Clontarf / Bantry Bay

Data Compilation
&
Estuary Processes Study

FINAL REPORT

Part – III (All Appendices)

August, 2007

Completed as part of the Clontarf / Bantry Bay Estuary Management Planning Process

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i EXECUTIVE SUMMARY

NSW has over 130 estuaries that vary in size from small coastal creeks and lagoons to large lakes and rivers. Collectively, they are immensely valuable from ecological, social and economic perspective. These estuaries contribute $400 M to the State's economy per annum (DNR 2006). The natural beauty of estuaries attracts many visitors and development, and as a result they are under constant pressure. To improve the management of these estuaries, the NSW Department of Environment & Climate Change (DECC) administers the Estuary Management Program. This program aims to provide a strategic approach to the sustainable management of estuaries and sets out a clearly defined process, culminating in the production and implementation of a comprehensive Estuary Management Plan.

Manly is known to people distinctively for its beaches and foreshore areas. For this reason, it is important that the waters and natural features around these beaches and foreshores are nurtured and protected. In line with efforts of NSW State Government, Manly Council has also embarked on planning and management of coastal and estuarine areas. The importance of coastal and estuarine management has been highlighted in all key policy, strategy, plan and management documents adopted by the Manly Council. Manly Lagoon Estuary Management Plan was adopted back in 1998. Manly Council has, since long, adopted a staged approach to cover the entire Manly foreshore. Coastal Zone Management Plans have been prepared, or are being prepared, for the following areas: Forty Baskets, Little Manly, Manly Cove, North Harbour, Cabbage Tree Bay and Manly Ocean Beach. The preparation of the Clontarf / Bantry Bay Estuary Management Plan will complete the coverage of the entire foreshore.

The Study

One of the key steps in the formulation of the Estuary Management Plan (EMP) is the preparation of an Estuary Processes Study, aimed at determining the baseline condition of the various estuarine processes (eg- physical, biological, chemical) and the interactions between these processes. This document aims to provide information on the baseline conditions in the Clontarf / Bantry Bay section of the Middle Harbour estuary.

To support the formulation of the EMP, the 'Clontarf / Bantry Bay Estuary Management Working Group' was established in May 2006 with representations from the Manly Council, community Precincts, Government organisations, Manly Council's Scientific Advisory Panel, neighbouring councils, community and Aboriginal community. An *Internal Staff Working Group* was also formed to support the development of the Clontarf / Bantry Bay Estuary Management Plan through expert contributions.

An extensive public consultation process and awareness campaign was undertaken through a variety of mechanisms including display panels, Manly Council's webpage, information through Precinct Newsletters, formal questionnaires and organized Field Days.

This study has been developed in-house with contribution from the 'Internal Working Group' under the guidance of the 'Clontarf / Bantry Bay Estuary Management Working Group'. The study report has gone through an extensive peer review including by state agencies.

Study Area

This study area relates to the northern portion of the Middle Harbour (part of the greater Port Jackson / Sydney Harbour) estuary and foreshore that corresponds with the Manly Local Government Area boundary. It covers an area of 350 hectares between Castle Rock and Bantry Bay and includes parts of Balgowlah Heights, Clontarf and Seaforth suburbs. The Spit Bridge, a landmark connecting northern beaches with Sydney, is located halfway along the foreshore of the study area. Population of the study area, according to 2001 census, is 5,873.

The entire study area is covered within the Sydney Harbour Foreshores and Waterways Area and excluded from the legally defined NSW coastal zone. The entire study area is also covered within the 'Sydney Metropolitan Catchment Area'.

The current land use remains predominantly residential development (65.5%), followed by road surfaces (22.0%) and open spaces and parks (10.2%). Pockets of bushland remain scattered throughout the area (which total 18.5 hectares in size), occurring mostly around the immediate estuary foreshore. Manly Scenic Walkway and Harbour to Hawkesbury Walking Tracks run through the study area. The estuary is used actively for walking, swimming, boating, sailing and passive recreation (eg- reading, meditation, picnicking). In addition, the estuary is also popular for kayaking, recreational fishing, sunbathing and walking dogs.

The study area is zoned under both the *Manly Local Environment Plan* 1988 and the *Sydney Regional Environmental Plan - Sydney Harbour Catchments 2005* or simply the Harbour REP. The Manly LEP establishes land use zones within the study area as zone 2 – Residential, 3 – Business Zone, 5 – Special Uses Zone, 6 - Open Space and Zone 8 – National Parks existing. The foreshores and waterways of the study area are located in five of the nine zones under Sydney Harbour REP: W1 (Maritime Waters), W2 (Environment Protection), W5 (Water Recreation), W6 (Scenic Waters – Active Use) and W8 (Scenic Waters – Passive Use).

The study area has a rich history, beginning with extensive Aboriginal occupation, which is evidenced through the many middens that are still present. The area was used extensively by the Aboriginals, known locally as the Gayemal clan of the Guringai tribe. The oldest Aboriginal site known in the Manly LGA is dated to about 4100 years before present. There are 22 recorded Aboriginal sites within the study area. Following European settlement in Sydney, the study area was slowly developed, until improved access made the area more desirable. In 1850 a punt began running from the Spit giving easier access to the north side. Access was further enhanced in 1924 with the opening of the first Spit Bridge. By the 1970s the area was already extensively developed.

Natural Environment – Physical Processes

The estuary within the study area exhibits semidiurnal tidal characteristics, with two high and two low tides each day. The area is not fed by any permanent creeks; however various water courses provide freshwater inflows during and after rain. In periods of wet weather, the estuary becomes stratified with the more buoyant fresh water sitting as a thin layer on the surface of the salt water.

Groundwater is an integral part of the “water cycle” and maintains the dynamics of estuarine and near-shore marine water bodies. The major aquifer class, in the study area, is consolidated porous rocks containing limited quantities of groundwater. However along the foreshores there occurs the aquifer termed ‘unconsolidated sediments’. This aquifer contains significant groundwater resources with a well defined water table that is responsive to recharge events, and even tidal influences in some cases.

Wind waves generated in Middle Harbour are generally less than 0.1m in height. Ocean swell waves penetrate lower Middle Harbour through the heads of Sydney Harbour, and undergo severe refraction and diffraction. The only place in the study area that is subject to waves from a consistent direction is the lower half (Castle Rock Beach to Sandy Bay), where ocean swell waves run along the shore. Sediment has been observed to move along the shore in the same direction, providing possible evidence of a longshore current.

Significant storm events affecting the Middle Harbour area are known to have occurred in April 1893, June 1923 and May-June 1974. The 1974 storm reported wall collapse near Middle Harbour Yacht Club and minor beach erosion at the Spit and Clontarf. The study area experienced waves and high winds from a recent storm on June 9-10, 2007 which resulted in a cruiser washing ashore at Clontarf but no serious erosion. The study area also experienced the impact of a tsunami on May 22, 1960 when a strip 100 yards by 60 yards wide was swept away from Clontarf Reserve Point Park.

From the Spit Bridge to the north western extremity of the study area, the foreshore is predominantly stable rock, with estuarine mud on the sea floor. This area is beyond the normal limit of ocean waves, and is reasonably deep, therefore creating a relatively stable sedimentary environment. However, the lower reaches, from Castle Rock Beach to the Spit Bridge, consists largely of unstable sandy shores, with a mixture of marine sand and estuarine mud on the sea floor. The estuary in this section consists of both a shallow sand bar and a deep channel. The marina at Clontarf lies directly in the path of the sand transport corridor between the tidal delta and Sandy Bay. However, the beach profile appears to have been modified from its natural state, due to the irregular shape of the shoreline between Clontarf Reserve and Sandy Bay. The large sand flat of Sandy Bay

transforms into a narrow beach with a steep drop-off on either side of Clontarf Marina, and then back into a sand flat to the south of the marina. There are many forces impacting on this part of the estuary, creating a complex system.

Natural Environment – Ecological Processes

The ecosystems within the study area are highly fragmented and have signs of the many pressures placed on them through development and high usage.

The marine environment within the study area has a diverse range of habitats. There are significant seagrass beds within the study area: the largest bed is adjacent to Castle Rock Beach and reasonably large meadows exist at Clontarf and Sandy Bay. Compared to the past, large losses of seagrass have been reported. There are several relatively deep holes within the mud basin section that provide habitat, with the deepest located upstream of the Spit Bridge. The mud basin provides habitat for various species, including invertebrates such as worms and molluscs. Over 570 species of fish have been recorded in greater Sydney Harbour, and it is likely that a large proportion of these are also present within the study area. The list includes 3 endangered, 5 vulnerable and 18 protected species.

The intertidal area within the study area has a range of habitats including rocky reefs and platforms, sandy beaches and mudflats, a few remaining mangroves and artificial habitat including seawalls, jetties and pontoons. The entire foreshore of the study area is protected as Intertidal Protected Area (IPA). Many types of algae (eg- red, green, brown) inhabit the intertidal zone, providing a food source for the many grazing invertebrates. Numerous types of invertebrates, such as worms, crabs and molluscs, can be found in the sediment. There is only one small pocket and few individual mangroves remaining within the study area. However, no salt marsh has been identified. A total of 62 species are known to be present in or directly adjacent to (and hence expected to also be in) the study area. The majority of these species are invertebrates. The Little Penguin is often sighted within the study area but no information is available on its nesting place. It feeds in the estuary during the day and nests on land during the night.

The terrestrial environment within the study area has seen the largest change. Bushland reserves occur in a total 18.5 hectares and are scattered throughout the study area. Six reserves have SEPP 19 status under EP&A Act, requiring preparation of management plans. Smaller patches of bushland on both public and private land do exist throughout, and in some places provide corridors between the reserves. There are seven specific vegetation communities present within these reserves. A total of 3 amphibian, 49 birds, 6 mammal and 13 reptile species have been recorded. Grey-headed Flying Fox (*Pteropus poliocephalus*) is the only threatened species recorded.

Human Interventions & Usage

Human activities have altered and modified the natural system of the study area. Foreshore development has been extensive. The first and major foreshore development in the study area happened with the construction of the Spit Bridge in 1924 (which was replaced by the existing bridge in 1958) and some other developments prior to this at the site: first punt operation in 1849, ferry operation in 1880 and tram services in 1900. Seawalls, both public and private, exist throughout the study area. Total length of seawalls is 2.4km, that approximately 46% of the foreshore length. Swimming baths/enclosures, Clontarf Marina and walkways including Manly Scenic Walkway are some other developments on the shore. Public access to foreshore is available at several points. There is no public pontoon/jetty in the study area but one to be constructed soon. There are sailing and yacht clubs providing boating facilities and contributing to estuary use through a number of events including racing, training etc. Manly Council is extracting 1.64 mega litres of groundwater at a depth of 6.1m for irrigation of Clontarf Reserve. Many private properties are also abstracting groundwater. Stormwater now flows through 16.0 km artificial drainage networks. The estuary is used actively for walking, swimming, boating & sailing and passive recreation (eg- reading, meditation, picnicking) with reasonable degree of use for kayaking, recreational fishing, sunbathing and walking dogs. Dogs are allowed on a leash in the Clontarf Reserve. These alterations have all impacted the natural environment.

There exist conflicts between different user groups and the impacts that competing users have on the environment. Examples of some of these conflicts identified include:

- Seawalls for protection of properties versus its damaging impact on natural ecosystem
- Groundwater abstraction and possible saline water intrusion in aquifer
- Beach raking for safety versus its impact on invertebrates
- Dog walking off leash and impact on shore birds
- Powered and sailing boats and their wake impacting on seawalls and beach erosion
- Access to mooring versus their impact on seagrass beds, ability to spread *caulerpa taxifolia*
- Powered boats and the safety aspects for swimmers and kayakers
- Ad hoc boat storage and its impact on amenity and habitat:
- Ad hoc access ways to foreshore for convenience versus destruction of habitat.

Processes & Impacts

With most parts of the Clontarf/Bantry Bay EMP study area being highly urbanised, there is significant pressure placed on water quality health. Despite the reported improvements in water quality recently, pollution is indeed still evident, particularly in times of rain when stormwater transports terrestrial pollutants into the estuary. Loads of pollutants in the estuary from the study area have been estimated at 2250 kg/year of total nitrogen; 260 kg/year of total phosphorus; 180 kg/year of copper, 230 kg/year of lead, 490 kg/year of zinc, and 128,000 kg/year of sediment. Four Gross Pollutant Traps (GPTs) are currently installed in the Clontarf / Bantry Bay Catchments. The Department of Primary Industries has placed a ban on all commercial fishing within Sydney Harbour including the study area, because of the presence of elevated levels of dioxins in fish and crustaceans. Of the three swimming pool/baths, Sangrado bath is the worst in terms of bacterial contamination. There are 5 known sewer overflow locations within the study area.

The study area is used extensively by a variety of vessels, particularly between Castle Rock Beach and Seaforth Bluff. This section of the waterway is the only access between greater Sydney Harbour and upper Middle Harbour, so all vessels wishing to travel between the two must pass through. Boat generated waves over time can cause foreshore erosion and weaken sea walls. They can impact on habitat. Boating can, in addition, impact on water quality via spills, anti-foul paints, littering from boats and from marinas where boats are washed and fixed etc. A No Wash Zone is in place between Clontarf Point and Seaforth Bluff. An 8 knot speed limit zone is also in place, between Clontarf Point and d'Albora Marina (Mosman side of Spit Bridge).

Erosion in the study area occurs along beaches, in front of stormwater outlets, along ad hoc access tracks, and where foreshore protection structures such as seawalls are collapsing. Beach erosion has been experienced at 4 sections of Clontarf Beach and Sandy Bay with varying degrees of severity, and fluctuations over time. Accelerated erosion occurs as a result of the concentration of stormwater flows through artificial drainage networks. The study area, specially the Clontarf Swimming area, also regularly experience siltation. The study area is susceptible to slope and cliff instability, with a large landslip having occurred at Seaforth Crescent in 1956.

An ecosystem health card has also been developed for the study area.

The study area will experience many of the impacts of climate change, with the low lying areas close to the foreshore likely to be subject to more of the impacts than the elevated areas. These impacts are likely to include: sea level rise; increases in extreme weather events; temperature increases; reductions in water availability; altered hydrology and increased flash flooding; and more frequent and more severe droughts (Hennessy et al, 2006).

