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BENEDICT INDUSTRIES PTY LTD

Georges Cove Marina, Moorebank

Preliminary Marina Concept Design and Environmental Assessment

301015-01167

7-Oct-10

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SYNOPSIS

This report has been prepared to support the development application for the proposed Georges Cove Marina. It addresses the engineering, river and water related aspects of the proposed development.

The proposed marina, with appropriate design and mitigation measures as recommended in this report, would not have a significant adverse impact on the river processes, flooding or water quality and would provide a facility which is in short supply along the Georges River.

Disclaimer

PROJECT 301015-01167 - GEORGES COVE MARINA, MOOREBANK

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
B	per client comments	FC	MT	N/A	11 Mar 2009	N/A	
C	Revised for new marina concept	FC	MT	N/A	11 June 2010		N/A
D	Added copper discussion	FC	MT	MT	30 July 2010		N/A
E	Minor Edits	FC	MT	MT	7 Oct 2010		

CONTENTS

1. INTRODUCTION

Benedict Sand & Gravel Pty Ltd proposes to redevelop the Moorebank quarry site to incorporate a marina. This report has been prepared to support the development application for the proposed Georges Cove Marina. It addresses the engineering, river and water related aspects of the proposed development.

The site is located south of Newbridge Road at Moorebank and adjacent to the Georges River.

The marina basin would be formed in the location of the current quarry excavation.

The proposed marina site is adjacent to an area where a combination of residential and commercial development is proposed.

The proposed development site location is shown on **Diagram 1–1**.

Diagram 1–1– Site Location Plan

2. DESCRIPTION OF THE EXISTING ENVIRONMENT

2.1 River Processes

River processes relate to sediment transport, tidal flows, flood flows and water quality. Detailed analysis of tidal flows and water quality can be found in **Sections 5 and 6**.

2.1.1 Sediment Transport

The tidal velocities in the river are sufficient to transport sand as bed load along the river. This has been established in the Georges River Database Compilation and Assessment report prepared by PWD in 1991. It also identified that the Chipping Norton Lakes System formed in the early 1980s acts as a large trap for sand transported along the river.

2.1.2 Tidal Flows

Tidal flows in the river represent a significant volume of flow. The basin would create a small additional waterway area with a tidal prism forming a negligible fraction of the tidal volume.

2.1.3 Flooding

The site is located on a floodplain. Typically, a 2-year ARI event would overtop a river bank, in this case the bank has been artificially modified and it is uncertain if this would occur. The basin would provide a small increase in flood conveyance and storage area and would have a beneficial impact by marginally lowering the flood level in the local area.

2.1.4 Water Levels

The Georges River Database Compilation and Assessment prepared in February 1991 by the then Public Works Department provides a review of tidal measurements in the Georges River. The tidal planes determined at Milperra Bridge (closest location to the subject site) are presented in **Table 2–1**.

The predicted Georges River flood levels are presented in the Georges River Flood Study undertaken by Bewsher Consulting in 2000 which established a MIKE 11 model to reproduce the original levels predicted in the PWD physical flood model for Georges River. The predicted flood levels for the site are:

- 20 yr ARI RL 4.6 m AHD
- 100 yr ARI RL 5.6 m AHD
- PMF RL 10.2 m AHD

Table 2–1 – Tidal Water Levels

Plane	Datum (m)	
	ISLW	AHD
Higher High Water Springs	1.913	0.988
Mean High Water	1.466	0.541
Mean Water Level	1.002	0.077
Mean Low Water	0.538	-0.387
ISLW	0.193	-0.732

2.1.5 Water Quality

The major influences on water quality in the river are stormwater discharges, treated and untreated sewage discharges, tidal flushing and flood flows. The proposed development would not influence these major processes in the river.

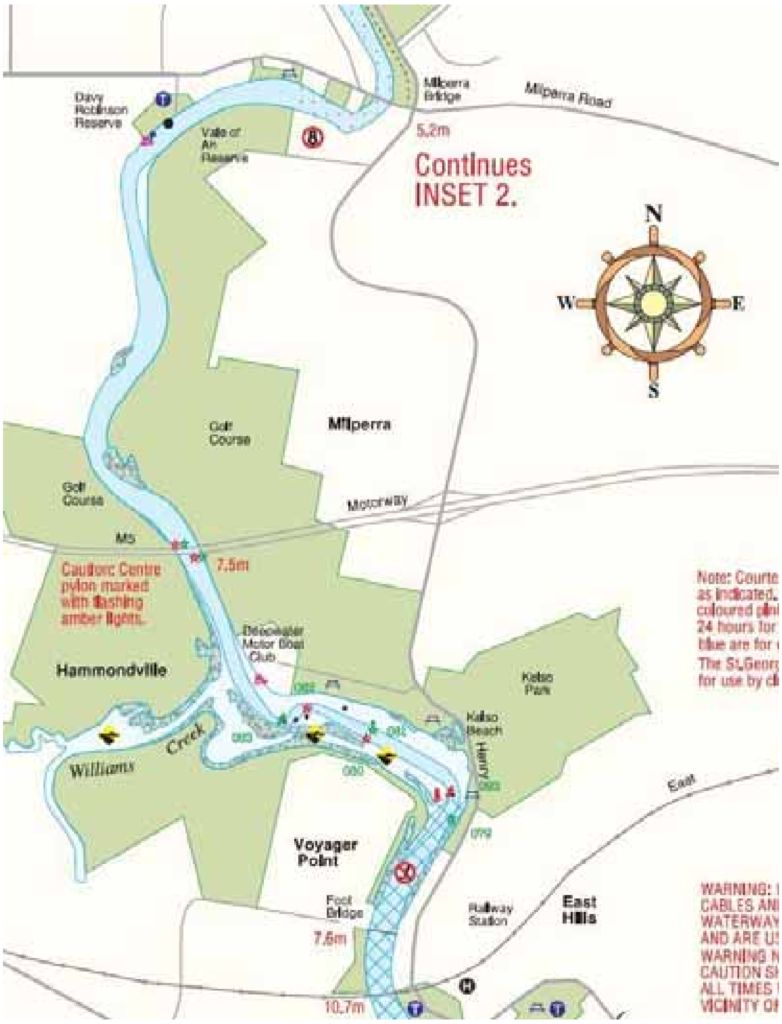
The water quality in the basin would therefore be primarily influenced by the tidal flushing from the river, i.e. the ability to maintain the same water quality in the basin as in the river. The basin has been designed to maximise circulation by maintaining an open connection to the river. The depth of the basin would be above the adjacent river bed level, avoiding poor circulation of water at the bed of the basin.

2.2 Sediment

2.2.1 Recreational Use of the River

There are numerous existing boat ramps along the Georges River supporting use of trailered recreational craft. **Diagram 2–1** shows the NSW Maritime Boating map for the area which indicates the location of existing facilities and any boating restrictions. The proposed marina is located within a length of river that is heavily used for speed boat racing and water skiing (between Davy Robinson boat ramp and the Deep Water Motor Club). This area has no speed restrictions (speed restrictions exist along most of the Georges River) and it is therefore an important amenity area for speed boat activities.

Diagram 2–1 – Local Boating Map (NSW Maritime)



Discussions with NSW Maritime indicate that there are no proposals to limit the speed along this reach of the river, so as to continue its availability for water skiing and other high speed uses.

The only aquatic licences in the area would be for events held by the Deepwater Motor Boat Club, which runs racing events.

3. DESCRIPTION OF THE PROJECT

3.1 Marina Basin

The proposal includes a marina basin of approximate dimensions of 150 m by 350 m. The marina would open to the Georges River with a short entrance channel 40-50 m wide. The layout of the proposed marina development and basin is shown in **Figure 1**.

The proposed approximately rectangular plan shape of the marina basin with dimensions of approximately 150 m by 380 m has been designed to alleviate the potential for the formation of poorly flushed corners and will assist to maintain good water quality and visual appearance.

The marina basin would be located on a relatively straight section of the river. These sections are generally more stable and less prone to the significant variations in flow velocity at bends in the river. These velocity variations typically result in sediment deposition on the inside of the bend and significant erosion on the outside of the bend. The location of the marina on the relatively straight river section will provide more stable bank and bed conditions and less potential for sedimentation in the marina basin or entrance.

The basin would be formed by filling the existing quarry to shape it into the final landform using a dredge and land based earth moving machinery. The dredge would operate as at present in a water filled basin. The excavated sand would be used for forming the Vessel Access Channel and associated land areas required for the marina. This work would commence at the landward end forming the basin and land base prior to breakthrough of the banks to the river. In this way, these works would not impact on the river water quality. The breakthrough to the river would be undertaken as the last activity after the water quality in the basin had stabilised and was suitable to discharge to the river once the banks were excavated. Water quality testing through the quarry pond and the river area adjacent to the site demonstrates that the water in the pond is of a similar quality to that of the Georges River (refer to **Table 6–2** for results of water quality testing).

3.2 Marina Basin Depth

The basin water depth is a function of the craft draught and the water depths available in the adjacent river.

The craft to be catered for in the marina would be power craft up to around 20 m in length. The Australian Standard AS 3962 – 2001, Guidelines for Design of Marinas recommends the draught of these craft of 1.5 m. The standard recommends that the basin water depth be determined by adding a freeboard of 0.3m to the largest vessel draught and half the design wave height as well as an allowance for sedimentation. The recommended basin bed level would be RL 2.2 m below the local Indian Spring Low Water (ISLW) which includes the 1.5 m draught, 0.3 m freeboard, 0.1 m half wave height and 0.3 m for sedimentation. ISLW is the chart datum or lowest expected tidal water level in the river. The proposed basin bed level would therefore be RL-2.932 m AHD.

The Georges River Flood Study employed a model from which the cross-sectional elevations were used to generate a terrain model of the river.

Survey of the depth of the river was undertaken adjacent to the proposed marina.

3.3 Berths Details

From consultation with NSW Maritime and boat user groups, the proposed marina is within a highly utilised stretch of the river. The existing layout would accommodate a total of 186 wet berths and 250 dry berths as indicated in the following tables. The number of berths is restricted by the site and space available. The marina layout is shown in **Figure 1**.

