Cardno LawsonTreloar

Shaping the Future

St George Boat Club Marina

Coastal Processes Investigations

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Executive Summary

St George Motor Boat Club is seeking approval from the Department of Planning for the proposed re-development of their marina facilities in Kogarah Bay, NSW. The proposed development includes the authorisation of 23 existing berths and the construction of a new floating arm pontoon to the south of the existing marina footprint that would accommodate an additional 78 berths. No dredging is proposed as sufficient draught is currently available.

Cardno Lawson Treloar have been commissioned by Planning Ingenuity to provide Coastal Processes input for inclusion in the submission for approval. These coastal processes investigations have included wave climate investigations, hydrodynamic investigations and water quality investigations.

No measured wave data was available for the St George Motor Boat Club site; hence numerical wave modelling was required to develop a wave climate for marina analysis. The wave climate was derived from long-term measured wind data at Sydney Airport and hence includes extreme wind events.

Due to the orientation of the marina and its location, the most severe wave height cases occurring inside the marina are caused by westerly winds. Waves generated by these westerly winds are able to better penetrate through the marina entrances. The largest significant wave heights are found at the unprotected areas outside the western end of the marina wharves.

As a result the wave climate in the marina sits somewhere in between 'moderate' and 'good' as described by the Australian Standards Guidelines for design of marinas (AS3962). It should be noted, however, that the majority of berths satisfy the criteria of a good wave climate under AS3962.

Swell wave energy is not of particular concern at this site due to its locality. Including estimated diffraction effects, swell at the St George Motor Boat Club will not exceed 0.25m (H_s) at the 100-years ARI.

Hydrodynamic investigations were primarily concerned with morphological, sea bed and shoreline stability issues. Flood impacts were also considered. To do this a calibrated Delft3D hydrodynamic model was applied covering the whole of Botany Bay and the Georges River upstream to its tidal extent.

Changes in current speeds in and around the site were investigated, with no change in current speed identified. There are no existing shoreline or seabed instabilities at the site and hence the proposed development would not change this state. Furthermore, there has been no requirement for maintenance dredging at the site since the redevelopment of the marina in 2001. Current speeds in the vicinity of the marina are not strong enough to enable significant sediment transport at the seabed, and as a result significant maintenance dredging is unlikely to be required.

Flood flows from the Georges River were also investigated with no identifiable change identified as a result of the proposed development. Flood flows near the marina are also not capable of causing significant seabed transport. Sediment loads from the upper catchments were not included in these investigations; however, should these be an issue for maintenance dredging the proposed development would not exacerbate these processes.

Water Quality sampling was undertaken on two occasions at selected locations within the marina and together with previous sampling undertaken at the site provided a basic description of the background water quality. In general, the snapshot of the existing water quality undertaken for the site complies with the various guidelines and objectives for the Georges River.

Furthermore, the proposed marina development demonstrates excellent tidal flushing due to the floating nature of the majority of the facility. Maximum flushing times (e-folding times) are in the order of 3.5 hours which suggests that no accumulation of dissolved contaminants would occur within the expanded marina.

Overall, the expansion of the marina will have little effect on the existing coastal processes with no changes to the hydrodynamic, morphological and water quality being evident from the investigations. This report describes the study approach, data, model systems and results of these investigations.

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1 Introduction

Planning Ingenuity have been commissioned by St George Motor Boat Club to assist in the preparation of an application to the Department of Planning for proposed re-development of their marina facilities at San Souci, NSW. The proposed re-development includes an extension to the existing marina footprint, through the addition of a new marina arm which would accommodate 78 new berths. The application also seeks to gain authorisation for 23 existing berths.

As part of this application, a range of investigation requirements must be fulfilled, as specified by the Director General and the Department of Planning. Cardno Lawson Treloar have been engaged by Planning Ingenuity to undertake Coastal Processes Investigations in line with these requirements.

The scope of works defined under this engagement include:-

- Wave Climate Investigations, including assessment of the marina against AS3962 - Guidelines for Design of Marinas.
- Hydrodynamic Investigations, including morphological, bed and shoreline stability and flood impacts.
- Water Quality Investigations.

This report describes the study approach, data, model systems and results of these investigations.

Cardno Lawson Treloar, then Lawson & Treloar, has undertaken both wave climate (Lawson & Treloar, 2000) and natural processes (Lawson & Treloar, 2001) studies for input into the EIS that was prepared for the previous re-development of the marina in 2001. Where appropriate, findings from those studies will be utilised within these investigations.

Normal conventions are followed, namely that:-

- Wind and wave directions are coming from
- Currents are flowing towards.

Unless specified otherwise, all depths are specified to Chart Datum (CD), which is lowest astronomical tide (LAT) at Botany Bay.

Appendix A provides a description of relevant physical processes and Appendix B provides a glossary of terms.

2 Site Characteristics

The St George Motor Boat Club is located in Sans Souci on the south-eastern corner of Kogarah Bay, NSW; see Figure 2.1. This region lies at the downstream end of the Georges River where it enters Botany Bay.

As a result the marina facilities are exposed to a range of coastal processes including wind waves propagating from the south-east through west to north, swell wave energy, tidal currents and flood flows. The existing and proposed facilities are not protected by any breakwater structures and hence boats at-berth are simply protected by the floating pontoon structures that act as attenuators for local sea.

Two site visits were undertaken, on 20 October, 2009 and 17 November, 2009 by the study team. The shoreline perimeter of the marina area is formed of fully reflecting vertical sandstone walls. During the site visits it was observed that with a large number of vessels at berth most of the wave energy incident on the site was reflected/absorbed by the moored vessels, with little penetrating to the perimeter wall. Conditions in the marina were considered calm during these periods.

The proposed development includes the construction of a new floating arm to the south of the existing marina footprint that would accommodate 78 berths. The proposed marina layout is presented in Appendix C. No dredging is proposed as sufficient draught is currently available. Furthermore, there has been no requirement for maintenance dredging at the site since the redevelopment of the marina in 2001 (pers. comm. David Blyth – Vice President St George Motor Boat Club).

3 Data

A range of data items were required to describe the wave climate, hydrodynamic and water quality setting of the Georges River area, and to set up the numerical models applied to local wind-wave and hydrodynamic modelling.

3.1 Bathymetry

Bathymetric data from AUS Chart 198 was digitized to provide a basis for preparation of numerical wave model grids. Together with site specific hyrdo-survey undertaken for this project, covering the marina site, it provided sufficient resolution throughout the area for this study. The hydro-survey undertaken for this project is presented in Appendix D. It shows that depths in the marina are between 2.0m and 7.3m below AHD.

3.2 Water Levels

Australian National Tide Tables (2009) present tidal plane information based on analysis of long term water level data from Fort Denison. Tides in Sydney Harbour are described as predominantly semi-diurnal. Tides in Botany Bay, immediately downstream of Kogarah Bay, have similar levels, though there is a small phase lag behind Sydney tides. The tidal planes at Botany Bay are: -

Highest Astronomical Tide (HAT)	2.1m
Mean Higher High Water (MHWS)	1.5m
Mean Lower High Water (MHWN)	1.3m
Mean Higher Low Water (MLWN)	0.6m
Mean Lower Low Water (MLWS)	0.3m

Tidal plane levels are to tide datum (Lowest Astronomical Tide). AHD is approximately 0.93m above tide datum.

Meteorological phenomena cause water level variations from predicted astronomical tide in the order of 0.1m to 0.2m on a day-to-day basis. Based on analysis of long term water level data from Fort Denison, the peak storm surge water level at the 100-years average recurrence interval (ARI) is 1.5m AHD.

Due to its location, the site is also subject to flood flows from catchment discharges during high rainfall events. Review of the Georges River Flood Study suggests that a level of 1.6m AHD should be considered to allow for Georges River flood effects at the site.

Recently the Department of Planning, within the Draft NSW Coastal Planning Guideline: Adapting to Sea Level Rise, adopted the NSW Sea Level Rise Policy Statement (DECCW, 2009), that sets down climate change benchmarks for the 2050 and 2100 planning periods. These benchmarks are specified for the NSW coast as 0.4m (2050) and 0.9m (2100) above

1990 levels. Due to the nature of this development, a planning period to 2050 is considered to be appropriate and hence a sea level rise of 0.4m will be included in the coastal processes investigations.

Although rare, tsunami in the order of 0.8m height (crest to trough) have been observed at Fort Denison and were caused by Pacific Ocean seabed seismic activity near Chile. Wave period was in the order of 20 minutes. About six waves were observed. Similar tsunami could occur at this site.

3.3 Wind Data

Wind data is available from Mascot airport from 1939. The location and impact of airport development on wind recordings 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 Mascot airport wind speeds up to 16 August, 1994 and this adjustment was made for this study. Data to 31 December, 1997 was obtained from the Bureau of Meteorology.

Table E1 in Appendix E presents a description of wind speed and direction joint occurrence at Mascot. Note that calms occur for about 17% of the time. Wind speeds are in terms of 10-minute averages.

This data is suitable for local sea wave climate investigations in Botany Bay and Kogarah Bay.

3.4 Water Quality Data

Water quality data was collected at the site during these investigations to gain an appreciation of the background water quality in the marina. A series of samples were taken during each of the two site visits and were sent for laboratory analysis. Results of this testing is presented in Appendix F. Furthermore, water quality data was available from previous studies undertaken in 2001 (Lawson & Treloar, 2001). These results were included in this assessment. Further discussion on water quality within the marina is presented in Section 6.

3.5 Sediment Data

Seabed sediments from the site were examined by Fielder Engineers Pty Ltd (2001). Four samples were analysed for particle size distribution: two sites within the marina at two depths below the seabed at each of those two sites. On the basis of those analyses, there is a wide range of particle sizes at the site from gravel to clay. On average there is 5% of silt (0.002 to 0.02mm diameter) in the seabed sediments at the site. The sediment tests undertaken by Fielder Engineers did not encompass acid sulphate soil testing and were confined to the consideration of meeting guidelines for ocean disposal.

Further discussion on sea bed stability and morphology is presented in Section 7.

4 Wave Climate

No measured wave data was available for the St George Motor Boat Club site; hence numerical wave modelling was required to develop a wave climate for marina analysis. The wave climate was derived from long-term measured wind data at Sydney Airport applied to a numerical wave model, see Section 3.3, and hence includes extreme wind events.

4.1 SWAN Wave Model

The wave model system applied to this investigation was the SWAN model developed at the Delft University of Technology (2000). The model can provide full spectral solutions to third order and includes wind input, refraction, diffraction, shoaling, bed friction, white capping, wave breaking, the effect of currents and non-linear wave-wave interaction. It also includes obstacles that can be used to describe the effects of the pontoon breakwaters from their wave transmissivity characteristics - pre-determined by analytical or physical model tests.

It can be applied as a steady-state model for local sea developed from spatially and temporally constant winds and provides a very reliable basis for generating local sea. The model has been well verified by its authors and is considered to be one of the most reliable systems available at present. It is incorporated into the Delft3D modelling system developed by Delft Hydraulics. Wave breaking and white capping processes were 'turned-on' for this study.

For wind/wave modelling, a nested rectangular model grid setup was applied to this study. Three grids were developed in order to provide adequate spatial coverage while incorporating high refinement over the study site. Grid cell sizes ranged from 40m for the larger, coarser grid down to 1m for the local grid encompassing the marina area. Figure 4.1 presents the SWAN model grid system setup for this investigation.

To accurately assess conditions within the marina it is important to describe the effect of the floating pontoons on wave propagation. Due to the nature of the local wave climate the floating pontoons act as a partly transmissive breakwater that reduce the wave energy as the wave passes by. Waves propagating to the site will be blocked partially by the existing and proposed pontoons acting as wave attenuators. Wave transmission may occur by wave energy under-passing the pontoons or diffracting around of their ends. Wave transmission coefficients beneath the floating pontoons breakwaters were calculated externally and then the appropriate transmissivities included in the SWAN wave penetration modelling along the respective breakwater alignments. Wave diffraction was included in the SWAN wave modelling.

Wiegel (1964) developed a relationship to describe wave transmission beneath a screen (baffle wall or floating pontoon). That relationship was in terms of monochromatic waves.

Pierson and Cox (1989) investigated Wiegel's relationship in a wave flume, also using monochromatic waves. They showed that, for the range of water depths relevant to this project, Wiegel's relationship was realistic, but under-estimated the transmissivity by 5 to 10%.

