff, stream flow and estuarine/sea flows. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with wave and current processes.
MHL	Manly Hydraulics Laboratory
MSL	Mean Sea Level
Neap Tides	Tides with the smallest range in a monthly cycle. Neap tides occur when the sun and moon lie at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean).
NSW	New South Wales
NTU	Nephelometric Turbidity Units

Numerical Model	A mathematical representation of a physical, chemical or biological process of interest. Computers are often required to solve the underlying equations.
Phase Lag	Difference in time of the occurrence between high (or low water) and maximum flood (or ebb) velocity at some point in an estuary or sea area.
Salinity	The total mass of dissolved salts per unit mass of water. Seawater has a salinity of about 35g/kg or 35 parts per thousand.
Saltation	The movement of sediment particles along the bed of a water body in a series of 'hops' or 'jumps'. Turbulent fluctuations near the bed lift sediment particles off the bed and into the flow where they are carried a short distance before falling back to the bed.
Sediment Load	The quantity of sediment moved past a particular cross-section in a specified time by estuarine flow.
Semi-diurnal	A twice-daily variation, eg. two high waters per day.
Shear Strength	The capacity of the bed sediments to resist shear stresses caused by flowing water without the movement of bed sediments. The shear strength of the bed depends upon bed material, degree of compaction, armouring,
Shear Stress	The stress exerted on the bed of an estuary by flowing water. The faster the velocity of flow the greater the shear stress.

Shoals	Shallow areas in an estuary created by the deposition and build-up of sediments.
Slack Water	The period of still water before the flood tide begins to ebb (high water slack) or the ebb tide begins to flood (low water slack).
Spring Tides	Tides with the greatest range in a monthly cycle, which occur when the sun, moon and earth are in alignment (the gravitational effects of the moon and sun act in concert on the ocean)
SS	Suspended Solids
Storm Surge	The increase in coastal water levels caused by the barometric and wind set-up effects of storms. Barometric set-up refers to the increase in coastal water levels associated with the lower atmospheric pressures characteristic of storms. Wind set-up refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast.
Suspended Sediment Load	That portion of the total sediment load held in suspension by turbulent velocity fluctuations and transported by flowing water.
Tidal Amplification	The increase in the tidal range at upstream locations caused by the tidal resonance of the estuarine water body, or by a narrowing of the estuary channel.
Tidal Exchange	The proportion of the tidal prism that is flushed away and replaced with 'fresh' coastal water each tide cycle.
Tidal Excursion	The distance travelled by a water particle from low water slack to high water slack and vice versa.

Tidal Lag	The delay between the state of the tide at the estuary mouth (eg. high water slack) and the same state of tide at an upstream location.
Tidal Limit	The most upstream location where a tidal rise and fall of water levels is discernible. The location of the tidal limit changes with freshwater inflows and tidal range.
Tidal Planes	A series of water levels that define standard tides, eg. 'Mean High Water Spring' (MHWS) refers to the average high water level of Spring Tides.
Tidal Prism	The total volume of water moving past a fixed point in an estuary during each flood tide or ebb tide.
Tidal Propagation	The movement of the tidal wave into and out of an estuary.
Tidal Range	The difference between successive high water and low water levels. Tidal range is maximum during Spring Tides and minimum during Neap Tides.
Tidally Varying Models	Numerical models that predict estuarine behaviour within a tidal cycle, ie, the temporal resolution is of the order of minutes or hours.
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the Sun, Moon and Earth.
Tributary	Catchment, stream or river which flows into a larger river, lake or water body

Training Walls	Walls constructed at the entrances of estuaries to improve navigability by providing a persistently open entrance.
Turbidity	A measure of the ability of water to absorb light.
T_z (Zero Crossing Period)	The average period of waves in a train of waves observed at a location.
Velocity Shear	The differential movement of neighbouring parcels of water brought about by frictional resistance within the flow, or at a boundary. Velocity shear causes dispersive mixing, the greater the shear (velocity gradient), the greater the mixing.
Wind Shear	The stress exerted on the water's surface by wind blowing over the water. Wind shear causes the water to pile up against downwind shores and generates secondary currents.

* A number of definitions have been derived from the Estuary Management Manual (1992).

Appendix D

Joint Wind Speed and Direction - Mascot Airport

Table D.1: Joint Occurrence of Wind Speed and Direction at Mascot

Percentage Calms - 17.4

Dirn	Wind Speed (m/s)										
	0.0-2.5	2.5-5.0	5.0-7.5	7.5-10.0	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-22.5	22.5-25.0	TOTAL
N	0.48	1.73	0.98	0.33	0.07	0.01	0.00	0.00	0.00	0.00	3.60
NNE	0.25	1.36	1.39	0.88	0.37	0.08	0.01	0.00	0.00	0.00	4.34
NE	0.34	1.94	2.51	1.72	0.74	0.15	0.01	0.00	0.00	0.00	7.41
ENE	0.22	1.10	1.18	0.48	0.08	0.01	0.00	0.00	0.00	0.00	3.07
E	0.33	1.66	1.32	0.28	0.03	0.01	0.00	0.00	0.00	0.00	3.63
ESE	0.21	1.09	0.82	0.21	0.04	0.01	0.00	0.00	0.00	0.00	2.38
SE	0.31	1.82	1.95	0.79	0.19	0.05	0.02	0.00	0.00	0.00	5.13
SSE	0.19	1.61	2.28	1.31	0.56	0.18	0.05	0.01	0.00	0.00	6.19
S	0.31	1.84	3.13	2.86	1.62	0.67	0.18	0.03	0.01	0.00	10.66
SSW	0.16	0.84	1.05	1.01	0.54	0.23	0.06	0.02	0.00	0.00	3.92
SW	0.37	1.25	0.98	0.55	0.18	0.06	0.02	0.01	0.00	0.00	3.41
WSW	0.29	1.32	1.13	0.64	0.24	0.07	0.02	0.00	0.00	0.00	3.71
W	0.86	3.03	2.00	1.03	0.52	0.20	0.06	0.01	0.00	0.00	7.70
WNW	1.08	2.87	0.98	0.45	0.26	0.12	0.04	0.00	0.00	0.00	5.79
NW	1.78	4.34	1.19	0.44	0.22	0.07	0.02	0.00	0.00	0.00	8.07
NNW	0.59	1.90	0.69	0.26	0.10	0.02	0.01	0.00	0.00	0.00	3.56
TOTAL (%)	7.78	29.71	23.56	13.23	5.77	1.92	0.49	0.08	0.02	0.01	82.58
P of E (%)	82.58	74.79	45.08	21.52	8.29	2.52	0.60	0.11	0.03	0.01	

Appendix E

Wind Setup and Wave Results

Table E.1: Delft3D and SWAN Model Output Results

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

** Design Water Level included the Storm Tide at Fort Denison, local wind set-up adjustment and a mean sea level rise of 0.3m

Loc ID	200yrARI				100yrARI				50yrARI				20yrARI				10yrARI				5yrARI			
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)
1	0.27	1.7	0.12	2.02	0.26	1.7	0.11	1.96	0.25	1.7	0.11	1.94	0.23	1.6	0.1	1.84	0.22	1.6	0.11	1.80	0.2	1.6	0.08	1.72
2	0.3	1.8	0.11	2.01	0.28	1.8	0.1	1.95	0.27	1.7	0.1	1.93	0.25	1.7	0.1	1.84	0.24	1.7	0.1	1.79	0.23	1.6	0.09	1.73
3	0.34	1.9	0.11	2.01	0.33	1.9	0.10	1.95	0.31	1.9	0.10	1.93	0.29	1.8	0.09	1.83	0.28	1.8	0.09	1.78	0.26	1.7	0.09	1.73
4	0.38	2.0	0.10	2.00	0.36	2.0	0.09	1.94	0.35	1.9	0.09	1.92	0.32	1.9	0.08	1.82	0.31	1.8	0.08	1.77	0.29	1.8	0.08	1.72
5	0.45	2.2	0.10	2.00	0.43	2.2	0.09	1.94	0.41	2.1	0.09	1.92	0.39	2.0	0.08	1.82	0.37	2.0	0.08	1.77	0.35	1.9	0.08	1.72
6	0.42	2.1	0.10	2.00	0.40	2.1	0.09	1.94	0.39	2.0	0.09	1.92	0.36	2.0	0.08	1.82	0.34	1.9	0.08	1.77	0.33	1.9	0.08	1.72
7	0.42	2.1	0.09	1.99	0.40	2.1	0.09	1.94	0.38	2.0	0.08	1.91	0.36	2.0	0.08	1.82	0.34	1.9	0.07	1.76	0.33	1.9	0.07	1.71
8	0.38	2.0	0.09	1.99	0.36	2.0	0.09	1.94	0.35	1.9	0.08	1.91	0.33	1.9	0.08	1.82	0.31	1.9	0.07	1.76	0.30	1.8	0.07	1.71
9	0.38	2.0	0.09	1.99	0.36	2.0	0.09	1.94	0.35	1.9	0.08	1.91	0.32	1.9	0.07	1.81	0.31	1.8	0.07	1.76	0.29	1.8	0.07	1.71
10	0.39	2.0	0.09	1.99	0.37	2.0	0.08	1.93	0.36	2.0	0.07	1.90	0.34	1.9	0.07	1.81	0.32	1.9	0.07	1.76	0.30	1.8	0.06	1.70
11	0.45	2.2	0.09	1.99	0.43	2.1	0.08	1.93	0.41	2.1	0.07	1.90	0.38	2.0	0.07	1.81	0.36	2.0	0.07	1.76	0.34	1.9	0.06	1.70
12	0.44	2.2	0.08	1.98	0.43	2.1	0.08	1.93	0.41	2.1	0.07	1.90	0.38	2.0	0.07	1.81	0.37	2.0	0.06	1.75	0.35	1.9	0.06	1.70
13	0.37	2.0	0.08	1.98	0.36	2.0	0.08	1.93	0.34	1.9	0.07	1.90	0.32	1.9	0.06	1.80	0.31	1.8	0.06	1.75	0.29	1.8	0.06	1.70
14	0.31	1.8	0.08	1.98	0.30	1.8	0.07	1.92	0.29	1.8	0.07	1.90	0.27	1.7	0.06	1.80	0.26	1.7	0.06	1.75	0.24	1.7	0.06	1.70
15	0.36	2.0	0.08	1.98	0.34	1.9	0.07	1.92	0.33	1.9	0.07	1.90	0.31	1.8	0.06	1.80	0.29	1.8	0.06	1.75	0.28	1.8	0.06	1.70
16	0.40	2.1	0.08	1.98	0.38	2.0	0.07	1.92	0.36	2.0	0.07	1.90	0.34	1.9	0.06	1.80	0.32	1.9	0.06	1.75	0.31	1.8	0.06	1.70
17	0.36	2.0	0.08	1.98	0.34	1.9	0.07	1.92	0.33	1.9	0.07	1.90	0.31	1.8	0.06	1.80	0.29	1.8	0.06	1.75	0.28	1.8	0.06	1.70
18	0.37	2.0	0.07	1.97	0.36	2.0	0.07	1.92	0.34	1.9	0.06	1.89	0.32	1.9	0.06	1.80	0.30	1.8	0.06	1.75	0.29	1.8	0.06	1.70
19	0.37	2.0	0.07	1.97	0.36	2.0	0.07	1.92	0.34	1.9	0.06	1.89	0.32	1.9	0.06	1.80	0.31	1.8	0.05	1.74	0.29	1.8	0.05	1.69
20	0.35	2.0	0.07	1.97	0.34	1.9	0.07	1.92	0.32	1.9	0.06	1.89	0.30	1.8	0.05	1.79	0.29	1.8	0.05	1.74	0.27	1.8	0.05	1.69
21	0.48	2.3	0.07	1.97	0.46	2.2	0.07	1.92	0.44	2.2	0.06	1.89	0.41	2.1	0.06	1.80	0.39	2.0	0.05	1.74	0.37	2.0	0.05	1.69
22	0.54	2.4	0.07	1.97	0.52	2.4	0.07	1.92	0.49	2.3	0.06	1.89	0.46	2.2	0.06	1.80	0.44	2.2	0.05	1.74	0.41	2.1	0.05	1.69
23	0.37	2.0	0.07	1.97	0.36	2.0	0.07	1.92	0.34	1.9	0.06	1.89	0.33	1.9	0.05	1.79	0.31	1.8	0.05	1.74	0.30	1.8	0.05	1.69
24	0.32	1.9	0.07	1.97	0.30	1.8	0.07	1.92	0.29	1.8	0.06	1.89	0.28	1.8	0.05	1.79	0.26	1.7	0.05	1.74	0.25	1.7	0.05	1.69
25	0.41	2.1	0.06	1.96	0.39	2.1	0.06	1.91	0.38	2.0	0.06	1.89	0.35	2.0	0.05	1.79	0.34	1.9	0.05	1.74	0.32	1.9	0.05	1.69
26	0.50	2.3	0.07	1.97	0.48	2.3	0.06	1.91	0.46	2.2	0.06	1.89	0.43	2.1	0.05	1.79	0.41	2.1	0.05	1.74	0.39	2.0	0.05	1.69
27	0.43	2.1	0.06	1.96	0.41	2.1	0.06	1.91	0.39	2.1	0.06	1.89	0.37	2.0	0.05	1.79	0.35	1.9	0.05	1.74	0.33	1.9	0.05	1.69
28	0.36	2.0	0.06	1.96	0.34	1.9	0.06	1.91	0.33	1.9	0.06	1.89	0.31	1.8	0.05	1.79	0.30	1.8	0.05	1.74	0.28	1.8	0.05	1.69
29	0.33	1.9	0.06	1.96	0.31	1.8	0.06	1.91	0.30	1.8	0.06	1.89	0.28	1.8	0.05	1.79	0.27	1.7	0.05	1.74	0.25	1.7	0.05	1.69
30	0.30	1.8	0.06	1.96	0.29	1.8	0.06	1.91	0.28	1.8	0.06	1.89	0.26	1.7	0.05	1.79	0.25	1.7	0.05	1.74	0.24	1.7	0.05	1.69
31	0.36	2.0	0.06	1.96	0.34	1.9	0.06	1.91	0.33	1.9	0.05	1.88	0.31	1.8	0.05	1.79	0.29	1.8	0.05	1.74	0.28	1.8	0.05	1.69
32	0.39	2.0	0.06	1.96	0.37	2.0	0.06	1.91	0.36	2.0	0.05	1.88	0.33	1.9	0.05	1.79	0.32	1.9	0.05	1.74	0.30	1.8	0.05	1.69
33	0.42	2.1	0.06	1.96	0.41	2.1	0.06	1.91	0.39	2.0	0.05	1.88	0.37	2.0	0.05	1.79	0.35	1.9	0.05	1.74	0.33	1.9	0.04	1.68
34	0.38	2.0	0.06	1.96	0.36	2.0	0.05	1.90	0.35	1.9	0.05	1.88	0.33	1.9	0.05	1.79	0.32	1.9	0.04	1.73	0.30	1.8	0.04	1.68
35	0.34	1.9	0.06	1.96	0.33	1.9	0.06	1.91	0.32	1.9	0.05	1.88	0.30	1.8	0.05	1.79	0.29	1.8	0.04	1.73	0.28	1.8	0.04	1.68
36	0.37	2.0	0.06	1.96	0.35	2.0	0.06	1.91	0.34	1.9	0.05	1.88	0.32	1.9	0.05	1.79	0.31	1.8	0.05	1.74	0.30	1.8	0.04	1.68
37	0.53	2.4	0.06	1.96	0.51	2.3	0.06	1.91	0.49	2.3	0.05	1.88	0.45	2.2	0.05	1.79	0.43	2.1	0.04	1.73	0.41	2.1	0.04	1.68
38	0.56	2.5	0.06	1.96	0.54	2.4	0.06	1.91	0.51	2.4	0.05	1.88	0.48	2.3	0.05	1.79	0.45	2.2	0.04	1.73	0.43	2.1	0.04	1.68
39	0.78	3.0	0.05	1.95	0.74	2.9	0.05	1.90	0.71	2.8	0.05	1.88	0.66	2.7	0.04	1.78	0.63	2.6	0.04	1.73	0.59	2.5	0.04	1.68
40	0.77	3.0	0.05	1.95	0.74	2.9	0.05	1.90	0.70	2.8	0.05	1.88	0.66	2.7	0.04	1.78	0.62	2.6	0.04	1.73	0.59	2.5	0.04	1.68
41	0.74	2.9	0.06	1.96	0.70	2.8	0.05	1.90	0.67	2.7	0.05	1.88	0.63	2.6	0.05	1.79	0.59	2.6	0.04	1.73	0.56	2.5	0.04	1.68
42	0.63	2.6	0.06	1.96	0.60	2.6	0.06	1.91	0.57	2.5	0.06	1.89	0.54	2.4	0.05	1.79	0.51	2.3	0.05	1.74	0.48	2.3	0.04	1.68
43	0.56	2.5	0.06	1.96	0.54	2.4	0.06	1.91	0.51	2.4	0.05	1.88	0.48	2.3	0.05	1.79	0.46	2.2	0.05	1.74	0.43	2.2	0.04	1.68
44	0.57	2.5	0.05	1.95	0.55	2.4	0.05	1.90	0.52	2.4	0.05	1.88	0.49	2.3	0.04	1.78	0.46	2.2	0.04	1.73	0.44	2.2	0.04	1.68
45	0.48	2.3	0.04	1.94	0.46	2.2	0.04	1.89	0.44	2.2	0.04	1.87	0.41	2.1	0.04	1.78	0.39	2.0	0.03	1.72	0.37	2.0	0.03	1.67
46	0.46	2.2	0.04	1.94	0.44	2.2	0.04	1.89	0.42	2.1	0.04	1.87	0.39	2.1	0.04	1.78	0.37	2.0	0.03	1.72	0.35	2.0	0.03	1.67