Table 3–1 – Marina

Length (m)	Beam (m)	Percentage	Draft (m)	Berth Widths (m)	Number Of Berths
Small Craft (<15m) ≥8m <10m	4	28%	1	9	52
Small Craft (<15m) ≥10m <12m	4.4	59%	1	9.8	110
Small Craft (<15m) ≥12m <15m	5	11%	1.2	11	20
Vessels ≥15m <18m	5.4	1%		11.8	2
Vessels <20	5.7	1%	1.5	12.4	2
Vessels >20m					0
Total					186

Table 3–2 – Dry Store

Length (m)	Beam (m)	Percentage	Draft (m)	Berth Widths (m)	Number Of Berths
Small Craft (<15m) ≥4m <6m	2.8	50%		4	125
Small Craft (<15m) ≥6m <8m	3.4	20%	0.9	4.6	125
Vessels ≥15m					0
Total					**250**

3.4 Marina Building

The proposed marina building would include parking on the ground floor, a conference facility, kiosks, function centre/ casual dining, dry storage for boats, marina office, amenities. The details of the dry berths are presented in **Table 3–2** and a cross section through the marina building is shown in **Figure 2**.

3.5 Marina Entrance

The proposed marina is recessed into the riverbank and entrance to the river would be via a short entrance channel (approximately 50 m long). The entrance would be 40 to 50 m wide.

A pedestrian bridge would be provided across the river entrance to the marina to allow pedestrian connectivity along the Georges River foreshore. This bridge would also act to limit the size of vessels entering the marina by precluding vessels above a set height.

3.6 Finished Levels

The foreshore levels for the marina area are influenced by the need for convenient access to craft, adjacent land and proposed development levels and flood levels.

The marina building would consist of parking, a conference facility, function centre, kiosks, waterside casual dining and dry boat sales, repair and storage. The minimum habitable floor level for the conference as designated by Liverpool City Council policy would be the flood planning level (0.5m above the 100yr ARI flood level) which would be RL 6.1 m AHD. The mean tide level in the marina basin would be around RL 0 m AHD and as such, provision of convenient access to craft is an issue which requires careful design consideration.

The northern carpark would be formed at the 20 year ARI flood level of RL 4.6 m AHD. Otherwise, the ground surrounding the marina building would generally be at a level of RL 2.5 m AHD. The entrance roadway, connecting to the residential area to the north, would need to rise to approximately RL 5.7 m AHD, at a relatively low grade (say 8%) to allow ease of transport of boats on trailers.

It will be necessary to incorporate a number of benches into the foreshore fronting the marina berths. The uses at the foreshore level have been selected to minimise flood damages. Given the flood warning time, which would be greater that 12 hours, important equipment or records could be relocated to higher ground to minimise flood damages even further. It would be necessary to work closely with Council to devise controls which were sufficiently practical to warrant a special “merits based” dispensation through Council’s flood policy for development at a level of RL 2.5 m AHD.

A timber boardwalk would be located at a level of RL 1.5 m AHD to provide a better amenity for access to craft and further opportunity for passive recreation close to the river/basin water level. A hinged ramp would provide access from the promenade level (RL 2.5 m AHD) to the floating pontoon berths. Access would be provided from the promenade level in order that the access ramp would not be damaged in a 100 yr ARI flood as it would be able to rotate up to the flood level of RL 5.6 m AHD.

The sections in **Figure 2** illustrate the proposed levels and their relationship with the surrounding area.

3.7 Bank Edge Treatments

The main function of the basin edge treatments is bank stability with a strong focus on creating environmental enhancement. Two potential edge treatments have been identified for use within the marina. The marina edge treatment locations have been suggested based on an appreciation of their integration with the proposed river bank protection, proposed development layout and the existing ecology.

Two edge treatments have been considered within the basin; **Type 1** is a combination of rock revetments and integrated vegetation zone; and **Type 2** is a concrete wall. Type 1 would be similar to those proposed to stabilise the river banks along the site.

A freshwater wetland is proposed along the inside of the river bank to treat runoff from the adjacent proposed residential area. The wetland would be vegetated with suitable macrophytes and would enhance the riparian zone with more diverse aquatic habitats and diverse vegetation.

Type 1 - Rock Revetment with Integrated Vegetation Zone

For this edge treatment the rock revetment would incorporate a berm of saltmarsh (or other suitable habitat) between the rock revetment and the edge treatment to improve the ecological and aesthetic value of the foreshore. The foreshore would then be backed by littoral vegetation and possibly an access path.

This option stabilises the slope through a rock revetment with the benefit of creating specific habitat environments within it. The revetment would consist of layers of rock armour to comply with the wave climate, over a geotextile fabric.

Further design of this option would be required in consultation with a specialist ecologist to establish the required height for the mid level vegetation and suitable native species.

Type 2 – Rock Revetment with Boardwalk

To enable access to berths, the use of a rock revetment with a timber boardwalk is suggested.

Where the boat moorings are proposed a timber boardwalk and a walkway down to floating pontoons would be constructed over the rock revetment. The boardwalk and pontoon would extend sufficiently over the revetment so that the required depth would be achieved below the moored boats. Alternatively, the walkway could extend directly from the shore out to floating pontoons.

3.8 Carparking

Carparking has been provided in accordance with the numbers agreed with Council. The carpark layout is shown on **Figure 2**.

3.9 River Bank and Riparian Zone

The existing riverbank over the 500 m of the site foreshore is generally devoid of any vegetation. The river banks are eroding thereby undermining what foreshore vegetation exists at present. Without this development, these processes will continue to remove the riparian vegetation and there will continue to be no public access to the foreshore.

This project proposes to rehabilitate the foreshore and re-establish the riparian corridor vegetation representing a significant improvement to the aquatic and riparian environment. The NSW government does not have the resources to undertake these regionally significant river works which is their responsibility. The residents of the region will benefit greatly from the improved river environment and foreshore access. The loss of a small section (40 to 50 m wide) of the river foreshore for the basin entrance is minor and readily compensated for with the proposed foreshore stabilisation and riparian rehabilitation over the 500m of the remainder of the site foreshore. The marina basin would provide additional river foreshore and riparian vegetation and habitats to compensate for the foreshore loss at the basin entrance.

It should be noted that the existing length of river bank, at the proposed basin entrance, is degraded. The bank is also continuing to erode. The proposed works would improve the river bank in a number of ways:

- reduce ongoing scour/erosion of the river bank;
- provide additional habitats (including wetlands) and improve local biodiversity;
- improve visual quality; and
- improve foreshore amenity.

The basin entrance has been located to avoid any significant existing vegetation. The impact of this entrance on the riparian zone is considered minimal given the overall positive benefits to be derived from the bank stabilisation and re-establishment of the riparian zone vegetation over the entire site.

3.10 Sedimentation of the Basin

Sedimentation of the basin could occur due to inflow of sand size sediments being transported along the bed of the river by tidal and flood processes and with the deposition of fine sediments from floodwaters.

The deposition of fine sediments in the basin during a large flood would occur but at a very slow rate. The velocities in the over bank flood area in which the basin would be located are sufficient to transport fine sediment and to prevent its deposition. The basin is not deep enough to provide sufficiently low velocities during a flood to cause significant deposition of fine sediments. At the conclusion of a flood, there will be the gradual deposition of an insignificant amount of fine sediments remaining in the water column.

The tidal velocities in the river are sufficient to transport sand as bed load along the river. This has been established in the Georges River Database Compilation and Assessment report prepared by PWD in 1991. It also identified that the Chipping Norton Lakes System formed in the early 1980s acts as a large trap for sand transported along the river. As such, the sand transport rate past the proposed marina basin will be low for many decades, until such time as the lakes are full of sediments or the landform is otherwise changed. Hence, the source of sediment from the Georges River would be low.

The reasons the sedimentation rate in the basin of sand size sediments will be low include:

- location of the basin entrance on a straight section of the river channel not exposed to the large depositional episodes on river bends;
- the bed of the basin has been located above the general bed level of the river and hence bed load sand transport will not enter the basin; and
- the bed load sand transport rate past the basin entrance will be low.

The depth of sediment collected in 100 years was estimated using the following parameters:

- an average suspended solids concentration of 30 mg/L,
- an average particle size of 2 micron (clay),
- a fluid density of 1000 kg/m^3,
- a sediment density of 2500 kg/m^3, and
- a fluid viscosity of 0.01 Pa s.

The depth of sediment was thus estimated to be approximately 120 mm.

A 300 mm allowance has been adopted to accommodate minor sedimentation in the basin.

3.11 Construction

It is proposed to construct the marina using conventional land based plant and equipment *(such as excavators and all terrain trucks*), as is currently used to quarry material on the site. This marina basin is substantially already formed by the quarrying activities.

Connection to the river would be delayed for as long as practicable and would be completed during favourable water level conditions (i.e. at or around slack water) to enable management of the breakthrough with the deployment of an appropriate turbidity curtain.

The excavation works would be managed to minimise the total area to be disturbed and the exposure time of any disturbed area.

4. FLOODING

The Georges River Flood Study was completed in 2000 by Bewsher Consulting. The flood study was based on a MIKE11 hydraulic model and has been adopted by the Bankstown, Fairfield and Liverpool Councils. Results from the study have been incorporated into the Georges River Floodplain Risk Management Study and Plan, (Bewsher Consulting, 2004).

The model extends over a distance of some 46km, from above Cambridge Avenue to Botany Bay. There are over 278 cross sections and a number of separate overland flow paths.

The mid section of the model used for the Georges River Flood Study is the section relevant to this project, as it extends from Liverpool to Picnic Point. Prior to the MIKE11 model, this reach was modelled by the Georges River physical model, which had been extensively calibrated to floods that occurred in 1956, 1978, 1986 and 1988. Consequently, there is a high degree of confidence in the results from the physical model. The MIKE-11 model was calibrated to the physical model in the reach between Liverpool and Picnic Point.

