

APPENDIX 13

Soil and Water Management Report




**Soil and Water Report to support
the Environmental Assessment
for**

Headland Park Barangaroo
Barangaroo Delivery Authority



October 2010
WSP Environment & Energy

QUALITY MANAGEMENT

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1 INTRODUCTION

Barangaroo is a 22 hectare area of Sydney Harbour foreshore, immediately adjoining the western edge of the Sydney CBD which has been designated for redevelopment by the NSW State Government. The redevelopment of the Barangaroo site will comprise land dedicated to open space (Headland Park and Northern Cove) at the northern end (the Site), and approximately 500,000m² of primarily commercial and residential space at the southern end.

The redevelopment project requires the Minister for Planning's approval of two project applications for the works at Headland Park and Northern Cove under Part 3A of the *Environmental Planning and Assessment Act 1979*. They relate to (1) the Early Works and (2) the Main Works. The Main works for the Headland Park and Northern Cove construction are planned to commence in February 2011.

The Main Works portion of the Headland Park development will incorporate the following components:

- Retention of the seawall and caisson structures for almost the entire duration of the works;
- Bulk earthworks to build up the levels on the site created by the early works program to the finished levels of the Headland Park. This will involve the relocation of materials from the excavation of the Northern Cove and uncontaminated or remediated soils from the southern part of the development;
- Remedial works to any soils within this area if not already completed;
- Construction of shoreline sandstone beachfront;
- Construction of required infrastructure including cooling water circuits for the future Cultural Facility;
- Planting of vegetation and landscaping; and,
- Towards the end of the works, removal of the top cap of the caisson structure to allow the new waterfront to establish.

WSP Environment and Energy (WSP) are of the understanding that a site Construction Environmental Management Plan (CEMP) will be prepared by the selected Contractor and will be specific to their works plan.

WSP was engaged by the Barangaroo Development Authority (BDA) to address certain parts of Section 8 'Soil and Water' of the Director General's Requirements (DGRs) as outlined below.

Section 2 of this report outlines a Project Overview – providing a simplified explanation of the activities associated with the development of the Site.

Section 3 outlines Management Protocol in relation Section 8 of DGRs - Soil and Water. The DGRs are as follows:

- Assess impacts on water quality of Sydney Harbour and proposed management, mitigation and monitoring measures;
- Erosion and sediment controls during remediation and excavation;
- Details of water quality monitoring program for Sydney Harbour, with a focus on turbidity and key contaminants;
- Assess the impacts on surface and groundwater hydrology and quality;
- Assessment for the potential impacts on marine vegetation and aquatic ecology;
- Management measures for any barging of any excavated or contaminated material;
- Stormwater management and strategies during construction;
- Assess impacts on estuarine circulation, estuarine water quality and aquatic ecology of land formation works (including impacts on aquatic vegetation from direct smothering and any changes that may result from altered hydrological regimes of surrounding waters and bays). Any modification of estuarine foreshores (including the incorporation of measures to improve the habitat value of newly created waters (such as

environmentally friendly seawalls) should consider *Environmentally Friendly Seawalls – A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries* (DECC, 2009).

- The discharge of stormwater or other water should be assessed by comparison to the relevant water quality objectives and environmental values for Sydney Harbour estuarine waters, see <http://www.environment.nsw.gov.au/ieo/index.htm> for NSW Water Quality Objectives; and refer to related Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000); http://www.mincos.gov.au/publications/Australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality.
- Consideration of the collection, treatment and management of contaminated surface and groundwater across the site. No contaminated or treated site waters (surface, collected groundwater, or contaminated construction waters) are permitted to enter Sydney Harbour and should be discharged under a trade waste agreement with Sydney Water.
- Consideration of the collection, treatment and management of contaminated surface and groundwater across the site.

Section 3.8 of this report has been produced by SMEC as sub-consultants to WSP with their full report included in Appendix A.

2 PROJECT OVERVIEW

This section provides a simplified explanation of the activities associated with the development of the Site. The proposal includes all works required to construct the final landform including the park and northern cove. In addition the works include construction of a car park with up to 300 spaces and a space for a future use (as a Cultural Facility which will be subject to a separate project application) comprising a volume of up to 100,000m³ within the Headland (i.e. below finished ground level adjacent to the existing sandstone cutting). Works include:

Land formation utilising fill from Stage 1, ranging from the 150,000m³ identified in the Early Works application to 230,000m³ (additional 80,000m³ from Stage 1) along with excavated material from Stage 3 (120,000m³) to build the headland up to finished levels;

Construction of structural earth retaining walls;

Creation of a naturalistic shoreline and Northern Cove through excavation behind the existing caisson walls, formation of retaining walls using rock armouring etc;

Placement of fill (amount included above) within the sandstone extraction area;

General landscaping and planting;

Construction of a network of pedestrian pathways connecting the foreshore walkway and Merriman Street;

Construction of a shoreline promenade;

Jetty / viewing platform extending into the Northern Cove from the southern shoreline;

Construction of a car park totalling up to 300 spaces within the headland with vehicular access from Towns Place and pedestrian access from various locations within Headland Park;

Construction of a space for a future use (Cultural Facility) of initially up to 75,000m³ and ultimately up to 100,000m³;

In conjunction with the space for the future Cultural Centre, cooling water infrastructure will be installed allowing use of harbour water; and

Site remediation - limited contamination of fill material was identified on the Headland Park site and no significant groundwater contamination was identified. On-site reuse/placement of impacted fill materials will meet the Site Acceptance Criteria.

The Sydney Harbour Control Tower will remain onsite and be operational in accordance with Sydney Ports Corporation's requirements until future modification for reuse or demolition is required. Any changes to the Sydney Harbour Control Tower will be the subject of a separate application.

Drawings showing the proposed Headland Park and Northern Cove Main Works are provided within Appendix 1 of the Environmental Assessment.

2.1 MAIN WORKS STAGING AND SEQUENCING

The Main Works phase of the Headland Park and Northern Cove construction requires certain staging and sequencing of the works in order to deliver the park in the most efficient and effective way. The project will be delivered from North to South, working adjacent to Sydney Harbour and progressing toward Darling Harbour and Wharf No 5. The temporary Passenger Cruise Terminal is located at Wharf No 5 and is required to be decommissioned prior to the southern portion of the Headland Park and the Northern Cove excavation commencing. Accordingly, the Main Works will be constructed in distinct phases and within each phase, sequencing of the works will be necessary as outlined in **Table 1** below.

Table 1: Main Works Staging and Sequencing (Source; BDA, 2010)

Key Stages	Sequencing of Key Activities
Early Works	1. Site establishment north of the existing temporary cruise passenger terminal with a 6m wide walkway around the perimeter
	2. Establish environmental controls and adjust existing services including a temporary sewer pump station on Hickson Road
	3. New sewers draining Towns Place along Hickson Road to Sydney Water SPS1129
	4. Commence sandstone extraction
	5. Commence drainage layer over existing pavement
	6. Development of traffic management for fill transport from Stage 1
	7. Commence placement of approved fill material from Stage 1 and retaining wall construction
Main Works	8. Continue sandstone extraction and storage
	9. Continue receipt of approved fill from Stage 1 until no longer required (nominally 190,000m ³) and retaining wall construction
	10. Commence new Shoreline construction and relocation of the public walking and cycling from Towns Place to a point adjacent Gate No 4 on Hickson Road.
	11. Commence Northern Cove excavation
	12. Stage 1 Fill placed (up to 80,000m ³) in the Sandstone extraction pit
Buildings and Landscaping	13. Car park and structures
	14. Hard and soft landscaping
	15. Excavate Northern Cove and construct new Shoreline
	16. Construct Water Taxi facility April
	17. Heavy soft and hard landscape maintenance
Establishment Period	18. Decreasing degree of maintenance as Hard and Soft landscape elements 'settle-in'

2.2 SEAWALL DESIGN AND POTENTIAL IMPACTS

The seawall design for the Site area is described in detail in the Maritime Works Concept Design Report (Hyder, 2010). In addition, Hyder produced a series of sketches (reproduced here by WSP) showing the construction and post construction staging (**Figure 1**) to enhance understanding of potential impacts during construction.

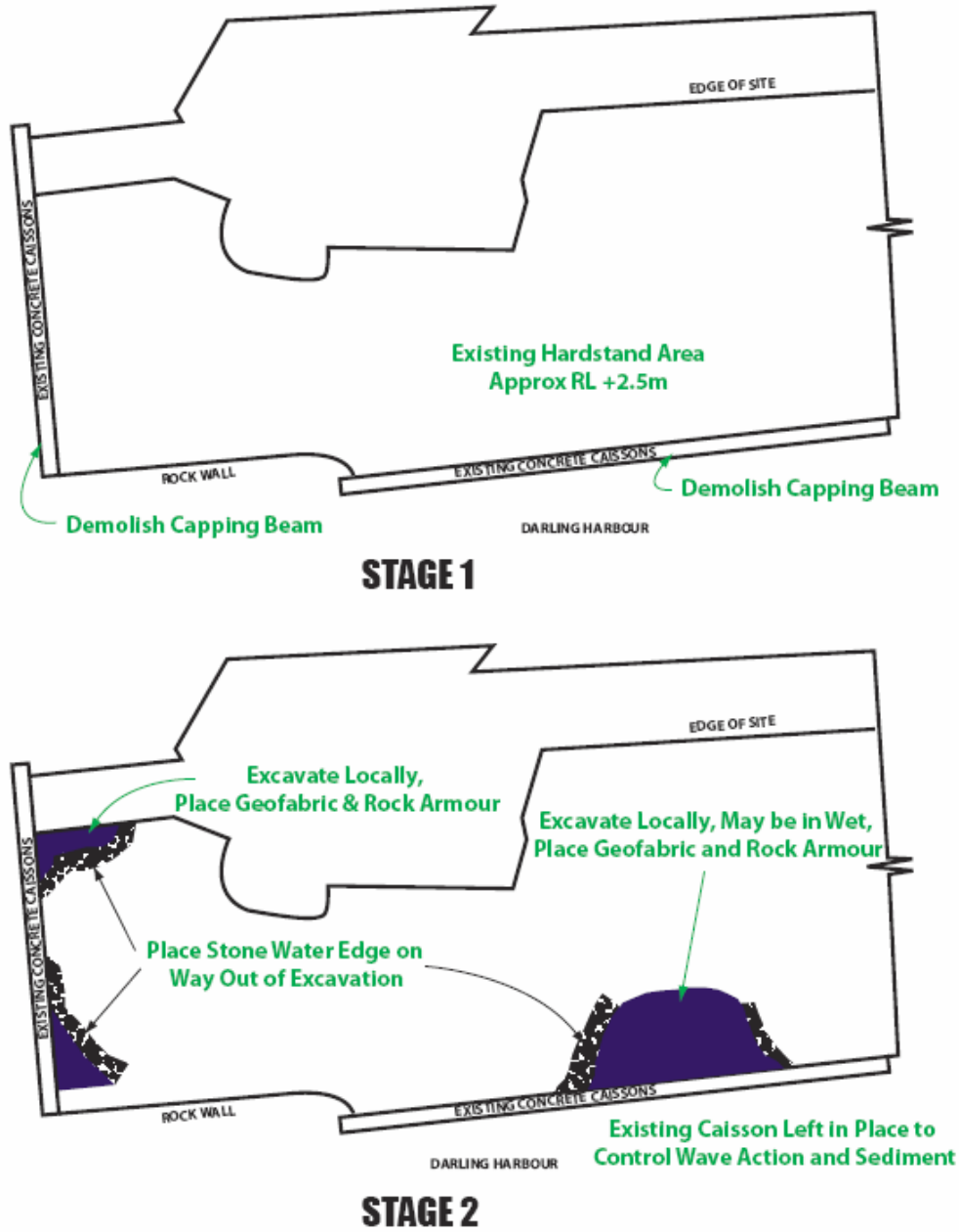
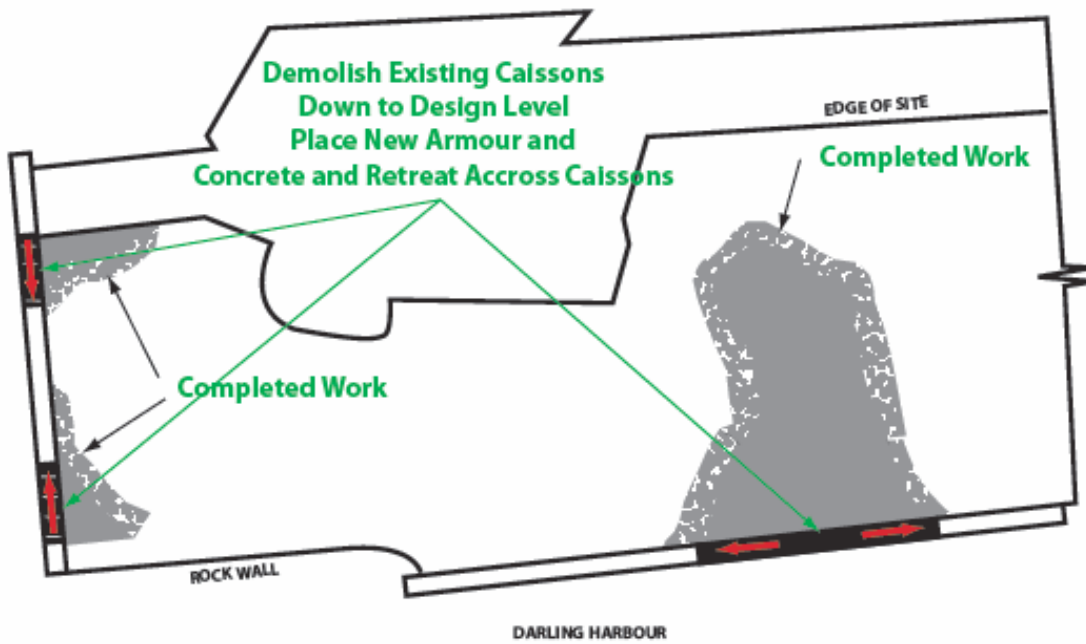


Figure 1: Seawall construction and post construction stages.