Table E.1: Delft3D and SWAN Model Output Results

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

** Design Water Level included the Storm Tide at Fort Denison, local wind set-up adjustment and a mean sea level rise of 0.3m

Loc ID	200yrARI				100yrARI				50yrARI				20yrARI				10yrARI				5yrARI			
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)
47	0.49	2.3	0.04	1.94	0.47	2.2	0.04	1.89	0.45	2.2	0.04	1.87	0.42	2.1	0.04	1.78	0.40	2.1	0.04	1.73	0.38	2.0	0.03	1.67
48	0.62	2.6	0.04	1.94	0.59	2.5	0.04	1.89	0.56	2.5	0.04	1.87	0.53	2.4	0.04	1.78	0.50	2.3	0.03	1.72	0.47	2.2	0.03	1.67
49	0.59	2.6	0.04	1.94	0.57	2.5	0.04	1.89	0.54	2.4	0.04	1.87	0.51	2.3	0.03	1.77	0.48	2.3	0.03	1.72	0.45	2.2	0.03	1.67
50	0.53	2.4	0.04	1.94	0.51	2.3	0.04	1.89	0.49	2.3	0.04	1.87	0.46	2.2	0.03	1.77	0.43	2.2	0.03	1.72	0.41	2.1	0.03	1.67
51	0.50	2.3	0.04	1.94	0.48	2.3	0.04	1.89	0.46	2.2	0.04	1.87	0.43	2.1	0.03	1.77	0.41	2.1	0.03	1.72	0.38	2.0	0.03	1.67
52	0.47	2.3	0.04	1.94	0.45	2.2	0.04	1.89	0.43	2.2	0.04	1.87	0.40	2.1	0.03	1.77	0.38	2.0	0.03	1.72	0.36	2.0	0.03	1.67
53	0.44	2.2	0.05	1.95	0.42	2.1	0.04	1.89	0.40	2.1	0.04	1.87	0.37	2.0	0.04	1.78	0.35	1.9	0.04	1.73	0.33	1.9	0.03	1.67
54	0.39	2.0	0.05	1.95	0.37	2.0	0.04	1.89	0.35	2.0	0.04	1.87	0.33	1.9	0.04	1.78	0.31	1.9	0.04	1.73	0.29	1.8	0.03	1.67
55	0.44	2.2	0.04	1.94	0.42	2.1	0.04	1.89	0.41	2.1	0.04	1.87	0.38	2.0	0.03	1.77	0.36	2.0	0.03	1.72	0.34	1.9	0.03	1.67
56	0.40	2.1	0.04	1.94	0.39	2.0	0.04	1.89	0.37	2.0	0.04	1.87	0.35	1.9	0.03	1.77	0.33	1.9	0.03	1.72	0.31	1.8	0.03	1.67
57	0.34	1.9	0.04	1.94	0.33	1.9	0.04	1.89	0.31	1.9	0.03	1.86	0.29	1.8	0.03	1.77	0.28	1.8	0.03	1.72	0.26	1.7	0.03	1.67
58	0.35	1.9	0.04	1.94	0.34	1.9	0.04	1.89	0.32	1.9	0.03	1.86	0.30	1.8	0.03	1.77	0.29	1.8	0.03	1.72	0.27	1.7	0.03	1.67
59	0.39	2.0	0.04	1.94	0.37	2.0	0.04	1.89	0.36	2.0	0.03	1.86	0.34	1.9	0.03	1.77	0.32	1.9	0.03	1.72	0.31	1.8	0.03	1.67
60	0.49	2.3	0.03	1.93	0.47	2.2	0.03	1.88	0.44	2.2	0.03	1.86	0.42	2.1	0.03	1.77	0.40	2.1	0.03	1.72	0.37	2.0	0.02	1.66
61	0.57	2.5	0.04	1.94	0.55	2.4	0.03	1.88	0.52	2.4	0.03	1.86	0.49	2.3	0.03	1.77	0.46	2.2	0.03	1.72	0.44	2.2	0.03	1.67
62	0.52	2.4	0.03	1.93	0.50	2.3	0.03	1.88	0.48	2.3	0.03	1.86	0.45	2.2	0.03	1.77	0.42	2.1	0.03	1.72	0.40	2.1	0.02	1.66
63	0.55	2.4	0.03	1.93	0.53	2.4	0.03	1.88	0.50	2.3	0.03	1.86	0.47	2.3	0.03	1.77	0.45	2.2	0.02	1.71	0.43	2.1	0.02	1.66
64	0.67	2.8	0.03	1.93	0.64	2.7	0.03	1.88	0.61	2.6	0.03	1.86	0.57	2.5	0.03	1.77	0.54	2.4	0.02	1.71	0.51	2.4	0.02	1.66
65	0.68	2.8	0.03	1.93	0.65	2.7	0.03	1.88	0.62	2.6	0.03	1.86	0.58	2.5	0.03	1.77	0.54	2.4	0.03	1.72	0.51	2.4	0.02	1.66
66	0.66	2.7	0.03	1.93	0.63	2.6	0.03	1.88	0.60	2.6	0.03	1.86	0.56	2.5	0.03	1.77	0.53	2.4	0.03	1.72	0.50	2.3	0.03	1.67
67	0.65	2.7	0.03	1.93	0.62	2.6	0.03	1.88	0.59	2.6	0.03	1.86	0.56	2.5	0.03	1.77	0.53	2.4	0.03	1.72	0.50	2.3	0.03	1.67
68	0.56	2.5	0.04	1.94	0.54	2.4	0.04	1.89	0.51	2.4	0.03	1.86	0.48	2.3	0.03	1.77	0.46	2.2	0.03	1.72	0.43	2.2	0.03	1.67
69	0.51	2.3	0.04	1.94	0.49	2.3	0.04	1.89	0.47	2.2	0.04	1.87	0.44	2.2	0.03	1.77	0.42	2.1	0.03	1.72	0.40	2.1	0.03	1.67
70	0.38	2.0	0.04	1.94	0.36	2.0	0.04	1.89	0.35	1.9	0.03	1.86	0.33	1.9	0.03	1.77	0.32	1.9	0.03	1.72	0.30	1.8	0.03	1.67
71	0.49	2.3	0.04	1.94	0.47	2.2	0.04	1.89	0.45	2.2	0.03	1.86	0.42	2.1	0.03	1.77	0.40	2.1	0.03	1.72	0.38	2.0	0.03	1.67
72	0.56	2.5	0.04	1.94	0.54	2.4	0.03	1.88	0.51	2.4	0.03	1.86	0.48	2.3	0.03	1.77	0.46	2.2	0.03	1.72	0.43	2.2	0.03	1.67
73	0.58	2.5	0.04	1.94	0.56	2.5	0.03	1.88	0.53	2.4	0.03	1.86	0.50	2.3	0.03	1.77	0.48	2.3	0.03	1.72	0.45	2.2	0.03	1.67
74	0.57	2.5	0.04	1.94	0.55	2.4	0.04	1.89	0.52	2.4	0.03	1.86	0.49	2.3	0.03	1.77	0.47	2.2	0.03	1.72	0.44	2.2	0.03	1.67
75	0.56	2.5	0.04	1.94	0.54	2.4	0.04	1.89	0.51	2.4	0.03	1.86	0.48	2.3	0.03	1.77	0.46	2.2	0.03	1.72	0.43	2.2	0.03	1.67
76	0.59	2.5	0.04	1.94	0.56	2.5	0.04	1.89	0.54	2.4	0.03	1.86	0.50	2.3	0.03	1.77	0.48	2.3	0.03	1.72	0.45	2.2	0.03	1.67
77	0.64	2.7	0.04	1.94	0.62	2.6	0.04	1.89	0.59	2.5	0.03	1.86	0.55	2.4	0.03	1.77	0.52	2.4	0.03	1.72	0.49	2.3	0.03	1.67
78	0.56	2.5	0.04	1.94	0.53	2.4	0.04	1.89	0.51	2.3	0.04	1.87	0.48	2.3	0.03	1.77	0.45	2.2	0.03	1.72	0.43	2.1	0.03	1.67
79	0.50	2.3	0.04	1.94	0.48	2.3	0.04	1.89	0.46	2.2	0.04	1.87	0.43	2.1	0.03	1.77	0.41	2.1	0.03	1.72	0.39	2.0	0.03	1.67
80	0.46	2.2	0.04	1.94	0.44	2.2	0.04	1.89	0.42	2.1	0.04	1.87	0.40	2.1	0.03	1.77	0.38	2.0	0.03	1.72	0.36	2.0	0.03	1.67
81	0.44	2.2	0.05	1.95	0.42	2.1	0.04	1.89	0.40	2.1	0.04	1.87	0.37	2.0	0.04	1.78	0.36	2.0	0.03	1.72	0.34	1.9	0.03	1.67
82	0.38	2.0	0.05	1.95	0.36	2.0	0.04	1.89	0.34	1.9	0.04	1.87	0.32	1.9	0.04	1.78	0.31	1.8	0.04	1.73	0.29	1.8	0.04	1.68
83	0.32	1.9	0.05	1.95	0.31	1.8	0.04	1.89	0.29	1.8	0.04	1.87	0.28	1.8	0.04	1.78	0.26	1.7	0.04	1.73	0.25	1.7	0.04	1.68
84	0.30	1.8	0.05	1.95	0.29	1.8	0.04	1.89	0.27	1.8	0.04	1.87	0.26	1.7	0.04	1.78	0.24	1.7	0.04	1.73	0.23	1.6	0.04	1.68
85	0.30	1.8	0.04	1.94	0.29	1.8	0.04	1.89	0.28	1.8	0.04	1.87	0.26	1.7	0.03	1.77	0.25	1.7	0.03	1.72	0.23	1.7	0.03	1.67
86	0.34	1.9	0.04	1.94	0.33	1.9	0.04	1.89	0.31	1.9	0.04	1.87	0.30	1.8	0.03	1.77	0.29	1.8	0.03	1.72	0.27	1.8	0.03	1.67
87	0.40	2.1	0.04	1.94	0.39	2.0	0.04	1.89	0.37	2.0	0.04	1.87	0.35	1.9	0.03	1.77	0.33	1.9	0.03	1.72	0.32	1.9	0.03	1.67
88	0.42	2.1	0.04	1.94	0.40	2.1	0.04	1.89	0.38	2.0	0.04	1.87	0.36	2.0	0.03	1.77	0.34	1.9	0.03	1.72	0.33	1.9	0.03	1.67
89	0.45	2.2	0.04	1.94	0.44	2.2	0.04	1.89	0.42	2.1	0.04	1.87	0.39	2.1	0.03	1.77	0.37	2.0	0.03	1.72	0.35	2.0	0.03	1.67
90	0.55	2.5	0.04	1.94	0.53	2.4	0.04	1.89	0.50	2.3	0.03	1.86	0.47	2.3	0.03	1.77	0.45	2.2	0.03	1.72	0.42	2.1	0.03	1.67
91	0.53	2.4	0.04	1.94	0.50	2.3	0.04	1.89	0.48	2.3	0.04	1.87	0.45	2.2	0.03	1.77	0.43	2.1	0.03	1.72	0.41	2.1	0.03	1.67
92	0.54	2.4	0.04	1.94	0.52	2.4	0.04	1.89	0.49	2.3	0.04	1.87	0.46	2.2	0.03	1.77	0.44	2.2	0.03	1.72	0.41	2.1	0.03	1.67

Table E.1: Delft3D and SWAN Model Output Results

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

** Design Water Level included the Storm Tide at Fort Denison, local wind set-up adjustment and a mean sea level rise of 0.3m

