Report to:

NSW Department of Lands

Sinking of Ex-HMAS Adelaide off the Central Coast NSW

Review of Constraints and Site Selection

FINAL

June 2008

The Ecology Lab Pty Ltd

Marine and Freshwater Studies

Sinking of Ex-HMAS Adelaide off the Central Coast, NSW
Review of Constraints and Site Selection

June 2008

Report Prepared for:

NSW Department of Lands
Level 4, 437 Hunter Street
Newcastle, NSW, 2309

Report Prepared by:

The Ecology Lab Pty Ltd
4 Green Street
Brookvale, NSW, 2100
Phone: (02) 9907 4440

Report Number – 58/0708 A
Report Status – Final, 11 June 2008

TABLE OF CONTENTS

SUMMARY

The long range escort frigate 'HMAS Adelaide' was decommissioned by the Australian government in January 2008 and plans are now being made to scuttle the vessel for the purpose of creating a recreational dive site and artificial reef. Preliminary investigations have identified an area for scuttling the ship, between Terrigal Headland (Broken Head) and Avoca Beach (referred to as the 'study area'). Selecting a suitable site for the ship within the study area is dependent on a range of physical, environmental and operational factors. The Ecology Lab Pty Ltd has been commissioned by NSW Department of Lands to undertake a review of all constraints and issues in the study area so that a suitable site for the Ex-HMAS Adelaide can be recommended. Worley Parsons Pty Ltd was sub-contracted by The Ecology Lab to provide expert advice on geotechnical and oceanographic aspects of the study area and to assist with GIS constraints mapping. Once a specific site is selected, a more detailed environmental assessment at the site will be required for further planning approval. The aims of the study were to:

- Outline major physical, environmental and operational constraints on site selection, including details and sources of data;
- Undertake a site inspection to characterise the nature of the seabed and associated biota within the study area;
- Recommend a suitable site within the study area based on the outcome of the desktop analysis and site inspection;
- Provide high quality maps identifying potentially constraining features and the location of the recommended site.

Current literature was searched using library resources from The Ecology Lab, Worley Parsons and the internet to produce the main constraints review. Constraint maps were constructed using 'Mapinfo' GIS (Geographic Information Systems) software. In addition, a site inspection was undertaken on 5 April 2008 using SCUBA divers to collect core samples and take underwater photographs within the study area. 'Baited, Remote, Underwater, Video Stations' (BRUVS) were also deployed to quantify and identify fish species present.

Results of the site inspection showed that substratum in the study area was composed mainly of compact, rippled sand, coarse sand (approximately 90 % shell) and interspersed with occasional rocky outcrops and low relief reef habitat. Sandy habitat observed during the dive survey was generally bare apart from a few demersal fish species such as flatheads and rays. Some patches of sand were bioturbated indicating the presence of burrowing organisms such as polychaete worms and/or crabs. Sponges, ascidians, echinoderms, turfing algae and kelp were observed attached to rocky reef. A diverse assemblage of fish species were also recorded within the investigation site during the dive surveys and by 'BRUVS'. One threatened marine reptile (a hawksbill turtle) was observed during the site inspection. Eight other threatened species were identified to have a high likelihood of occurring within the study area and it is recommended that these species are assessed under part 5A of the EP&A (*Environmental Planning and Assessment*) Act (the 7 –Part Test).

Of all the constraints considered, distribution and characteristics of the substratum (such as the presence of unsuitable reef surfaces) and suitable penetration depth of sediments were the major factors in determining a potential location for the Ex-HMAS Adelaide dive site. These factors considered together with the preferred depth range (30 m – 35 m), allowed selection of a target area approximately 1.67 km offshore of north Avoca Beach (1.51 km

south-west of the Skillion). Single-beam side scan sonar survey of the seabed was carried out over the target area in May 2008 by the Department of Environment and Climate Change (DECC). Results indicated that seabed characteristics had not changed significantly over time (with the exception of one small reef outcrop) and confirmed suitability of the target area. Within the targeted area, two site options were identified, with the preferred option located at the northern section of the target area. Further information however, is required in order to confirm the suitability of the site.

It is recommended that formal consultation with commercial fishers and industry stakeholders is undertaken to determine whether they operate in or in the vicinity of the selected site. It is also recommended that further information on the nature of the seabed and associated biological communities is assessed at the selected site. This would involve ground truth sampling by benthic grab to determine sediment particle size composition (PSA) and biological community structure (including benthos, epibenthos and fish). This would give an indication of existing conditions and importantly, provide a baseline for future monitoring of the Ex-HMAS Adelaide dive site over time. Further studies would be required to confirm sediment penetration depths are 2 m or greater (to adequately support the ship).

Based on coastal and oceanographic conditions in the study area, it is evident that a deeper scuttling of the Ex-HMAS Adelaide within the 30 m to 35 m depth limits would be favoured. This is because at depth, possible effects of wave refraction, wave-driven and oceanographic currents and sediment transport are minimised. Further site specific numerical modelling would be required to quantify potential effects.

Preliminary advice from NSW Maritime recommends a depth clearance of 6 m – 8 m at low astronomical tide to allow for the navigational safety of vessels operating in the area. To achieve a 6 m – 8 m depth clearance, the main mast of the Ex-HMAS Adelaide would need to be removed. Assuming this is the case, the foremast would still extend approximately 30 m above the seabed. Positioning the ship deeper (≥34 m) and allowing for burial into the seabed (≥2 m) would therefore meet NSW Maritime recommendations and reduce the risk of damage to the main mast under wave loading.

It is recommended that an exclusion zone between 250 m and 500 m (as an indication) is established around the ship to ensure navigational safety and allow management of activities within the zone. The zone would be appropriately marked by navigation aids.

It is recommended that the ship is orientated in a SSE direction (bow facing SSE) into the dominant wave direction. Orientation is, however, a complex issue and further site specific assessment (such as numerical wave modelling) should be considered.

Timing for deployment of the ship is recommended from December to February, when coastal storms are less frequent, wave conditions are likely to be calmer and interaction with migrating whales along the coast is least likely. If weather conditions were favourable, deployment during September may also be an option, as humpback whales (the most common migratory whale species along this stretch of coastline) are not usually present along the Central Coast at this time.

1.0 INTRODUCTION

1.1 Background and Aims

HMAS Adelaide was decommissioned by the Australian Navy in January 2008 and has been handed over to the NSW government for the purpose of creating a recreational dive site and artificial reef in waters off the Central Coast near Terrigal. Creation of the artificial reef is expected to boost the local economy (particularly from increased dive tourism and hospitality), enhance marine biodiversity in the vicinity of the scuttled ship and provide ongoing research opportunities for the University of Newcastle which is located nearby.

HMAS Adelaide was a long-range escort frigate (Frigate Fast Guided Missile 7 Class), 138.1 m in length, with a beam of 14.3 m, a displacement of 4100 tonnes and draft of approximately 7m (Plate 1)(Figure 6). Heights above the waterline are about 5.1 m to the deck midships, 11.1 m to the bridge floor (equivalent to the top of the main ship superstructure), 23 m to the top of the foremast (the mast closest to the bow), and 35.5 m to the top of the mainmast (NavFac handout No. 99). Not considering any burial into the seabed and assuming no removal of masts or superstructure, the sunken Ex-HMAS Adelaide deck, superstructure, foremast and mainmast would extend approximately 12 m, 18 m, 30 m and 42 m respectively above the seabed. Preliminary advice from NSW Maritime recommends a depth clearance of 6 m – 8 m at low astronomical tide to allow for the navigational safety of vessels operating in the area. To achieve a 6 m – 8 m depth clearance, the main mast of the Ex-HMAS Adelaide would need to be removed. Assuming this is the case, the foremast would still extend approximately 30 m above the seabed. Positioning the ship deeper (≥34 m) and allowing for burial into the seabed (≥2 m) would therefore meet NSW Maritime preliminary requirements.

Selecting a suitable site is critical to the success of the project and there are a range of physical, environmental and operational constraints which need to be considered prior to selecting a suitable location. Preliminary investigations and discussions between NSW Department of Lands and local diving organisations have identified the waters off Terrigal Headland and Avoca Beach as a potential site for the Ex-HMAS Adelaide to be scuttled. The selected site should be significantly larger than the footprint of the ship itself to allow for a margin of error during the scuttling operation and include an exclusion zone around the ship for navigational safety.

The Ecology Lab Pty Ltd has been commissioned by NSW Department of Lands to undertake a desktop review of all constraints and issues in the study area in order to recommend a suitable site for the Ex-HMAS Adelaide to be scuttled. Once a specific site has been recommended this will be used as the basis for a more detailed environmental assessment required for planning approval under the *Environmental Planning and Assessment Act*. Worley Parsons Pty Ltd was sub contracted by The Ecology Lab to provide expert advice on geotechnical and oceanographic aspects of the study area and assist with GIS constraints mapping.

The aims of this study are to:

- Outline major physical, environmental and operational constraints on site selection, including details and sources of data;
- Undertake a site inspection to help characterise the nature of the seabed and associated biota within the selected area;

- Recommend a suitable site based on the outcome of the desktop analysis and the site inspection;
- Provide high quality maps identifying potentially constraining features and the location of the recommended site.

1.2 Study Area

The study area is defined as the waters between Terrigal Headland (Broken Head) and south Avoca Beach, near the town of Terrigal on the Central Coast of NSW (approximately 1 hour north of Sydney)(Figure 1). From Broken Head (Terrigal Head) to the southern end of Avoca Beach it is approximately 3 km, and approximately 2 km offshore to the 30 m – 35 m depth contour (the preferred depth range for scuttling the Ex-HMAS Adelaide).

1.3 Appreciation of the Issues

Constraints and issues that require consideration prior to scuttling of the Ex-HMAS Adelaide have been identified by the Department of Lands and are listed below:

- Exclusion zones, including:
  - Designated commercial fishing areas (e.g. trawl and trap)
  - Port restrictions/commercial shipping lanes
  - Submarine pipes and cables
  - Marine protected areas (State and Commonwealth)
  - Historical ship wrecks and other historical sites
  - Spoil grounds
  - Ocean outfalls
  - Mining exploration leases
  - Recreational sailing paths and courses
  - Marinas/moorings
- Recreational fishing areas
- Recreational dive sites (Including SCUBA, spearfishing and snorkelling)
- FAD's (Fish Aggregation Devices)
- Depth

Depth is a significant factor in considering placement of artificial reefs (JARTC 1998). This is because the artificial structures need to be placed in water deep enough to accommodate the draft of vessels expected to operate in the area. Preliminary advice from NSW Maritime recommends a depth clearance of 6 m – 8 m at low astronomical tide to allow for the navigational safety of vessels operating in the area. To achieve this depth clearance, the main mast of the vessel would need to be removed and the ship sunk in depths greater than 34 m. Suitable depth is also important for the stability of the ship on the seabed in terms of its ability to withstand hydrodynamic forces. It will also influence the assemblages of species living on and around the ship. Depth will also determine the level of experience required by divers using the dive site.

- Distribution of substrata and suitability of substrata to support the vessel.

It is important that the substratum is composed mainly of sand that will allow the ship to penetrate 1 m to 2 m into the sediment, maintaining a stable upright position. Any areas of

very soft sediments (e.g. silts or clays) or hard substratum (e.g. rocky reef) should therefore be avoided (JARTC 1998).

- Distribution of habitats, flora and fauna.

Existing reef habitats, habitats unique within an area, or locations known to support diverse benthic/epibenthic communities should be avoided. Beds of macroalgae, oyster reefs, scallop, clam or mussel beds and rocky outcrops supporting assemblages of sessile marine invertebrates such as sponges, sea fans and corals should be avoided. Habitats that are critical to the survival of a particular species and generally protected under NSW legislation and should also be avoided. Protected habitats may require an additional buffer zone around them where fishing or development activity is restricted. Legislative requirements relating to conservation issues are outlined in section 1.4 (Statutory Requirements).

- Threatened species issues, including fish, invertebrates, marine mammals and marine reptiles.

Information on the occurrence and distribution of threatened species is generally sparse and may be limited to predictions based on presence of suitable habitat and/or records of a species occurring at one location at a particular point in time. It is especially difficult to predict where highly mobile individuals (such as fish or migratory marine mammals) occur due to their itinerant nature.

- Coastal and oceanographic processes.

Artificial structures placed on the ocean floor are subject to the forces of currents (variable in speed and direction), waves, tides and hydrostatic changes in water levels. Combined, these forces can produce stresses on the seafloor and artificial reef structures (Sheng *et al*, 2000). Excessive physical forces may lead to erosion of benthic sediments and instability or movement of the ship. Apart from the direct impact of coastal processes on the ship itself there is potential for indirect effects on the nearby coastline through an alteration of existing wave patterns (for example, through increased erosion due to altered wave climate).

Spatial information on near-shore hydrodynamics and wave modelling is recommended in order to avoid potentially high energy areas with bottom stresses unsuitable for placement of the ship and to ensure placement of the ship will not have detrimental impacts on the surrounding coastline. Information from wave modelling is also necessary to ensure that the ship is orientated in an angle to the shore that will minimise forces acting on the ships structure and also minimise indirect impacts on the surrounding coastline.

- Operational feasibility

In order for a recreational diving reef to operate successfully, it is important to assess beforehand whether the surrounding locality has adequate amenities and facilities to cope with the expected increase in tourism (both diving and non-diving visitors). The site should be located a suitable distance from shore-based infrastructure (e.g. boat ramps, car parking, dive centres, medical services) and ideally be close to other popular dive areas. Depth range between 30 m – 35 m has been selected to allow divers with a range of experience to benefit from the site, although less experienced divers will be limited to the upper parts of the ship. Physical conditions at the site itself, such as water clarity and average current velocities are important to ensure the site is safe under normal diving conditions.

All of the above constraints and issues have been considered in this review, however, only those issues considered directly relevant to the study area have been addressed from here on.

1.4 Statutory Requirements

The following statutory requirements have been identified as relevant to this review.

1.4.1 Commonwealth Legislation

Historic Shipwrecks Act (1976)

The *Historic Shipwrecks Act (1976)* administered by the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA) protects historic wrecks and relics in Commonwealth waters, extending from below the low water mark to the edge of the continental shelf. In NSW, all shipwrecks over 75 years of age are automatically protected from disturbance under the *NSW Heritage Act 1977* (Section 1.4.2). Some historic shipwrecks lie within protected or no-entry zones. These zones may cover an area up to a radius of 800 m around a wreck site, and may be declared where circumstances place it at particular risk of interference. This declaration prohibits all entry into this zone without a permit. Permits are also required to undertake any activities otherwise prohibited or restricted by the Act.

Sea Dumping Act (1981)

The placement and construction of artificial reefs are regulated under the Commonwealth *Environment Protection* (Sea Dumping) *Act 1981 (the Sea Dumping Act)* which is administered by the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA). The *Sea Dumping Act* applies to Australian waters, from the low water mark to the limits of the Exclusive Economic Zone (EEZ), other than internal waters within the limits of a State or Territory (such as Sydney Harbour or Port Phillip Bay). A permit is required to place materials for the creation of an artificial reef in order to ensure that a suitable site is selected, that the materials are suitable and properly prepared, that no significant adverse impacts occur on the marine environment and that the reef does not pose a danger to navigation, fishermen or divers. Once a permit is issued then it becomes charted on maritime maps.

Environmental Protection and Biodiversity Conservation Act (1999)

The *Environmental Protection and Biodiversity Conservation Act 1999* (*EPBC Act)* administered by the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) assesses actions that are likely to have a significant impact on a matter of national environmental significance (NES). In the aquatic environment, the Act lists threatened species, ecological communities and key threatening processes, migratory species, cetaceans, marine species and Ramsar areas of national significance. The Act applies to waters in the Australian jurisdiction, which generally includes the coastal waters of Australian States.

1.4.2 State Legislation

NSW Heritage Act (1977)

The *NSW Heritage Act (1977)* protects archaeological relics from being disturbed without a permit from the Heritage Council, which administers the Act. A relic is defined as anything over 50 years old. In addition, shipwrecks over 75 years of age are automatically protected

as heritage items and entered onto a register of historic shipwrecks. Under the Heritage Act all shipwrecks within NSW that were wrecked over 75 years ago are protected. It is also possible to extend this protection to important shipwrecks less than 75 years old through an order by the Minister for Planning published in the NSW Government Gazette. Specific provisions for historic shipwrecks were included in amendments to the Heritage Act in 2001. Shipwrecks off the NSW coast are subject to the Commonwealth *Historic Shipwrecks Act 1976* (section 1.4.1).

Threatened Species Conservation Act (1995), the Fisheries Management Act (1994) and the Fisheries Management Amendment Act (1997)

In NSW the *Threatened Species Conservation Act 1995 (TSC Act)* the *Fisheries Management Act 1994* (*FM Act*) and the *Fisheries Management Amendment Act 1997* (*FMA Act*) include provisions to declare threatened species, populations, ecological communities and key threatening processes. Provisions for the protection of fish and marine plants are administered through the Department of Primary industries (NSW DPI) and those for marine birds, mammals and reptiles are administered through the NSW Department of Environment and Climate Change (DECC). Part 2 (19) of the *FM Act* also allows for the declaration of 'protected species', which, though not currently declining, must be protected so they do not become threatened in future. Species protected under NSW and Commonwealth legislation relevant to this review are listed in Table 1.

National Parks and Wildlife Act 1974 No 80 and the *National Parks and Wildlife Regulation*

Under the *National Parks and Wildlife Act*, the Director-General of the National Parks and Wildlife Service (NPWS) is responsible for the care, control and management of all national parks, historic sites, nature reserves, reserves, Aboriginal areas and State game reserves. State conservation areas, karst conservation reserves and regional parks are also administered under the Act. The Director-General is also responsible under this legislation for the protection and care of native fauna and flora and Aboriginal places and objects throughout NSW. On 1 September 2002 the *National Parks and Wildlife Regulation* came into effect. The regulation governs various activities under the *National Parks and Wildlife Act 1974*, including:

- regulation of the use of national parks and other areas administered by the Act
- preservation of public health in Kosciuszko National Park
- licences and certificates
- protection of fauna
- exemption of Aboriginal people from the restrictions imposed by various sections of the Act on the hunting of certain animals and the gathering of certain plants
- boards of management and plans of management in relation to Aboriginal land
- advisory committees constituted under section 24 of the *National Parks and Wildlife Act 1974*

1.5 Ex- Naval Vessels as Artificial Reefs

A number of Ex-naval vessels have been scuttled in Australian waters with the purpose of creating artificial recreational dive reefs. Examples include the Ex-HMAS Swan (off Dunsborough, WA) the Ex-HMAS Hobart (off Yankalilla Bay, South Australia), the Ex-HMAS Perth (off King George Sound in Albany, WA) and most recently the Ex-HMAS

Brisbane (off the Sunshine Coast in Queensland). Prior to scuttling, all vessels were prepared so that they are safe to dive on and do not present any hazard to marine life (i.e. through leaching of contaminants) or to divers themselves. All hazardous materials e.g. antifouling paints, hydrocarbons, toxic paints etc were removed and any other debris or loose objects (which could be hazardous to divers) stripped from the vessels. The ships are located at depths of approximately 30 m.

Activities within the newly established dive sites are now strictly controlled and in all cases exclusion zones have been established around the wrecks, prohibiting commercial and recreational fishing activities and also limiting the number of commercial and private dive boats moored in the area at any one time. In the case of the Ex-HMAS Hobart, a 550 m exclusion zone has been placed around the wreck and it is illegal to enter the zone without a permit (Web Reference 4). It is also illegal to damage the wreck or remove relics from it. Divers are issued with permits to enter the zone providing they abide by conditions. It is also illegal to take fish in an area bounded by a circle of radius 0.5 nm from the wreck centre point. In the case of the Ex-HMAS Brisbane, a 35.3 ha marine conservation park (managed under the *Nature Conservation Act 1992* and the Queensland Parks and Wildlife Service) has been established around the wreck (Queensland EPA, 2007). Within this area access to the site and diving activities are regulated and general tourism operations, fishing, boating and other water craft activities are not permitted at the site.

Colonisation of sessile invertebrates has proven to be relatively fast in the case of the Ex-HMAS Brisbane, with red, brown and blue/green algae, limpets and goose barnacles colonising within the first three months of deployment (Queensland EPA, 2007). Mobile invertebrates such as crabs, shrimps, crayfish and octopus were recorded within the first nine months. A diverse assemblage of pelagic and reef fish, marine reptiles and also species of marine mammal were observed around the wreck within the first nine months.

Approximately 80 different species of fish and a diverse assemblage of mobile marine invertebrates including nudibranchs, opisthobranchs, cuttlefish, octopus and starfish have been observed around the wreck of the Ex-HMAS Hobart since its deployment in November 2002. Sessile sponges, ascidians, polychaete worms and soft corals are well established. Biological monitoring of the HMAS Swan over a two year period has shown that the structure was initially colonised by hydroids, covering approximately 70 % – 90 % of the area surveyed (Morrison, 2001). Algal growth also dominated the encrusting marine life during the summer months of 1998 and 1999, particularly on the upper surfaces. Other sessile groups such as sponges, ascidians, anemones and soft corals were shown to proliferate on shaded portions of the vessel. Monitoring of the fish community over the two year period showed an average increase in richness from 2 to 32 species with a shift from omnivorous weed/sand fishes to one dominated by planktivorous and carnivorous reef fishes. When compared to control sites in the region, species diversity and abundance on the HMAS Swan was comparable, however, the community composition on the vessel was distinctly different.

2.0 METHODS

2.1 Constraints Review

Current literature was searched using library resources from The Ecology Lab, Worley Parsons and the internet to produce the main constraints review. Constraint Maps were produced using GIS (Geographic Information System) software and data from the Ecology Lab and Worley Parsons. Areas with major constraining features (such as unsuitable depth or substratum type) were first eliminated to leave a target area. Within the target area a preliminary site was selected according to optimal conditions.

2.2 Site Inspection

The investigation site was chosen according to seabed maps produced by the Public Works Department (1989) and targeted a rectangular area (approximately 0.42 km^2) within the preferred depth range (30 m -35 m). This area was approximately 1.14 km in length (north to south) and 0.45 km in width (at its widest point). The north and southernmost boundaries of the area were limited by sand covered reef at either end of the Avoca Beach embayment.

Visual inspection of the investigation site (including sediment cores and photography) was carried out by SCUBA divers to gain a general overview of substratum, habitat characteristics and fish species present at the site. Two teams of two SCUBA divers navigated transects along the seabed within the 30 m - 35 m depth range for approximately 30 minutes. One transect was carried out at the northern end of the investigation site and one at the southern end (Appendix 4). Two 30 cm core samples were collected at each location for visual inspection of sediment type.

'BRUVS' (Baited, Remote, Underwater, Video, Stations) were deployed at 2 locations adjacent to reef habitats at the northern end of the inspection site to provide a qualitative indication of fish species and their abundance within the investigation site (Appendix 4). Sony HDR-HC5E high-definition (1080i) digital video cameras, fitted with x0.6 wide angle conversion lens, and 60 minute Sony MiniDV digital tapes were used (Plate 1). When underwater and operational, the high definition cameras capture footage from an area measuring approximately 1.8 metres wide and 1.1 metres high at the bait jar (1.5 m from the camera lens). Pilchard bait was used to attract fish to the units. A 5 m vessel equipped with a depth sounder and GPS was used to navigate to locations within the study area. The BRUVS units were deployed by hand over the down-current side of the boat, and the time, depth and position (UTM, WGS84) were recorded. Depth was measured using a single beam echosounder, and positions measured using a handheld Garmin 72 global positioning system (GPS).