Cardno Lawson Treloar have applied Wiegel's relationship to wave transmission in terms of a wave spectrum for the pontoons. That is, his monochromatic relationship was applied to each frequency of the incident wave spectrum and a transmission coefficient determined on the basis of transmitted H_s. The spectrum was described with a narrow peak (JONSWAP spectrum with $\gamma=4$) because there will be a very narrow band of wave periods at this short fetch site.

This spectral transmission approach has been applied to the present study and then checked by referring to the nearest available result from Pierson and Cox (1989). The transmission results then applied in the SWAN wave penetration model. Analyses have been undertaken for a very low tide (0m CD), at which level wave transmissivity (Kt) is greatest. Dimension of the existing floating pontoons was provided by the Boat Club, and it was advised that the new extension will be a replica of the existing outer (southern) pontoon. In line with this transmission coefficients (Kt) of 0.31 for the outer pontoons and 0.64 for the inner pontoons were adopted.

The effect on wave propagation is presented in Figure 4.2, which shows the reduction in wave heights as they penetrate into the marina area for an example south-westerly wave condition. In all, 43 locations throughout the marina were selected for wave model output, as shown in Figure 4.3.

4.2 SWAN Model Calibration

Wave model calibration provides confidence that the model system applied to this investigation will reproduce wave conditions at the marina reliably. The model has been calibrated for local sea in Botany Bay using Sydney airport wind data (which dates back to 1939) in depths similar to those used for this study, see Lawson and Treloar (2003). Due to the close proximity of the marina to the collection point of this data, no site specific characteristics required changing and so the SWAN model could be used at this site also with confidence.

4.3 Local Sea Wave Climate

The SWAN wave model was used to develop the wave 'climate' at 43 locations around and inside the marina study area (see Figure 4.3). Wave model simulations were undertaken at directional increments of 22.5º around the clock (that is, a 360º range) using wind speed increments of 2.5m/s from 0 to 30m/s. Model output comprised wave height (H_s) wave period (T_z) and mean direction at each location and for each simulated direction-wind speed case; a total of 208 wave model simulations in all.

This wave model output provided the basis for the development of wave climate descriptions at the marina site by transferring the time series of Sydney Airport wind data onto the matrix of SWAN model results. For each record, the wind speed and direction were applied to the matrix of model results in order to determine wave parameters by interpolation. Hence the wind data time series were converted to a 70 years wave parameter time series at selected marina locations.

The time series results were then examined to identify peak storm wave heights, which were then analysed using a statistical technique that included non-linear and maximum likelihood solution methods to calculate design values and confidence intervals. A particular feature of maximum likelihood method is the ability to reliably handle smaller data samples with large variance compared to alternative methods (for example, least squares methods).

Jointly occurring wave period parameters were then determined by correlation analysis. The results are presented in Table 4.1 for selected average recurrence intervals (ARI) from 1 to 100 years.

Table 4.1: Wave Climate Results

Output Location	ARI (years)											
	1		5		10		20		50		100	
	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)
1	0.29	1.76	0.34	1.86	0.36	1.89	0.37	1.93	0.39	1.96	0.41	2.00
2	0.30	1.78	0.34	1.86	0.36	1.89	0.37	1.93	0.39	1.96	0.40	1.98
3	0.40	1.98	0.49	2.18	0.51	2.24	0.54	2.29	0.57	2.36	0.59	2.42
4	0.28	1.73	0.35	1.88	0.37	1.91	0.39	1.97	0.42	2.03	0.43	2.06
5	0.29	1.76	0.36	1.90	0.38	1.93	0.39	1.97	0.42	2.03	0.43	2.06
6	0.20	1.55	0.25	1.66	0.27	1.70	0.29	1.74	0.30	1.78	0.32	1.81
7	0.26	1.69	0.32	1.81	0.33	1.83	0.35	1.87	0.36	1.90	0.38	1.94
8	0.28	1.73	0.33	1.84	0.35	1.87	0.36	1.91	0.39	1.96	0.41	2.00
9	0.26	1.69	0.29	1.75	0.31	1.79	0.32	1.80	0.32	1.82	0.33	1.83
10	0.41	2.00	0.50	2.22	0.53	2.28	0.56	2.34	0.59	2.42	0.62	2.47
11	0.19	1.53	0.24	1.64	0.25	1.66	0.27	1.70	0.28	1.71	0.29	1.75
12	0.28	1.73	0.35	1.88	0.37	1.91	0.38	1.95	0.41	2.01	0.43	2.04
13	0.34	1.84	0.42	2.03	0.44	2.08	0.47	2.14	0.49	2.20	0.52	2.25
14	0.27	1.71	0.33	1.84	0.35	1.87	0.36	1.91	0.39	1.96	0.41	2.00
15	0.28	1.73	0.34	1.86	0.36	1.89	0.37	1.93	0.39	1.96	0.41	2.00
16	0.29	1.76	0.34	1.86	0.35	1.87	0.36	1.91	0.38	1.94	0.40	1.98
17	0.40	1.99	0.50	2.21	0.53	2.27	0.55	2.33	0.59	2.40	0.61	2.46
18	0.27	1.71	0.34	1.86	0.36	1.89	0.37	1.93	0.39	1.96	0.41	2.00
19	0.28	1.73	0.35	1.88	0.37	1.91	0.38	1.95	0.41	2.01	0.43	2.04
20	0.27	1.71	0.34	1.86	0.37	1.91	0.38	1.95	0.41	2.01	0.43	2.04
21	0.26	1.69	0.31	1.79	0.33	1.83	0.35	1.87	0.36	1.90	0.37	1.92
22	0.27	1.71	0.32	1.81	0.34	1.85	0.36	1.89	0.37	1.92	0.39	1.96
23	0.26	1.69	0.31	1.79	0.33	1.83	0.35	1.87	0.36	1.90	0.38	1.94
24	0.30	1.78	0.36	1.90	0.38	1.93	0.40	1.99	0.42	2.03	0.43	2.06
25	0.40	1.99	0.50	2.21	0.53	2.27	0.55	2.33	0.59	2.40	0.61	2.46
26	0.23	1.62	0.29	1.75	0.30	1.76	0.32	1.80	0.33	1.84	0.35	1.88
27	0.24	1.64	0.30	1.77	0.32	1.81	0.34	1.85	0.35	1.88	0.37	1.92
28	0.28	1.73	0.34	1.86	0.36	1.89	0.37	1.93	0.39	1.96	0.41	2.00
29	0.36	1.89	0.44	2.07	0.46	2.13	0.49	2.19	0.52	2.26	0.55	2.31
30	0.24	1.64	0.29	1.75	0.31	1.79	0.33	1.83	0.34	1.86	0.36	1.90
31	0.24	1.64	0.28	1.73	0.30	1.76	0.31	1.78	0.32	1.82	0.33	1.83
32	0.23	1.62	0.27	1.71	0.29	1.74	0.30	1.76	0.31	1.80	0.32	1.81
33	0.25	1.67	0.29	1.75	0.30	1.76	0.32	1.80	0.33	1.84	0.34	1.86
34	0.33	1.82	0.37	1.92	0.39	1.96	0.40	1.99	0.42	2.03	0.43	2.06
35	0.25	1.67	0.32	1.81	0.34	1.85	0.36	1.89	0.38	1.94	0.40	1.98
36	0.27	1.71	0.33	1.84	0.36	1.89	0.37	1.93	0.40	1.99	0.42	2.02
37	0.43	2.05	0.51	2.22	0.53	2.28	0.56	2.33	0.59	2.41	0.60	2.44

Table 4.1 cont.: Wave Climate Results

Output Location	ARI (years) 1 Hs (m)	1 Tp (s)	5 Hs (m)	5 Tp (s)	10 Hs (m)	10 Tp (s)	20 Hs (m)	20 Tp (s)	50 Hs (m)	50 Tp (s)	100 Hs (m)	100 Tp (s)
38	0.24	1.64	0.30	1.77	0.32	1.81	0.34	1.85	0.35	1.88	0.37	1.92
39	0.23	1.62	0.27	1.71	0.29	1.74	0.30	1.76	0.31	1.80	0.32	1.81
40	0.47	2.14	0.55	2.31	0.57	2.36	0.60	2.42	0.62	2.47	0.64	2.52
41	0.53	2.28	0.66	2.57	0.70	2.66	0.74	2.74	0.79	2.85	0.83	2.93
42	0.55	2.31	0.69	2.63	0.73	2.72	0.77	2.81	0.82	2.93	0.86	3.01
43	0.54	2.30	0.68	2.62	0.73	2.71	0.77	2.80	0.82	2.91	0.86	3.00

Due to the orientation of the marina and its location, the most severe wave height cases occurring inside the marina are caused by south-westerly winds. Waves generated by these westerly winds are able to better penetrate through the marina entrances, that is, in between the floating pontoon ends with less interruption to the berths. The largest significant wave heights are found at the unprotected areas outside the western end of the marina wharves.

Comparison of the wave results to the Australian Standards Guidelines for design of Marinas (AS3962) allows for the qualitative assessment of the wave climate at the marina berths. Table 4.2 describes the conditions that define a 'good' marina wave climate.

Table 4.2: AS3962 Good Wave Climate Conditions

Direction and Peak Period of Design Harbour Wave	Significant Wave Height, Hs (m): Wave event exceeded once in 50 years	Significant Wave Height, Hs (m): Wave event exceeded once a year
Head Seas less than 2s	Conditions not likely to occur during this event	Less than 0.3m wave height
Head seas greater than 2s	Less than 0.6m wave height	Less than 0.3m wave height
Oblique seas greater than 2s	Less than 0.4m	Less than 0.3m wave height
Beam seas less than 2s	Conditions not likely to occur during this event	Less than 0.3m wave height
Beam seas greater than 2s	Less than 0.25m wave height	Less than 0.15m wave height

The largest 'design' waves, as presented in Table 4.1, would approach from the west and due to the orientation of the berths and the marina entrances would affect vessels at berth at an oblique angle. Therefore the conditions to achieve satisfactory wave conditions at berth are:-

- Less than 0.4m (seas greater than 2 seconds) for the 50-years ARI condition
- Less than 0.3m (seas greater than 2 seconds) for the 1-year ARI condition

Furthermore, CEM (2001 - page V-5-74) recommends that a wave height of 0.3m not be exceeded more than 10% of the time for small-craft harbours. Given that the 1-year ARI conditions correspond to the marina sea-state that occurs less than 0.1% of time, this condition is satisfied.

4.4 Swell Wave Climate

An analysis of long term offshore wave data from offshore Botany Bay provides the values presented in Table 4.3.

Table 4.3: Offshore Wave Climate

Average Recurrence Interval (years)	Offshore Peak Storm Hs (m)
20	9
50	10
100	10.5

Based on wave climate modelling undertaken for southern Botany Bay, a severe ocean storm (H_s offshore > 6.5m) may cause swell of height (H_s) in the order of 0.3m to propagate under the Captain Cook bridge. Including estimated diffraction effects, swell at the St George Motor Boat Club will then not exceed 0.25m (H_s) and 0.4m (H_{max}) at the 100-years ARI.

Based on Waverider buoy data recorded in Botany Bay in May, 1974 and May, 1997, T_p for swell at this site will be from 10 to 15 seconds. This result is considered to be reliable, based on confidence in the offshore wave climate and wave modelling procedures.

It is considered unlikely that long period waves (T>20 seconds) will affect these proposed facilities.

4.5 Boat Waves

This investigation has not addressed the potential impacts of boat waves. Although no ferries are known to pass close by this location, from time to time large vessels will cause boat waves of height in the order of 0.4m with a wave period in the order of 3 to 4 seconds.

It is possible that fast ferries may operate in the Georges River at a future date. These vessels cause longer period boat waves.

4.6 Wave Parameter Relationships

For structural design in the marine environment it may be necessary to define the H_{max} parameter related to storms having average recurrence intervals (ARI) of R 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 T_z.

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.

Note that extrapolation of extremal distributions does not include non-linear processes such as wave breaking, which tends to limit the maximum wave heights. Where the design waves are sufficiently large, wave breaking may limit wave heights at nearshore locations. Note that breaking wave heights are based on design storm tide levels.