STAGE 3



STAGE 4

Figure 1 (cont.): Seawall construction and post construction stages

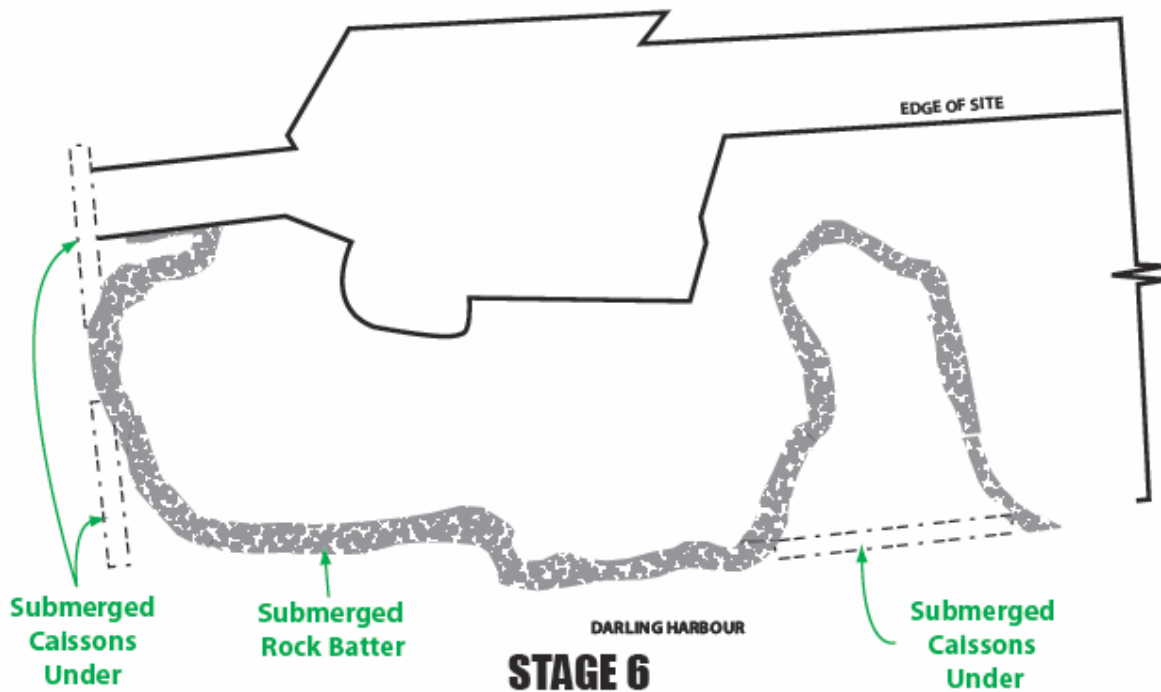
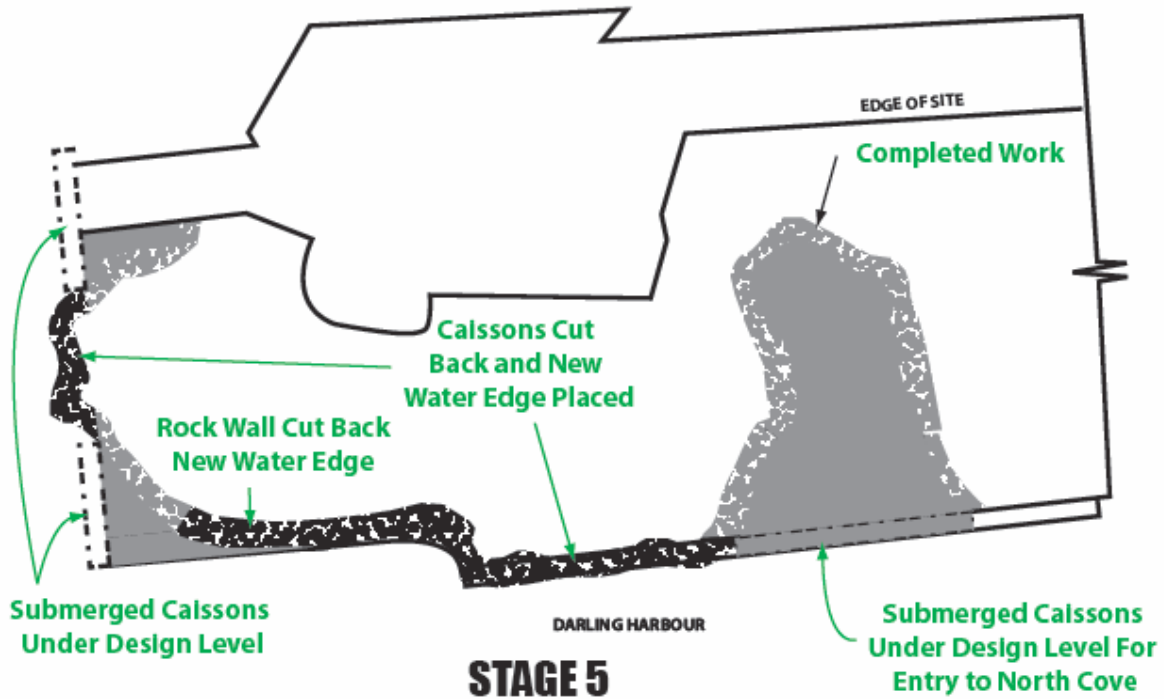


Figure 1 (cont.): Seawall construction and post construction stages.

Further information on each of the stages shown in Figure 1 is provided below.

Stage 1 is the demolition of the capping beam which previously served as a means for attaching protective buffers for mooring ships alongside of the wharf. For the most part, this will be done with only very minor spillage of concrete material onto the adjacent harbour floor.

Stage 2 indicates the excavation to about RL – 3.0m within the caisson enclosure (blue areas) and the replacement with geofabric and rock armour to a RL of about -2.0m. This represents the perched surface adjoining the park which will eventually allow a small boat to reach the shore. Note that the harbour floor adjacent is at about RL – 13m. The retention of the existing caisson at its current height will control wave action and prevent sediment from the excavation from entering the harbour. This stage has no direct impact on the harbour.

Stage 3 extends the south-western excavation to the east to the border of the ultimate beach redevelopment (to meet the original shoreline). Again, this will effectively have no effect on the harbour.

Stage 4 shows that after the work in the excavated areas is complete that the existing caissons are then demolished from the top down to the park/water interface design level at which point new armour and concrete are placed on top of the new caisson design level. While measures will be put in place to contain the demolition material, there is some small risk that some spillage of concrete may occur into the adjacent harbour.

Stage 5 shows further re-shaping of the park/water interface involving work in the north and west, south-west. Note that there is a portion of the existing wharf on the western side that has no caissons, but instead has a rock wall. For this area it will be necessary to install a silt curtain along the western edge to contain any potential spread of silt. As before, there will be some very minor chance of rock spillage onto the adjacent harbour floor and in the area where there are no caissons, and there will be potential for some minor spread of silt through the silt curtain.

Stage 6 shows the finished park foreshore.

Figure 2 below illustrates cross-sections showing the completed foreshore at various locations.

In summary, what the sketches and technical report indicate is that all of the excavation work that requires excavation to redevelop the coastal edge of the new park (i.e. the two areas to the north and the south-west area) is done behind the caissons. Similarly, the potential impacts associated with the demolition of the top sections of the caissons and the rock walls will be limited to a small amount of concrete debris falling into the adjacent seabed and a limited amount of silt being generated and dispersed in the harbour. This impact will be mitigated through the use of a construction silt curtain.

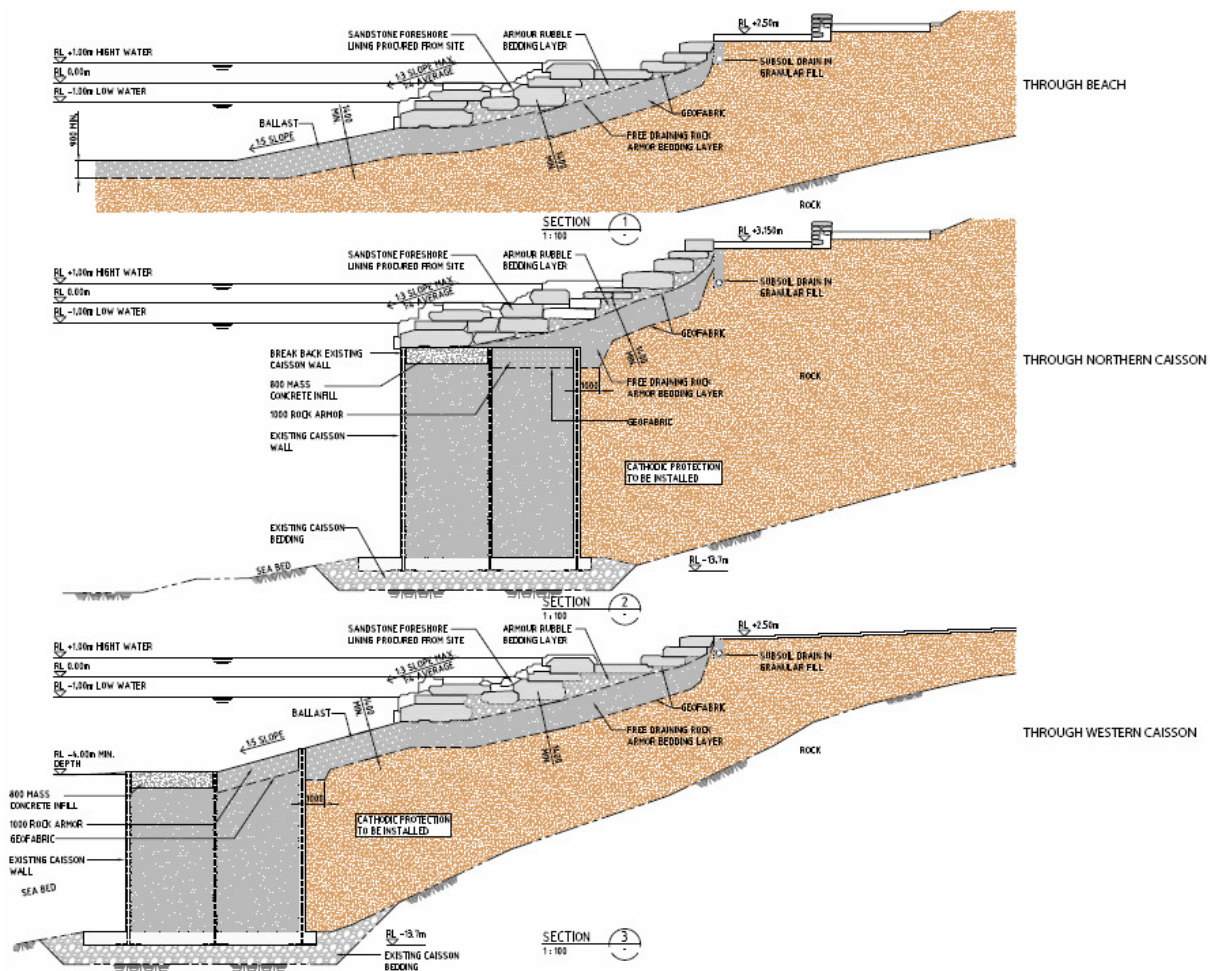


Figure 2: Illustrated cross-sections of completed foreshore at various locations (Source: Hyder, 2010 - Appendix A - SK02)

2.3 SURFACE LAYER TREATMENT AND POTENTIAL IMPACTS

2.3.1 Construction Phase

The existing ground layer at the Site is a hardstanding asphalt surface. The placement of fill material at the Site includes the retention and covering of the existing asphalt surface with a layer of clean fill. The fill will be graded to create the required drainage. This will be overlain by an impermeable membrane, drainage layer and surface fill to the finished level. The placement of the impermeable membrane and drainage layer will capture and direct infiltrated surface water to the proposed stormwater management system.

The hardstanding asphalt surface at the site presently restricts surface water infiltration to the underlying groundwater. The retention of this surface will maintain this situation.

The proposed filling for the Main Works is in addition to the receipt and placement of up to 150,000m³ of fill from Stage 1, as provided for in the Early Works Project Application. Fill created on site through excavation of the shoreline and Northern Cove will be used to form the final landform. Any further fill to be placed on site required would likely come from Stage 1 basement excavations. In total there is approximately 350,000m³ of fill to be placed, inclusive of the topsoils layer placed over the planted and turfed areas. The landform contours in the vicinity of the south western face where a slope of 1:1.5 is shown may be modified to accommodate the actual fill materials available from Stage 1 and excavated from the site. In the event that insufficient materials of the required engineering quality are available then certain materials may need to be sourced from elsewhere.

2.3.2 Post Construction Phase

Mitigation measures in regards to stormwater impacts to the water quality of Sydney Harbour generated from the site following construction are outlined within the Integrated Water Management Plan (Warren Smith and Partners, October 2010). The report details proposed bio-swales, subsoil drainage and stormwater drainage inlet pits and associated landscaping which form part of the water sensitive urban design (WSUD) solution for the site to collect runoff. Further, Built Ecology (2010) outlines water quality objectives for stormwater runoff within the ESD Report for development at the Site, as follows. Water leaving the site will be treated to meet national best practice standards – reducing TSS (Total Suspended Solids) by 80%, nutrients by 45% and litter reduction by 95%. This will be achieved through the inclusion of the following water sensitive urban design initiatives (**Figure 3**):

- Gross Pollutant Traps;
- Swales/Bio-swales; and
- Stormwater collection and re-use.