4.1 Flood Impact Assessment

As the Georges River Flood Study (2000) is considered to be representative of the state of the current catchment, the flood impact assessment was based on the results of the existing study. The available flood storage is presented in **Table 4–1**. The calculations account for a loss of flood storage caused by the residential development, there is an overall gain in flood storage, which is largely due to the marina basin.

Table 4–1 – Flood Storage

Location	**Plan Area (m^2)**	**Existing Level (m AHD)**	**Proposed Level (m AHD)**	**Change in Elevation (m)**	**Change in Flood Storage (m^3)**
Northern Carpark (raised above 20 year ARI level)	7,801	2.7	4.6	-1.9	-14,822
Dry Storage Building	21,807	2.5	4.6	-2.1	-45,795
Southern Carpark	15,120	2.5	2.8	-0.3	-4,536
Riparian Zone	18,973	2	1.8	0.2	3,795
Wetlands	4,648	2	0.541	1.459	6,781
Marina Basin	48,727	2.7	0.541	2.159	105,202
Entrance to Basin	3,656	2	0.541	1.459	5,334
Net change					**55,959**

4.2 Marina Flood Management

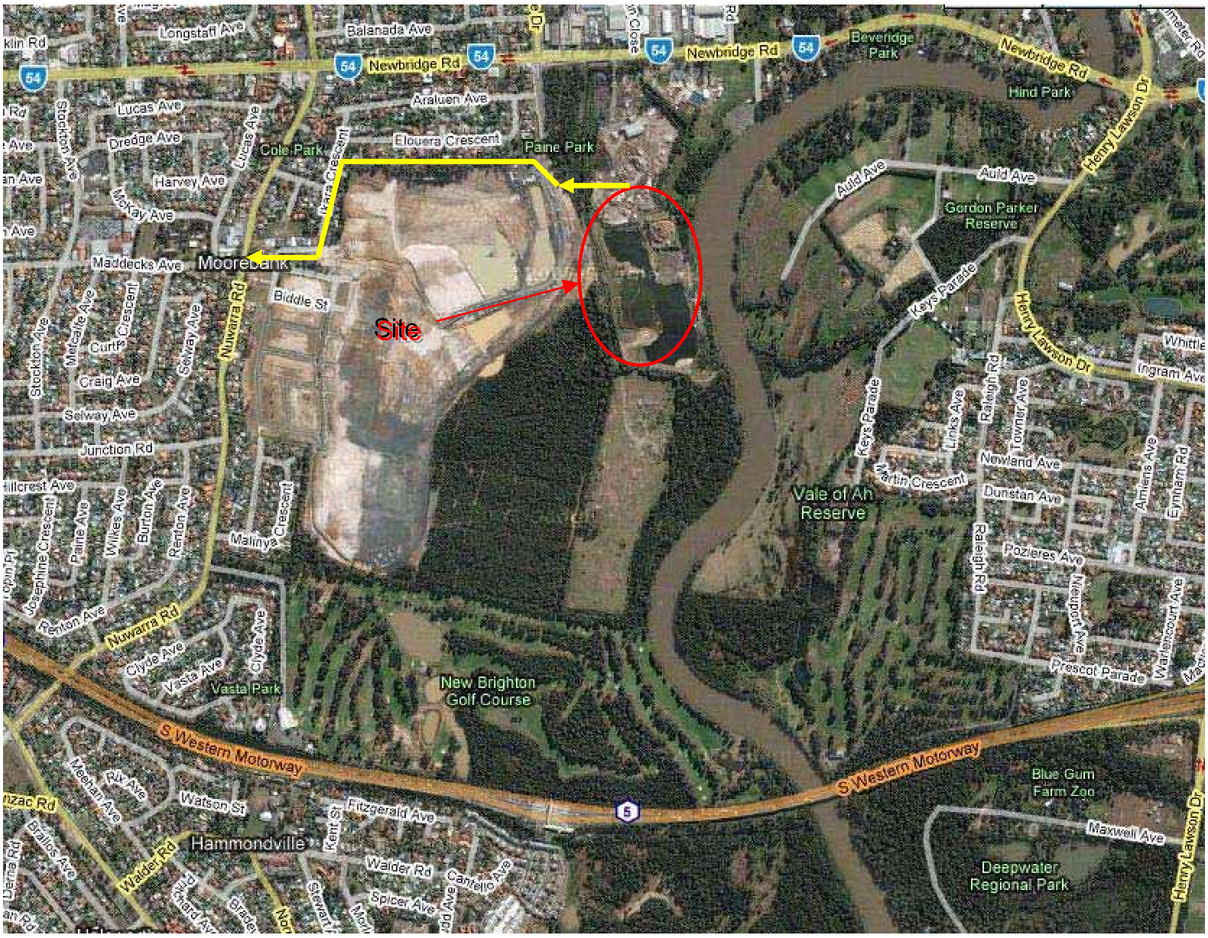
The floating marina pontoons would be designed to cater for the flood levels and flow and debris forces imposed by the 100yr ARI flood flows. This could be achieved with appropriate pile design in combination with consideration of the access connection between the floating pontoons and the foreshore areas. It is typical that the foreshore be gradually stepped down in a series of levels and boardwalks to provide a convenient amenity, access and visual aesthetics to this area.

4.3 Preliminary Flood Emergency Response Plan

The flood emergency response plan (FERP) is required for the marina and building to provide a strategy for dealing with floods more severe than the 100yr ARI event. There would be many hours warning for a severe flood. The key principle in the FERP is to provide an evacuation strategy from the site to a location above the water level in the Probable Maximum Flood (PMF).

The egress route for the marina is initially to the north, through the residential and commercial areas, to Newbridge Road, and then turning left to travel west along Newbridge Road. The route is indicated on **Diagram 4–1**.

Diagram 4–1 – Flood Evacuation Route



A full FERP would be prepared at a later date once the full details of the occupation of the building are known, including nomination of individual staff for emergency roles.

Flood warnings for the Georges River are available from the Bureau of Meteorology. For a fee, these can be sent directly to a site, to the Flood Warden.

Given the nature of the conference facility, the space would not be permanently occupied, reducing the risk of a flood occurring while people are on site. It would also be possible to prevent access to the site when a flood warning had been received.

A backup anchor pile and chain system would hold in place the marina pontoons should the piles fail or the pontoons float free of them.

All craft would also be readily tied to the chain system with quick lock fixtures when a severe flood warning was received.

5. TIDAL HYDRODYNAMICS

A hydraulic model was created using the RMA 2 software which provides results detailing the flow behaviour.

RMA-2 is a two dimensional fluid flow program which allows complicated and detailed flow systems to be designed and modelled. RMA-2 effectively simulates water flow through different networks; however it is essential that the network has been created carefully in order to efficiently model the land topography.

The model network consists of a mesh of variable sized quadrilaterals and triangles, similar in nature to a triangulated irregular network (*TIN*). Each quadrilateral or triangular element represents a portion of the ground surface defined by elevations at the corner and midside nodes. The elements also represent roughness of the surface defined by Manning's n or Chezy C values. The flexible nature of the network permits complex changes in topography, built environment and hydraulic conditions to be modelled with appropriate degrees of accuracy or representation. Elements represent areas of land, therefore the smaller the elements the more effectively the area is modelled, however the associated processing time increases. Due to these factors a compromise is sought to effectively model the network with sufficient detail, yet while not complicating the model unnecessarily.

5.1 Model Extents

In order to capture the full tidal prism, it was necessary to create a model of the Georges River from downstream of the subject site extending upstream to the Chipping Norton lakes system.

The cross-sectional model extents were limited to the area wet under average conditions, i.e. overbank areas were not included. This created a more stable model without losing any necessary information for the water quality modelling.

5.2 Boundary Conditions

The location and model boundary conditions were selected based on a range of criteria, so that the model results were stable and produced an accurate replication at the subject site.

The upstream and downstream boundary condition needed to be located a sufficient distance away from the subject site to ensure that the model stabilises and produces accurate results. The upstream and downstream boundary conditions were adopted from historical data supplied by the Manly Hydraulics Laboratory. The upstream site of Lansvale was adopted as it lies at the upstream boundary of the Chipping Norton lakes system. For the downstream boundary, the next suitable location was at Picnic Point. Despite the closer Kelso Creek station being located closer to the subject site, yet sufficiently downstream, it was not suitable as it did not capture the full tidal range thereby producing inaccurate results.

5.3 Model Terrain

The model terrain used to construct the RMA model, was adopted using a combination of data. Specifically, the information used included:

- Aerial photography supplied by the NSW Department of Lands;
- A digital terrain model generated from cross-sectional survey data from the Georges River Flood Study; and
- Visual inspections and measurements (which were used to accurately define the Manning's "n" values along the channel and the dimensions of hydraulic features).

5.4 Marina Basin

The marina basin layout was adopted based on the current layout drawing as shown in **Figure 2**. An entrance 40 m wide and 50 m long was adopted. This is represents a worse case for flushing than a 50 m wide entrance.

5.5 Model Calibration

Once the 2D RMA model was built it was checked to ensure that it behaved correctly and represented the terrain. The model cross sections (specifically bridge structures which can have significant localised affects) were compared against the survey data (obtained from the Georges River Flood Study) and site inspection data and adjusted accordingly so that it correctly represented the terrain.

The Manning's "n" values were also checked and adjusted against site inspection and aerial photos to correctly determine and model the river's behaviour.

5.6 Tidal Exchange

The model results indicated that a high degree of exchange would occur between the river and the marina, due to the relatively wide marina entrance. The river is approximately 80 m wide in this location, while the entrance is at least 40 m wide. The water levels in the marina mimic those in the river, indicating that the entrance does not control flows entering and leaving the marina basin.

5.7 Flow Velocities

The model indicated that flow velocities due to tidal flows were low. Velocities in the marina basin were below 0.05 m/s and velocities in the river adjacent to the proposed marina were generally less than 0.3 m/s.

5.8 Bank Stability

Although the tidal flow velocities are low, other factors also affect bank stability. The 1.5 year ARI flow is considered to be the “bank forming” flow, during which velocities would likely be higher than those during tidal flow conditions. Waves generated by boats on the river also affect bank stability. The bank protection would be designed to withstand these forces.