Loc ID	200yrARI				100yrARI				50yrARI				20yrARI				10yrARI				5yrARI			
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level** (mAHD)
93	0.61	2.6	0.04	1.94	0.58	2.5	0.04	1.89	0.55	2.5	0.04	1.87	0.52	2.4	0.03	1.77	0.49	2.3	0.03	1.72	0.46	2.2	0.03	1.67
94	0.61	2.6	0.04	1.94	0.58	2.5	0.04	1.89	0.55	2.5	0.04	1.87	0.52	2.4	0.03	1.77	0.49	2.3	0.03	1.72	0.46	2.2	0.03	1.67
95	0.59	2.5	0.04	1.94	0.56	2.5	0.04	1.89	0.54	2.4	0.04	1.87	0.50	2.3	0.04	1.78	0.48	2.3	0.03	1.72	0.45	2.2	0.03	1.67
96	0.55	2.4	0.05	1.95	0.52	2.4	0.04	1.89	0.50	2.3	0.04	1.87	0.47	2.2	0.04	1.78	0.44	2.2	0.04	1.73	0.42	2.1	0.04	1.68
97	0.51	2.4	0.05	1.95	0.49	2.3	0.05	1.90	0.47	2.2	0.04	1.87	0.44	2.2	0.04	1.78	0.41	2.1	0.04	1.73	0.39	2.0	0.04	1.68
98	0.51	2.3	0.05	1.95	0.49	2.3	0.05	1.90	0.46	2.2	0.04	1.87	0.43	2.2	0.04	1.78	0.41	2.1	0.04	1.73	0.39	2.0	0.04	1.68
99	0.51	2.3	0.05	1.95	0.48	2.3	0.05	1.90	0.46	2.2	0.05	1.88	0.43	2.2	0.04	1.78	0.41	2.1	0.04	1.73	0.39	2.0	0.04	1.68
100	0.47	2.2	0.06	1.96	0.45	2.2	0.05	1.90	0.43	2.1	0.05	1.88	0.40	2.1	0.05	1.79	0.38	2.0	0.04	1.73	0.36	2.0	0.04	1.68
101	0.42	2.1	0.06	1.96	0.40	2.1	0.05	1.90	0.38	2.0	0.05	1.88	0.36	2.0	0.05	1.79	0.34	1.9	0.05	1.74	0.32	1.9	0.04	1.68
102	0.39	2.0	0.06	1.96	0.37	2.0	0.05	1.90	0.35	1.9	0.05	1.88	0.33	1.9	0.05	1.79	0.31	1.8	0.05	1.74	0.29	1.8	0.04	1.68
103	0.35	2.0	0.06	1.96	0.34	1.9	0.05	1.90	0.32	1.9	0.05	1.88	0.30	1.8	0.05	1.79	0.29	1.8	0.05	1.74	0.27	1.7	0.04	1.68
104	0.35	1.9	0.06	1.96	0.33	1.9	0.05	1.90	0.32	1.9	0.05	1.88	0.30	1.8	0.05	1.79	0.28	1.8	0.05	1.74	0.27	1.7	0.04	1.68
105	0.30	1.8	0.05	1.95	0.29	1.8	0.05	1.90	0.27	1.8	0.05	1.88	0.26	1.7	0.05	1.79	0.24	1.7	0.05	1.74	0.23	1.6	0.04	1.68

Appendix F

Estuarine Planning Level Results

Cardno Lawson Treloar

Table F.1: 100yr ARI Planning Levels - 1.5mAHD Crest Level

Edge Treatment Types
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 10 Beach Face - 1.5mAHD crest
3. 1 in 5 Embankment - 1.5mAHD crest
4. 1 in 2 Seawall - 1.5mAHD crest
5. Vertical Wall - 1.5mAHD crest

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

100-year ARI Storm Tide at Fort Denison is **1.45mAHD** (excluding Sea Level Rise)
Mean Sea Level Rise Allowances taken from State and Federal Govt Policy and included within Table
Freeboard of 0.3m included within Table

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
							Sea Level Rise Allowance (m)														
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
001	0.26	1.7	0.11	1.96	2.46	2.66	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
002	0.28	1.8	0.10	1.95	2.45	2.65	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
003	0.33	1.9	0.10	1.95	2.45	2.65	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
004	0.36	2.0	0.09	1.94	2.44	2.64	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
005	0.43	2.2	0.09	1.94	2.44	2.64	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
006	0.40	2.1	0.09	1.94	2.44	2.64	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14
007	0.40	2.1	0.09	1.94	2.44	2.64	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14
008	0.36	2.0	0.09	1.94	2.44	2.64	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
009	0.36	2.0	0.09	1.94	2.44	2.64	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
010	0.37	2.0	0.08	1.93	2.43	2.63	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
011	0.43	2.1	0.08	1.93	2.43	2.63	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
012	0.43	2.1	0.08	1.93	2.43	2.63	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
013	0.36	2.0	0.08	1.93	2.43	2.63	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11
014	0.30	1.8	0.07	1.92	2.42	2.62	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
015	0.34	1.9	0.07	1.92	2.42	2.62	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
016	0.38	2.0	0.07	1.92	2.42	2.62	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11
017	0.34	1.9	0.07	1.92	2.42	2.62	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
018	0.36	2.0	0.07	1.92	2.42	2.62	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
019	0.36	2.0	0.07	1.92	2.42	2.62	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
020	0.34	1.9	0.07	1.92	2.42	2.62	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
021	0.46	2.2	0.07	1.92	2.42	2.62	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
022	0.52	2.4	0.07	1.92	2.42	2.62	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
023	0.36	2.0	0.07	1.92	2.42	2.62	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
024	0.30	1.8	0.07	1.92	2.42	2.62	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
025	0.39	2.1	0.06	1.91	2.41	2.61	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11
026	0.48	2.3	0.06	1.91	2.41	2.61	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
027	0.41	2.1	0.06	1.91	2.41	2.61	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
028	0.34	1.9	0.06	1.91	2.41	2.61	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08
029	0.31	1.8	0.06	1.91	2.41	2.61	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
030	0.29	1.8	0.06	1.91	2.41	2.61	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06
031	0.34	1.9	0.06	1.91	2.41	2.61	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08
032	0.37	2.0	0.06	1.91	2.41	2.61	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
033	0.41	2.1	0.06	1.91	2.41	2.61	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
				Sea Level Rise Allowance (m)																	
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
034	0.36	2.0	0.05	1.90	2.40	2.60	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08
035	0.33	1.9	0.06	1.91	2.41	2.61	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08
036	0.35	2.0	0.06	1.91	2.41	2.61	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
037	0.51	2.3	0.06	1.91	2.41	2.61	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17
038	0.54	2.4	0.06	1.91	2.41	2.61	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
039	0.74	2.9	0.05	1.90	2.40	2.60	2.57	3.07	3.27	2.57	3.07	3.27	2.57	3.07	3.27	2.57	3.07	3.27	2.57	3.07	3.27
040	0.74	2.9	0.05	1.90	2.40	2.60	2.57	3.07	3.27	2.57	3.07	3.27	2.57	3.07	3.27	2.57	3.07	3.27	2.57	3.07	3.27
041	0.70	2.8	0.05	1.90	2.40	2.60	2.55	3.05	3.25	2.55	3.05	3.25	2.55	3.05	3.25	2.55	3.05	3.25	2.55	3.05	3.25
042	0.60	2.6	0.06	1.91	2.41	2.61	2.51	3.01	3.21	2.51	3.01	3.21	2.51	3.01	3.21	2.51	3.01	3.21	2.51	3.01	3.21
043	0.54	2.4	0.06	1.91	2.41	2.61	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
044	0.55	2.4	0.05	1.90	2.40	2.60	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
045	0.46	2.2	0.04	1.89	2.39	2.59	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
046	0.44	2.2	0.04	1.89	2.39	2.59	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11
047	0.47	2.2	0.04	1.89	2.39	2.59	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13
048	0.59	2.5	0.04	1.89	2.39	2.59	2.49	2.99	3.19	2.49	2.99	3.19	2.49	2.99	3.19	2.49	2.99	3.19	2.49	2.99	3.19
049	0.57	2.5	0.04	1.89	2.39	2.59	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
050	0.51	2.3	0.04	1.89	2.39	2.59	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
051	0.48	2.3	0.04	1.89	2.39	2.59	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13
052	0.45	2.2	0.04	1.89	2.39	2.59	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12	2.42	2.92	3.12
053	0.42	2.1	0.04	1.89	2.39	2.59	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
054	0.37	2.0	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08
055	0.42	2.1	0.04	1.89	2.39	2.59	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
056	0.39	2.0	0.04	1.89	2.39	2.59	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
057	0.33	1.9	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06
058	0.34	1.9	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06
059	0.37	2.0	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08	2.38	2.88	3.08
060	0.47	2.2	0.03	1.88	2.38	2.58	2.41	2.92	3.12	2.41	2.92	3.12	2.41	2.92	3.12	2.41	2.92	3.12	2.41	2.92	3.12
061	0.55	2.4	0.03	1.88	2.38	2.58	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
062	0.50	2.3	0.03	1.88	2.38	2.58	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13
063	0.53	2.4	0.03	1.88	2.38	2.58	2.44	2.95	3.15	2.44	2.95	3.15	2.44	2.95	3.15	2.44	2.95	3.15	2.44	2.95	3.15
064	0.64	2.7	0.03	1.88	2.38	2.58	2.50	3.00	3.20	2.50	3.00	3.20	2.50	3.00	3.20	2.50	3.00	3.20	2.50	3.00	3.20
065	0.65	2.7	0.03	1.88	2.38	2.58	2.50	3.01	3.21	2.50	3.01	3.21	2.50	3.01	3.21	2.50	3.01	3.21	2.50	3.01	3.21
066	0.63	2.6	0.03	1.88	2.38	2.58	2.49	3.00	3.20	2.49	3.00	3.20	2.49	3.00	3.20	2.49	3.00	3.20	2.49	3.00	3.20
067	0.62	2.6	0.03	1.88	2.38	2.58	2.49	2.99	3.19	2.49	2.99	3.19	2.49	2.99	3.19	2.49	2.99	3.19	2.49	2.99	3.19
068	0.54	2.4	0.04	1.89	2.39	2.59	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
069	0.49	2.3	0.04	1.89	2.39	2.59	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14
070	0.36	2.0	0.04	1.89	2.39	2.59	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
071	0.47	2.2	0.04	1.89	2.39	2.59	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13
072	0.54	2.4	0.03	1.88	2.38	2.58	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
073	0.56	2.5	0.03	1.88	2.38	2.58	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
074	0.55	2.4	0.04	1.89	2.39	2.59	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17
075	0.54	2.4	0.04	1.89	2.39	2.59	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
076	0.56	2.5	0.04	1.89	2.39	2.59	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17
077	0.62	2.6	0.04	1.89	2.39	2.59	2.50	3.00	3.20	2.50	3.00	3.20	2.50	3.00	3.20	2.50	3.00	3.20	2.50	3.00	3.20
078	0.53	2.4	0.04	1.89	2.39	2.59	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
079	0.48	2.3	0.04	1.89	2.39	2.59	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13
080	0.44	2.2	0.04	1.89	2.39	2.59	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11
081	0.42	2.1	0.04	1.89	2.39	2.59	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
				Sea Level Rise Allowance (m)																	
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
082	0.36	2.0	0.04	1.89	2.39	2.59	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
083	0.31	1.8	0.04	1.89	2.39	2.59	2.35	2.85	3.05	2.35	2.85	3.05	2.35	2.85	3.05	2.35	2.85	3.05	2.35	2.85	3.05
084	0.29	1.8	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.34	2.84	3.04	2.34	2.84	3.04	2.34	2.84	3.04	2.34	2.84	3.04
085	0.29	1.8	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.34	2.84	3.04	2.34	2.84	3.04	2.34	2.84	3.04	2.34	2.84	3.04
086	0.33	1.9	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06	2.36	2.86	3.06
087	0.39	2.0	0.04	1.89	2.39	2.59	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
088	0.40	2.1	0.04	1.89	2.39	2.59	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
089	0.44	2.2	0.04	1.89	2.39	2.59	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11	2.41	2.91	3.11
090	0.53	2.4	0.04	1.89	2.39	2.59	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16	2.46	2.96	3.16
091	0.50	2.3	0.04	1.89	2.39	2.59	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14
092	0.52	2.4	0.04	1.89	2.39	2.59	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
093	0.58	2.5	0.04	1.89	2.39	2.59	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
094	0.58	2.5	0.04	1.89	2.39	2.59	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18	2.48	2.98	3.18
095	0.56	2.5	0.04	1.89	2.39	2.59	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17	2.47	2.97	3.17
096	0.52	2.4	0.04	1.89	2.39	2.59	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
097	0.49	2.3	0.05	1.90	2.40	2.60	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
098	0.49	2.3	0.05	1.90	2.40	2.60	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15	2.45	2.95	3.15
099	0.48	2.3	0.05	1.90	2.40	2.60	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14	2.44	2.94	3.14
100	0.45	2.2	0.05	1.90	2.40	2.60	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13	2.43	2.93	3.13
101	0.40	2.1	0.05	1.90	2.40	2.60	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10	2.40	2.90	3.10
102	0.37	2.0	0.05	1.90	2.40	2.60	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09	2.39	2.89	3.09
103	0.34	1.9	0.05	1.90	2.40	2.60	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
104	0.33	1.9	0.05	1.90	2.40	2.60	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07	2.37	2.87	3.07
105	0.29	1.8	0.05	1.90	2.40	2.60	2.35	2.85	3.05	2.35	2.85	3.05	2.35	2.85	3.05	2.35	2.85	3.05	2.35	2.85	3.05

Cardno Lawson Treloar

Table F.2: 100yr ARI Planning Levels - 2mAHD Crest Level

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

100-year ARI Storm Tide at Fort Denison is **1.45mAHD** (excluding Sea Level Rise)
Mean Sea Level Rise Allowances taken from State and Federal Govt Policy and included within Table
Freeboard of 0.3m included within Table

Edge Treatment Types
1. 1 in 20 Natural Slope - 2mAHD crest
2. 1 in 10 Beach Face - 2mAHD crest
3. 1 in 5 Embankment - 2mAHD crest
4. 1 in 2 Seawall - 2mAHD crest
5. Vertical Wall - 2mAHD crest