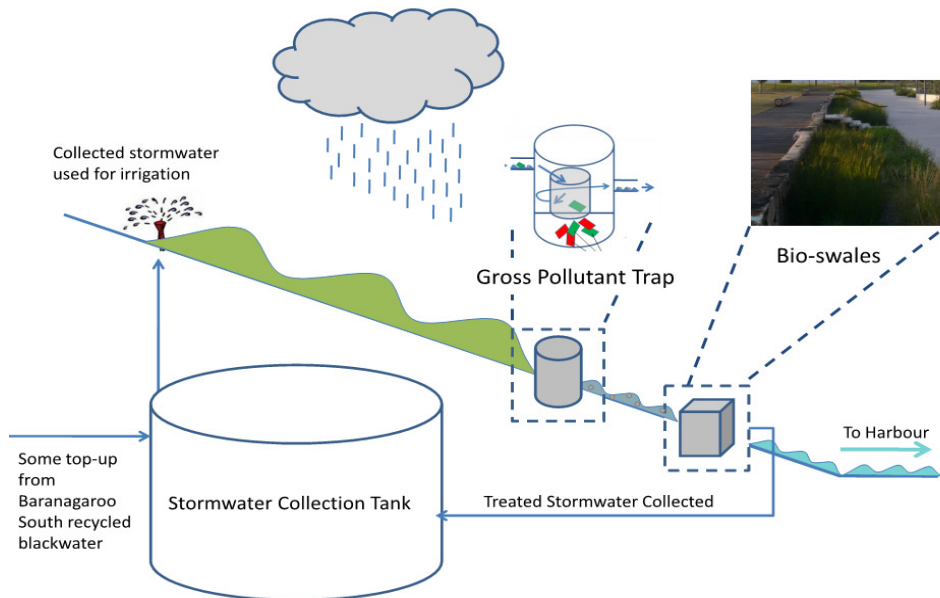


Figure 3: Diagram of water sensitive urban design measures to be included at the site (Source: Built Ecology, 2010)

Drainage from the site is to be re-used for on-site irrigation. Full details of the drainage design are included in the Integrated Water Management Plan (October 2010) with the description here providing an overview. A water balance report prepared by AgEnviro Solutions (September 2010) which is an Appendix to the Integrated Water Management Plan sets out the watering and tank requirements. Figure 2 of the AgEnviro report (reproduced here as Figure 4) shows schematically how the drainage is captured. The drains on the upper level are captured directly to the water tanks for reuse after passing through bioswales. The drains on the steep sections pass directly to the reuse tank. The lower drain which picks up water that has infiltrated through the fill and from the path is directed to a treatment plant prior to being added to the reuse tanks.

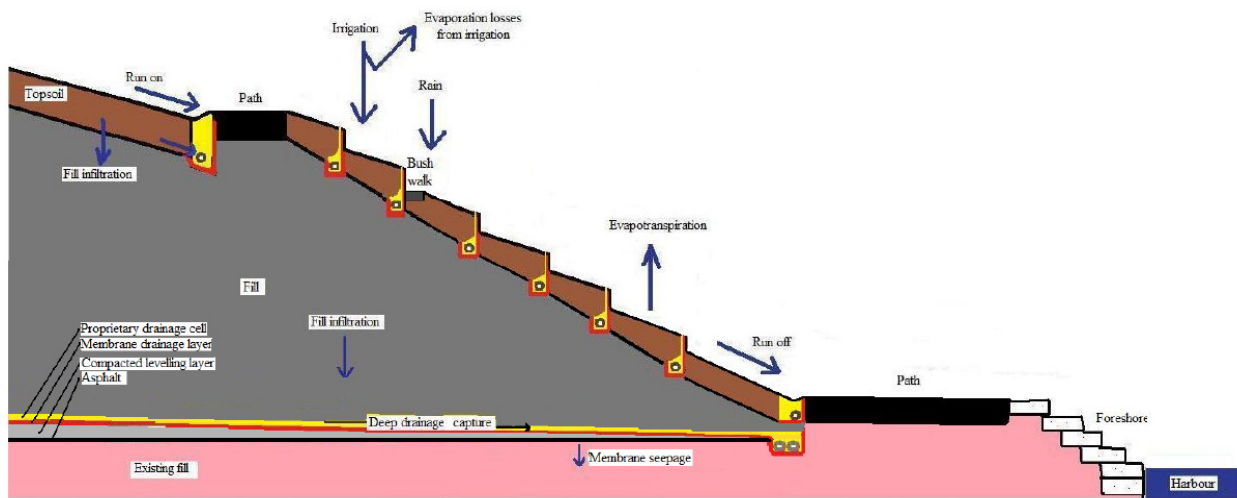


Figure 4: Schematic of water balance model showing various input components. The park is essentially divided into three areas: the upper sections (mostly turf) where runoff and interface flow are captured in bioswales. The steeper sloped areas consisting mainly of indigenous plants, where runoff is captured in drains associated with the retaining walls and a lower bioswale. The lower sections of the site where the path surface runoff is captured.

Underlying the upper and steep slope sections of the site is a membrane drainage layer (and overlying proprietary drainage cell) that assists in drainage capture (RBG, 2010), with this water reused in the irrigation system.

There is a swale on the lower level (not shown in Figure 4) which will be used to treat higher storm flows that exceed the capacity of the lower drain system prior to overflow into the harbour. Any of these overflows will effectively represent clean run-off.

Figure 4 indicates the potential for seepage through the membrane liner. In practice this will not occur due to the low transmissivity of the membrane and due to the properties of the existing fill (discussed in 2.3.1 above).

Collected stormwater will be used preferentially with the reuse tanks being able to be topped up by blackwater recycle from the southern development or by fresh water supply when necessary. The reuse tanks will be managed so as to have available capacity to be able to receive stormwater collection under normal rainfall patterns. The tanks will not be able to cater for longer periods of high rainfall in which case excess water will be discharged to the harbour. Again, any of these overflows will effectively represent clean runoff.

2.4 SITE INFRASTRUCTURE AND OTHER POTENTIAL IMPACTS

The principal potential impacts that could arise from the other construction activities for the park will arise from the potential for surface water discharge into the harbour possibly containing materials such as sediment, grass, concrete wash down and fertiliser. The DGRs require that there be construction mitigation measures to prevent such discharges.

There is provision in the Headland Park for a future Cultural Facility including an underground car park and seawater cooled air conditioning system. Because this facility is not expected to be built for 3-4 years its potential impacts to the groundwater system at the Site can not be considered in detail as part of this assessment although it is expected that the drainage collection system (described here in Sections 2.3 and 3.1.2) will successfully address future potential impacts. However it is necessary to construct the services and piping/pumping infrastructure associated with the air conditioning system (cooling water inlet/ outlet) as part of the current development. Figures 5 and 6 are preliminary sketches of this installation.

It is considered that this construction will have minimal impact on the groundwater system at the Site. The potential impacts of the seawater cooling system are discussed later in this report.

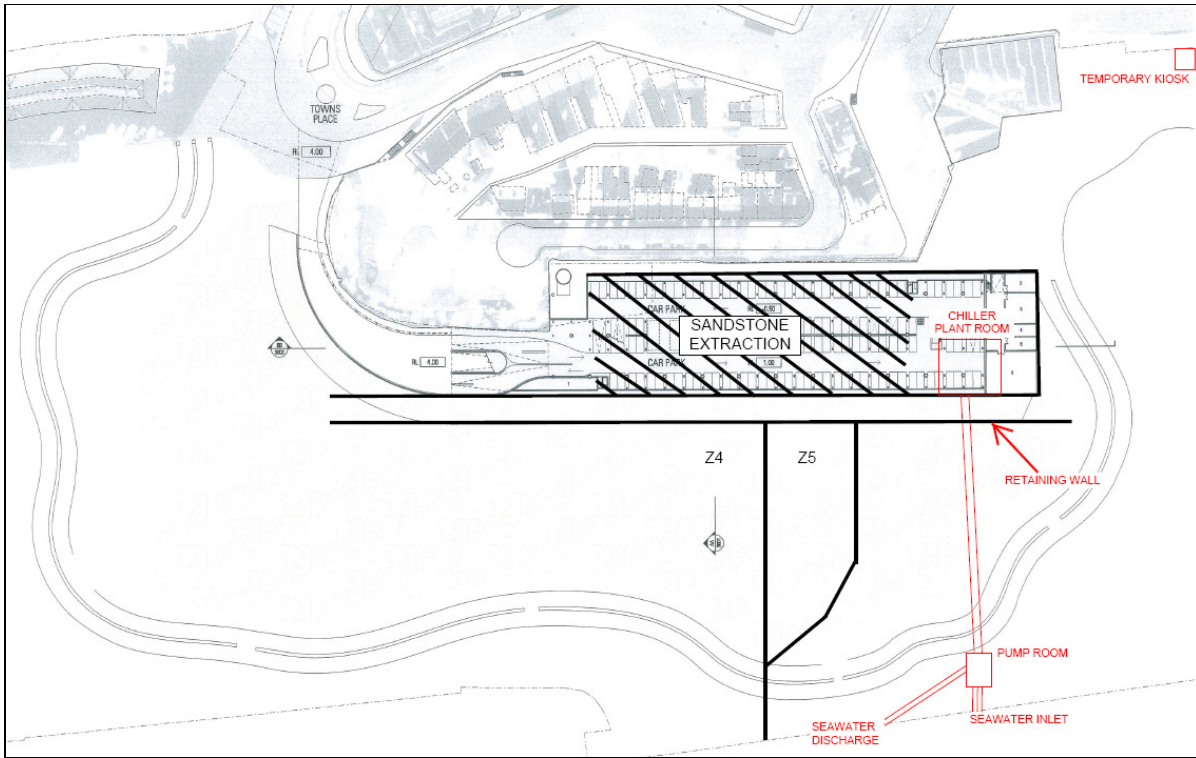


Figure 5 – Seawater Cooling Concepts Plan

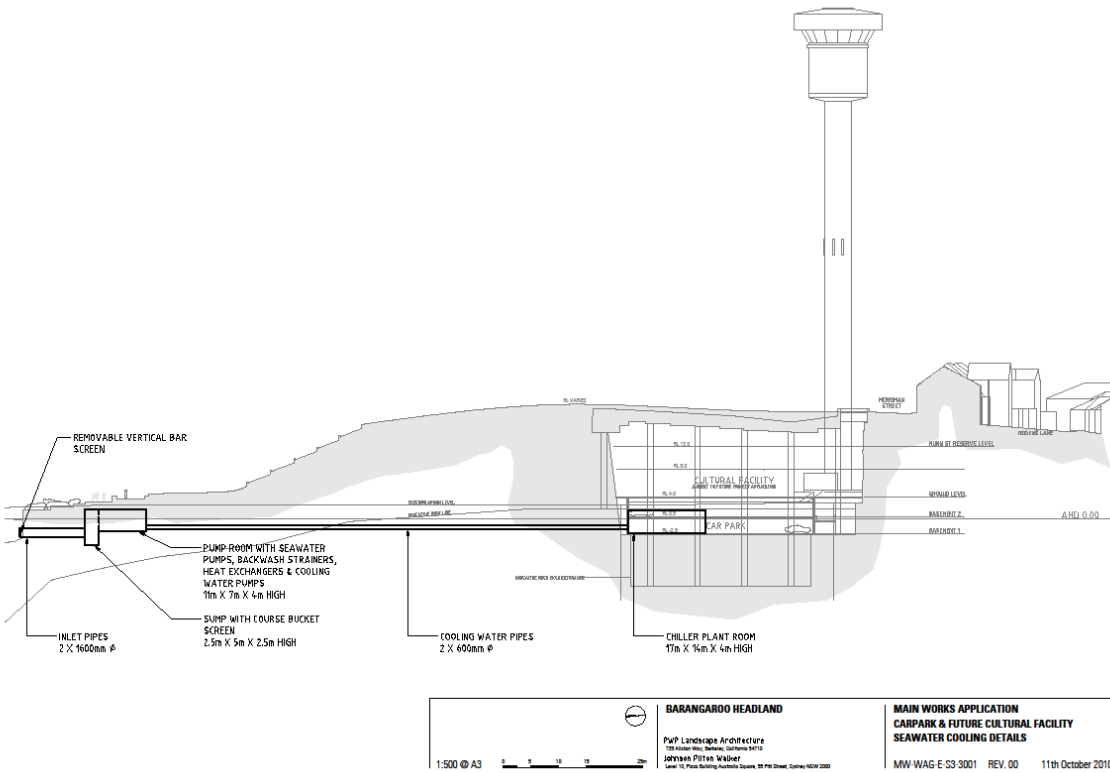


Figure 6 – Seawater Cooling Concepts Section

3 MAIN WORKS MANAGEMENT PROTOCOLS

3.1 ASSESSMENT OF IMPACTS ON WATER QUALITY OF SYDNEY HARBOUR AND PROPOSED MANAGEMENT, MITIGATION AND MONITORING MEASURES

Based on the proposed scope of the Main Works Program, WSP understands that impacts to water quality in Sydney Harbour will be a result of surface water runoff/ discharge via onsite stormwater outlets. Given that runoff water quality and sources will differ during the construct and post construct phases, this report outlines measures to manage, mitigate and monitor associated impacts separately.

3.1.1 Construction Phase

All surface water runoff from work areas will be captured in sedimentation basins/ overflow tanks, prior to discharge or disposal. The details of this will be provided by the Contractor selected for the tender for this portion of the works. This will be presented in the Construction Environmental Management Plan (CEMP) which will be developed as part of the work.

Water will be reused where possible and if required, treated to meet requirements for discharge to either Trade Waste or the Harbour.

The impacts of the Main Works to water quality in the Sydney Harbour will be assessed regularly from all onsite stormwater/ runoff discharge outlets. The assessment of potential impacts will be based on comparisons between baseline data, collected prior to the Early Works program commencing, and data collected during all works, both the Early and Main. The assessment of impacts to water quality to establish both the baseline conditions and during routine testing will be undertaken using the following monitoring procedures:

- Collection of water samples discharging from stormwater outlets (in accordance with Australian Standard 5667:1998: Water quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples).
- Measurements of physico-chemical parameters including pH, temperature, electrical conductivity, oxidative reduction potential, dissolved oxygen and turbidity, using a calibrated water quality probe.
- Laboratory analysis of surface water samples for parameters associated with site works and contaminants of concern (associated with historical or present site uses), as listed in **Table 2** below.

The baseline surface water sampling should be conducted across different climatic conditions including:

- Within 1 hour of the beginning of a storm event;
- Within 4 hours after the storm event; and
- During dry climatic conditions, at least 10 days after a storm event.