Each unit was deployed for at least one hour. Although a pilot study has shown that the majority of fish were found after 30 minutes of video sampling. This may however, vary between sites and depend on conditions (The Ecology Lab 2007).

Video footage was analysed using the BRUVS tape reading interface program developed at the Australian Institute of Marine Science (AIMS). During tape reading, the following attributes were recorded for each video sample:

- Habitat/habitats in view;

- Time at first appearance;
- Time at first feed;
- Maximum number (MaxNum);
- Time at maximum number for each species (TimeMaxNum).

In instances where large numbers of a species were present in a single frame, the video was paused and a still image used to count numbers of individuals in view at any one time (MaxNum). All mobile species, large enough to be accurately identified, recorded on video during this study, including Osteichthyes (fish), Chondrichthyes (sharks and rays), and Cephalopods (squid, octopus, and cuttlefish), were used in the analyses. Sedentary and sessile species such as echinoderms (starfish) and ascidians (sea squirts) were included if observed.

3.0 CONSTRAINTS

3.1 Depth Range

Data Source: Webster, M. A and Petkovic, P. (2005). Australian Bathymetry and Topography Grid, Geoscience Australia. Bathymetry contours are derived from the 250m bathymetry raster grid.

Depth contours (isobaths) have been mapped at 20 m, 40 m and 60 m intervals by Webster and Petkovic (2005) and at 2 m intervals by the Public Works Department (Gordon and Hoffman 1985). Depth range for the sinking of the Ex-HMAS Adelaide specified by the Department of Lands is between 30 m and 35 m. Depth increases gradually from the centre of Avoca Beach offshore with steeper inclines characterised by rocky reefs present at the north and south ends of Avoca Beach. Taken from the centre of Avoca Beach, the 30 m isobath begins approximately 1.72 km offshore and the 34 m isobath approximately 2.2 km offshore. The area within the specified depth range is therefore limited to a rectangular area of approximately 0.42 km ^{2}, 1.14 km in length (north to south) and 0.45 km in width (at its widest point). The north and southernmost boundary of the rectangular area is limited by the sand covered reef in the north and rocky reef in the south (Figure 5).

3.2 Exclusion Zones

3.2.1 Commercial Fishing Areas

Data Source: Larcombe *et al* (2006) Atlas of Australian Marine Fishing and Coastal Communities, Tanner and Liggins (2001) NSW Commercial Fisheries Statistics and NSW DPI.

Commercial Fisheries potentially affected by the proposal are those that can operate in State waters. These include those under the jurisdiction of the State of NSW and also those under the jurisdiction of the Commonwealth of Australia that may operate within the 3 nm limit under a Section 37 permit of the *FM Act* (The Ecology Lab, 2007).

Fisheries permitted to operate within the study region include the Ocean Hauling Fishery, the Ocean Prawn Trawl Fishery, the Ocean Fish Trawl Fishery and the Ocean Trap and Line Fishery. The Lobster, Abalone, Sea Urchin and Turban Shell fisheries are also known to operate within these waters although to a much lesser extent. Commercial fishers known to operate in the study area are thought to use Trap and Line and Trawl methods mostly (Pers. Comm. Rowling, K. 2008) although Trap and Line is more likely to be used in the 30 m - 35 m depth range. Boats operating in the Terrigal region generally operate out of Newcastle or Swansea (Pers. Comm. Harrison, B. 2008), however one family who operate out of Sydney are known to trawl the sandy area offshore of Avoca (Pers. Comm. Bagnato, R. 2008, Sydney Trawl Management Advisory Committee) and have been consulted on location of common trawling grounds in the study area.

The Ocean Trap and Line Fishery

The Ocean Trap and Line Fishery is a multi-method, multi-species fishery targeting demersal and pelagic fishes along the NSW coast (NSW DPI, 2006a). Snapper (*Pagrus auratus*), spanner crabs (*Ranina ranina*), yellowtail kingfish (*Seriola lalandii*), leatherjackets

(Monacanthidae), bonito (*Sarda australis*) and silver trevally (*Pseudocaranx dentex*) form the bulk of the commercial catch. Other key species include rubberlip morwong (*Nemadactylus douglasi*), blue-eye (*Hyperoglyphe antarctica*), gummy shark (*Mustelus antarcticus*), bar cod (*Epinephalus septemfasciatus*) and yellowfin bream (*Acanthopagrus australis*). In 2000/01 an estimated 1,742 t of fish were caught in the whole fishery with an estimated value of $10 million at first point of sale (Web Reference 5). The fishery uses a variety of methods, most commonly involving a line with hooks, or traps. Demersal fish trapping and line-fishing (for snapper, rubber-lipped morwong and leatherjackets) occurs in the Terrigal area.

The Lobster, Abalone and Sea Urchin and Turban Shell Fisheries

The Lobster Fishery is a small but valuable fishery with a state-wide value of approximately $4.6 million (Web Reference 6). Eastern rock lobster (*Jasus verreauxi*) is the main species harvested with southern rock lobster (*Jasus novaehollandiae*) and tropical rock lobster (*Panulirus* spp.) forming a minor component. The fishery has an inshore sector that uses small beehive or square traps in waters up to 10 m deep. Offshore grounds are beyond the State limit so it is unlikely that this fishery would be a constraint.

The Abalone Fishery is one of the most valuable fisheries in NSW with a total catch of 130 tonnes of blacklip abalone (*Haliotis rubra*), worth more than $5 million at first point of sale, harvested annually (Web Reference 7). In practice, most commercial abalone fishing takes place on the south coast of NSW, primarily from Jervis Bay to the Victorian border (and is unlikely to be a constraint in the study area) with most abalone found close to the shore. The Sea Urchin and Turban Shell Fishery is a small fishery where divers collect two species of sea urchin and two species of turban shell.

The Ocean Hauling Fishery

The Ocean Hauling Fishery targets approximately 20 finfish species using commercial hauling and purse seine nets from sea Beaches and in ocean waters within 3 nautical miles of the NSW coast. On average 3,500 t of fish is taken by the whole fishery each year; mainly sea mullet (*Mugil cephalus*), luderick (*Girella tricuspidate*), yellowtail scad (*Trachurus novaezelandiae*), blue mackerel (*Scomber australasicus*), pilchards (*Sardinops neopilchardus*) and sea garfish (*Hyporhamphus melanochir*). The total catch is worth around $6 million at first point of sale (Web Reference 8). Purse seining for garfish, yellowtail scad and blue mackerel may occur occasionally within the vicinity of the proposed route.

The Ocean Prawn Trawl Fishery

The Ocean Prawn Trawl Fishery is the most valuable fishery in NSW and is worth around $32 million at first point of sale each year (Web Reference 9). In 2000/01 the total catch for the fishery was 3,411 tonnes with 1,739 tonnes of that being prawn catch only.

Prawn trawlers use trawl nets to target prawns on soft sediments. Incidental catches of other species of fish may also be landed. A total of 312 fishing businesses hold endorsements to operate in one or more sectors of the Ocean Prawn Trawl Fishery in NSW. Of these, 267 are endorsed to trawl for prawns in the inshore sector of the fishery (from the coast to three nautical miles to sea), where the main species harvested are school prawns, school whiting and eastern king prawns.

The Ocean Fish Trawl Fishery

The Ocean Fish Trawl Fishery uses the demersal otter trawl to target a large number of species, such as silver trevally, tiger flathead (*Platycephalus richardsoni*), redfish (*Centroberyx gerrardi*), john dory (*Zeus faber*) and numerous species of sharks and rays. Total catches reported by fish trawl operators from NSW managed waters in 2000/01 were 1,171 tonnes, valued at $4 million at first point of sale (Web Reference 10). A total of 99 fishing businesses hold endorsements to operate in the Ocean Fish Trawl Fishery. Commercial fisheries under the jurisdiction of the Commonwealth of Australia with potential to be affected by the project would be the Eastern Tuna and Billfish Fishery, Southern and Eastern Scalefish and Shark Fishery, Jack Mackeral (Small Pelagics) Fishery, Southern Squid Jig Fishery, Eastern Skipjack Tuna Fishery and the Southern Bluefin Tuna Fishery. Although these fisheries operate mostly outside of state waters, some operators in the Commonwealth tuna fisheries may catch bait (yellowtail, slimy mackerel and pilchards) within 3 nm of the coast under a permit issued in terms of Section 37 of the NSW *FM Act*.

The study area is located in catch reporting zone 6 (Figure 2). Total catch landed at Terrigal Haven in 1999/2000 was 60 tonnes at a value of $284,000 (Tanner and Liggins, 2001). The total number of fishers operating out of Terrigal was 11. In general, total catch (tonnes), fishing effort and number of fishers appear to have declined in the region over the past 5 years.

There is a lack of information available on the specific locations where fishing effort is concentrated. This is mostly due to the confidential nature of fisheries log book data. Spatial fisheries information would be required from DPI and/or formal consultation with relevant cooperatives, fishers and the Seafood Industry Advisory Council in order to map areas with a high frequency of trawling activity.

3.2.2 Recreational Fishing Areas

Data Source

McEnally and McEnally (2004) AFN Fishing Guide to the Central Coast and North Coast of NSW. Ross and Duffy (1998) The New South Wales Fishing Atlas.

Recreational fishing in the study area is popular, with 3 DPI listed charter vessels operating out of the Terrigal Haven (Web Reference 1) and a number of other vessels operating from the surrounding suburbs (National Oceans Office, 2004). It should be noted however that DPI listed vessels (those wishing to be listed) represent approximately 70% of all registered vessels operating in the area, so the actual figure is likely to be greater. Chartered recreational fishing vessels operating out of Terrigal Haven are equipped for estuary, nearshore, deep sea bottom fishing and gamefishing. Details of chartered recreational fishing vessels operating out of Terrigal Haven, the Hunter, Lake Macquarie, Brisbane Water and the Hawkesbury/Pittwater are listed in Appendix 3.

Recreational fishers use hook and line to target demersal reef species such as yellowfin bream (*Acanthopagrus australis*), silver trevally (*Pseudocaranx dentex*), mulloway (*Argyrosomus hololepidotus*), snapper (*Pagrus auratus*) and kingfish (*Seriola lalandi*) on offshore reefs and species such as leatherjacket (Monacanthidae) and flathead (Platycephalidae) on sandy areas. Between Terrigal and south Avoca there are a number of options for recreational fishing from the Beach, rocks and offshore. Terrigal Beach, Terrigal Haven, The Skillion, Avoca Beach and south Avoca Headland are popular locations due to easy access and good fishing results. The Skillion is a well known location for catching tailor (*Pomatomus saltatrix*), eastern Australian salmon (*Arripis trutta*), bonito (*Sarda australis*), southern bluefin tuna

(*Thunnus maccoyi*) and kingfish (*Seriola lalandi).* Terrigal Headland (Broken Head) has a number of ledges around it suitable for fishing, good parking and amentities in close proximity making it a popular location. North of the Skillion, Terrigal Beach is noted for catches of tailor (*Pomatomus saltatrix*) and bream (Sparidae) particularly when Terrigal lagoon is open to the sea. GPS Positions, target species and names of known offshore recreational fishing locations are listed in Appendix 1. There are three offshore sites within the study area, namely Avoca Drop Off, Avoca Reef and The Pips. The general environment and fishing operations in these areas would be unaffected if the ex *HMAS Adelaide* scuttling location was to be as shown.

Spearfishing and lobster gathering is popular on headlands and reefs between Maitland Bay in the south (near Broken Bay), up to the Entrance. In NSW, these activities are permitted using snorkel (i.e. no SCUBA or surface air supply) and are restricted to waters of 20 m depth or less. The coastline between Terrigal and Avoca Beach is noted as a popular location to collect rock lobsters due to the caves, gutters and reef overhangs (Byron, T. 1997). The rocky reef fringing the Skillion is also popular for spearfishing. Species such as bream (Sparidae), trumpeter (Latrididae), luderick (Girellidae), kingfish (*Seriola lalandi*) and bonito (*Sarda australis*) are known to be caught here. North of the Skillion spearfishing access is limited as it requires a boat to reach the offshore reefs and shoreline.

3.2.3 Recreational Diving and Snorkelling

Data Source: GPS positions from Terrigal Dive Centre (Pers. Comm. Graham, L, 2008) and Byron, T. (1997) The Scuba Diving, Snorkelling and Spearfishing Guide to Northern/Southern NSW.

Popular dive locations in the Terrigal area have been mapped in Figure 5. The main dive sites located within this region (listed from north to south) are:

- The wreck of the Yambacoona (offshore from Broken Head/Terrigal Headland)
- The wreck of the Galava (offshore from Terrigal Haven)
- The Skillion cave (between the southern point of Terrigal Headland and the Skillion)
- San Francisco Reef (offshore from south Avoca Beach)
- Fifeshire Reef (offshore from north Avoca Beach)
- Lighthouse Reef/Little Jew Ground(offshore from south Avoca headland)
- First Point (off the cliffs at first point)

Details of all sites in the vicinity of the study area are outlined in Table 2. There is a wide variety of high quality dive sites in the Terrigal region including shore and boat dives suited to all levels. Snorkelling is limited to the area around the Skillion and at south Avoca Headland which are easily accessed on foot. Dive sites located within the study area are shown in Figure 5

3.2.4 Recreational Sailing and Boating

Data Source: Gosford Sailing Club.

Gosford Sailing Club schedule races between Terrigal and Broken Bay during summer months, although for the 2007/08 season only 3 races were scheduled. The Gosford to Lord Howe Island Yacht Race takes place annually on the last Saturday in October and is the only

other significant race scheduled by Gosford Sailing Club. A rounding mark is positioned approximately 200 m off the headland at Terrigal (Figure 5). In February 2008 Gosford Sailing Club hosted the World Laser Championships which drew hundreds of competitors from Australia and abroad. The event consisted of two regattas, the Laser Standard World Championship and the Laser World Masters. Racing took place offshore of Terrigal and boats were launched from Terrigal Haven. Gosford Sailing Club do not see the positioning of the Ex-HMAS Adelaide to have any impact on their sailing activities (Pers. Comm. Eddie, L. 2008. Secretary, Gosford Sailing Club).

3.2.5 Marine Protected Areas

Data Source: Breen *et al* (2005) Broadscale Biodiversity Assessment of the Hawkesbury Shelf Marine Bioregion and NSW DPI and the Marine Parks Authority (Web Reference 18).

There are three types of Marine Protected Areas (MPA's) recognised within NSW, Marine Parks, Aquatic Reserves and National Parks and Nature Reserves (which are generally terrestrial but with associated marine components). MPA's are protected under *The Marine Parks Act 1997* which aims to promote and conserve marine biodiversity, habitats and ecological processes, provide for the ecologically sustainable use of fish and marine vegetation and provide opportunity for public appreciation, enjoyment and education (Breen *et al*, 2005).

Aquatic Reserves aim to conserve the biodiversity of fish and marine vegetation, but may also concentrate on the protection of fish habitat, threatened species, populations and ecological communities and on education and scientific research.

National Parks and Nature Reserves are established under the *National Parks and Wildlife Act 1974* and managed by the NSW National Parks and Wildlife Service (part of the NSW Department of the Environment Conservation and Climate Change). Marine protected areas occur where National Parks and nature reserves are specifically gazetted over subtidal and intertidal areas. National Parks and Nature Reserves differ from other MPA's as there is no zoning or regulation for multiple uses (NSW MPA, 2001) and while these areas concentrate on the protection of terrestrial animals, vegetation and substratum, they do not directly protect fish and marine invertebrates. There is one National Park (Bouddi National Park) and four Nature Reserves in the wider region of the study area, including (from north to south) Wamberal Lagoon (covering 139 ha), Rileys Island (46 ha), Pelican Island (40 ha) and Cockle Bay (44 ha). In the case of Bouddi National Park (located approximately 5 km south of Terrigal) however, special arrangements have been made with the NSW Department of Primary Industry for the direct protection of all marine life over a marine extension covering an area of 300 ha. The Bouddi National Park marine extension stretches from the southern end of Macmasters Beach, south to Wagstaff Point at the entrance to Broken Bay. It is one of the first National Parks in NSW, where all marine life is protected.

The Bouddi National Park area also lies in the traditional territory of the Guringai (Kuringgai) people, which covers the coastal area bounded by Gosford, Port Jackson and Parramatta. Around 100 Aboriginal sites have been recorded in the park and nearby areas and many more sites are likely to exist. Sites include rock engravings, rock shelters, middens and other archaeological deposits.

There are also important wetlands in the region of the study area including Budgewoi Lake and Tuggerah to the north of Terrigal and Brisbane Water Estuary to the south. All are classed as Marine and Coastal Zone Wetlands (Environment Australia, 2001) which include sand, shingle or pebble Beaches, estuarine waters, intertidal mud, brackish to saline lagoons

and marshes and intertidal forested wetlands. No Marine Protected Areas occur either within or in the immediate vicinity of the study area, although the rocky shore at Tudibaring Head (extending from south Avoca Beach to the north of Copacabana Beach) has been identified as a candidate aquatic reserve (Otway, 1999).

3.2.6 Historical Ship Wrecks

Data Source: NSW Maritime Heritage database/ NSW Heritage Office (Web Reference 2), The Department for the Environment, Water, Heritage and the Arts (DEWHA) historical shipwrecks database (Web reference 3). The Shipwreck Atlas of NSW (1996) Department of Urban Affairs and Planning (positions rectified for GIS format).

Details of historic shipwrecks known and predicted to occur in the study area were searched on the DEWHA historic shipwrecks database with the search area defined as 'Terrigal'. Results showed a total of 24 vessels either known or likely to have been wrecked in this region (Appendix 2). Exact locations are unknown for the majority of the wrecks and many are likely to be disintegrated with debris spread over a wide area. There are three wrecks known (with reasonable accuracy) to occur within the study area (Figure 5). These are the 'Lord Ashley', the 'Yambacoona' and the 'Galava'. The Lord Ashley is located on the eastern side of Terrigal Reef at a depth of approximately 9 m. Little remains of the hull structure. The bow area is marked by a pile of anchor chain and the stern by the remains of the two cylinder engine. The wreck is protected under the Commonwealth *Historic Shipwrecks Act 1976.* The 'Yambacoona' (also a dive site) is located east of Broken Head at a depth of approximately 26 m - 28 m. The vessel is approximately 34 m in length although very little of the actual structure is left. The 'Yambacoona' is also protected under the *Historic Shipwrecks Act 1976.* The wreck of the 'Galava' is located approximately 3 nm east of Terrigal and lies at a depth of around 50 m (it is not marked on Figure 5 as it is outside the scale of the map). The engine, boiler and ribs of the hull can remain at the site and are known to attract dense schools of fish. The wreck is protected under the *NSW Heritage Act (1977).* The three vessels occurring within the study area are either sitting on rocky reef substratum (in the case of the 'Yambacoona' and 'Lord Ashley') or in the case of the 'Galava', is outside the suitable depth range for the sinking of the Ex- HMAS Adelaide . The presence of these historic shipwrecks would therefore not be a constraining issue. However, as there are a number of wrecks documented to have been lost within the vicinity of the study region (Appendix 2), it is recommended that acoustic seabed survey techniques be employed to determine the presence of any remains or debris which could potentially obstruct the siting of the Ex-HMAS Adelaide.

3.2.7 Offshore Mineral and Petroleum Resources

Data Source: NSW DPI 'TAS Map' Minerals tenement GIS database and Gosford City Beach Nourishment Feasibility Study (Stages 1 and 2) prepared by Manly Hydraulics Laboratory (MHL) for Gosford City Council (2002).

Offshore minerals and petroleum exploration titles (within the 3 nm limit of State waters) are issued under the *Offshore Minerals Act (1999)* and the *Petroleum (Offshore Act) 1991*. Beyond the 3 nm limit, titles are issued under Commonwealth legislation, administered jointly by NSW State and Commonwealth governments. A search of the NSW Department of Primary Industry 'TAS Map' database (a GIS enabled database providing details of current and expired tenement titles) (Web Reference 14), showed no current mining exploration titles within the 30 m - 35 m suitable depth range of the study area. Just within and beyond the 3 nm limit of State waters, (well beyond the suitable depth range for the Ex-

HMAS Adelaide) Sydney Marine Sand Pty Ltd hold a Marine Exploration License (issued August 2006) for an area of 58 units (approximately 130 km^2 in total) for depths >50 m. The area runs from The Entrance, south to Broken Bay and begins approximately 4.4 km offshore from Terrigal Headland and approximately 5.9 km offshore from the centre of Avoca Beach. Although an exploration license has been issued there are no current plans to exploit the resource due to legislative restrictions.

Coastal erosion and receding shoreline is a major issue on the Gosford Beaches, particularly at Wamberal where storms from the 1960's through to the 1990's have resulted in severe erosion threatening properties located close to the foreshores. A number of methods have since been adopted to help prevent further erosion although these may not be adequate to cope with ongoing loss of sand, shoreline retreat and potential sea level rise related to climate change. The Gosford City Open Coast Beaches Coastal Management Plan (1995) recommended that a review of the practical, economic and environmental feasibility of sand nourishment be undertaken for Gosford Beaches as a means of long term mitigation for coastal erosion. The feasibility study was completed in 2002 and prepared by Manly Hydraulics Laboratory. Gosford City open Beaches (Macmasters, Avoca, Terrigal, Wamberal and Forresters) were identified for potential Beach nourishment. Potential sand resources included the Stockton Bight dune system, Lake Macquarie entrance channel (at Swansea) and sand reserves offshore from the Gosford City Beaches in deep water. Based on overall assessment of economic/environmental impacts and resource availability, the Gosford offshore resource was considered the most favourable, due to the properties of the sand resource, potential for extensive demand (for Beach nourishment and commercial uses), natural distribution and the proximity of the resource to the Beaches. Access to the resource however, has not been secured since the time of the feasibility study in 2002 and at present there are no immediate plans to extract sand resources offshore from the Gosford Beaches. This has been due to the legislative restrictions and the approvals process which is still underway (Pers. Comm. Moore, P, 2008, Gosford City Council). Exploitation of sand resources would not be a constraining issue at this stage. Should plans proceed in future (either for Beach nourishment or commercial for purposes) it is likely that sand extraction operations could be managed outside the area of the Ex-HMAS Adelaide, as the resource is located in depths >35 m. It is estimated that the volumes of sand required for nourishment of the Gosford Beaches would be easily met by these resources.

Petroleum Exploration Licence (PEP) 11 is the only offshore petroleum exploration area in NSW. The extent of the area is from Port Stephens to Wollongong (200 km) covering 2,000,000 acres, starting from 3 nm offshore. Bounty Oil and Gas NL currently have plans to drill the first exploratory oil rig in the licence area, Biggus – 1. Location of the exploratory oil rig is expected to be 25 km south of Newcastle and approximately 22 km offshore at a depth of 125 m. A 2 nm exclusion zone will apply around the rig for the time that it is in place. Due to the depth and planned location of the exploratory rig, it would not be a constraining feature in the region. As the exploration licence area is so large it has not been mapped in the figures, although the data layer is available in GIS format.