Loc ID	100yrARI						Estuarine Planning Level (m)															
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##															
							1			2			3			4			5			
							Sea Level Rise Allowance (m)															
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
001	0.26	1.7	0.11	1.96	2.46	2.66	2.37	2.89	3.09	2.40	2.89	3.09	2.42	2.89	3.09	2.43	2.89	3.09	2.41	2.89	3.09
002	0.28	1.8	0.10	1.95	2.45	2.65	2.37	2.89	3.09	2.41	2.89	3.09	2.42	2.89	3.09	2.43	2.89	3.09	2.42	2.89	3.09
003	0.33	1.9	0.10	1.95	2.45	2.65	2.39	2.92	3.12	2.43	2.92	3.12	2.45	2.92	3.12	2.46	2.92	3.12	2.44	2.92	3.12
004	0.36	2.0	0.09	1.94	2.44	2.64	2.39	2.92	3.12	2.44	2.92	3.12	2.46	2.92	3.12	2.47	2.92	3.12	2.45	2.92	3.12
005	0.43	2.2	0.09	1.94	2.44	2.64	2.43	2.96	3.16	2.47	2.96	3.16	2.50	2.96	3.16	2.51	2.96	3.16	2.49	2.96	3.16
006	0.40	2.1	0.09	1.94	2.44	2.64	2.41	2.94	3.14	2.46	2.94	3.14	2.48	2.94	3.14	2.49	2.94	3.14	2.47	2.94	3.14
007	0.40	2.1	0.09	1.94	2.44	2.64	2.41	2.94	3.14	2.46	2.94	3.14	2.48	2.94	3.14	2.49	2.94	3.14	2.47	2.94	3.14
008	0.36	2.0	0.09	1.94	2.44	2.64	2.39	2.92	3.12	2.44	2.92	3.12	2.46	2.92	3.12	2.47	2.92	3.12	2.45	2.92	3.12
009	0.36	2.0	0.09	1.94	2.44	2.64	2.39	2.92	3.12	2.44	2.92	3.12	2.46	2.92	3.12	2.47	2.92	3.12	2.45	2.92	3.12
010	0.37	2.0	0.08	1.93	2.43	2.63	2.38	2.92	3.12	2.43	2.92	3.12	2.46	2.92	3.12	2.48	2.92	3.12	2.45	2.92	3.12
011	0.43	2.1	0.08	1.93	2.43	2.63	2.41	2.95	3.15	2.46	2.95	3.15	2.49	2.95	3.15	2.51	2.95	3.15	2.48	2.95	3.15
012	0.43	2.1	0.08	1.93	2.43	2.63	2.41	2.95	3.15	2.46	2.95	3.15	2.49	2.95	3.15	2.51	2.95	3.15	2.48	2.95	3.15
013	0.36	2.0	0.08	1.93	2.43	2.63	2.38	2.91	3.11	2.43	2.91	3.11	2.46	2.91	3.11	2.47	2.91	3.11	2.45	2.91	3.11
014	0.30	1.8	0.07	1.92	2.42	2.62	2.33	2.87	3.07	2.39	2.87	3.07	2.42	2.87	3.07	2.44	2.87	3.07	2.41	2.87	3.07
015	0.34	1.9	0.07	1.92	2.42	2.62	2.35	2.89	3.09	2.41	2.89	3.09	2.44	2.89	3.09	2.46	2.89	3.09	2.43	2.89	3.09
016	0.38	2.0	0.07	1.92	2.42	2.62	2.37	2.91	3.11	2.43	2.91	3.11	2.46	2.91	3.11	2.48	2.91	3.11	2.45	2.91	3.11
017	0.34	1.9	0.07	1.92	2.42	2.62	2.35	2.89	3.09	2.41	2.89	3.09	2.44	2.89	3.09	2.46	2.89	3.09	2.43	2.89	3.09
018	0.36	2.0	0.07	1.92	2.42	2.62	2.36	2.90	3.10	2.42	2.90	3.10	2.45	2.90	3.10	2.47	2.90	3.10	2.44	2.90	3.10
019	0.36	2.0	0.07	1.92	2.42	2.62	2.36	2.90	3.10	2.42	2.90	3.10	2.45	2.90	3.10	2.47	2.90	3.10	2.44	2.90	3.10
020	0.34	1.9	0.07	1.92	2.42	2.62	2.35	2.89	3.09	2.41	2.89	3.09	2.44	2.89	3.09	2.46	2.89	3.09	2.43	2.89	3.09
021	0.46	2.2	0.07	1.92	2.42	2.62	2.41	2.95	3.15	2.47	2.95	3.15	2.50	2.95	3.15	2.52	2.95	3.15	2.49	2.95	3.15
022	0.52	2.4	0.07	1.92	2.42	2.62	2.44	2.98	3.18	2.50	2.98	3.18	2.53	2.98	3.18	2.55	2.98	3.18	2.52	2.98	3.18
023	0.36	2.0	0.07	1.92	2.42	2.62	2.36	2.90	3.10	2.42	2.90	3.10	2.45	2.90	3.10	2.47	2.90	3.10	2.44	2.90	3.10
024	0.30	1.8	0.07	1.92	2.42	2.62	2.33	2.87	3.07	2.39	2.87	3.07	2.42	2.87	3.07	2.44	2.87	3.07	2.41	2.87	3.07
025	0.39	2.1	0.06	1.91	2.41	2.61	2.36	2.91	3.11	2.43	2.91	3.11	2.46	2.91	3.11	2.48	2.91	3.11	2.45	2.91	3.11
026	0.48	2.3	0.06	1.91	2.41	2.61	2.41	2.95	3.15	2.48	2.95	3.15	2.51	2.95	3.15	2.53	2.95	3.15	2.50	2.95	3.15
027	0.41	2.1	0.06	1.91	2.41	2.61	2.37	2.92	3.12	2.44	2.92	3.12	2.47	2.92	3.12	2.49	2.92	3.12	2.46	2.92	3.12
028	0.34	1.9	0.06	1.91	2.41	2.61	2.33	2.88	3.08	2.40	2.88	3.08	2.44	2.88	3.08	2.46	2.88	3.08	2.43	2.88	3.08
029	0.31	1.8	0.06	1.91	2.41	2.61	2.32	2.87	3.07	2.39	2.87	3.07	2.42	2.87	3.07	2.44	2.87	3.07	2.41	2.87	3.07
030	0.29	1.8	0.06	1.91	2.41	2.61	2.31	2.86	3.06	2.38	2.86	3.06	2.41	2.86	3.06	2.43	2.86	3.06	2.40	2.86	3.06
031	0.34	1.9	0.06	1.91	2.41	2.61	2.33	2.88	3.08	2.40	2.88	3.08	2.44	2.88	3.08	2.46	2.88	3.08	2.43	2.88	3.08
032	0.37	2.0	0.06	1.91	2.41	2.61	2.35	2.90	3.10	2.42	2.90	3.10	2.45	2.90	3.10	2.47	2.90	3.10	2.44	2.90	3.10
033	0.41	2.1	0.06	1.91	2.41	2.61	2.37	2.92	3.12	2.44	2.92	3.12	2.47	2.92	3.12	2.49	2.92	3.12	2.46	2.92	3.12

Loc ID	100yrARI						Estuarine Planning Level (m)															
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##															
							1			2			3			4			5			
				Sea Level Rise Allowance (m)																		
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
034	0.36	2.0	0.05	1.90	2.40	2.60	2.33	2.88	3.08	2.41	2.88	3.08	2.45	2.88	3.08	2.47	2.88	3.08	2.43	2.88	3.08
035	0.33	1.9	0.06	1.91	2.41	2.61	2.33	2.88	3.08	2.40	2.88	3.08	2.43	2.88	3.08	2.45	2.88	3.08	2.42	2.88	3.08
036	0.35	2.0	0.06	1.91	2.41	2.61	2.34	2.89	3.09	2.41	2.89	3.09	2.44	2.89	3.09	2.46	2.89	3.09	2.43	2.89	3.09
037	0.51	2.3	0.06	1.91	2.41	2.61	2.42	2.97	3.17	2.49	2.97	3.17	2.52	2.97	3.17	2.55	2.97	3.17	2.51	2.97	3.17
038	0.54	2.4	0.06	1.91	2.41	2.61	2.43	2.98	3.18	2.51	2.98	3.18	2.54	2.98	3.18	2.56	2.98	3.18	2.53	2.98	3.18
039	0.74	2.9	0.05	1.90	2.40	2.60	2.53	3.07	3.27	2.60	3.07	3.27	2.64	3.07	3.27	2.66	3.07	3.27	2.63	3.07	3.27
040	0.74	2.9	0.05	1.90	2.40	2.60	2.53	3.07	3.27	2.60	3.07	3.27	2.64	3.07	3.27	2.66	3.07	3.27	2.63	3.07	3.27
041	0.70	2.8	0.05	1.90	2.40	2.60	2.50	3.05	3.25	2.58	3.05	3.25	2.62	3.05	3.25	2.64	3.05	3.25	2.61	3.05	3.25
042	0.60	2.6	0.06	1.91	2.41	2.61	2.47	3.01	3.21	2.54	3.01	3.21	2.57	3.01	3.21	2.59	3.01	3.21	2.56	3.01	3.21
043	0.54	2.4	0.06	1.91	2.41	2.61	2.43	2.98	3.18	2.51	2.98	3.18	2.54	2.98	3.18	2.56	2.98	3.18	2.53	2.98	3.18
044	0.55	2.4	0.05	1.90	2.40	2.60	2.42	2.98	3.18	2.50	2.98	3.18	2.54	2.98	3.18	2.56	2.98	3.18	2.53	2.98	3.18
045	0.46	2.2	0.04	1.89	2.39	2.59	2.36	2.92	3.12	2.45	2.92	3.12	2.49	2.92	3.12	2.52	2.92	3.12	2.48	2.92	3.12
046	0.44	2.2	0.04	1.89	2.39	2.59	2.36	2.91	3.11	2.44	2.91	3.11	2.48	2.91	3.11	2.51	2.91	3.11	2.47	2.91	3.11
047	0.47	2.2	0.04	1.89	2.39	2.59	2.36	2.93	3.13	2.45	2.93	3.13	2.50	2.93	3.13	2.52	2.93	3.13	2.48	2.93	3.13
048	0.59	2.5	0.04	1.89	2.39	2.59	2.43	2.99	3.19	2.51	2.99	3.19	2.56	2.99	3.19	2.58	2.99	3.19	2.54	2.99	3.19
049	0.57	2.5	0.04	1.89	2.39	2.59	2.42	2.98	3.18	2.51	2.98	3.18	2.55	2.98	3.18	2.57	2.98	3.18	2.53	2.98	3.18
050	0.51	2.3	0.04	1.89	2.39	2.59	2.39	2.95	3.15	2.47	2.95	3.15	2.52	2.95	3.15	2.54	2.95	3.15	2.50	2.95	3.15
051	0.48	2.3	0.04	1.89	2.39	2.59	2.38	2.93	3.13	2.46	2.93	3.13	2.50	2.93	3.13	2.53	2.93	3.13	2.49	2.93	3.13
052	0.45	2.2	0.04	1.89	2.39	2.59	2.36	2.92	3.12	2.44	2.92	3.12	2.49	2.92	3.12	2.51	2.92	3.12	2.47	2.92	3.12
053	0.42	2.1	0.04	1.89	2.39	2.59	2.34	2.90	3.10	2.43	2.90	3.10	2.47	2.90	3.10	2.50	2.90	3.10	2.46	2.90	3.10
054	0.37	2.0	0.04	1.89	2.39	2.59	2.32	2.88	3.08	2.40	2.88	3.08	2.45	2.88	3.08	2.47	2.88	3.08	2.43	2.88	3.08
055	0.42	2.1	0.04	1.89	2.39	2.59	2.34	2.90	3.10	2.43	2.90	3.10	2.47	2.90	3.10	2.50	2.90	3.10	2.46	2.90	3.10
056	0.39	2.0	0.04	1.89	2.39	2.59	2.32	2.89	3.09	2.41	2.89	3.09	2.46	2.89	3.09	2.48	2.89	3.09	2.44	2.89	3.09
057	0.33	1.9	0.04	1.89	2.39	2.59	2.30	2.86	3.06	2.38	2.86	3.06	2.43	2.86	3.06	2.45	2.86	3.06	2.41	2.86	3.06
058	0.34	1.9	0.04	1.89	2.39	2.59	2.30	2.86	3.06	2.39	2.86	3.06	2.43	2.86	3.06	2.46	2.86	3.06	2.42	2.86	3.06
059	0.37	2.0	0.04	1.89	2.39	2.59	2.32	2.88	3.08	2.40	2.88	3.08	2.45	2.88	3.08	2.47	2.88	3.08	2.43	2.88	3.08
060	0.47	2.2	0.03	1.88	2.38	2.58	2.35	2.92	3.12	2.44	2.92	3.12	2.49	2.92	3.12	2.52	2.92	3.12	2.48	2.92	3.12
061	0.55	2.4	0.03	1.88	2.38	2.58	2.39	2.96	3.16	2.49	2.96	3.16	2.53	2.96	3.16	2.56	2.96	3.16	2.52	2.96	3.16
062	0.50	2.3	0.03	1.88	2.38	2.58	2.37	2.93	3.13	2.46	2.93	3.13	2.51	2.93	3.13	2.54	2.93	3.13	2.49	2.93	3.13
063	0.53	2.4	0.03	1.88	2.38	2.58	2.38	2.95	3.15	2.48	2.95	3.15	2.52	2.95	3.15	2.55	2.95	3.15	2.51	2.95	3.15
064	0.64	2.7	0.03	1.88	2.38	2.58	2.44	3.00	3.20	2.54	3.00	3.20	2.58	3.00	3.20	2.61	3.00	3.20	2.57	3.00	3.20
065	0.65	2.7	0.03	1.88	2.38	2.58	2.45	3.01	3.21	2.54	3.01	3.21	2.59	3.01	3.21	2.61	3.01	3.21	2.57	3.01	3.21
066	0.63	2.6	0.03	1.88	2.38	2.58	2.43	3.00	3.20	2.53	3.00	3.20	2.57	3.00	3.20	2.60	3.00	3.20	2.56	3.00	3.20
067	0.62	2.6	0.03	1.88	2.38	2.58	2.43	2.99	3.19	2.52	2.99	3.19	2.57	2.99	3.19	2.60	2.99	3.19	2.55	2.99	3.19
068	0.54	2.4	0.04	1.89	2.39	2.59	2.40	2.96	3.16	2.49	2.96	3.16	2.53	2.96	3.16	2.56	2.96	3.16	2.52	2.96	3.16
069	0.49	2.3	0.04	1.89	2.39	2.59	2.38	2.94	3.14	2.46	2.94	3.14	2.51	2.94	3.14	2.53	2.94	3.14	2.49	2.94	3.14
070	0.36	2.0	0.04	1.89	2.39	2.59	2.32	2.87	3.07	2.40	2.87	3.07	2.44	2.87	3.07	2.47	2.87	3.07	2.43	2.87	3.07
071	0.47	2.2	0.04	1.89	2.39	2.59	2.36	2.93	3.13	2.45	2.93	3.13	2.50	2.93	3.13	2.52	2.93	3.13	2.48	2.93	3.13
072	0.54	2.4	0.03	1.88	2.38	2.58	2.39	2.95	3.15	2.48	2.95	3.15	2.53	2.95	3.15	2.56	2.95	3.15	2.51	2.95	3.15
073	0.56	2.5	0.03	1.88	2.38	2.58	2.40	2.96	3.16	2.49	2.96	3.16	2.54	2.96	3.16	2.57	2.96	3.16	2.52	2.96	3.16
074	0.55	2.4	0.04	1.89	2.39	2.59	2.41	2.97	3.17	2.49	2.97	3.17	2.54	2.97	3.17	2.56	2.97	3.17	2.52	2.97	3.17
075	0.54	2.4	0.04	1.89	2.39	2.59	2.40	2.96	3.16	2.49	2.96	3.16	2.53	2.96	3.16	2.56	2.96	3.16	2.52	2.96	3.16
076	0.56	2.5	0.04	1.89	2.39	2.59	2.42	2.97	3.17	2.50	2.97	3.17	2.54	2.97	3.17	2.57	2.97	3.17	2.53	2.97	3.17
077	0.62	2.6	0.04	1.89	2.39	2.59	2.45	3.00	3.20	2.53	3.00	3.20	2.57	3.00	3.20	2.60	3.00	3.20	2.56	3.00	3.20
078	0.53	2.4	0.04	1.89	2.39	2.59	2.40	2.96	3.16	2.49	2.96	3.16	2.53	2.96	3.16	2.55	2.96	3.16	2.51	2.96	3.16
079	0.48	2.3	0.04	1.89	2.39	2.59	2.38	2.93	3.13	2.46	2.93	3.13	2.50	2.93	3.13	2.53	2.93	3.13	2.49	2.93	3.13
080	0.44	2.2	0.04	1.89	2.39	2.59	2.36	2.91	3.11	2.44	2.91	3.11	2.48	2.91	3.11	2.51	2.91	3.11	2.47	2.91	3.11
081	0.42	2.1	0.04	1.89	2.39	2.59	2.34	2.90	3.10	2.43	2.90	3.10	2.47	2.90	3.10	2.50	2.90	3.10	2.46	2.90	3.10