Community Key Concerns

Concerns of the community were expressed through different means and at different occasions. More directly, a total of 120 survey forms were completed and returned throughout the consultation process. On marine based issues, water pollution, marine flora & fauna and conservation management issues, in broader perspectives, are of high concern of the community. Among land-based issues, pollution, storm water management, terrestrial flora & fauna, conservation management and foreshore walkway issues are of high concern. Climate change issue is also appeared to be of key concern.

Significance and Values of the Estuary

The Clontarf/Bantry Bay estuary is locally significant in its role as a habitat for native animals and plants, a provider of popular recreational resource for locals and visitors alike. The attraction of Clontarf/Bantry Bay is enhanced by its generally good water quality. Because of its scenic beauty and views, foreshores have already become highly sought after residential area. At present, 65% of the foreshore is under residential land use compared to 37% within Manly LGA. The Clontarf/Bantry Bay waterway has a very high economic value and is important to a range of stakeholders, ranging from local retailers to commercial tourism operators, real estate operators, boating services, marinas and support industries.

The study area is rich in Aboriginal cultural heritage giving it significance at the regional and state level. European cultural heritage is also an important feature of the study area with numerous heritage listed sites and buildings including public baths located along the shoreline, including Clontarf, Sangrado and Pickering Point. There exists several floras and fauna recorded as threatened, making the study area important.

The following values reflect attributes, activities and processes that are of importance to the community, and are the qualities on which the study area depends for its attractiveness, desirability, liveability and use.

- aesthetic values associated with a pleasant, appropriate and 'green' landscape character.
- physical values associated with estuary foreshore and processes. For example residents and visitors value being able to access and experience the foreshore and associated views.
- biophysical values associated with the protection and improvement of aquatic, inter-tidal and terrestrial environments. These include estuarine habitat, intertidal habitat, mixed rocky intertidal with sand, sandy beaches, sea grass beds, open forests, urban bush lands and reserves, mangrove forests and wetlands.
- cultural values associated with the area's indigenous and non-indigenous heritage and the identification of significant Aboriginal sites. The Aboriginal Heritage Office has recorded 22 Aboriginal sites within the study area.
- accessibility values associated with convenient access to all public areas. For example people value the ability for all people to access foreshores and enjoy the area.
- recreational values associated with an enjoyable environment for all users, visitors and local residents. For example people value being able to undertake various recreational activities in public places, both on land and on the estuary.
- Economic values associated with a number of economic activities.

Data Gaps & Further Studies Required

There exist various data gaps. These are related to sediment budget & movement, water quality, cliff & seawall stability, groundwater abstraction, loss of seagrass, little penguins and climate change issues. DECC will undertake photogrammetry of sandy shorelines (and possibly further hydro surveys) to better understand sediment processes.

ii ABBREVIATIONS

ANZECC	Australian and New Zealand Environment Conservation Council
AHO	Aboriginal Heritage Office
CBD	Central Business District
CSIRO	Australia's Commonwealth Scientific and Industrial Research Organisation
DCP	Development Control Plan
DDT	Dichlorodiphenyltrichloroethane
DEC	NSW Department of Environment and Conservation
DECC	NSW Department of Environment and Climate Change
DIPNR	The former NSW Department of Infrastructure Planning and Natural Resources
DNR	NSW Department of Natural Resources
DPI	NSW Department of Primary Industries
EIS	Environmental Impact Statement
EMA	Emergency Management Authority
EMP	Estuary Management Plan
EMS	Estuary Management Study
EPI	Environmental Planning Instrument (includes LEP, REP and SEPP)
EPS	Estuary Process Study
EPA	NSW Environment Protection Authority (DEC, recently changed to DECC)
ESD	Ecologically Sustainable Development
GIS	Geographic Information System
GSE	Graduate School of Environment, Macquarie University
IPA	Intertidal Protected Area
IPCC	Inter-Governmental Panel for Climate Change
LEP	Local Environmental Plan
LGA	Local Government Area
MSW	Manly Scenic Walkway
MSB	Maritime Services Board
NHT	National Heritage Trust
NRM	Natural Resources Management
NSW	New South Wales
RAN	Royal Australian Navy
REP	Regional Environmental Plan
SAP	Scientific Advisory Panel (of the Manly Council)
SCCG	Sydney Coastal Council Group
SEPP	State Environmental Planning Policy
SREP	Sydney Regional Environmental Plan
SREPP	Sydney Regional Environmental Planning Policy
UWS	University of Western Sydney
WPA	Wetlands Protection Area

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APPENDIX A

Data Acquisition

DATA ACQUISITION

DATA SOURCES & QUALITY

Data was gathered through a variety of means and sources, and was predominantly based on a desktop study of existing data. An extensive search of relevant Manly Council data was undertaken first. Following this, letters were distributed to a wide variety of organisations such as universities, local businesses, community groups and government bodies, requesting information relevant to the study area. Further, requests were put out to the general community via advertisements, newsletters and local community groups requesting relevant information.

The types of information requested included photos, studies, reports, newspaper clippings and historic material. Only a limited amount of information was voluntarily supplied, with the majority coming from targeted research into likely sources. Key sources for data included Manly Council, Manly Library, Manly Environment Centre, NSW Department of Natural Resources, and various state government web sites.

All data compiled for inclusion in this report was firstly screened to ensure its validity. The source of each piece of information was determined, along with the date of publishing / production, and the target audience for the data. All factors were then reviewed together to ensure the document was valid for use.

HISTORICAL PHOTOGRAPHS

The Local Studies Unit of Manly Library was able to provide a broad range of historical photos and information relating to the study area. The photos are of great assistance in determining changes over time for various issues, such as sand bar movement, development and changes in vegetation. These photographs are located in Appendix C. The photographs are also used in other parts this document to assist in understanding the history and trends of various issues.

DATA & INFORMATION AVAILABLE

A broad range of previous studies, reports, and documents relevant to the study area, and the features and issues present within the study area, were utilised during this research. These are listed below, along with some brief information about each. Description of the key topics addressed relates to the various sections of this document. For those non-internet based documents, a code is given in brackets at the end of its reference to indicate the physical location of the document, to assist in any future research. Table 3.4 (below) provides the key to the location codes.

Table A1– Codes for Location of Documents

Code	Location of Document
1	Manly Council, 1 Belgrave St, Manly, NSW, 2095
2	Manly Library, Market Lane, Manly, NSW, 2095
3	Manly Library – Local Studies Unit, Market Lane, Manly, NSW, 2095
4	Manly Environment Centre, 41 Belgrave St, Manly, NSW, 2095

- Aboriginal Heritage Office, *Aboriginal Heritage*, online, cited 11/01/07, www.Aboriginalheritage.org
  - **Key Topics Addressed** – Aboriginal Occupation
  - **Key Localities Addressed** – Northern Sydney region

- Afferent Media, *Balgowlah Online*, online, cited 12/10/06, www.balgowlahonline.com.au
  - **Key Topics Addressed** – Past, Present & Future Uses
  - **Key Localities Addressed** – Manly LGA

- Australian Greenhouse Office, *Living With Climate Change: An Overview of Potential Climate Change Impacts on Australia*, online, cited 6/2/07, www.greenhouse.gov.au/impacts/overview/index.html

  - **Key Topics Addressed** – The Hazards of Climate Change
  - **Key Localities Addressed** – Australia

- Australian Museum, *Full Fact Sheet List*, online, cited 16/01/07, www.amonline.net.au/factsheets/
  - **Key Topics Addressed** – Natural Environment – Ecological Processes
  - **Key Localities Addressed** – Australia

- Australian Museum Business Services, 2002, *Port Survey for Introduced Marine Species – Sydney Harbour: Final Report*, Sydney Ports Corporation, Sydney (1)
  - **Key Topics Addressed** – Ecological Impacts
  - **Key Localities Addressed** – Sydney Harbour

- Birch, Gavin & Taylor, Stuart, 2004, *The Contaminant Status of Sydney Harbour Sediments: A Handbook for the Public and Professionals*, Geological Society of Australia, Sydney (1)
  - **Key Topics Addressed** – Sediment Contamination
  - **Key Localities Addressed** – Sydney Harbour

- Broadleaf Capital International, Marsden Jacob Associates, 2006, *Climate Change Impacts & Risk Management: A guide for Business and Government*, Australian Greenhouse Office, Department of Environment and Heritage, Australian Government, Canberra (1)
  - **Key Topics Addressed** – Climate Change
  - **Key Localities Addressed** – Australia

- Bryant, Edward, 1980, *Bathymetric Changes in Three Estuaries of the Central New South Wales Coast*, Australian Journal of Marine and Freshwater Research, 1980, 31: 553-571 (1)
  - **Key Topics Addressed** – Sediment Budget & Movement; Beach Erosion – Estuary Processes
  - **Key Localities Addressed** – Sydney Harbour

- Burns, Cassie & Davey, Greg, *Fishnote – Salt marsh*, online, cited 31/01/2007, www.fisheries.nsw.gov.au/__data/assets/pdf_file/5046/Saltmarsh-Fishnote-dec11.pdf
  - **Key Topics Addressed** – Interconnected Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- Champion, G & S, 2006, *North Shore to Manly*, unpublished monograph (3)
  - **Key Topics Addressed** – Past, Present & Future Uses
  - **Key Localities Addressed** – Northern Beaches of Sydney

- Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, *Estuary Assessment Framework for Non-Pristine Estuaries – Estuary 37 (Port Jackson),* online, cited 14/09/06, http://dbforms.ga.gov.au/pls/www/npm.ozest.show_mm?pBlobno=9071#search=%22estuary%20assessment%20framework%20for%20non-pristine%20estuaries%20port%20jackson%22
  - **Key Topics Addressed** – Tidal Characteristics; Wave Climate; Sediment Contamination; Marine Ecology; Terrestrial Ecology
  - **Key Localities Addressed** – Sydney Harbour

- Edgar, Graham, 2001, *Australian Marine Habitats in Temperate Waters*, Reed New Holland, Sydney (2)
  - **Key Topics Addressed** – Marine Ecology; Interconnected Ecology
  - **Key Localities Addressed** – Australia

- Frew, Wendy, 30/10/2006, *Sydney's Vanishing Future*, Sydney Morning Herald (1)
  - **Key Topics Addressed** – The Hazards of Climate Change
  - **Key Localities Addressed** – Sydney

- GHD, 2003, *Proposed Widening of the Spit Bridge over Middle Harbour: Statement of Environmental Effects / Review of Environmental Factors*, NSW Roads and Traffic Authority, Sydney (1)
  - **Key Topics Addressed** – Aquatic Ecology; Terrestrial Ecology; Topography; Water Quality; Past, Present & Future uses

  - **Key Localities Addressed** – Middle Harbour

- Graduate School of the Environment, Macquarie University, 1990, *Clontarf Marine Services Marina Extension Environmental Impact Statement*, Clontarf Marine Services (1)
  - **Key Topics Addressed** – Tidal Characteristics; Wave Climate; Sediment Budget & Movement; Aquatic Ecology; Water Quality; Ecological Impacts
  - **Key Localities Addressed** – Middle Harbour

- Harris, Peter, & O'Brien, Phil, 1998, *Australian Ports – Environmental Data & Risk Analysis Phase 1: Literature Review*, Australian Quarantine Inspection Service, Canberra (1)
  - **Key Topics Addressed** – Tidal Characteristics; Wave Climate; Sediment Budget & Movement
  - **Key Localities Addressed** – Sydney Harbour

- Henderson, C W T, date indecipherable, Harbour Havoc when Gale Hit, *The Manly Daily,* date & page number unknown (3)
  - **Key Topics Addressed** – Storms & Elevated Water Levels
  - **Key Localities Addressed** – Sydney Harbour

- Hennessy, Kevin, Macadam, Ian, Whetton, Penny, CSIRO Marine & Atmospheric Research, 2006, *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance*, Australian Greenhouse Office, Department of Environment and Heritage, Australian Government, Canberra (1)
  - **Key Topics Addressed** – The Hazards of Climate Change
  - **Key Localities Addressed** – Australia

- Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis - Summary for Policymakers*, online, cited 5/2/07, www.ipcc.ch/SPM2feb07.pdf
  - **Key Topics Addressed** – The Hazards of Climate Change
  - **Key Localities Addressed** – International

- Kennedy, David, 2002, *Estuarine Beach Morphology in Microtidal Middle Harbour, Sydney*, Australian Geographical Studies 40(2): 231-240 (1)
  - **Key Topics Addressed** – Sediment Budget & Movement; Wave Climate; Tidal Characteristics; Storms & Elevated Water Levels; Beach Erosion – Estuary Processes
  - **Key Localities Addressed** – Middle Harbour

- Lau, Connie, 2006, *Subregional Planning (presentation)*, unpublished (1)
  - **Key Topics Addressed** – Past, Present & Future Uses
  - **Key Localities Addressed** – Manly LGA

- Lawson and Treloar, 2003, *Pittwater Estuary Process Study*, Lawson and Treloar, Gordon (1)
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – Pittwater

- Lord, Doug, Watson, Phil, Coates, Bruce, Hanslow, David, 2006, *Coastal Zone Management Planning under the New South Wales Coastal Protection Act (1979)*, Proceedings from NSW Coastal Conference 2006, Coffs Harbour (1)
  - **Key Topics Addressed** – Coastal Zone Management
  - **Key Localities Addressed** – NSW

- Lynch, Peter, Burchmore, Jenny, NSW Department of Primary Industries, *Fishcare – Our Mangrove Forests*, online, cited 13/07/06, www.fisheries.nsw.gov.au/aquatic_habitats/aquatic_habitats/fishcare_-_our_mangrove_forests
  - **Key Topics Addressed** – Marine Ecology; Interconnected Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- Lynch, Peter, Burchmore, Jenny, Johnson, Tom, NSW Department of Primary Industries, *Fishcare - Saving Our Seagrasses Fishnote DF/29*, online, cited 13/07/06, www.fisheries.nsw.gov.au/aquatic_habitats/aquatic_habitats/fishcare_-_saving_our_seagrasses_fishnote
    - **Key Topics Addressed** –
    - **Key Localities Addressed** –

- Manly Council, 2006, *Bushland News – February 2006*, Manly Council, Manly (1)
    - **Key Topics Addressed** – Terrestrial Ecology
    - **Key Localities Addressed** – Manly LGA