3.2.8 FAD's (Fish Aggregation Devices)

Data Source: NSW Department of Primary Industry

One fish aggregation device (FAD) is located within the study area, although it is positioned a significant distance offshore and well outside the specified depth range for the Ex-HMAS Adelaide. This is therefore not considered a constraint.

3.3 Geotechnical Assessment

Data Source: Public Works Department (1989). Seabed Information Chart 1:25,000 Gosford 83042-1001. Near shore subtidal reef was mapped by NSW National Parks and Wildlife Service. Sediment isopach data was obtained from the Gosford City Beach Nourishment Feasibility Study (Stages 1 and 2) prepared by Manly Hydraulics Laboratory (MHL) for Gosford City Council (2002). The MHL Reports incorporate s an 'Investigation of Marine Sand Resources' prepared by Coastal & Marine Geosciences (CMG) 1999.

Detailed seabed maps from the NSW Public Works Department (1989) for the Gosford region, were scanned and digitised for the purpose of this study.

Characteristics of seabed morphology were classified into the following distinct classes:

- Medium to coarse grained, orange coloured sand with typically 40 % shell;
- Very coarse grained orange coloured, gravelly sand;
- Fine to medium grained, golden coloured sand, with varying shell content;
- Areas of reef partly covered by sand;
- Rock reef;
- Reef materials consisting of shell, reef and coral fragments and small amounts of sand and gravel;

Estimated horizontal accuracy is within 10 m and estimated vertical accuracy is within 1 m. It should be noted that movement of sand on the seabed can result in changes to rock/sand boundaries over time and that this effect would be more marked in shallow depths and flat reef. Similarly, where the seabed is sandy, the seabed contours may vary due to the action of waves and currents. This is more marked within shallow areas, particularly within the surf zone. These maps are therefore limited to describing average conditions at the time of survey. In May 2008 DECC (Department of Environment and Climate Change) carried out a single beam side-scan sonar survey of the study area. Results of the survey and comparison with the PWD maps area discussed in Section 3.3.2 (Offshore Geomorphology).

Rocky reef is considered a significant constraining feature for deployment of the Ex-HMAS Adelaide. This is because reef is unlikely to provide a stable platform to support the ship in an upright position and existing reef habitat would be lost or impaired by the disturbance. Previous vessels scuttled for the purpose of artificial dive reefs (Section 1.5) have been positioned on sandy substratum allowing penetration into the sediment (1 m -2 m) to maintain a stable upright position. It is therefore important to define not only the characteristics of the substratum but also sediment depth.

3.3.1 Coastal Geomorphology

The coastline within the study area is typical of that encountered along central NSW (CMG, 1999). Bedrock cliffs and headlands comprised of gently westward dipping sedimentary rocks (Narrabeen group sandstones, siltstones and claystones) several hundreds of millions of years old separate sandy embayments, infilled by younger unconsolidated barrier, estuarine and fluvial deposits (Figure 3). The barrier estuary systems occurring at Avoca, Terrigal and Wamberal Beaches are classified by Roy (1984), as stationary/receded barrier systems (dunes/Beaches) impounded by saline coastal lakes which at Avoca Beach, is intermittently open to the ocean.

Avoca Beach is backed by a dune system which increases in height to the north (MHL, 2002). The Beach faces east-south-east and has a gradually sloping profile with an average slope of 1:50 out to a depth of 30 m. Mainland Beaches (marine sands deposited on bedrock with no associated estuary) such as Avoca and Terrigal, occur within the embayments where bedrock approaches the coast, at the southern ends of Avoca and Terrigal Beaches (Figure 2). Geotechnical investigations (MHL, 2002) show that Beach deposits at Avoca consist of marine sands some 4 m - 6 m thick, gravelly (rounded shell and rock fragments) at depth, overlying weathered silt stones, claystones and iron-rich sandstones. The dull orange to yellow marine sands are stained due to this iron content of the grains. The marine sands are comprised of moderately well, to well sorted, medium grained quartz with a variable but generally low component of shell fragments (typically less than 10 % - 15 %) (Coastal and Marine Geosciences, 1997).

3.3.2 Offshore Geomorphology

Three main geotechnical surveys have been carried out in the study area:

- 1989, Public Works Department (PWD). Note that this survey was carried out in 1984 (Figure 5);
- 1998, Coastal & Marine Geosciences (CMG) as part of the 2002 Gosford City beach nourishment feasibility study (prepared by Manly Hydraulics Laboratory (MHL, 2002)(Figure 5);
- 2008, Department of Environment and Climate Change (DECC) for the present study (Figure 5).

According to marine surveys conducted in 1989 by the Public Works Department (PWD), sediments offshore from Avoca Beach are shown to consist of fine to medium grained, golden sand and extend seaward to a depth of approximately 36 m where they give way to coarser orange coloured inner shelf sediments (typically with 40 % shell). Rock reef separates this nearshore sediment from the adjacent sandbodies of Macmasters and Terrigal/Wamberal embayments (Figure 5). Within the 30 m - 35 m suitable depth range there is an area of fine to medium grained sand (approximately 1.72 km offshore from Avoca Beach) extending from a sand covered reef in the north, for approximately 1 km south until reaching a large area of rock reef (extending out from First Point). Within this area PWD maps show some isolated patches of rock reef and sand covered reef which should be avoided in site selection (Figure 5). Sediment composition of samples collected by CMG (1999) showed a mean grain size of 0.34 mm for beach samples and 0.28 mm for shoreface samples and mean carbonate content of 14 .3 % and 16.2 % for Beach and shoreface samples respectively. Shoreface samples collected on the 30 m depth contour (offshore from Avoca Beach) had a mean grain size of 0.23 mm carbonate content of approximately 16.2 %.

Further marine surveys conducted by Coastal and Marine Geosciences (as part of the MHL Gosford City Beach Nourishment Feasibility Study, 2002) aimed to estimate seabed sediment thickness over an area of seabed between Macmasters Beach and Forresters Beaches. The investigation consisted of a high resolution seismic reflection (Boomer) survey (conducted in 1998). Boomer seismic techniques provide good resolution of the top 10 m - 20 m of the seabed (CMG, 1999). Sound pulses emitted from the 'Boomer' to the seabed are reflected back to the surface are detected by hydrophones towed on the surface and recorded on a chart. Not all the sound pulse is reflected from the seabed. Lower frequencies

that penetrate below the seabed are reflected back to the surface by layers within the sediments. Delays in the arrival of the reflected sound waves are recorded, depicted as layers below the seabed. This then enables stratification of the seabed to be interpreted. Interpretation of seabed thickness is combined with GPS data which allows the construction of a sediment 'isopach' map of the study area (Figure 4). According to MHL, (2002), the seismic data collected during the survey correlated well with the existing seabed data mapped previously by the Public Works Department in 1989. Figure 4 illustrates the relatively thin (>5 m) cover of seabed sediments over bedrock in water depths less than 40 m - 45 m. Relatively thicker deposits can be observed along the channels of old drainage channels (bedrock valleys) that extend seaward of each Beach system and are particularly pronounced for the Avoca Beach system within the study area. Innershelf sediments are relatively thick (>10 m) in the ancient drainage channels and offshore of Avoca Beach in water depths of 40 m - 50 m (3 km - 4 km).

In addition to previous geotechnical surveys, the Central Coast Artificial Reef Project (CCARP) an organisation made up of local dive groups and professional operators undertook dive surveys to determine potentially suitable sites for an artificial diving reef. The survey (carried out in 2000) involved ground truthing existing maritime charts and seabed maps to determine sediment depths at 4 potentially suitable sites. Divers used 3 m long probes of 8 mm plastic tubing attached to compressed air. The depth to which the probes penetrated gave relatively accurate sand depths within the areas surveyed. The preferred site was located south of The Skillion, offshore from north Avoca Beach where sand depths within the defined survey area were recorded in excess of 2 m.

Single-beam side scan sonar survey of the seabed was carried over the study area in May 2008 by the Department of Environment and Climate Change (DECC). The survey targeted the area offshore from Avoca Beach which previous surveys by the Public Works Department (PWD) and CMG (1999) identified as sand with suitable penetration depths. The acoustic survey mapped areas of exposed rock reef and depth. Results indicated that seabed characteristics mapped in the current survey closely resembled maps produced by the Public Works Department in 1989 (allowing for current driven changes in rock/sand boundaries over time). Areas of exposed rock reef, a re-interpretation of 1984 seismic surveys (PWD) and the outline of the PWD Maps (1989) are shown in Figure 5. At the northern end of the survey area four outcrops of low relief rocky reef have been mapped in the current survey whereas previous surveys have mapped two additional outcrops. One small area of reef (approximately 75 m by 50 m in the northern section of the survey area) was mapped in the current survey at 32 m which had not been mapped previously. Depth contours from earlier PWD maps were also shown to be consistent with the current survey. Although some areas of reef have not been mapped in the latest 2008 survey, all current and previously mapped areas shown to have reef should be avoided.

3.4 Distribution of Habitats, Flora and Fauna

Data Source: Breen *et al* (2005) Broadscale Biodiversity Assessment of the Hawkesbury Shelf Marine Bioregion and Literature sourced from the Ecology Lab Library

Distribution and diversity of macrofauna (invertebrates >0.5 mm) living on or within sediments, vary in space and time depending on a range of physical and biological factors. Physical factors include water depth and movement, salinity and type of sediment. Biological factors include food availability, competition and predation (McCaulry *et al.* 1977; Jones, 1986; Morrisey *et al.* 1992; Snelgrove and Butman, 1994; Newell *et al.* 1998). The nature of the sediment in particular, has a major influence on the animals living within it (Morrisey

et al, 1998) and in general, sub tidal sediments support a large variety of invertebrates and fish. The invertebrates include 'infauna' which burrow to depths of about 50 cm into the sediments, and 'epifauna' which live on the surface of the sediments. Macrofauna in soft sediments are composed mainly of polychaetes, crustaceans and molluscs (Hutchings 1998, 1999, Snelgrove 1999). Other common taxa include nemerteans, echiurans, phoronids, echinoderms, sipunculids and some sponges, cnidarians and tunicates.

Sub-tidal rocky reefs support very different communities to sandy habitats. They also show some degree of 'stratification', with turfing macroalgae and kelp occurring in shallower waters, bare rock (which is actually covered by encrusting red algae) at intermediate depths and 'sponge gardens' in deeper water (Underwood *et al.* 1991).

Habitats mapped by Breen *et al* (2005) show rocky intertidal, reef shoal and Beach habitats as dominant in the coastal zone of the study area. Rocky intertidal platforms are distributed from Terrigal headland around to north Avoca Beach, then continues on from south Avoca Headland to Tudibaring Head. This stretch of rocky intertidal habitat has previously been a candidate for an aquatic reserve (NSW Fisheries, 2001) due to high species diversity and habitat heterogeneity (i.e. platforms, boulders, pools and crevice microhabitats).

Seagrass has been mapped within Avoca Lagoon. Seagrass is unlikely to occur seaward of this as it does not occur in high wave energy environments (Larkum *et al.* 2006). No mangrove or saltmarsh communities have been mapped in the study area.

Very few ecological surveys have been conducted within the study area, although some studies on benthos, intertidal rock platforms and subtidal reefs have been completed at Crackneck Point (approximately 4 km north of Terrigal) Pelican Point (approximately 19 km north of Terrigal) and on subtidal sands within Broken Bay (approximately 13 km south of Terrigal). WBM Oceanics Australia (1997) investigated impacts of sewage effluent outlets at Norah Head and Wonga Point (north of the study area). Two control sites at Crackneck Point and Pelican Point were used to compare long term monitoring results. Results showed that at both locations, subtidal rocky habitats were typical of Australian east coast temperate shallow rocky subtidal communities (Underwood and Kenelly, 1990, Dakin 1987). Horizontal rock surfaces were dominated by alga including *Eklonia radiata* (Kelp), *Phyllospora comosa* and *Sargassum* spp, lithothamnion pavement, turfing and coralline algae. Lithothamnion pavement, an association of hard coralline algae, other encrusting algaes and macrofauna, was observed beneath the canopy of *Eklonia radiata* and *Phyllospora comosa* and also alongside turfing algae. Areas of boulders and rock were also extensively covered by the lithothamnion. Beneath the algal canopy a variety of sponges, anemones, hydroids, ascidians, echinoderms and a few corals were present. Overall, subtidal rocky benthos communities were diverse, patchy and exhibited variation between locations and seasons, but remained essentially similar over a period of almost two decades (WBM, 1997). These are natural fluctuations, typical for benthic communities of these habitats.

Rooney and Talbot (1980) investigated benthic community structure at two locations at the entrance of Broken Bay at 15 m and 30 m depths. The substratum at these sites consisted mainly of medium to coarse grained sand. Ten replicate samples, ($0.05m^2$) in area were collected at each site. Biota at the shallow (15 m) site was dominated by crustaceans which made up 75 % of the species composition and 70% of the total number of individuals. Dominant species (in order of relative abundance) were tanaids (isopods), the heart urchin *(Echinocardium cordatum)*, the cumacean (*Leptocuma* sp), an unidentified amphipod and a polychaete worm (family, Pisionidae). Analyses indicated that there was an order of 4000 individuals per m^2 of sediment surface, although individuals had a relatively low biomass.

Biota at the 30 m depth was dominated by polychaete worms which made up 55 % of the species composition and 75 % of the total number of individuals. Dominant species were polychaetes from the family Sabellidae and Archiannelida (*Polygordius* sp). Samples indicated an order of 6000 individuals per m^2 of sediment surface.

It would be expected that benthic community assemblages inhabiting the fine to medium grained sand of the study area (in the 30 m - 35 m depth range), would be fairly typical of temperate east coast Australia consisting of polychaetes, crustaceans and molluscs. Due to the large area of similar habitat available within the study area, it is unlikely that there would be any significant loss of benthic communities, apart from the footprint where the Ex-HMAS Adelaide will be positioned.

3.5 Threatened Species Issues, Including Fish, Invertebrates, Marine Mammals and Marine Reptiles.

Data Source: The NSW DPI threatened species database and (Web Reference 15), the NSW Government BioNet System (Web Reference 16) and literature sourced from the Ecology Lab reference library.

Threatened and protected species listed under the Commonwealth *Environmental Protection and Biodiversity Conservation (EPBC) Act*, the NSW *Fisheries Management* (*FM) Act*, and the *Threatened Species Conservation* (*TSC*) *Act* were searched using the NSW Government 'Bionet' database and the DECC (Department of Environment and Climate Change) threatened species database in April 2008. The database was searched for records of fish, marine invertebrates, marine mammals and marine reptiles occurring in the Gosford Local Government Area (Bionet) and the Hunter/Central Rivers – marine zone CMA sub-region (DECC). The Bionet database contains records from the Australian Museum, National Parks, Fisheries and State Forests.

Eight species of fish, 14 species of marine mammal (including cetaceans, pinnipeds and sirenians) and 3 species of marine reptile were found to occur within the Gosford LGA and Hunter/Central Rivers – marine zone CMA sub-region (Table 1). Of these, there are records of seven species in total observed within the actual study area between Broken Head and south Avoca. This includes the grey nurse shark (*Carcharias Taurus*), bleekers devil fish (*Paraplesiops bleekeri*), the common dolphin (*Delphinus delphis*), the dwarf minke whale (*Balaenoptera acutorostrata*), the southern right whale (*Eubalaena australis*), the leopard seal (*Hydrurga leptonyx)* and the green turtle (*Chelonia mydas*).

Grey nurse sharks have been recorded off the Skillion and are regularly sighted by divers off reefs in the Terrigal region. The sharks are listed as 'critically endangered' and typically occur on shallow rocky reefs along the NSW coastline (Last and Stevens, 1994) preferring small sandy gutters within the reef matrix as microhabitats. Young are born live and also occur on shallow rocky reefs, often segregated from the adults (The Ecology Lab, 2002). There is some likelihood that grey nurse sharks migrate along the NSW coastline.

There is a major aggregation site (designated a critical habitat) located north of Port Stephens, at Little Broughton Island and also at the 'Pinnacle' near Forster (Otway *et.al*. 2003). Grey nurse sharks are active mainly at night and feed on a wide range of bony fishes, sharks, rays, squids and crustaceans. They are not considered a threat to divers or swimmers unless provoked. Their placid nature and preference for shallow inshore reef areas has allowed diving with grey nurse sharks to become a valuable ecotourism industry (NSW DPI, 2002b).

Bleekers devil fish (*Paraplesiops bleekeri*), also known as eastern blue devil fish, are found in caves, crevices and under ledges on inshore reefs and estuaries and have been recorded off Avoca Beach. They can also be found offshore in waters from 3 m to 30 m deep (NSW DPI, 2006b).

There are a number of records of the common dolphin (*Delphinus delphis*) within the study area at Broken Head, off Avoca Beach and south Avoca headland and a number of records of the species occurring within Broken Bay to the south of the study area. In general, they appear to favour continental shelf and pelagic waters of the Atlantic and Pacific Oceans within the broad zones of the temperate and tropical latitudes. The presence of warm water influences the distribution of this species (Web Reference 11).

Little is known about the distribution of dwarf minke whales (*Balaenoptera acutorostrata*) although they are mostly sighted in sub Antarctic waters to the south of Australia and New Zealand between December and March. Between March and October, they are found in the northern Great Barrier Reef, with most sightings in June and July. The species is listed as migratory under the EPBC Act. Dwarf minke whales have been sighted within the study area off Broken Head and further north, at Forresters Beach.

Southern right whales (*Eubalaena australis*) are increasingly being sighted off the NSW coast within inshore waters whilst travelling between coastal locations (Allen & Bejeder, 2003). They are seasonally present on the Australian coast between about May and November with peak sightings around the Sydney region in June/July (Web Reference 19). Records of southern right whale sightings on the east coast of Australia between 1993 and 2002 compiled by Allen & Bejeder (2003) show a number of sightings of cow-calf pairs reported off Port Stephens. Distribution and migration maps produced by the Department of Environment and Heritage (2005) show that although southern right whales are known to occur along the whole NSW coastline, they do not usually aggregate in waters off the east coast of NSW. Calving females with young are sometimes observed close to the shore within a water depth of between 5 m – 10 m and it is recommended that placement of infrastructure in this zone is avoided, partly for this reason.

Australia's east coast population of humpback whales (*Megaptera novaeangliae)* migrate from summer cold-water feeding grounds in sub-Antarctic waters to warm-water winter breeding grounds in the central Great Barrier Reef. They are regularly observed in NSW waters in June and July, on northward migration and between October and November, on southward migration (Web Reference 20).

Seals located in all Australian Commonwealth waters are protected under the EPBC Act (Web Reference 13). The leopard seal (*Hydrurga leptonyx)* is not listed as threatened under the EPBC Act, but like all marine mammals occurring in Australian waters it is listed as 'Marine' (under section 248). Leopard seals are most commonly found along the coast of Antarctica and on most sub-Antarctic islands but also occur on the south/southeastern coasts of Australia and have been recorded at a number of locations between Broken Bay and Broken Head including Avoca Beach.

All marine turtles found in Australian waters are protected under the Commonwealth EPBC Act. The green turtle (*Chelonia mydas*) is listed as vulnerable and migratory species under the EPBC Act. It is widely distributed in tropical and sub-tropical seas and usually found in tropical waters around Australia, but also in coastal waters of NSW, where it known to occur on the north and central coast, with occasional records from the south coast (Web Reference 12). There are a number of records for this species occurring within Brisbane Water, off Macmasters Beach and Wamberal. The turtles often occur in estuaries in warmer months of the year, when they leave the open ocean to breed on ocean Beaches.

The hawksbill turtle (*Eretmochelys imbricata)* observed during the site inspection, is listed as 'vulnerable' and 'migratory', although it has not been listed under the NSW TSC Act for the Hunter/Central Rivers – marine zone CMA sub-region. Hawksbill turtles typically occur in tidal and sub-tidal coral and rocky reef habitats (similar to that of the investigation site) feeding on sponges, soft corals, algae and seagrass. They are generally distributed throughout tropical waters, extending into warm temperate areas as far south as northern New South Wales (Web Reference 17). They are not known to breed or nest in temperate NSW.

In Summary, there are 9 species with a high likelihood of occurring within the study area (based on presence of suitable habitat and bionet records). These are the grey nurse shark (*Carcharias Taurus*), bleekers devil fish (*Paraplesiops bleekeri*), the common dolphin (*Delphinus delphis*), the dwarf minke whale (*Balaenoptera acutorostrata*), the southern right whale (*Eubalaena australis*), the humpback whale (*Megaptera novaeangliae)*, the leopard seal (*Hydrurga leptonyx),* the green turtle (*Chelonia mydas*) and the hawksbill turtle (*Eretmochelys imbricata*). It is therefore recommended that these species are assessed under part 5A of the EP&A (*Environmental Planning and Assessment*) Act (the 7 –Part Test). The 7-Part test assesses whether the proposal is likely to have a significant impact on threatened species, populations or ecological communities. Should the proposal be considered to have a significant impact on a threatened species, population or ecological community then a species impact statement would be required for further assessment.

3.6 Coastal and Oceanographic Processes

Data Source: Worley Parsons Pty Ltd

Detailed assessment of coastal and oceanographic processes is in Appendix 6.

Based on a consideration of the coastal and oceanographic processes occurring in the study area, it is evident that a deeper scuttling of the Ex-HMAS Adelaide within the 30 m to 35 m depth limits would generally be favoured. This is because, at deeper depths:

- the scuttled ship would be less likely to affect wave refraction patterns and the like;
- wave-driven currents are smaller and therefore so are dynamic forces on the ship;
- navigation is less likely to be restricted;
- oceanographic currents are likely to be smaller and;
- sediment transport is more likely to be negligible.

That stated, detailed analysis and modelling may find that a ship placed at 30 m depth is stable under extreme waves and currents, and does not significantly affect the nearshore wave climate.

The predominant wave direction offshore of the study area is from the SSE (Appendix 6). It is therefore recommended that the ship is orientated in a SSE direction (bow facing SSE) into the dominant wave direction. Wave transformation issues (such as wave focussing) altering the nearshore wave climate are complex. Further detailed studies may result in realignment of the ship to make nearshore wave patterns more favourable. Calmer wave conditions normally occur from October to February, which are most favourable for deployment. Coastal storms can however, occur at any time, and whatever period is chosen for deployment it would be necessary to refer to Bureau of Meteorology coastal waters forecasts and to ensure that conditions would be acceptable.

3.7 Operational Feasibility

Data Source: NSW Maritime, McEnally and McEnally (2004) AFN Fishing Guide to the Central Coast and North Coast of NSW.

Access by boat to the study area is limited to sheltered entrances via Broken Bay and Brisbane Water in the south or via the Swansea Channel in the north from Lake Macquarie. Ocean access points involve either a Beach or ocean launch. Terrigal Haven has a good quality sealed boat ramp (although in large swells the boat ramp may be affected by ocean surges). Boats up to 8 m can be launched from Terrigal Haven. A sealed boat ramp and parking is also located off Norah Head approximately 21 km north of Terrigal, although access from this ramp is restricted to aluminium boats less than 6 m in length. Boats <5.5 m length can also be launched over sand behind a sheltered reef at Bateau Bay 11 km north of Terrigal. Terrigal Haven has parking facilities, toilets, picnic areas and a public telephone nearby to the boat ramp. A dive shop, motel, post office and shops are all within a few minutes accessibility of the boat ramp and parking area.