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
				Sea Level Rise Allowance (m)																	
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
082	0.36	2.0	0.04	1.89	2.39	2.59	2.32	2.87	3.07	2.40	2.87	3.07	2.44	2.87	3.07	2.47	2.87	3.07	2.43	2.87	3.07
083	0.31	1.8	0.04	1.89	2.39	2.59	2.29	2.85	3.05	2.37	2.85	3.05	2.41	2.85	3.05	2.44	2.85	3.05	2.40	2.85	3.05
084	0.29	1.8	0.04	1.89	2.39	2.59	2.29	2.84	3.04	2.36	2.84	3.04	2.41	2.84	3.04	2.43	2.84	3.04	2.39	2.84	3.04
085	0.29	1.8	0.04	1.89	2.39	2.59	2.29	2.84	3.04	2.36	2.84	3.04	2.41	2.84	3.04	2.43	2.84	3.04	2.39	2.84	3.04
086	0.33	1.9	0.04	1.89	2.39	2.59	2.30	2.86	3.06	2.38	2.86	3.06	2.43	2.86	3.06	2.45	2.86	3.06	2.41	2.86	3.06
087	0.39	2.0	0.04	1.89	2.39	2.59	2.32	2.89	3.09	2.41	2.89	3.09	2.46	2.89	3.09	2.48	2.89	3.09	2.44	2.89	3.09
088	0.40	2.1	0.04	1.89	2.39	2.59	2.33	2.89	3.09	2.42	2.89	3.09	2.46	2.89	3.09	2.49	2.89	3.09	2.45	2.89	3.09
089	0.44	2.2	0.04	1.89	2.39	2.59	2.36	2.91	3.11	2.44	2.91	3.11	2.48	2.91	3.11	2.51	2.91	3.11	2.47	2.91	3.11
090	0.53	2.4	0.04	1.89	2.39	2.59	2.40	2.96	3.16	2.49	2.96	3.16	2.53	2.96	3.16	2.55	2.96	3.16	2.51	2.96	3.16
091	0.50	2.3	0.04	1.89	2.39	2.59	2.38	2.94	3.14	2.47	2.94	3.14	2.51	2.94	3.14	2.54	2.94	3.14	2.50	2.94	3.14
092	0.52	2.4	0.04	1.89	2.39	2.59	2.40	2.95	3.15	2.48	2.95	3.15	2.52	2.95	3.15	2.55	2.95	3.15	2.51	2.95	3.15
093	0.58	2.5	0.04	1.89	2.39	2.59	2.42	2.98	3.18	2.51	2.98	3.18	2.55	2.98	3.18	2.58	2.98	3.18	2.54	2.98	3.18
094	0.58	2.5	0.04	1.89	2.39	2.59	2.42	2.98	3.18	2.51	2.98	3.18	2.55	2.98	3.18	2.58	2.98	3.18	2.54	2.98	3.18
095	0.56	2.5	0.04	1.89	2.39	2.59	2.42	2.97	3.17	2.50	2.97	3.17	2.54	2.97	3.17	2.57	2.97	3.17	2.53	2.97	3.17
096	0.52	2.4	0.04	1.89	2.39	2.59	2.40	2.95	3.15	2.48	2.95	3.15	2.52	2.95	3.15	2.55	2.95	3.15	2.51	2.95	3.15
097	0.49	2.3	0.05	1.90	2.40	2.60	2.39	2.95	3.15	2.47	2.95	3.15	2.51	2.95	3.15	2.53	2.95	3.15	2.50	2.95	3.15
098	0.49	2.3	0.05	1.90	2.40	2.60	2.39	2.95	3.15	2.47	2.95	3.15	2.51	2.95	3.15	2.53	2.95	3.15	2.50	2.95	3.15
099	0.48	2.3	0.05	1.90	2.40	2.60	2.39	2.94	3.14	2.47	2.94	3.14	2.51	2.94	3.14	2.53	2.94	3.14	2.49	2.94	3.14
100	0.45	2.2	0.05	1.90	2.40	2.60	2.37	2.93	3.13	2.45	2.93	3.13	2.49	2.93	3.13	2.51	2.93	3.13	2.48	2.93	3.13
101	0.40	2.1	0.05	1.90	2.40	2.60	2.35	2.90	3.10	2.43	2.90	3.10	2.47	2.90	3.10	2.49	2.90	3.10	2.45	2.90	3.10
102	0.37	2.0	0.05	1.90	2.40	2.60	2.33	2.89	3.09	2.41	2.89	3.09	2.45	2.89	3.09	2.47	2.89	3.09	2.44	2.89	3.09
103	0.34	1.9	0.05	1.90	2.40	2.60	2.32	2.87	3.07	2.40	2.87	3.07	2.43	2.87	3.07	2.46	2.87	3.07	2.42	2.87	3.07
104	0.33	1.9	0.05	1.90	2.40	2.60	2.31	2.87	3.07	2.39	2.87	3.07	2.43	2.87	3.07	2.45	2.87	3.07	2.42	2.87	3.07
105	0.29	1.8	0.05	1.90	2.40	2.60	2.30	2.85	3.05	2.37	2.85	3.05	2.41	2.85	3.05	2.43	2.85	3.05	2.40	2.85	3.05

Cardno Lawson Treloar

Table F.3: 100yr ARI Planning Levels - 2.5mAHD Crest Level

**Edge Treatment Types**
1. 1 in 20 Natural Slope - 2.5mAHD crest
2. 1 in 10 Beach Face - 2.5mAHD crest
3. 1 in 5 Embankment - 2.5mAHD crest
4. 1 in 2 Seawall - 2.5mAHD crest
5. Vertical Wall - 2.5mAHD crest

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

100-year ARI Storm Tide at Fort Denison is **1.45mAHD** (excluding Sea Level Rise)
Mean Sea Level Rise Allowances taken from State and Federal Govt Policy and included within Table
Freeboard of 0.3m included within Table

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
							Sea Level Rise Allowance (m)														
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
001	0.26	1.7	0.11	1.96	2.46	2.66	2.35	2.87	3.09	2.43	2.90	3.09	2.61	2.92	3.09	2.85	2.93	3.09	2.52	2.91	3.09
002	0.28	1.8	0.10	1.95	2.45	2.65	2.35	2.87	3.09	2.44	2.91	3.09	2.63	2.92	3.09	2.86	2.93	3.09	2.53	2.92	3.09
003	0.33	1.9	0.10	1.95	2.45	2.65	2.36	2.89	3.12	2.47	2.93	3.12	2.69	2.95	3.12	2.88	2.96	3.12	2.58	2.94	3.12
004	0.36	2.0	0.09	1.94	2.44	2.64	2.36	2.89	3.12	2.48	2.94	3.12	2.72	2.96	3.12	2.89	2.97	3.12	2.60	2.95	3.12
005	0.43	2.2	0.09	1.94	2.44	2.64	2.38	2.93	3.16	2.53	2.97	3.16	2.81	3.00	3.16	2.93	3.01	3.16	2.67	2.99	3.16
006	0.40	2.1	0.09	1.94	2.44	2.64	2.37	2.91	3.14	2.51	2.96	3.14	2.77	2.98	3.14	2.91	2.99	3.14	2.64	2.97	3.14
007	0.40	2.1	0.09	1.94	2.44	2.64	2.37	2.91	3.14	2.51	2.96	3.14	2.77	2.98	3.14	2.91	2.99	3.14	2.64	2.97	3.14
008	0.36	2.0	0.09	1.94	2.44	2.64	2.36	2.89	3.12	2.48	2.94	3.12	2.72	2.96	3.12	2.89	2.97	3.12	2.60	2.95	3.12
009	0.36	2.0	0.09	1.94	2.44	2.64	2.36	2.89	3.12	2.48	2.94	3.12	2.72	2.96	3.12	2.89	2.97	3.12	2.60	2.95	3.12
010	0.37	2.0	0.08	1.93	2.43	2.63	2.35	2.88	3.12	2.47	2.93	3.12	2.72	2.96	3.12	2.90	2.98	3.12	2.60	2.95	3.12
011	0.43	2.1	0.08	1.93	2.43	2.63	2.37	2.91	3.15	2.51	2.96	3.15	2.78	2.99	3.15	2.93	3.01	3.15	2.66	2.98	3.15
012	0.43	2.1	0.08	1.93	2.43	2.63	2.37	2.91	3.15	2.51	2.96	3.15	2.78	2.99	3.15	2.93	3.01	3.15	2.66	2.98	3.15
013	0.36	2.0	0.08	1.93	2.43	2.63	2.35	2.88	3.11	2.47	2.93	3.11	2.71	2.96	3.11	2.89	2.97	3.11	2.59	2.95	3.11
014	0.30	1.8	0.07	1.92	2.42	2.62	2.32	2.83	3.07	2.42	2.89	3.07	2.61	2.92	3.07	2.86	2.94	3.07	2.52	2.91	3.07
015	0.34	1.9	0.07	1.92	2.42	2.62	2.33	2.85	3.09	2.44	2.91	3.09	2.66	2.94	3.09	2.88	2.96	3.09	2.56	2.93	3.09
016	0.38	2.0	0.07	1.92	2.42	2.62	2.34	2.87	3.11	2.47	2.93	3.11	2.71	2.96	3.11	2.90	2.98	3.11	2.60	2.95	3.11
017	0.34	1.9	0.07	1.92	2.42	2.62	2.33	2.85	3.09	2.44	2.91	3.09	2.66	2.94	3.09	2.88	2.96	3.09	2.56	2.93	3.09
018	0.36	2.0	0.07	1.92	2.42	2.62	2.34	2.86	3.10	2.46	2.92	3.10	2.70	2.95	3.10	2.89	2.97	3.10	2.58	2.94	3.10
019	0.36	2.0	0.07	1.92	2.42	2.62	2.34	2.86	3.10	2.46	2.92	3.10	2.70	2.95	3.10	2.89	2.97	3.10	2.58	2.94	3.10
020	0.34	1.9	0.07	1.92	2.42	2.62	2.33	2.85	3.09	2.44	2.91	3.09	2.66	2.94	3.09	2.88	2.96	3.09	2.56	2.93	3.09
021	0.46	2.2	0.07	1.92	2.42	2.62	2.37	2.91	3.15	2.52	2.97	3.15	2.81	3.00	3.15	2.94	3.02	3.15	2.68	2.99	3.15
022	0.52	2.4	0.07	1.92	2.42	2.62	2.39	2.94	3.18	2.57	3.00	3.18	2.84	3.03	3.18	2.97	3.05	3.18	2.74	3.02	3.18
023	0.36	2.0	0.07	1.92	2.42	2.62	2.34	2.86	3.10	2.46	2.92	3.10	2.70	2.95	3.10	2.89	2.97	3.10	2.58	2.94	3.10
024	0.30	1.8	0.07	1.92	2.42	2.62	2.32	2.83	3.07	2.42	2.89	3.07	2.61	2.92	3.07	2.86	2.94	3.07	2.52	2.91	3.07
025	0.39	2.1	0.06	1.91	2.41	2.61	2.34	2.86	3.11	2.47	2.93	3.11	2.73	2.96	3.11	2.90	2.98	3.11	2.60	2.95	3.11
026	0.48	2.3	0.06	1.91	2.41	2.61	2.37	2.91	3.15	2.53	2.98	3.15	2.82	3.01	3.15	2.95	3.03	3.15	2.69	3.00	3.15
027	0.41	2.1	0.06	1.91	2.41	2.61	2.34	2.87	3.12	2.48	2.94	3.12	2.75	2.97	3.12	2.92	2.99	3.12	2.62	2.96	3.12
028	0.34	1.9	0.06	1.91	2.41	2.61	2.32	2.83	3.08	2.43	2.90	3.08	2.65	2.94	3.08	2.88	2.96	3.08	2.55	2.93	3.08
029	0.31	1.8	0.06	1.91	2.41	2.61	2.31	2.82	3.07	2.41	2.89	3.07	2.61	2.92	3.07	2.86	2.94	3.07	2.52	2.91	3.07
030	0.29	1.8	0.06	1.91	2.41	2.61	2.31	2.81	3.06	2.40	2.88	3.06	2.60	2.91	3.06	2.85	2.93	3.06	2.50	2.90	3.06
031	0.34	1.9	0.06	1.91	2.41	2.61	2.32	2.83	3.08	2.43	2.90	3.08	2.65	2.94	3.08	2.88	2.96	3.08	2.55	2.93	3.08
032	0.37	2.0	0.06	1.91	2.41	2.61	2.33	2.85	3.10	2.45	2.92	3.10	2.70	2.95	3.10	2.89	2.97	3.10	2.58	2.94	3.10
033	0.41	2.1	0.06	1.91	2.41	2.61	2.34	2.87	3.12	2.48	2.94	3.12	2.75	2.97	3.12	2.92	2.99	3.12	2.62	2.96	3.12