6. WATER QUALITY

6.1 Introduction

The Georges Cove Marina would be connected to the Georges River. The river encompasses a large part of the Sydney urban area catchment and as such, receives significant pollutant loads from urban runoff and sewage overflows/discharges from the sewerage system and sewage treatment works. The proposed marina water quality will reflect the river water quality because the river flows are enormous in comparison to the volume of water in the marina basin. Nonetheless, the aim is for the marina to provide water quality which is better than the river quality so that it will not preclude the longer term improvement in river water quality. Also, it will be important that the marina does not contribute to make one element of water quality worse in the river. This will be achieved by targeting ANZECC water quality guidelines in the marina suitable for estuarine ecology.

The potential pollutant sources in the marina development are runoff from the land, copper from antifouling paints on the craft hulls and indiscriminate discharge of sewage from craft while at the marina berths. The development would incorporate water sensitive urban design measures to treat runoff prior to entering the marina basin and a sewage pumpout facility would be provided to alleviate unlawful discharges of sewage from craft holding tanks.

The proposed marina on the Georges River was assessed for the following purposes:

- To determine the potential impacts on the water quality in the river; and
- To determine the water quality within the waterbody of the marina.

The key consideration is the introduction of copper, used in antifouling paints, to the aquatic system. The introduction of copper would be limited through the management measures listed in **Section 6.1.1**. The other important parameters are suspended solids, nitrogen and phosphorus. These parameters are to be assessed on two bases:

- Comparison with existing water quality in the river; and
- Comparison with water quality guidelines.

The relevant water quality guidelines are the Australian and New Zealand Environment and Conservation Council (*ANZECC*), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* 2000.

6.1.1 Environmental Measures

Specific facilities within the development will reduce the environmental impact of the marina. A brief description of the facilities is provided below:

- The dry storage facility reduces the exposure of anti-fouling paint on craft hulls in the marina;

- The sewage and bilge pumpout facility within the marina will alleviate nutrient loads entering the marina through indiscriminate discharge of sewage from craft while at the marina berths; and
- Water sensitive design elements throughout the development will provide treatment of stormwater runoff and a reduction of pollutant load prior to entry into the marina/Georges River.

Management has decided not to sell anti-fouling paint that contains copper through the marina. This measure will decrease the copper load through the berthing facility.

6.1.2 Guidelines

The ANZECC/ARMCANZ 2000 guidelines aim to maintain or improve the environmental value of natural or semi-natural water resources. The guidelines recommend monitoring a range of indicators, collecting biological effect data for the existing ecosystem and the use of reference sites where no site-specific data is available. The guidelines are recommend tailoring for local conditions. Currently the site of the proposed marina is occupied by a sand extraction operation, including water bodies created through the dredging process. The construction of the marina would result from the sand extraction operation. This investigation compares predicted water quality indicators with default guideline values to assess the water quality performance of the proposed design.

6.1.3 Trigger values

'Trigger values' are defined as numerical values of an indicator (*such as concentration of total copper*) at which some management action is triggered.

As the marina does not exist, indicators were used predict the water quality behaviour. The aim of investigations is to ensure, to the extent possible, that the water quality indicators will be below the trigger values for a sufficient proportion of the time.

In line with current guidelines, the predicted stormwater water quality will need to be modelled and assessed in terms of the concentration of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS).

Copper loading from stormwater and copper leaching from antifouling has been calculated in terms of total copper (TCu). The TCu concentrations do not always meet the trigger values so, in accordance with the guidelines, copper speciation in the marina has been modelled and the labile (*bioavailable*) concentration (LCu) compared with the trigger values.

Nutrients

The guidelines give a set of default trigger values for physical and chemical stressors, such as nutrients, below which there is considered to be a low risk to the aquatic ecosystem from the physical and chemical stressors (Table 3.3.2 in ANZECC/ARMCANZ, 2000). The Guidelines are given in terms of the 80th percentile of measurements.

	Total Nitrogen (μg/L)	Total Phosphorus (μg/L)
Estuarine waters	300	30

The estuarine values have been adopted for the marina and the Georges River.

The primary mechanism by which excessive nutrients threaten the aquatic ecosystem is the same as for recreational and aesthetic values - algal blooms. A low risk to the aquatic ecosystem means a low risk of algal blooms and hence low risk also to the recreational and aesthetic values of the water body.

Suspended Solids

Estuaries typically experience a wide range of TSS concentrations. No absolute trigger values for TSS are given in the guidelines in relation to secondary contact recreational use, aesthetic value or risk to aquatic ecosystems. Effects of TSS loading on the aquatic ecosystem and aesthetic value can be discussed in terms of change from pre-development conditions. TSS loads to the marina are also relevant to the fate of copper in the marina.

Copper

The initial indicator for assessing the toxic effect of copper is concentration of total copper. However not all forms of copper are equally toxic. The decision tree for metal speciation given in the guidelines (Figure 3.4.2 in ANZECC/ARMCANZ, 2000) describes how if the total copper concentration fails to meet the trigger value then copper speciation and bonding with sediment can be considered to establish a bioavailable or 'labile' concentration that can be compared to the trigger value.

For protection of aquatic ecosystems the trigger values for concentration of labile copper are given in the guidelines (Table 3.4.1 in ANZECC/ARMCANZ, 2000) and presented in Table 6–1. The values for marine water are applicable to the site. The values for freshwater are shown for comparison purposes.

Table 6–1 – ANZECC Trigger Values for Copper

	Level of Protection (Percent of Species)			
	99%	95%	90%	80%
Trigger values for marine water (μg/L)	**0.3**	**1.3**	**3.0**	**8.0**
Trigger values for freshwater (μg/L)	1.0	1.4	1.8	2.5

For recreational use, the guidelines give a trigger value for copper concentration of 1000µg/L (Table 5.2.3 in ANZECC/ARMCANZ, 2000).

The guidelines do not give specific advice on copper concentrations for protection of human consumers of aquatic food. For the protection of aquaculture species a default trigger value of 5µg/L is given (Table 4.4.3 in ANZECC/ARMCANZ, 2000).

The marina's primary purpose is to provide a facility for recreational boats and the marina is not intended to extend the existing aquatic habitats available in the Georges River. Hence, the 90% or even 80% species protection value (**3.0** *or* **8.0 µg/L**) may be appropriate trigger values for the in-marina water quality. This should allow colonisation of the marina by copper tolerant species.

6.1.4 Water Quality Monitoring

Water quality monitoring of the existing waterbodies has been undertaken, primarily by Marine Pollution Research in 2006. **Table 6–2** lists the results of monitoring by Marine Pollution Research as reported in 2010.

Table 6–2 – Water Quality Test Results by Marine Pollution Research

Analyte**	Units	DetLim	Site	N	Min	Max	Mean	SE
pH	pH units		Bank	48	3.2	6.3	5.0	0.14
pH			Pond	12	6.8	8.7	7.9	0.16
pH			River	24	6.5	7.6	7.3	0.06
Cond	µS/cm		Bank	16	5400	14600	10038	695
Cond			Pond	4	7200	14800	11250	1571
Cond			River	8	8700	21000	16488	1771
TDS	mg/L		Bank	16	4700	10000	7438	441.10
TDS			Pond	4	7300	9600	8450	608.96
TDS			River	8	9600	14000	11950	562.84
Alkalinity	mg/L	< 0.1	Bank	16	0.05	150	32.6	11.86
Alkalinity			Pond	4	110	140	122.5	7.50
Alkalinity			River	8	65	95	75.1	3.41
TOC	mg/L		Bank	16	4	29	13.1	1.42
TOC			Pond	4	16	30	24.3	2.95
TOC			River	8	2	7	3.8	0.56
NH4-N	mg/L	<0.1	Bank	16	0.64	3.8	1.5	0.23
NH4-N			Pond	4	0.042	0.2	0.1	0.04
NH4-N			River	8	0.044	0.05	0.0	0.00

Analyte**	Units	DetLim	Site	N	Min	Max	Mean	SE
NOx	mg/L	<0.005	Bank	22	0.0025	0.22	0.1	0.01
NOx			Pond	4	0.0025	0.43	0.1	0.10
NOx			River	8	0.031	0.62	0.2	0.07
Al	mg/L	< 0.1	Bank	8	0.05	65	17.7	9.84
Al			Pond	2	0.05	0.2	0.1	0.08
Al			River	4	0.05	0.05	0.1	0.00
Cu	mg/L	<0.01	Bank	12	0.005	0.1	0.023	0.01
Cu			Pond	3	0.005	0.005	0.005	0.00
Cu			River	6	0.005	0.005	0.005	0.00
Fe	mg/L	<0.02	Bank	8	22	230	87.4	26.22
Fe			Pond	2	0.05	0.22	0.1	0.09
Fe			River	4	0.01	0.36	0.1	0.08
Mn	mg/L		Bank	16	0.7	4.4	1.8	0.25
Mn			Pond	4	0.04	0.15	0.1	0.02
Mn			River	8	0.02	0.06	0.0	0.01
Pb	mg/L	<0.01	Bank	12	0.005	0.07	0.0	0.00
Pb			Pond	3	0.005	0.015	0.0	0.00
Pb			River	6	0.005	0.015	0.0	0.00
Zn	mg/L	<0.02	Bank	10	0.03	0.3	0.1	0.03
Zn			Pond	0	0	0	0.0	0.00
Zn			River	2	0.01	0.01	0.0	0.00

* Bank = 4 bore sites on riverbank, pond is single dredge pond site and river = two river edge sites

**All other analytes (As, Ba, Cd, Cr, Hg, Se, OC pesticides, PAH & Phenols) were below detection or non-significant.

Additional monitoring was undertaken by quarry staff in 2008 for testing of the various copper components and associated suspended sediment levels in the river adjacent to the site. The samples were tested by the CSIRO laboratory at Lucas Heights. Sampling was undertaken on both spring and neap tides and at both high and low tides to gather the widest possible range of information on water quality at the site. Wet weather sampling was also undertaken for a rain event during which 27.2 mm of rain fell at Liverpool and 32 mm of rain fell at Bankstown. The results of this monitoring are shown in **Table 6–3**. It can be seen from the test results that the water has a dry weather labile copper concentration of 1.5 ± 0.40 µg/L, while combining the dry and wet weather results gives a concentration of 1.4 ± 0.41 µg/L. Thus, the water in the Georges River in the vicinity of the site generally only complies with the copper trigger value for protection of 90% of species.