- Manly Council, 2006, *Unmade Road Reserves in Manly: Summary – Ecological Importance*, Manly Council, Manly (1)
    - **Key Topics Addressed** – Terrestrial Ecology
    - **Key Localities Addressed** – Manly LGA

- Manly Council, 2007, *LEP, DCP's + Policies*, online, cited 08/01/2007, www.manly.nsw.gov.au/sp/PlanningDocs.aspx?PageID=518
    - **Key Topics Addressed** – Past, Present & Future Uses
    - **Key Localities Addressed** – Manly LGA

- Manly Council, *Manly Council – Regional Significance*, online, cited 05/10/2006, http://www.manly.nsw.gov.au/Regional-Significance.html
    - **Key Topics Addressed** – Past, Present & Future Uses
    - **Key Localities Addressed** – Manly LGA

- Manly Council, year unknown, *It's all About Dogs* (brochure), Manly Council, Manly (4)
    - **Key Topics Addressed** – Ecological Impacts
    - **Key Localities Addressed** – Manly LGA

- Manly Council, year unknown, *Native Plant Guide – Manly Coastal*, Manly Council, Manly (4)
    - **Key Topics Addressed** – Terrestrial Ecology
    - **Key Localities Addressed** – Manly LGA

- Manly Council, year unknown, *Potentially Contaminated Sites Register*, Manly Council, Manly (1)
    - **Key Topics Addressed** – Human Impacts & Risks
    - **Key Localities Addressed** – Manly LGA

- Manly Council Scientific Advisory Panel, 2005, *The Enhanced Greenhouse Effect: Local Climate Change in the 21st Century*, Manly Council, Manly (1)
    - **Key Topics Addressed** – The Hazards of Climate Change
    - **Key Localities Addressed** – Manly LGA

- Manly Hydraulics Laboratory, *New South Wales Tide Glossary*, online, cited 17/10/2006, http://www.mhl.nsw.gov.au/www/tide_glossary.htmlx#SEM
    - **Key Topics Addressed** – Tidal Characteristics
    - **Key Localities Addressed** – NSW

- Martin, Bob, Minister for Mineral Resources and Minister for Fisheries, 1996, Letter to Dr Peter Macdonald, Member for Manly (4)
    - **Key Topics Addressed** – Marine Ecology
    - **Key Localities Addressed** – Middle Harbour

- McAteer, John, 2006, *Seaforth Moth Sailing Club*, unpublished (3)
    - **Key Topics Addressed** – Past, Present & Future Uses
    - **Key Localities Addressed** – Middle Harbour

- Mcgill, Craig, *Sydney's Middle Harbour*, online, cited 04/10/06, www.fishnet.com.au/default.aspx?id=234&articleId=3856
  - **Key Topics Addressed** – Marine Ecology; Water Quality; Ecological Impacts
  - **Key Localities Addressed** – Middle Harbour

- McIntosh, Edgar, 1988, *Recollections by Former Manly Municipal Engineer*, online, cited 5/2/07, www.manly.nsw.gov.au/Recollections---Reminiscences-about-Manly.html
  - **Key Topics Addressed** – Past, Present & Future Uses
  - **Key Localities Addressed** – Manly LGA

- McLoughlin, Lynette, 2000, *Shaping Sydney Harbour: sedimentation, dredging and reclamation 1788-1990's,* Australian geographer, 31(2): 183-208 (1)
  - **Key Topics Addressed** – Sediment Budget & Movement; Beach Erosion – Estuary Processes
  - **Key Localities Addressed** – Sydney Harbour

- Middle Harbour Catchment Management Committee, 1996, *Middle Harbour Catchment Management Committee: Strategic Plan*, Middle Harbour Catchment Management Committee (1)
  - **Key Topics Addressed** – Marine Ecology; Interconnected Ecology; Terrestrial Ecology; Water Quality; Ecological Impacts
  - **Key Localities Addressed** – Middle Harbour

- Noxious Weeds Committee – Sydney North, *Stop the Spread – Noxious Weeds are Spoiling our Environment* (brochure), Noxious Weeds Committee – Sydney North (4)
  - **Key Topics Addressed** – Ecological Impacts
  - **Key Localities Addressed** – Sydney

- NSW Department of Environment & Conservation, *Beachwatch & Harbour watch State of the Beaches 2005-2006*, online, cited 03/01/07, www.environment.nsw.gov.au/beach/ar2006/
  - **Key Topics Addressed** – Water Quality
  - **Key Localities Addressed** – NSW

- NSW Department of Environment & Conservation, *Nature and Conservation*, online, cited 2/2/07, www.nationalparks.nsw.gov.au/npws.nsf/content/wildife+corridors
  - **Key Topics Addressed** – Terrestrial Ecology
  - **Key Localities Addressed** – NSW

- NSW Department of Natural Resources, *Accessing Bore Water / Groundwater*, online, cited 06/12/06, www.dnr.nsw.gov.au/water/pdf/bore_drilling_factsheet.pdf
  - **Key Topics Addressed** – Groundwater
  - **Key Localities Addressed** – New South Wales

- NSW Department of Natural Resources, *Acid Sulphate Soil*, online, cited 05/10/06, http://www.dnr.nsw.gov.au/soils/sulfate.shtml
  - **Key Topics Addressed** – Geology & Soils
  - **Key Localities Addressed** – New South Wales

- NSW Department of Natural Resources, *Estuaries in NSW*, online, cited 11/09/06, www.dnr.nsw.gov.au/estuaries
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – New South Wales

- NSW Department of Primary Industries, *Caulerpa taxifolia*, online, cited 13/07/06, www.fisheries.nsw.gov.au/threatened_species/general/content/fn_caulerpa1.htm
  - **Key Topics Addressed** – Marine Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Department of Primary Industries, *Estuarine Habitats*, online, cited 13/07/06, www.fisheries.nsw.gov.au/aquatic_habitats/estuarine
  - **Key Topics Addressed** – Marine Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Department of Primary Industries, *Fish Habitat Protection Plan No 2: Seagrasses*, online, cited 15/01/07, www.fisheries.nsw.gov.au/__data/assets/pdf_file/5050/protplan_2.pdf
  - **Key Topics Addressed** – Marine Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Department of Primary Industries, *Fishing in Sydney Harbour*, online, cited 15/2/07, www.dpi.nsw.gov.au/fisheries/sydney-harbour-closure
  - **Key Topics Addressed** – Marine Ecology; Water Quality; Ecological Impacts
  - **Key Localities Addressed** – Sydney Harbour

- NSW Department of Primary Industries, *Intertidal Protected Areas*, online, cited 14/09/06, www.fisheries.nsw.gov.au/marine_protected_areas/ipa
  - **Key Topics Addressed** – Interconnected Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Department of Primary Industries, *Pacific Oyster – Crassostrea gigas*, online, cited 26/07/06, www.fisheries.nsw.gov.au/threatened_species/general/content/fn_pacific_oyster.htm
  - **Key Topics Addressed** – Marine Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Department of Primary Industries, *Policy & Guidelines - Aquatic Habitat Management and Fish Conservation 1999 Update*, online, cited 14/09/06, www.fisheries.nsw.gov.au/aquatic_habitats/aquatic_habitats/policy__and__guidelines
  - **Key Topics Addressed** – Marine Ecology; Interconnected Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Department of Primary Industries, *Recreational Fishing*, online, cited 19/2/07, http://www.fisheries.nsw.gov.au/recreational
  - **Key Topics Addressed** – Past, Present & Future Uses; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Fisheries, 2004, *NSW Control Plan for the noxious marine weed Caulerpa taxifolia in NSW Waters*, NSW Fisheries (1)
  - **Key Topics Addressed** – Marine Ecology; Ecological Impacts
  - **Key Localities Addressed** – NSW

- NSW Maritime, 2006, *Moorings in the Manly LGA*, unpublished (1)
  - **Key Topics Addressed** – Past, Present & Future Uses
  - **Key Localities Addressed** – Manly LGA

- NSW Maritime, *Boating Handbook*, online, cited 2/1/2007, www.maritime.nsw.gov.au/sbh.html
  - **Key Topics Addressed** – Marine Ecology; Boat Generated Waves
  - **Key Localities Addressed** – NSW

- NSW Maritime, *Boating Map For Port Jackson – Sydney, Middle And North Harbours*, online, cited 14/09/06, www.maritime.nsw.gov.au/maps.html#sydney
  - **Key Topics Addressed** – Boat Generated Waves; Sediment Budget & Movement
  - **Key Localities Addressed** – Middle Harbour

- OzEstuaries, *Beach & Dune Indicators*, online, cited 6/2/07, www.ozestuaries.org/oracle/ozestuaries/indicators/In_beach_dune_area_f.html
  - **Key Topics Addressed** – Sediment Budget & Movement; Interconnected Ecology

  - **Key Localities Addressed** – Australia

- OzEstuaries, *Benthic Invertebrates,* online, cited 14/09/06, www.ozestuaries.org/indicators/benthic_inverts.jsp
  - **Key Topics Addressed** – Marine Ecology; Interconnected Ecology; Ecological Impacts
  - **Key Localities Addressed** – Australia

- OzEstuaries, *Glossary of Terms*, online, cited 21/12/06, www.ozestuaries.org/glossary.jsp
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – Australia

- OzEstuaries, *Port Jackson*, online, cited 28/06/06, www.dbforms.ga.gov.au/pls/www/npm.ozest.report
  - **Key Topics Addressed** – Natural Environment – Physical Processes; Natural Environment – Ecological Processes; Human Impacts & Risks; Past, Present & Future Uses
  - **Key Localities Addressed** – Sydney Harbour

- Parliamentary Council's Office, 2007, *State Environmental Planning Policy No 19—Bushland in Urban Areas*, online, cited 5/2/2007, www.legislation.nsw.gov.au/viewtop/inforce/epi+014+1986+FIRST+0+N/?fullquery=(((%22state%22%20AND%20%22environmental%22%20AND%20%22planning%22%20AND%20%22policy%22)))
  - **Key Topics Addressed** – Terrestrial Ecology
  - **Key Localities Addressed** – NSW

- Patterson, Britton & Partners, 2004, *Davis Marina to Manly Point Coastline Hazard Definition Study*, Manly Council, Manly (1)
  - **Key Topics Addressed** – Tidal Characteristics; Wave Climate; Wave Induced Currents; Storms & Elevated Water Levels; Sediment Budget & Movement; Foreshore Development; The Hazards of Climate Change; Boat Generated Waves; Slope & Cliff Instability
  - **Key Localities Addressed** – Manly LGA

- Piorewicz, Jurek, *Proceedings of the Public Workshop "Beach protection: risk and management"*, Yeppoon, 7 February 2002, online, cited 7/2/07, www.coastal.crc.org.au/pdf/beach_protection_yeppoon_feb02.pdf
  - **Key Topics Addressed** – Sediment Budget & Movement; Beach Erosion – Estuary Processes
  - **Key Localities Addressed** – Australia

- Pittock, Barrie, 2003, *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, Canberra (1)
  - **Key Topics Addressed** – The Hazards of Climate Change
  - **Key Localities Addressed** – Australia

- Richards, Russell, Scheltinga, David, Barchiesi, Donna, 2006, *Local Government Authority NRM Information Fact sheets*, Cooperative Research Centre for Coastal Zone, Estuary & Waterway Management, Queensland (1)
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – Australia

- Ryan, D., Brooke, B., Bostock, H., Smith, J., Buchanan, C., and Skene, D., 2006, *Report on sediment characteristics, sub-bottom profiles, backscatter data and seabed morphological classification*, Coastal CRC Coastal Water Habitat Mapping Project, Milestone CG 6.01, 71 pp. (1)
  - **Key Topics Addressed** – Sediment Budget & Movement; Tidal Characteristics
  - **Key Localities Addressed** – Sydney Harbour

- Ryan, David, Heap, Andrew, Radke, Lynda & Heggie, David, 2003, *Conceptual Models Of Australia's Estuaries And Coastal Waterways: Applications For Coastal Resource Management*, Geoscience Australia, ACT (1)
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – Australia

- Sharpe, Alan, 2004, *Pictorial Memories – Manly to Palm Beach*, Kingsclear Books, Alexandria (2)
  - **Key Topics Addressed** – Past, Present & Future Uses
  - **Key Localities Addressed** – Northern Beaches of Sydney

- Skelton, Nick, Donner, Erica & Wong, Purdey, 2004, *Flora and Fauna of Manly Council's Bushland Reserves*, GIS Environmental Consultants (1)
  - **Key Topics Addressed** – Terrestrial Ecology
  - **Key Localities Addressed** – Manly LGA

- Skelton, Nick, Gilson, Tony & Donner, Erica, 2002, *Stormwater Impact on Manly Bushland Reserves*, GIS Environmental Consultants, North Curl Curl (1)
  - **Key Topics Addressed** – Terrestrial Ecology; Water Quality; Ecological Impacts
  - **Key Localities Addressed** – Manly LGA

- Smith, Tim, 2001, *Australian Estuaries : a framework for management*, Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Queensland (2)
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – Australia

- Sydney Fish Finder, *Sydney Fish Finder Forum*, online, cited 15/2/07, www.sydneyfishfinder.com.au/sffforum
  - **Key Topics Addressed** – Marine Ecology;
  - **Key Localities Addressed** – Sydney

- Sydney Harbour Federation Trust, 2004, *Phytophthora & Vegetation Dieback in Sydney Harbour's Bushland* (brochure), Sydney Harbour Federation Trust, Sydney (4)
  - **Key Topics Addressed** – Terrestrial Ecology; Ecological Impacts
  - **Key Localities Addressed** – Sydney

- Sydney Water, 2005, *Environmental Indicators Compliance Report (volume 1-2) – Sydney Water Annual Report 2005*, Sydney Water, Sydney (1)
  - **Key Topics Addressed** – Water Quality; Ecological Impacts
  - **Key Localities Addressed** – Sydney

- Taylor, S, Birch, G, Links, F, 2004, *Historical Catchment Changes and Temporal Impact on Sediment of the Receiving Basin, Port Jackson, New South Wales*, Australian Journal of Earth Sciences, 51:233-246 (1)
  - **Key Topics Addressed** – Sediment Budget & Movement
  - **Key Localities Addressed** – Sydney Harbour

- The Ecology Lab Pty Ltd, 2002, *Aquatic Habitats in the Vicinity of Clontarf Marina – Ecological Audit, 2002*, Clontarf Marina, Clontarf (1)
  - **Key Topics Addressed** – Marine Ecology
  - **Key Localities Addressed** – Middle Harbour

- Turner, Lynne, Tracey, Dieter, Tilden, Jan, Dennison, William, 2004, *Where River Meets Sea: Exploring Australia's Estuaries*, Cooperative Research Centre for Coastal Zone, Estuary & Waterway Management, Queensland (2)
  - **Key Topics Addressed** – Estuary Management
  - **Key Localities Addressed** – Australia

- Underwater Research Group, *Research & the URG*, online, cited 19/01/07, www.urgdiveclub.org.au
  - **Key Topics Addressed** – Marine Ecology; Ecological Impacts
  - **Key Localities Addressed** – Sydney Harbour

- West, G., Williams, R., & Laird, R., 2004, *Distribution of Estuarine Vegetation in the Parramatta River and Sydney Harbour, 2000*, NSW Department of Primary Industries, Nelson Bay (1)

- **Key Topics Addressed** – Marine Ecology; Ecological Impacts
- **Key Localities Addressed** – Sydney Harbour

EXISTING MANAGEMENT PLANS & PLANNING DOCUMENTS

There are many existing management plans and planning documents, produced by various government agencies and other groups, which are also relevant to the study area. These are listed below, with some brief information about the content and location of each. The codes are again used to identify the location of the documents.