At least 2 sampling rounds, for each of the climatic conditions specified above, should be conducted to ensure representativeness of baseline conditions. The above protocol was presented as part of the Early Works program and will establish baseline conditions for both the Early and Main Works.

Following the commencement of site works, routine water sampling is to be conducted on a fortnightly basis, and after major storm events, to assess the impacts of the proposed Main site works.

The DECCW (May 2006) NSW Water Quality Objectives document for the lower estuary of Sydney Harbour, where the Site is located, are focused on the protection of aquatic ecosystems, visual amenity, secondary contact recreation, primary contact recreation and aquatic foods (cooked). Based on the water quality objectives, the ANZECC (2000) Marine Water Quality Guidelines for the protection of 95% of species are considered appropriate for use as water quality protection guidelines.

The objectives of the protection of aquatic ecosystems guidelines are to maintain or improve the ecological condition of waterbodies and their riparian zones over the long term. The ANZECC (2000) Marine Water Quality Guidelines for the protection of 95% of species threshold values were adopted for the protection of aquatic ecosystems and are presented in **Table 2** below.

Management and mitigation methods to prevent contaminated runoff associated with the Main Works from entering the Harbour are proposed below.

Table 2: ANZECC (2000) Marine Water Quality Guidelines for the Protection of 95% of Species.

Parameters	Trigger values/ criteria (µg/L)
Ammonia (as N)	910
Arsenic	50*
Benzene	700
Benzo(a)pyrene	0.01*
Cadmium	0.7
Chromium	27.4
Copper	1.3
Lead	4.4
Mercury	0.1
Nickel	7
Nitrate (as N)	10,000*
Nitrite	1,000*
Polychlorinated biphenyls	0.1*
Phenol	400
Suspended Solids	50 (mg/L)**
Sulphate	400,000*
Turbidity	<6 (Nephelometric turbidity units [NTU])**
Visual clarity and colour:	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%. (Approximately 6 NTU)
Surface films:	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
Zinc	15

*Guideline values have been adopted from ANZECC (2000) Recreation Water Quality Guidelines in the absence of ANZECC (2000) Marine Water Quality Guidelines for the Protection of 95% of Species.

**Guideline value has been adopted from Landcom (2004) Managing Urban Stormwater – Soils & Construction, Volume 1

***Based on "A 200m diameter black disc should be able to be sighted horizontally from a distance of more than 1.6m".

If water quality parameters of samples collected from the stormwater outlets during site works exceed baseline levels and/or a trigger criteria' of 85% of the adopted ANZECC (2000) guideline value for any water quality parameter, discharges should cease and mitigation measures should be reviewed.

Monthly reporting of the water quality discharging from site should be completed by an experienced environmental consultant.

No contaminated or treated site waters exceeding the adopted water quality criteria are permitted to enter Sydney Harbour. Prior to any discharge of water from the sedimentation basin/ overflow tanks, the water quality at each location will be determined and assessed against relevant water quality guidelines. This will be completed by:

- Collection of water samples from the sedimentation basins/ overflow tanks, prior to discharge, (in accordance with Australian Standard 5667:1998: Water quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples).
- Measurement of field parameters including pH, temperature, electrical conductivity, oxidative reduction potential, dissolved oxygen and turbidity.

- Laboratory analysis of water samples for the contaminants of concern (including turbidity) as listed in **Table 2**.
- Comparison against the ANZECC (2000) Marine Water Quality Guidelines for the Protection of 95% of Species listed in **Table 2**.

Groundwater encountered in excavation pits (or otherwise) will be sampled and assessed against the ANZECC (2000) Marine Water Quality Guidelines for the Protection of 95% of Species prior to transfer into sedimentation basins/ overflow tanks and discharged.

Any water exceeding the adopted ANZECC (2000) Marine Water Quality Guidelines for the Protection of 95% of Species is not permitted to enter Sydney Harbour and is to be discharged under a trade waste agreement with Sydney Water or collected and disposed offsite by a NSW EPA approved waste contractor.

Regular water quality monitoring will be undertaken (in accordance with Section 3.1 and 3.2) to monitor the effectiveness of erosion and sediment controls. Any discharges from the sedimentation basins/ overflow tanks into the Harbour will be recorded and maintained in a Water Discharge Register.

Regular water quality monitoring will be undertaken to monitor the effectiveness of erosion and sediment controls. Any discharges from the sedimentation basins/ overflow tanks into the Harbour will be recorded and maintained in a Water Discharge Register.

3.1.2 Post-Construction Phase

As described in Section 2.3 above, surface water run-off and infiltration is to be collected and treated for reuse under normal circumstances. The treatment for the infiltration water will meet the HHERA Risk Based Irrigation Water Criteria as proposed by the JBS letter report to BDA "Summary of Information Relating to Irrigation / Seepage Water Quality, dated 30 August 2010. Under these circumstances there will be no discharge to the harbour.

Section 2.3 identifies rainfall periods which will exceed the capacity of the on-site collection and treatment circumstances which will result in overflow to the harbour. In these circumstances the discharged water quality will meet the criteria for discharge as described in Table 2 above. Water quality monitoring will be undertaken to verify this outcome. This is standard acceptable stormwater management practice.

The capacity of the treatment and reuse tanks directly relates to the rainfall criteria limits which will be part of the BDA design and as such is subject to the project approval.

3.2 DETAILS OF EROSION AND SEDIMENT CONTROLS TO BE USED DURING SITE WORKS

The stormwater soil erosion and sediment control measures will be designed in accordance with *Managing Urban Stormwater – Soils & Construction, Volume 1* (Landcom, 2004). A more detailed description of erosion and sediment controls during works will be provided in the site CEMP which will be prepared by the Contractor selected to undertake the Works. A summary of some of the required control measures that need to be included in the CEMP include:

- Construction of truck entry/exit points including cleaning facilities and wheel wash facilities, managed by a gate controller.
- Existing on-site stormwater drainage pits and grates to be cleaned, and then securely covered with suitable geotextile fabric.
- Ongoing dust suppression using recycled water from on-site.
- Construction of a sediment-laden water management system, through installation sedimentation ponds (with adjacent overflow tanks), based on:
 - a run-off coefficient of 1 and a 5 year design storm event; and,
 - a storage of 200m³ per hectare of exposed fill area;
- Installation of swale drains/ pits around the site perimeter to collect and divert runoff into the sedimentation ponds.

- Setup and installation of sediment silt fences/ hay bale, sand bag bunds around the active works areas.
- Construction of bunding and isolation fencing in undisturbed areas of the site to divert clean water runoff through the site.
- Stabilisation of fill materials during placement and graded to direct runoff towards established swale drains.

All surface water runoff within active site work areas will be collected and diverted to the sedimentation ponds. The maintenance of all erosion and sediment controls will be continually monitored on a daily basis to ensure correct implementation and modification (if necessary).

3.3 DETAILS OF WATER QUALITY MONITORING PROGRAM FOR SYDNEY HARBOUR, WITH A FOCUS ON TURBIDITY AND KEY CONTAMINANTS

Following the commencement of Main Works, water samples are to be collected from all onsite stormwater discharge outlets on a monthly basis and within 1 hour after a storm event, to assess the effectiveness of mitigation measures. Water samples will be collected and analysed as detailed in Section 3.1 to ensure representativeness.

The water samples collected during the site works will be compared against baseline water quality conditions and the ANZECC (2000) Recreational Water Quality Guidelines (as listed in Table1 – Section 3.1). Should laboratory results exceed baseline and the adopted guideline values, discharges should cease and mitigation measures are to be reviewed and upgraded.

3.4 ASSESSMENT OF IMPACTS OF THE PROPOSAL ON SURFACE AND GROUNDWATER HYDROLOGY AND QUALITY

3.4.1 Introduction

A number of investigations of soil and groundwater have been undertaken at the site, the main works being undertaken in June/July 2006 by ERM (2007a). This Section initially outlines WSP's review of the available information, including the main hydrogeological controls and groundwater resource potential together with contaminant types and concentrations found in soils and groundwater. An assessment of the expected impact of the proposed development on groundwater hydrology and quality is presented throughout and comment is made on the validity of the groundwater control and assessment aspects of the Draft Remedial Action Plan (RAP) prepared by JBS (2010)².

3.4.2 Geology and Hydrogeology

The Headland Park area is underlain by fill of varying composition and thickness. In addition to 46 shallow soil bores, a total of nine (9) deep bores were drilled to between 7.5 and 22m depth on the site (MW1, MW2, MW3, MW4, MW5, MW6, MW7, MW19 and MW25). Fill was encountered to depths of between approximately 3m and 12m bgl and generally comprised sandy gravel and gravelly sand with varying quantities of tile, brick concrete and charcoal. Sandstone fill was also encountered in a number of bores. The fill material was found to be directly underlain by Hawkesbury Sandstone in all bores except MW25 (located in the north east corner of the site) in which marine sediments (sandy clay) were recorded between the fill and Sandstone between 9.5m and 13m bgl.

The majority of groundwater monitoring wells were installed with slotted screens across fill material only with the exceptions of MW1 and MW7, which were screened across both fill and sandstone i.e. groundwater samples collected from MW1 and MW7 are expected to be mixed samples from both the fill and Hawkesbury Sandstone while the samples from the remaining bores are derived from groundwater within fill only.

Groundwater levels were measured between 1.96 and 2.3m below ground level (bgl) by ERM (2007a) in July 2007. The information indicated that short term fluctuations in groundwater levels were occurring. Potential tidal influences on groundwater levels and flow directions were further investigated by installing 14 logging pressure transducers in a number of monitoring wells across the whole of the Barangaroo site (including Headland Park) during August 2007. Groundwater levels and temperature were recorded over a 72 hour period. Comparison of the groundwater levels with tidal data from Sydney Harbour indicated a strong correlation in all monitoring wells (WSP, 2007³). The range of tidal movement varied from approximately 1.6m in several of the wells close to the harbour to 0.2m in a well located in the centre of the site. Owing to the tidal influences and the likely time difference between measurements of groundwater levels in the bores, existing groundwater contour plots of

groundwater levels recorded over a number of days have little relevance due to the observed fluctuations. Groundwater is expected to generally flow from east to west, discharging into the harbour. Tidal influences have been shown to result in temporal changes to groundwater flow directions beneath the site. The salinity of groundwater recorded during the July 2006 monitoring event indicates highly saline groundwater, further indicating a strong tidal influence.

3.4.3 Beneficial Uses of Groundwater

Groundwater salinity levels varied from 32.4 to 49.5 mS/cm (19,440 to 29,500 mg/l Total Dissolved Solids (TDS)) in July 2006 in the nine (9) wells located at Headland Park. These concentrations are similar to seawater, which is typically 35,000mg/l TDS. According to the Department of Primary Industries (Victoria) (2009)⁴, a TDS of 14,000 mg/l precludes the use of groundwater for any purpose (other than Maintenance of Marine Ecosystems). Due to the high salinity of the on-site groundwater quality, contaminant concentrations should be assessed against the ANZECC 2000 95% Protection Trigger Values for Marine Waters. In the absence of a 95% trigger value for specific compounds, ANZECC 2000 Low Reliability Trigger Values should be applied. This has been appropriately undertaken by ERM for the June/July 2006 and August 2007 groundwater monitoring events (ERM 2007 (a) and (b)) and should continue for future monitoring events.

3.4.4 Potential Sources of Groundwater Contamination

Two main sources of soil and groundwater contamination have been identified at the site by ERM (2007) i.e.

- The former location of an underground storage tank (UST), above ground storage tank (AST) and Dangerous Goods (DG) storage in the northeast of the site (location defined in **Figure 7** below); and
- Fill thickness of up to approximately 12m, some of which was potentially derived from the former gasworks.

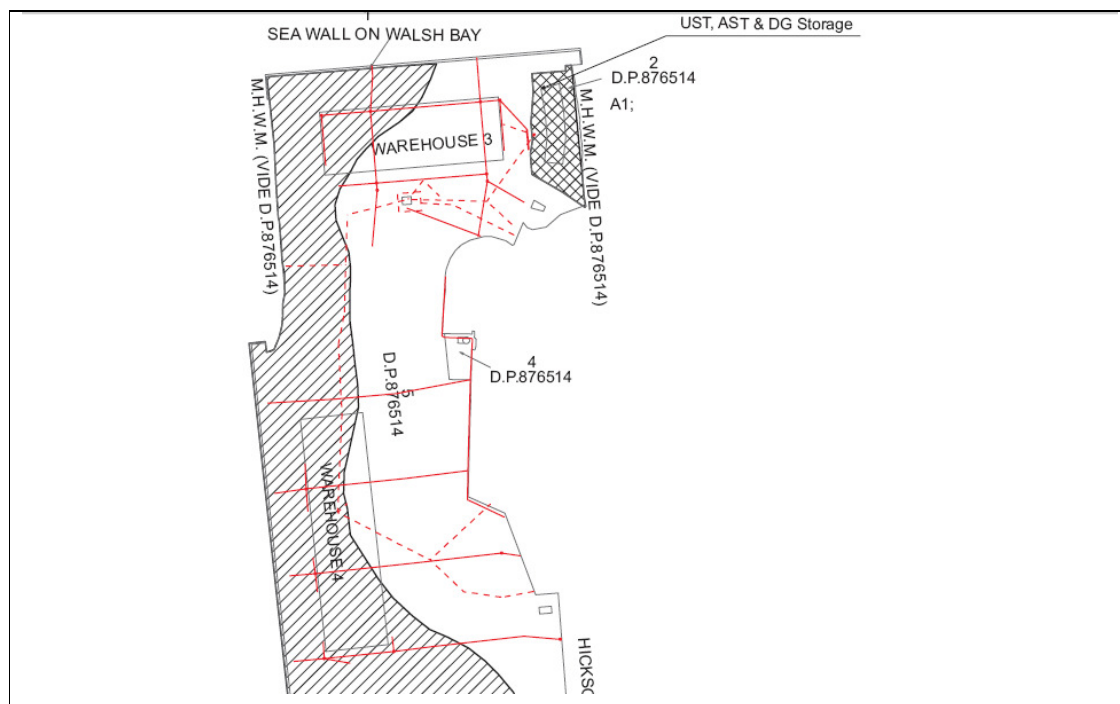


Figure 7 Areas of potential concern showing UTS, AST and DG Storage (Source ERM, 2007a (Figure 2))

ERM (2007a) detailed the drilling of 46 soil bores to investigate subsurface conditions including the presence of contaminants in soils. The number of bores is considered sufficient to enable the characterisation of soil contamination for the purposes of identifying potential source of ongoing contamination to groundwater.