Table 6–3 – Water Quality Test Results by Benedict / CSIRO

Laboratory I.D.	Sample I.D.	Date Sampled	Time Sampled	Conditions	Total Copper (µg/L)	Dissolved Copper (µg/L)	Labile Copper (µg/L)	Total Suspended Solids (mg/L)
CE5-1	MBK001	16/01/2008	10.10	Low neap tide	3.0	2.4	1.3	8
CE5-2	MBK002	16/01/2008	16.15	High neap tide	2.6	2.0	1.3	8
CE5-3	MBK003	22/01/2008	10.05	High spring tide	3.3	2.2	2.1	15
CE5-4	MBK004	22/01/2008	16.50	Low spring tide	3.0	2.2	1.3	15
CE5-5	MBK005	1/02/2008	12.00	Wet weather	3.0	2.3	1.0	21

6.2 Pollutant Inputs

6.2.1 Stormwater

Runoff from urban areas in the marina's catchment is not the primary source of pollutants entering the marina, but this source has been taken into account in the modelling for nutrients (*nitrogen and phosphorous*), suspended solids and copper.

A MUSIC water quality model was created to determine the pollutant inputs from stormwater in the catchment.

Rainfall data was collected from the *Bureau of Meteorology* (*BoM*) to be used in the MUSIC model. Pluvial rainfall data from Liverpool rainfall station (*station number 67035*) was used as it is the closest rainfall station to the marina and provided all years of data (*excluding 1994 where a complete year was not recorded*) between 1963 and 2000. The average annual rainfall depth for this period was 866 mm.

For this study the pluviograph record from 1st January 1972 through until 31st December 1975 was utilised for the MUSIC modelling because this relatively recent period contained both a dry, average and wet year, and has an annual average rainfall of 885 mm which is close to the long term average for the region.

The default soil parameter values in the MUSIC program were calibrated to reflect the runoff characteristics of the site. The soil parameters used for marina model were adopted from a previous study, where the soil parameters were calibrated to reflect the flood plain characteristics of a nearby site also located on the Georges River. The soil parameters adopted are shown in **Table 6–4**.

Table 6–4 – Adopted Soil Parameters

Parameters	Value
Soil Storage Capacity	120 mm
Initial Storage	30 %
Field Capacity	30 mm
Daily Deep Seepage Rate	30 %

The total rainfall catchment flowing into the marina is enclosed by the site boundaries with a total area of 16.5 ha. The site does not receive any water from any external catchments. The site comprises of 7.5 ha of residential development, 1.53 ha of commercial development and 9.94 ha of open space for the marina.

The development was modelled with general urban pollutant characteristics within the MUSIC model. Based on descriptions of the site, geographical maps and architectural drawings, the proposed development was modelled with impervious percentage of 70%.

The volumetric runoff coefficient (Cv) was assessed to check whether the adopted impervious percentage was acceptable. Calculations showed that an impervious percentage of 70% and the adopted soil parameters yielded a Cv value of 0.65 and a runoff volume of 94 ML/year. This Cv value typically reflects the characteristics of an urbanised site, and concludes that the adopted values in the MUSIC model will produce reliable indicative results. MUSIC results of pollutant discharge are shown in **Table 6–5**. Site runoff will be treated to attain best practice standards of 80% reduction in suspended solids and 45% reduction in nitrogen and phosphorus. It is assumed that copper concentrations would also be reduced through treatment. A reduction rate of 45% was conservatively adopted.

Table 6–5 – Music Results

Pollutant	Load Before Treatment (kg/year)	Minimum Reductions	Maximum Resultant Load (kg/year)
TSS	9,320	80 %	1,864
TP	22.5	45 %	12.4
TN	187	45 %	103
TCu	7.44	45 %	4.1

6.2.2 Discharges from Moored craft

General

The marina is being designed to accommodate 182 small craft and 4 larger vessels as per **Table 3–1**. Of these it is predicted that 176 will be private recreational craft and 10 will be commercial craft. Pumpout facilities as well as associated management practices will be incorporated within the marina to cater for the disposal of bilge water and sewage from craft while at berths. Notwithstanding these precautions the modelling has incorporated allowance for some illegal discharges of sewage and bilge water from craft.

All vessels berthed within the marina are expected to be painted with antifouling paint to slow the growth of marine organisms on the hull. Antifouling paint typically incorporates a biocide that is slowly leached from the paint into the surrounding water. By far the most common biocide currently used on recreational craft and small commercial vessels is copper. Copper leaching from antifouling paint represents a pollution load into the marina, as referred to in Section 6.1.1, anti-fouling paint which contains copper will not be sold at the marina.

Illegal or Accidental Discharge of Sewage and Bilge Water

With the pump-out facilities and management controls, accidental or illegal discharges of bilge water and sewage are expected to be minor. The pollution loadings for these discharges from vessels have been included in the marina water quality modelling.

Vessel usage will vary over the year, with a predicted maximum usage of 40% of craft moored at berths in peak summer periods. If it is assumed that the peak usage rate is extended over the entire year, the estimated weekly pollutant load from accidental sewage would conservatively be:

- Number of craft in the development = 186
- Usage rate of craft in any one week = 40%
- Average number of people on craft = 4
- Number of craft which cause discharges of sewage to the waterway = 20%

- All discharges occur within the marina waterway and not in the river
- Previous studies indicate the following loading factors for the use of toilets:
  - Suspended Solids 50 g/person/day
  - Total Nitrogen 8 g/person/day
  - Total Phosphorus 2 g/person/day

The total number of people who are assumed to contribute to unauthorised sewage discharge during a week can be calculated as follows:

186 craft x 40% occupancy x 4 people x 20% causing discharge = 60 persons

Hence, the pollution loading from accidental sewage discharge weekly by 60 persons would be approximately:

- Suspended Solids 21.0 kg/wk
- Total Nitrogen 3.36 kg/wk
- Total Phosphorous 0.84 kg/wk

The estimated potential quantity of accidental bilge water which may be discharged to the marina has been based on the craft usage noted above and the following conservative assumptions:

- Average craft bilge water pumpout volume per annum is 400 L (i.e. about 8L per week);
- Usage rate of craft in any one week = 40%;
- Number of craft which cause accidental discharge of bilge water = 20%;
- All discharge occurs within the marina waterway;
- Number of craft causing discharge per week = 15;
- Volume of bilge water discharged per week = 120 L.

Typical concentrations in bilge water, based on data collected in an earlier study by Dames and Moore, are as follows (rates for steel-hulled vessels have been conservatively adopted):

- Suspended Solids 355 mg/L
- Total Nitrogen 14 mg/L
- Total Phosphorous 1380 mg/L
- Copper 0.8 mg/L

The conservatively estimated pollutant loads entering the marina waterway in a week due to accidental bilge water discharge are presented below:

- Suspended Solids 42.6 g/wk
- Total Nitrogen 1.68 g/wk
- Total Phosphorous 166 g/wk
- Copper 0.096 g/wk

6.2.3 Copper Leaching from Antifouling Paint

The copper loading from antifouling is a function of the number and size of craft, the usage patterns of the craft, and the copper leaching rate from the antifouling paint.

Vessel Type and Size Distributions

The marina is being designed to accommodate 182 small craft and 4 larger vessels as per **Table 3–1**, with an assumed average wetted surface area of 24.6 m^2.

The distribution of berths in the marina is based on the predicted craft size distribution, taking into account the river location. The adopted craft size distribution is given in **Table 3–1**.

A craft-type distribution was estimated considering that typically most private marinas are dominated by power boats and, due to its location on the Georges River, this marina would have a particular bias towards power boats.

Curves are shown in **Figure W** relating hull length to wetted surface area for traditional long-keeled sailing boats, modern fin-keeled sailing boats, and a high and low curve for power boats which can vary greatly in shape and underwater appendages.

Vessel Usage Patterns

The usage patterns of vessels can have a significant effect on the copper leaching rate from the antifouling paint. Prior studies indicate that:

- most vessels are antifouled once per year;
- in water hull cleaning is either banned or discouraged on environmental grounds;
- most private marinas are dominated by power cruisers;
- on a busy weekend typically 10%-40% of boats may depart the marina;

- marinas surrounded by good cruising grounds, sheltered waterways with plenty of destinations within easy reach tend to have a higher rate of departures;
- up to 60% of vessels leave their berth very rarely or never.

Commercial vessels are predicted to be limited at the marina, due to its location on a river, distant from more popular coastal destinations.

Occupancy rates of 95% and 80% were adopted for private vessels and commercial vessels, respectively. These values are considered conservative.

Copper Leaching Rates

Copper leaching rates from antifouling paint may vary with many factors including the amount of copper in the paint, type of paint, water flow past the paint surface, temperature, salinity and pH of the water, presence of a bio-film on the paint surface, time since application and mechanical cleaning.

An emerging alternative to copper based antifouling systems are silicone based coatings which aim to make the surface so slippery that fouling organisms are washed off as the vessel moves through the water. These systems are considered to be superior from an environmental point of view as the do not include any biocide that is released into the water. However, at the current time and for the foreseeable future, copper based paints are considerably cheaper and more effective and are much more commonly used on both recreational and commercial vessels.

Valkirs et al 2003 conducted an extensive set of experiments to quantify leaching rates under a range of exposure conditions in San Diego Bay. Seven different self-polishing paints and one ablative antifouling paint were tested. Based on this study and other available information, a leaching rate of 7 $\mu g/cm^2/day$ was adopted.