Cardno Lawson Treloar

Loc ID	100yrARI						Estuarine Planning Level (m)															
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##															
							1			2			3			4			5		
							Sea Level Rise Allowance (m)															
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
034	0.36	2.0	0.05	1.90	2.40	2.60	2.32	2.83	3.08	2.44	2.91	3.08	2.68	2.95	3.08	2.89	2.97	3.08	2.56	2.93	3.08
035	0.33	1.9	0.06	1.91	2.41	2.61	2.32	2.83	3.08	2.43	2.90	3.08	2.65	2.93	3.08	2.87	2.95	3.08	2.54	2.92	3.08
036	0.35	2.0	0.06	1.91	2.41	2.61	2.33	2.84	3.09	2.45	2.91	3.09	2.68	2.94	3.09	2.88	2.96	3.09	2.56	2.93	3.09
037	0.51	2.3	0.06	1.91	2.41	2.61	2.37	2.92	3.17	2.54	2.99	3.17	2.83	3.02	3.17	2.97	3.05	3.17	2.72	3.01	3.17
038	0.54	2.4	0.06	1.91	2.41	2.61	2.39	2.93	3.18	2.56	3.01	3.18	2.84	3.04	3.18	2.98	3.06	3.18	2.75	3.03	3.18
039	0.74	2.9	0.05	1.90	2.40	2.60	2.45	3.03	3.27	2.70	3.10	3.27	2.95	3.14	3.27	3.08	3.16	3.27	2.87	3.13	3.27
040	0.74	2.9	0.05	1.90	2.40	2.60	2.45	3.03	3.27	2.70	3.10	3.27	2.95	3.14	3.27	3.08	3.16	3.27	2.87	3.13	3.27
041	0.70	2.8	0.05	1.90	2.40	2.60	2.43	3.00	3.25	2.67	3.08	3.25	2.93	3.12	3.25	3.06	3.14	3.25	2.85	3.11	3.25
042	0.60	2.6	0.06	1.91	2.41	2.61	2.41	2.97	3.21	2.61	3.04	3.21	2.88	3.07	3.21	3.01	3.09	3.21	2.81	3.06	3.21
043	0.54	2.4	0.06	1.91	2.41	2.61	2.39	2.93	3.18	2.56	3.01	3.18	2.84	3.04	3.18	2.98	3.06	3.18	2.75	3.03	3.18
044	0.55	2.4	0.05	1.90	2.40	2.60	2.38	2.92	3.18	2.56	3.00	3.18	2.84	3.04	3.18	2.98	3.06	3.18	2.75	3.03	3.18
045	0.46	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.12	2.49	2.95	3.12	2.79	2.99	3.12	2.94	3.02	3.12	2.65	2.98	3.12
046	0.44	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.11	2.48	2.94	3.11	2.77	2.98	3.11	2.93	3.01	3.11	2.63	2.97	3.11
047	0.47	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.13	2.49	2.95	3.13	2.79	3.00	3.13	2.94	3.02	3.13	2.66	2.98	3.13
048	0.59	2.5	0.04	1.89	2.39	2.59	2.38	2.93	3.19	2.57	3.01	3.19	2.86	3.06	3.19	3.00	3.08	3.19	2.78	3.04	3.19
049	0.57	2.5	0.04	1.89	2.39	2.59	2.38	2.92	3.18	2.57	3.01	3.18	2.86	3.05	3.18	2.99	3.07	3.18	2.76	3.03	3.18
050	0.51	2.3	0.04	1.89	2.39	2.59	2.35	2.89	3.15	2.52	2.97	3.15	2.82	3.02	3.15	2.96	3.04	3.15	2.70	3.00	3.15
051	0.48	2.3	0.04	1.89	2.39	2.59	2.35	2.88	3.13	2.51	2.96	3.13	2.81	3.00	3.13	2.95	3.03	3.13	2.67	2.99	3.13
052	0.45	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.12	2.48	2.94	3.12	2.78	2.99	3.12	2.93	3.01	3.12	2.64	2.97	3.12
053	0.42	2.1	0.04	1.89	2.39	2.59	2.33	2.84	3.10	2.46	2.93	3.10	2.73	2.97	3.10	2.92	3.00	3.10	2.61	2.96	3.10
054	0.37	2.0	0.04	1.89	2.39	2.59	2.31	2.82	3.08	2.43	2.90	3.08	2.68	2.95	3.08	2.89	2.97	3.08	2.56	2.93	3.08
055	0.42	2.1	0.04	1.89	2.39	2.59	2.33	2.84	3.10	2.46	2.93	3.10	2.73	2.97	3.10	2.92	3.00	3.10	2.61	2.96	3.10
056	0.39	2.0	0.04	1.89	2.39	2.59	2.31	2.82	3.09	2.44	2.91	3.09	2.69	2.96	3.09	2.90	2.98	3.09	2.58	2.94	3.09
057	0.33	1.9	0.04	1.89	2.39	2.59	2.30	2.80	3.06	2.41	2.88	3.06	2.63	2.93	3.06	2.87	2.95	3.06	2.52	2.91	3.06
058	0.34	1.9	0.04	1.89	2.39	2.59	2.30	2.80	3.06	2.41	2.89	3.06	2.63	2.93	3.06	2.88	2.96	3.06	2.53	2.92	3.06
059	0.37	2.0	0.04	1.89	2.39	2.59	2.31	2.82	3.08	2.43	2.90	3.08	2.68	2.95	3.08	2.89	2.97	3.08	2.56	2.93	3.08
060	0.47	2.2	0.03	1.88	2.38	2.58	2.33	2.85	3.12	2.48	2.94	3.12	2.78	2.99	3.12	2.94	3.02	3.12	2.65	2.98	3.12
061	0.55	2.4	0.03	1.88	2.38	2.58	2.36	2.89	3.16	2.54	2.99	3.16	2.84	3.03	3.16	2.98	3.06	3.16	2.73	3.02	3.16
062	0.50	2.3	0.03	1.88	2.38	2.58	2.34	2.87	3.13	2.51	2.96	3.13	2.81	3.01	3.13	2.96	3.04	3.13	2.68	2.99	3.13
063	0.53	2.4	0.03	1.88	2.38	2.58	2.35	2.88	3.15	2.53	2.98	3.15	2.83	3.02	3.15	2.97	3.05	3.15	2.71	3.01	3.15
064	0.64	2.7	0.03	1.88	2.38	2.58	2.40	2.94	3.20	2.61	3.04	3.20	2.89	3.08	3.20	3.03	3.11	3.20	2.81	3.07	3.20
065	0.65	2.7	0.03	1.88	2.38	2.58	2.40	2.95	3.21	2.62	3.04	3.21	2.90	3.09	3.21	3.03	3.11	3.21	2.82	3.07	3.21
066	0.63	2.6	0.03	1.88	2.38	2.58	2.39	2.93	3.20	2.59	3.03	3.20	2.88	3.07	3.20	3.02	3.10	3.20	2.81	3.06	3.20
067	0.62	2.6	0.03	1.88	2.38	2.58	2.38	2.93	3.19	2.59	3.02	3.19	2.88	3.07	3.19	3.02	3.10	3.19	2.80	3.06	3.19
068	0.54	2.4	0.04	1.89	2.39	2.59	2.37	2.90	3.16	2.54	2.99	3.16	2.84	3.03	3.16	2.98	3.06	3.16	2.73	3.02	3.16
069	0.49	2.3	0.04	1.89	2.39	2.59	2.35	2.88	3.14	2.51	2.96	3.14	2.81	3.01	3.14	2.95	3.03	3.14	2.68	2.99	3.14
070	0.36	2.0	0.04	1.89	2.39	2.59	2.31	2.82	3.07	2.43	2.90	3.07	2.67	2.94	3.07	2.89	2.97	3.07	2.55	2.93	3.07
071	0.47	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.13	2.49	2.95	3.13	2.79	3.00	3.13	2.94	3.02	3.13	2.66	2.98	3.13
072	0.54	2.4	0.03	1.88	2.38	2.58	2.36	2.89	3.15	2.53	2.98	3.15	2.83	3.03	3.15	2.98	3.06	3.15	2.72	3.01	3.15
073	0.56	2.5	0.03	1.88	2.38	2.58	2.37	2.90	3.16	2.55	2.99	3.16	2.85	3.04	3.16	2.99	3.07	3.16	2.74	3.02	3.16
074	0.55	2.4	0.04	1.89	2.39	2.59	2.37	2.91	3.17	2.55	2.99	3.17	2.84	3.04	3.17	2.98	3.06	3.17	2.74	3.02	3.17
075	0.54	2.4	0.04	1.89	2.39	2.59	2.37	2.90	3.16	2.54	2.99	3.16	2.84	3.03	3.16	2.98	3.06	3.16	2.73	3.02	3.16
076	0.56	2.5	0.04	1.89	2.39	2.59	2.38	2.92	3.17	2.56	3.00	3.17	2.85	3.04	3.17	2.99	3.07	3.17	2.75	3.03	3.17
077	0.62	2.6	0.04	1.89	2.39	2.59	2.39	2.95	3.20	2.60	3.03	3.20	2.88	3.07	3.20	3.02	3.10	3.20	2.81	3.06	3.20
078	0.53	2.4	0.04	1.89	2.39	2.59	2.36	2.90	3.16	2.54	2.99	3.16	2.83	3.03	3.16	2.97	3.05	3.16	2.72	3.01	3.16
079	0.48	2.3	0.04	1.89	2.39	2.59	2.35	2.88	3.13	2.51	2.96	3.13	2.81	3.00	3.13	2.95	3.03	3.13	2.67	2.99	3.13
080	0.44	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.11	2.48	2.94	3.11	2.77	2.98	3.11	2.93	3.01	3.11	2.63	2.97	3.11
081	0.42	2.1	0.04	1.89	2.39	2.59	2.33	2.84	3.10	2.46	2.93	3.10	2.73	2.97	3.10	2.92	3.00	3.10	2.61	2.96	3.10

Loc ID	100yrARI						Estuarine Planning Level (m)														
							Edge Treatment Type ##														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			1			2			3			4			5		
				Sea Level Rise Allowance (m)																	
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
082	0.36	2.0	0.04	1.89	2.39	2.59	2.31	2.82	3.07	2.43	2.90	3.07	2.67	2.94	3.07	2.89	2.97	3.07	2.55	2.93	3.07
083	0.31	1.8	0.04	1.89	2.39	2.59	2.29	2.79	3.05	2.39	2.87	3.05	2.59	2.91	3.05	2.86	2.94	3.05	2.50	2.90	3.05
084	0.29	1.8	0.04	1.89	2.39	2.59	2.29	2.79	3.04	2.38	2.86	3.04	2.58	2.91	3.04	2.85	2.93	3.04	2.48	2.89	3.04
085	0.29	1.8	0.04	1.89	2.39	2.59	2.29	2.79	3.04	2.38	2.86	3.04	2.58	2.91	3.04	2.85	2.93	3.04	2.48	2.89	3.04
086	0.33	1.9	0.04	1.89	2.39	2.59	2.30	2.80	3.06	2.41	2.88	3.06	2.63	2.93	3.06	2.87	2.95	3.06	2.52	2.91	3.06
087	0.39	2.0	0.04	1.89	2.39	2.59	2.31	2.82	3.09	2.44	2.91	3.09	2.69	2.96	3.09	2.90	2.98	3.09	2.58	2.94	3.09
088	0.40	2.1	0.04	1.89	2.39	2.59	2.32	2.83	3.09	2.46	2.92	3.09	2.72	2.96	3.09	2.91	2.99	3.09	2.59	2.95	3.09
089	0.44	2.2	0.04	1.89	2.39	2.59	2.34	2.86	3.11	2.48	2.94	3.11	2.77	2.98	3.11	2.93	3.01	3.11	2.63	2.97	3.11
090	0.53	2.4	0.04	1.89	2.39	2.59	2.36	2.90	3.16	2.54	2.99	3.16	2.83	3.03	3.16	2.97	3.05	3.16	2.72	3.01	3.16
091	0.50	2.3	0.04	1.89	2.39	2.59	2.35	2.88	3.14	2.52	2.97	3.14	2.82	3.01	3.14	2.96	3.04	3.14	2.69	3.00	3.14
092	0.52	2.4	0.04	1.89	2.39	2.59	2.36	2.90	3.15	2.54	2.98	3.15	2.83	3.02	3.15	2.97	3.05	3.15	2.71	3.01	3.15
093	0.58	2.5	0.04	1.89	2.39	2.59	2.38	2.92	3.18	2.57	3.01	3.18	2.86	3.05	3.18	3.00	3.08	3.18	2.77	3.04	3.18
094	0.58	2.5	0.04	1.89	2.39	2.59	2.38	2.92	3.18	2.57	3.01	3.18	2.86	3.05	3.18	3.00	3.08	3.18	2.77	3.04	3.18
095	0.56	2.5	0.04	1.89	2.39	2.59	2.38	2.92	3.17	2.56	3.00	3.17	2.85	3.04	3.17	2.99	3.07	3.17	2.75	3.03	3.17
096	0.52	2.4	0.04	1.89	2.39	2.59	2.36	2.90	3.15	2.54	2.98	3.15	2.83	3.02	3.15	2.97	3.05	3.15	2.71	3.01	3.15
097	0.49	2.3	0.05	1.90	2.40	2.60	2.36	2.89	3.15	2.52	2.97	3.15	2.82	3.01	3.15	2.95	3.03	3.15	2.69	3.00	3.15
098	0.49	2.3	0.05	1.90	2.40	2.60	2.36	2.89	3.15	2.52	2.97	3.15	2.82	3.01	3.15	2.95	3.03	3.15	2.69	3.00	3.15
099	0.48	2.3	0.05	1.90	2.40	2.60	2.36	2.89	3.14	2.52	2.97	3.14	2.81	3.01	3.14	2.95	3.03	3.14	2.68	2.99	3.14
100	0.45	2.2	0.05	1.90	2.40	2.60	2.35	2.87	3.13	2.49	2.95	3.13	2.79	2.99	3.13	2.93	3.01	3.13	2.65	2.98	3.13
101	0.40	2.1	0.05	1.90	2.40	2.60	2.33	2.85	3.10	2.47	2.93	3.10	2.73	2.97	3.10	2.91	2.99	3.10	2.60	2.95	3.10
102	0.37	2.0	0.05	1.90	2.40	2.60	2.32	2.83	3.09	2.44	2.91	3.09	2.69	2.95	3.09	2.89	2.97	3.09	2.57	2.94	3.09
103	0.34	1.9	0.05	1.90	2.40	2.60	2.31	2.82	3.07	2.42	2.90	3.07	2.64	2.93	3.07	2.88	2.96	3.07	2.54	2.92	3.07
104	0.33	1.9	0.05	1.90	2.40	2.60	2.31	2.81	3.07	2.42	2.89	3.07	2.64	2.93	3.07	2.87	2.95	3.07	2.53	2.92	3.07
105	0.29	1.8	0.05	1.90	2.40	2.60	2.30	2.80	3.05	2.39	2.87	3.05	2.59	2.91	3.05	2.85	2.93	3.05	2.49	2.90	3.05

Table F.4: 100yr ARI Planning Levels - 3mAHD Crest Level

**Edge Treatment Types**
1. 1 in 20 Natural Slope - 3mAHD crest
2. 1 in 10 Beach Face - 3mAHD crest
3. 1 in 5 Embankment - 3mAHD crest
4. 1 in 2 Seawall - 3mAHD crest
5. Vertical Wall - 3mAHD crest

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

100-year ARI Storm Tide at Fort Denison is **1.45mAHD** (excluding Sea Level Rise)
Mean Sea Level Rise Allowances taken from State and Federal Govt Policy and included within Table
Freeboard of 0.3m included within Table