Soil samples were collected between 0.3 and 12 m bgl with the majority collected within 2m of the ground surface. Since groundwater was encountered at between 1.95 and 2.3m bgl in July 2007, the majority of samples were taken above the water table in the unsaturated aquifer zone.

Soil samples were analysed for heavy (metals arsenic, cadmium, chromium, copper, lead, mercury nickel and zinc), cyanide, sulphate, PAH (16), PCBs, OCP/OPP, BTEX (benzene, toluene, ethylbenzene, xylene) and TPH.

Reported concentrations were assessed against NEPM (1999) HIL A. No assessment of risk to groundwater from soil contamination has been undertaken and no leach tests or assessment of the risk to groundwater from soil contamination were undertaken.

The Draft Remedial Action Plan (RAP) for the site (JBS, 2010) (Section 4.2.2, P.11) indicates that *'the underlying natural soils in the headland Park site do not appear to have been substantially impacted by overlying impacted fill'*. As outlined in Section 3.4.2, the majority of the Headland Park site is underlain by fill which lies directly over Hawkesbury Sandstone. A general absence of natural marine sediments was recorded during the main investigation works by ERM (2007a).

WSP did not have access to information pertaining to the UST, AST and Dangerous Goods Store in the north-east of the site and is not aware of whether the tanks and any associated contaminated soil have been removed and appropriately validated. Works undertaken or the need for any further works in relation to these contaminant sources will be documented in the final Remedial Action Plan for the site. All soil contamination associated with these tanks should be appropriately remediated to a level which is protective of both human health and groundwater.

3.4.5 Groundwater Quality

Previous Findings on Groundwater Quality (Pre-Construction)

The nine (9) on-site groundwater wells were sampled in July 2006 and August 2007 and analysed for heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc), ammonia, cyanide, sulphate, PAH (16), PCBs, BTEX (benzene, toluene, ethylbenzene, xylene) and TPH.

Ammonia, arsenic, cadmium, copper, lead, nickel and zinc, were found above ANZECC 2000 95% Protection Trigger Values for Marine Water. Benzo(a)pyrene, fluoranthene, anthracene and phenanthrene were found above the ANZECC 2000 Low Reliability Trigger Values.

The Draft (RAP) for the Site (JBS, 2010) indicates that contaminants of concern (COCs) in groundwater are 'generally low' and consistent with urban sites of a similar nature. WSP is not aware of supporting evidence for this assumption. An assessment of background groundwater quality to identify whether the identified contaminants are derived from on-site or off-site contaminant sources has not been undertaken for the site to WSP's knowledge.

Potential Impacts to Groundwater Hydrology

As outlined in section 2.2, there are two options being considered for the treatment of the ground surface at the Site. While Option 2 includes the removal of the existing hardstanding asphalt surface, both Options 1 and 2 include the addition of an impermeable membrane layer. Thus, after completion of either Option there is expected to be no increase in infiltration, or the leaching of any contaminants to the underlying groundwater.

Potential Impacts to Groundwater Quality

It should be ensured that the fill to be re-used on the site and any imported fill is fit for purpose and does not contain contaminants with leachable concentrations which pose a risk to groundwater quality (above ANZECC 2000 guidelines for Marine Waters). In addition, works should be undertaken in a manner which prevents the movement of fill materials around the site without appropriate validation and assessment prior to re-use. Fill should not be moved from the unsaturated zone (above the water table) to below the water table without an initial complete assessment of potential impacts to groundwater.

The Draft RAP (JBS, 2010) indicates that the proposed remediation strategy should be designed *'to address the potential future migration of contaminants in in-situ soils via groundwater'* and a specific remediation plan is to be prepared for each site area to *'establish remediation objectives applicable to both human health and the environment by a risk Assessment that considers future landuse and potential long-term impacts to Darling Harbour'*. The strategy for the risk assessment should be included in the final RAP. Site acceptance criteria should be developed by means of an assessment of potential risks to groundwater from (a) residual contamination in in-situ soils to remain on-site and (b) the maximum acceptable concentrations of the COCs in fill material (whether re-used from other areas of the site or imported) which do not pose a risk to groundwater (please note that human health risk will also need consideration).

The Draft RAP (JBS, 2010) also indicates potential impacts to building structures from sulphate rich groundwater. It is noted that, due to the evidence of tidal effects on groundwater, the sulphate concentrations are likely to be mainly derived from seawater.

3.4.6 Summary of Potential Impacts on Groundwater and Surface Water Hydrology

- The groundwater investigations undertaken to date focused primarily on the quality and flux of groundwater within the fill material. This is considered to be appropriate given the primary receptor of concern is Darling Harbour and groundwater in the fill is shown to be in direct hydraulic connection with seawater. Reported salinity concentrations preclude the use of groundwater for any other purpose other than Maintenance of Ecosystems.
- The final RAP needs to include a strategy for the removal of all fuel and dangerous goods storage tanks including all associated residual contaminated soil (if not undertaken to date). Soil contamination associated with these tanks should be appropriately remediated to a level which is protective of both human health and groundwater.
- Several contaminants have been found above ANZECC 2000 95% Trigger Values for Marine Waters in groundwater at the site. An assessment of background groundwater quality has not been undertaken for the site to determine whether the identified contaminant concentrations are derived from the site or from an off site contaminant source. In the absence of this data it must be assumed that the contaminants are derived on-site.
- Construction works (including any necessary dewatering works) are not expected to substantially alter groundwater levels or flow patterns as previous investigations indicate that groundwater is heavily influenced by the tide.
- Potential impacts to building structures from sulphate rich groundwater. WSP notes that, due to the evidence of tidal effects on groundwater, the sulphate concentrations are likely to be mainly derived from seawater.

3.4.7 Groundwater Management and Monitoring Requirements

- Although no medium or long-term impacts on groundwater levels or groundwater flow are expected during excavation works (due to the extent of the tidal influence), monitoring of groundwater levels is advised to assist in anticipating the need for dewatering works. The installation of water level loggers in two wells would provide information on the fluctuations in groundwater levels on the site.
- The Draft RAP (JBS, 2010) states that water quality data *'is to be compared against the criteria presented in Table 6.5 of the Draft RAP prior to release of water to Darling Harbour and against the draft criteria presented in Table 6.6 prior to reuse of collected seepage water/stormwater as irrigation water on the Headland Park Site. The final irrigation water criteria will be included following review/acceptance by the Site Auditor'*. This approach is considered to be generally acceptable.
- The Draft RAP (JBS, 2010) outlined measures to collect, treat, test and dispose of groundwater and seawater encountered during excavation works. Treated water is to be discharged to stormwater/sewer, depending on volumes, water quality and discharge requirements from City of Sydney Council (CoS) or Sydney Water Corporation (SWC). If this is not possible, the water from excavations will be required to be either discharged to sewer under license to SWC or be treated in the Water Treatment Plant so that it is suitable. It is considered that this is a suitable approach and recommends that the analytical suite and sampling frequency is agreed with SWC prior to the initiation of the works. This approach should be included in the Construction and Environmental Management Plan (CEMP).
- The Draft RAP (JBS, 2010) indicates that water samples shall be collected from the outlet of the groundwater treatment system at a frequency of two samples per day at the commencement of treatment. Once the treatment capabilities of the plan has been demonstrated by way of 6 consecutive monitoring results below the nominated treatment criteria, monitoring frequency shall be reduced to a weekly basis. This is considered to be an appropriate strategy.
- A minimum of three (3) groundwater wells in the Headland Park area are monitored prior to and during construction works to set a baseline and ensure no adverse impacts to groundwater from the construction works. A sampling plan, including monitoring frequency and analytical suite is designed in line with the

planned timescales for the construction works. The analytical suite should include the identified contaminants of concern i.e. metals, TPH, ammonia, PAH and BTEX.

- Groundwater arising from the Park post-construction will be captured and treated by the drainage system as described in Section 2.3 above.

3.5 ASSESSMENT OF POTENTIAL IMPACTS ON MARINE VEGETATION AND AQUATIC ECOLOGY

3.5.1 Background Information

Lend Lease Millers Point had separately commissioned the following two reports by Worley Parsons in support of the southern part of the Barangaroo development:

- Water Quality Monitoring Requirements Report (Worley Parsons, 2010a)
- Marine Ecology, Water Quality and Contaminated Sediment Impact Assessment (Worley Parsons, 2010b)

The baseline data included in these reports covers a larger part of the harbour than just the Lend Lease Millers Point site and so is applicable and has been used in this assessment.

Worley Parsons (2010a and b) summarise the existing conditions of the project vicinity as follows:

“Water quality measurements reported from sampling during the marine ecology study (undertaken by Worley Parsons on the 5th and 6th of May 2010) indicates that physico-chemical conditions in Darling Harbour, within the vicinity of Barangaroo, were typical of a sub-tropical estuary in eastern Australia. Mean surface water temperature was 19 °C and mid water temperature was reported at 19.2 °C. This was somewhat higher than the harbour average for May of 15.9 °C +/- 0.2 °C (winter) (Hatje et al. 2001 in Worley Parsons, 2010a), likely attributed to uncharacteristically warmer air temperatures. An average surface pH of 8.2, dissolved oxygen concentration of 8.2 mg/L (8.1 mg/L mid water) and conductivity of 53 µS/cm were reported adjacent to Barangaroo. Turbidity in surface waters (1.6 NTU) was slightly higher than mid water (1.2 NTU), but were within the general acceptable range (0.5 – 10 NTU) for subtropical eastern Australia (ANZECC/ARMCANZ, 2000).

The benthic habitat in Darling Harbour, adjacent to Barangaroo, consisted of silty sand. There was considerable bioturbation, likely from burrowing organisms like polychaete worms and invertebrate crustaceans. The substrate towards the southern end of the development, contained clay and was relatively undisturbed. This was in contrast with the middle and northern sections of the site, which contained higher percentage silt. One solitary sponge was reported at Site 3, towards the northern end of the site.

Further, marine vegetation was not observed during diver investigations or through underwater towed video investigations undertaken adjacent to the site. Contaminated sediments have been previously reported within the vicinity of the redevelopment site.”

The brevity of reporting here should not detract from the comprehensive coverage by the Worley Parsons, 2010b) report in responding to the DGRs in relation to the aquatic ecology of Sydney Harbour.

Further, West and Williams (2008) documented no seagrass communities in the vicinity of the Site and indicated that the general locality was predicted to be unsuitable for seagrass community establishment.

3.5.2 Potential Impacts

Park Foreshore

The lack of marine vegetation adjacent to the park area is an important fact and indicates that the anticipated small amount of concrete debris that will probably enter the harbour adjacent to the park edge will not cause any direct damage and will not result in long term adverse impacts.

Worley Parsons (2010a) also included a description of the application and use of a turbidity (silt) curtain which should serve as a generic guide for Stage 5 of the seawall design (Section 2.2). The description is repeated here but with a slight modification as to the activity.

“Turbidity (silt) curtains could be designed (material type, extent and depth) and installed in front of the existing wharf prior to the commencement of the cutting back of the rock wall activities to confine large particle suspended sediments in the water column from entering the adjacent harbour waters. It is expected that the turbidity curtains will only need to remain in place while the rock wall cutting back activities is being undertaken.

Turbidity curtains could comprise a floating boom with a weighted curtain of either an approved porous geotextile fabric or an impervious fabric. This fabric would be capable of containing suspended sediment such that the turbidity criterion developed for the project is not exceeded. The turbidity curtains would be affixed so that there are no breaches or gaps in the curtain and between the curtain and any seawall interface.

The curtains would be appropriately managed while in operation. The perimeter of the curtain would be inspected on a regular basis and following a major rainfall or swell event. The outcomes of each inspection of the turbidity curtain should be documented and provided to the BDA regularly and immediately after the curtain is deemed not to be operating effectively.

Turbidity curtains would not be removed until it is confirmed that any sediment within the curtains has settled from the water column to further minimise the dispersion of suspended sediments.”

The use of silt curtains is a well established construction technique and has been demonstrated to provide effective silt mitigation. Keeping in mind that the cutting back of the rock wall will be a limited construction activity, the potential impact of any silt escapes can be considered to have a very low impact and “smothering of aquatic habitat” will not occur.

There is no dredging involved in constructing the park that would expose contaminated sediments or acid sulphate soils.

The surface water controls to be applied to the land construction of the park (as described in Sections 2.3 and 3.2 above) will prevent any significant adverse impact on the aquatic ecology of the harbour. Similarly, the creation of the park will not generate any adverse impacts on the groundwater passing through the park (refer Section 3.4 above). As such, neither of these potential impacts will lead to adverse effects on the aquatic ecology of the harbour.

Worley Parsons, (2010b) report responds to threatened species legislation as follows:

“Due to the high level of boating activity and lack of suitable feeding and nesting habitats at Barangaroo, it is highly unlikely that any species of threatened fauna listed under the *Threatened Species Conservation Act 1995* or *Environment Protection and Biodiversity Conservation Act 1999*, which have the potential to occur in Sydney Harbour, would utilise this area.”

This conclusion would equally apply to the construction phase of the new park project.

3.5.3 Potential Operational Impacts

The estuarine foreshores at the north and west sides of Barangaroo will be changed due to the creation of the new park foreshore. The existing foreshore is a rectangular man-made wharf whereas the new park foreshore will more resemble a natural foreshore with the rounded north-east corner and the new beach area to the west being designed to recreate an approximate original shoreline (**Figure 2**). Note that this change only occurs from the interface of the park/water line over a range of about 2m which is the approximate difference between tidal levels. Below this level there is effectively no change to the existing vertical conditions of the wharf structure.