Distance from the Ex-HMAS Adelaide dive site to the boat ramp is a factor for consideration in diver safety as well as convenience. It is therefore preferable to locate the site closer to Terrigal Haven and amenities if this does not significantly compromise other factors such as quality of diving. There are three large hospitals within approximately 10 km of the boat ramp, located in Gosford and North Gosford and recompression chambers located in Sydney or Newcastle. There are five main dive centres in the Gosford Area offering training courses, air refills and equipment. These are located at Terrigal, Umina Beach, Killarney Vale, Toukley and Erina.

A clearly marked exclusion zone would be required around the dive site for the safety of divers, other recreational boat users and commercial operators. An area between 250 m and 500 m (as an indication) around the Ex-HMAS Adelaide is recommended. Within the exclusion zone, recreational and commercial fishing operations would need to be restricted. Access to the dive site itself would also be limited to a certain number of private boats and charter vessels to minimise navigation hazards. This would be achieved by providing a limited number of moorings (private and commercial) at the site. The exclusion zone should be clearly marked by navigation markers. It is anticipated that the main mast of the ship would be removed in order to maintain depth clearance between 6 m – 8 m (as recommended by NSW Maritime).

Quality of recreational diving in the area is considered to be good with a range of other dive sites suited to divers of different standards throughout the region (section 3.2.3) (Table 2).

4.0 SITE INSPECTION

The site inspection was carried out between 08:00 and 15:00 on the 5th April 2008. Weather conditions were calm in the morning with a light ESE breeze around 9 km/hr (Bureau of Meteorology) increasing to a moderate SE breeze in the afternoon. The tide was at a high of 1.69 m at 08:19 on the drop to a low of 0.31 m at 14:36. Visibility was below average (approximately 9 m) at a depth of 30 m. Sampling sites were chosen within a target area identified as potentially suitable (through results of the constraints review). The target area was located offshore of Avoca Beach (1.15 km southwest of the Skillion) covering an area of 0.42 km^2 between the 30 m and 34 m isobaths and was roughly rectangular. Diver transects were undertaken to the north and south of the target area. GPS points and site inspection details are in Appendix 4.

4.1 Substrate

Substratum types observed within the investigation site (during the dive survey) included expansive areas of compact, bare, rippled sand (Plate 1) occasionally interspersed with reef outcrops, shelly sand and areas of rocky reef of varying height above the seafloor (Plate 1). Examples of two distinct sediment types were collected with sediment cores (20 cm deep) during the dive surveys. The first consisted of very fine, compact, light brown sand (Plate 2) and the second of much coarser sediment, with a large proportion of shell fragments (approximately 90 %) and a small percentage of complete bivalve shells (Plate 2). Bare sandy sediment types are considered generally suitable for artificial reef structures.

4.2 Biota

Sandy habitat observed during the dive survey was generally bare apart from a few demersal fish species such as flatheads (*Platycephalus caeruleopunctatus and Platycephalus* sp.)(Plate 2) and rays such as the shovelnose ray (*Aptychotrema rostrate*) and the fiddler ray (*Trygonorrhina fasciata*)(Plate 2). Some patches of sand were bioturbated indicating the presence of burrowing organisms such as polychaete worms and/or crabs. Sponges (Plate 3), ascidians (*Pyura* sp.), echinoderms (Asteriodea), turfing algae and small tufts of kelp (*Ecklonia radiata*) were observed attached to rocky reef.

During the diver surveys, a total of 32 species of fish from 19 families were recorded (Table 4). Hula fish (*Trachinops taeniatus*), yellowtail (*Trachurus novaezelandiae*)(Plate 3), snapper (*Pagrus auratus*) and tarwhine (*Rhabdosargus sarba*) were abundant in the first dive transect in schools >100 individuals. White ear (*Parma microlepis*), long-finned sea pike (*Dinolestes lewini*) and red morwong (*Cheilodactylus fuscus*) were also common in the first dive transect. Snapper, red mullet, common sweep (*Scorpis lineolatus*), white ear, red morwong and blue morwong (*Cheilodactylus Douglasi*) were present in both dives, however all other species recorded in the second dive were not recorded in the first (indicating the variation in fish species throughout the investigation site). 20 species in total were observed during the second dive (at the southern end of the investigation site). Common species (>10) included silver trevally (*Psuedocaranx dentex*), blackspot goatfish (*Parupeneus signatus*), red mullet (*Upeneichthys lineatus*), mado (*Atypichthys strigatus*) and comb wrasse (*Coris picta*). Other species present in fewer numbers (<10), included ling (*Lotella rhacina*), nannygai (*Centroberyx affinis*), yellow-fin bream (*Acanthopagrus australis*), bullseye (*Pempheris* sp.), old wife (*Enoplosus armatus*), one-spot puller (*Chromis hypsilepis*), crimson banded wrasse (*Notolabrus gymnogenis*), gobies (gobiidae) and leatherjackets (monocanthidae).

A single hawksbill turtle (*Eretmochelys imbricata)* was observed during the second dive amongst the rocky reef habitat (Plate 3).

Baited Remote Underwater Video Stations (BRUVS) were deployed at two locations on sand and nearby to reef habitats at the northern end of the investigation site (Appendix 4).

A total of 11 species were recorded by BRUVS over a period of approximately 1 hr. Yellowtail were most abundant (>100 individuals) and spent the longest time period (up to 1 hr) in view of the camera. Snapper were common at both stations in view between 30 mins and 40 mins. Tarwhine, silver trevally, common sweep and Kingfish (*Seriola* sp.) were also common with flathead, leatherjacket, bream and maori wrasse present at times.

5.0 CONCLUSIONS

A summary of the identified constraints are outlined in Table 5. Distribution and characteristics of the substratum, such as the presence of unsuitable reef surfaces and suitable penetration depth of sediments were major factors in determining a potential location for the Ex-HMAS Adelaide dive site. These factors considered together with the preferred depth range (30 m – 35 m), allowed selection of a target area offshore from Avoca Beach (Figure 5). The target area is approximately 0.42 km^2, 1.14 km in length (north to south), between 0.26 km and 0.45 km wide (between the 30 m and 34 m isobaths) and roughly rectangular. The northern boundary of the area is approximately 1.67 km offshore from north Avoca Beach (approximately 1.5 km south-west of the Skillion) and limited by sand covered reef. The southern boundary (approx 1.73 km offshore from south Avoca) is limited by sand covered reef and rocky reef extending out from south Avoca headland.

5.1 Preliminary Site Selection

Option 1 (target area – north)

It is recommended that the preliminary site for the location of the Ex-HMAS Adelaide be at the northern section of the target area (Figure 5). The northern section is preferable as it is closest to the nearest boat ramp (approximately 2.8 km), amenities and other popular dive sites in the area. At this site, there is less likely to be concern with altered wave patterns in nearshore rocky areas south of Broken Head and the Skillion as opposed to affecting sediment transport on Avoca Beach. Commercial trawling is a significant issue that remains to be addressed throughout the study area and further information is required (see Section 5.2). The selected site at the northern end of the target area is less likely to be worked by commercial trawlers due to patches of reef located to the north, east and west of the site (Figure 5). The disadvantage of this site is that penetration depths of sand (according to CMG, 1999) are <5 m. Further surveys may be required to confirm that sand penetration depths are ≥2 m (the recommended penetration depth to sufficiently stabilise the ship). It is likely that depth of sand would increase further south, closer to the drowned river valley extending offshore from Avoca Beach. Due the extensive reef habitat north of the site, there may be conflict of interest with recreational fishing if an exclusion zone is in operation.

Option 2 (target area – south)

An alternative location for the Ex-HMAS Adelaide dive site would be the southern section of the target area. The advantage of this location is that penetration depth of sand (according to CMG, 1999) is likely to be between 5 m - 10 m (due to infilling of the ancient bedrock valley extending offshore from Avoca Beach) and therefore may not require further geological survey. Disadvantages are that this section may be more likely to interact with commercial trawl and/or trap and line fishermen due the expanse of unobstructed sandy habitat. This location would also be further from the sheltered waters at Terrigal Haven boat ramp and amenities and have more potential to affect nearshore sediment transport at Avoca Beach.

5.2 Gaps in Information

- Commercial fishing areas. Spatial information on the location of regularly fished areas is sensitive and not easily accessed due to the confidential nature of fisheries log book data. Further consultation with local stakeholders (cooperatives, fishers

and the Seafood Industry Advisory Council) is required to determine whether the selected site would interact with commercial fisheries.

- Seabed Morphology. Isopach maps produced by CMG (1999) indicate that sediment penetration depth in the study area is <5 m deep. Further survey work over the selected site may be required to confirm depths are not < 2 m.
- Habitat distribution. Data is sparse and very few studies on benthic/epibenthic and fish communities have been completed within the study area and along this stretch of coastline. Species composition of benthic communities, are however, related to sediment grain size and it is likely that benthic communities within the study area are fairly typical of temperate east coast sandy habitats.
- Coastal and oceanographic processes. Information on broad scale coastal and oceanographic processes is adequate, however, further site specific studies would be required to provide detailed information on wave climate, currents and nearshore sediment transport at the selected site.

6.0 RECOMMENDATIONS

This study has identified a broad target area and within this two potential options for the Ex-HMAS Adelaide dive site, where constraining factors are demonstrated to be minimal. However, in order to validate the suitability of either option, further information is required to avoid conflict of interest between user groups and to gain a more detailed assessment of the seabed within the target area. It is therefore recommended that more site specific information be collected in the following areas:

6.1 Commercial Fishing Areas

Spatial information on commercial fishing activity is sensitive and not readily available in the public domain. NSW Department of Primary Industries (DPI, Cronulla) and the Central Coast District Fisheries Office have been contacted in regards to siting of the Ex-HMAS Adelaide in relation to commercial fisheries. It is confirmed that fish trawl and trap and line fisheries are known to operate in the area, however, it has not been determined whether these fisheries operate within the selected site. It would therefore be necessary to obtain log book data for selected areas and/or address this issue through consultation with the relevant cooperatives, fishers and the Seafood Industry Advisory Council.

6.2 Seabed Morphology

Data compiled in this study and recent side scan sonar surveys (May 2008) have enabled us to map the distribution of seabed characteristics at a broad spatial scale, however, more information is required on sediment properties and penetration depths at the selected sites. This may be achieved through grab sampling and sediment probing techniques.

6.3 Habitat Distribution

Due to limited biological information available for the study area, further survey work would be required to provide a detailed assessment of benthos, epibenthos and fish within the study area involving grab sampling and non-invasive fish sampling techniques (such as 'BRUVS'). This would provide baseline data to compare with long term monitoring work. Ground truthing by analysis of benthic grab samples (for example) could be done within acoustically distinct areas identified in the single-beam sonar survey (i.e. to match specific acoustic signatures with specific sediment types). Combination of particle size composition data and biological data could enable the construction of habitat maps to assist in fine scale site selection.

6.4 Coastal and Oceanographic Processes

Based on consideration of coastal and oceanographic processes occurring in the study area, it is evident that a deeper scuttling of the Ex-HMAS Adelaide within the 30 m to 35 m depth limits would generally be favoured. This is because, at deeper depths:

- the ship would be less likely to affect wave refraction patterns;
- wave-driven currents are smaller and therefore so are dynamic forces on the ship;
- navigation is less likely to be restricted;
- oceanographic currents are likely to be smaller and;

- sediment transport is more likely to be negligible.

Detailed analysis and modelling may find that a ship placed at 30 m depth is stable under extreme waves and currents, and does not significantly affect the nearshore wave climate.

6.5 Exclusion Zone

It is recommended that an exclusion zone between 250 m and 500 m in radius (as an indication) be established around the Ex-HMAS Adelaide to encompass the 'dive site'. This is for navigational safety and also to safely manage activities within the dive site. It is recommended that the number of moorings for chartered and commercial vessels be limited and recreational/commercial fishing operations restricted within the area. The zone should be appropriately marked by navigation aids and on Aus Charts by NSW Maritime.

6.6 Orientation

The predominant wave direction offshore of the study area is from the SSE (Appendix 6). It is therefore recommended that the ship is orientated in a SSE direction (bow facing SSE) into the dominant wave direction. Wave transformation issues (such as wave focussing) altering the nearshore wave climate are complex. Further detailed studies may result in realignment of the ship to make nearshore wave patterns more favourable.

6.7 Timing

Calmer wave conditions normally occur from October to February, which are most favourable for deployment. Coastal storms can however, occur at any time, and whatever period is chosen for deployment it would be necessary to refer to Bureau of Meteorology coastal waters forecasts to ensure that conditions would be acceptable. Annual migration of the southern right whale (*Eubalaena australis*) is known to occur between mid May and mid November. Humpback whales (*Megaptera novaeangliae*) are known to migrate north mainly between June and July and south between October and November (for the central coast area). In order to avoid any potential disturbance to migrating whales and to benefit from calmer conditions, it would be preferable to time the sinking of the Ex-HMAS Adelaide from December to February. If weather conditions were favourable, deployment during September may also be an option, as humpback whales (the most common migratory whale species along this stretch of coastline) are not usually present along the Central Coast at this time.

7.0 ACKNOWLEDGEMENTS

This report was written by Kate Reeds and reviewed by Theresa Dye. Worley Parsons Pty Ltd assisted by providing information on coastal and oceanographic processes and GIS mapping.

8.0 REFERENCES

Allen, S. and Bejder, L. (2003). Southern Right Whale *Eubalaena australis* sightings on the Australian coast and the increasing potential for entanglement. *Pac Conserv Biol* **9**, pp. 228-233.

Boyd, S. E., Coggan, R. A. Birchenough, S. N. R., Limpenny, D. S., Eastwood, P.E., Foster Smith, R.L., Philpot, S., Meadows, W. J.,james, J.W.C., Vanstaen, K., Soussi, S and Rogers, S. (2006). The Role of Seabed Mapping Techniques in Environmental Monitoring and Management. Sci,. Ser. Tech Rep., CEFAS Lowestoft, 127:170pp.

Breen, D.A., Avery, R.P., and Otway, N.M. (2005). Broadscale biodiversity assessment of marine protected areas in the Hawkesbury Shelf marine bioregion - Final report, Prepared for: Natural Heritage Trust//Department of Environment and Heritage. NSW Marine Parks Authority , NSW.

Byron, T (1997b). *Scuba Diving, Snorkelling and Spearfishing Guide to Northern New South Wales (4th Edition)*. Tom Byron Publishers Pty Ltd, Sydney NSW.

Coastal and Marine Geosciences, (1997). Gosford City Council open ocean beaches geotechnical investigations – Avoca, Wamberal, Forresters Beaches. Results of conductivity and drilling investigations. Report to Gosford City Council. January 1997. 62p.

Coastal and Marine Geosciences, (1999). Gosford City Beach Nourishment Feasibility Study Stage 2 – Investigation of Marine Sand Resources –Report to Manly Hydraulics Laboratory. September, 1999.

Dakin, W.D. (1987). Australian Seashores. A guide to the temperate shores. Angus and Robertson Publishers.

Department of the Environment and Heritage (2005). Distribution and recognised aggregation areas of the southern right whale. Department of Environment and Heritage, Canberra.

Department of Urban Affairs & Planning (1996). *Shipwreck Atlas of New South Wales - 3rd Edition*. NSW Government Heritage Office, Sydney NSW.

Environment Australia (2001). A Directory of Important Wetlands in Australia 3rd Edition. Environment Australia. Canberra.

Gosford City Council (1995). Coastal Management Study and Coastal Management Plan Gosford City Open Beaches, prepared by WBM Oceanics Australia and Planning Workshop for Gosford for Gosford City Council.

Hutchings P. (1998). Biodiversity and functioning of polychaetes in benthic sediments. *Biodiversity and Conservation* 7:1133-1145.

Hutchings P. (1999). Taxonomy of estuarine invertebrates in Australia. *Australian Journal of Ecology* 24:381-394.

JARTC (Joint Artificial Reef Technical Committee) of the Atlantic and Gulf States Marine Fisheries Commissions (1998). *Coastal Artificial Reef Planning Guide*. Report prepared in cooperation with the U.S. Fish and Wildlife Service and funded by federal aid in Sport Fish Restoration Administrative Funds.

Jones, A.R. (1986). The Effects of Dredging and Spoil Disposal on Macrobenthos, Hawkesbury Estuary,N.S.W. *Marine Pollution Bulletin* **17**, pp. 17-20.

Larcombe, J., Charalambou, C., Herreria, E., Caset, A.M. and Hobsbawn, P. (2006). Marine Matters National. Atlas of Australian Marine Fishing and Coastal Communities. Bureau of Rural Sciences, Canberra.

Larkum, A.W.D., Orth, R.J., and Duarte, C.M. (2006). *Seagrasses: Biology, Ecology and Conservation*. Springer, The Netherlands, 690 pp

Last , P.R. and Stevens, J.D. (1994). *Sharks and Rays of Australia*. CSIRO, Australia, 513 pp.

Manly Hydraulics Laboratory (2002). Gosford City Beach Nourishment Feasibility Study Stage Two – Detailed Assessment of Potential Sand Resources. In Association with Coastal and Marine Geosciences DLWC Sustainable Water Management. Report No MHL929

Marshall, N., Norall, T., Grove, R.S., Elway, M.H.S. (2003) Artificial reef site selection:geophysical surveys for San Clemente kelp reef. Oceans 2003. Proceedings, vol 2, issue 22-26 Sept. pp.793-803.

McCauley, J.E., Parr, R.A., and Hancock, D.R. (1977). Benthic Infauna and Maintenance Dredging: a Case Study. *Water Research* **11**, pp. 233-242.

McEnally, J., and McEnally L. (2004). AFN (Australian Fishing Network) Fishing Guide to the Central Coast and North Coast of New South Wales. Australian Fishing Network Ltd, South Croydon, Victoria.

Morrisey, D. J., Howitt, L., Underwood, A. J. and Stark, J. S. (1992). Spatial variation in soft-sediment benthos. *Marine Ecology Progress Series* **81**, pp. 197-204.

Morrisey, D.J., Turner, S.J., and MacDiarmid, A.B. (1998). Subtidal soft assemblages of soft substrata. In: *Studying Temperate Marine Environments A Handbook for Ecologists*, Kingsford, M and Battershill, C., (eds). Canterbury University Press, New Zealand. pp. 194-226

Morrison, P.F (2001). Biological Monitoring of the HMAS Swan. Prepared for Geographe Bay Artificial Reef Society Inc.

National Oceans Office (2004). Charter Boat Operations in the Eastern Central Zone. Canberra, NSW.

NavFac Handout No99

Newell, R.C., Seiderer, L.J. & Hitchcock, D.R. (1998). The Impact of Dredging Works in Coastal Waters: a Review of the Sensitivity to Disturbance and Subsequent Recovery of Biological Resources on the Sea Bed. Oceanography and Marine Biology: an Annual Review 36: 127-178.

NSW Fisheries (2001). Identification of candidate aquatic reserves in the Hawkesbury and Twofold shelf bioregions. NSW Fisheries Report, Cronulla NSW.

NSW Department of Environment and Climate Change (2002a). Beachwatch and Harbourwatch State of the Beaches Sydney, Hunter, Illawarra 2001 – 2002. Hurstville, NSW.

NSW Department of Primary Industries (2002b). Threatened Species in NSW – Fishnote NSWF1075 Grey Nurse Shark.

NSW Department of Primary Industries (2005). Threatened and Protected Species Identification Guide for Fishers, Cronulla, NSW.

NSW Department of Primary Industries (2006a). Fishery Management Strategy for the NSW Ocean Trap and Line Fishery, Cronulla, NSW.

NSW Department of Primary Industries (2006b). Threatened Species in NSW – Primefact 165 Eastern blue devil fish.

NSW Marine Parks Authority (2001). Developing a representative system of marine protected areas in NSW – an overview

Otway, N.M. (1999). Identification of candidate sites for declaration of aquatic reserves for the conservation of rocky intertidal communities in the Hawkesbury Shelf and Batemans Shelf bioregions. Report to Environment Australia by NSW Fisheries.

Otway, N.M., Burke, N.S., Morison, N.S., and Parker, P.C. (2003). *Monitoring and identification of NSW Critical Habitat Sites for conservation of Grey Nurse Sharks*, NSW Fisheries Final Report Series, 47. Prepared for: Environment Australia. NSW Fisheries, Nelson Bay NSW.

Public Works Department (1989). Seabed Information Chart 1:25,000 Gosford 83042-1001

Queensland EPA & Queensland Parks and Wildlife Service (2007). The Brisbane – Wreck to Reef…one year on. Produced by the Queensland Government.

Rooney, W.S. and Talbot, F.H. (1980). *Preliminary study on the sand bottom fauna of Broken Bay*, Macquarie University Centre for Environmental Studies

Ross, J and Duffy, H. The New South Wales Fishing Atlas (1998). Penguin Books Australia Ltd. Ringwood, Victoria.

Roy, P.S. (1984) The geology of marine sediments on the south Sydney inner shelf, south-eastern Australia. Geological Survey of NSW, Report No. GS 1984/158 Parts 1 and 2.

Sheng, Y.P. (2000). Physical characteristics and engineering at reef sites. In: *Artificial Reef Evaluation*, Seaman, W., (eds). Crc Press Inc, 2000 Corporate Blvd NW/Boca Raton/FL 33431/USA. pp. 51-94.

Snelgrove, P. V. R. (1999). Getting to the bottom of marine biodiversity: sedimentary habitats. *Bioscience* 49:129-138.

Snelgrove, P. V. R. and Butman, C. A. (1994). Animal sediment relationships revisited: cause versus effect. In: *Oceanography and Marine Biology, Vol 32*, Ansell, A. D.; Gibson, R. N., and Barnes, M., (eds). U C L Press Ltd, Univ Coll London/Gower Street/London WC1E 6BT/United Kingdom. pp. 111-177.

Tanner, M. and Liggins, G.W. (2001). *New South Wales Commercial Fisheries Statistics 1999/00,* NSW Fisheries, Cronulla, NSW.

The Ecology Lab Pty Ltd (2002). *Wamberal Beach property protection EIS: Aquatic ecology*, Prepared for: Manly Hydraulics Laboratory. The Ecology Lab Pty Ltd, Brookvale, NSW.

The Ecology Lab (2007). Trials for Fish Surveys Using Baited Remote Underwater Video Stations (BRUVS). Prepared for Sydney Water Corporation, May 2007.

Underwood, A.J. and Kenelly, S.J. (1990). Ecology of marine algae on rocky shores and subtidal reefs in temperate Australia. *Hydrobiologia*. 192, 2-20.

Underwood, A.J., Kingsford, M.J., and Andrew, N.L. (1991). Patterns of abundance in Shallow Subtidal Marine Assemblages Along the Coast of New South Wale. Australian Journal of Ecology **6**,pp.231-249.