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
							Sea Level Rise Allowance (m)														
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
001	0.26	1.7	0.11	1.96	2.46	2.66	2.35	2.85	3.05	2.43	2.93	3.13	2.61	3.11	3.30	3.09	3.35	3.38	2.52	3.02	3.22
002	0.28	1.8	0.10	1.95	2.45	2.65	2.35	2.85	3.05	2.44	2.94	3.14	2.63	3.13	3.31	3.15	3.36	3.39	2.53	3.03	3.23
003	0.33	1.9	0.10	1.95	2.45	2.65	2.36	2.86	3.06	2.47	2.97	3.17	2.69	3.19	3.33	3.30	3.38	3.41	2.58	3.08	3.28
004	0.36	2.0	0.09	1.94	2.44	2.64	2.36	2.86	3.06	2.48	2.98	3.18	2.72	3.22	3.35	3.31	3.39	3.43	2.60	3.10	3.30
005	0.43	2.2	0.09	1.94	2.44	2.64	2.38	2.88	3.08	2.53	3.03	3.23	2.82	3.31	3.38	3.35	3.43	3.46	2.67	3.17	3.34
006	0.40	2.1	0.09	1.94	2.44	2.64	2.37	2.87	3.07	2.51	3.01	3.21	2.77	3.27	3.37	3.34	3.41	3.45	2.64	3.14	3.32
007	0.40	2.1	0.09	1.94	2.44	2.64	2.37	2.87	3.07	2.51	3.01	3.21	2.77	3.27	3.37	3.34	3.41	3.45	2.64	3.14	3.32
008	0.36	2.0	0.09	1.94	2.44	2.64	2.36	2.86	3.06	2.48	2.98	3.18	2.72	3.22	3.35	3.31	3.39	3.43	2.60	3.10	3.30
009	0.36	2.0	0.09	1.94	2.44	2.64	2.36	2.86	3.06	2.48	2.98	3.18	2.72	3.22	3.35	3.31	3.39	3.43	2.60	3.10	3.30
010	0.37	2.0	0.08	1.93	2.43	2.63	2.35	2.85	3.05	2.47	2.97	3.17	2.72	3.22	3.35	3.32	3.40	3.43	2.60	3.10	3.30
011	0.43	2.1	0.08	1.93	2.43	2.63	2.37	2.87	3.07	2.51	3.01	3.21	2.78	3.28	3.37	3.35	3.43	3.46	2.66	3.16	3.33
012	0.43	2.1	0.08	1.93	2.43	2.63	2.37	2.87	3.07	2.51	3.01	3.21	2.78	3.28	3.37	3.35	3.43	3.46	2.66	3.16	3.33
013	0.36	2.0	0.08	1.93	2.43	2.63	2.35	2.85	3.05	2.47	2.97	3.17	2.71	3.21	3.34	3.31	3.39	3.42	2.59	3.09	3.29
014	0.30	1.8	0.07	1.92	2.42	2.62	2.32	2.82	3.02	2.42	2.92	3.12	2.61	3.11	3.31	3.18	3.36	3.39	2.52	3.02	3.22
015	0.34	1.9	0.07	1.92	2.42	2.62	2.33	2.83	3.03	2.44	2.94	3.14	2.66	3.16	3.32	3.30	3.38	3.41	2.56	3.06	3.26
016	0.38	2.0	0.07	1.92	2.42	2.62	2.34	2.84	3.04	2.47	2.97	3.17	2.71	3.21	3.34	3.32	3.40	3.43	2.60	3.10	3.30
017	0.34	1.9	0.07	1.92	2.42	2.62	2.33	2.83	3.03	2.44	2.94	3.14	2.66	3.16	3.32	3.30	3.38	3.41	2.56	3.06	3.26
018	0.36	2.0	0.07	1.92	2.42	2.62	2.34	2.84	3.04	2.46	2.96	3.16	2.70	3.20	3.34	3.31	3.39	3.42	2.58	3.08	3.28
019	0.36	2.0	0.07	1.92	2.42	2.62	2.34	2.84	3.04	2.46	2.96	3.16	2.70	3.20	3.34	3.31	3.39	3.42	2.58	3.08	3.28
020	0.34	1.9	0.07	1.92	2.42	2.62	2.33	2.83	3.03	2.44	2.94	3.14	2.66	3.16	3.32	3.30	3.38	3.41	2.56	3.06	3.26
021	0.46	2.2	0.07	1.92	2.42	2.62	2.37	2.87	3.07	2.52	3.02	3.22	2.82	3.31	3.39	3.36	3.44	3.47	2.68	3.18	3.34
022	0.52	2.4	0.07	1.92	2.42	2.62	2.39	2.89	3.09	2.57	3.07	3.27	2.91	3.34	3.42	3.39	3.47	3.50	2.74	3.24	3.37
023	0.36	2.0	0.07	1.92	2.42	2.62	2.34	2.84	3.04	2.46	2.96	3.16	2.70	3.20	3.34	3.31	3.39	3.42	2.58	3.08	3.28
024	0.30	1.8	0.07	1.92	2.42	2.62	2.32	2.82	3.02	2.42	2.92	3.12	2.61	3.11	3.31	3.18	3.36	3.39	2.52	3.02	3.22
025	0.39	2.1	0.06	1.91	2.41	2.61	2.34	2.84	3.04	2.47	2.97	3.17	2.73	3.23	3.35	3.33	3.40	3.44	2.60	3.10	3.30
026	0.48	2.3	0.06	1.91	2.41	2.61	2.37	2.87	3.07	2.53	3.03	3.23	2.85	3.32	3.39	3.37	3.45	3.48	2.69	3.19	3.35
027	0.41	2.1	0.06	1.91	2.41	2.61	2.34	2.84	3.04	2.48	2.98	3.18	2.75	3.25	3.36	3.34	3.42	3.45	2.62	3.12	3.31
028	0.34	1.9	0.06	1.91	2.41	2.61	2.32	2.82	3.02	2.43	2.93	3.13	2.65	3.15	3.32	3.30	3.38	3.41	2.55	3.05	3.25
029	0.31	1.8	0.06	1.91	2.41	2.61	2.31	2.81	3.01	2.41	2.91	3.11	2.61	3.11	3.30	3.20	3.36	3.40	2.52	3.02	3.22
030	0.29	1.8	0.06	1.91	2.41	2.61	2.31	2.81	3.01	2.40	2.90	3.10	2.60	3.10	3.30	3.14	3.35	3.39	2.50	3.00	3.20
031	0.34	1.9	0.06	1.91	2.41	2.61	2.32	2.82	3.02	2.43	2.93	3.13	2.65	3.15	3.32	3.30	3.38	3.41	2.55	3.05	3.25
032	0.37	2.0	0.06	1.91	2.41	2.61	2.33	2.83	3.03	2.45	2.95	3.15	2.70	3.20	3.34	3.31	3.39	3.43	2.58	3.08	3.28
033	0.41	2.1	0.06	1.91	2.41	2.61	2.34	2.84	3.04	2.48	2.98	3.18	2.75	3.25	3.36	3.34	3.42	3.45	2.62	3.12	3.31

Loc ID	100yrARI						Estuarine Planning Level (m)														
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)			Edge Treatment Type ##														
							1			2			3			4			5		
				Sea Level Rise Allowance (m)																	
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
034	0.36	2.0	0.05	1.90	2.40	2.60	2.32	2.82	3.02	2.44	2.94	3.14	2.68	3.18	3.33	3.31	3.39	3.42	2.56	3.06	3.26
035	0.33	1.9	0.06	1.91	2.41	2.61	2.32	2.82	3.02	2.43	2.93	3.13	2.65	3.15	3.32	3.27	3.37	3.41	2.54	3.04	3.24
036	0.35	2.0	0.06	1.91	2.41	2.61	2.33	2.83	3.03	2.45	2.95	3.15	2.68	3.18	3.33	3.30	3.38	3.42	2.56	3.06	3.26
037	0.51	2.3	0.06	1.91	2.41	2.61	2.37	2.87	3.07	2.54	3.04	3.24	2.87	3.33	3.41	3.39	3.47	3.50	2.72	3.22	3.36
038	0.54	2.4	0.06	1.91	2.41	2.61	2.39	2.89	3.09	2.56	3.06	3.26	2.91	3.34	3.42	3.40	3.48	3.51	2.75	3.25	3.38
039	0.74	2.9	0.05	1.90	2.40	2.60	2.45	2.95	3.15	2.70	3.20	3.37	3.20	3.45	3.53	3.50	3.58	3.61	2.94	3.37	3.47
040	0.74	2.9	0.05	1.90	2.40	2.60	2.45	2.95	3.15	2.70	3.20	3.37	3.20	3.45	3.53	3.50	3.58	3.61	2.94	3.37	3.47
041	0.70	2.8	0.05	1.90	2.40	2.60	2.43	2.93	3.13	2.67	3.17	3.35	3.14	3.43	3.50	3.48	3.56	3.59	2.90	3.35	3.45
042	0.60	2.6	0.06	1.91	2.41	2.61	2.41	2.91	3.11	2.61	3.11	3.31	3.01	3.38	3.46	3.43	3.51	3.54	2.81	3.31	3.41
043	0.54	2.4	0.06	1.91	2.41	2.61	2.39	2.89	3.09	2.56	3.06	3.26	2.91	3.34	3.42	3.40	3.48	3.51	2.75	3.25	3.38
044	0.55	2.4	0.05	1.90	2.40	2.60	2.38	2.88	3.08	2.56	3.06	3.26	2.91	3.34	3.42	3.41	3.48	3.52	2.75	3.25	3.38
045	0.46	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.49	2.99	3.19	2.79	3.29	3.37	3.36	3.44	3.47	2.65	3.15	3.33
046	0.44	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.48	2.98	3.18	2.77	3.27	3.37	3.35	3.43	3.46	2.63	3.13	3.32
047	0.47	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.49	2.99	3.19	2.79	3.29	3.38	3.36	3.44	3.47	2.66	3.16	3.33
048	0.59	2.5	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.57	3.07	3.27	2.96	3.36	3.44	3.42	3.50	3.54	2.78	3.28	3.39
049	0.57	2.5	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.57	3.07	3.27	2.94	3.36	3.43	3.41	3.49	3.53	2.76	3.26	3.38
050	0.51	2.3	0.04	1.89	2.39	2.59	2.35	2.85	3.05	2.52	3.02	3.22	2.85	3.32	3.40	3.38	3.46	3.49	2.70	3.20	3.35
051	0.48	2.3	0.04	1.89	2.39	2.59	2.35	2.85	3.05	2.51	3.01	3.21	2.83	3.31	3.39	3.37	3.45	3.48	2.67	3.17	3.34
052	0.45	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.48	2.98	3.18	2.78	3.28	3.37	3.35	3.43	3.46	2.64	3.14	3.32
053	0.42	2.1	0.04	1.89	2.39	2.59	2.33	2.83	3.03	2.46	2.96	3.16	2.73	3.23	3.35	3.34	3.42	3.45	2.61	3.11	3.31
054	0.37	2.0	0.04	1.89	2.39	2.59	2.31	2.81	3.01	2.43	2.93	3.13	2.68	3.18	3.33	3.31	3.39	3.42	2.56	3.06	3.26
055	0.42	2.1	0.04	1.89	2.39	2.59	2.33	2.83	3.03	2.46	2.96	3.16	2.73	3.23	3.35	3.34	3.42	3.45	2.61	3.11	3.31
056	0.39	2.0	0.04	1.89	2.39	2.59	2.31	2.81	3.01	2.44	2.94	3.14	2.69	3.19	3.34	3.32	3.40	3.43	2.58	3.08	3.28
057	0.33	1.9	0.04	1.89	2.39	2.59	2.30	2.80	3.00	2.41	2.91	3.11	2.63	3.13	3.31	3.25	3.37	3.40	2.52	3.02	3.22
058	0.34	1.9	0.04	1.89	2.39	2.59	2.30	2.80	3.00	2.41	2.91	3.11	2.63	3.13	3.31	3.28	3.38	3.41	2.53	3.03	3.23
059	0.37	2.0	0.04	1.89	2.39	2.59	2.31	2.81	3.01	2.43	2.93	3.13	2.68	3.18	3.33	3.31	3.39	3.42	2.56	3.06	3.26
060	0.47	2.2	0.03	1.88	2.38	2.58	2.33	2.83	3.03	2.48	2.98	3.18	2.78	3.28	3.37	3.36	3.44	3.47	2.65	3.15	3.33
061	0.55	2.4	0.03	1.88	2.38	2.58	2.36	2.86	3.06	2.54	3.04	3.24	2.89	3.34	3.41	3.40	3.48	3.51	2.73	3.23	3.37
062	0.50	2.3	0.03	1.88	2.38	2.58	2.34	2.84	3.04	2.51	3.01	3.21	2.83	3.31	3.39	3.38	3.46	3.49	2.68	3.18	3.34
063	0.53	2.4	0.03	1.88	2.38	2.58	2.35	2.85	3.05	2.53	3.03	3.23	2.88	3.33	3.41	3.39	3.47	3.50	2.71	3.21	3.36
064	0.64	2.7	0.03	1.88	2.38	2.58	2.40	2.90	3.10	2.61	3.11	3.31	3.04	3.39	3.47	3.45	3.53	3.56	2.82	3.31	3.41
065	0.65	2.7	0.03	1.88	2.38	2.58	2.40	2.90	3.10	2.62	3.12	3.31	3.05	3.40	3.47	3.45	3.53	3.56	2.83	3.32	3.42
066	0.63	2.6	0.03	1.88	2.38	2.58	2.39	2.89	3.09	2.59	3.09	3.29	3.00	3.38	3.46	3.44	3.52	3.55	2.81	3.31	3.41
067	0.62	2.6	0.03	1.88	2.38	2.58	2.38	2.88	3.08	2.59	3.09	3.29	3.00	3.38	3.45	3.44	3.52	3.55	2.80	3.30	3.40
068	0.54	2.4	0.04	1.89	2.39	2.59	2.37	2.87	3.07	2.54	3.04	3.24	2.89	3.34	3.42	3.40	3.48	3.51	2.73	3.23	3.37
069	0.49	2.3	0.04	1.89	2.39	2.59	2.35	2.85	3.05	2.51	3.01	3.21	2.83	3.31	3.39	3.37	3.45	3.48	2.68	3.18	3.34
070	0.36	2.0	0.04	1.89	2.39	2.59	2.31	2.81	3.01	2.43	2.93	3.13	2.67	3.17	3.33	3.31	3.39	3.42	2.55	3.05	3.25
071	0.47	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.49	2.99	3.19	2.79	3.29	3.38	3.36	3.44	3.47	2.66	3.16	3.33
072	0.54	2.4	0.03	1.88	2.38	2.58	2.36	2.86	3.06	2.53	3.03	3.23	2.88	3.33	3.41	3.40	3.48	3.51	2.72	3.22	3.36
073	0.56	2.5	0.03	1.88	2.38	2.58	2.37	2.87	3.07	2.55	3.05	3.25	2.93	3.35	3.43	3.41	3.49	3.52	2.74	3.24	3.37
074	0.55	2.4	0.04	1.89	2.39	2.59	2.37	2.87	3.07	2.55	3.05	3.25	2.90	3.34	3.42	3.40	3.48	3.52	2.74	3.24	3.37
075	0.54	2.4	0.04	1.89	2.39	2.59	2.37	2.87	3.07	2.54	3.04	3.24	2.89	3.34	3.42	3.40	3.48	3.51	2.73	3.23	3.37
076	0.56	2.5	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.56	3.06	3.26	2.94	3.35	3.43	3.41	3.49	3.52	2.75	3.25	3.38
077	0.62	2.6	0.04	1.89	2.39	2.59	2.39	2.89	3.09	2.60	3.10	3.30	3.01	3.38	3.46	3.44	3.52	3.55	2.81	3.31	3.41
078	0.53	2.4	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.54	3.04	3.24	2.89	3.33	3.41	3.39	3.47	3.50	2.72	3.22	3.36
079	0.48	2.3	0.04	1.89	2.39	2.59	2.35	2.85	3.05	2.51	3.01	3.21	2.83	3.31	3.39	3.37	3.45	3.48	2.67	3.17	3.34
080	0.44	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.48	2.98	3.18	2.77	3.27	3.37	3.35	3.43	3.46	2.63	3.13	3.32
081	0.42	2.1	0.04	1.89	2.39	2.59	2.33	2.83	3.03	2.46	2.96	3.16	2.73	3.23	3.35	3.34	3.42	3.45	2.61	3.11	3.31