As outlined above, the proposed foreshore modifications will render the site to a more natural state. It is considered that these modifications will provide shelter for aquatic species which was previously lacking; and hence affect an improvement in the habitat value of the site.

Section 3.8 of this report describes the potential changes in the estuarine circulation and hydrological regimes in the surrounding harbour waters to be beneficial without any adverse impacts as a result of the change in the foreshore.

Seawater cooling has been used successfully and without adverse on the environment in Sydney Harbour in the past, notably with the Opera House. More recently there has been a further application in Sydney Harbour at the Museum of Contemporary Art (MCA) which was reported on as part of a 3A Approval process by Worley Parsons (MCA Redevelopment – Seawater Heat Exchange – Preliminary Marine Risk Assessment, 24 March 2010). This report highlighted the following features that need to be incorporated into the design of a seawater cooling system:

- Temperature differential between the intake and discharge – DECCW will accept ≤ 2 degrees C which is part of the Barangaroo concept design.
- High velocity discharge to ensure that there is rapid dissipation of the discharge water temperature. The Barangaroo concept design discharge is near to the main channel through the harbour which will promote temperature dissipation.
- Adequate separation of the intake and discharge pipes – the MCA document recommends a minimum of 25m for their location. Modelling for the detailed design for Barangaroo will determine the adequacy of this and the previous condition.
- Use of an acceptable anti-fouling agent. The MCA report identifies Mexel 432 as being acceptable to DECCW. The Barangaroo detail design will address this and the suitable dosage concentrations and pipe residence times.
- Incorporation of suitable filters and cages on the intake pipe to prevent adverse impacts on marine life and humans.
- The intake to be below the low tide mark, but suitably above the harbour floor to avoid sediment impacts. The depth of the harbour at the proposed location in the Barangaroo concept design allows this to occur.
- Incorporation of a filter backwash system and a system to regularly maintain and clean the intake pipe.
- Use of adequate materials for the system to withstand the effects of the marine waters.

If the detailed design for Barangaroo addresses these and other relevant design issues, then the seawater cooling system will not cause any adverse environmental impacts.

3.6 MANAGEMENT MEASURES FOR ANY BARGING OF ANY EXCAVATED OR CONTAMINATED MATERIAL

WSP understands that barging of excavated or contaminated material will not to be conducted as part of the Main Works.

3.7 STORMWATER MANAGEMENT STRATEGIES DURING CONSTRUCTION

Stormwater management and strategies during the Main Works is presented in Section 3.2. The monitoring program for water quality of stormwater/ runoff discharges is detailed in Sections 3.1.

3.8 ASSESSMENT OF IMPACTS ON ESTUARINE CIRCULATION, ESTUARINE WATER QUALITY AND AQUATIC ECOLOGY OF LAND FORMATION WORKS

SMEC has prepared a desktop review of existing studies and the current design of the land formation works for the Barangaroo Shoreline (Appendix A). Specifically, this report addresses the Director General's Requirements with respect to assessing impacts on estuarine circulation, and any changes that may result from altered hydrological regimes of surrounding waters and bays. The SMEC report has provided a commentary on how the proposed re-structure of the outer perimeter of the site would impact on estuarine circulation and coastal processes in general, based on a review of existing information.

Based on the desktop review, it was found that;

- Removal of the caissons and rounding of the corner at the north-western end of the site is likely to improve the tidal circulation in this area as this would make it less likely that a localised flow reversal eddy could occur in this area;
- The design of the cove to allow a shallow depth and wide entrance is appropriate to maximise tidal exchange between the cove and Darling Harbour;

- The proposed shoreline reconstruction would not have a significant impact on overall tidal exchange within Darling Harbour;
- The removal of the caissons from the shoreline and introduction of rocky shoreline would result in a dissipation of wave energy from ferries and wind waves as well as a reduction in wave reflection within the harbour, potentially improving the operating conditions at East Balmain Wharf; and
- The creation of the Headland Park would not significantly impact the volume of freshwater inflows into the estuary, but response times and peak flow rates would likely be reduced due to the reduction in overall paved area.

The DGRs requirement for “Any modification of estuarine foreshores (including the incorporation of measures to improve the habitat value of newly created waters such as environmentally friendly seawalls) should consider *Environmentally Friendly Seawalls – A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries* (DECC, 2009)” have been considered in the Hyder design report.

With specific regard for the guidelines the nature of the design addresses many recommendations including:

- Low slopes;
- Use of natural material – local sandstones; and
- Form that assists habitat diversity and complexity.

3.9 ASSESS THE POTENTIAL IMPACTS ON AQUATIC HABITAT FROM ALTERED HYDROLOGICAL REGIMES, CONTAMINATED SEDIMENTS AND POTENTIAL ACID SULPHATE SOILS FROM DREDGING ACTIVITIES

As discussed in section 3.5 potential impacts on water quality and aquatic ecology arising from construction would be negligible, temporary and localised. Also once construction is complete, there would be no significant or lasting adverse negative impacts on the marine environment (including water quality impacts and impacts on aquatic flora and fauna) as no significant changes are proposed seaward side of the existing caissons.

3.10 QUALITY ASSESSMENT OF DISCHARGE FROM STORMWATER OR OTHER WASTES, COMPARED AGAINST RELEVANT WATER QUALITY OBJECTIVES AND ENVIRONMENTAL VALUES FOR SYDNEY HARBOUR

The quality assessment of discharge from stormwater or other wastes, compared against relevant water quality objectives and environmental values for Sydney Harbour are provided in Sections 3.1 and 3.2.

3.11 CONSIDERATION OF THE COLLECTION, TREATMENT AND MANAGEMENT OF CONTAMINATED SURFACE AND GROUNDWATER ACROSS THE SITE

See Section 2.3 and 3.2. All surface water runoff from the construction work areas will be captured in sedimentation basins/ overflow tanks. Surface water samples from the sedimentation basins/ overflow tanks will be collected and analysed prior to any discharging into the Harbour. Groundwater encountered in excavation pits (or otherwise) will be sampled and assessed against the ANZECC (2000) Recreation Water Quality Guidelines prior to transfer into sedimentation basins/ overflow tanks and discharged.

Any water exceeding the adopted ANZECC (2000) Recreation Water Quality Standards is not permitted to enter Sydney Harbour and is to be discharged under a trade waste agreement with Sydney Water or collected and disposed offsite by a NSW EPA approved waste contractors.

4 REFERENCES

ANZECC (2000) Australian and New Zealand – Recreational Water Quality Guidelines, National Water Quality Management Strategy, Commonwealth of Australia.

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ERM (2017b) Ambient Air, Vapour Flux and Groundwater Assessment, Barangaroo, Hickson Road, Sydney, NSW undertaken for Sydney Harbour Foreshore Authority, REF: 0071015RP02Draft,(August 2007).

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West, G. and Williams, R.J. (2008) A preliminary assessment of the historical, current and future cover of seagrass in the estuary of the Parramatta River. NSW Department of Primary Industries, Cronulla.

Worley Parsons (2010a) Barangaroo Stage 1 – PA1. Bulk Excavation and Basement Car Park – Water Quality Requirements. Prepared for Lease Lend (Millers Point) PTY Limited. (Document Dated June 2010).

Worley Parsons (2010b) Marine Ecology, Water Quality and Contaminated Sediment Impact Assessment (Document dated 28 July 2010).

WSP Environmental Pty Ltd (2007) Site Audit Report: Barangaroo, Hickson Road, Darling Harbour, NSW undertaken for the Sydney Harbour Foreshore Authority, 5 September 2007.

Appendix A – Barangaroo Desktop Hydrodynamic Assessment, SMEC, 18 August 2010



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18 August 2010

WSP Environment and Energy
Level 1, 41 McLaren Street
North Sydney NSW 2060
Attention: Dennis Zines

Dear Dennis,

RE: Barangaroo Desktop Hydrodynamic Assessment

Please find attached our report as requested which documents a desktop review of existing studies and the design of the land formation works for the Barangaroo Shoreline. Specifically, this report addresses the Director General's Requirements with respect to:

- Assessing impacts on estuarine circulation, and any changes that may result from altered hydrological regimes of surrounding waters and bays.

This report provides a commentary on how the proposed re-structure of the outer perimeter of the site would impact on estuarine circulation and coastal processes in general, based on a review of existing information.

Project Background

Barangaroo is located on the western side of Sydney's CBD, between Millers Point and Darling Harbour. The site was a prominent natural headland until the early 19th Century. During the 1970's, concrete caisson walls were installed around the perimeter of the site to provide a quayline for container and cargo ships (Hyder, 2010).

The proposed works involve the creation of a naturalistic parkland, which involves the creation of a headland similar to other major headlands in Sydney Harbour such as Lady Macquarie's Chair or Balls Head (Hyder, 2010). The proposal involves removal of the concrete caissons around the shoreline and the creation of a new shoreline based on horizontal rock platforms and pools stepping down into the harbour, with underwater slopes and cliffs dropping to the harbour floor.

The proposed design of the site is shown in Figure 1.

This report describes a desktop assessment of the impact of the concept design on the estuarine hydrodynamics and coastal processes in general.

Existing hydrodynamic environment

Sydney Harbour is a drowned river valley type estuary (Roy, 1984) with the valleys having been infilled significantly since sea levels rose to close to their present level around 6,000 years ago. Several deep holes exist within the harbour, with the deepest being 46 m deep just upstream of the Sydney Harbour Bridge (Harris and O'Brien, 1998).

Tidal range is microtidal (1m on neaps and 2m on springs) and tidal currents dominate the mixing and circulation of estuarine water within Sydney Harbour (Harris and O'Brien, 1998). Current speeds are in the order of 0.3 to 0.5 m/s and the strongest tidal currents of up to 1 m/s occur in the narrowest parts of the harbour (i.e. just upstream of the Sydney Harbour Bridge, where the deep scour hole suggests scour caused by tidal currents).

Bottom sediments in the vicinity of the development consist of fluvial sediments (sandy muds or muddy sands), as the study area is beyond the reach of the flood tide delta (which only extends around 2km inside the entrance of Sydney Harbour). The study area was historically dredged to its current depth of around 14 m to allow for passage of ships.

Tidal and Wind Currents

Tidal and wind currents within the study area can be estimated by means of a 2D hydrodynamic model. It is likely that tidal currents within Darling Harbour would be very low in comparison to the tidal currents within the main channel of Sydney Harbour. While a hydrodynamic model has not been developed for the purpose of this investigation, SMEC have constructed a validated hydrodynamic model for the lower Georges River, which is a drowned river valley estuary of similar morphology to the study area and driven by the same tidal forcing function.

An extract from this model is shown in Figure 2. This extract shows maximum current velocities that would occur during a spring flood tide, combined with extreme winds. It can be seen that maximum tidal currents in the main channel of the river may reach around 0.5 m/s, with tidal currents in the small coves and within the estuary arms generally less than 0.2 m/s. It is likely that this model represents an analogous situation with Sydney Harbour in the vicinity of the study area and that tidal currents in Darling Harbour would generally be less than 0.3 m/s.

Impact of the proposal on flow patterns

A conceptual model of the estuarine tidal currents is shown in Figure 3 for both the existing and proposed shorelines. Existing tidal currents within Darling Harbour would be affected by the configuration of the caissons at the existing northwest corner of the site. This corner would likely generate a tidal eddy or flow reversal on either side (depending on the direction of the tide) as shown in Figure 3. This flow reversal could generate an area of dead water where tidal exchange is limited.

The proposed removal of the caissons at this location is likely to reduce this effect, resulting in the reduction of the localised flow reversal and better tidal exchange around the proposed shoreline.

Impact of the proposal on tidal flushing and exchange

Tidal flushing predominantly depends on the tidal prism. The tidal prism is the volume of water in an estuary or inlet between mean high tide and mean low tide or the volume of water leaving an estuary at ebb tide. Calculations of tidal prism are useful in determining the residence time of water (and pollutants) in an estuary. If the tidal prism forms a large proportion of the water in an estuary at high tide, then when the tide ebbs, it will take with it the majority of the water (this occurs in shallow estuaries) and any pollutants or sediments suspended in that water. This means that the estuary has a good flushing time, or that the residence time of water in that estuary is low. On the contrary, in deeper estuaries, the amount of water that is influenced by the tides forms a smaller proportion of the total water volume.

As Darling Harbour has been historically dredged, the estuary is deeper than it was prior to dredging and the flushing time of the estuary is likely to have increased when compared with its natural state.

The principal driver of the currents are tides, floods, winds, wave breaking and wave orbital motion at the seabed. The currents increase within narrow sections of the main Sydney Harbour channel and are very low in the bays and bends of the harbour.

The proposed Northern Cove is likely to facilitate some surface tidal exchange with the adjacent Darling Harbour, with a volume of around 20,000 to 40,000 m³ of additional tidal exchange daily. Being relatively shallow (around 2 m depth), the waters of the cove itself are likely to be more variable in density due to greater variations in salinity and temperature when compared with the waters of Darling Harbour. This density variation would facilitate vertical mixing caused by the velocity shear at the interface between the bed of the cove and the vertical drop off into Darling Harbour (surface and mid-depth velocities are faster than bed velocities). This would result in the generation of turbulence, principally at the bed, which promotes the mixing of overlying waters. In addition, the proposed shallow depth and wide entrance of the cove into Darling Harbour would result in a relatively low residence time of tidal flow within the Cove.

The overall change in estuary volume as a result of the new shoreline configuration would be negligible when compared with existing conditions.

Wave Climate Analysis

A wave climate analysis of the study area has been carried out to assess the existing wave environment and the impact of the proposed shoreline re-configuration. Wave climate in the study area is dominated by local wind waves and vessel wakes, as the area is beyond the reach of any ocean swell penetration.

Wind Climate

Wind climate was assessed using wind data from the Bureau of Meteorology. One wind station from the Bureau is located on Sydney Observatory Hill (less than 400m from the study area). This station recorded 3-hourly data between 1955 and 1992.

The wind roses of the average 9am and 3pm wind speed at Sydney Observatory Hill are illustrated in Figures 4 and 5 respectively. It is noted that the main wind direction for the 9am wind data is the westerly direction along which there is the longest fetch into the proposed cove area (i.e. length of water over which a given wind has blown). For the 3pm wind data, this same direction is the one including most of the significant wind speeds (>30km/h). This direction was selected for the wind-generated wave climate analysis.