The following parameter relationships are recommended: -

H_{max} = 1.87 x H_s
T_p = 1.4 x T_z
T_{Hs} = 1.3 x T_z
H_b = *0.85 x depth*

These maximum wave heights may exceed the breaking wave heights, in which case breaking wave height is adopted.

A JONSWAP peakedness parameter of 4 is recommended for the wave spectral shape, based on previous analyses of wave data in the region undertaken by Cardno Lawson Treloar (CLT, 2006).

5 Hydrodynamic Investigations

Hydrodynamic investigations at San Souci required the application of a high level model capable of simulating tidal and meteorological forcing. Previously Lawson and Treloar have undertaken numerical current modelling of Botany Bay and the Georges River. That model was based on the MIKE-21 modelling system using a 50m grid. The model was verified using data recorded for Sydney Ports Corporation. For the purposes of this study a numerical model was developed using the Delft3D modelling system. Similar model parameters to the calibrated MIKE-21 model were adopted.

5.1 Hydrodynamic Model Setup and Calibration

The Delft3D modelling system has been applied to water level, current and wave investigations at many international locations, as well as within Australia by Cardno Lawson Treloar – Port Botany (Sydney), Cairns Navy Base (Queensland), Gulf of Papua, 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.

A Delft3D model of the Georges River and Botany Bay was created using a curvilinear grid with resolution in the vicinity of the Marina of approximately 5m, see Figure 5.1. Forcing of the model was applied with a tidal time-series at the entrance to Botany Bay. The model was calibrated using water level data recorded by Manly Hydraulics Laboratory at Pulpit Point. This location can be seen in Figure 5.1. Comparison of water levels between recorded data and model output at this site can be seen in Figure 5.2. They show that the model setup performs well, providing good agreement with the measured data. Any discrepancies between the modelled and measured signals can be attributed to the model's description of the river bed and tributaries. Limited bed and depth information is available for the upper reaches of the estuary.

Nevertheless, the close agreement between the modelled and observed data provides assurance that the model adequately represents the hydrodynamics of the Georges River for the purposes of this study.

5.2 Tidal Hydraulics

A 2-weeks spring-neap tidal cycle was run in the calibrated Delft3D hydrodynamic model for both pre- and post- extension marina layouts.

5.2.1 Water Levels

The results show that the additional floating pontoon which would be part of the extension will have negligible effect on tidal levels at the site. Tidal planes are presented in Section 3.2.

5.2.2 Tidal Currents

Inspection of the tidal currents shows that the presence of floating pontoons causes a slight increase in drag on tidal currents and therefore a slight reduction in current speeds in the upper water column amongst the moored boats. Figure 5.3 presents a plan plot of tidal currents during an spring ebb tide. Comparison of the pre- and post- extension layouts, however, shows that the drag area provided by the additional floating pontoons is insignificant when compared with the drag area provided by the existing pontoons and moored boat hulls, and hence the impact on current speeds will be indiscernible. Currents at the seabed are not affected.

Peak current speeds (depth averaged) at the site are less than 0.1m/s and are likely to occur on the ebb tide. For design purposes, a current jointly occurring with waves having a speed of 0.1m/s is advised.

5.3 Tidal Flushing

The concept of tidal flushing refers to the rate of water exchange between waters within and outside the marina due to tidal flows. Quantitative investigations into flushing can be used to describe the likely character of water quality responses within a given area.

A simulation using the Delft3D model was undertaken with a tracer dispersed initially uniformly (concentration 100) over the entire water column throughout the extended marina footprint. The initial tracer concentration outside the investigation area; that is, within Kogarah Bay, was defined as zero.

The simulation was undertaken in 3D for a spring-neap tide cycle (14-days). No catchment flows were supplied to the models; that is, the flushing times determined by these analyses were maxima because catchment flows reduce flushing times by causing a net transport through an area.

Note that the outcome in terms of flushing times depends upon the initial model set up and distribution of tracer. Flushing times have been defined in terms of e-folding times. The e-folding time refers to the time taken for a tracer to reach 1/e or 0.3679 of its initial concentration. At any location in an estuary subject to dynamic equilibrium forcing, the concentration of a particular tracer can be described by Equation 5.1.

$$C_i = C_0 e^{-kt_i} \tag{5.1}$$

$$\begin{aligned} &where \\ &\quad C_i = \text{concentration at time i}, \\ &\quad C_0 = \text{initial concentration at time } 0, \\ &\quad t_i = \text{time i}, \\ &\quad k = \text{dispersion constant}, \end{aligned}$$

Following-on from Equation 5.1, k can be calculated by Equation 5.2.

$$k = \frac{\ln\left(\frac{C_i}{C_0}\right)}{-t_i} \tag{5.2}$$

The e-folding time is then the inverse of k shown in Equation 5.3.

$$e - fold = {}^{1}\!/_{k} \tag{5.3}$$

An e-folding time distribution has been calculated for the marina basin using Equations 5.2 and 5.3, and is presented in Figure 5.4 – depth averaged result.

Depth averaged output shows that the majority of the marina area displays e-folding times of less than 2 hours, with a maximum e-folding time of 3.2 hours. This outcome is to be expected as there are no significant barriers to tidal flows through the marina area. Even at the surface, where flushing would be inhibited by the floating pontoons, e-folding times are in the order of 4 hours (maximum). E-folding times in this order demonstrate an area of high turnover.

5.4 Flood Flows

Being at the downstream end of the Georges River, Kogarah Bay is periodically subject to river/estuarine flooding from large catchment run-off events. Information was sought form available sources, most notable the Georges River Flood Study that investigated flooding of the upper catchment area.

5.4.1 Water Levels

Review of the Georges River Flood Study (1991) suggests that a level of 1.6mAHD should be considered to allow for Georges River flood effects at the site.

5.4.2 Flood Currents

Discharge hydrographs for the 100-years ARI flood event were extracted from the Flood Study at a number of upper tributary locations. Where required, discharge information for catchments not encompassed by the flood study were scaled according to catchment size. These flows were then applied to the calibrated Delft3D hydrodynamic model to assess the magnitude of currents during major flood events. The peak of the flood was timed to occur with the ebbing tide, a worst case scenario in terms of current speeds.

The results show that although flows along the main channel are in the order 0.3-0.4m/s, at the marina site current speeds peak around 0.12m/s. This is due to the fact that the marina area is outside the main conveyance channel of the estuary.

6 Water Quality

The water quality at the site is affected by a number of sources in the area, as well as the hydraulic character of the site, as discussed in Section 5. To gain an indication of the water quality setting at the existing marina, two site inspections were undertaken and water quality samples collected for analysis.

Previous investigations (Lawson & Treloar, 2001) addressed water quality aspects of the marina development and noted a number of sources that contribute to the water quality at the marina site. Site visits undertaken for the current investigations endorsed those findings. In general, water quality at the site is affected by marina operation, local and regional sources. These are briefly discussed below.

6.1.1 Marina Operation

The environmental management plan for the marina (Golder Associates, 2009) identifies a number of marina activities and amenities that may influence water quality at the site. These include berthing, refuelling, wastewater pump-out, boat mechanics, workshop, the dual slipway, wastewater treatment plant and the boat ramp. Waste materials from these activities/amenities; including oil, fuel and paint spills, sewage and solid wastes discharges; are likely to be washed into the waters of the Bay. It is understood that these practices are the subject of a separate Environment Protection Licence and their management is addressed through an environmental management plan (Golder Associates, 2009).

Further to these on-site practices the application of anti-fouling paints and leaching of these anti-foulants from boat hulls can be significant. Investigations of seabed sediments at the site show slightly elevated levels of tributyltin.

It should also be noted that a wastewater treatment plant exists on sites, that collects and treats wastewater generated at the dual slipway, before any release into the river system.

6.1.2 Stormwater Run-off

Stormwater runoff from the local catchment, including the club house roof area, club carpark, local roads and surrounding residential area are likely to include sediments and associated attached pollutants, litter and oils. Five stormwater discharge points were identified within the vicinity of the marina, three within the confines of the marina area and two outside of the marina area, each respectively at either edge of the marina limits. The pipes are all 450mm in diameter and discharge generally above the mean high water mark.

Inspection of Sydney Water records demonstrated that the nearest sewer overflows are distant from the marina however; some sewer overflows exist within the local catchment. These overflows are unrelated to the marina itself and are the responsibility of Sydney Water.

6.1.3 Boat Discharges

While the existing marina facilities include a sewage pump-out facility, for general boating on the Georges River it is not compulsory for boats to be fitted with holding tanks for pump-out. If this facility is not utilised then any discharges by boat users that occur in the area of the marina are likely to compromise the water quality of the marina including sediments, faecal matter and dissolved pollutants.

6.1.4 Environmental Processes

Other influences to water quality can include:-

- biological processes occurring in the vicinity of the marina
- fluxing of pollutants from sediments in the vicinity of the marina
- movement and/or mobilisation of sediments and attached pollutants by boat wakes or tidal currents
- the passage of ebb and flood tides and freshwater flows bringing clean and contaminated waters into the general marina area. The contribution of these sources to the quality of the waters in the area is not affected by the marina development, see Section 5.

6.2 Field Sampling

To assist with quantifying the existing water quality for the site, two water samples were taken on two separate occasions. The first samples were taken on the 20 October, 2009 during dry conditions. That is there had been no significant rainfall for at least a week prior to the site visit. The second set of samples were taken on the 17 November, 2009 during wet conditions, that is, significant rainfall had fallen in the days prior to 17 November, 2009. The locations of this sampling are presented in Figure 6.1. Both sets of sampling were undertaken in the morning shortly after high water on an ebbing tide.

Physical water quality profiling was also undertaken on these days at approximately the same time, using a Hydrolab Datasonde 4a. These profiles were located to be roughly in-line with previous water quality sampling undertaken as part of Lawson and Treloar (2001), see 6.2.1 below.

Samples were collected in accordance with general procedures outlined in AS 5667 (1998) and forwarded with appropriate chain of custody forms to Australian Laboratory Services laboratories for analysis within 24 hours of the sample collection.

Results from the analytical and in-situ monitoring are summarised in Tables 6.1 (analytical) and Figure 6.2 (in-situ), together with appropriate water quality objectives and guidelines set for the area. Reference is made here to the ANZECC (2000) guidelines and the Water Quality Objectives for the Georges River (EPA, 2006). Note that in some cases the guideline or objective is currently set lower than the detection limit that can be achieved by laboratories. The certificate of analysis and original analysis sheets are provided in Appendix F.

6.2.1 Previous Water Quality Sampling

As part of previous investigations at the marina (Lawson & Treloar, 2001), water samples were taken on a representative day (1 March 2001) near high tide and low tide. These samples were drawn from the centre of the marina area from a floating pontoon. This is shown on Figure 6.1.

At the same time as the samples were drawn, in-situ profiling of physical water quality parameters (at the surface, at mid-depth and near the bed) was undertaken using a Hydrolab Datasonde 4a. In addition, profiles were undertaken around the perimeter of the site at five other locations on an ebbing tide. These locations are also marked on Figure 6.1.

At the time as the high tide samples were drawn, it was raining lightly with no apparent runoff generated from the immediate catchment. It was overcast, but not raining when the low tide samples were collected. There had been rainfall in the Georges River catchment on the day prior to the sampling. These results are presented alongside the current water quality sampling in Tables 6.1 (analytical) and Figure 6.2 (in-situ).

6.2.2 Interpretation of Water Quality Results

The overall snapshot of water quality at the marina site complies with the various guidelines and objectives for the Georges River. Many of the guidelines and objectives have been prepared for the assessment of a longer term time series of data as compared with the limited data points basis available for this assessment. However, the data indicate that the marina is currently having minimal to no impact with regard to most parameters.

Previous investigations, in 2001, noted that oil/petrochemicals were present (visual observation) on the surface. This was thought most likely to be a result of leakage from the fuel storage. The presence of any such oil/petrochemical was not observed in recent observations and analysed samples did not show any significant presence of these substances.

Concentrations of Lead and Zinc were previously found to be above guidelines. Sediment analysis by Fielder Engineers (2001) for this assessment did not detect levels of Zinc or Lead that exceeded sediment quality guidelines and hence the likely source being the presence of anti-foulant and paint products. The sampling undertaken for this investigation did not show any elevated concentrations of either Zinc or Lead. It is thought that the on-site wastewater treatment plant has alleviated these concerns by redirecting wastewater from the slipway.