- Manly Council, 1988, *Manly Local Environment Plan*, Manly Council (1)
  - **Key Topics Addressed –** Past, Present & Future Uses
  - **Key Localities Addressed –** Manly LGA

- Manly Council, 1998, *Manly Scenic Walkway Plan of Management*, Manly Council (1)
  - **Key Topics Addressed –** Past, Present & Future Uses; Terrestrial Ecology
  - **Key Localities Addressed –** Manly LGA

- Manly Council, 2002, *Manly's Sustainability Strategy: Blueprint for the Future*, Manly Council (1)
  - **Key Topics Addressed –** Past, Present & Future Uses; Human Impacts & Risks
  - **Key Localities Addressed –** Manly LGA

- Manly Council, 2004, *Plans of Management for Seaforth Oval, Keirle Park and Tania Park*, Corporate Planning & Strategy Division, Manly Council (1)
  - **Key Topics Addressed –** Past, Present & Future Uses; Terrestrial Ecology
  - **Key Localities Addressed –** Manly LGA

- Manly Council, 2006, *Surfing the Future: A Vision for the Manly Local Government Area for 2025*, Manly Council, Manly (1)
  - **Key Topics Addressed –** Past, Present & Future Uses
  - **Key Localities Addressed –** Manly LGA

- Natural Resource Management Ministerial Council, 2006, *National Cooperative Approach to Integrated Coastal Zone Management – Framework and Implementation Plan*, Australian Government, Department of Environment and Heritage, Canberra (1)
  - **Key Topics Addressed –** Estuary Management
  - **Key Localities Addressed –** Australia

- NSW Department of Infrastructure, Planning & Natural Resources, 2005, *Sydney Harbour Catchment: Sydney Regional Environment Plan*, NSW Government Department of Infrastructure, Planning & Natural Resources (1)
  - **Key Topics Addressed –** Past, Present & Future Uses
  - **Key Localities Addressed –** Sydney

- NSW Department of Infrastructure, Planning & Natural Resources, 2005, *Sydney Harbour Foreshores and Waterways Area: Development Control Plan*, NSW Department of Infrastructure, Planning & Natural Resources (1)
  - **Key Topics Addressed –** Past, Present & Future Uses
  - **Key Localities Addressed –** Sydney

- NSW Department of Infrastructure, Planning & Natural Resources and Waterways Authority, 2004, *Boat Storage Policy for Sydney Harbour*, Department of Infrastructure, Planning and Natural Resources, Sydney (1)
  - **Key Topics Addressed –** Past, Present & Future Uses
  - **Key Localities Addressed –** Sydney Harbour

- NSW Government, 1992, *Estuary Management Manual*, NSW Government (1)
    - **Key Topics Addressed –** Estuary Management
    - **Key Localities Addressed –** NSW

- NSW National Parks & Wildlife Service, 1998, *Garigal National Park Plan of Management*, NSW National Parks & Wildlife Service, Sydney (1)
    - **Key Topics Addressed –** Terrestrial Ecology
    - **Key Localities Addressed –** Manly LGA

- NSW National Parks & Wildlife Service, 1998, *Sydney Harbour National Park Plan of Management*, NSW National Parks & Wildlife Service, Sydney (1)
    - **Key Topics Addressed –** Terrestrial Ecology
    - **Key Localities Addressed –** Manly LGA

- Patterson Britton & Partners Pty Ltd, 1999, *Northern Beaches Stormwater Management Plan*, Northern Beaches Stormwater Management Plan Committee, Sydney (1)
    - **Key Topics Addressed –** Water Quality
    - **Key Localities Addressed –** Northern Beaches of Sydney

- Willing & Partners, 1999, *Middle Harbour Catchment Stormwater Management Plan*, Middle Harbour Stormwater Management Committee, Sydney (1)
    - **Key Topics Addressed –** Water Quality; Past, Present & Future Uses; Climate; Geology & Soils; Topography; Natural Environment – Physical Processes; Natural Environment – Ecological Processes; Foreshore Development; Groundwater; Ecological Impacts
    - **Key Localities Addressed –** Middle Harbour

APPENDIX B
SPECIES LISTS

Table B1 - Fish Observed at Sandy Bay, Clontarf
Five Separate Occasions between March 1996 & April 2002

Species		Where Present	
Common name	*Scientific name*	*Under Clontarf Marina*	*Sandy Habitat Adjacent to Marina*
Bar-tailed goatfish	*Upeneus tragula*	Y	Y
Blackspot goatfish	*Parupeneus signatus*	Y	N
Blackspot snapper	*Lutjanus fulviflamma*	Y	N
Black-spotted wrasse	*Austrolabrus maculatus*	Y	N
Blue groper	*Achoerodus viridis*	Y	N
Common stingaree	*Urolophus testaceus*	Y	Y
Common triplefun	*Norfolkia clarkei*	Y	N
Crested morwong	*Cheilodactylus vestitus*	Y	N
Crimson banded wrasse	*Notolabrus gymnogenis*	Y	N
Diamond fish	*Monodactylus argenteus*	Y	Y
Dusky flathead	*Platycephalus fuscus*	Y	Y
False Tasmanian blenny	*Pictiblennius intermedius*	Y	N
Fan belly leatherjacket	*Monacanthus chinensis*	Y	N
Five-lined Trumpeter	*Pelates quadriliniatus*	N	Y
Flat-tailed mullet	*Liza argentea*	Y	Y
Flutemouth	*Fistularia sp.*	Y	N
Fortesque	*Centropogon australis*	Y	Y
Glassfish	*Ambassis jackoniensis*	Y	Y
Gobies	*Gobiidae*	Y	Y
Hamilton's toadfish	*Tetractenos hamiltoni*	Y	N
Hula fish	*Trachinops taeniatus*	Y	N
Immaculate damsel	*Mechaenichthys immaculatus*	Y	N
Leatherjacket	*paramonacanthus otisensis*	Y	N
Little weed whiting	*Neoodax balteatus*	Y	N
Luderick	*Girella tricuspidata*	Y	Y
Mado	*Atypichthys strigatus*	Y	N
Numbfish	*Hypnos monopterygium*	N	Y
Ogilby's hardhead	*Atherinomorus ogilbyi*	Y	Y
Old wife	*Enoplosus armatus*	Y	N
Oyster blenny	*Omobrachus anolius*	Y	N
Pipefish (P)	unidentified species	N	Y
Porcupine fish	*Dicotylichthys punctulatus*	Y	N
Rainbow wrasse	*Pseudolabrus guntheri*	Y	N
Red morwong	*Cheilodactylus fuscus*	Y	N
Red mullet	*Upeneichthys porosus*	Y	N
Rough leatherjacket	*Scobinichthys granulatus*	Y	N
Sabretooth blenny	*Petroscrites lupus*	Y	N
Sand mullet	*Myxus elongatus*	Y	Y
Sand whiting	*Sillago ciliata*	Y	Y
Scribbled rockcod	*Epinephelus undulatostriatus*	Y	N
Sea mullet	*Mugil cephalus*	Y	N
Seahorse (P)	*Hippocampus* sp.	N	N
Sergeant major	*Abudefduf vaigiensis*	Y	N
Silver trevally	*Pseudocaranx dentex*	Y	N
Six-spined leatherjacket	*Meuschenia freycineti*	Y	N

Table B1 - Fish Observed at Sandy Bay, Clontarf *Five Separate Occasions between March 1996 & April 2002*			
Species		**Where Present**	
Snapper	*Pagrus auratus*	Y	Y
Spinefoot	*Siganus fuscescens*	Y	N
Spotted sawtail surgeon fish	*Prionurus maculatus*	Y	N
Striped anglerfish	*Antennarius striatus*	N	Y
Striped catfish	*Plotosus lineatus*	Y	N
Stripey	*Microcanthus strigatus*	Y	N
Sweep	*Scorpis lineolatus*	Y	N
Sydney cardinal fish	*Apogon limenus*	Y	N
Tailor	*Pomatomus saltatrix*	Y	Y
Tarwhine	*Rhabdosargus sarba*	Y	N
Toadfish	*Tetractenos* sp.	Y	Y
Unidentified apogonid - a	-	Y	N
Unidentified apogonid - b	-	Y	N
Unidentified butterfly fish	Chaetodontidae	Y	N
Unidentified fusilier	Caesionidae	Y	N
Unidentified small juveniles	-	Y	Y
Unidentified wrasse	-	Y	N
Weeping toadfish	*Torquigoner pleurogramma*	Y	N
White ear	*Parma microlepis*	Y	N
Yellowfin bream	*Acanthopagrus australis*	Y	Y
Yellow-fin leatherjacket	*Meuschenis trachylepis*	Y	Y
Yellowtail	*Trachurus novaezelandiae*	Y	N
P = Protected Species, Fisheries Management Act, 2004			
Nb- fish were noted present above if recorded during one or more of the five surveys between 1996 & 2002. **Source:** The Ecology Lab, 2002			

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Amberjack	*Seriola dumerili*	Mackerel Tuna	*Euthynnus affinis*
Arrow Dartgoby	*Ptereleotris evides*	Magpie Morwong	*Cheilodactylus gibbosus*
Australian anchovy	*Engraulis australis*	Mangrove Jack	*Lutjanus argentimaculatus*
Australian Angelshark	*Squatina australis*	Manta Ray	*Manta birostris*
Australian Bandfish	*Cepola australis*	Manyband Sole	*Zebrias scalaris*
Australian Bonito	*Sarda australis*	Many-host Cling-Goby	*Pleurosicya mossambica*
Australian Damsel	*Pomacentrus australis*	Maori Wrasse	*Ophthalmolepis lineolatus*
Australian Herring	*Arripis georgianus*	Maray	*Etrumeus teres*
Australian Mado	*Atypichthys strigatus*	Marble Dragonet	*Neosynchiropus ocellatus*
Australian Pilchard	*Sardinops sagax*	Marbled Flathead	*Platycephalus marmoratus*
Australian Rainbow Wrasse	*Suezichthys devisi*	Messmate Fish	*Echiodon rendahli*
Australian Smelt	*Retropinna semoni*	Milkfish	*Chanos chanos*
Axilspot Hogfish	*Bodianus axillaris*	Mimic Leatherjacket	*Paraluteres prionurus*
banded bellowsfish	*Centriscops humerosus*	Miracle Threefin	*Enneapterygius mirabilis*
Banded Morwong	*Cheilodactylus spectabilis*	Mirrorwing Flyingfish	*Hirundichthys speculiger*
Banded Rockcod	*Epinephelus ergastularius*	Moon Wrasse	*Thalassoma lunare*
Banded Scat	*Selenotoca multifasciata*	Moorish Idol	*Zanclus cornutus*