The three-hourly wind data were converted into hourly data using the following formula (Leenknecht et al, 1992):

$$\frac{U_i}{U_{3600}} = -0.15 \log t_i + 1.5334$$

where: U_i is the i-second wind speed (here $i = 10800$)

U_{3600} is the hourly wind speed

t_i is the three-hour length (10800s)

Wind data from the Observatory Hill wind station were analysed to determine an annual exceedance graph of the wind speed which is illustrated in Figure 6.

Wind-generated Wave Climate

Wave climate analysis was undertaken using the previous wind data and the algorithms of the Automated Coastal Engineering Software (ACES). The southern part of the study area where the cove has been proposed, is directly exposed to the longest fetch length from the west-southwest and this location has been selected as

reference location for the wind wave calculation. A maximum fetch of around 1900m was measured at this location (Figure 7).

Using these fetches and the previously determined wind speeds as input in ACES wave prediction algorithms, wind-generated waves were assessed for several return periods. The *significant* wave heights (average of the highest third of the wave heights) and the wave period generated by a south-westerly wind (i.e. the direction which has the most significant impact on the study area) for different wind conditions are shown in Table 1.

Waves reach up to 0.70m *significant* wave height and 2.39s wave period for a 1 in 100 year wind speed.

Table 1 – Wave characteristics results from ACES for a south-westerly wind

Wind Speed Condition	3-hourly Wind Speed from Observatory Hill Wind Station (km/h)	Hourly Wind Speed		Wave Characteristics Results	
		km/h	m/s	Significant Wave Height (m)	Wave Period (s)
1 year ARI	52	56.0	15.6	0.4	1.98
10 year ARI	66	71.1	19.7	0.54	2.19
50 year ARI	75	80.8	22.4	0.64	2.32
100 year ARI	80	86.2	23.9	0.7	2.39

Boat Wake Wave Climate

Boat wake management is a relatively complex issue. It is difficult to determine a standardised approach as the impact of boat waves depends on various criteria including the shape and speed of the boat, the depth of the waterway, the type and condition of the embankment. Numerous wake wave management criteria are available as illustrated in Table 2 below.

Table 2 – Wake wave management criteria (Glamore, 2008)

Wave Characteristic	Wave Management Criteria	Source
Maximum Wave Height (H_{max})	28 cm from peak to trough measured 300 m from sailing line in deep water.	Stumbo <i>et al.</i> (1999).
Maximum Wave Height (H_{max})	< 20 cm no action on bank stabilisation required. 20-30 cm requires monitoring. 30-40 cm requires bank engineering assessment and remediation.	Patterson Britton and Partners (2001).
Maximum Wave Height (H_{max})	Based on wave height criteria: $H_h \leq 0.5 \sqrt{\frac{4.5}{T_h}}$ Where H_h is H_{max} and T_h is mean wave period. (Equates to 0.75m for 2.0 second wave period.)	Parnell and Kofoed-Hansen (2001)
Wave Energy	< 2450 joules/m (150 lb/ft) in the highest significant wave of the wave train as measured 300m from sailing line in deep water.	Stumbo <i>et al.</i> (1999).
Wave Energy, Wave Period and Speed	Energy: $1962H_m^2 T_m^2 < 60$ joules/m or <180 joules/m; Period: Comparison of boat length and energy in the form of $3.04\sqrt{L}$. Speed: Blanket Speed Limit of 5-6 knots	Australian Maritime College (2003)

Propagation of the boat wake waves are schematised in Figure 8. A wave train (i.e. group of fully formed boat waves) initially appears as an accumulation of super-imposed waves travelling away from the sailing line. Waves start to be fully developed around 2.5 to 3 boat lengths from the sailing line and then attenuation occurs with a decreasing wave height while the wave periods remains constant. Several boat wake wave analyses have been undertaken into Port Jackson and the results of these studies are shown in Table 3.

Table 3 – Results of boat wake wave analysis in Port Jackson (DECC, 2008)

Location	Craft Class	Averages		Maxima		Distance From Sail Line (m)	Power (W/m) ⁽⁵⁾
		H _{max} (m)	T (sec)	H _{max} (m)	T (sec)		
Sydney Cove ⁽¹⁾	Hydrofoil	0.45	2.3	0.72	2.0	50-100	1017
	Lady Ferry	0.25	2.2	0.44	2.2		418
	Water Taxi	0.38	2.2	0.44	1.8		342
Manly Cove ⁽¹⁾	Hydrofoil	0.56	2.4	0.87	2.6	50-100	1931
Drummoyne ⁽²⁾	River Cat	0.32	8.4	0.40	10.0	100-200	1570
	First Fleet Ferry	0.45	4.0	0.54	4.3		1230
	Cruiser	0.2	2.6	0.25	3.0		184
Pulpit Point ⁽³⁾	River Cat	0.45	4.0	0.60	5.2	25-150	1837
	First Fleet Ferry	0.2	2.3	0.25	2.5		153
Sydney Harbour ⁽⁴⁾	25m Cat Ferry			0.62	2.0	90	754
	Lady Ferry			0.39	2.8		418

- Notes:
1. (Cox and Blumberg, 1984).
 2. (WPGeomarine, 1998).
 3. (Patterson, et al. 1997). This study made the observation that due to instrument problems the wave height measurements were generally inconsistent with the observed conditions.
 4. (Blumberg, 1991).
 5. After Edwards and Lord (1998). Wave power calculated through a vertical plane in the direction of wave advance (UASACE, 2002) based on maxima values for wave height and period.

Wave Climate Analysis - Summary

Study of the wind and wave climate in the study area shows that hourly winds can reach a speed of up to around 24 m/s in a 1-in-100-year event. This 100 year ARI speed could generate waves of up to around 0.70m significant wave height and around 2.4s wave period. These wave parameters would only occur in case of strong wind in a south-westerly direction. Moreover, Blumberg et al. (2003) undertook a study at Walsh Bay (directly north-east of the study area) and found maximum wave height of around 0.6m which is comparable to the present results, the slight difference being due to different fetch lengths.

Regarding boat wake waves, wave parameters can reach a maximum of around 0.6 m wave height and a 2 – 4 s wave period for ferry waves, with wave heights and periods of around 0.4 m and up to 8 s for the River Cats.

Impact of proposed foreshore re-development on wave climate

The foreshore development will involve removal of the existing caissons from the shoreline and replacement with a shoreline consisting primarily of sandstone blocks placed on a free-draining armour rubble layer at a relatively shallow slope. In contrast, the existing shoreline is highly reflective of wave energy, with close to 100% of wave energy reflected from the existing vertical caisson face. The new shoreline would result in a high degree of wave dissipation, with waves (including ferry waves) breaking on the sandstone shoreline as they reach shallow water. Long period waves from River Cats would enter the proposed cove area and dissipate onto the shoreline.

The increase in wave energy dissipation (and reduced wave reflection) within the northern portion of Darling Harbour as a result of the proposal would reduce the ambient wave climate within northern Darling Harbour which could have a beneficial impact for ferries operating at East Balmain Wharf.

Hydrology

The proposed reconstruction of the terrain over Headland Park is likely to alter the hydrological regime over the site. At present, the site is relatively flat and paved. The proposed terrain of the redevelopment will create local drainage catchments, which will result in concentrated localised flows into the northern cove and at set points along the shoreline.

While the flows may be more localised than at present, the peak flow volumes and response times would be reduced for the Headland Park portion of the development area when compared with existing conditions due to the reduced portion of paved area.

Summary and Conclusions

This report has presented a desktop review of existing studies and the design of the land formation works for the Barangaroo Shoreline. Specifically, this report addresses the Director General's Requirements with respect to:

- Assessing impacts on estuarine circulation, and any changes that may result from altered hydrological regimes of surrounding waters and bays.

This report has provided a commentary on how the proposed re-structure of the outer perimeter of the site would impact on estuarine circulation and coastal processes in general, based on a review of existing information.

Based on the desktop review, it was found that

- Removal of the caissons and rounding of the corner at the north-western end of the site is likely to improve the tidal circulation in this area as this would make it less likely that a localised flow reversal eddy could occur in this area;
- The design of the cove to allow a shallow depth and wide entrance is appropriate to maximise tidal exchange between the cove and Darling Harbour
- The proposed shoreline reconstruction would not have a significant impact on overall tidal exchange within Darling Harbour
- The removal of the caissons from the shoreline and introduction of rocky shoreline would result in a dissipation of wave energy from ferries and wind waves as well as a reduction in wave reflection within the harbour, potentially improving the operating conditions at East Balmain Wharf
- The creation of the Headland Park would not significantly impact the volume of freshwater inflows into the estuary, but response times and peak flow rates would likely be reduced due to the reduction in overall paved area.

This report represents a desktop study only as the design is at concept stage. Additional studies can be done if required. In particular a 2 dimensional hydrodynamic model study of Darling Harbour and the surrounding Sydney Harbour estuary showing tidal and wind current velocities and how they would vary between existing and proposed conditions would be beneficial. Field measurements of hydrodynamic parameters and further literature review would also be of benefit.

We trust that this suits your requirements and should you have any queries, please contact the undersigned.

Yours sincerely,

Chris Adamantidis
Manager Coasts and Estuaries

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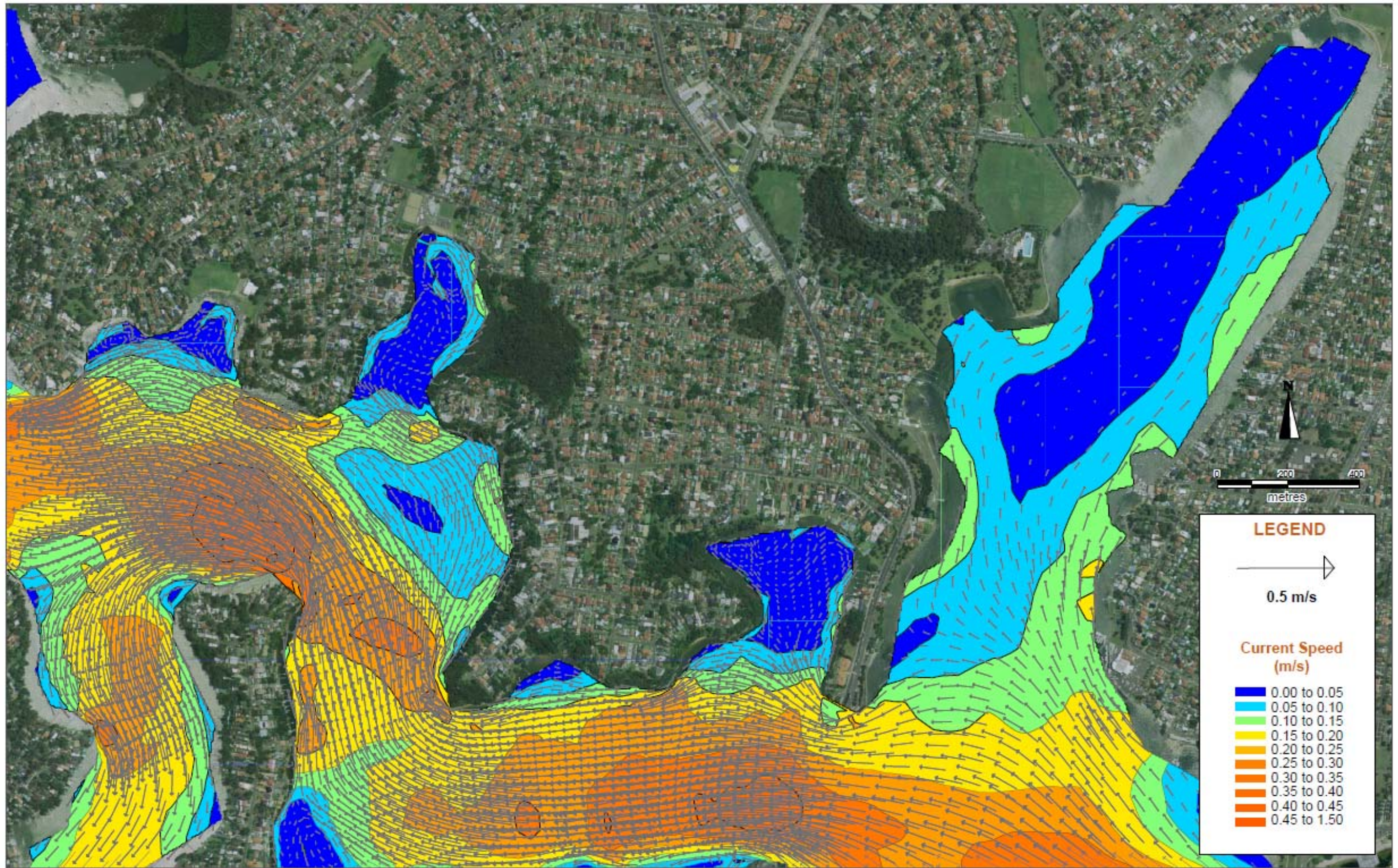