Total Phosphorous is shown to be above the ANZECC (2000) triggers levels for estuarine environments, although when considering values for lowland rivers these concentrations are not of concern. These levels were consistent across all monitoring and hence it is likely that a regional source of phosphorous, that is, not site specific, is the cause of these levels. Total Nitrogen was shown to exceed trigger levels on 2 of the 3 sampling occasions. It is worth noting that on these occasions sampling was undertaken in 'wet' conditions. During dry conditions Total Nitrogen levels were below that of detection. Preliminary conclusions suggest that storm water run-off is the cause of elevated nitrogen levels and therefore thought to be short-lived following rainfall events.

Inspection of the physical water quality results, see Figure 6.2, shows that generally all parameters are within ANZECC Guideline for estuarine waters. On occasion values of Dissolved Oxygen and Turbidity exceeded these values although these results are thought to be isolated short-lived events.

6.3 Post-development Water Quality

Given the existing water quality assessment it is considered that the marina facility currently has very little effect on the water quality within the marina area. The proposed marina expansion does not include any significant changes to the operation of much of the marina facilities. Operations such as re-fuelling, sewage pump-out, slipway operation and dry dock activities will remain unchanged. Hence, on these bases potential contaminant loads will not change noticeably. As a result, the proposed marina expansion will not have any significant effect on the existing water quality in the marina, which is considered good.

Table 6.1: Analytical Water Quality Testing Results

Analyte grouping / Analyte	Units	LOR	20-Oct-09		17-Nov-09		01-Mar-01		ANZECC 1999 Guidelines/Water Quality Objectives for the Georges River (EPA, 2006)	
			Site S1	Site S2	Site S1	Site S2	High tide	Low tide	Trigger Value	Note
Arsenic	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	<0.01	<0.01	*0.0023, 0.0045*	(As III, As V)
Chromium	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	0.002	0.002	*0.0077, 0.014*	(Cr III, Cr VI)
Lead	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	0.002	0.002	*0.007*	99% protection
Nickel	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	0.006	0.006	*0.0022*	99% protection
Zinc	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	0.014	0.012	*0.007*	99% protection
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	*0.0001*	99% protection
Ammonia as N	mg/L	0.01	<0.10	<0.10	<0.10	<0.10	0.03	0.02	*0.5*	
Nitrite + Nitrate as N	mg/L	0.01	0.01	0.02	<0.01	0.02	0.07	0.05	*0.7*	Guideline for Nitrate only
Total Kjeldahl Nitrogen as N	mg/L	0.1	<0.1	<0.1	2.9	0.1	0.4	0.4	-	
Total Nitrogen as N	mg/L	0.1	<0.1	<0.1	2.9	0.2	0.5	0.5	*0.3*	
Total Phosphorus as P	mg/L	0.01	0.07	0.05	0.06	0.04	0.04	0.04	*0.03*	
Oil & Grease	mg/L	5	<5	<5	<5	<5	<5	<5	-	Guideline is confined to no visible oil and grease.
TPH	µg/L	50	<50	<50	<50	<50	<5000	<5000	-	Guideline is confined to no visible oil and grease.
Faecal Coliforms	CFU / 100mL	1	<2	<2	~4	~2	2	2	*150*	Median bacterial content of < 150 counts per 100 mL for Primary Contact, < 1000 for Secondary Contact Recreational
Enterococci	CFU / 100mL	1	<2	~2	~2	~8	44	64	*35*	Maximum number in any one sample bacterial content of 60 - 100 organisms per 100 mL for Primary Contact, 450 - 700 for Secondary Contact Recreational

7 Morphological Investigations

Being a river estuary, it is generally understood that the system is a natural area of siltation. The major source of sediments would be from catchment flows and hence siltation would generally be located around major creek/tributary inlets. For this sediment to progress much further into the estuary it must be able to be shifted by the prevailing flood and tidal currents.

Seabed sediments from the site were analysed for particle size distribution examined by Fielder Engineers Pty Ltd (2001), Section 3.5. Those analyses found that there is a wide range of particle sizes at the site from gravel to clay. On average there is 5% of silt (0.002 to 0.02mm diameter) in the seabed sediments at the site.

In order for there to be significant morphological change at the sea bed, current speeds must exceed the threshold speed for initiation of sediment movement. This is normally about 0.3m/s, which does not occur in Kogarah Bay from either tidal or flood flows.

The extension has been designed so that there currently exists sufficient draught for moored vessels and hence no dredging is proposed as part of the marina extension. Furthermore, there has been no requirement for maintenance dredging at the site since the redevelopment of the marina in 2001 (pers. comm. David Blyth – Vice President St George Motor Boat Club). That redevelopment included the dredging of the berthing area which has provided uninterrupted navigable depths since that time.

There is some anecdotal evidence that siltation has occurred at the site in the past. Prior to the redevelopment of the marina in 2001, some pontoons at the Boat Club sat on the seabed at low tide (pers. comm. P D Treloar - Mr Terry Cox, former Vice-President St George Motor Boat Club). This would have not been the case some ten years prior when they were designed and installed. During this time, however, the estuary has undergone significant changes in catchment and storm water management (refer to the Georges River Combined Councils' Committee) and hence sediment loads from the catchments are likely to have been reduced in recent years.

Large catchment flood flows are likely to carry with them significant sediment loads. No information about the magnitude of these loads was available and hence did not form part of these investigations. Sediment loads from the upper catchments were not included in the simulation discussed in Section 5.4; however, should these be an issue for maintenance dredging the proposed development would not exacerbate these processes.

7.1 Changes to Sea Bed Morphology

Hydrodynamic investigations see Section 5, showed that the marina extension will not cause any discernable change to either water levels or current speeds in the vicinity of the marina area. Furthermore, prevailing tidal and flood flow currents do not exceed thresholds for the initiation of sediment. Coupled with the fact that no dredging will be undertaken it can be assumed that the marina extension will have no influence on the existing sea bed morphology.

To confirm this conclusion a Delft3D hydrodynamic simulation with sediment transport module was undertaken over a spring neap tidal cycle. Delft3D allows the application a morphological acceleration factor (morfac) that allows greater length of bed changes to be simulated from shorter periods of hydrodynamics. For this simulation a morfac of 12 was adopted that allowed the simulation of approximately 6 months of bed change from 2 weeks of tides.

The outcome, in terms of bed change, shows that little to no bed change would occur as a result of tidal currents.

7.2 Contaminated Sediments

No testing of contaminated sediments was undertaken as part of these investigations. Previously, sediment tests undertaken by Fielder Engineers considered the appropriateness of the proposed dredged spoil for ocean disposal.

The results of the sediment testing showed that sediment from the site is free from major contamination. With the exception of tributlytin (TBT), concentrations of all contaminant parameters were below ANZECC guidelines. TBT is an organic substance commonly found in antifouling paint and although above ANZECC screening levels, is well below the ANZECC contamination guide levels (Fielder Engineers, 2001).

The testing did not encompass acid sulphate soil testing. In light of the fact that no capital dredging is to occur this is thought to not be required, although should it be deemed appropriate, acid sulphate soil testing should be carried out in accordance with the relevant guidelines. The pH of the waters indicates that there are no actual acid sulphate soils, however, the high salinity may be buffering any changes in pH as a result of actual acid sulphate soils. Furthermore Fielder Engineers (2001) note that without the presence of decomposable material in the sediment samples, acid sulphate conditions are unlikely to be present.

Overall, sediment contamination is considered low and there would be minimal risk to overall water quality should the seabed in the vicinity of the marina be disturbed.

8 Concluding Remarks

This report has summarised the methodology and findings of Coastal Processes Investigations undertaken as part of a re-development application for the St George Motor Boat Club. The proposed re-development includes an extension to the existing marina footprint, through the addition of a new marina arm which would accommodate 78 new berths. Furthermore the application seeks to gain authorisation for 23 existing marina berths.

Cardno Lawson Treloar were commissioned by Planning Ingenuity to provide Coastal Processes input for inclusion in the submission for approval. These coastal processes investigations have included wave climate investigations, hydrodynamic investigations and water quality investigations.

Wave climate investigations have shown that the marina is classified as having a 'moderate' to 'good' wave climate as described by the Australian Standards Guidelines for design of marinas (AS3962). It should be noted, however, that the majority of berths satisfy the criteria of a good wave climate under AS3962.

Hydrodynamic and morphological investigations have shown that current speeds in the vicinity of the marina are not strong enough to enable significant sediment transport at the seabed, and as a result significant maintenance dredging is unlikely to be required. There are no existing shoreline or seabed instabilities at the site and hence the proposed development would not change this state.

Water Quality sampling was undertaken on two occasions at selected locations within the marina and together with previous sampling undertaken at the site provided a basic description of the background water quality. In general, the snapshot of the existing water quality undertaken for the site complies with the various guidelines and objectives for the Georges River.

Following the range of coastal processes investigations undertaken it is considered that the expansion of the marina will have little effect on the existing coastal processes with no changes to the hydrodynamic, morphological and water quality setting being likely.

9 References

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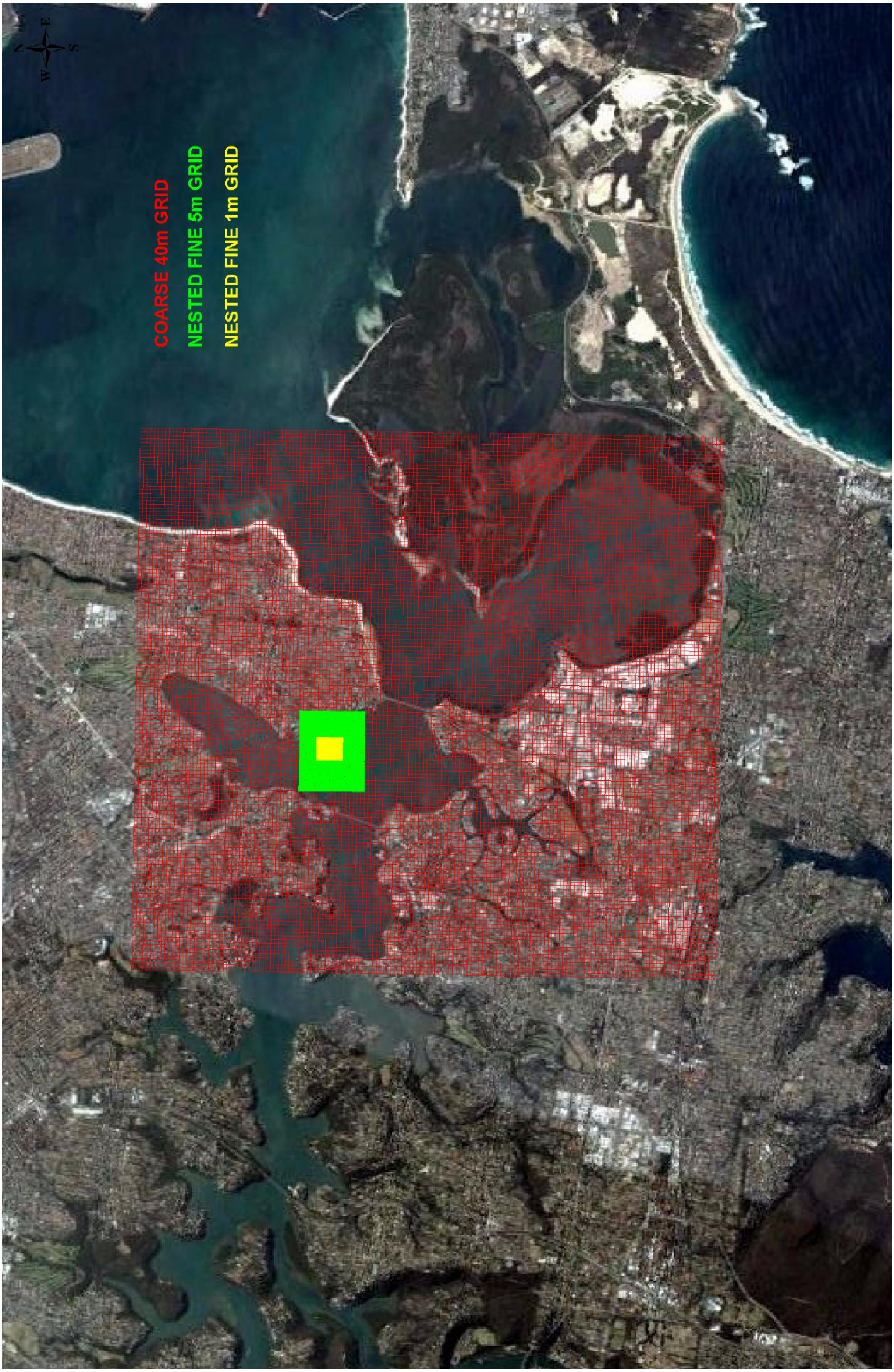
St George Boat Club Marina – Coastal Processes Investigations