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Banded Seaperch	*Hypoplectrodes nigroruber*	Mosaic Leatherjacket	*Eubalichthys mosaicus*
Barracouta	*Thyrsites atun*	Moses Perch	*Lutjanus russelli*
Barred Longtom	*Ablennes hians*	Mother-of-Pearl Pipefish (P)	*Vanacampus margaritifer*
Barred Soapfish	*Diploprion bifasciatum*	Mud Flathead	*Ambiserrula jugosa*
Barred Threefin	*Brachynectes fasciatus*	Mulloway	*Argyrosomus japonicus*
Bar-tailed Goatfish	*Upeneus tragula*	Nannygai	*Centroberyx affinis*
Bastard Red Cod	*Pseudophycis breviuscula*	Narrow-Banded Sergeant Major	*Abudefduf bengalensis*
Bastard Trumpeter	*Latridopsis forsteri*	Narrow-banded Sole	*Aseraggodes macleayanus*
Beaked Coralfish	*Chelmon rostratus*	Narrow-barred Spanish Mackerel	*Scomberomorus commerson*
Beaked Salmon	*Gonorynchus greyi*	Nebulous Wrasse	*Halichoeres nebulosus*
Bearded Rock Cod	*Pseudophycis barbata*	Numbfish	*Hypnos monopterygium*
Beardie	*Lotella rhacina*	Oarfish	*Regalecus glesne*
Bicolour Goatfish	*Parupeneus barberinoides*	Ocean Jacket	*Nelusetta ayraudi*
Bigbelly Seahorse (P)	*Hippocampus abdominalis*	Ocellate Butterflyfish	*Parachaetodon ocellatus*
Bigeye Trevally	*Caranx sexfasciatus*	Ogilby's Hardyhead	*Atherinomorus vaigiensis*
Bigscale Scalyfin	*Parma oligolepis*	Ogilby's weedfish	*Heteroclinus heptaeolus*
Bigscale Soldierfish	*Myripristis berndti*	Old Wife	*Enoplosus armatus*
Bigtooth Twin-spot Flounder	*Pseudorhombus dupliciocellatus*	One-spot Puller	*Chromis hypsilepis*
Black Kingfish	*Rachycentron canadum*	Orangeband Surgeonfish	*Acanthurus olivaceus*
Black Leopard-Wrasse	*Macropharyngodon negrosensis*	Orangebar Threefin	*Ceratobregma helenae*
Black Rockcod (V)	*Epinephelus daemelii*	Orangeline Cardinalfish	*Apogon cyanosoma*
Black Sole	*Brachirus nigra*	Orange-line Wrasse	*Halichoeres hartzfeldi*
Black Spinefoot	*Siganus fuscescens*	Orangelined Wirrah	*Acanthistius paxtoni*
Black Triggerfish	*Sufflamen chrysopterum*	Ornate Ghostpipefish (P)	*Solenostomus paradoxus*
Blackback Butterflyfish	*Chaetodon melannotus*	Ornate Wobbegong	*Orectolobus ornatus*
Blackbanded Seaperch	*Hypoplectrodes annulatus*	Oxeye Herring	*Megalops cyprinoides*
Blackhead Leatherjacket	*Pervagor melanocephalus*	Oyster Blenny	*Omobranchus anolius*
Black-head Threefin	*Enneapterygius larsonae*	Pacific Blue-eye	*Pseudomugil signifer*
Black-lined Sleeper Goby	*Valenciennea helsdingenii*	Pacific Rockcod	*Trachypoma macracanthus*
Blackmargin Dartfish	*Parioglossus marginalis*	Painted Lizardfish	*Trachinocephalus myops*
Blackmargin Maori Wrasse	*Oxycheilinus nigromarginatus*	Painted Rainbow Wrasse	*Suezichthys arquatus*
Blackspot Boarfish	*Zanclistius elevatus*	Painted Stinkfish	*Eocallionymus papilio*
Black-spot Goatfish	*Parupeneus spilurus*	Painted Sweetlips	*Diagramma pictum*
Blackspot Gurnard	*Lepidotrigla umbrosa*	Peacock Rockskipper	*Istiblennius meleagris*
Black-spot Mangrove-goby	*Mugilogobius stigmaticus*	Peacock Sole	*Pardachirus pavoninus*
Blackspot Snapper	*Lutjanus fulviflamma*	Pearl Perch	*Glaucosoma scapulare*
Black-spotted Porcupinefish	*Diodon hystrix*	Pennantfish	*Alectis ciliaris*
Black-spotted Wrasse	*Austrolabrus maculatus*	Piano Fangblenny	*Plagiotremus tapeinosoma*
Blacktail Snapper	*Lutjanus fulvus*	Pigfish	*Bodianus unimaculatus*
Black-tipped Bullseye	*Pempheris affinis*	Pike	*Sphyraena novaehollandiae*
Black-tipped Fusilier	*Pterocaesio digramma*	Pilotfish	*Naucrates ductor*
Blindshark	*Brachaelurus waddi*	Pineapplefish	*Cleidopus gloriamaris*
Blotched Hawkfish	*Cirrhitichthys aprinus*	pink clingfish	*Aspasmogaster costatus*
Blue Angelfish	*Pomacanthus semicirculatus*	Pink-banded Grubfish	*Parapercis nebulosa*
Blue Damsel	*Pomacentrus coelestis*	Pinkbreast Siphonfish	*Siphamia roseigaster*
Blue Groper	*Achoerodus viridis*	Pink-lined Wrasse	*Coris dorsomacula*
Blue Mackerel	*Scomber australasicus*	Port Jackson glassfish	*Ambassis jacksoniensis*

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Blue Morwong	*Nemadactylus douglasii*	Port Jackson Shark	*Heterodontus portusjacksoni*
Blue Sprat	*Spratelloides robustus*	Premature Floater	*Schindleria praematura*
Blue Warehou	*Seriolella brama*	Purple Flying Gurnard	*Dactyloptena orientalis*
Blue-barred Parrotfish	*Scarus ghobban*	Purple Rockcod	*Epinephelus cyanopodus*
Bluebottle-fish	*Nomeus gronovii*	Purple Tuskfish	*Choerodon cephalotes*
Bluefish	*Girella cyanea*	Pygmy Scorpionfish	*Scorpaenodes scaber*
Blue-lined Goatfish	*Upeneichthys lineatus*	Queensland Yellowtail Angelfish	*Chaetodontoplus meredithi*
Blue-spot Goby	*Pseudogobius sp 9*	Racoon Butterflyfish	*Chaetodon lunula*
Blue-spotted Parrotfish	*Leptoscarus vaigiensis*	Ragged-finned Firefish	*Pterois antennata*
Bluestripe Seaperch	*Lutjanus kasmira*	Rainbow Cale	*Odax acroptilus*
Bluestriped Fangblenny	*Plagiotremus rhinorhynchos*	Rainbow Monocle-bream	*Scolopsis monogramma*
Bluntheaded Wrasse	*Thalassoma amblycephalum*	Red Firefish	*Pterois volitans*
Bony Flyingfish	*Hirundichthys oxycephalus*	Red Gurnard	*Chelidonichthys kumu*
Bridled Goby	*Arenigobius bifrenatus*	Red Morwong	*Cheilodactylus fuscus*
Bridled Leatherjacket	*Acanthaluteres spilomelanurus*	Red Pipefish (P)	*Notiocampus ruber*
Bridled Monocle Bream	*Scolopsis bilineatus*	Red Rockcod	*Scorpaena cardinalis*
Bridled Triggerfish	*Sufflamen fraenatum*	Redbanded Grubfish	*Parapercis binivirgata*
Broadhead Goosefish	*Lophiomus setigerus*	Redspot Wrasse	*Stethojulis bandanensis*
Broadnosed Sevengill Shark	*Notorynchus cepedianus*	Remora	*Remora remora*
Broadstripe Cardinalfish	*Apogon angustatus*	Ribbonfish	*Trachipterus arawatae*
Brokenline Wrasse	*Stethojulis interrupta*	Ring-scale Triplefin	*Enneapterygius atrogulare*
Bronze Whaler	*Carcharhinus brachyurus*	River Garfish	*Hyporhamphus regularis*
Brown Sabretooth Blenny	*Petroscirtes lupus*	Robust Ghost Pipefish (P)	*Solenostomus cyanopterus*
Brown Sweetlips	*Plectorhinchus gibbosus*	Rock Blackfish	*Girella elevata*
Bull Shark	*Carcharhinus leucas*	Rock Cale	*Aplodactylus lophodon*
Bullrout	*Notesthes robusta*	Rock Flathead	*Thysanophrys cirronasus*
Butterfly Perch	*Caesioperca lepidoptera*	rosy perch	*Callanthias allporti*
Capricorn Cardinalfish	*Apogon capricornis*	Rosy Weedfish	*Heteroclinus roseus*
Carp	*Cyprinus carpio*	Rotund Blenny	*Omobranchus rotundiceps*
Checkerboard Wrasse	*Halichoeres hortulanus*	Rough Flutemouth	*Fistularia petimba*
Clouded Saury	*Saurida nebulosa*	Rough Leatherjacket	*Scobinichthys granulatus*
Coastal Cubehead	*Cubiceps whiteleggi*	Rough-head Dragonet	*Repomucenus limiceps*
Cockatoo Waspfish	*Ablabys taenianotus*	Roundbelly Cowfish	*Lactoria diaphana*
Cockerel Wrasse	*Pteragogus enneacanthus*	Roundsnout Gurnard	*Lepidotrigla mulhalli*
Cocos Frillgoby	*Bathygobius cocosensis*	Ruby Cardinalfish	*Apogon coccineus*
Comb Wrasse	*Coris picta*	Saddled Puffer	*Canthigaster valentini*
Common Bullseye	*Pempheris multiradiata*	Sailfin Goby	*Nesogobius pulchellus*
Common Dolphinfish	*Coryphaena hippurus*	Samson fish	*Seriola hippos*
Common Galaxias	*Galaxias maculatus*	Sand Flathead	*Platycephalus bassensis*
Common Jack Mackerel	*Trachurus declivis*	Sand Mullet	*Myxus elongatus*
common name unknown	*Gymnothorax kidako*	Sand Whiting	*Sillago ciliata*
Common Pike Eel	*Muraenesox bagio*	Sandy Sprat	*Hyperlophus vittatus*
Common Saury	*Saurida tumbil*	Sandyback Stingaree	*Urolophus bucculentus*
Common Sawshark	*Pristiophorus cirratus*	Sargassum Anglerfish	*Histrio histrio*
Common Shore-eel	*Alabes dorsalis*	Sawtail Surgeonfish	*Prionurus microlepidotus*
Common Silverbiddy	*Gerres subfasciatus*	Saw-tooth Moray	*Gymnothorax prionodon*
Common Stingaree	*Trygonoptera testacea*	Sawtooth Pipefish (P)	*Maroubra perserrata*

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Common Stinkfish	*Foetorepus calauropomus*	Scalloped Hammerhead	*Sphyrna lewini*
Common Threefin	*Trinorfolkia clarkei*	Scalytail Toadfish	*Torquigener squamicauda*
Common Toadfish	*Tetractenos hamiltoni*	School Mackerel	*Scomberomorus queenslandicus*
Convict Surgeonfish	*Acanthurus triostegus*	School Shark	*Galeorhinus galeus*
Coral Sea Gregory	*Stegastes gascoynei*	Schooling Bannerfish	*Heniochus diphreutes*
Cottonmouth Trevally	*Uraspis secunda*	Scissortail Sergeant	*Abudefduf sexfasciatus*
Cox's Gudgeon	*Gobiomorphus coxii*	Scribbled Leatherjacket	*Aluterus scripta*
Crescent Perch	*Terapon jarbua*	Scribbled Rockcod	*Epinephelus undulatostriatus*
Crested Flounder	*Lophonectes gallus*	Scribbled Wrasse	*Anampses geographicus*
Crested Horn shark	*Heterodontus galeatus*	Sea Mullet	*Mugil cephalus*
Crested Oyster Goby	*Cryptocentroides gobioides*	Seagrass Ghost-goby	*Pleurosicya bilobata*
Crested Pipefish (P)	*Histiogamphelus briggsii*	Senator Wrasse	*Pictilabrus laticlavius*
Crested Weedfish	*Cristiceps australis*	Sergeant Baker	*Aulopus purpurissatus*
Crimsonband Wrasse	*Notolabrus gymnogenis*	Serpent Eel	*Ophisurus serpens*
Crowned Puffer	*Canthigaster coronata*	Sharpnose Grubfish	*Parapercis cylindrica*
Darkbar Flyingfish	*Cypselurus hexazona*	Shortfin Eel	*Anguilla australis*
Dash-dot Goatfish	*Parupeneus barberinus*	Shortfin Worm Eel	*Scolecenchelys australis*
Diamond Wrasse	*Anampses caeruleopunctatus*	Shorthead Lamprey	*Mordacia mordax*
Diamondfish	*Monodactylus argenteus*	Shorthead Worm Eel	*Scolecenchelys breviceps*
Diamondscale Goatfish	*Parupeneus ciliatus*	Shoulder-spot Sandgoby	*Gnatholepis anjerensis*
Doublesaddle Butterflyfish	*Chaetodon ulietensis*	Shoulderspot Wrasse	*Leptojulis cyanopleura*
Dusky Butterflyfish	*Chaetodon flavirostris*	Sieve-patterned Moray	*Gymnothorax cribroris*
Dusky Flathead	*Platycephalus fuscus*	Silver Sweep	*Scorpis lineolata*
Dusky Morwong	*Dactylophora nigricans*	Silver Toadfish	*Lagocephalus sceleratus*
Dusky Shark	*Carcharhinus obscurus*	Silver Trevally	*Pseudocaranx dentex*
Dusky Wrasse	*Halichoeres marginatus*	Silverline Cardinalfish	*Apogon hartzfeldi*
Dwarf Hawkfish	*Cirrhitichthys falco*	Silverside Weedfish	*Cristiceps argyropleura*
Dwarf Lionfish	*Dendrochirus brachypterus*	Silverstreak Wrasse	*Stethojulis strigiventer*
Eastern Australian Salmon	*Arripis trutta*	Six-spine Leatherjacket	*Meuschenia freycineti*
Eastern Blue Devil	*Paraplesiops bleekeri*	Skipjack Tuna	*Katsuwonus pelamis*
Eastern Blue-spotted Flathead	*Platycephalus caeruleopunctatus*	Slender Flounder	*Pseudorhombus tenuirastrum*
Eastern Cleaner-clingfish	*Cochleoceps orientalis*	Slender Longtom	*Strongylura leiura*
Eastern Conger	*Conger wilsoni*	Slender Rainbow Wrasse	*Suezichthys gracilis*
Eastern Fiddler Ray	*Trygonorrhina sp a*	Slender Roughy	*Optivus agastos*
Eastern Frogfish	*Batrachomoeus dubius*	Slender Sandburrower	*Creedia haswelli*
Eastern Gambusia	*Gambusia holbrooki*	Slender Seamoth (P)	*Pegasus volitans*
Eastern Gobbleguts	*Vincentia novaehollandiae*	Slender Suckerfish	*Echeneis naucrates*
Eastern Hulafish	*Trachinops taeniatus*	Slimy Cuskeel	*Brosmophyciops pautzkei*
Eastern Jumping Blenny	*Lepidoblennius haplodactylus*	Small-head Sole	*Soleichthys microcephalus*
Eastern King Wrasse	*Coris sandeyeri*	Smallmouth Hardyhead	*Atherinosoma microstoma*
Eastern Longfin-goby	*Favonigobius lentiginosus*	Small-scale Bullseye	*Pempheris compressa*
Eastern Pomfred	*Schuettea scalaripinnis*	Smallscale Hardyhead	*Atherinason hepsetoides*
Eastern School Whiting	*Sillago flindersi*	Smallspot Dart	*Trachinotus baillonii*
Eastern Sea Garfish	*Hyporhamphus australis*	Smalltooth Flounder	*Pseudorhombus jenynsii*
Eastern Shovelnose Ray	*Aptychotrema rostrata*	Smooth Flutemouth	*Fistularia commersonii*
Eastern Smooth Boxfish	*Anoplocapros inermis*	Smooth Golden Pufferfish	*Lagocephalus inermis*
Eastern Stargazer	*Kathetostoma laeve*	Smooth Hammerhead	*Sphyrna zygaena*