WBM Oceanics Australia (1997). *Norah Head and Wonga Point Benthic and Bioaccumulation Study*, Prepared for: Wyong Shire Council. WBM Oceanics Australia, Spring Hill Qld

Webster, MA and P Petkovic (2005). Australian Bathymetry and Topography Grid, June, Geoscience Australia, Record 2005/12, ISSN 1448-2177, ISBN 1920871 46 2

Internet References

Web Reference 1: List of NSW Charter Boats and Ports. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/_data/assests/pdf-file/0005/118265/CFB-Weblist.pdf

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/118265/charter-boats.pdf

Web Reference 2: NSW Maritime Heritage Online, Shipwrecks database. http://maritime.heritage.nsw.gov.au

Web Reference 3: Australia Government Dept of Environment, Water, Heritage and the Arts. http://www.environment.gov.au/cgibin/heritage/nsd/nsd_list.pl?text=terrigal&state=NSW&status=2&type=&fromyear=&toyear=&do=y

Web Reference 4: Dive the HMAS Hobart http://www.diveexhmashobart.com/ship/scuttling.html

Web Reference 5: NSW Department of Primary Industries. http://fisheries.nsw.gov.au/commercial/commercial2/ocean_trap_and_line_fishery

Web Reference 6: NSW Department of Primary Industries

http://www.fisheries.nsw.gov.au/commercial/commercial2/lobster_fishery

Web Reference 7: NSW Department of Primary Industries

http://www.fisheries.nsw.gov.au/commercial/commercial2/abalone_fishery

Web Reference 8: NSW Department of Primary Industries

http://www.fisheries.nsw.gov.au/commercial/commercial2/ocean_hauling_fishery

Web Reference 9: NSW Department of Primary Industries

http://www.fisheries.nsw.gov.au/commercial/commercial2/ocean_prawn_trawl_fishery

Web Reference 10: NSW Department of Primary Industries. http://www.fisheries.nsw.gov.au/commercial/commercial2/ocean_fish_trawl_fishery

Web Reference 11: Australian Museum Online Fact sheet: Common Dolphin http://www.austmus.gov.au/factSheets/common_dolphin.htm

Web Reference 12: Department of the Environment, Water, Heritage and the Arts. http://www.environment.gov.au/coasts/species/turtles/index.html

Web Reference 13: Department of the Environment, Water, Heritage and the Arts http://www.environment.gov.au/coasts/species/seals/index.html

Web Reference 14: NSW Department of Primary Industry. TAS Map. http://www.minerals.nsw.gov.au/tasmap/jsp/Viewer.jsp?cmd=login

Web Reference 15: NSW Department of Primary Industries, Threatened Species lists. http://www.fisheries.nsw.gov.au/threatened_species/general/what_is_currently_listed

Web Reference 16: Bionet – NSW Government Biodiversity Database http://www.bionet.nsw.gov.au/BioNet.cfm?is_ie5up

Web Reference 17: Department of the Environment, Water, Heritage and the Arts. http://www.environment.gov.au/coasts/species/turtles/index.html

Web Reference 18: Marine Parks Authority NSW (2007). Department of Environment and Climate Change. http://www.mpa.nsw.gov.au/psglmp.html

Web Reference 19: NSW Department of Primary Industries. Threatened Species Profile - Southern Right Whale. http://www.threatenedspecies.environment.nsw.gov.au/tsprofile

Web Reference 20: NSW Department of Environment and Climate Change. Threatened Species Profile - Humpback Whale. http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10914

TABLES

Table 1. NSW marine species and populations listed under the Fisheries Management (FM) Act, Threatened Species Conservation (TSC) Act, National Parks and Wildlife (NP&W) Act and the Environment Protection and Biodiversity Conservation (EPBC) Act. Species potentially or known to occur within the Gosford LGA and Hunter/Central Rivers – marine zone CMA sub-region are listed. CE = critically endangered, E = endangered, V = vulnerable. M = migratory, L = listed and P = protected. (*) indicates threatened species observed during the site inspection (05.04.08)

Common Name	Species Name	Status under *TSC/FM Act*	Status under *NP &W Act*	Status under *EPBC Act*
Fish				
Weedy sea dragon	*Phyllopteryx taeniolatus*	P		L
Grey nurse sharks	*Carcharias taurus*	E		CE
Great white shark	*Carcaradon carcharias*	V		V, M
Bleekers devil fish	*Paraplesiops bleekeri*	P		
Queensland grouper	*Epinephelus lanceolatus*	P		
Green sawfish	*Pristis zijsron*	E		
Black cod	*Ephinephelus daemelii*	V		
Southern bluefin tuna	*Thunnus maccoyii*	E		
Marine Mammals				
Southern right whale	*Eubalaena australis*	V		E, M
Dwarf minke whale	*Balaenoptera acutorostrata*		P	
Blue whale	*Balaenoptera musculus*	E		E, M
Humpback whale	*Megaptera novaeangliae*	V		V, M
Common dolphin	*Delphinus delphis*		P	
Bottlenose dolphin	*Tursiops truncatus*		P	
Sperm whale	*Physeter macrocephalus*	V		
Strap-toothed beaked whale	*Mesoplodon layardii*		P	
New Zealand fur-seal	*Arctocephalus forsteri*	V		L
Australian fur-seal	*Arctocephalus pusillus doriferus*	V		L
Subantarctic fur-seal	*Arctocephalus tropicalis*		P	V,
Leopard seal	*Hydrurga leptonyx*		P	L
Dugong	*Dugong dugon*	E		E, M
Pygmy sperm whale	*Kogia breviceps*		P	
Marine Reptiles				
Green turtle	*Chelonia mydas*	V		V, M
Loggerhead turtle	*Caretta caretta*			
Leatherback turtle	*Dermochelys coriacea*	V		V, M
Hawksbill Turtle*	*Eretmochelys imbricata*			V, M

Table 2. Summary of popular dive sites between The Entrance and Macmasters beach (sites are listed

Name	Location	Depth (m)	Common Species	Description
The Bommies/Tuggerah Reef	Offshore from The Entrance	–	–	–
Hempy's Cave	Offshore of Shelly Beach	–	–	–
Crackneck Reef	offshore Crackneck Point	–	–	–
Foggy Shark Cave	4 km offshore of Crackneck Point	31-39	Grey Nurse Sharks (*Carcharias taurus*)	Boat dive. Comprises caves, gullies and swim throughs. Advanced divers
White House Reef	Offshore and south of Crackneck Point	–	–	–
Forresters Reef	2 km offshore from north end of Forresters Beach	30	Trumpeter (Latrididae) and groupers. Diverse sponge and coralline assemblages	Boat dive. Deep crevices and overhangs. Advanced divers
The Pines	Further offshore than Forresters Reef	30	sponge gardens, anemones, crinoids, Grey nurse sharks	Continuous drop off and stacked boulders
Two Poles Reef	Offshore from the centre of Forresters Beach	18	Dense schools of Fish. Corals sponges and crinoids	Suitable for both inexperienced and experienced divers
Spoon Reef	Offshore from the southern end of Crackneck Reef	17	Sponge growth, cuttlefish, blue devil fish(*Paraplesiops* sp), banded coral shrimp	Suitable for inexperienced divers. Overhangs and swim throughs
The Haven	South of the Skillion to Broken Head	15	Abundant fish life, sponges,soft corals,	100 m out from the rock platform is a high quality shore dive

Continued

Table 2. Continued

Name	Location	Depth (m)	Common Species	Description
Yambacoona Wreck	Offshore from Broken Head/Terrigal Headland	28	No outstanding marine ilfe	Large flat reef area. Wreck is disintegrated very little of the wreck is left
Galava Wreck	Offshore from Terrigal Haven	50	Dense schools of fish aggregate around the wreck	Boat dive. Experienced divers only. Engine, boiler and ribs of the vessel remain
Skillion Cave	Between the southern point of Terrigal Headland and the Skillion	20-25	Sponge gardens, anemones, crinoids, ophiuroids, ascidians	Shore dive. Steep canyon suitable for open water divers
San Francisco Reef	Offshore from south Avoca Beach	30-35	Typical reef fish, sponge gardens, anemones, nudibranchs, ophiuroids and crinoids	Boat dive. Large boulders, drop-offs and ledges
Fifeshire Reef	Offshore from north Avoca Beach	18-20	Soft corals and sponges abundant	Boat dive. Shallow reef complex pointing to the SE. Named after the shipwreck of the Fifeshire (now disintegrated)
Little Jew Ground	Offshore from south Avoca Headland, further seaward of first point	30-39	Sponges, soft coral, typical reef fish	–
Lighthouse Reef	Offshore from First Point	25	Sponge gardens, blue grouper (*Achoerodus viridis*), red rock cod (Serranidae), black banded sea perch (*Hypoplectrodes nigrorubrum*), leatherjackets (Monacanthidae), cuttlefish	Drop off, gullies and overhangs
1st Point	Off the cliffs at first point	26	Typical marine life	Cliffs and swim throughs. Reef plateau at 19 m

Table 3. Results of BRUVS (Baited, Remote, Underwater, Video, Station) analyses. MaxN = Maximum number of species observed, Time MaxN = Time max number of species observed.

Site: 1

Time Start: 0:05:29

Time Finish: 1:02:13

Habitat Description: Sandy bottom

Species	Common Name	Time first observed	MaxN	Time MaxN
Platycephalus sp1.	Flathead	6:42	1	
Pseudocaranx dentex	Silver trevally	13:45	5	
Pagrus auratus	Snapper	14:05	8	29:05
Trachurus novaezelandiae	Yellowtail	15:50	7	16:22
Platycephalus sp2.	Flathead	31:00	1	
Rhabdosargus sarba	Tarwhine	44:38	8	

Site: 2

Time Start: 0:03:39

Time Finish: 1:02:32

Habitat Description: Adjacent to reef habitat

Species		Time first observed	MaxN	Time MaxN
Pseudocaranx dentex	Silver trevally	51:40	2	
Trachurus novaezelandiae	Yellowtail	3:52	100	59:47
Scorpis lineolata	Common sweep	9:14	3	14:43
Meusehenia freycineti	Yellow striped leatherjacket	11:04	1	
Seriola sp	Kingfish	14:20	2	23:33
Pagrus auratus	Snapper	11:14	9	38:35
Sparidae sp.	Bream	28:22	1	
Opthalmolepis lineolata	Maori Wrasse	29:20	1	

Table 4. List of fish species and numbers observed during SCUBA dive transects on 5 April 2008.

Family	Genus & Species	Common name	Approx number counted	
			Dive 1	Dive 2
Rhinobatidae	*Trygonorrhina fasciata*	Fiddler ray	1	
Rhinobatidae	*Aptychotrema rostrata*	Shovelnose ray	1	
Aulopidae	*Aulopus purpurissatus*	Sergeant baker	1	
Moridae	*Lotella rhacina*	Beardie (ling)		1
Berycidae	*Centroberyx affinis*	Nannygai		6
Platycephalidae	*Platycephalus caeruleopunctatus*	Eastern blue-spotted flathead	1	
Platycephalidae	*Platycephalus* sp.	Unidentified flathead	1	
Dinolestidae	*Dinolestes lewini*	Long-finned sea pike	10	
Serranidae	*Hypoplectrodes maccullochi*	Half-banded sea perch	2	
Pleasiopidae	*Trachinops taeniatus*	Hula	>100	
Carangidae	*Pseudocaranx dentex*	Silver trevally		10
Carangidae	*Trachurus novaezelandiae*	Yellowtail	>100	
Sparidae	*Acanthopagrus australis*	Yellow-fin bream		1
Sparidae	*Pagrus auratus*	Snapper	>100	5
Sparidae	*Rhabdosargus sarba*	Tarwhine	>100	
Mullidae	*Parupeneus signatus*	Blackspot goatfish		10
Mullidae	*Upeneichthys lineatus*	Red mullet	4	10
Pempheridídae	*Pempheris sp.*	Bullseye		6
Scorpididae	*Scorpis lineolatus*	Common sweep	1	1
Scorpididae	*Atypichthys strigatus*	Mado		20
Enoplosidae	*Enoplosus armatus*	Old wife		1
Pomacentridae	*Chromis hypsilepis*	One-spot puller		5
Pomacentridae	*Parma microlepis*	White ear	6	8
Cheilodactylidae	*Cheilodactylus fuscus*	Red morwong	6	5
Cheilodactylidae	*Cheilodactylus douglasi*	Blue morwong	1	2
Labridae	*Achoerodus viridis*	Eastern blue groper	1	
Labridae	*Coris picta*	Comb wrasse		10
Labridae	*Notolabrus gymnogenis*	Crimson-banded wrasse		3
Labridae	*Opthalmolepis lineolatus*	Maori wrasse	2	
Gobiidae	-	Unidentified goby		2
Monacanthidae	*Eubalichthys bucephalus*	Black reef leatherjacket		2
Monacanthidae	*Meuschenia flavolineata*	Yellow-striped leatherjacket		3

Table 5. Summary of constraints within the study area. Level of constraint has been ranked as high, moderate or low i.e. a feature or issue unlikely to be a constraint in site selection is ranked as 'low'.

Constraint	Level of Constraint	Comments
1). Depth		
	High	The 30 m - 35 m preferred depth range constrains site selection to an area 0.42 $km^{2,}$ approx. 1.72 km offshore from Avoca beach.
2). Exclusion Zones		
• Commercial Fishing	High	Potential conflict of interest with commercial fisherman, particularly trawlers. Further stakeholder consultation is required.
• Recreational Fishing	Moderate	Recreational fishing from beaches, rock platforms and offshore is popular in the study area. Operation of an exclusion zone around the Ex-HMAS Adelaide dive site could potentially conflict with offshore reef fishing.
• Recreational Diving, Snorkelling and Spearfishing	Low	The additional Ex-HMAS Adelaide dive site would complement existing nearby sites such as The Skillion Cave, Fifeshire Reef and San Francisco Reef.
• Recreational Sailing and Boating	Low	2-3 significant sailing events occur annually offshore of Terrigal. Gosford sailing club do not see the Ex-HMAS Adelaide dive site as a navigational issue.
• Marine Protected Areas (MPA's)	Low	No MPA's exist within the study area. Bouddi National Park marine protection zone is located south of Macmasters beach to Wagstaff Point. This would not be a constraint in site selection for the Ex-HMAS Adelaide.
• Historical Ship Wrecks	Moderate	Wrecks of the Lord Ashley (approx. 9 m depth), Yambacoona (26 m-28 m depth) and the Galava (approx. 50 m depth) are located within the study area. These wrecks are not likely to be a constraint in site selction as they are either outside the preferred depth range or located on or near reef.
• Offshore Mineral and Petroleum Resources	Moderate	Possibility of future exploitation of sand resources for beach nourishment and/or commercial purposes. Future extraction operations would be at depths > 35 m.
• FAD's (Fish Aggregation Devices)	Low	One FAD is located in the study area outside the preferred depth range. It is not considered a constraint.
3). Geotechnical Constraints		
• Substratum Type	High	Sand covered reefs limit site selection to a rectangular area of fine to medium sand approximately 0.42 km^2, 1 km in length (north to south) and 0.45 km in width (at its widest point).
• Penetration Depth	High	Site selection is limited to areas where sand penetrates ≥ 2 m. Isopach data suggest sand in the target area as <5 m depth apart from a channel of sand > 10 m depth which runs offshore from the centre of Avoca beach.

Continued.

Table 5. Continued

Constraint	Level of Constraint	Comments
4). Distribution of Habitats Flora		
	Moderate	Likely to be typical benthic/epibenthic habitat associated with fine to medium grained shelf sand. A diverse assemblage of typical reef and demersal fish were observed in the site inspection. Further investigation would be required.
5). Threatened Species		
	Moderate	7 protected marine species were shown to occur within the study area according to threatened species databases. In addition 1 marine reptile (listed as vulnerable/migratory) was recorded during the site inspection.
6). Coastal and Oceanographic		
	Moderate	Deeper scuttling of the Ex-HMAS Adelaide within the 30 m to 35 m depth limits would generally be favoured to minimise impacts on wave refraction, currents and nearshore sediment transport.
7). Operational feasibility		
• Access	Moderate	One main boat ramp at Terrigal Haven. Access via sheltered moorings is either from Swansea Channel or Broken Bay.
• Amenities	Low	5 Dive shops in the locality, 3 large hospitals. Good public amenties at Terrigal Haven boat ramp mean that amenities available to visitors are unlikely to be a constraining factor and level of consrtaint is low.
• Quality	Low	Other high quality dive sites in the study area indicate suitable diving conditions.

FIGURES

Figure 1. Map showing location of the study area at Terrigal, on the Central Coast of NSW. (Inset) map of the study area between Broken Head and south Avoca beach.

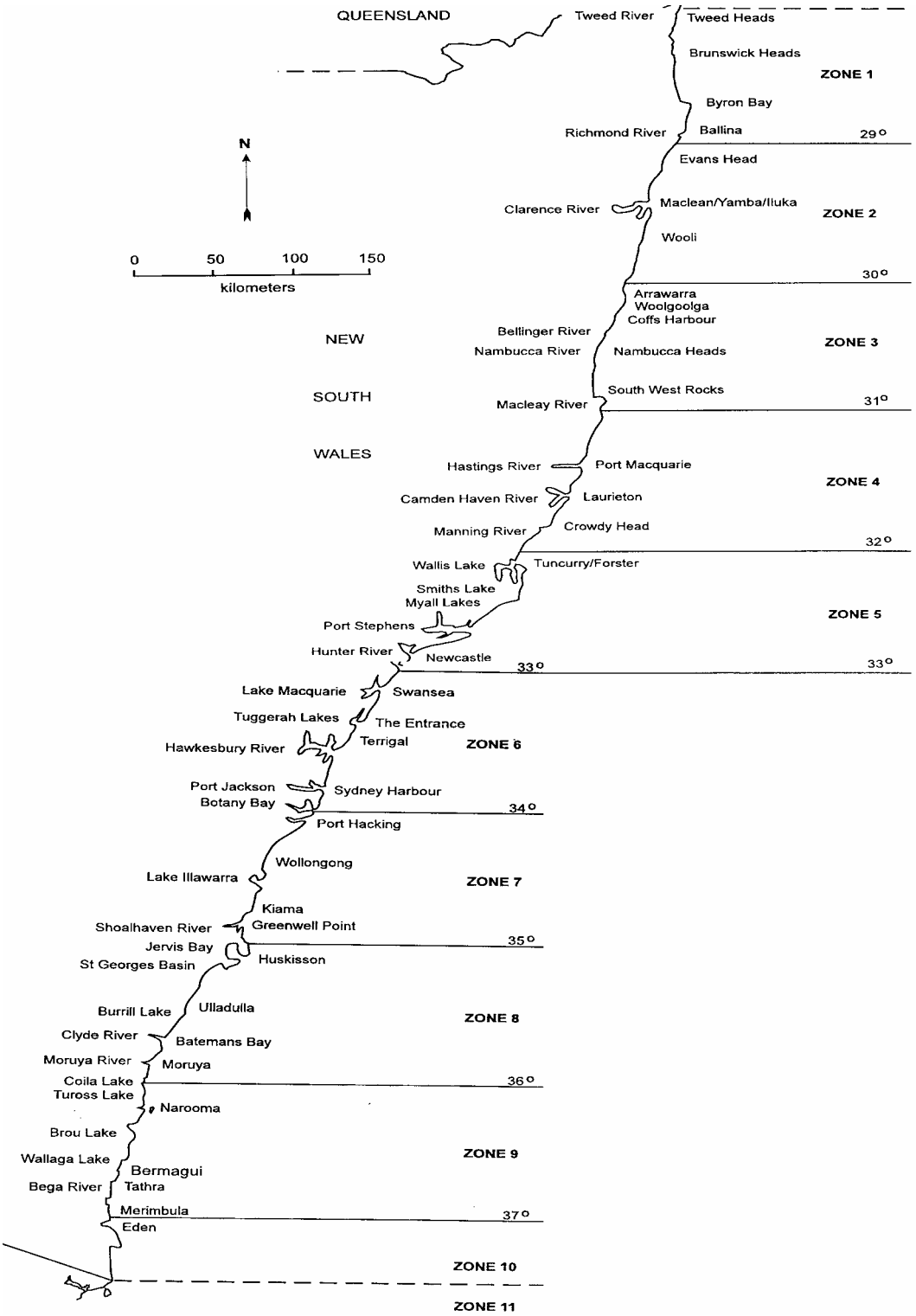

Figure 2. Catch reporting zones for Ocean Trap and Line, Ocean Prawn Trawl and Ocean Fish Trawl Fisheries.

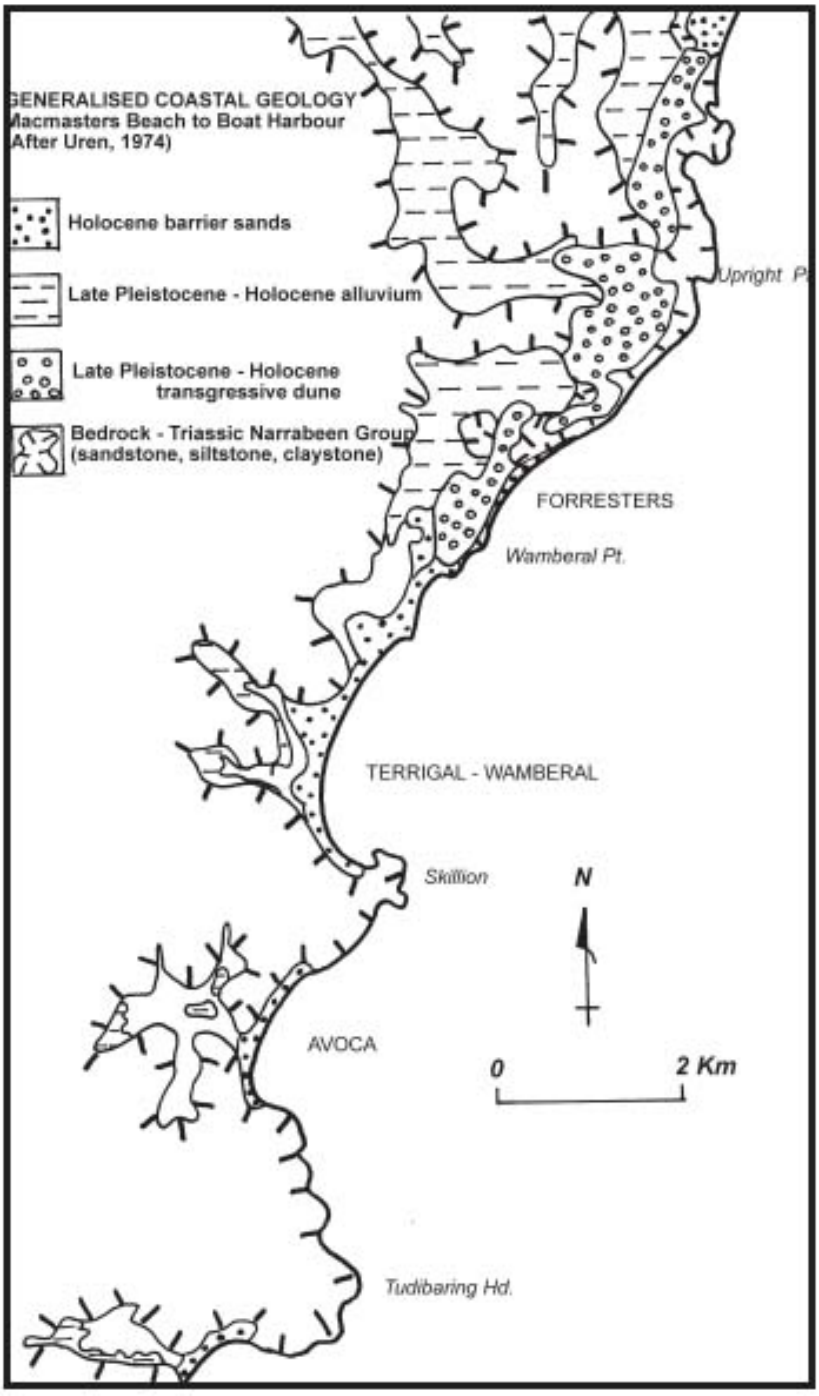

Figure 3. Generalised onshore Quaternary geology for the NSW Central Coast between Macmasters Beach and Forresters Beach (after Uren, 1974) Source: Hudson (1999).