LOCALITY PLAN

Figure 2.1



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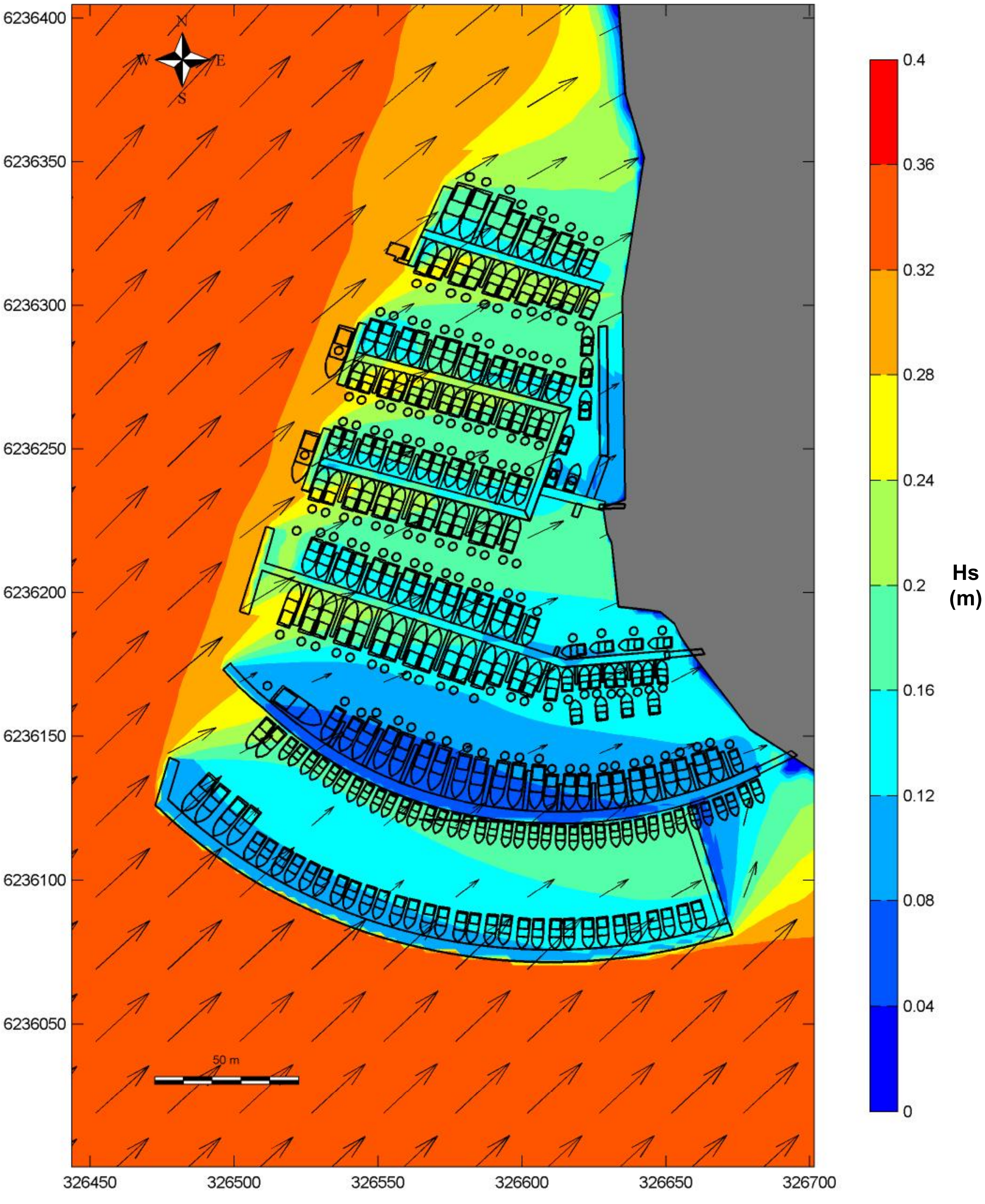
St George Boat Club Marina – Coastal Processes Investigations

SWAN MODEL GRID SETUP

Figure 4.1



WAVE PENETRATION EXAMPLE
Wind Speed =15m/s, Dir = 225degTN
Figure 4.2

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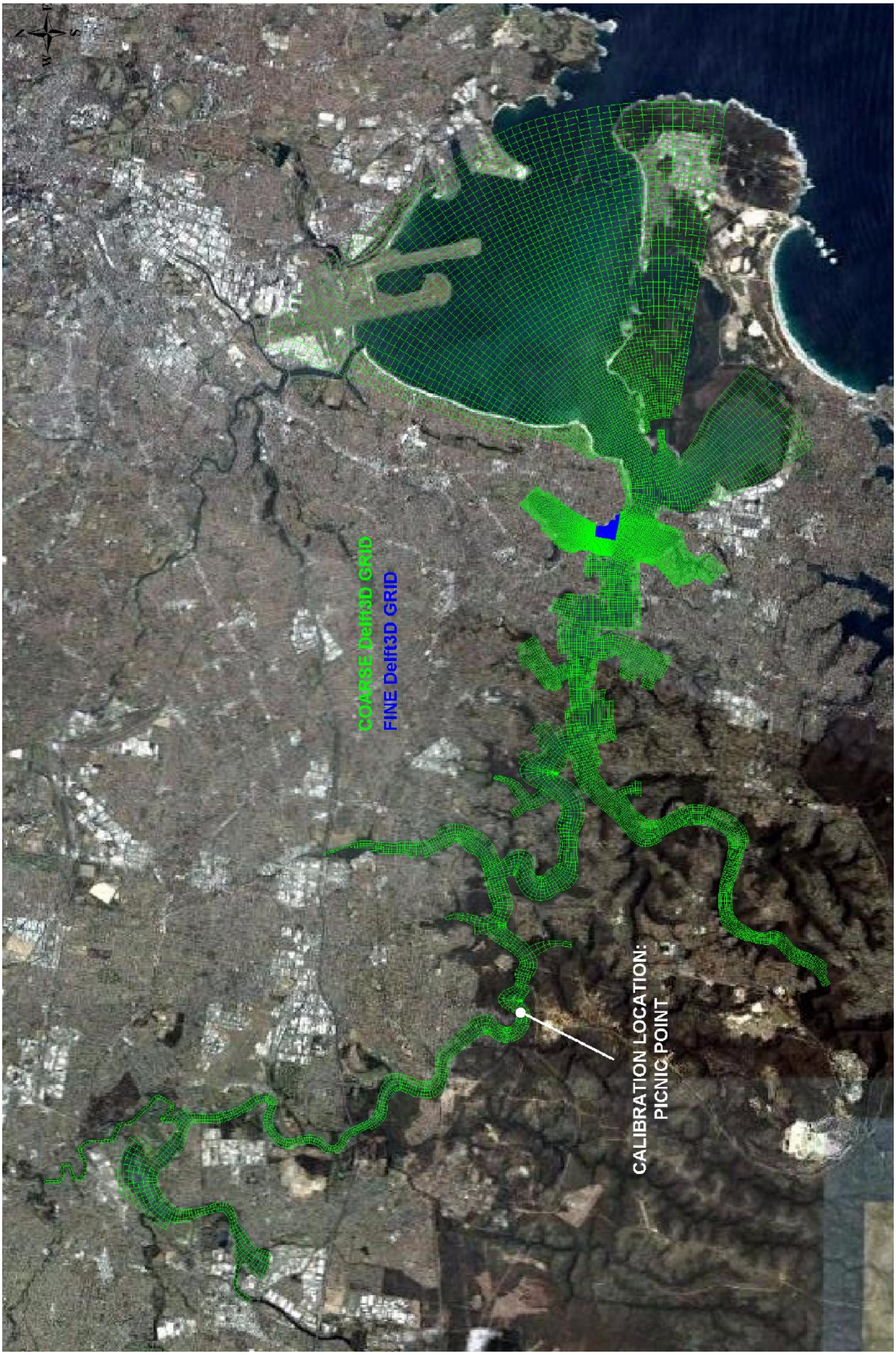
St George Boat Club Marina – Coastal Processes Investigations

SWAN MODEL OUTPUT LOCATIONS

Figure 4.3



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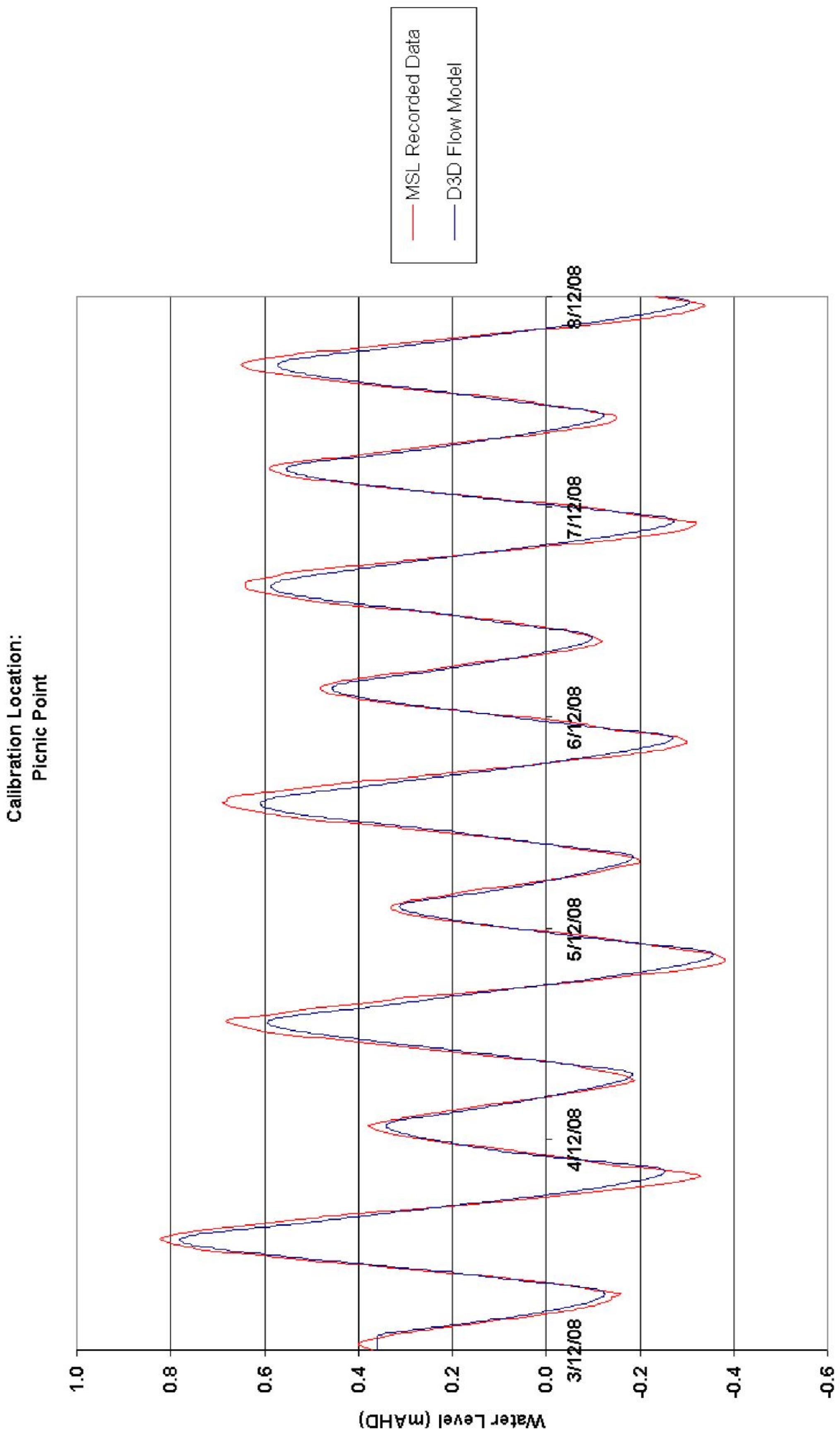
St George Boat Club Marina – Coastal Processes Investigations