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Eastern Striped Trumpeter	*Pelates sexlineatus*	Smooth Stingray	*Dasyatis brevicaudata*
Eastern Talma	*Chelmonops truncatus*	Smooth Toadfish	*Tetractenos glaber*
Eastern Wirrah	*Acanthistius ocellatus*	Snakeskin Wrasse	*Eupetrichthys angustipes*
Eastern Yellow Blindfish	*Dermatopsis macrodon*	Snapper	*Pagrus auratus*
Elegant Wrasse	*Anampses elegans*	Snubnose Dart	*Trachinotus blochii*
Elephantfish	*Callorhinchus milii*	snubnose Garfish	*Arrhamphus sclerolepis*
Empire Gudgeon	*Hypseleotris compressa*	Southern Conger	*Conger verreauxi*
Epaulette Shark	*Hemiscyllium ocellatum*	Southern Demoiselle	*Chrysiptera notialis*
Estuary Catfish	*Cnidoglanis macrocephalus*	Southern Eagle Ray	*Myliobatis australis*
Estuary Perch	*Macquaria colonorum*	Southern Fanfish	*Pteraclis velifera*
Estuary Perchlet	*Ambassis marianus*	Southern Peacock Sole	*Pardachirus hedleyi*
Estuary Stingray	*Dasyatis fluviorum*	Southern Pygmy Leatherjacket	*Brachaluteres jacksonianus*
Exquisite Sandgoby	*Favonigobius exquisitus*	Southern Red Scorpionfish	*Scorpaena papillosus*
Eye Gurnard	*Lepidotrigla argus*	Southern Roughy	*Trachichthys australis*
Eyestripe Surgeonfish	*Acanthurus dussumieri*	Southern Silver Drummer	*Kyphosus sydneyanus*
False Cleanerfish	*Aspidontus taeniatus*	Southern Smiler	*Opistognathus jacksoniensis*
False Fusilier	*Paracaesio xanthura*	Southern Sprat	*Herklotsichthys castelnaui*
False Kelpfish	*Sebastiscus marmoratus*	Spangled emperor	*Lethrinus nebulosus*
Fan-bellied Leatherjacket	*Monacanthus chinensis*	Sparse Eviota	*Eviota sparsa*
Fantail Mullet	*Valamugil georgii*	Spikey Dogfish	*Squalus megalops*
Fine-spotted Wrasse	*Cirrhilabrus punctatus*	Spineless Toadfish	*Torquigener perlevis*
Finny Scad	*Megalaspis cordyla*	Spiny Gurnard	*Lepidotrigla papilio*
Firetailed Gudgeon	*Hypseleotris galii*	Spiny Pipehorse (P)	*Solegnathus spinosissimus*
Fisons Flounder	*Arnoglossus fisoni*	Spinyeye Cardinalfish	*Apogon fraenatus*
Five-line Snapper	*Lutjanus quinquelineatus*	Spinytooth Parrotfish	*Calotomus spinidens*
Five-lined Cardinalfish	*Cheilodipterus quinquelineatus*	Spot-tail wide-eye Flounder	*Engyprosopon grandisquama*
Flag-tail Flathead	*Platycephalus arenarius*	Spotted Bigeye	*Priacanthus macracanthus*
Flat-backed Mangrove-goby	*Mugilogobius platynotus*	Spotted Butterfish	*Scatophagus argus*
Flathead Goby	*Callogobius depressus*	Spotted Dragonet	*Repomucenus calcaratus*
Flathead Gudgeon	*Philypnodon grandiceps*	Spotted Grubfish	*Parapercis ramsayi*
Flathead Sandfish	*Lesueurina platycephala*	Spotted Pipefish (P)	*Stigmatopora argus*
Flat-tail Mullet	*Liza argentea*	Spotted Sawtail	*Prionurus maculatus*
Fortescue	*Centropogon australis*	Spotted Wobbegong	*Orectolobus maculatus*
Fourline Cardinalfish	*Apogon doederleini*	Starck's Demoiselle	*Chrysiptera starcki*
Foxfish	*Bodianus frenchii*	Starry Goby	*Asterropteryx semipunctatus*
Freckled Porcupinefish	*Diodon holocanthus*	Starry Pufferfish	*Arothron stellatus*
Freshwater Catfish	*Tandanus tandanus*	Starry Toadfish	*Arothron firmamentum*
Freshwater Herring	*Potamalosa richmondia*	Stars and Stripes Leatherjacket	*Meuschenia venusta*
Frigate Mackerel	*Auxis thazard*	Stars and Stripes Toadfish	*Arothron hispidus*
Fringed Stargazer	*Ichthyscopus barbatus*	Stick Pipefish (P)	*Trachyrhamphus bicoarctatus*
Frostfish	*Lepidopus caudatus*	Stout Longtom	*Tylosurus gavialoides*
Gelatinous Cardinalfish	*Pseudamia gelatinosa*	Stout Whiting	*Sillago robusta*
Giant Anglerfish	*Antennarius commersoni*	Striped Anglerfish	*Antennarius striatus*
Giant Boarfish	*Paristiopterus labiosus*	Striped Cardinalfish	*Apogon fasciatus*
Giant Herring	*Elops hawaiensis*	Striped Catfish	*Plotosus lineatus*
Giant Sea Catfish	*Arius thalassinus*	Striped Cleaner Wrasse	*Labroides dimidiatus*
Giant Squirrelfish	*Ostichthys japonicus*	Striped Gudgeon	*Gobiomorphus australis*

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Giant Trevally	*Caranx ignobilis*	Striped Sandgoby	*Acentrogobius pflaumii*
Girdled Parma	*Parma unifasciata*	Striped Seapike	*Sphyraena obtusata*
Girdled Pipefish (P)	*Festucalex cinctus*	Stripey	*Microcanthus strigatus*
Girdled Reef-goby	*Priolepis cincta*	Surge Demoiselle	*Chrysiptera brownriggii*
Glassgoby	*Gobiopterus semivestitus*	Sweetlip Emperor	*Lethrinus miniatus*
Glassy Sprat	*Hyperlophus translucidus*	Sydney Cardinalfish	*Apogon limenus*
Goblinfish	*Glyptauchen panduratus*	Sydney Scorpionfish	*Scorpaenopsis insperatus*
Goldband Fusilier	*Caesio caerulaurea*	Sydney Skate	*Dipturus australis*
Golden Weedfish	*Cristiceps aurantiacus*	Tailor	*Pomatomus saltatrix*
Goldfish	*Carassius auratus*	Tallfin Flyingfish	*Cheilopogon pinnatibarbatus*
Goldlined Wrasse	*Coris aurilineata*	Tamar Goby	*Afurcagobius tamarensis*
Goldspot Pigfish	*Bodianus perditio*	Tarwhine	*Rhabdosargus sarba*
Gold-spotted Sweetlips	*Plectorhinchus flavomaculatus*	Tasmanian Blenny	*Parablennius tasmanianus*
Grass Whiting	*Haletta semifasciata*	Tasmanian clingfish	*Aspasmogaster tasmaniensis*
Green Moray	*Gymnothorax prasinus*	Tasmanian numbfish	*Narcine tasmaniensis*
Green Sawfish (E)	*Pristis zijsron*	Tasselled Leatherjacket	*Chaetodermis penicilligera*
Greenback Stingaree	*Urolophus viridis*	Teira Batfish	*Platax teira*
Greeneye Dartgoby	*Ptereleotris microlepis*	Temperate Scad	*Decapterus muroadsi*
Grey Nurse Shark (E)	*Carcharias taurus*	Teraglin	*Atractoscion aequidens*
Grey Spotted Catshark	*Asymbolus analis*	Theodore's Threadfin-bream	*Nemipterus theodorei*
Gulf Damsel	*Pristotis obtusirostris*	Thicklip Trevally	*Carangoides orthogrammus*
Gummy Shark	*Mustelus antarcticus*	Thicklip Wrasse	*Hemigymnus melapterus*
Günther's Butterflyfish	*Chaetodon guentheri*	Thorny-back Cowfish	*Lactoria fornasini*
Gunther's wrasse	*Pseudolabrus guentheri*	Threadfin Butterflyfish	*Chaetodon auriga*
Hairy Pipefish (P)	*Urocampus carinirostris*	Threadfin Emperor	*Lethrinus genivittatus*
Halfband Cardinalfish	*Apogon semiornatus*	Threadfin Leatherjacket	*Paramonacanthus filicauda*
Halfband Snake Eel	*Malvoliophis pinguis*	Threadfin Reef-goby	*Priolepis nuchifasciata*
Half-banded Seaperch	*Hypoplectrodes maccullochi*	Thread-tail Dartgoby	*Ptereleotris hanae*
Half-bridled Goby	*Arenigobius frenatus*	Threeband Demoiselle	*Chrysiptera tricincta*
Half-scale Sandburrower	*Creedia partimsquamigera*	Three-bar Porcupinefish	*Dicotylichthys punctulatus*
Halstead's Toadfish	*Reicheltia halsteadi*	Three-by-two Garfish	*Hemiramphus robustus*
Hasselt's Flaphead Goby	*Callogobius hasseltii*	Three-spot Dascyllus	*Dascyllus trimaculatus*
Herring Cale	*Odax cyanomelas*	Tiger Cardinalfish	*Cheilodipterus macrodon*
Highfin Toadfish	*Torquigener altipinnis*	Tiger Flathead	*Platycephalus richardsoni*
Hoese's Sandgoby	*Istigobius hoesei*	Tiger Pipefish (P)	*Filicampus tigris*
Horned Blenny	*Parablennius intermedius*	Tiger Shark	*Galeocerdo cuvier*
Hussar	*Lutjanus adetii*	Tommyfish	*Limnichthys fasciatus*
Immaculate Damsel	*Mecaenichthys immaculatus*	Toothbrush Leatherjacket	*Acanthaluteres vittiger*
Indo-Pacific sergeant	*Abudefduf vaigiensis*	Trident Goby	*Tridentiger trigonocephalus*
Jameson's Seaperch	*Hypoplectrodes jamesoni*	Tripletail	*Lobotes surinamensis*
Javelin Pipefish (P)	*Lissocampus runa*	Trumpeter Whiting	*Sillago maculata*
John Dory	*Zeus faber*	Turretfish	*Tetrosomus reipublicae*
Keel-head Razorfish	*Xyrichtys jacksonensis*	Two-eye Cardinalfish	*Apogon nigripinnis*
Kelpfish	*Chironemus marmoratus*	Two-spine Angelfish	*Centropyge bispinosa*
keyhole angelfish	*Centropyge tibicen*	Twospot Maori Wrasse	*Oxycheilinus bimaculatus*
King Gar	*Scomberesox saurus*	Twotone Wrasse	*Halichoeres prosopeion*
Klein's Butterflyfish	*Chaetodon kleinii*	Unicorn Leatherjacket	*Aluterus monoceros*

Table B2 - Fishes of Sydney Harbour			
Common name	*Scientific name*	Common name	*Scientific name*
Krefft's Frillgoby	*Bathygobius krefftii*	Upside Down Pipefish (P)	*Heraldia nocturna*
Kuiter's Goby	*Valenciennea immaculata*	Variegated Lizardfish	*Synodus variegatus*
Kuiter's Wrasse	*Macropharyngodon kuiteri*	Velvetfish	*Aploactisoma milesii*
Lance Blenny	*Aspidontus dussumieri*	Waite's Seapike	*Sphyraena waitii*
Largehead Hairtail	*Trichiurus lepturus*	Ward's Damsel	*Pomacentrus wardi*
Largemouth Goby	*Redigobius macrostoma*	Weedy Seadragon (P)	*Phyllopteryx taeniolatus*
Largenose Weedfish	*Heteroclinus nasutus*	Weeping Toado	*Torquigener pleurogramma*
Largescale Saury	*Saurida undosquamis*	White Shark (V)	*Carcharodon carcharias*
Largespotted Herring	*Herklotsichthys koningsbergeri*	White-barred Goby	*Amblygobius phalaena*
Largetooth Flounder	*Pseudorhombus arsius*	White-Ear	*Parma microlepis*
Latchet	*Pterygotrigla polyommata*	Whitelegg's Weedfish	*Heteroclinus whiteleggii*
Leaf Scorpionfish	*Taenianotus triacanthus*	Whitelined Eviota	*Eviota albolineata*
Leaping Bonito	*Cybiosarda elegans*	White's Seahorse (P)	*Hippocampus whitei*
Lemon Tongue-sole	*Paraplagusia bilineata*	Whitespotted Guitarfish	*Rhynchobatus australiae*
Leopard Shark	*Stegostoma fasciatum*	Whitetail Angelfish	*Centropyge flavicauda*
Lesser Moray	*Gymnothorax minor*	Wide-body Pipefish (P)	*Stigmatopora nigra*
Little Conger	*Gnathophis longicaudatus*	Woods Siphonfish	*Siphamia cephalotes*
Little Dragonfish	*Eurypegasus draconis*	Yellow Boxfish	*Ostracion cubicus*
Little Weed Whiting	*Neoodax balteatus*	Yellow Tang	*Zebrasoma flavescens*
Long Green Wrasse	*Pseudojuloides elongatus*	Yellowback Bream	*Dentex tumifrons*
Longfin Bannerfish	*Heniochus acuminatus*	Yellow-back Puller	*Chromis nitida*
Longfinned Eel	*Anguilla reinhardtii*	Yellowband Fusilier	*Pterocaesio chrysozona*
Long-finned Perch	*Caprodon longimanus*	Yellowedge Lyretail	*Variola louti*
Long-finned Pike	*Dinolestes lewini*	Yellowfin Bream	*Acanthopagrus australis*
Longhorn Cowfish	*Lactoria cornuta*	Yellowfin Goby	*Acanthogobius flavimanus*
Longsnout Flounder	*Ammotretis rostratus*	Yellowfin Pigfish	*Bodianus flavipinnis*
Longspine Flathead	*Platycephalus longispinis*	Yellow-finned Leatherjacket	*Meuschenia trachylepis*
Longtail Catfish	*Euristhmus lepturus*	Yellow-striped Leatherjacket	*Meuschenia flavolineata*
Lowe's Leatherjacket	*Paramonacanthus lowei*	Yellowtail Demoiselle	*Neopomacentrus azysron*
Luculentus Wrasse	*Pseudolabrus luculentus*	Yellowtail Kingfish	*Seriola lalandi*
Luderick	*Girella tricuspidata*	Yellowtail Scad	*Trachurus novaezelandiae*
Lyre-tail Hawkfish	*Cyprinocirrhites polyactis*	Zebra Lionfish	*Dendrochirus zebra*
		Zebra Sole	*Zebrias quagga*
		Zebrafish	*Girella zebra*
		Zig-zag Ponyfish	*Leiognathus moretoniensis*
P = Protected Species, Fisheries Management Act, 2004			
E = Endangered Species, Fisheries Management Act, 1994			
V = Vulnerable, Fisheries Management Act, 1994 **Source:** Australian Museum, 2007			