Copper Loading from Antifouling

The copper loading from antifouling is calculated from the number of vessels, vessel size distribution, the wetted surface area curves, the proportion of time the vessels are expected to be in the marina and the adopted leaching rates. The predicted copper loading is 123 kg/yr.

6.2.4 Summary of Pollutant Inputs

A summary of the pollutant loadings adopted for modelling of the marina water quality is presented in **Table 6–6**.

Table 6–6 Summary of Pollutant Inputs to the Marina, ultimate developed scenario (kg/yr)

Pollutant	Load

From Stormwater	
Total Nitrogen	103
Total Phosphorus	12.4
Total Suspended Solids	1,864
Total Copper	4.1
Discharges from Craft	
Total Nitrogen	1094
Total Phosphorus	175
Suspended Solids	52.3
Copper	0.005
Copper from Antifouling	123
Total Copper from Stormwater, Craft Discharges and Antifouling	127

6.3 Flushing

6.3.1 General

Flushing is the exchange of water between the marina and the river, and it is an important mechanism for removal of pollutants from the marina. Natural flushing is driven by tidal flows, wind, density currents, stormwater inflows and diffusion. Tidal and stormwater flows would be the most important processes for the proposed marina.

6.3.2 Tidal Flushing

The proposed marina is situated on the Georges River, connected by a 40 m wide, 50 m long entrance channel. The tidal flushing of the marina is predominant because water will move all the way out of the channel and well beyond in one tidal cycle. There is the potential for up to 40 to 60% of the marina water to be exchanged between each peak and trough of a tidal cycle, varying with the tidal range.

6.3.3 Stormwater Flushing

Stormwater flushing is not considered to be the dominant flushing mechanism for the marina, as tidal flushing would occur daily and thus be more significant to the typical water quality in the marina.

Due to the relatively small catchment size, only 94 ML/year of runoff passes through the marina. This equates to approximately half the volume of the marina. Hence the tidal flushing of 40 to 60% per tidal cycle is of greater significance than 50% per year due to stormwater flushing.

6.4 Water Quality Modelling

Using the results from the hydraulic RMA-2 model, a water quality model describing the transportation and dispersion of pollutants could then be developed using the RMA-11 software.

RMA-11 is a two dimensional water quality and environmental transport software package, which can be used to model the advection-diffusion process in the aquatic environment along with basic algal, nitrogen, phosphorus and oxygen processes. RMA-11 operates on a physical hydrodynamic environment provided by the results of the RMA-2 modelling, that is, it is designed to accept velocity and depth data generated from the two-dimensional hydrodynamic model (*i.e., RMA-2*).

The RMA-11 model indicated that, under the tidal conditions modelled, approximately 53% of a conservative pollutant would be washed out of the marina in a day. This indicates that the marina basin layout and entrance configuration are not constraining tidal flushing.

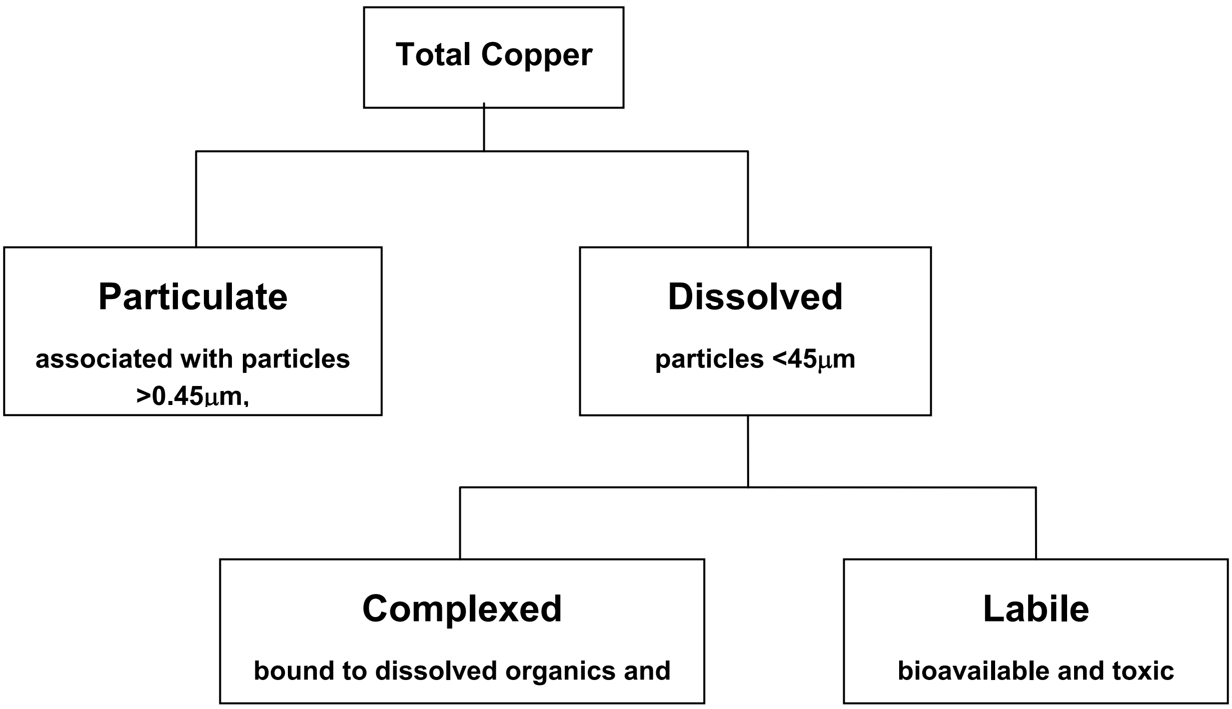
6.5 Copper

6.5.1 Copper Loading

Inputs to the model are average copper loadings from stormwater and vessel antifouling paint as described in **Section 6.1.4**.

6.5.2 Copper Partitioning

The terminology used to describe the copper partitioning is illustrated below.



Following the method of Chadwick et al (2004), the total copper within the water of the marina is divided into dissolved and particulate phases so that:

$$c_t = c_d + c_p$$

where: c_t = concentration of total copper

c_d = concentration of dissolved copper

c_p = concentration of particulate copper

'Particulate copper' is copper associated with particles greater than 0.45 µm diameter and is less toxic. 'Dissolved copper' is everything less than 0.45 µm diameter. A suspended solid dependant equilibrium between the particulate and dissolved copper is assumed such that:

$$c_p = K_d \, c_d \, TSS$$

where: K_d = partitioning coefficient (L/mg)

TSS = total suspended solids (mg/L)

The dissolved phase is further divided into complexed and labile phases:

$$c_d = c_c + c_l$$

where: c_c = concentration of complexed copper

c_l = concentration of labile copper

'Labile copper' is the bioavailable and therefore more toxic phase. 'Complexed copper' is bound to dissolved organics or colloids and is not bioavailable. The partitioning coefficient for the complexed and labile phases varies with the amount of available complexing material in the water. Based on advice from Dr Graeme Batley of CSIRO for coastal/estuarine waters, the complexed copper concentration has been determined as (refer **Appendix**):

$$c_c = 0.65\ c_d\text{, up to a maximum of } 4.0\ \mu\text{g/L}$$

6.5.3 Flushing

Flushing exchanges a portion of the water of the marina with water from the river every day, as described in **Section 6.3.2**, so the flux of copper out of the marina due to flushing is:

$$F = f\,V\,(c_t - c_{t,\ background}) \quad \text{(g/day)}$$

where: f = flushing rate (% per day)

V = volume of marina

$c_{t,\ background}$ = Georges River background total copper concentration

<u>Flux to Sediments</u>

Chadwick et al (2004) investigated a uniform first order loss to sediments as well as a simple partial settling model. They found that the particle settling model better predicted the copper concentration in San Diego Bay and this model has been adopted for the marina, so the flux to sediments over the marina is:

$$L = w\ V\ c_p / h \qquad \text{(g/day)}$$

where: w = effective fall velocity (m/day)

h = depth of marina

Chadwick et al acknowledge that this particle settling model is a simplification of the actual sediment-water exchange of copper which results from a number of processes including particle settling and re-suspension, as well as pore water advection and diffusion. Even in existing systems where data can be collected it is difficult to characterise all of these processes so an 'effective' fall velocity which integrates all of the processes is used.

6.5.4 Mass Balance Model of Copper in the Marina Basin

Copper from antifouling paint enters the water as copper ions, a large portion of which quickly binds to suspended solids or forms complexes with dissolved organics and colloids. This leaves only a fraction of the total copper in a bioavailable or 'labile' form. A mass balance model of copper in the marina has been constructed based on the work of Chadwick et al (2004) who modelled the mass balance and fate of copper in San Diego Bay and earlier studies.

The mass balance model considers the marina as a single, well mixed element in steady-state. The model considers the attachment of copper to sediments and settling to the bed, the complexing of dissolved copper and the removal of copper from the marina by tidal flushing.

Evaluation of Parameters in Copper Mass Balance Model

The particulate-dissolved partitioning coefficient, K_d, can be calculated from physical measurements in an existing system of interest but the effective fall velocity, w, is to a large extent a calibration parameter. Calibration of the model was based on the results of calibration in other projects.

The particulate-dissolved partitioning coefficient, K_d for the Georges River averaged 0.033 for dry weather events.

San Diego Bay

Chadwick et al (2004) calibrated their model of San Diego Bay to 4 sets of measured data. Their best-fit parameters are given below in **Table 6–7**:

Table 6–7 Best-fit parameters for San Diego Bay (from Chadwick et al 2004)

	Combined	**Aug 2000**	**Jan 2001**	**May 2001**	**Sept 2001**
K_d (L/mg)	0.1	0.22	0.06	0.05	0.08
w (m/day)	1.4	0.85	4.8	3.3	1.3

It was noted that the two parameters were not independent, with high partitioning coefficients occurring with low effective fall velocities and vice versa. It is thought that the sediment in the bay in May 2001 was coarser and less reactive than the sediment in August 2000. The difference may be explained by the variation in river and stormwater flows entering the bay. Coarse sediments have proportionally less surface area by weight and therefore less affinity for copper (*smaller* K_d) and higher fall velocities than fine sediment. Organic sediment tends to have a higher affinity for copper than inorganic sediment.