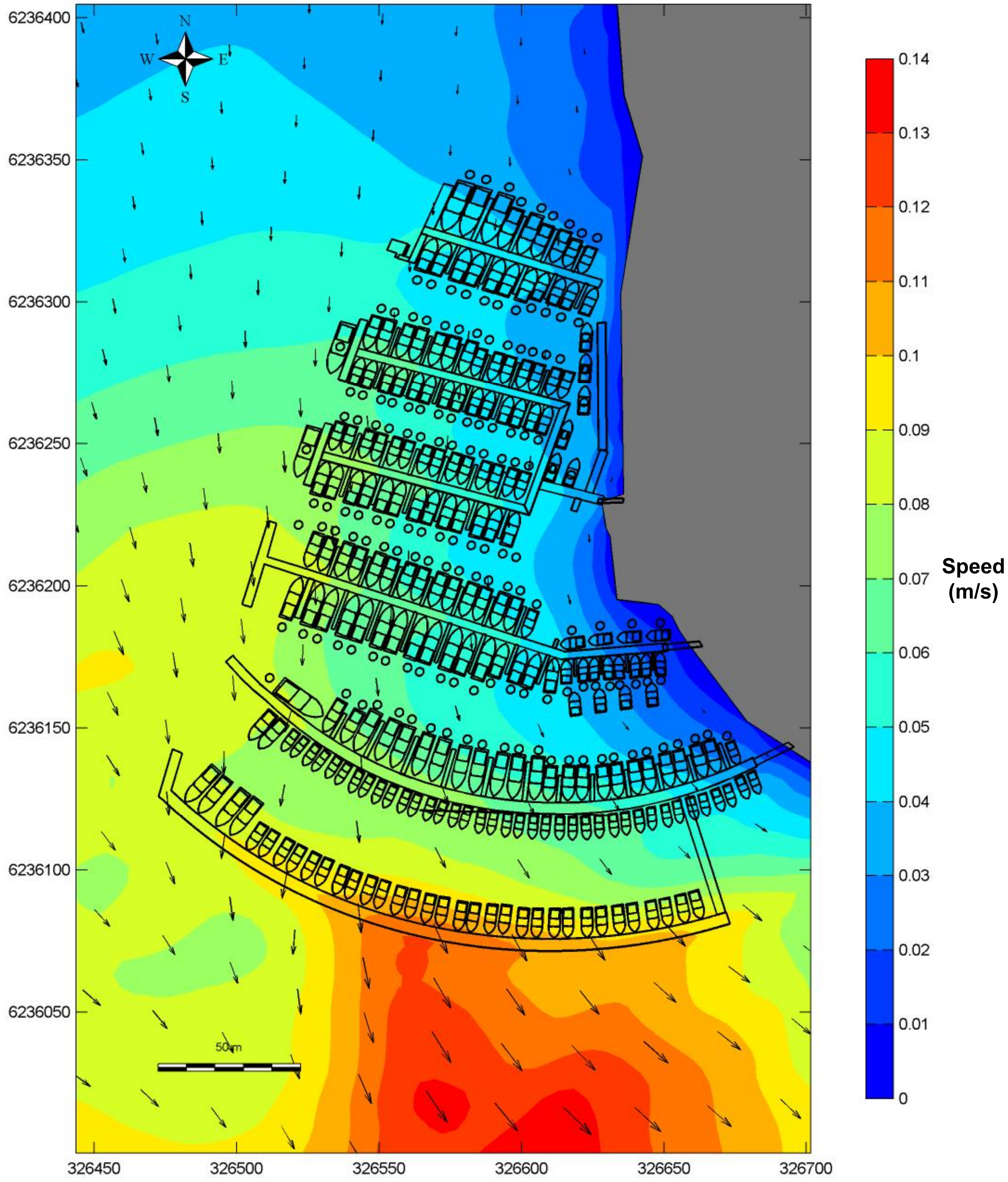
DELFT3D MODEL GRID SETUP

Figure 5.1



DELFT3D HYDRODYNAMIC CALIBRATION

Figure 5.2



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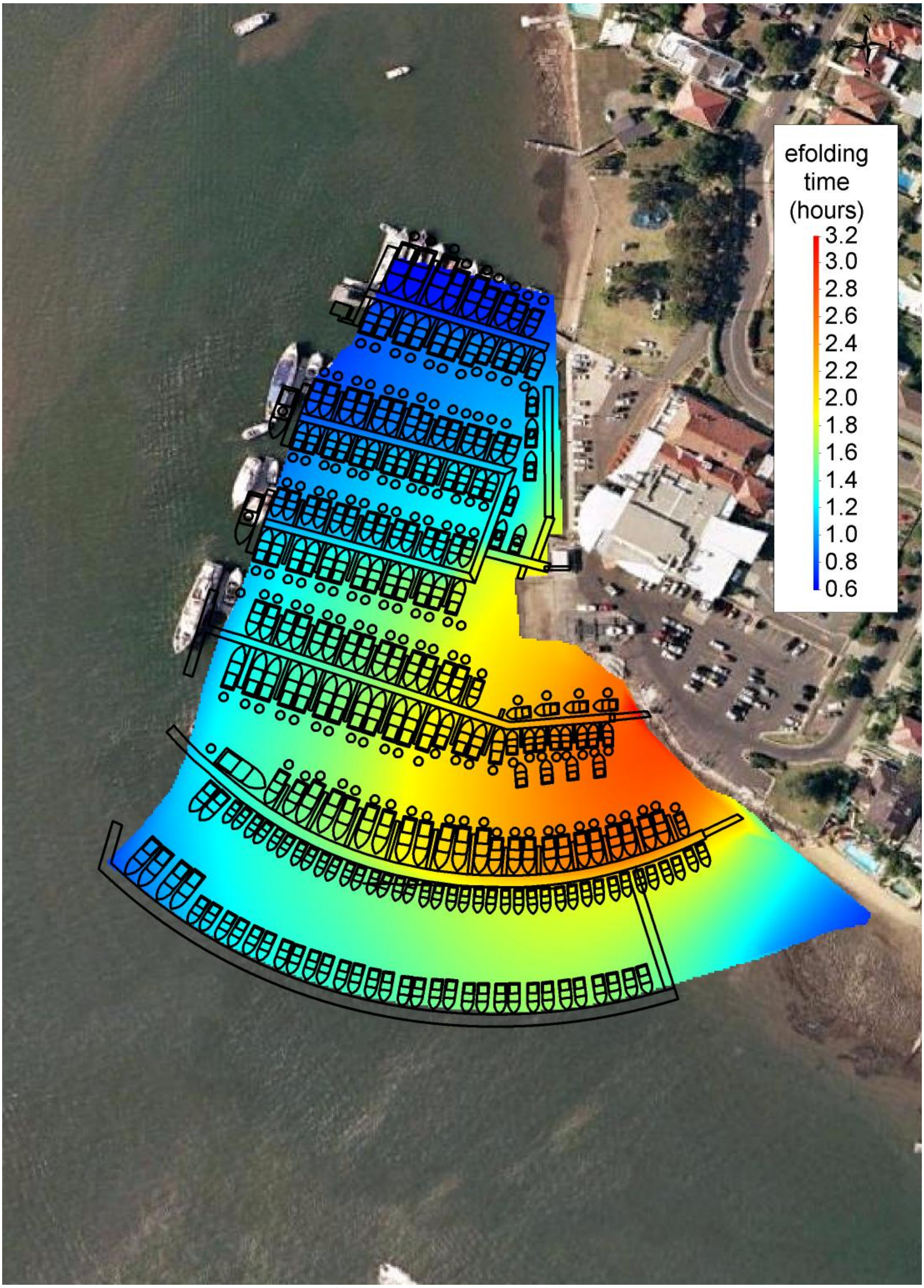
St George Boat Club Marina – Coastal Processes Investigations

SPRING TIDE CURRENTS – EBB TIDE

Figure 5.3



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St George Boat Club Marina – Coastal Processes Investigations

MARINA FLUSHING – e-FOLDING TIME

Figure 5.4

St George Boat Club Marina – Coastal Processes Investigations

WATER QUALITY SAMPLING LOCATIONS

Figure 6.1

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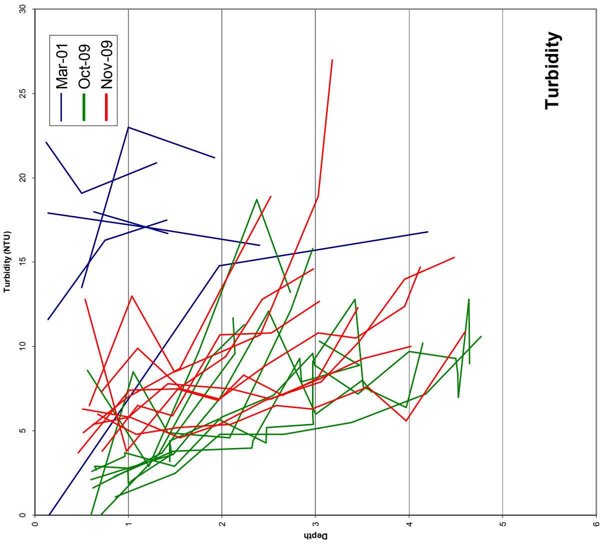

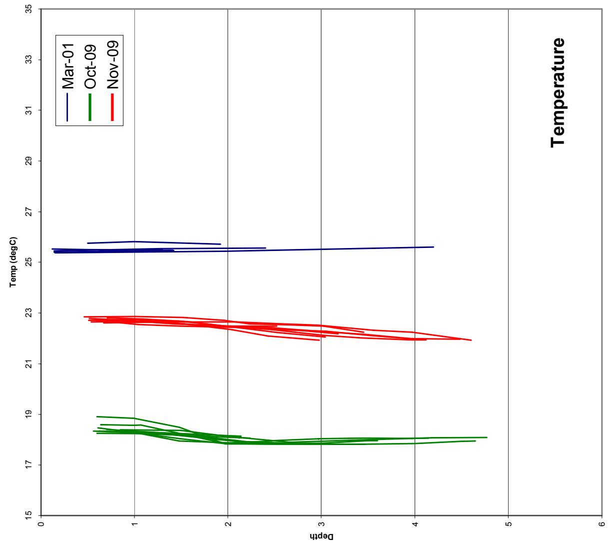

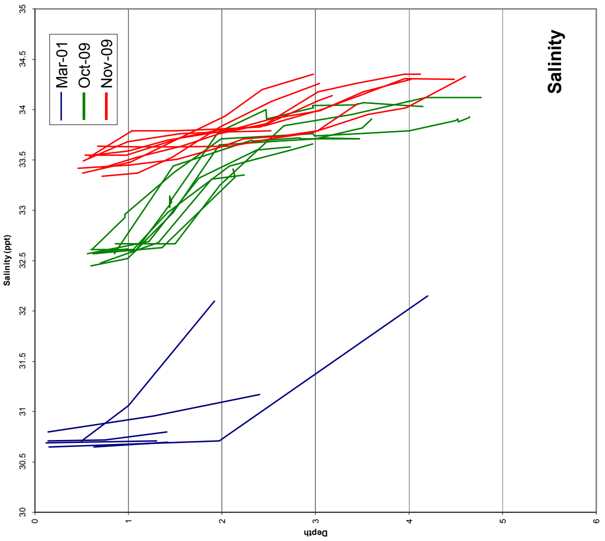

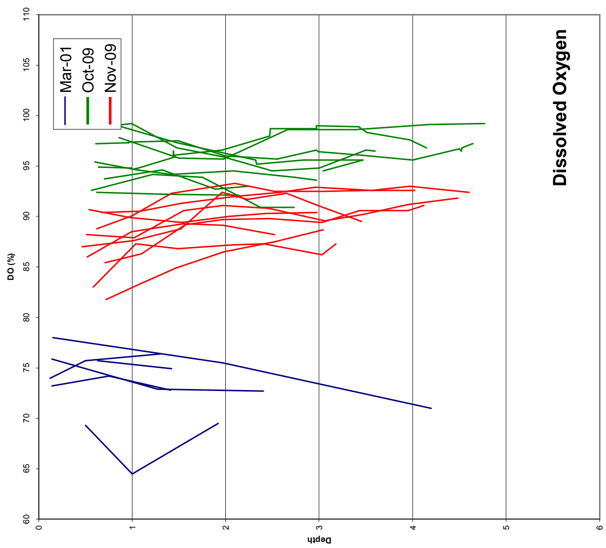

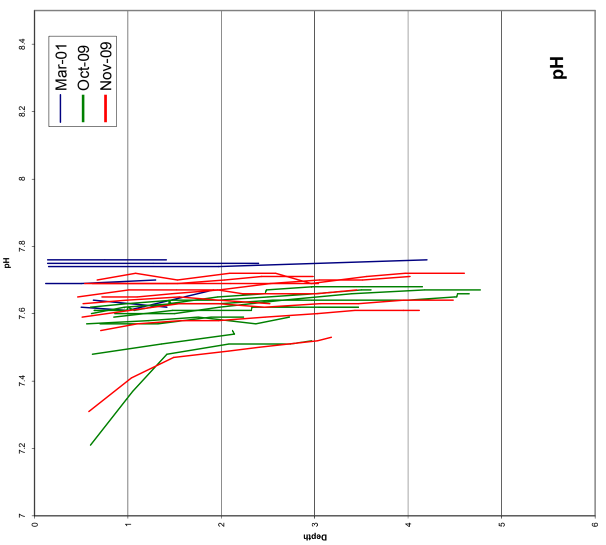

Cardno Lawson Treloar

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St George Boat Club Marina – Coastal Processes Investigations