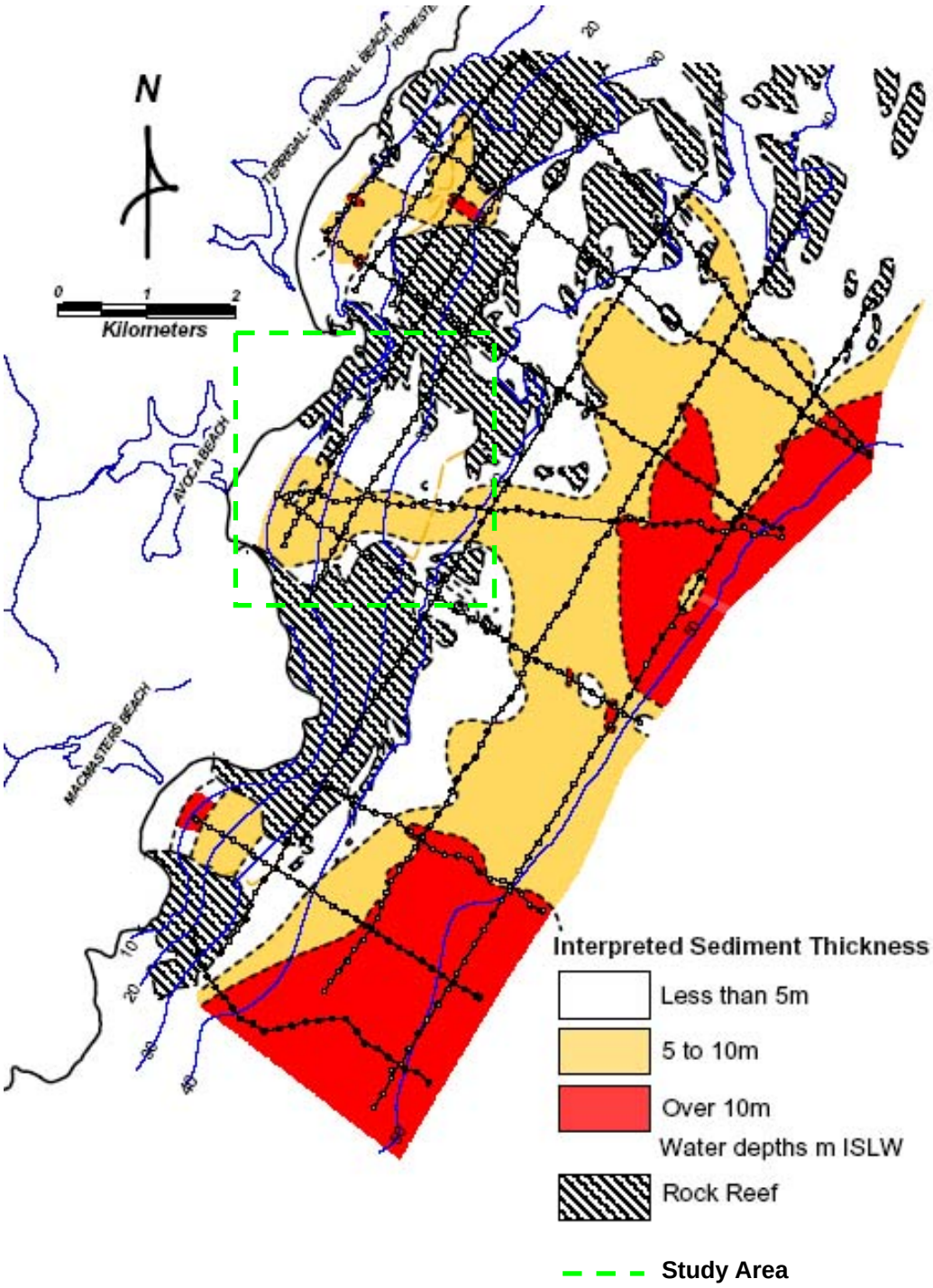

Figure 4. Sediment isopach map of the study area and surrounds. The study area is highlighted in green. Beaded lines indicate seismic line runs. Note thick shore-faced innershelf deposits infilling the ancient bedrock valleys extending seaward of the main beach system. Source: MHL (2002).

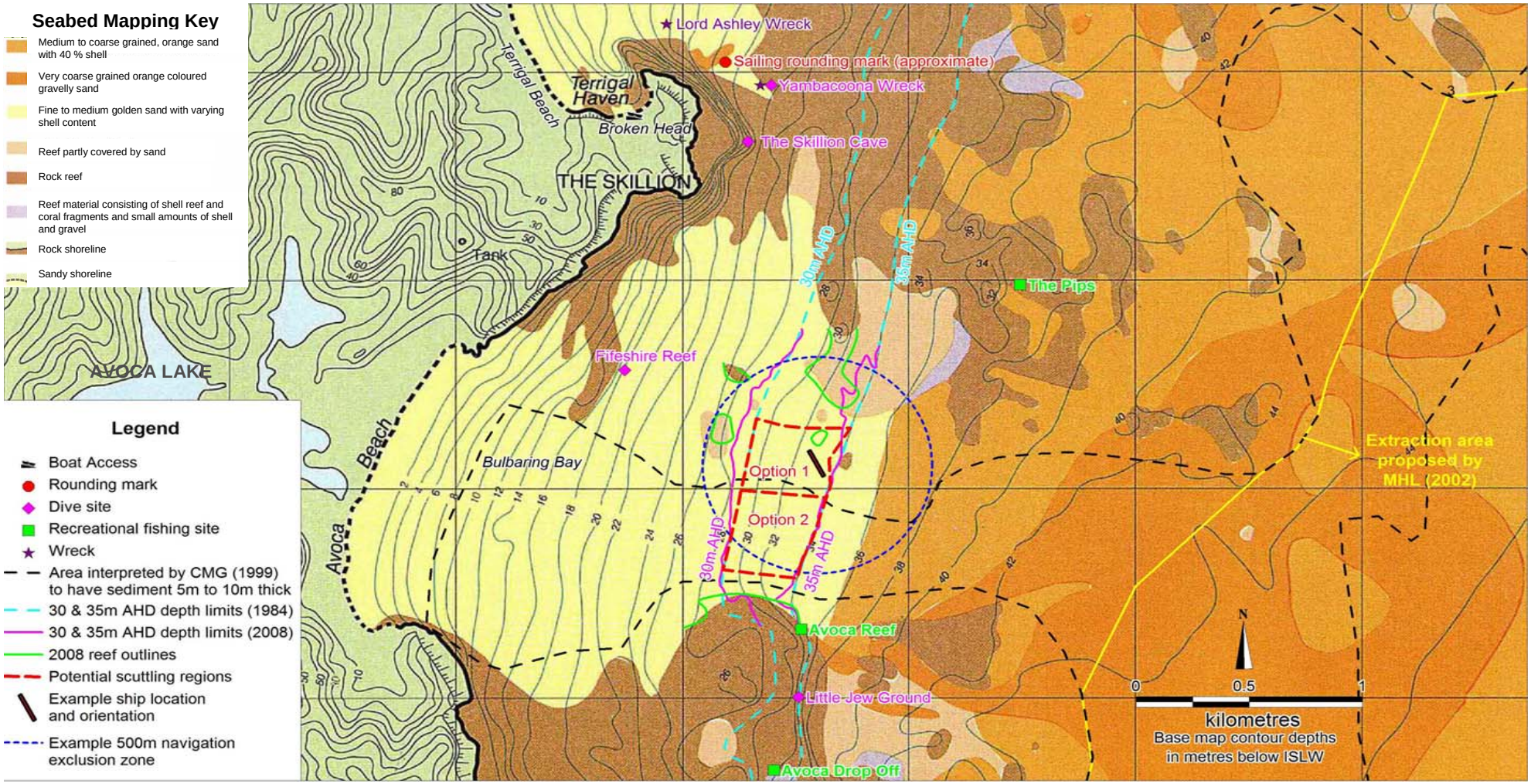

Figure 5. Constraints map of the Study Area including the potential scuttling region (target area) for the Ex-HMAS Adelaide dive site. An example exclusion zone, preliminary location and the recommended orientation of the ship are indicated.

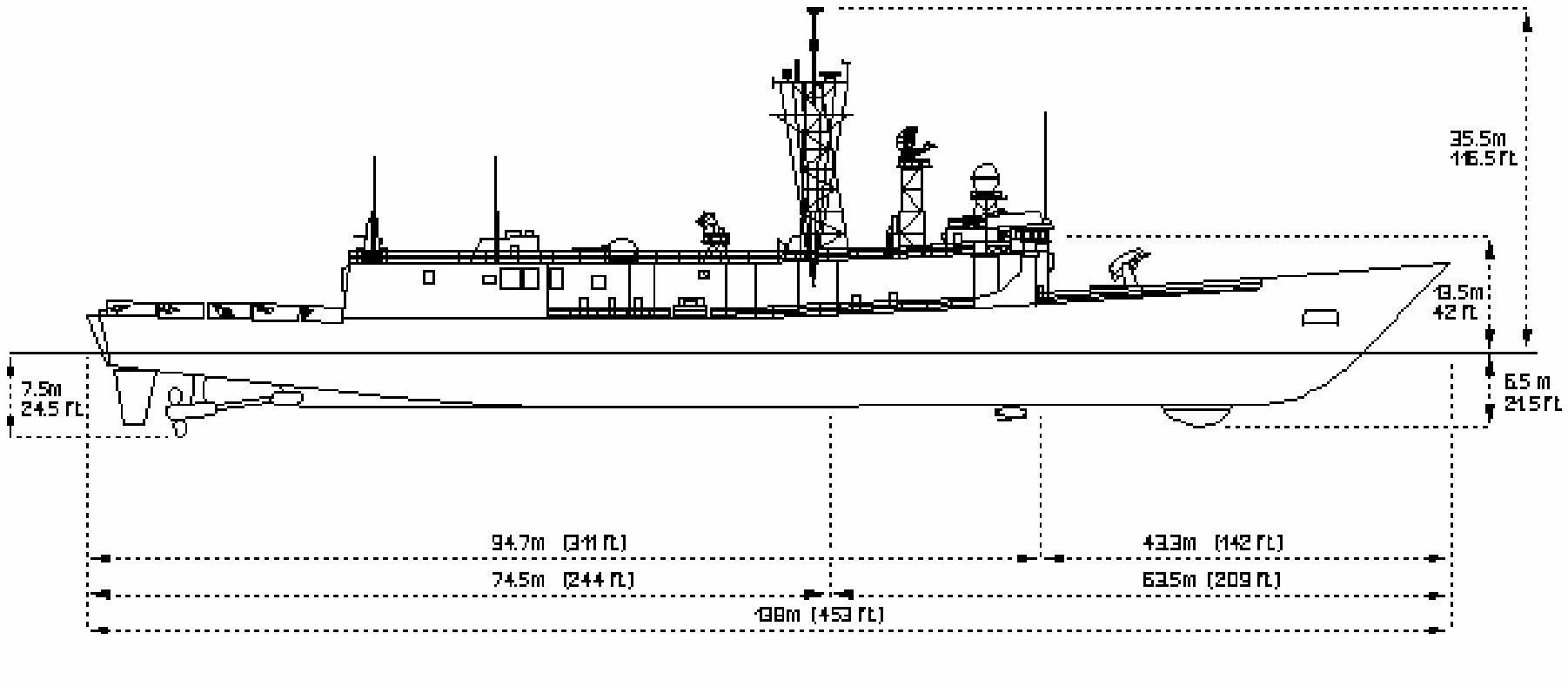

Figure 6. Dimensions of the long-range escort frigate Ex-HMAS Adelaide (Frigate Fast Guided Missile 7 Class).

PLATES

Plate 1: Upper: (a) The Ex-HMAS Adelaide on route to Terrigal for preparation for scuttling 28 January 2008 (b) BRUVS (Baited, Remote, Underwater, Video Station) deployed at the investigation site on 5 April 2008.

Plate 1: Lower: (a) Example of compact, fine sand ripples observed during dive survey 1 on 5 April 2008 (b) Rocky reef habitat observed on dive survey 1 on 5 April 2008. Sponges and encrusting bryozoans can be seen on the reef surface.

Plate 2: Upper: (a) Fine, compact sand collected by core sample from dive survey 1on the 5 April 2008 (b) Coarse sediment (consisting of 90 % shell fragment) collected by core sample from dive survey 2 on 5 April 2008.

Plate 2: Lower: (a) Example of compact, fine sand ripples observed during dive survey 1 on 5 April 2008 (b) Rocky reef habitat observed on dive survey 1 on 5 April 2008. Sponges and encrusting bryozoans can be seen on the reef surface.

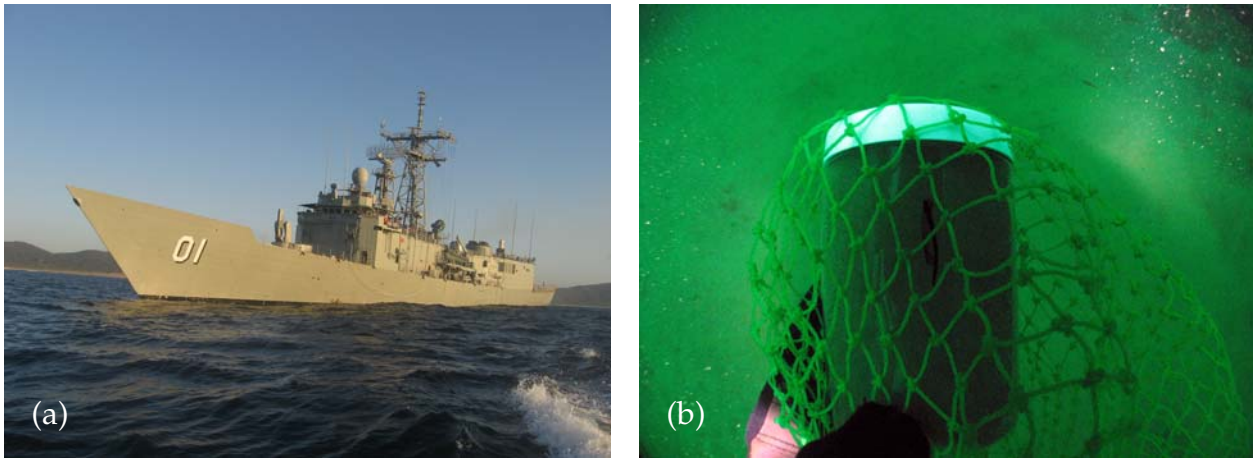

Plate 1 Upper: (a) The Ex-HMAS Adelaide on route to Terrigal for preparation for scuttling on 28 January 2008 (b) BRUVS (Baited, Remote, Underwater, Video Station) deployed at the investigation site on 5 April 2008.

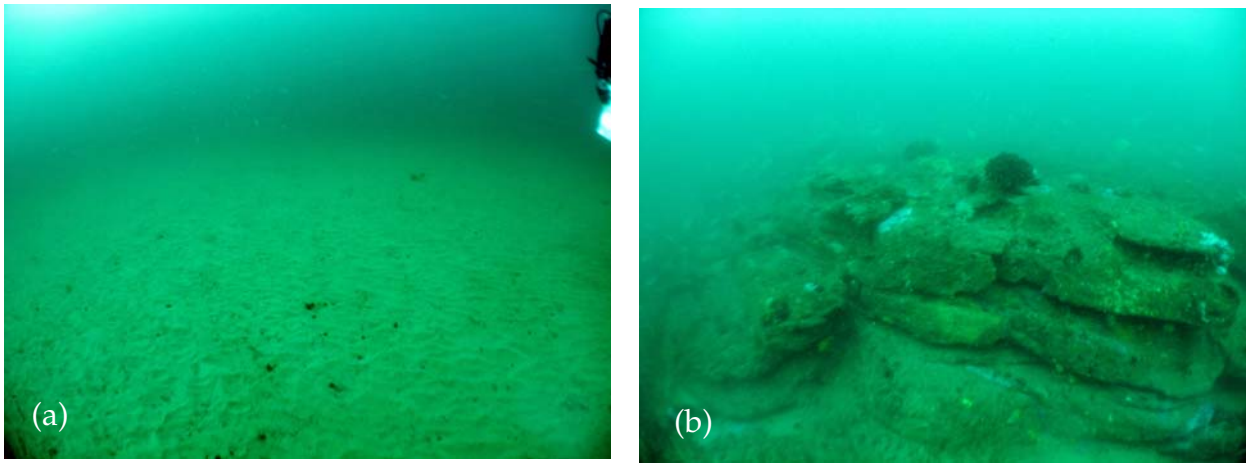

Plate 1 Lower: (a) Example of compact, fine sand ripples observed during dive survey 1 on 5 April 2008 (b) Rocky reef habitat observed on dive survey 1 on 5 April 2008. Sponges and encrusting bryozoans can be seen on the reef surface.

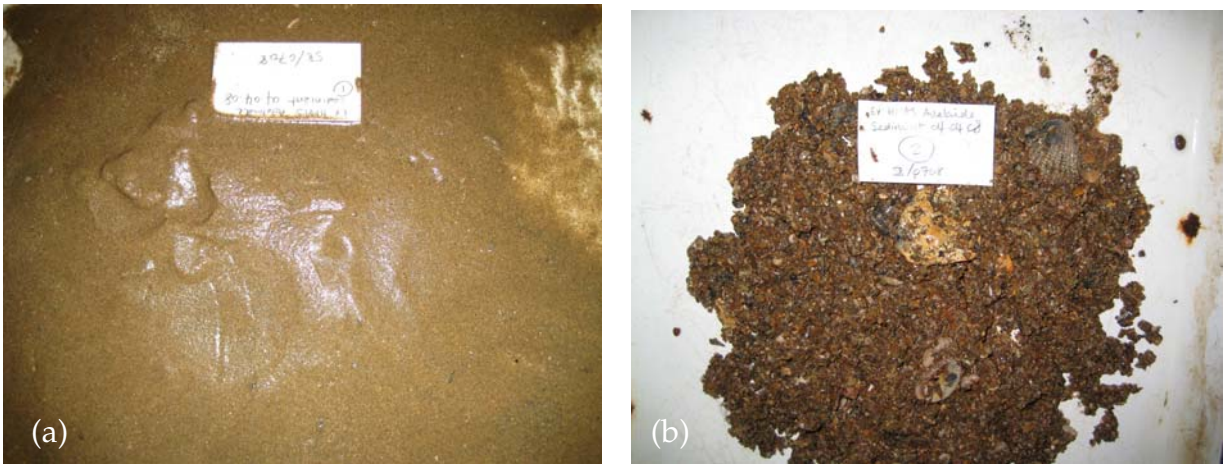

Plate 2 Upper: (a) Fine, compact sand collected by core sample from dive survey 1 on the 5 April 2008 (b) Coarse sediment (consisting of 90 % shell fragment) collected by core sample from dive survey 2 on 5 April 2008.

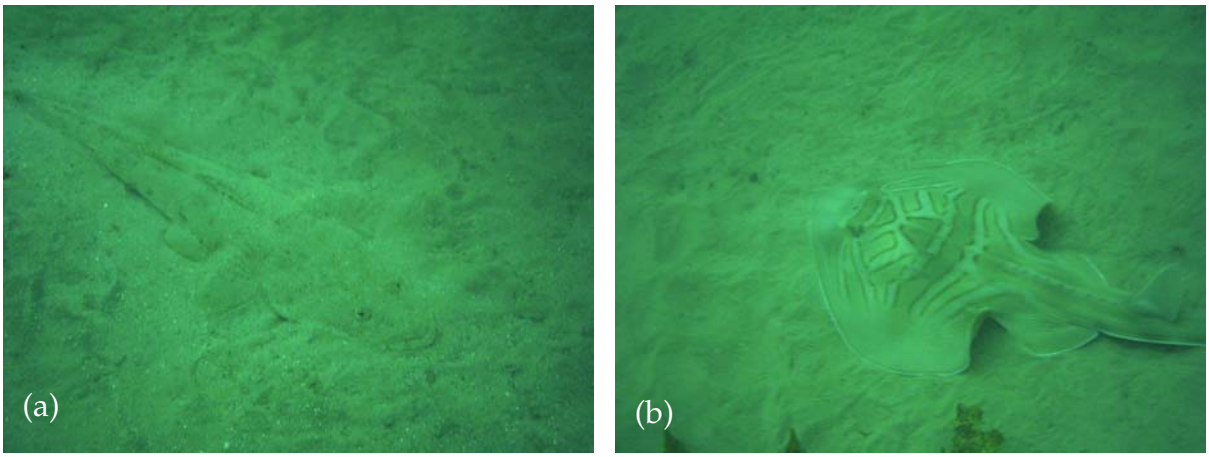

Plate 2 Lower: (a) Flathead (Monocanthidae) observed during dive survey 2 on 5 April 2008 (b) Fiddler ray (*Trygorrhina fasciata*) observed on dive survey 2 on 5 April 2008.

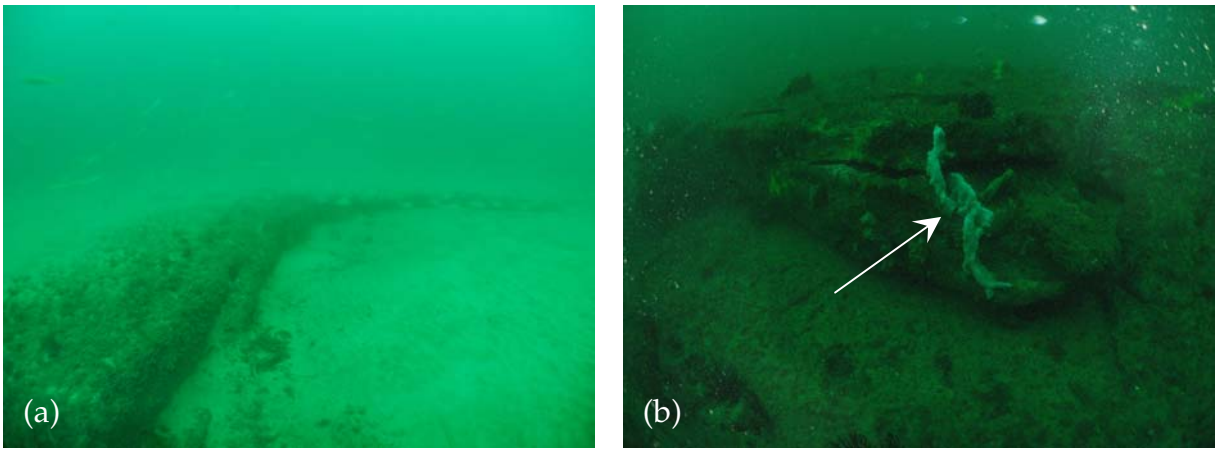

Plate 3 Upper: (a) School of Yellowtail (*Trachurus novaezelandiae*) over low relief reef habitat (b) Sponges (indicated by arrow), encrusting bryozoans and algae observed during dive survey 1 on the 5 April 2008.