Table B3 - Other Marine Fauna Species Recorded in the Study Area & Sydney Harbour

Common Name	Scientific Name	Where Observed	Source of Information
Australian Fur Seal (V1)	*Arctocephalus pusillus doriferus*	Sydney Harbour	Australian Museum, 2007
Blue Swimmer Crab	*Portunus pelagicus*	Manly Wharf	Author*
Bottlenose Dolphin	*Tursiops Truncatus*	Sydney Harbour	Australian Museum, 2007
Common Dolphin	*Delphinus delphis*	Sydney Harbour	Australian Museum, 2007
Crab-eater Seal	*Lobodon carcinophagus*	Sydney Harbour	Australian Museum, 2007
Dugong (E1)	*Dugong dugon*	Sydney Harbour	Australian Museum, 2007
Green Turtle	*Chelonia Mydas*	Sydney Harbour	Australian Museum, 2007
Humpback Whale (V1)	*Megaptera novaeangliae*	Sydney Harbour	Author*
Killer Whale	*Orcinus orca*	Sydney Harbour	Australian Museum, 2007
Leatherback Turtle	*Dermochelys Coriacea*	Sydney Harbour	Australian Museum, 2007
Leopard Seal	*Hydrurga leptonyx*	Sydney Harbour	Australian Museum, 2007
Loggerhead Turtle	*Caretta Caretta*	Sydney Harbour	Australian Museum, 2007
Pygmy Sperm Whale	*Kogia breviceps*	Sydney Harbour	Australian Museum, 2007
Risso's Dolphin	*Grampus griseus*	Sydney Harbour	Australian Museum, 2007
Southern Calamari	*Sepioteuthis australis*	Adjacent to Balmoral Beach	Author*
Southern Elephant Seal	*Mirounga leonina*	Sydney Harbour	Australian Museum, 2007
Sperm Whale (V1)	*Physeter macrocephalus*	Sydney Harbour	Australian Museum, 2007
Spotted Dolphin	*Stenella attenuata*	Sydney Harbour	Australian Museum, 2007
Yellow-bellied Sea Snake	*Pelamis platurus*	Sydney Harbour	Australian Museum, 2007
E1 = Endangered Species, NSW Threatened Species Conservation Act, 1995 V1 = Vulnerable Species, NSW Threatened Species Conservation Act, 1995			
* = species observed by the author - Scott Machar, Estuary Management Officer, Manly Council			

Table B4 - Estuarine Flora Species within the Study Area

Common Name	Scientific Name
Caulerpa*	*Caulerpa taxifolia*
Eelgrass	*Zostera capricorni*
Halophila	*Paddleweed*
Kelp / Algae	*Various / Unknown*
Strapweed	*Posidonia australis*
* Class 1 Noxious Marine Vegetation on Fisheries Management Act, 1994	
Source: DPI, 2006	

Table B5

Port Survey for Introduced Marine Species - Sydney Harbour

Schedule 1

Target Introduced Pest Species

Alexandrium catenella

Alexandrium tamarense

Schedule 2

Marine Species that Pose a Threat to Australia

Mytilus galloprovincialis

Schedule 3

Known or Likely Exotic Marine Species in Australian Waters

Euchone limnicola

Hydroides elegans

Ficopomatus enigmaticus

Table B5 Port Survey for Introduced Marine Species - Sydney Harbour
Pseudopolydora paucibranchiata
Megabalanus rosa
Notomegabalanus algicola
Cirolana harfordi
Eurylana arcuata
Limnoria lignorum
Limnoria quadripunctata
Limnoria tripunctata
Paracerceis sculpta
Sphaeroma walkeri
Botrylloides leachi
Botryllus schlosseri
Ciona intestinalis
Styela plicata
Tridentiger trigonocephalus
Bugula flabellata
Bugula neritina
Conopeum tenuissimum
Schizoporella unicornis
Teredo navalis
Theora lubrica
Polycera hedgpethi
Zeacumantus subcarinatus
Caulerpa filiformis
Source: Australian Museum Business Services, 2002

Table B6 - Intertidal Species Within the Study Area	
Common Name or Taxon	**Scientific Name**
Austrocochlea*	*Austrocochlea constricta*[3]
Barnacle[2]	*Austrobalanus imperator*
Barnacle[2]	*Balanus variegates / amphitrite*
Barnacle[2]	*Chthamalus antennatus*
Barnacle[2]	*Elminius covertus*
Barnacle[2]	*Ibla quadrivalvis*
Barnacle[2]	*Tesseropora rosea*
Barnacle[2]	*Tetraclitella purpurescens*
Bembicium*	*Unknown*
Chiton[2]	*Chiton pelliserpentis*
Chiton[2]	Chiton sp.
Crab[2]	*Cyclograpsus audoinii*
Crab[2]	*Helograpsus haswellianus*
Cunjevoi[1]	*Pyura stolonifera*[3]
Galeolaria*	*Galeolaria caespitosa*[3]
Gastropoda (limpets, slugs, snails)[2]	Aplysia sp.
Gastropoda (limpets, slugs, snails)[2]	*Cf. Agnewia tritoniformis*
Gastropoda (limpets, slugs, snails)[2]	*Austrocochlea concamerata*

Table B6 - Intertidal Species Within the Study Area	
Common Name or Taxon	**Scientific Name**
Gastropoda (limpets, slugs, snails)[2]	*Austrocochlea porcata*
Gastropoda (limpets, slugs, snails)[2]	*Batillaria australis*
Gastropoda (limpets, slugs, snails)[2]	*Bembicium nanum*
Gastropoda (limpets, slugs, snails)[2]	*Bembicium melanostomum*
Gastropoda (limpets, slugs, snails)[2]	*Cellana tramoserica*
Gastropoda (limpets, slugs, snails)[2]	*Littoraria luteola*
Gastropoda (limpets, slugs, snails)[2]	*Morula marginalba*
Gastropoda (limpets, slugs, snails)[2]	*Nerita atramentosa*
Gastropoda (limpets, slugs, snails)[2]	*Nodilittorina unifasciata*
Gastropoda (limpets, slugs, snails)[2]	*Nodilittorina pyramidalis*
Gastropoda (limpets, slugs, snails)[2]	*Notoacmea*
Gastropoda (limpets, slugs, snails)[2]	*Onchidella/Onchidina*
Gastropoda (limpets, slugs, snails)[2]	Opisthobranchia sp.1
Gastropoda (limpets, slugs, snails)[2]	Opisthobranchia sp. 2
Gastropoda (limpets, slugs, snails)[2]	*Patelloida*
Gastropoda (limpets, slugs, snails)[2]	*Siphonaria*
Gastropoda (limpets, slugs, snails)[2]	*Umbraculum sinicum*
Green Algae*	*Unknown*
Limpets*	*Cellana tramoserica*[3]
Little Penguin[1]	*Eudyptula minor*
Marine Worm[2]	*Galeolaria caespitose*
Marine Worm[2]	Nereidae
Marine Worm[2]	Terebellidae
Marine Worm[2]	Polynoidae
Mollusca[2]	*Crassostrea gigas*
Mollusca[2]	*Lasaea australis*
Mollusca[2]	*Mytilus*
Mollusca[2]	*Saccostrea glomerate*
Mollusca[2]	*Trichomya hirsuta*
Morula*	*Morula marginalba*[3]
Mussels*	*Unknown*
Nerita*	*Unknown*
Onchidium*	*Unknown*
Oyster Limpet*	*Unknown*
Oysters*	*Unknown*
Pyrazus*	*Pyrazus ebeninus*[3]
Red Algae*	*Unknown*
Sea Squirt[2]	Ascidiacea sp.
Sea Squirt[2]	*Pyura stolonifera*
Seastar[2]	*Patiriella exigua*
Slater[2]	*Cirolana*
Slater[2]	Ligiidae
Soldier Crab[1]	*Mictyris longicarpus*
Yabby (Saltwater)[1]	*Trypaea australiensis*

Table B6 - Intertidal Species Within the Study Area	
Common Name or Taxon	**Scientific Name**
* species were observed by Sydney Water at monitoring locations at Sugarloaf Bay &/or Quakers Hat Bay (both adjacent to the study area, on the opposite side of Middle Harbour), and are therefore expected to also be present within the study area	
[1] Observed,within the study area, by Scott Machar, Estuary Management Officer, Manly Council	
[2] Species identified in the Spit Bridge Proposed Widening Statement of Environmental Effects, GHD, 2003	
[3] Scientific names were obtained through various websites, and are assumed to be the correct scientific names of the species observed by Sydney Water	

Table B7 - Oyster Populations in Middle Harbour			
Sugarloaf Bay		**Quakers Hat Bay**	
Year	**Oysters**	**Year**	**Oysters**
1994	44	1994	26
1994	102	1994	36
1994	121	1994	42
1994	140	1994	48
1994	166	1994	62
1994	178	1994	64
1994	182	1994	122
1994	188		
1994	205		
1994	210		
1995	110	1995	130
1995	150	1995	60
1995	100	1995	60
1995	100	1995	20
1995	60	1995	80
1995	50	1995	50
1995	30	1995	80
1996	105	1996	90
1996	140	1996	65
1996	110	1996	70
1996	100	1996	55
1996	71	1996	125
1996	32	1996	46
1996	59	1996	10
1997	187	1997	89
1997	115	1997	60
1997	120	1997	46
1997	79	1997	75
1997	115	1997	98
1997	76	1997	80
1997	30	1997	30
1998	110	1998	57
1998	132	1998	36
1998	71	1998	38
1998	170	1998	42
1998	175	1998	62

Table B7 - Oyster Populations in Middle Harbour			
Sugarloaf Bay		Quakers Hat Bay	
Year	Oysters	Year	Oysters
1998	75	1998	80
1998	120	1998	32
1999	180	1999	92
1999	115	1999	130
1999	53	1999	81
1999	32	1999	105
1999	65	1999	99
1999	78	1999	125
1999	79	1999	170
2000	125	2000	125
2000	150	2000	130
2000	160	2000	60
2000	65	2000	65
2000	70	2000	150
2000	130	2000	45
2000	85	2000	110
2001	90	2001	135
2001	100	2001	125
2001	260	2001	100
2001	58	2001	100
2001	230	2001	125
2001	323	2001	97
2001	108	2001	108
2002	250	2002	155
2002	180	2002	175
2002	80	2002	180
2002	200	2002	250
2002	280	2002	205
2002	170	2002	265
2002	94	2002	315
2003	290	2003	175
2003	78	2003	190
2003	210	2003	160
2003	190	2003	130
2003	230	2003	305
2003	14	2003	89
2003	120	2003	140
2004	160	2004	190
2004	100	2004	85
2004	240	2004	45
2004	290	2004	180
2004	92	2004	92
2004	500	2004	80
2004	100	2004	160
2005	358	2005	55
2005	192	2005	60
2005	256	2005	105
2005	255	2005	150
2005	134	2005	172

Table B7 - Oyster Populations in Middle Harbour			
Sugarloaf Bay		**Quakers Hat Bay**	
Year	**Oysters**	**Year**	**Oysters**
2005	385	2005	258
2005	360	2005	123
Source: Sydney Water 2006			

Table B8 - Terrestrial Native Fauna Species within the Study Area		
Group	**Common Name**	**Scientific Name**
Amphibian	Common Eastern Froglet	*Crinia signifera*
Amphibian	Brown-striped Frog	*Limnodynastes peronii*
Amphibian	Peron's Tree Frog	*Litoria peronii*
Bird	Australian King Parrot	*Alisterus scapularis*
Bird	Australian Magpie	*Gymnorhina tibicen*
Bird	Australian Pelican	*Pelecanus conspicillatus*
Bird	Australian Raven	*Corvus coronoides*
Bird	Australian White Ibis	*Threskiornis molucca*
Bird	Australian Wood Duck	*Chenonetta jubata*
Bird	Bell Miner	*Manorina melanophrys*
Bird	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
Bird	Brown Gerygone	*Gerygone mouki*
Bird	Channel-billed Cuckoo	*Scythrops novaehollandiae*
Bird	Common Koel	*Eudynamys scolopacea*
Bird	Crested Pigeon	*Ocyphaps lophotes*
Bird	Crimson Rosella	*Platycercus elegans*
Bird	Dollarbird	*Eurystomus orientalis*
Bird	Eastern Rosella	*Platycercus eximius*
Bird*	Eastern spinebill	*Acanthorhynchus tenuirostris*
Bird	Eastern Whipbird	*Psophodes olivaceus*
Bird	Eastern Yellow Robin	*Eopsaltria australis*
Bird	Fan-tailed Cuckoo	*Cacomantis flabelliformis*
Bird	Galah	*Cacatua roseicapilla*
Bird	Grey Butcherbird	*Cracticus torquatus*
Bird	Grey Fantail	*Rhipidura fuliginosa*
Bird	Laughing Kookaburra	*Dacelo novaeguineae*
Bird	Little Black Cormorant	*Phalacrocorax sulcirostris*
Bird	Little Corella	*Cacatua sanguinea*
Bird	Little Wattlebird	*Anthochaera chrysoptera*
Bird	Magpie-lark	*Grallina cyanoleuca*
Bird	New Holland Honeyeater	*Phylidonyris novaehollandiae*
Bird	Noisy Friarbird	*Philemon coniculatus*
Bird	Noisy Miner	*Manorina melanocephala*
Bird	Pacific Black Duck	*Anas superciliosa*
Bird	Pied Cormorant	*Phalacrocorax varius*
Bird	Pied Currawong	*Strepera graculina*
Bird	Rainbow Lorikeet	*Trichoglossus haematodus*