WATER QUALITY RESULTS – PHYSICAL PARAMETERS

Figure 6.2

Appendix A

Physical Processes

The purpose of this section is to describe the physical processes that are important to the overall physiography of Kogarah Bay shoreline. These processes are: -

- Waves
- Currents
- Water Levels
- Winds
- Sediment Transport

Wave Processes

Waves that propagate to the study area may have energy in two distinct frequency bands. These are principally related to the generation and propagation of ocean swell and local sea (wind/waves). Large waves generated by a storm are generally categorised as sea because wind energy is still being transferred to the ocean. Local waves generated within the Lower Georges River region were considered sea.

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_{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 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.

Directional Spreading

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 undertaken to describe the wind-wave climate at Thursday Island. Directional spreading causes the sea surface to have a more short-crested wave structure in deep water.

Nearshore Processes

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 a 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 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 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.

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 diffraction will not be particularly important for this study, other than where waves propagate into the marina entrances. It is included in the SWAN wave propagation model applied to this study.

Wave Spectrum

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 and was applied in this study.

Maximum Wave Height

For structural design in the marine environment it may be necessary to define the H_{max} parameter related to storms having average recurrence intervals (ARI) of R 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 T_z.
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.

Hydrodynamic Effects

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.

Currents

Currents within Kogarah Bay are caused by a range of phenomena, including: -

- Astronomical Tides
- Winds
- Rainfall/Runoff and Density Flows
- Nearshore Wave Processes

Tides

The astronomical tides are caused by the relative motions of the Earth, Moon and Sun, see below. The regular rise and fall of the tide level in the sea causes a periodic inflow (flood tide) of oceanic water to the berth area and outflow (ebb tide) of water from the berth area to the sea. A consequence of this process is the generation of tidal currents. The volume of sea water that enters or leaves the berth area 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 as the proposed reclamation and canal areas, but not by dredged areas below low tide.

Winds

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. The berth area 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 Flows

Density currents may be caused by freshwater inflows, for example. This current structure will be minimal and rare in the berth area.

Nearshore Wave Processes

The propagation of waves into the nearshore region leads to wave breaking and energy dissipation. Where waves propagate obliquely to the shoreline this process leads to the generation of a longshore current in the wave breaking zone, and to some extent seaward of that line. These currents will be relatively low in the berth area, but will be part of the longshore current process.

Water Levels

Water level variations in the berth area 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
- Greenhouse Effect
- Global Changes in Meteorological Conditions

Eustatic and Tectonic Changes

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 although predictions of future climate change indicate a potential for such an outcome to occur (see below). 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

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 Set-up and the Inverse Barometer Effect

Wind set-up 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

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

Global Changes in Meteorological Conditions

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, for example.

Greenhouse Effect

General scientific consensus predicts that, under enhanced greenhouse conditions, sea levels will rise in response to isothermic expansion and melting of polar ice shelves. Predictions of global sea level rise due to the 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.

The 4th IPCC report on climate change published in 2007 predicts a sea level rise of between 0.09m to 0.88m by 2100. This includes potential sea level rise should recent ice sheet melting in polar-regions continue, estimated to contribute up to 0.23m.

For engineering design purposes, Engineers Australia recommends an allowance of 0.5m for sea level rise by 2100.

Winds

Wind affects the wave, current and water level climates in berth area, as discussed above. Data were obtained from the Bureau of Meteorology for Thursday and Horn Islands.

Appendix B

Glossary

GLOSSARY*

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
Beach Width	The distance seaward from an adopted base line to a nominated contour along a shore normal survey profile.
Calibration	The process by which the results of a computer model are brought to agreement with observed data.
CD	Chart Datum, common datum for navigation charts. Typically Lowest Astronomical Tide.
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.

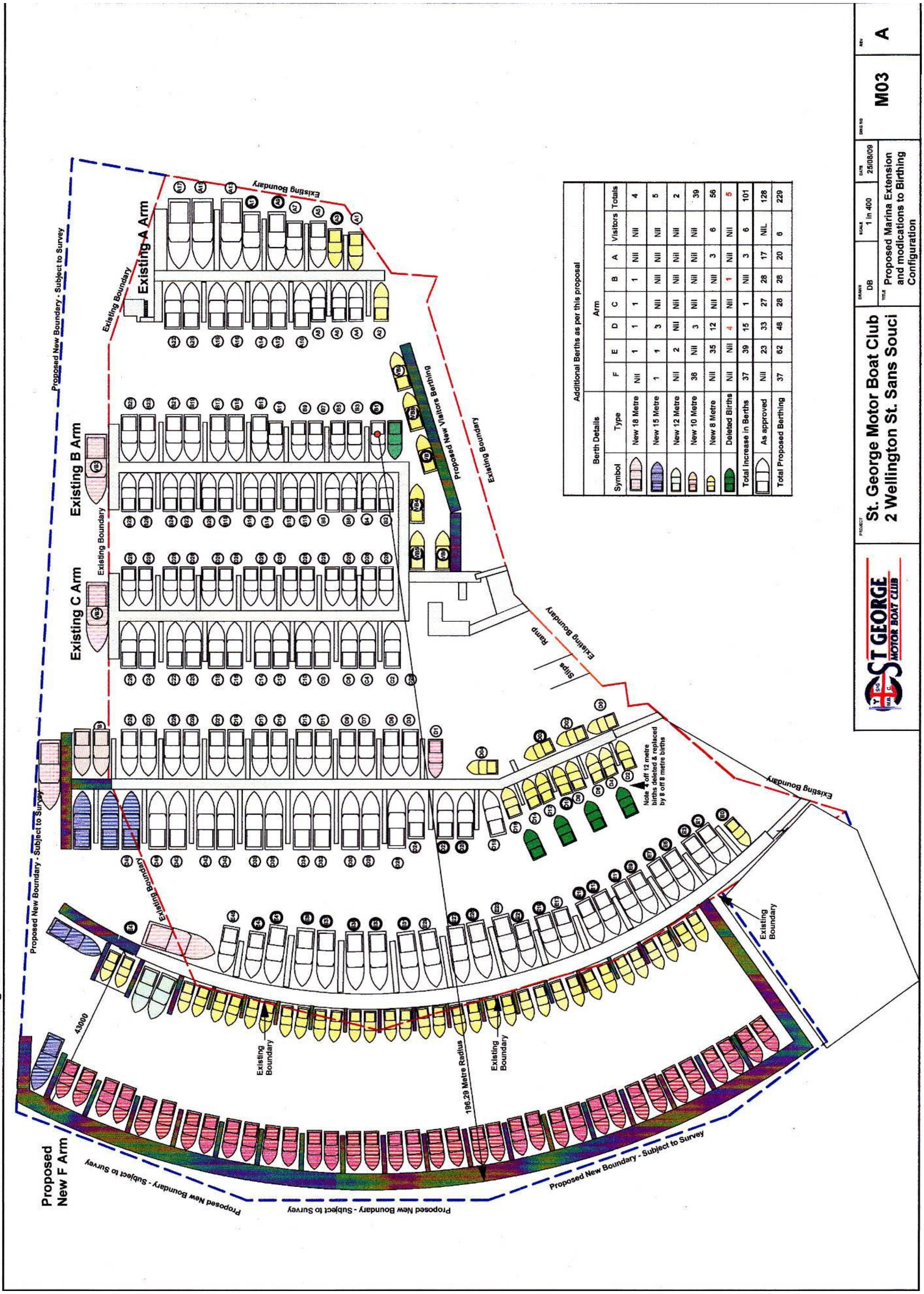
Estuary	An enclosed or semi-enclosed body of water having an open or intermittently open connection to coastal waters and in which water levels vary in a periodic fashion in response to ocean tides.
Flood Tide	The incoming tidal movement of water within an estuary.
Foreshore	The area of shore between low and high tide marks and land adjacent thereto.
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%.
Intertidal	Pertaining to those areas of land covered by water at high tide, but exposed at low tide, eg. intertidal habitat.
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.
Mathematical/Numerical Computer Models	The mathematical representation of the physical processes involved in sea flows and sediment transport. These models are often run on computers due to the complexity and detail of the mathematical relationships that describe the physical processes. In this report, the models referred to are mainly involved with wave, current and sediment transport processes.
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).
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.
Semi-diurnal	A twice-daily variation, eg. two high tides per day.
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 between the Sun, Moon and Earth.
T_z (Zero Crossing Period)	The average period of waves in a train of waves observed at a location.

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

Appendix C

Marina Layout



Additional Berths as per this proposal

Berth Details: Symbol	Berth Details: Type	Arm: F	Arm: E	Arm: D	Arm: C	Arm: B	Arm: A	Visitors	Totals
	New 18 Metre	Nil	1	1	1	1	Nil	Nil	4
	New 15 Metre	1	1	3	Nil	Nil	Nil	Nil	5
	New 12 Metre	Nil	2	Nil	Nil	Nil	Nil	Nil	2
	New 10 Metre	36	Nil	3	Nil	Nil	Nil	Nil	39
	New 8 Metre	Nil	35	12	Nil	Nil	3	6	56
	Deleted Births	Nil	Nil	4	Nil	1	Nil	Nil	5
Total Increase in Berths		37	39	15	1	Nil	3	6	101
	As approved	Nil	23	33	27	28	17	NIL	128
Total Proposed Berthing		37	62	48	28	28	20	6	229