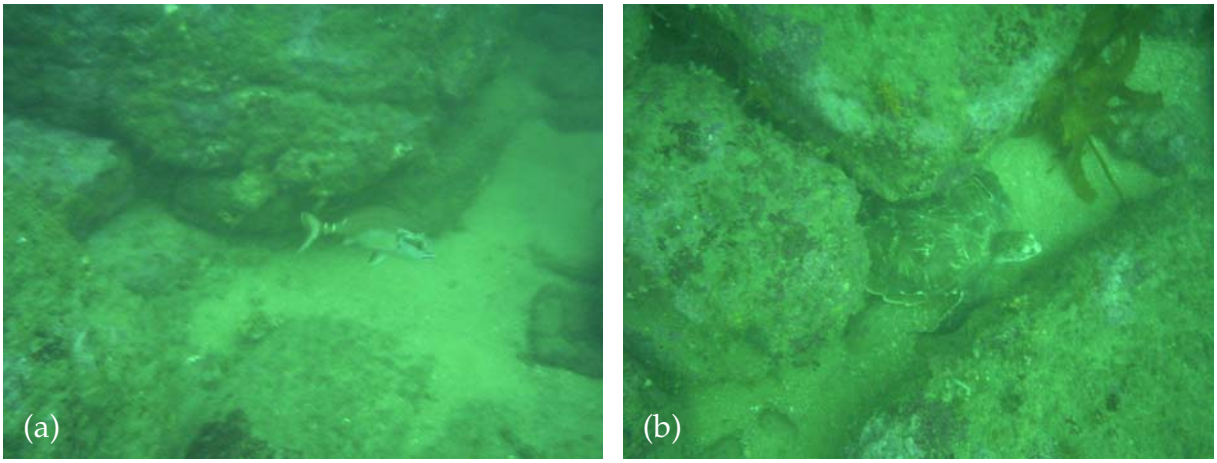

Plate 3 Lower: (a) Red Morwong (*Cheilodactylus fuscus*) observed during dive survey 2 on the 5 April 2008 (b) Hawksbill turtle (*Eretmochelys imbricata*), encrusting bryozoans/algae and Kelp (*Ecklonia radiata*) observed during dive survey 2 on the 5 April 2008.

APPENDICES

Appendix 1: Names and GPS positions of popular recreational fishing locations between Box Head and Red Head, NSW.

Appendix 2: Historic shipwrecks known (and predicted) to occur in the vicinity of the study area. GPS positions are listed where known.

Appendix 3: Chartered fishing vessels registered with NSW DPI operating between the Hunter region and Hawkesbury/Pittwater.

Appendix 4: Details of BRUVS (Baited, Remote, Underwater, Video, Stations) & diver deployments carried out on 5 April 2008.

Appendix 5: Details of persons and organisations consulted during the Ex-HMAS Adelaide constraints review.

Appendix 6: Coastal and oceanographic processes.

Appendix 1. Names and GPS positions of popular recreational fishing locations between Box Head and Red Head, NSW. Source: McEnally and McEnally (2004).

Location Name	Target Species	Latitude (S)	Longitude (E)
Box Head	Reef fish, grouper and hairtail	33.33.200	151.20.600
West Reef	Bream, leatherjacket, trevally, small snapper	33.32.761	151.22.128
East Reef	Leatherjacket, snapper, bream, kingfish, teraglin and mulloway	33.32.902	151.23.881
Kilcare Wide	Snapper, morwong, kingfish and mulloway	33.34.021	151.23.848
Midway Reef	Mixed reef fish	33.32.700	151.23.200
Avoca Drop Off	Snapper and morwong	33.28.581	151.27.339
Avoca Wide	Snapper and kingfish	33.30.050	151.32.200
Avoca Reef	Morwong and snapper with flathead between reefs	33.28.217	151.27.423
Three Points	Snapper, morwong, trevally	33.30.052	151.32.221
The Pips	Snapper, morwong, trevally	33.27.331	151.28.064
Terrigal Wide 1	Snapper, kingfish, morwong and leatherjacket	33.28.372	151.31.901
Terrigal Wide 2	Snapper, kingfish, morwong and deep sea flathead	33.28.283	151.33.265
Terrigal East	Snapper, morwong and other reef fish	33.26.504	151.30.032
Snapper Ground	Snapper, morwong, trevally	33.25.413	151.30.225
Foggy Reef	Snapper, morwong and flathead between reefs	33.24.112	151.32.033
Perch Ground	Snapper, trevally, long-finned perch, kingfish. Dolphin fish under trap markers during summer	33.25.961	151.45.149
Texas	Snapper, morwong, long-finned perch, kingfish and mulloway	33.24.112	151.45.978
The Cones	Snapper, long-finned perch, pigfish and kingfish	33.28.833	151.45.802
The Entrance Bommie	Produces kingfish, tailor and trevally, with mulloway on the eastern deep edge	33.21.377	151.32.308
The Faulkins	Snapper, teraglin, morwong, long-finned perch,	33.17.492	151.43.911
Faulkins East	Snapper, morwong and leatherjacket	33.17.223	151.48.441
Moey Ground	Snapper and morwong	33.18.941	151.40.511
Dougo's	Snapper, bream, trevally, flathead	33.16.629	151.42.119
Pro Ground	Snapper, morwong, leatherjacket, long-finned perch and kingfish	33.15.712	151.48.564
The Stack	Snapper and a variety of reef fish	33.14.623	151.45.051
Bird Island	Mixed species including kingfish, snapper, flathead and leatherjacket	33.13.920	151.36.280
Doctors	Snapper with some good flathead on the edges	33.12.179	151.38.402
The Farm 1	Snapper, morwong, long-finned perch, kingfish John dory and leatherjacket. Large numbers of dolphin fish hold here under trap floats in summer	33.11.884	151.49.324
The Farm 2	Snapper, morwong, long-finned perch, kingfish John dory and leatherjacket. Large numbers of dolphin fish hold here under trap floats in summer	33.11.386	151.49.325
The Farm North	Snapper, morwong, long-finned perch, kingfish	33.09.045	151.49.103
JR's	Snapper, mullloway, kingfish	33.12.730	151.38.212

Continued

Appendix 1. Continued.

Location Name	Target Species	Latitude (S)	Longitude (E)
Windlass	Bream, snapper, trevally	33.10.349	151.39.461
Cartho Wreck	Snapper, mulloway, kingfish	33.10.835	151.42.198
Shark Fin	Snapper,mulloway, mixed reef fish	33.10.959	151.43.362
Cartho Jetty Mark	Snapper, morwong, trevally	33.09.633	151.39.231
Swansea Gravel	Local drft area for flathead	33.05.571	151.43.379
Swansea Wreck	Snapper, mulloway, flathead	33.05.032	151.43.449
Jewells	Snapper, bream	33.01.924	151.43.022
Redhead Gravel	Snapper, flathead	33.01.497	151.44.194
Redhead Close	Snapper, mulloway, trevally, bream, flathead	33.00.713	151.44.043

Appendix 2. Historic shipwrecks known (and predicted) to occur in the vicinity of the study area. GPS positions are listed where known. Source: NSW Heritage and the Department for the Environment, Heritage, Water and the Arts (DEHWA)(Web References 2 and 3). GPS Positions are given in decimal degrees (WGS84).

Name	Description	Date Wrecked	Location	Latitude	Longitude	Protected (Y=Yes)		Comments
						Historic Shipwrecks Act 1976	NSW Heritage Act 1977	
Barangaroo	Hulk	3/01/1929	Off Terrigal					
Commonwealth	Steamer screw	18/08/1912	NE of Terrigal, at Foggy Reef	33.421667	151.516667	Y		
Fame	Schooner	1866/11/07	Broken Bay, between Cape Three Pts & Terrigal			Y		The Fame was a small wooden schooner of 60 tons and 17.7m in length and engaged in the coastal coal trade. The Fame was wrecked between Cape Three Points and Terrigal on 7 November 1866.
Friend	Cutter	1860	Terrigal Head			Y		
Galava	Steamer screw	8/02/1923	Terrigal, 3 nm east, bombora	33.60667	151.71472		Y	Depth of site ~51m.
Gitana	Ketch	1857/09/05	Terrigal Harbour			Y		
Hall Caine	Steamer screw	16/03/1933	Broken Bay, SE of Three Points					Depth of site ~45m.
Juno	Ketch	1879/04/26	Terrigal, 5-6 mls east			Y		
Kathleen	Barquentine	1867/12/04	Halfway between Terrigal & Norah Head, ashore			Y		

Continued

Appendix 2. Continued.

Name	Description	Date Wrecked	Location	Latitude	Longitude	Protected (Y=Yes)		Comments
						Historic Shipwrecks Act 1976	NSW Heritage Act 1977	
Lord Ashley	Steamer screw	1877/09/08	Terrigal Reef	33.4456	151.45	Y		The site lies in about 9 metres of water. The remains lie on the seaward side of Terrigal Reef. Little survives of the hull structure. The bow area is marked by a pile of anchor chain, the stern by the remains of the two cylinder engine. The early marine trunk engine is of special importance as a rare example of its type.
Maitland	Steamer paddle	1898/05/06	Broken Bay, Maitland Bay	33.5273	151.393			
Maud Weston	Steamer screw	9/11/1900	Near Terrigal Head			Y		
Narooma	Steamer screw	3/02/1905	Broken Bay, Boat Harbour ashore			Y		
Pompey	Schooner	1852/06	Lake Macquarie & Terrigal, btwn			Y		
Rainbow	Ketch	1857/06/17	Terrigal (Fenigal), ashore			Y		
Sir Robert Peel	Ship	1847/01/18	Near Terrigal, at Avoca Bay			Y		
Surprise	Schooner	1891/01/29	10 mls east of Terrigal			Y		

Continued

Appendix 2. Continued.

Name	Description	Date Wrecked	Location	Latitude	Longitude	Protected (Y=Yes)		Comments
						Historic Shipwrecks Act 1976	NSW Heritage Act 1977	
Tamar	Steamer paddle	1873/01/11	Terrigal, Norah Harbour, on nearby beach			Y		
Terrigal Jack	Ketch	1873/03/30	Off Seal Rocks			Y		
The Pathfinder	Motor vessel	8/04/1930	1.5 mls east of Terrigal					
Union	Ketch	1848/07	Near Terrigal off Avoca Bay				Y	
William and Alexander	Ketch	1892/08/21	Terrigal Beach			Y		
Yambacoona	Steamer screw	23/02/1913	Terrigal, off Broken Head	33. 65667	151. 551	Y		The site lies in about 26 metres of water. The vessel is wooden and 33.5 metres in length
Fifeshire	Steamer screw	1886/05/23	Terrigal, Moores Beach			Y		

Appendix 3. Chartered fishing vessels registered with NSW DPI which operate between the Hunter region and Hawkesbury/Pittwater. Source: NSW DPI (Web Reference 1). Key to Activities E = Estuary Fishing, G = Gamefishing, N = Nearshore, D = Deep Sea Bottom Fishing.

Hunter

Business Name	Boat Name	CFB No	Phone	Email	Activities
Kas Developments	Silver Shadow	21820	02 4634 1268	concealcw@ozemail.com.au	G, D
Sandy Bottom Boat Charter	Sandy	22307	02 4957 0400		E, N, G, D
Tailermade Fishing Adventures	Blue Horizon	21025	02 4428 2653	tailermadefishn@optusnet.com.au	E, N, G, D

Lake Macquarie

Business Name	Boat Name	CFB No	Phone	Email	Activities
B & L Fishing and Cruises Pty Ltd	Lake and Sea	20245	02 4971 3323	brad@blfishingcruises.com	E, N, G, D
Central Coast Ocean Adventures	Ocean Adventures	21638	02 4392 3144	tommo5@iprimus.com.au	E, N, G, D
Offshore Charters	Offshore	21103	02 4975 5599	pdbesoff@acay.com	E N, G

Terrigal

Business Name	Boat Name	CFB No	Phone	Email	Activities
Carter's Coastal Charters	Ruben J	22314	02 4368 3068	brettcharter@hotmail.com	E, N, G, D
Central Coast Reef and Game Fishing	Sea Runner	21037	0427 665 544	paulminto@bigpond.com	E, N, G, D
Terrigal Bluewater Fishing Charters	Freeya	407	02 4384 6871	tbwfishing@yahoo.com	E, N, G, D

Brisbane Waters

Business Name	Boat Name	CFB No	Phone	Email	Activities
Ausea Fiamsea Charters	Habana	21581	02 4324 2438	kckang@bigpond.com	E, N
Broken Bay Bluewater Charters	The Prophet	21104	02 4342 7207	bbcharters@bigpond.com.au	E, N, G
Estuary Fishing and Tours	Honey J	21818		ron@estuaryfishingandtours.com.au	E
Procat Charters	Gunbarrel	18388	02 4344 7778	hurkfish@optusnet.com.au	E, N, G, D
Relax Charters	Mauna Kea	13165	02 9906 2833	jeff@jenningsplumping.com.au	E, N, G, D
	Reel Time	21625	02 6646 2017	ports@reeltime.com.au	E

Hawkesbury /Pittwater

Business Name	Boat Name	CFB No	Phone	Email	Activities
Black Jack Fishing Charters	Black Jack	22304	02 9913 1435	langrgh@bigpond.com	E, N, G, D

Appendix 4. Details of BRUVS (Baited, Remote, Underwater, Video, Stations) & diver deployments carried out on 5 April 2008. Staff - M. Lincoln Smith (MLS); Chris Roberts (CR); Dan Pygas (DP) and Ian Puckeridge (IP). GPS positions recorded in WGS84 datum, degrees and minutes.decimal.

Site	Position		Depth (m)	Surface Water Temp (C)	Time in	Time out
	Latitude	Longitude				
BRUVS #1	33 27.788	151 27.546	34.6	19.4	10:00	12:10
BRUVS #2	33 27.706	151 27.232	28.6	19.2	10:18	12:20
Dive 1 (MLS & CR)	33 27.724	151 27.184	29.3	19.6	10:45	11:15
Dive 2 (IP & DP)	33 28.154	151 27.246	28.7	19.7	11:35	11:58

Appendix 5. Details of persons and organisations consulted by The Ecology Lab during the Ex-HMAS Adelaide constraints review.

Date	Contact Name	Contact Agency	Contact Info (Tel/Email address)	Details Discussed
4/04/2008	John Hudson	DECC	john.hudson@environment.nsw.gov.au	Geological survey information
4/04/2008	Bronson Macpherson	MHL	B.Macpherson@MHL.com.au	Geological survey information. Obtaining MHL Report 929
4/04/2008	Mark Kulmar	MHL	mkulmar@mhl.nsw.gov.au	Geological survey information. Obtaining MHL Report 929/Appendix A
7/04/2008	Les Graham	Terrigal Dive Centre	4384 1219	GPS locations of Terrigal dive sites
8/04/2008	Sue Dengate	CCARP	ddu.s@optusnet.com.au	Obtaining copy of the Central Coast Artificial Reef Project preliminary study
9/04/2008	Lawrie Eddie	Gosford Sailing Club	gossail@ozmail.com.au	Sailing courses and events in the Terrigal region
14/04/2008	Karen Tucker	Gosford City Council	4325 8222	Geological survey information and obtaining geological GIS layers
15/04/2008	Kevin Rowling	NSW DPI, Cronulla	9527 8411	Commercial Fisheries Information in the Terrigal Region
16/04/2008	Tony Andrews	NSW, DPI (Central Coast District Fisheries Office)	tony.andrews@dpi.nsw.gov.au	Commercial Fisheries Information in the Terrigal Region
17/04/2008	Bradley Harrison	NSW, DPI (Central Coast District Fisheries Office)	4328 8600	Commercial Fisheries Information in the Terrigal Region
16/04/2008	Richard Bagnato	Sydney Trawl Management Advisory Committee	0439 343465	Commercial Fisheries Information in the Terrigal Region
21/04/2008	Phil Moore	Gosford City Council	4325 8222	Information on status of beach nourishment activity for Gosford City beaches

Appendix 6

COASTAL AND OCEANOGRAPHIC PROCESSES

1.0 COASTAL AND OCEANOGRAPHIC PROCESSES

1.1 Wave Climate

1.1.1 Measurements in Study Area

The wave climate of the study area can be considered to be similar throughout, and reasonably well defined.

Manly Hydraulics Laboratory (MHL), part of the NSW Department of Commerce, operates a network of Waverider buoys in deep water along the NSW coast. Waverider buoys are spherical floating accelerometers which determine sea level surface displacement based on the double integration of measured vertical accelerations. Analysis of the collected data allows (amongst other things) the significant wave height (H_s) and peak spectral wave period (T_p) to be determined[1]. For the NSW network, records are collected for 2048s bursts (about 34 minutes) every hour at 0.5s intervals (Lord and Kulmar, 2001).

Waverider buoys can be non-directional or directional. Directional buoys allow the predominant wave direction to be determined.

In the vicinity of the study area, a directional Waverider buoy is located in about 80 m depth of water offshore of Curl Curl in Sydney[2]. This buoy has been operating since 1987 (directional since 1992). Sydney Ports also operates a non-directional Waverider buoy offshore of Botany Bay, which has been collecting data since 1971.

Based on all data collected at the Sydney buoy to the end of 2004, it is evident that the average H_s offshore of the study area is about 1.6 m. Storm conditions with H_s exceeding 4.5 m have occurred for less than 1 % of the time. Also, the average T_p is about 9.7s, with about 60 % of T_p values between 8s and 12s, and about 90 % of T_p values between 6s and 14s (Kulmar et al, 2005).

Kulmar *et al* (2005) predicted that the 100 year average recurrence interval (ARI) H_s exceeded a 1 hour and 6 hours duration offshore of Sydney was 9.5 m and 8.5 m respectively.

The predominant wave direction offshore of the study area is from the SSE. Based on all data collected at the directional Sydney Waverider buoy to the end of 2004, Kulmar et al (2005) found that about 31 % of waves were from the SSE, 19 % from the S, and 16 % from the SE. Furthermore, the SSE direction is dominant for larger waves.

1.1.2 Wave Transformation

As waves approach the shore from deep water, they may be transformed by the processes of refraction, shoaling, diffraction, attenuation, reflection and breaking. At the proposed water

[1] The significant wave height is the average height of the highest one-third of the waves in a particular record. The peak spectral wave period is determined by the inverse of the frequency at which the wave energy spectrum reaches its maximum.

[2] Given the relative uniformity of the wave climate along the NSW coast, wave statistics measured offshore of Sydney can be considered to be applicable to the study area.

depths for sinking of the Ex-HMAS Adelaide of 30 m to 35 m, the dominant wave transformation processes would be refraction and shoaling[3].

For example, under shoaling only (assuming a wave period of 10s and linear wave theory), a 9.5 m height wave in 80 m water depth has a height of 8.9 m and 8.8 m in 35 m and 30 m water depth respectively. For a 15s wave period, a 9.5 m height wave in 80 m water depth has a height of 9.5 m and 9.7 m in 35 m and 30 m water depth respectively. During any detailed assessment of the proposed Ex-HMAS Adelaide sinking, it would be necessary to consider the particular design wave conditions at the sinking site.

It would also be necessary to assess the potential for the sunken ship itself to alter wave patterns (in particular refraction) and therefore affect nearshore coastal processes such as longshore sediment transport and wave focussing. This would most conveniently be undertaken utilising a numerical wave transformation model that could resolve the sharp change in bathymetry caused by the scuttled ship sitting on the seabed.

Any potential effects would most likely be minimised by placement of the ship in deeper water and aligned into the dominant wave direction from the SSE (ie bow facing the SSE)[4]. However, ship alignment selection would also require assessment of the nearshore areas most affected by the ship placement. For example, there is likely to be less concern with altered wave patterns in nearshore rocky areas south of Broken Head and The Skillion, compared to affecting sand transport on Avoca Beach. That stated, issues such as wave focussing affecting rock fishing areas and potential advantages in altering the wave climate to reduce coastline hazards at sandy beaches are potential complexities that may alter the recommended ship alignment (that could be considered in a more detailed assessment)[5].

It can be noted that Geomarine (1993), in assessing the effects of offshore dredging in Sydney on nearshore wave climates, developed depth limit criteria such that there would be no measurable impact on shorelines. They found that a 25 m and 35 m depth limit offshore of rocky and sandy areas respectively was acceptable, for a 5 m extraction depth. Although the proposed ship sinking is a different concept (a variably shaped structure approximately 12 m to 18 m high on the seabed[6], rather than a dredged hole), this gives some indication that at the proposed depths around 30 m to 35 m there may be some influence on nearshore wave climate. Site specific detailed numerical modelling would be required to quantify any potential effects.

1.1.3 Wave Driven Currents and Forces

Waves also generate orbital velocities and accelerations in the water column below. At a particular location, the maximum horizontal velocity in the direction of wave propagation occurs at the wave crest, while the maximum horizontal velocity in the opposite direction to

---

[3] Note that all depths referred to herein are assumed to be average depths. Given the length of the Ex-HMAS Adelaide, scuttling at a particular average depth (depending on the ship orientation) may actually mean the ship traverses a depth variation of about 2m.

[4] There is likely to be a small advantage in placing the bow (rather than stern) into the dominant wave direction as the Ex-HMAS Adelaide is generally higher towards the bow, and the mainmast (highest point on the ship) is closer to the bow (distance of 64m) than the stern (distance of 74m). Further, with the bow facing the dominant wave direction, wave loading on the vessel would be less.

[5] Local currents would also be a consideration. For example, if oceanographic currents at the scuttling site are typically aligned in a particular direction, it may be warranted to align the ship parallel to these currents (depending on their magnitude relative to wave driven effects).

[6] Ignoring the mainmast and other masts.

wave propagation occurs at the wave trough. In between, velocities vary through all directions between vertical and horizontal.

Knowledge of velocities and accelerations allows the calculation of hydrodynamic wave forces (drag and inertial forces), which would be determined as part of any detailed assessment of the proposed sinking[7]. This would be necessary to ensure that the sunken ship and its components would be stable under storm wave conditions. Completion of this assessment would require knowledge of the detailed dimensions of the sunken ship, including appurtenances[8], also allowing for the thickness of any marine growth. Ship components of particular potential weakness would include the skeletal mainmast, other masts, and other relatively thin members protruding vertically above the ship superstructure (that have not been designed for wave loading).

WorleyParsons has an Advanced Analysis Group that has experience in determining wave and current forces on underwater offshore structures. Knowledge of the wave climates and oceanographic conditions at locations where Navy vessels have previously been sunk would also be useful in approximately predicting stability[9].

That stated, it can be generalised that for the 100 year ARI wave climate in the study area, maximum horizontal velocities at the top of the main ship superstructure would be in the order of about 1.7 m to 1.9 m/s (at the proposed depth ranges of 30 m to 35 m, assuming an 18 m structure height and linear wave theory[10], the smaller velocities applying at larger depths). At the water surface, maximum horizontal velocities would be in the order of 3.4 m/s. The drag force on a member caused by waves is proportional to the velocity squared. Generally speaking (for the same foundation conditions), larger depths would be favoured for stability as dynamic pressures under waves would be lower.