Loc ID	Hs (m)	Tz (sec)	Local Wind Setup* (m)	100yrARI Design Water Level (mAHD)			Estuarine Planning Level (m) – Edge Treatment Type ## 1			2			3			4			5		
				Sea Level Rise Allowance (m)																	
				0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1	0.4	0.9	1.1
082	0.36	2.0	0.04	1.89	2.39	2.59	2.31	2.81	3.01	2.43	2.93	3.13	2.67	3.17	3.33	3.31	3.39	3.42	2.55	3.05	3.25
083	0.31	1.8	0.04	1.89	2.39	2.59	2.29	2.79	2.99	2.39	2.89	3.09	2.59	3.09	3.29	3.18	3.36	3.39	2.50	3.00	3.20
084	0.29	1.8	0.04	1.89	2.39	2.59	2.29	2.79	2.99	2.38	2.88	3.08	2.58	3.08	3.28	3.12	3.35	3.38	2.48	2.98	3.18
085	0.29	1.8	0.04	1.89	2.39	2.59	2.29	2.79	2.99	2.38	2.88	3.08	2.58	3.08	3.28	3.12	3.35	3.38	2.48	2.98	3.18
086	0.33	1.9	0.04	1.89	2.39	2.59	2.30	2.80	3.00	2.41	2.91	3.11	2.63	3.13	3.31	3.25	3.37	3.40	2.52	3.02	3.22
087	0.39	2.0	0.04	1.89	2.39	2.59	2.31	2.81	3.01	2.44	2.94	3.14	2.69	3.19	3.34	3.32	3.40	3.43	2.58	3.08	3.28
088	0.40	2.1	0.04	1.89	2.39	2.59	2.32	2.82	3.02	2.46	2.96	3.16	2.72	3.22	3.35	3.33	3.41	3.44	2.59	3.09	3.29
089	0.44	2.2	0.04	1.89	2.39	2.59	2.34	2.84	3.04	2.48	2.98	3.18	2.77	3.27	3.37	3.35	3.43	3.46	2.63	3.13	3.32
090	0.53	2.4	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.54	3.04	3.24	2.89	3.33	3.41	3.39	3.47	3.50	2.72	3.22	3.36
091	0.50	2.3	0.04	1.89	2.39	2.59	2.35	2.85	3.05	2.52	3.02	3.22	2.84	3.32	3.39	3.38	3.46	3.49	2.69	3.19	3.35
092	0.52	2.4	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.54	3.04	3.24	2.88	3.33	3.41	3.39	3.47	3.50	2.71	3.21	3.36
093	0.58	2.5	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.57	3.07	3.27	2.95	3.36	3.44	3.42	3.50	3.53	2.77	3.27	3.39
094	0.58	2.5	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.57	3.07	3.27	2.95	3.36	3.44	3.42	3.50	3.53	2.77	3.27	3.39
095	0.56	2.5	0.04	1.89	2.39	2.59	2.38	2.88	3.08	2.56	3.06	3.26	2.94	3.35	3.43	3.41	3.49	3.52	2.75	3.25	3.38
096	0.52	2.4	0.04	1.89	2.39	2.59	2.36	2.86	3.06	2.54	3.04	3.24	2.88	3.33	3.41	3.39	3.47	3.50	2.71	3.21	3.36
097	0.49	2.3	0.05	1.90	2.40	2.60	2.36	2.86	3.06	2.52	3.02	3.22	2.84	3.32	3.39	3.37	3.45	3.49	2.69	3.19	3.35
098	0.49	2.3	0.05	1.90	2.40	2.60	2.36	2.86	3.06	2.52	3.02	3.22	2.84	3.32	3.39	3.37	3.45	3.49	2.69	3.19	3.35
099	0.48	2.3	0.05	1.90	2.40	2.60	2.36	2.86	3.06	2.52	3.02	3.22	2.84	3.31	3.39	3.37	3.45	3.48	2.68	3.18	3.34
100	0.45	2.2	0.05	1.90	2.40	2.60	2.35	2.85	3.05	2.49	2.99	3.19	2.79	3.29	3.37	3.35	3.43	3.47	2.65	3.15	3.33
101	0.40	2.1	0.05	1.90	2.40	2.60	2.33	2.83	3.03	2.47	2.97	3.17	2.73	3.23	3.35	3.33	3.41	3.44	2.60	3.10	3.30
102	0.37	2.0	0.05	1.90	2.40	2.60	2.32	2.82	3.02	2.44	2.94	3.14	2.69	3.19	3.33	3.31	3.39	3.42	2.57	3.07	3.27
103	0.34	1.9	0.05	1.90	2.40	2.60	2.31	2.81	3.01	2.42	2.92	3.12	2.64	3.14	3.32	3.29	3.38	3.41	2.54	3.04	3.24
104	0.33	1.9	0.05	1.90	2.40	2.60	2.31	2.81	3.01	2.42	2.92	3.12	2.64	3.14	3.31	3.26	3.37	3.40	2.53	3.03	3.23
105	0.29	1.8	0.05	1.90	2.40	2.60	2.30	2.80	3.00	2.39	2.89	3.09	2.59	3.09	3.29	3.13	3.35	3.38	2.49	2.99	3.19

Table F.5: Estuarine Planning Levels

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only

* Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to Fort Denison Level

100-year ARI Storm Tide at Fort Denison is **1.45mAHD** (excluding Sea Level Rise)
Mean Sea Level Rise of **0.9m** included within Table
Freeboard of 0.3m included within Table

Loc ID	100yrARI				Estuarine Planning Level (m)			
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)	Crest Level			
					1.5mAHD	2mAHD	2.5mAHD	3mAHD
001	0.26	1.7	0.11	2.46	2.89	2.89	2.93	3.35
002	0.28	1.8	0.10	2.45	2.89	2.89	2.93	3.36
003	0.33	1.9	0.10	2.45	2.92	2.92	2.96	3.38
004	0.36	2.0	0.09	2.44	2.92	2.92	2.97	3.39
005	0.43	2.2	0.09	2.44	2.96	2.96	3.01	3.43
006	0.40	2.1	0.09	2.44	2.94	2.94	2.99	3.41
007	0.40	2.1	0.09	2.44	2.94	2.94	2.99	3.41
008	0.36	2.0	0.09	2.44	2.92	2.92	2.97	3.39
009	0.36	2.0	0.09	2.44	2.92	2.92	2.97	3.39
010	0.37	2.0	0.08	2.43	2.92	2.92	2.98	3.40
011	0.43	2.1	0.08	2.43	2.95	2.95	3.01	3.43
012	0.43	2.1	0.08	2.43	2.95	2.95	3.01	3.43
013	0.36	2.0	0.08	2.43	2.91	2.91	2.97	3.39
014	0.30	1.8	0.07	2.42	2.87	2.87	2.94	3.36
015	0.34	1.9	0.07	2.42	2.89	2.89	2.96	3.38
016	0.38	2.0	0.07	2.42	2.91	2.91	2.98	3.40
017	0.34	1.9	0.07	2.42	2.89	2.89	2.96	3.38
018	0.36	2.0	0.07	2.42	2.90	2.90	2.97	3.39
019	0.36	2.0	0.07	2.42	2.90	2.90	2.97	3.39
020	0.34	1.9	0.07	2.42	2.89	2.89	2.96	3.38
021	0.46	2.2	0.07	2.42	2.95	2.95	3.02	3.44
022	0.52	2.4	0.07	2.42	2.98	2.98	3.05	3.47
023	0.36	2.0	0.07	2.42	2.90	2.90	2.97	3.39
024	0.30	1.8	0.07	2.42	2.87	2.87	2.94	3.36
025	0.39	2.1	0.06	2.41	2.91	2.91	2.98	3.40
026	0.48	2.3	0.06	2.41	2.95	2.95	3.03	3.45
027	0.41	2.1	0.06	2.41	2.92	2.92	2.99	3.42
028	0.34	1.9	0.06	2.41	2.88	2.88	2.96	3.38
029	0.31	1.8	0.06	2.41	2.87	2.87	2.94	3.36
030	0.29	1.8	0.06	2.41	2.86	2.86	2.93	3.35
031	0.34	1.9	0.06	2.41	2.88	2.88	2.96	3.38
032	0.37	2.0	0.06	2.41	2.90	2.90	2.97	3.39
033	0.41	2.1	0.06	2.41	2.92	2.92	2.99	3.42
034	0.36	2.0	0.05	2.40	2.88	2.88	2.97	3.39
035	0.33	1.9	0.06	2.41	2.88	2.88	2.95	3.37
036	0.35	2.0	0.06	2.41	2.89	2.89	2.96	3.38
037	0.51	2.3	0.06	2.41	2.97	2.97	3.05	3.47
038	0.54	2.4	0.06	2.41	2.98	2.98	3.06	3.48
039	0.74	2.9	0.05	2.40	3.07	3.07	3.16	3.58
040	0.74	2.9	0.05	2.40	3.07	3.07	3.16	3.58
041	0.70	2.8	0.05	2.40	3.05	3.05	3.14	3.56
042	0.60	2.6	0.06	2.41	3.01	3.01	3.09	3.51
043	0.54	2.4	0.06	2.41	2.98	2.98	3.06	3.48
044	0.55	2.4	0.05	2.40	2.98	2.98	3.06	3.48
045	0.46	2.2	0.04	2.39	2.92	2.92	3.02	3.44
046	0.44	2.2	0.04	2.39	2.91	2.91	3.01	3.43
047	0.47	2.2	0.04	2.39	2.93	2.93	3.02	3.44
048	0.59	2.5	0.04	2.39	2.99	2.99	3.08	3.50
049	0.57	2.5	0.04	2.39	2.98	2.98	3.07	3.49
050	0.51	2.3	0.04	2.39	2.95	2.95	3.04	3.46
051	0.48	2.3	0.04	2.39	2.93	2.93	3.03	3.45
052	0.45	2.2	0.04	2.39	2.92	2.92	3.01	3.43
053	0.42	2.1	0.04	2.39	2.90	2.90	3.00	3.42
054	0.37	2.0	0.04	2.39	2.88	2.88	2.97	3.39
055	0.42	2.1	0.04	2.39	2.90	2.90	3.00	3.42
056	0.39	2.0	0.04	2.39	2.89	2.89	2.98	3.40
057	0.33	1.9	0.04	2.39	2.86	2.86	2.95	3.37
058	0.34	1.9	0.04	2.39	2.86	2.86	2.96	3.38
059	0.37	2.0	0.04	2.39	2.88	2.88	2.97	3.39
060	0.47	2.2	0.03	2.38	2.92	2.92	3.02	3.44
061	0.55	2.4	0.03	2.38	2.96	2.96	3.06	3.48
062	0.50	2.3	0.03	2.38	2.93	2.93	3.04	3.46
063	0.53	2.4	0.03	2.38	2.95	2.95	3.05	3.47
064	0.64	2.7	0.03	2.38	3.00	3.00	3.11	3.53

Loc ID	100yrARI				Estuarine Planning Level (m)			
	Hs (m)	Tz (sec)	Local Wind Setup* (m)	Design Water Level (mAHD)	Crest Level			
					1.5mAHD	2mAHD	2.5mAHD	3mAHD
065	0.65	2.7	0.03	2.38	3.01	3.01	3.11	3.53
066	0.63	2.6	0.03	2.38	3.00	3.00	3.10	3.52
067	0.62	2.6	0.03	2.38	2.99	2.99	3.10	3.52
068	0.54	2.4	0.04	2.39	2.96	2.96	3.06	3.48
069	0.49	2.3	0.04	2.39	2.94	2.94	3.03	3.45
070	0.36	2.0	0.04	2.39	2.87	2.87	2.97	3.39
071	0.47	2.2	0.04	2.39	2.93	2.93	3.02	3.44
072	0.54	2.4	0.03	2.38	2.95	2.95	3.06	3.48
073	0.56	2.5	0.03	2.38	2.96	2.96	3.07	3.49
074	0.55	2.4	0.04	2.39	2.97	2.97	3.06	3.48
075	0.54	2.4	0.04	2.39	2.96	2.96	3.06	3.48
076	0.56	2.5	0.04	2.39	2.97	2.97	3.07	3.49
077	0.62	2.6	0.04	2.39	3.00	3.00	3.10	3.52
078	0.53	2.4	0.04	2.39	2.96	2.96	3.05	3.47
079	0.48	2.3	0.04	2.39	2.93	2.93	3.03	3.45
080	0.44	2.2	0.04	2.39	2.91	2.91	3.01	3.43
081	0.42	2.1	0.04	2.39	2.90	2.90	3.00	3.42
082	0.36	2.0	0.04	2.39	2.87	2.87	2.97	3.39
083	0.31	1.8	0.04	2.39	2.85	2.85	2.94	3.36
084	0.29	1.8	0.04	2.39	2.84	2.84	2.93	3.35
085	0.29	1.8	0.04	2.39	2.84	2.84	2.93	3.35
086	0.33	1.9	0.04	2.39	2.86	2.86	2.95	3.37
087	0.39	2.0	0.04	2.39	2.89	2.89	2.98	3.40
088	0.40	2.1	0.04	2.39	2.89	2.89	2.99	3.41
089	0.44	2.2	0.04	2.39	2.91	2.91	3.01	3.43
090	0.53	2.4	0.04	2.39	2.96	2.96	3.05	3.47
091	0.50	2.3	0.04	2.39	2.94	2.94	3.04	3.46
092	0.52	2.4	0.04	2.39	2.95	2.95	3.05	3.47
093	0.58	2.5	0.04	2.39	2.98	2.98	3.08	3.50
094	0.58	2.5	0.04	2.39	2.98	2.98	3.08	3.50
095	0.56	2.5	0.04	2.39	2.97	2.97	3.07	3.49
096	0.52	2.4	0.04	2.39	2.95	2.95	3.05	3.47
097	0.49	2.3	0.05	2.40	2.95	2.95	3.03	3.45
098	0.49	2.3	0.05	2.40	2.95	2.95	3.03	3.45
099	0.48	2.3	0.05	2.40	2.94	2.94	3.03	3.45
100	0.45	2.2	0.05	2.40	2.93	2.93	3.01	3.43
101	0.40	2.1	0.05	2.40	2.90	2.90	2.99	3.41
102	0.37	2.0	0.05	2.40	2.89	2.89	2.97	3.39
103	0.34	1.9	0.05	2.40	2.87	2.87	2.96	3.38
104	0.33	1.9	0.05	2.40	2.87	2.87	2.95	3.37
105	0.29	1.8	0.05	2.40	2.85	2.85	2.93	3.35

Appendix G

Wave Runup Equations

Paramters:

H_s - significant wave height

T - wave period

H_o - deepwater wave height

L_o - deepwater wave length $\left(= gT^2/2\pi\right)$

s_{op} - deepwater wave steepness $\left(= H_o/L_o\right)$

α - slope angle

ξ_{op} - surf similarity parameter $\left(= \tan\alpha/\sqrt{s_{op}}\right)$

$R_{u2\%}$ - Run-up height exceeded by 2% of waves

R_c - freeboard

K_{TO} - Transmitted overtopping wave coefficient

H_{TO} - Transmitted overtopping wave height

SWL - Still water level

Wave run-up without overtopping

De Waal and van der Meer (1992)

$$\frac{R_{u2\%}}{H_s} = \begin{cases} 1.6\xi_{op} & for \quad 0.5 < \xi_{op} \le 2 \\ 3.2 & for \quad 2 < \xi_{op} \le 3-4 \end{cases}$$

$$Level = SWL + R_{u2\%}$$

Wave run-up with overtopping

Van der Meer and Janssen (1995)

$$K_{TO} = C\left(1.0 - {R_c}\big/{R_{u2\%}}\right)$$

where $C = 0.51$ for transmitted wave at the crest

$$H_{TO} = K_{TO} \times H_s$$

$$Level = SWL + H_{TO}$$

Wave overtopping when still water is above the crest

Public Works Department (1990)

$$Level = SWL + \frac{H_s}{2}$$

Wave overtopping of a vertical wall

$$Level = SWL + H_s$$