Other Systems

Chadwick et al. (2004) also give some values for dissolved-particulate copper partitioning coefficients determined from other studies:

Location	K_d (L/mg)
Melbourne	0.076
Southern coast of England	0.0003-0.12
San Francisco Bay	0.07
Galverston Bay, Texas	0.03

Proposed Marina

The sources of sediment to the marina will be the river, treated local catchment stormwater, resuspension of sediments on the bed stirred up by craft movement, wave action and discharges from vessels. Much of the stormwater will have passed through a treatment train consisting of devices such as wetlands, swales and gross pollutant traps. Furthermore, the stormwater flushing is low relative to tidal flushing. It is therefore expected that the river will be the primary source of the suspended solids entering the marina.

The concentration of suspended solids (TSS) in the marina is an important parameter for prediction of copper partitioning. TSS in the marina has been established by measurements taken in the Georges River and taken as the average of dry weather conditions. The concentration as well as the characteristics of the suspended solids varies with the antecedent rainfall conditions. From the available data on TSS in the Georges River a value of 12 mg/L was chosen to represent average conditions. This value is conservative for modelling purposes, as a higher TSS concentration would lead to a greater loss of copper from the water column through sedimentation.

Table 6–8 Copper Mass Balance Parameters

Conditions	K_d (L/mg)	w (m/d)	TSS (mg/L)
average	0.033	1.4	12

The Georges River background total copper concentration as averaged from **Table 6–3** was 3 μg/L.

PREDICTED COPPER CONCENTRATIONS IN THE MARINA

The predicted copper concentrations are presented in **Table 6–9**. The labile copper concentration with TSS varies significantly and is most sensitive to the concentration of suspended solids during dry weather conditions. For average conditions, the labile copper concentration is predicted to meet the target for 90% of species (3 μg/L), just failing to meet the 95% target of 1.3 μg/L.

Table 6–9 Predicted Copper Concentrations

Case	Total (μg/L)	Particulate (μg/L)	Dissolved (μg/L)	Complexed (μg/L)	Labile (μg/L)
Average	5.82	1.65	4.17	2.71	1.46

6.5.5 Sensitivity Analysis

Sensitivity analyses were carried out as presented below.

Tidal Flux

The hydrodynamic model predicted a tidal exchange rate between the marina and the river of 53% of the marina water per day. The following table indicates that an extreme variation in the tidal flux value would be required in order to have a significant impact on the predicted labile copper concentration, in consideration of the monitored range of labile copper in the river (1.4 ± 0.41 μg/L).

Table 6–10 – Tidal Flux Sensitivity Analysis

Tidal Flux (%)	Predicted Labile Copper Concentration (μg/L)
30	1.79
40	1.59
50 (adopted value from hydrodynamic model)	1.46
60	1.36
70	1.29

Marina Occupancy

Occupancy rates of 95% for recreational vessels and 80% for commercial vessels were adopted for modelling. If a boat leaves the marina for two of the seven days of the week, it would occupy the marina 71% of the time. If a boat leaves the marina for a long day out (say 12 hours), it would occupy the marina 93% of the time. Model runs were carried out as below to represent both higher and lower occupancy rates than those adopted in the modelling.

Table 6–11 – Marina Occupancy Sensitivity Analysis

	Low Occupancy	Adopted Value	High Occupancy
Recreational Vessel Occupancy %	71	95	100
Commercial Vessel Occupancy %	50	80	93

Total Copper from Antifouling (kg/year)	89.7	123	131
Total Copper from Stormwater (kg/year)	4.1	4.1	4.1
Total Copper Discharges from Craft (kg/year)	0.005	0.005	0.005
Total Copper from Stormwater, Craft Discharges and Antifouling (kg/year)	93.8	127	135
Predicted Labile Copper Concentration in Marina (µg/L)	1.23	1.46	1.52

The occupancy sensitivity analysis indicates that modelling increased values for occupancy would not have a significant effect on the percentage of species protected as the predicted labile copper concentration lies within the existing monitored range in the river.

Boat Numbers

A sensitivity analysis for the number of boats was undertaken as presented in the following table

Table 6–12 Boat Number Sensitivity Analysis

	Low	**Adopted**	**High**
Number of Recreational Craft	164	176	200
Number of Commercial Craft	9	10	11
Total Copper from Antifouling (kg/year)	114	123	139
Total Copper from Stormwater (kg/year)	4.1	4.1	4.1

Total Copper Discharges from Craft (kg/year)	0.005	0.005	0.005
Total Copper from Stormwater, Craft Discharges and Antifouling (kg/year)	118	127	143
Predicted Labile Copper Concentration in Marina (μg/L)	1.40	1.46	1.57

The results indicate that the predicted labile copper concentration is not highly sensitive to the number of boats in the marina, as the predicted high and low concentrations still lie within the current monitored range of copper in the river (1.4 ± 0.41 μg/L).

6.5.6 Summary of Copper in the Marina

The toxicity of copper varies as copper is present in different chemical states. Of most concern to the aquatic environment is labile copper, which is a bioavailable form of copper, The ANZECC guidelines state trigger values for the concentration of labile copper in an aquatic environment, which correlate to a percentage of aquatic species that will be protected at this value.

As the marina's primary function is to provide a facility for recreational boats and not to extend the existing aquatic habitats which are available in the Georges River, 90-95% of species protection (which equates to a labile copper concentration of 1.3 – 3 μg/L) would be appropriate for in-marina water quality. Labile copper in the Georges River has been measured at 1.0 - 2.1 μg/L.

To calculate the quantity of copper entering the marina for comparison to the ANZECC trigger levels the following information was utilised and incorporated into a mass balance assessment:

- Sources of copper into the marina are stormwater runoff (this is treated by water sensitive urban design measures), illegal bilge discharge from moored craft and leaching from copper-based anti-fouling paint on craft hulls;
- The leaching from anti-fouling paint varies as a function of the number of boats in the marina and their size, usage patterns of craft and the leaching rate of paint;
- Tidal flushing provides an exchange of 40-60% of the water in the marina;
- The river is expected to be the main source of TSS in the proposed marina. TSS in the marina is important for the prediction of copper partitioning. The value of 12 mg/L was adopted as an average river value, based on water quality measurements. On average, the background level of total copper in the Georges River is 2.98 ±0.25 μg/L.

Using the above information in Chadwick's model, the quantity of labile copper in the marina is predicted to be 1.46 µg/L. Based on the ANZECC guidelines, a concentration of 1.46 µg/L of labile copper correlates to the protection of 90-95% of aquatic species, and also indicates no change from the monitored range of copper concentrations in the river (1.4 ± 0.41 µg/L).

6.5.7 Conclusion

This analysis demonstrates that development of the marina would not have a significant impact on the existing copper concentrations in the Georges River and the predicted concentrations would allow 90 to 95% of species to inhabit the marina in accordance with the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems.

6.6 Acid Sulfate Soils

Management of Acid Sulfate Soil is an important aspect of the construction and operation processes. A geotechnical investigation would be required to identify the presence of Acid Sulphate Soils on the site, and within the area where works would occur. If Acid Sulfate Soil is present on-site, an Acid Sulfate Soil Management Plan would be required.

Acid Sulfate Soil is the common name given to sediment and soil containing iron sulfide. The exposure of iron sulfides to air will result in oxidation and the generation of sulfuric acid. Acid leachate can strip metals such as aluminium and iron from the soil matrix and release them into water bodies. Toxic concentrations of these metals will affect water quality and adversely affect aquatic organisms (disease or death) that inhabit the water body.

When saturated mud, gravel or sand containing iron sulfides is disturbed by excavation, dredging or dewatering and exposed to air, the generated acid leaches from the soil (Acid Sulfate Soils Planning Guidelines, 1998). Acid leachate can cause severe environmental degradation and/or contamination. In discussion of acid sulfate soils the following definitions are important (ASSMAC, 1998):

Acid Sulfate Soils (ASS) include actual acid sulfate soils and potential acid sulfate soils. Actual and potential acid sulfate soils are often found in the same soil profile, with actual acid sulfate soils generally overlying potential acid sulfate soil horizons.

Actual Acid Sulfate Soils are soils containing highly acidic (pH ≤ 4) soil horizons or layers resulting from the aeration of soil materials that are rich in sulfides, primarily iron sulfide. This oxidation produces hydrogen ions in excess of the sediments capacity to neutralise the acidity of the soil. These soils can usually be identified by the presence of pale yellow mottles and coatings of jarosite.

Potential Acid Sulfate Soils are soils which contain iron sulfide material which have not been exposed to air and oxidised. However they pose a considerable environmental risk when disturbed, as they will become severely acidic when exposed to air and oxidised. Exposure of acid sulfate soils to the atmosphere (lowering of the watertable or disturbance through dredging/excavation) has the potential to produce acid generating conditions that may adversely affect the local environment.

The Acid Sulfate Soils Planning Guidelines (1998) have a hierarchy of management techniques for dealing with ASS. These are listed as follows:

1. **Avoid land where acid sulfate soils occur**

   If the preliminary soil survey indicates that the site contains high levels of acid sulfate soils, the most environmentally responsible action may be to investigate alternative feasible sites that meet the operational needs of the applicant.

   This principle applies equally when selecting routes for drains, roads or pipelines or for individual sites for residential developments, infrastructure projects, agricultural enterprises or quarries. In the case of quarries, dredging or other operations which have the potential to result in moving acid sulfate soils problems on to another site, the onsite mitigation measures prior to transport plus the cost of quality assurances programs will need to be factored into the project along with the costs associated with the liability for damages if acid is generated at the other site.