Note that although velocities would be smaller at larger depths, overall pressures generally increase with depth due to the effect of hydrostatic pressure. Hydrostatic pressure is not an issue with regard to the overall stability of the sunken ship, as it is equal in all directions at a given depth. However, stresses in individual hollow members on the ship would be affected by hydrostatic pressures (differential pressures) if the members were not filled with water of the same density as the ambient ocean.

1.2 Water Levels

The main factor that contributes to still water level movement offshore of NSW (offshore of the wave breaking zone, as per the study area) is astronomical tide. Barometric pressure changes also affect oceanic water levels amongst other oceanographic effects.

Astronomical tide is the regular rise and fall of sea level in response to the gravitational attraction of the sun, moon and planets, and the rotational effect due to the spin of the earth

---

[7] Additional pressures caused by oceanographic currents (Section 1.4) would also need to be considered in the estimation of the applied forces as part of the structural analysis.

[8] Such appurtenances could include sacrificial anodes to reduce the rate of corrosion of the steel components of the ship.

[9] For example, ex *HMAS Swan* was sunk in a depth of about 31m at Geographe Bay (around 220 km southwest of Perth) in 1997. The ex *HMAS Perth* was sunk in a depth of about 38m offshore of Albany in Western Australia in 2001. The ex *HMAS Hobart* was sunk in a depth of about 30m at Yankalilla Bay (South Australia) in 2002. The ex *HMAS Brisbane* was sunk in a depth of about 27m offshore of the Sunshine Coast (Queensland) in 2005.

[10] Assuming a wave height of 9.5m and wave period of 10s. Consideration should be given to using higher order wave theories so as to define wave loading for detailed design.

on its axis. Tides along the NSW coastline are semi-diurnal, with high and low water approximately equally spaced in time and occurring twice daily (that is, on average, there are two high tides and two low tides in any 24 hour period). There is also significant diurnal inequality in NSW coast tides, a difference in height of the two high waters or the two low waters of each tidal day.

Astronomical tide typically varies between about –1m AHD (Lowest Astronomical Tide) and 1m AHD (Highest Astronomical Tide) along the NSW coast, with 0 m AHD close to mean sea level[11]. On the NSW coast, these and other tidal planes vary approximately as shown in **Table 1**[12].

Table 1: Approximate tidal planes in NSW

Tidal Plane	Water Level (m AHD)
Lowest Astronomical Tide	-1.0
Mean Low Water Springs	-0.6
Mean Low Water	-0.5
Mean Low Water Neaps	-0.4
Mean Sea Level	0.0
Mean High Water Neaps	0.4
Mean High Water	0.5
Mean High Water Springs	0.6
Highest Astronomical Tide	1.0

Barometric pressure changes cause localised vertical rises and falls in the still water level due to a reduction and increase respectively in atmospheric pressure. The variation in water level is approximately 0.1 m for each 10 hectopascal difference to normal barometric pressure of 1013 hPa (MHL, 1992). Note that hectopascals are approximately equivalent to millibars.

Whatever the water level, it would be expected that the mainmast of the sunken vessel would be an obstruction to navigation, protruding about 7 m to 12 m above the waterline at mean sea level (depending on the depth to the bed at the scuttling site, and magnitude of embedment of the ship into the seabed)[13]. The top of the main superstructure would on average be at a depth of about 12 m to 17 m, so would also be a restriction to navigation for some commercial vessels (eg vessels using the Port of Newcastle have drafts of up to about 17.5 m). That stated, these vessel types would be unlikely to navigate near the scuttled ship, as (for example) vessels using Port Newcastle are generally required to wait at least 3 nautical miles (5.6 km) offshore, which would be in depths of about 50 m or greater.

[11] AHD stands for Australian Height Datum.

[12] Spring tides occur twice per month (during new or full moons) and result in higher high tides and lower low tides (that is, a larger tidal range, compared to the average). Neap tides also occur twice per month (during quarter moons) and result in lower high tides and higher low tides (that is, a smaller tidal range, compared to the average). The height of the spring tide also varies throughout the year and due to the lunar Metonic cycle, the 18.6 period over which the moon returns to the same position relative to the earth (MHL, 1992).

[13] The foremast would also be within 5m of the water surface for most of the time.

To avoid navigation issues, the ship mainmast would need to be clearly lit and surrounded by navigation markers. Given the difficultly of maintaining such markers and lighting in a high energy open coast environment, it is suggested that consideration is given to removing the mainmast (and other major vertically protruding features) from the Ex-HMAS Adelaide prior to scuttling.

1.3 Coastal Storms

The NSW coastline is subject to intense tropical and non-tropical storms at irregular intervals. The Public Works Department [PWD] (1985, 1986) has categorised coastal storms in NSW on the basis of estimated offshore significant wave heights. Category X storms were defined as those with an estimated $H_s \geq$ 6m, and Category A storms were as defined as those with 5 m $\leq H_s <$ 6 m.

When combined with available Waverider buoy data, it is evident that over the 1880 to 2003 period there was 1 Category X event every 2.3 years (on average). However, the time period between storms has not been uniform. For example, there were no Category X storms from 1880-1891, 1900-1907, 1946-1951, 1960-1965, 1969-1973 and 1979-1985. Also, there were 3 Category X storms in both 1978 and 1990.

PWD (1985, 1986) recognised 6 different major storm types which impacted on the NSW coast, namely, tropical cyclones, easterly trough lows, inland trough lows, continental lows, southern secondary lows, and anticyclonic intensification. PWD (1985, 1986) found that, on average:

- the Central Coast (incorporating the study area) and South Coast had more storms than areas further north in NSW;
- southern secondary lows and easterly trough lows were the dominant storm types in the study area; and,
- most storms in the study area occurred in Autumn and Winter, in particular due to the prevalence of southern secondary lows and easterly trough lows during these seasons.

This seasonal variation can be confirmed by analysis of the Sydney directional Waverider buoy data collected from 1992 to 2003, derived from MHL (2004). The relative wave energy[14] for storms with an H_s exceeding 3 m for each month is shown in **Figure 1**.

[14] A relative wave energy was defined relative to a value of 1.0 for an average month. Therefore, values exceeding 1.0 indicate months with greater wave energy than the monthly average. Conversely, values less than 1.0 indicate months with less wave energy than the monthly average.

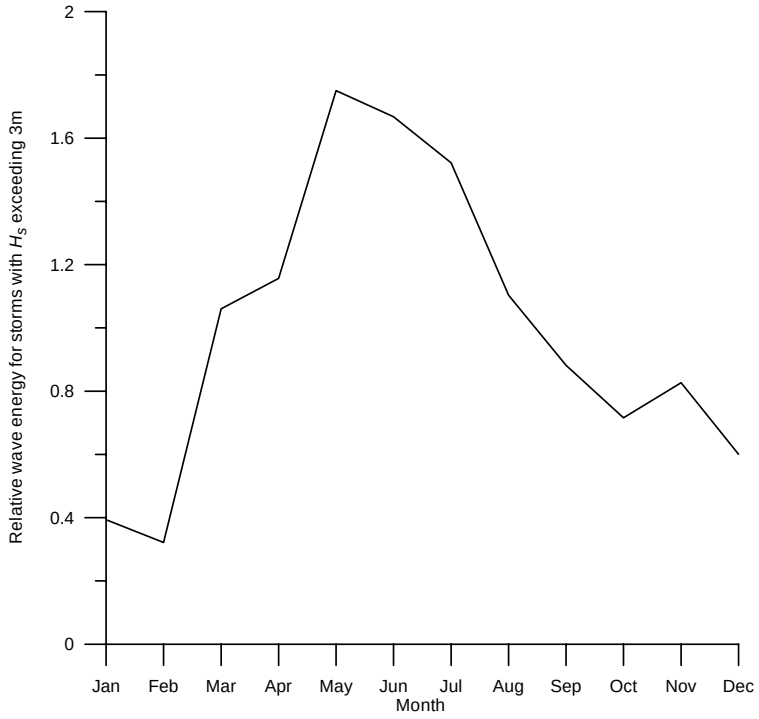

Figure 1: Relative monthly wave energy for storms offshore of Sydney, based on data collected from 1992 to 2003

It is evident that the Autumn and Winter seasons have been the most stormy, with May, June and July having been the most stormy months. The Winter period has been more than three times more stormy than Summer, with January and February being the least stormy months.

Knowledge of these seasonal variations may assist in planning the ship scuttling operations. For example, it would be most likely that wave conditions would be calmer from October to February, which would be favourable for deployment. However, coastal storms can occur at any time, and whatever period is chosen for deployment it would be necessary to refer to Bureau of Meteorology coastal waters forecasts and the like to ensure that conditions would be acceptable.

Structural analysis of the deployment process would be essential to ensure that structural integrity would not be compromised during the sinking operation.

1.4 Oceanographic Effects

1.4.1 Preamble

The main processes causing coastal circulation in the Sydney region (generally applicable to the study area) include the East Australia Current, coastal trapped waves, winds, internal waves, and outflows from major estuaries. These processes are each dynamically distinct and occur on differing time and space scales, such that the net current velocity and direction at a particular location can vary depending on the dominant processes occurring at the time (Middleton *et al*, 1997).

As further described by Middleton *et al* (1997), longer period currents are generally directed parallel to the bottom contours, with speeds usually less than 1m/s (although sometimes exceeding 1.5m/s)[15]. These currents generally occur in a depth range of about 20 m to 50 m. In general, currents would be expected to reduce with depth in the water column, particularly due to the East Australian Current and wind-driven currents being much stronger at the water surface (Geomarine, 1993).

1.4.2 East Australia Current

The East Australia Current (EAC) transports warmer waters from the Coral Sea southwards into the Tasman Sea. Although the EAC is strong and persistent offshore of northern NSW, it sometimes separates from the continental shelf[16] north of the study area, around Seal Rocks (about 90 km north of Newcastle)[17]. The EAC can also spawn large warm or cold core eddies that break off from the main EAC and move slowly southward. However, a typical EAC structure cannot be defined.

Roughan and Middleton (2004) noted that although currents upstream of the separation point are generally southward and strong, downstream currents are highly variable in both strength (generally lower speed than upstream) and direction. Encroachment of the EAC upon the coast was seen by Roughan and Middleton (2004) to have a profound effect on the coastal waters, accelerating the southward (alongshore) currents and decreasing the temperature in the bottom boundary layer by up to 5 °C.

The EAC is generally strongest in summer, peaking in February, and weakest (by as much as half the flow) in winter (CSIRO Marine Research, 2000).

Australian Hydrographic Service charts (AUS Charts) available for the study area include notes on the EAC. For example, on AUS809 it is noted that the EAC is up to 2.1 m/s.

1.4.3 Wind-Driven Currents

Wind-driven currents also occur. For winds from the NE, surface waters are driven offshore through Ekman transport, which can drive deeper (colder and more nutrient rich) waters upward towards the surface near the coast, with a current in the direction of the wind. Conversely, for winds from the SW, surface waters are driven onshore through Ekman transport, which can drive warmer waters towards the coast and downward, again with a current in the direction of the wind (Middleton *et al*, 1997).

1.4.4 Coastal Trapped Waves

Coastal trapped waves are current oscillations which move northward from Bass Strait over time scales of 7 to 20 days, affecting the study area about two days after being generated by strong winds in Bass Strait. They can cause either northward or southward flowing currents in the nearshore region (Middleton *et al*, 1997).

---

[15] Cresswell (1998) noted that the EAC speed was up to 2m/s between 28°S and 33°S (that is all of NSW to just south of Newcastle).

[16] The continental shelf is the relatively gently sloping undersea area surrounding a continent at depths of up to 200m, at the edge of which the continental slope drops steeply to the ocean floor . The continental shelf of NSW is narrow, with an average width of about 25 km, and at midshelf it is 60 to 80 m deep (Cresswell, 1998).

[17] The separation point is variable. For example, Godfrey et al (1980) stated that the separation point was generally between 30°S and 34°S, which covers a distance of about 430km. However, most authors note that the usual separation point is around Seal Rocks to Port Stephens.

1.4.5 Internal Waves

Internal waves are disturbances which propagate along the interface between layers of water with different densities. In the study area, internal waves occur during most of the year when there is significant temperature stratification. They are manifested as periodic oscillations in currents and temperature, which are due to the orbital motions associated with waves.

Internal wave energy is concentrated in two bands, namely tidal frequencies and at a period of 10 to 30 minutes. The former, known as internal tides, cause currents of about 0.1 m/s and displacements of the thermocline of up to 20 m to 30 m, with the latter generally having a smaller effect (Middleton *et al*, 1997).

1.4.6 Estuarine Influences

Major estuaries nearest the study area include Tuggerah Lakes (70 km^2) about 14 km north, and Broken Bay (145 km^2) about 12 km south, refer to Roy *et al* (2001). Tidal outflows from these estuaries may have significant effects on current patterns, temperature and salinity extending several kilometres from the coastline. That stated, these estuarine systems are unlikely to significantly influence oceanographic processes in the study area.

1.4.7 Further Information

If required, details on currents at the proposed scuttling location may be enhanced through discussions with fishermen and other marine operators in the area, installation of instrumentation, and reference to Australian Pilot publications.

Also, numerous studies completed by Patterson Britton & Partners as part of investigations of the disposal of dredged spoil at Newcastle provide some details on currents in this area to the north of the study area (as well as details on seabed conditions, sediment movement etc). For example, refer to Patterson Britton & Partners (1989, 1992).

1.5 Sediment Transport

The majority of sediment transport along the NSW coast occurs between where waves break and the shoreline, inshore from the depth limits under consideration in this investigation.

Onshore/offshore (also known as cross-shore) sand movement is caused by natural variations in wave climate and water level. The offshore movement of sand is usually referred to as storm erosion. This onshore/offshore movement of sand results in short term fluctuations in the width of the beach profile.

During storms with relatively large waves and elevated water levels, beach sand moves offshore to form bars. This process typically occurs over a period of hours to days. When extended periods of calmer waves occur, the material held in these bars migrates onshore to rebuild the beach. Depending on the magnitude of the preceding storm, this beach building process can occur over a time scale of days to years.

Nielsen (1994a) found that, based on a synthesis of field and laboratory data and analytical studies (particularly offshore of SE Australia), there were consistent limits of subaqueous beach fluctuations, namely water depths (relative to AHD) of:

- 12 m ± 4 m being the limit of significant wave breaking and beach fluctuations (the position of the offshore face of surf zone bars);

- 22 m ± 4 m being the absolute limit of sand transport under extreme storm events; and,
- 30 m ± 5 m being the potential limit of reworking and onshore transport of beach sized sand under wave action alone (that is, the seaward limit of the foundation toe of the beach).

Nielsen (1994a) found that maximum seabed level variations were less than 0.2 m at depths exceeding 15 m.

Sedimentological data consistently shows distinct changes in the characteristics of sediments with water depth offshore of NSW. These changes include variations in grain size, sorting, carbonate content and colour. There are two distinctive sediment units immediately offshore of NSW, namely Nearshore Sand, and (further offshore and coarser) Inner Shelf Sand (also known as Shelf Plain Relict or Palimpsest Sand). Nearshore Sand is further subdivided into Inner and Outer Nearshore Sand units.

The boundary between Inner and Outer Nearshore Sand is typically found at about 11 m to 15 m depth (relative to AHD), while the boundary to Inner Shelf Sand is usually at 18 m to 26 m depth (consistent with the 22 m ± 4 m limit noted above). The boundary between Nearshore Sands and Inner Shelf Sands corresponds to those parts of the seabed considered to be active and relict. That is, there is no exchange of beach sediments with those of the Inner Shelf at depths exceeding at 22 m ± 4 m (Nielsen, 1994a).

Nielsen (1994b) has described the mechanism and depth limits for sediment transport in the study area and surrounding region under the action of waves and currents. Essentially, the back and forth motion of waves can place sediment into suspension, with net transport occurring in the presence of a superimposed steady current[18].

The sediment in the region including the study area in depths between about 25 m and 75 m is generally quartzose marine sand, medium to fine grained, moderately sorted, with variable shell content and up to about 20 % mud content (Nielsen, 1994b). Rock reefs are evident on the seabed between these sand bodies, for example offshore of Broken Head and The Skillion, and offshore of the southern end of Avoca Beach (Public Works Department, 1989).

Sand waves evident in the region including the study area between 25 m and 75 m depth are consistent with a general current structure flowing to the south. Wave-generated ripples are found on the seabed to depths of about 60 m, causing reworking of the seabed surface to depths of about 0.2 m on a daily basis at 25 m depth, and for about 25 % of the time at 60 m depth (Nielsen, 1994b).

However, Nielsen (1994b) found that there was negligible net sediment transport beyond 35 m depth.

In summary, at the depth limits of 30 m to 35 m for the proposed scuttling, there is unlikely to be sediment movement such that there would be significant regional seabed lowering or raising at the ship, or capture of sediment that would otherwise be worked on to beaches. To be conservative, some may argue that the scuttled ship should be in depths towards the 35 m depth limit, to ensure no possible interaction with nearshore sediment processes[19].

[18] At times, currents alone can be strong enough to transport sand.

[19] This issue would need to be addressed in a site specific manner as part of a detailed assessment of the proposed site.

However, allowance for additional localised seabed scour due to currents and waves interacting with the scuttled ship would need to be made as part of stability calculations in any detailed assessment carried out for the operation.

1.6 Synthesis

Based on a consideration of the coastal and oceanographic processes occurring in the study area, it is evident that a deeper scuttling of the Ex-HMAS Adelaide within the 30 m to 35 m depth limits would generally be favoured. This is because, at deeper depths:

- the scuttled ship would be less likely to affect wave refraction patterns and the like;
- wave-driven currents are smaller and therefore so are dynamic forces on the ship;
- navigation is less likely to be restricted[20];
- oceanographic currents are likely to be smaller and,
- sediment transport is more likely to be negligible.

That stated, detailed analysis and modelling may find that a ship placed at 30 m depth is stable under extreme waves and currents, and does not significantly affect the nearshore wave climate.

It is suggested that consideration is given to removal of the mainmast and other protrusions from the Ex-HMAS Adelaide that would be close to the water surface at the scuttling site, prior to sinking. This would reduce the risk of damage and break up of these components under wave loading, and would predominantly remove the navigation obstruction at the site.

[20] However, if the mainmast and other vertical protrusions are not removed from the vessel prior to sinking, a navigation exclusion zone would have to be administered no matter what depth limit was adopted.

2.0 REFERENCES

Coastal & Marine Geosciences (1999), "Gosford City Beach Nourishment Feasibility Study, Stage 2, Investigation of Marine Sand Resources", *Report No. GCC99_1*, for NSW Department of Public Works and Services Manly Hydraulics Laboratory, September

Cresswell. George (1998), "Satellite infrared images of the coastal and offshore waters of NSW", *Report GC-NPWS-1998*, CSIRO Marine Research, Hobart, Tasmania, for NSW Marine Parks Authority, July

CSIRO Marine Research (2000), "The East Australian Current", Information Sheet No. 37, February

Geomarine (1993), "Marine Aggregate Proposal, Coastal Processes", *Geomarine Report Number 50-002*-R10, Volume 1 of 3, July, for Metromix Pty Ltd

Godfrey JS; Cresswell GR; Boyd R; Golding, TJ and AF Pearce (1980), "The separation of the East Australian Current", *Journal of Physical Oceanography*, Volume 10, No. 3, March, pp. 430-440

Kulmar, M., Lord, D and Sanderson, B. (2005). "Future Directions for Wave Data Collection in New South Wales", *Proceedings of the 17th Australasian Conference on Coastal and Ocean Engineering and the 10th Australasian Port and Harbour Conference, 2005 Coasts and Ports Australasian Conference*, edited by M Townsend and D Walker, conference held from 20-23 September at Adelaide, South Australia, Institution of Engineers, Australia, ISBN 0 646 45130 8, pp. 167-172

Lord, Douglas and Mark Kulmar (2001), "The 1974 Storms Revisited: 25 Years Experience in Ocean Wave Measurement Along the South-East Australian Coast", *Coastal Engineering 2000, Proceedings of the 27th International Conference on Coastal and Ocean Engineering*, Sydney, 16-21 July 2000, Volume One, pp. 559-572

Manly Hydraulics Laboratory [MHL] (1992), "Mid New South Wales Coastal Region Tide-Storm Surge Analysis", *MHL Report No. 621*, Public Works Department, PWD Report No. 92028, 2 October, ISBN 0 7305 9420 3

Manly Hydraulics Laboratory [MHL] (2002), "Gosford City Beach Nourishment Feasibility Study, Stage 2, Detailed Assessment of Potential Sand Sources", *Report No. MHL929*, Department of Public Works and Services (DPWS) Report No. 98041, February, ISBN0731307933

Manly Hydraulics Laboratory [MHL] (2004), Sydney Directional Storm Time Series, updated to 31December 2003, provided by Mark Kulmar on 24 November

McEnally, Julie and Lawrie McEnally (2004), *Fishing Guide to the Central Coast and North Coast of New South Wales*

Middleton, Jason H; Cox, Deborah and Peter Tate (1997), "The Oceanography of the Sydney Region", *Marine Pollution Bulletin*, Volume 33, No. 7-12, pp. 124-131

Nielsen, AF (1994a), "Subaqueous Beach Fluctuations on the Australian South-Eastern Seaboard", *Australian Civil Engineering Transactions*, Volume CE36, No. 1, January, Institution of Engineers Australia, ISSN 0819-0259, pp. 57-67

Nielsen, AF (1994b), "Sediment transport on the Inner Continental Shelf, Sydney, Australia", *Australian Civil Engineering Transactions*, Volume CE36, No. 4, November, Institution of Engineers Australia, ISSN 0819-0259, pp. 309-317

Patterson Britton & Partners (1989), *Mobility Study, Dumped Dredge Spoil, Port of Newcastle*, J585/R330, for MSB Hunter Ports Authority, December

Patterson Britton & Partners (1992), *Mobility Study, Dumped Dredge Spoil, Port of Newcastle, Stage 2*, J585.01/R765, for MSB Hunter Ports Authority, November

Public Works Department [PWD] (1985), "Elevated Ocean Levels, Storms Affecting NSW Coast 1880-1980", *PWD Report No. 85041*, Coastal Branch, prepared by Blain Bremner and Williams Pty Ltd, in conjunction with Weatherex Meteorological Services Pty Ltd, December

Public Works Department [PWD] (1986), "Elevated Ocean Levels, Storms Affecting NSW Coast 1980-1985", *PWD Report No. 86026*, Coastal Branch, prepared by Lawson and Treloar Pty Ltd, in conjunction with Weatherex Meteorological Services Pty Ltd, August

Public Works Department [PWD] (1989), *Gosford 83042-1001 Seabed Information Chart*

Roughan, M and JH Middleton (2004), "On the East Australian Current: variability, encroachment, and upwelling", *Journal of Geophysical Research - Oceans*, Volume 109, No. C7, Article 10.1029/2003JC001833

Roy, PS; Williams, RJ; Jones, AR; Yassinid, I; Gibbs, PJ; Coates, B; West, RJ; Scanes, PR; Hudson, JP and S Nichol (2001), "Structure and Function of South-east Australian Estuaries", *Estuarine, Coastal and Shelf Science*, Volume 53, pp. 351–384, Academic Press