Figure 2 – Extract from SMEC hydrodynamic model of the Lower Georges River

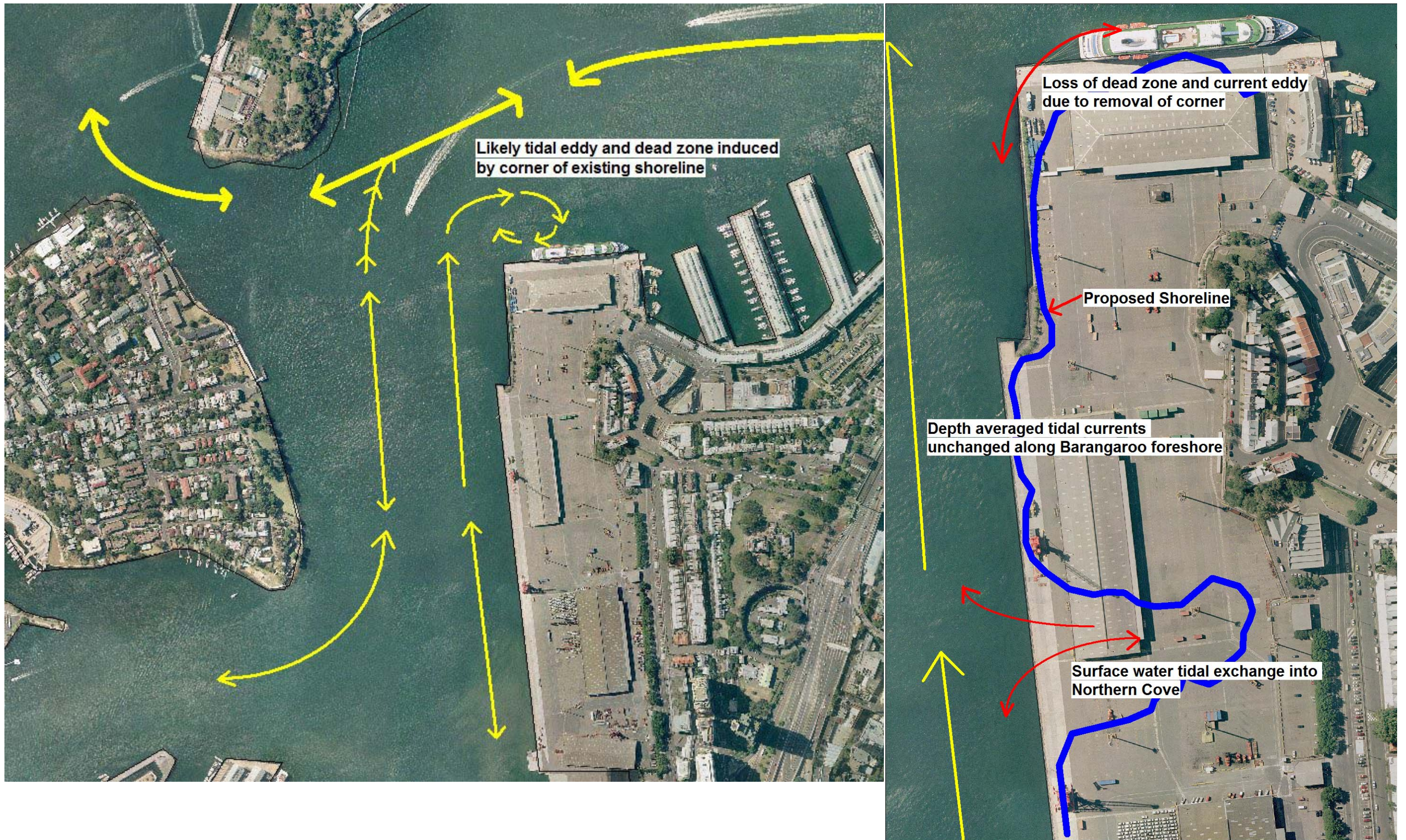


Figure 3 – Conceptual tidal current model – left – existing, right – proposed shoreline

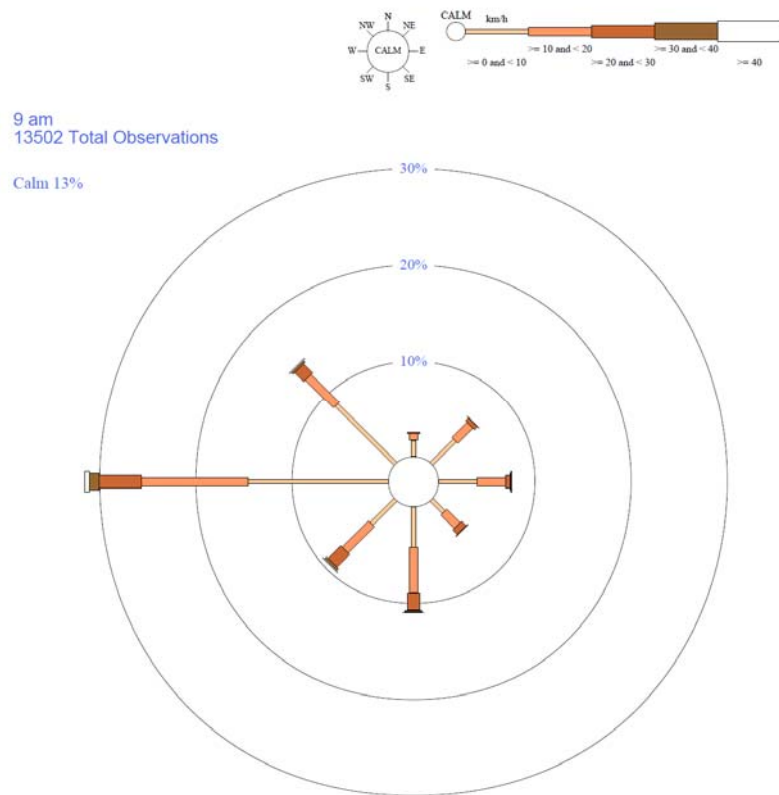


Figure 4 – Average 9am Wind Speed at Observatory Hill Wind Station (Bureau of Meteorology)

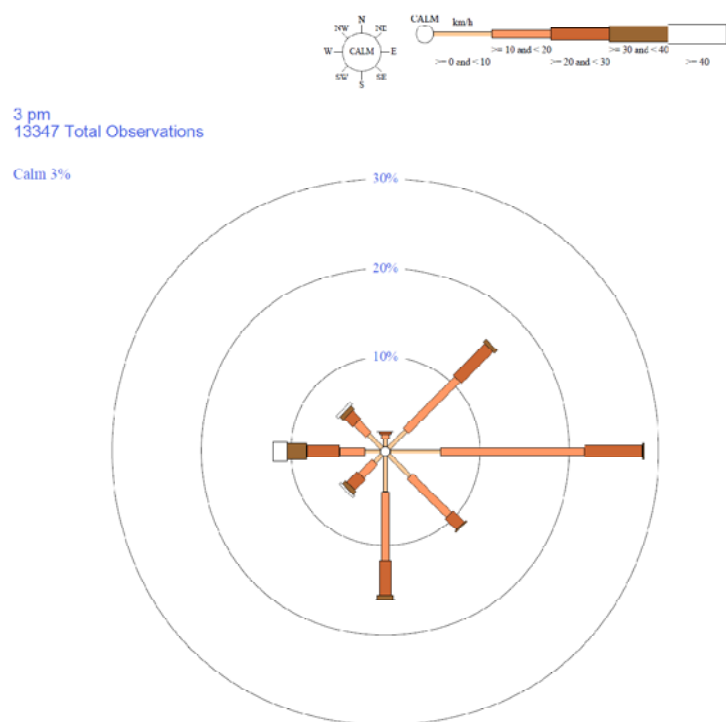


Figure 5 – Average 3pm Wind Speed at Observatory Hill Wind Station (Bureau of Meteorology)

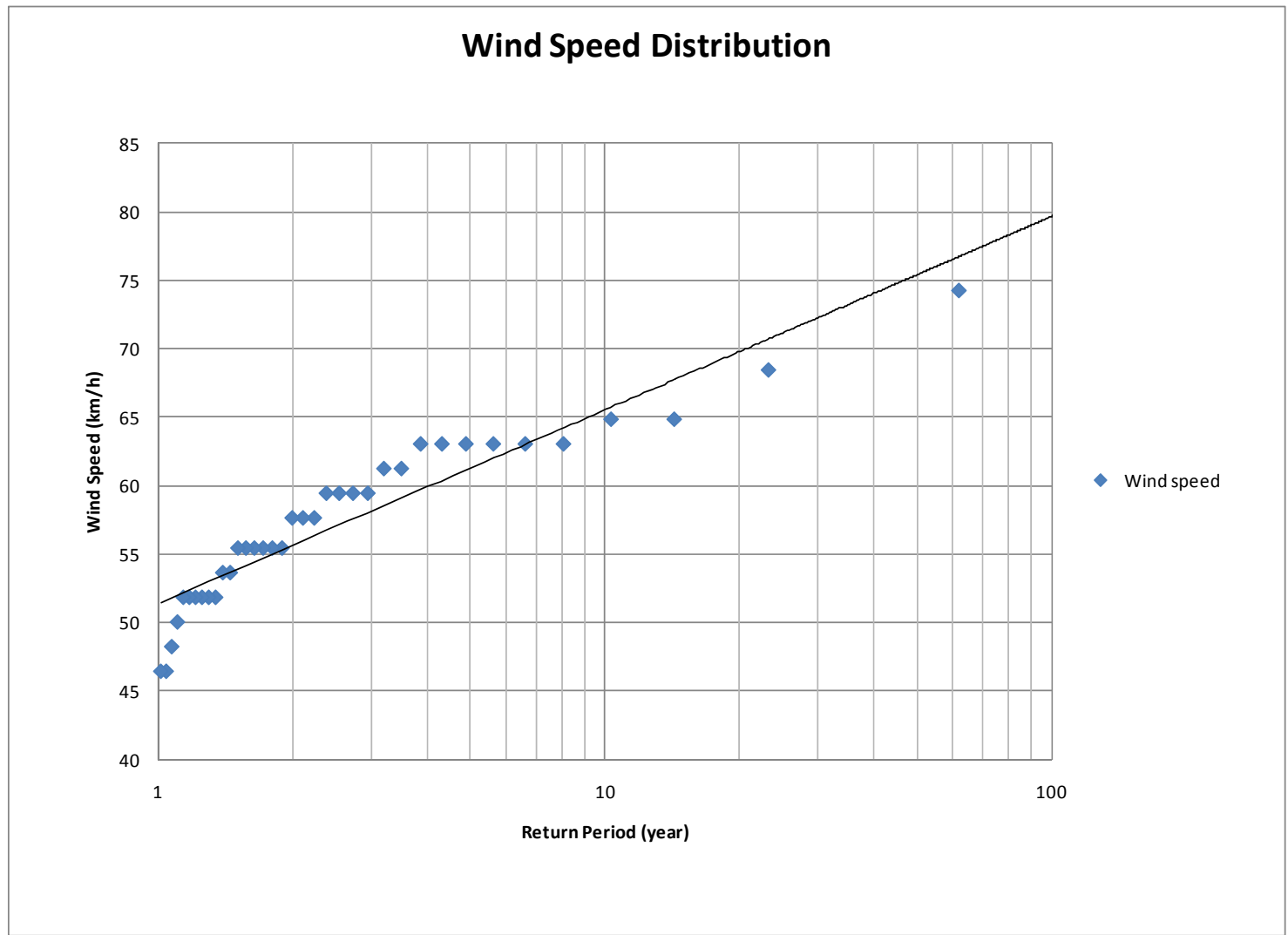


Figure 6 – Annual exceedance plot of wind data from Observatory Hill (from Bureau of Meteorology data)



Figure 7 – Maximum fetch measured for Barrangaroo future development Wave Climate Analysis

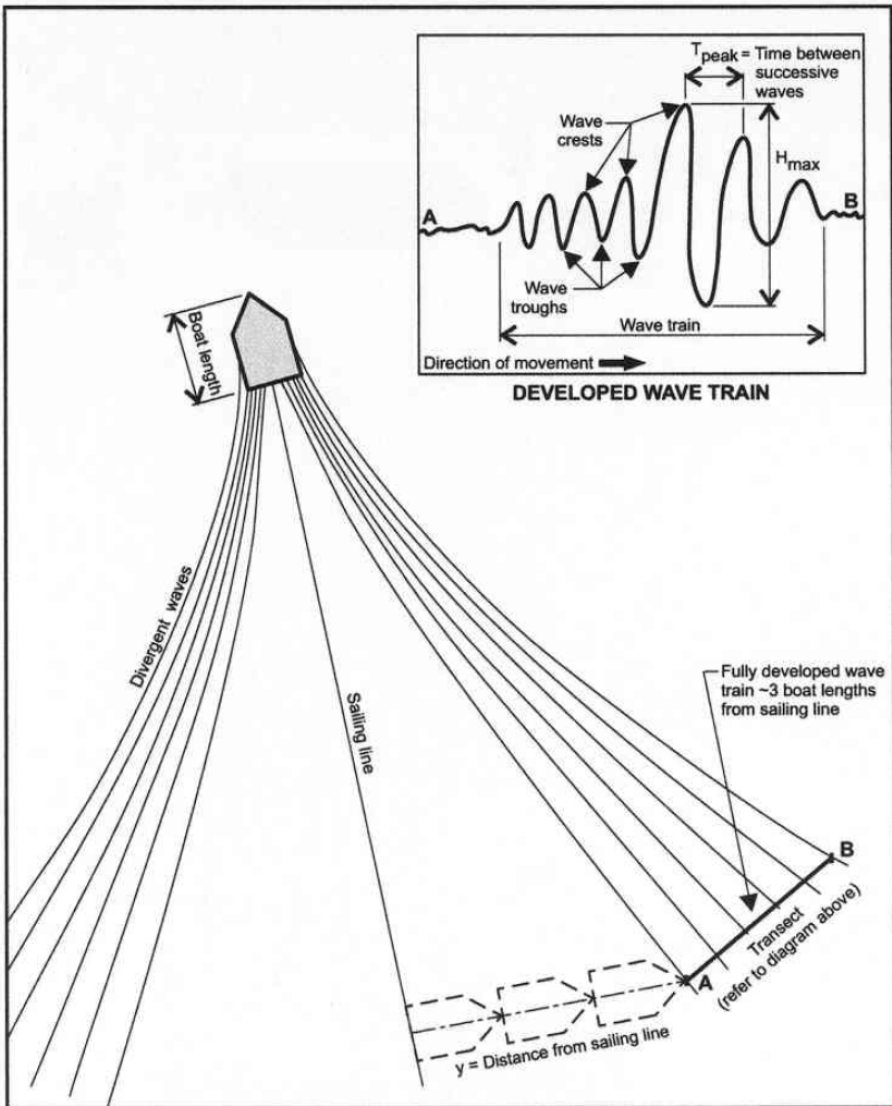


Figure 8 – Boat wake waves generation (Glamore, 2008)