2. **Avoid disturbing ASS if present on land**

   To develop effective avoidance strategies, a more detailed investigation is required to understand the soils, surface and sub-surface water characteristics on the site and the sensitivity of the surrounding environment. In many cases, the site should be mapped indicating the depth to sulfide material and groundwater and the variation in the soil characteristics including the concentration of the sulfidic material. The advantage of an "avoidance" approach is that there is no ongoing mitigation required. Possible avoidance mitigation options include the following options.

   a. Undertake shallow soil disturbance so as not to disturb acid sulfate soils;

   b. Redesign existing drains so they are shallow and do not disturb acid sulfate soils

   c. Avoid activities which result in the fluctuation of groundwater, in particular the lowering of groundwater

   d. Cover acid sulfate soils with clean fill material so as not to disturb them

   e. Set aside acid sulfate soil areas and not disturb them

   f. Set aside highest sulfide areas and disturb only the lowest

3. **Prevent the oxidation of sulfide**

   Mitigation strategies to prevent oxidation depend on maintaining the sulfidic material in an anaerobic environment. However, soils or soil layers with existing acidity from previous oxidation of sulfide (indicated by field $pH_F < 4.5$) are more difficult to prevent further oxidation by denial of oxygen alone, as oxidation may proceed by electron transfer between compounds at different oxidation states. Usually some addition of a neutralising agent will also be necessary when acidity has already been produced.

a. Stage projects to prevent oxidation

b. Place any excavated sulfidic material immediately under water

c. Raise the watertable to maintain potential acid sulfate soils in a saturated state

d. Cap the acid sulfate soil material

4. Oxidation of sulfide and neutralising acid as it is produced

The most common acid sulfate soils mitigation methods relies on providing sufficient neutralising agent to neutralise acid as it is produced over time due to the gradual oxidation of acid sulfate soils. Most mitigation strategies will result in a certain amount of oxidation of acid sulfate soils either deliberately or inadvertently. In most cases, the natural buffering capacity of the system will initially contribute to the neutralisation of acid produced. However, depending on the sulfide content, substantially more neutralising material usually needs to be added.

a. Oxidation of sulfide and neutralising using lime or similar agents

b. Neutralisation using the buffering capacity of estuarine water

c. Vertical mixing and neutralisation using the buffering capacity of soil

5. Separate out and treat the sulfidic component

With some types of sediments extracted by dredging, it may be possible to partially or fully separate the acid sulfate fines from the sand resource by mechanical methods such as sluicing or hydrocycloning techniques. The method is a particularly attractive mitigation option when full separation can be easily achieved, as the resource can be considered to be “clean” and require the addition of little or no neutralising agent prior to use.

7. NAVIGATION

7.1 Marina Entrance

The proposed marina is recessed into the riverbank and entrance to the river would be via a short entrance channel (approximately 50 m long). Navigation through the entrance would be available at all states of tide as sufficient water depth would be provided at low water for the types and size of vessels likely to use this facility.

Due to the location of the marina entrance, within the speed boat area, measures are proposed to maintain safety and minimise the impact on existing river users. Navigation markers could be positioned near the marina entrance to denote a specific entry channel and keep passing boats away from the entrance side of the river. The design and location of the navigation markers would be undertaken in close consultation with NSW Maritime.

Signs would also be used to alert those leaving the marina to proceed with caution at a maximum of 4 knots onto the river. River users could also be alerted to the marina entrance by appropriate signage.

7.2 Impact on Bank Stability

The marina would result in additional craft using the adjacent stretch of water in the Georges River compared to current conditions, however this would not necessarily impact the river banks, as the reach is already currently heavily used at high speeds.

The marina design incorporates bank stabilisation works, which would be an improvement on the existing scenario, where the river bank is eroding. The bank stabilisation works would be undertaken in consideration of the boat generated waves in the river, hence resulting in a more stable stretch of foreshore.

8. SUMMARY AND CONCLUSION

The proposed design of the Georges Cove Marina has incorporated a number of measures to address flooding, tidal hydrodynamics, water quality and navigation issues. These are summarised below:

- Floor levels of the building and marina facilities have been determined utilising the 100-year ARI flood levels produced in the Georges River Flood Study (adopted by Liverpool Council) and incorporate the appropriate amount of freeboard;
- Tidal hydrodynamics have been assessed through hydraulic modelling. There is a high degree of tidal exchange between the marina and the river, this is not significantly affected by varying the entrance channel between 40 and 50 metres in width.
- Based on water quality testing, the water quality in the quarry is of a similar quality to that in the Georges River. Breakthrough of the bank from the marina to the Georges River would not significantly affect the water quality of either bodies;
- Pollutants sources for the marina are stormwater runoff, illegal discharges of sewage and bilge water, copper leaching from anti-fouling paint on boat hulls and sediment from the Georges River.
    - The incorporation of water sensitive urban design elements provides stormwater treatment to reduce nitrogen, phosphorus, TSS and heavy metals;
    - Bilge and sewage pump-out facilities would be provided in the proposed marina. It is expected that there will still be a small amount of illegal discharge. This pollutant load was modelled and due to the high flushing rate of the marina through the tidal cycle, nutrients will not accumulate in the basin; and
    - Modelling of copper concentrations indicates that the development of the marina would not have a significant impact on the existing copper concentrations in the Georges River and the predicted concentrations would allow 90 to 95% of species to inhabit the marina per the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems.
- Navigation through the channel to enter the marina would be available through all states of the tide. Measures are proposed to maintain safety in the area as the entrance of the marina is within a speed boat area;

The marina design incorporates bank stabilisation works; currently there is no bank protection and erosion is occurring.

The proposed marina basin, with appropriate design and mitigation measures as recommended in this report would provide a facility which would meet the community environmental standards and would provide a recreational asset, which is in short supply along the Georges River.

9. REFERENCES

1. Australian Standard AS 3962 – 2001, Guidelines for Design of Marinas
2. ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*
3. Public Works Department (June 1990) *The East Hills Bank Erosion Study, Georges River*
4. Public Works Department (February 1991) *The Georges River Database Compilation and Assessment*
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6. Chadwick D, Zirino A, Rivera-Duarte I, Katz C and Blake A (2004) *Modelling the mass balance and fate of copper in San Diego Bay*, Limnology and Oceanography, vol.49(2), 355-366
7. Marine Pollution Research (2010) *Georges River Marina, Moorebank Aquatic Ecology Aspects & Environmental Assessment Of Marina Concept Design Report Prepared For Benedict Industries Pty Ltd*
8. Valkirs A, Seligman P, Haslbeck E and Caso J (2003) *Measurements of copper release rates from antifouling paint under laboratory and in situ conditions: implications for loading estimation to marine water bodies* Marine Pollution Bulletin 46

Figures

FIGURE 1

LEGEND

EXISTING CONTOURS

Numbers

Carparking	Number
Carpark A	70 on-grade car spaces
Carpark B	133 on-grade car spaces
Carpark C	70 on-grade car spaces
Carpark - Dry Store	216 under-cover car spaces
Total Car Spaces	**489**

Marina	Length	Number
Small Craft (<15m)	≥ 8m < 10m	52 Marina Berths
Small Craft (<15m)	≥ 10m < 12m	110 Marina Berths
Small Craft (<15m)	≥ 12m < 15m	20 Marina Berths
Vessels	≥ 15m < 18m	2 Marina Berths
Vessels less than	20m	2 Marina Berths
Vessels	20m or more	0 Marina Berths
Total Marina Berths		**186**

Dry Store	Length	Number
Small Craft (<15m)	≥ 4m < 6m	125 Dry Berths
Small Craft (<15m)	≥ 6m < 8m	125 Dry Berths
Vessels	≥ 15m	0 Dry Berths
Total Dry Berths		**250**

Note Berths & fairways have been designed in accordance with AS. 3962-2001

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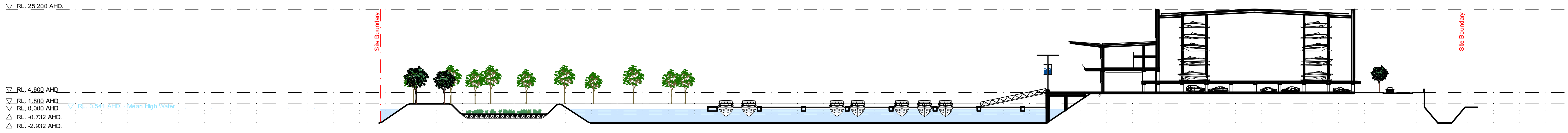
MARINA BASIN LAYOUT

LOCATION: W:_Infrastructure\Projects\301015\01167 - BS&G Marina\Drawings\SKETCHES\01167 FIGURE 1.dwg DATE & TIME: 30-Sep-10, 1:58:00 PM

FIGURE 2



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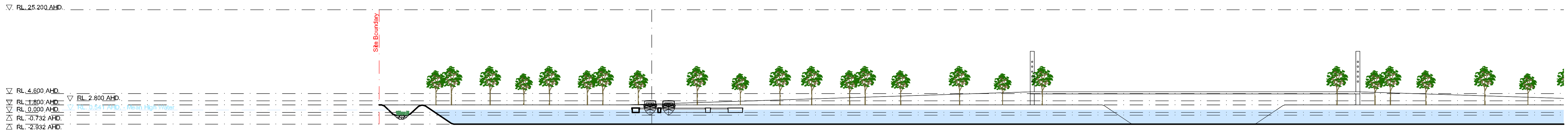

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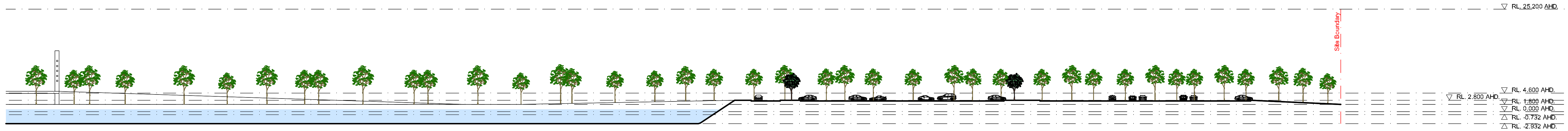

03 Section BB - South
1 : 500

0 10 20 30 40 50m
1:500(A1) 1:1000(A3)

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SITE SECTIONS

LOCATION: W:__Infrastructure\Projects\301015\01167 - BS&G Marina\Drawings\SKETCHES\01167 FIGURE 1.dwg

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