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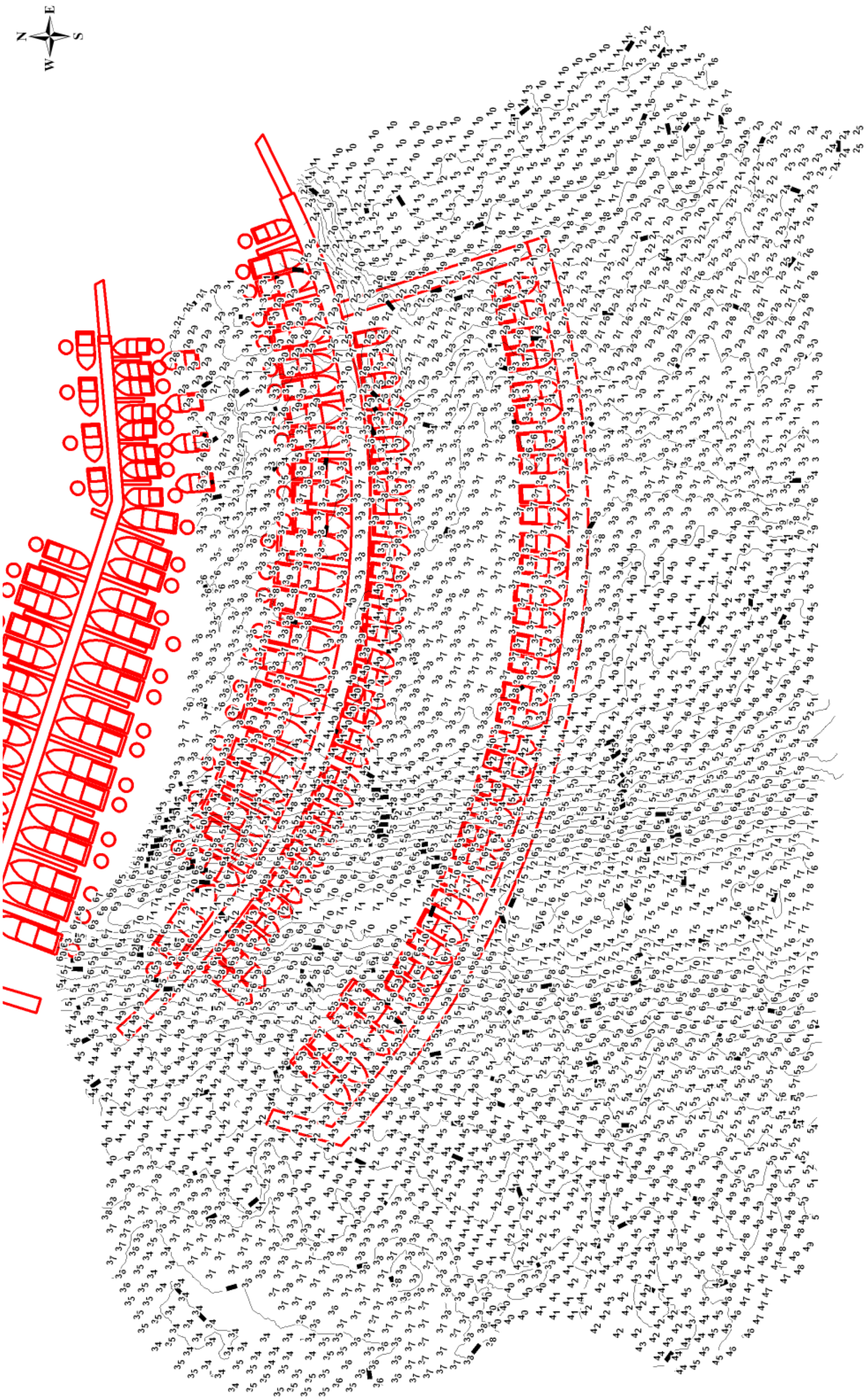
St George Boat Club Marina – Coastal Processes Investigations

PROPOSED MARINA LAYOUT

Figure C1

Appendix D

Hydro-Survey



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LJ2841/R2601 February 2010

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St George Boat Club Marina – Coastal Processes Investigations

HYDRO-SURVEY

Figure D1

Appendix E

Wind Data

Table E1: Joint Occurrence of Wind Speed and Direction at Mascot (1939-2007)

	Wind Speed (m/s)										
Dirn	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	0.38	1.56	1.11	0.39	0.14	0.02	0.00	0.00	0.00	0.00	3.61
NNE	0.20	1.12	1.36	0.92	0.54	0.17	0.02	0.00	0.00	0.00	4.34
NE	0.28	1.62	2.22	1.82	1.09	0.33	0.05	0.00	0.00	0.00	7.43
ENE	0.17	0.94	1.17	0.58	0.19	0.02	0.00	0.00	0.00	0.00	3.07
E	0.26	1.42	1.44	0.42	0.08	0.01	0.00	0.00	0.00	0.00	3.64
ESE	0.18	0.93	0.89	0.29	0.08	0.02	0.01	0.00	0.00	0.00	2.39
SE	0.24	1.53	1.92	0.97	0.36	0.08	0.03	0.00	0.00	0.00	5.14
SSE	0.13	1.23	1.96	1.50	0.88	0.34	0.11	0.03	0.01	0.00	6.20
S	0.21	1.44	2.47	2.76	2.17	1.03	0.44	0.12	0.03	0.01	10.67
SSW	0.13	0.67	0.90	0.90	0.76	0.37	0.14	0.03	0.02	0.00	3.92
SW	0.28	1.09	0.97	0.61	0.33	0.09	0.04	0.01	0.01	0.00	3.43
WSW	0.22	1.10	1.10	0.70	0.41	0.13	0.04	0.01	0.00	0.00	3.72
W	0.67	2.67	2.04	1.13	0.70	0.34	0.13	0.04	0.01	0.00	7.73
WNW	0.92	2.74	1.15	0.43	0.33	0.16	0.09	0.01	0.00	0.00	5.83
NW	1.42	4.31	1.44	0.48	0.28	0.13	0.04	0.01	0.00	0.00	8.10
NNW	0.47	1.83	0.78	0.30	0.15	0.05	0.01	0.00	0.00	0.00	3.58
TOTAL	6.16	26.19	22.91	14.21	8.50	3.29	1.15	0.28	0.07	0.02	82.79
P of E (%)	82.79	76.63	50.44	27.53	13.32	4.82	1.52	0.37	0.09	0.02	

Appendix F

Water Quality Sampling Analysis

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES0915935**	Page	: 1 of 6
Client	: **CARDNO LAWSON TRELOAR PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR SEAN GARBER	Contact	: Charlie Pierce
Address	: 910 PACIFIC HWAY GORDON NSW, AUSTRALIA 2072	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: sean.garber@cardno.com.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: +61 02 9499 3000	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 9499 3033	Facsimile	: +61-2-8784 8500
Project	: LJ2841	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 20-OCT-2009
Sampler	: SG	Issue Date	: 27-OCT-2009
Site	: ST GEORGE MOTOR BOAT CLUB		
		No. of samples received	: 2
Quote number	: SY/487/09	No. of samples analysed	: 2

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Spectroscopist	Inorganics
Duyen Nguyen	Senior Microbiologist	Microbiology
Edwandy Fadjar	Senior Organic Chemist	Organics
Sarah Millington	Senior Inorganic Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **2/ MIC/04, <2 CFU/100mL is reported where the sample is untreated/not too turbid or effluent water, 50mL is filtered instead and there is no growth on the filtered membrane.**
- **EK055G: LOR raised for ammonia due to sample matrix.**
- **Microbiological comments: 1/ QWI-MIC04, estimate (~) is reported where the colonies forming unit on the filtered membrane is counted <10cfu and/or >100cfu.**
- **MW006 is ALS's internal code and is equivalent to AS4276.7.**
- **MW023 is ALS's internal code and is equivalent to AS4276.9.**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**S1**	**S2**	----	----	----
			Client sampling date / time	20-OCT-2009 11:00	20-OCT-2009 11:15	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915935-001**	**ES0915935-002**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.050	mg/L	<0.050	<0.050	----	----	----
Chromium	7440-47-3	0.005	mg/L	<0.005	<0.005	----	----	----
Lead	7439-92-1	0.005	mg/L	<0.005	<0.005	----	----	----
Nickel	7440-02-0	0.050	mg/L	<0.050	<0.050	----	----	----
Zinc	7440-66-6	0.050	mg/L	<0.050	<0.050	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	<0.10	<0.10	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N	14797-55-8	0.01	mg/L	**0.01**	**0.02**	----	----	----
EK059G: NOX as N by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.01**	**0.02**	----	----	----
EK061: Total Kjeldahl Nitrogen (TKN)								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.1	<0.1	----	----	----
EK062: Total Nitrogen as N								
^ Total Nitrogen as N	----	0.1	mg/L	<0.1	<0.1	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.07**	**0.05**	----	----	----
EP020: Oil and Grease (O&G)								
Oil & Grease	----	5	mg/L	<5	<5	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	----	----	----
MW006: Faecal Coliforms & E.coli by MF								
Faecal Coliforms	----	1	CFU/100mL	<2	<2	----	----	----
MW023: Enterococci by Membrane Filtration								
Enterococci	----	1	CFU/100mL	<2	**~2**	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**110**	**123**	----	----	----
Toluene-D8	2037-26-5	0.1	%	**102**	**104**	----	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	S1	S2	----	----	----
			Client sampling date / time	20-OCT-2009 11:00	20-OCT-2009 11:15	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915935-001**	**ES0915935-002**	**----**	**----**	**----**
EP080S: TPH(V)/BTEX Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.1	%	**92.5**	**101**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	Recovery Limits (%) High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	120
Toluene-D8	2037-26-5	88	110
4-Bromofluorobenzene	460-00-4	86	115

CERTIFICATE OF ANALYSIS

Work Order	: **ES0917539**	Page	: 1 of 6
Client	: **CARDNO LAWSON TRELOAR PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR CHRISTOPHER BEADLE	Contact	: Charlie Pierce
Address	: 910 PACIFIC HWAY GORDON NSW, AUSTRALIA 2072	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: christopher.beadle@cardno.com.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: +61 02 9499 3000	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 9499 3033	Facsimile	: +61-2-8784 8500
Project	: ----	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 17-NOV-2009
Sampler	: CB	Issue Date	: 24-NOV-2009
Site	: ----		
		No. of samples received	: 2
Quote number	: SY/487/09	No. of samples analysed	: 2

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Spectroscopist	Inorganics
Duyen Nguyen	Senior Microbiologist	Microbiology
Hoa Nguyen	Inorganic Chemist	Inorganics
Pabi Subba	Senior Organic Chemist (Semi-Volatile)	Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **2/ QWI-MIC/04, <2 CFU/100mL is reported where the sample is not drinking or treated water, 50mL is filtered instead and there is no growth of target organisms on the filtered membrane.**
- **EG020A-T: LOR's for samples have been raised due to matrix interference (High sample salinity)**
- **EK055G: LOR raised for ammonia for samples 'SAMPLE 3' and 'SAMPLE 4' due to sample matrix.**
- **EK061G: Spike failed for TKN due to matrix interference, confirmed by re-analysis.**
- **Microbiological comments: 1/ QWI-MIC04, estimate (~) is reported where the colonies forming unit on the filtered membrane is counted <10cfu and/or >100cfu.**
- **MW006 is ALS's internal code and is equivalent to AS4276.7.**
- **MW023 is ALS's internal code and is equivalent to AS4276.9.**

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**SAMPLE 3**	**SAMPLE 4**	----	----	----
			Client sampling date / time	17-NOV-2009 09:00	17-NOV-2009 09:30	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES0917539-001**	**ES0917539-002**	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.050	mg/L	<0.050	<0.050	----	----	----
Chromium	7440-47-3	0.005	mg/L	<0.005	<0.005	----	----	----
Lead	7439-92-1	0.005	mg/L	<0.005	<0.005	----	----	----
Nickel	7440-02-0	0.050	mg/L	<0.050	<0.050	----	----	----
Zinc	7440-66-6	0.050	mg/L	<0.050	<0.050	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	<0.10	<0.10	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N	14797-55-8	0.01	mg/L	<0.01	**0.02**	----	----	----
EK059G: NOX as N by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	**0.02**	----	----	----
EK061: Total Kjeldahl Nitrogen (TKN)								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**2.9**	**0.1**	----	----	----
EK062: Total Nitrogen as N								
^ Total Nitrogen as N	----	0.1	mg/L	**2.9**	**0.2**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.06**	**0.04**	----	----	----
EP020: Oil and Grease (O&G)								
^ Oil & Grease	----	5	mg/L	<5	<5	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	----	----	----
MW006: Faecal Coliforms & E.coli by MF								
Faecal Coliforms	----	1	CFU/100mL	**~4**	**~2**	----	----	----
MW023: Enterococci by Membrane Filtration								
Enterococci	----	1	CFU/100mL	**~2**	**~8**	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**110**	**102**	----	----	----
Toluene-D8	2037-26-5	0.1	%	**93.6**	**94.4**	----	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	SAMPLE 3	SAMPLE 4	----	----	----
			Client sampling date / time	17-NOV-2009 09:00	17-NOV-2009 09:30	----	----	----
Compound	CAS Number	LOR	Unit	ES0917539-001	ES0917539-002	----	----	----
EP080S: TPH(V)/BTEX Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.1	%	**88.0**	**96.3**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	*CAS Number*	*Recovery Limits (%)* Low	*Recovery Limits (%)* High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	120
Toluene-D8	2037-26-5	88	110
4-Bromofluorobenzene	460-00-4	86	115