Table B8 - Terrestrial Native Fauna Species within the Study Area		
Group	**Common Name**	**Scientific Name**
Bird	Red Wattlebird	*Anthochaera carunculata*
Bird*	Red-browed finch	*Emblema temporalis*
Bird	Rufous Fantail	*Rhipidura rufifrons*
Bird	Sacred Kingfisher	*Todiramphus sanctus*
Bird*	Silver Eye	*Zosterops lateralis*
Bird	Silver Gull	*Larus novaehollandiae*
Bird	Spotted Pardalote	*Pardalotus punctatus*
Bird	Sulphur-crested Cockatoo	*Cacatua galerita*
Bird	Superb Fairy-wren	*Malurus cyaneus*
Bird	Tawny Frogmouth	*Podargus strigoides*
Bird	Variegated Fairy-wren	*Malurus lamberti*
Bird	Welcome Swallow	*Hirundo neoxena*
Bird	Whistling Kite	*Haliastur sphenurus*
Bird*	White-breasted Sea Eagle	*Haliaeetus leucogaster*
Bird	White-browed Scrubwren	*Sericornis frontalis*
Bird*	White-cheeked Honeyeater	*Phylidonyris nigra*
Bird	White-faced Heron	*Egretta novaehollandiae*
Bird	Willie Wagtail	*Rhipidura leucophrys*
Bird	Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*
Mammal	Common Brushtail Possum	*Trichosurus vulpecula*
Mammal	Common Ringtail Possum	*Pseudocheirus peregrinus*
Mammal	Gliders (unknown type)	*not specified*
Mammal	Grey-headed Flying-fox (T2 & E2)	*Pteropus poliocephalus*
Mammal	Short-beaked Echidna	*Tachyglossus aculeatus*
Mammal	Water Rat	*Hydromys chrysogaster*
Reptile	Bearded Dragon	*Pogona barbata*
Reptile	Copper-tailed Skink	*Ctenotus taeniolatus*
Reptile	Dark-flecked Garden Sunskink	*Lampropholis delicata*
Reptile	Eastern Blue-tongued Lizard	*Tiliqua scincoides*
Reptile	Eastern Water Dragon	*Physignathus lesueurii*
Reptile	Eastern Water-skink	*Eulamprus quoyii*
Reptile	Golden Crowned Snake	*Cacophis squamulosus*
Reptile	Green Tree Snake	
Reptile	Lace Monitor	*Varanus varius*
Reptile	Pale-flecked Garden Sunskink	*Lampropholis guichenoti*
Reptile	Robust Ctenotus	*Ctenotus robustus*
Reptile	Southern Leaf-tailed Gecko	*Phyllurus platurus*
Reptile	Yellow-bellied Three-toed Skink	*Saiphos equalis*
T2 = Vulnerable on Schedule 2, NSW Threatened Species Conservation Act, 1995 E2 = Endangered on Commonwealth Environmental Protection and Biodiversity Conservation Act, 1999		
Source: Skelton et al, 2004, * Observed & reported by Dr. Jan Ritchie (personal communication)		

Table B9 - Terrestrial Exotic Fauna Species within the Study Area		
Group	**Common Name**	**Scientific Name**
Bird	Spotted Turtle-Dove	*Streptopelia chinensis*
Bird	Mallard	*Anas platyrhynchos*
Bird	Common Myna	*Acridotheres tristis*
Bird	Common Starling	*Sturnus vulgaris*
Bird	House Sparrow	*Passer domesticus*
Mammal	Black Rat	*Rattus rattus*
Mammal	Cat	*Felis catus*
Mammal	Dog	*Canis familiaris*
Mammal	Rabbit	*Oryctolagus cuniculus*
Source: Skelton et al, 2004		

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Cycad	Burrawang	*Macrozamia communis*
Fern	Batswing Fern	*Histiopteris incisa*
Fern	Birds Nest Fern	*Asplenium australasicum*
Fern	Bracken	*Pteridium esculentum*
Fern	Cartilage Fern	*Blechnum cartilagineum*
Fern	Christella	*Christella dentata*
Fern	Coral Fern	*Gleichenia microphylla*
Fern	Elk Horn	*Platycerium bifurcatum subsp. bifurcatum*
Fern	False Bracken Fern	*Calochlaena dubia*
Fern	Harsh Ground Fern	*Hypolepis muelleri*
Fern	King Fern	*Todea barbara*
Fern	Lacy Wedge Fern	*Lindsaea microphylla*
Fern	Maidenhair Fern	*Adiantum aethiopicum*
Fern	Necklace Fern	*Asplenium flabellifolium*
Fern	Pouched Coral Fern	*Gleichenia dicarpa*
Fern	Rasp Fern	*Doodia aspera*
Fern	Rough Tree Fern	*Cyathea australis*
Fern	Screw Fern	*Lindsaea linearis*
Fern	Straw Tree Fern	*Cyathea cooperi*
Fern	Trim Shield Fern	*Lastreopsis decomposita*
Fern	Trim Shield Fern	*Lastreopsis decomposita*
Fern	Umberella Fern	*Sticherus flabellatus*
Fern	Umberella Fern	*Sticherus flabellatus*
Fern	Unknown	*Doodia caudata var. caudata*
Fern	Unknown	*Doodia caudata var. caudata*
Fern	Unknown	*Doodia caudata var. caudata*
Fern	Unknown	*Selaginella uliginosa*
Grass	Basket Grass	*Oplismenus aemulus*
Grass	Blady Grass	*Imperata cylindrica var. major*
Grass	Common Couch	*Cyanodon dactylon*
Grass	Common Couch	*Cyanodon dactylon*
Grass	Kangaroo Grass	*Themeda australis*
Grass	Oat Speargrass	*Anisopogon avenaceus*

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Grass	Paspalidium	*Paspalidium distans*
Grass	Sand Couch	*Sporobolus virginicus*
Grass	Two Colour Panic	*Panicum simile*
Grass	Unknown	*Entolasia marginata*
Grass	Unknown	*Entolasia marginata*
Grass	Unknown	*Entolasia marginata*
Grass	Unknown	*Entolasia marginata*
Grass	Unknown	*Poa affinis*
Grass	Unknown	*Poa labillardieri*
Grass	Weeping Grass	*Microlaena stipoides var. stipoides*
Grass	Wiry Panic	*Entolasia stricta*
Grass Tree	Broad-leaved Grass Tree	*Xanthorrhoea arborea*
Grass Tree	Forest Grass Tree	*Xanthorrhoea media/resinifera*
Grass Tree	Grass Tree	*Xanthorrhoea minor ssp. minor*
Herb	Blue Flax Lily	*Dianella caerulea*
Herb	Bush Pea	*Pultanaea stipularis*
Herb	Carrot Tops	*Platysace linearifolia*
Herb	Centella	*Centella asiatica*
Herb	Christmas Bells	*Blandfordia nobilis*
Herb	Cockspur Flowers	*Plectranthus parviflorus*
Herb	Common Stinkweed	*Opercularia aspera*
Herb	Creeping Christian	*Commelina cyanea*
Herb	Crucifix Orchid	*Epidendrum ibaguense*
Herb	Cup Orchid	*Cryptostylis erecta*
Herb	Daisy-bush	*Olearia tomentosa*
Herb	Dwarf Trumpet	*Brunoniella pumilio*
Herb	Flannel Flower	*Actinotus helianthi*
Herb	Forest Clematis	*Clematis glycinoides var. glycinoides*
Herb	Geranium	*Geranium homeanum*
Herb	Germander Raspwort	*Gonocarpus teucrioides*
Herb	Gymea Lily	*Doryanthes excelsa*
Herb	Heathy Platysceae	*Platysace ericoides*
Herb	Kidney Weed	*Dichondra repens*
Herb	Lesser Flannel Flower	*Actinotus minor*
Herb	Lesser joy weed	*Alternanthera denticulata*
Herb	Mat-rush	*Lomandra gracilis*
Herb	Mitre Weed	*Mitrasacme polymorpha*
Herb	Native Bluebell	*Wahlenbergia gracilis*
Herb	Native Parsnip	*Platysace lanceolata*
Herb	Native Violet	*Viola hederacea*
Herb	Pale Mat-rush	*Lomandra glauca*
Herb	Pomax	*Pomax umbellata*
Herb	Rock Xanthosia	*Xanthosia tridentata*
Herb	Silky Purple Flag	*Patersonia sericea*
Herb	Spiny-headed Mat-rush	*Lomandra longifolia*
Herb	Stiff Cassinia	*Cassinia denticulata*
Herb	Swamp Lilly	*Crinum pedunculatum*

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Herb	Tongue Orchid	*Dendrobium linguiforme*
Herb	Unknown	*Astroloma pinifolium*
Herb	Unknown	*Comesperma volubile*
Herb	Unknown	*Duboisia myoporoides*
Herb	Unknown	*Gonocarpus micranthus*
Herb	Unknown	*Gonocarpus sp.*
Herb	Unknown	*Hydrocotyle peduncularis*
Herb	Unknown	*Hydrocotyle peduncularis*
Herb	Unknown	*Hydrocotyle peduncularis*
Herb	Unknown	*Hydrocotyle peduncularis*
Herb	Unknown	*Hydrocotyle peduncularis*
Herb	Unknown	*Hydrocotyle tripartita*
Herb	Unknown	*Hydrocotyle tripartita*
Herb	Unknown	*Lagenifera stipitata*
Herb	Unknown	*Morinda jasminoides*
Herb	Unknown	*Opercularia hispida*
Herb	Unknown	*Persicaria decipiens*
Herb	Unknown	*Phyllanthus hirtellus*
Herb	Unknown	*Phyllanthus hirtellus*
Herb	Unknown	*Rhagodia candolleana subsp. candolleana*
Herb	Unknown	*Rhagodia candolleana subsp. candolleana*
Herb	Unknown	*Schelhammera undulata*
Herb	Unknown	*Schelhammera undulata*
Herb	Unknown	*Veronica plebeia*
Herb	Unknown	*Veronica plebeia*
Herb	Warrigal Greens	*Tetragonia tetragonoides*
Herb	Wattle Mat-rush	*Lomandra filiformis ssp. filiformis*
Herb	White Root	*Pratia purpurascens*
Herb	Wooly Xanthosia	*Xanthosia pilosa*
Palm	Cabbage Tree Palm	*Livistona australis*
Rush	Rush	*Lepyrodia muelleri*
Rush	Scale-rush	*Lepyrodia scariosa*
Rush	Unknown	*Empodisma minus*
Sedge	Beardless Bog-rush	*Schoenus imberbis*
Sedge	Black Bog-rush	*Schoenus melanostachys*
Sedge	Cut Grass	*Gahnia aspera*
Sedge	Heath Bog-rush	*Schoenus ericetorum*
Sedge	Knobby Club-rush	*Isolepis nodosa*
Sedge	Old Man's Beard	*Caustis flexuosa*
Sedge	Rush	*Juncus usitatus*
Sedge	Sea Rush	*Juncus kraussii*
Sedge	Sword-sedge	*Lepidosperma lineare*
Sedge	Unknown	*Cyperus polystachyos*
Sedge	Unknown	*Cyperus sp.*
Sedge	Unknown	*Lepidosperma filiforme*
Sedge	Unknown	*Lepidosperma filiforme*
Sedge	Unknown	*Ptilothrix deusta*

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Sedge	Variable Sword Edge	*Lepidosperma laterale*
Shrub	Banksia	*Banksia oblongifolia*
Shrub	Bleeding Heart	*Omalanthus populifolius*
Shrub	Boobialla	*Myoporum boninense ssp. australe*
Shrub	Bossiaea	*Bossiaea heterophylla*
Shrub	Breynia	*Breynia oblongifolia*
Shrub	Broad-leaved Hakea	*Hakea dactyloides*
Shrub	Bushy Needlebush	*Hakea sericea*
Shrub	Coastal Rosemary	*Westringia fruticosa*
Shrub	Coastal Tea-tree	*Leptospermum laevigatum*
Shrub	Coastal Wattle	*Acacia longifolia var. sophorae*
Shrub	Common Acronychia	*Acronychia oblongifolia*
Shrub	Conesticks	*Petrophile pulchella*
Shrub	Crinkle Bush	*Lomatia silaifolia*
Shrub	Crowea	*Crowea saligna*
Shrub	Dagger Hakea	*Hakea teretifolia*
Shrub	Dog Rose	*Bauera capitata*
Shrub	Eggs and Bacon	*Dillwynia retorta*
Shrub	Elderberry Panax	*Polyscias sambucifolia*
Shrub	Flax-leaved Wattle	*Acacia linifolia*
Shrub	Fuchsia Heath	*Epacris longiflora*
Shrub	Guinea Flower	*Hibbertia linearis*
Shrub	Hairpin Banksia	*Banksia spinulosa var. spinulosa*
Shrub	Hairy Zieria	*Zieria pilosa*
Shrub	Hakea	*Hakea gibbosa*
Shrub	Handsome Flat-pea	*Platylobium formosum*
Shrub	Heath Leaved Banksia	*Banksia ericifolia var. ericifolia*
Shrub	Hickory	*Acacia implexa*
Shrub	Hop Bush	*Dodonaea triquetra*
Shrub	Indian Hawthorn	*Raphiolepis umbellata*
Shrub	Lance Bearded Heath	*Leucopogon lanceolatus*
Shrub	Lance Beard-heath	*Leucopogon lanceolatus var. lanceolatus*
Shrub	Lemon Scented Tea Tree	*Leptospermum polygalifolium*
Shrub	Micrantheum	*Micrantheum ericoides*
Shrub	Mock Olive	*Notelaea ovata*
Shrub	Mountain Devil	*Lambertia formosa*
Shrub	Narrow-leaved Geebung	*Persoonia linearis*
Shrub	Native Fuchsia	*Correa reflexa var. reflexa*
Shrub	Paperbark Tea Tree	*Leptospermum trinervium*
Shrub	Pine-leaved Geebung	*Persoonia pinifolia*
Shrub	Port Jackson Cypress	*Callitris rhomboidea*
Shrub	Prickly Broom-heath	*Monotoca scoparia*
Shrub	Prickly Moses	*Acacia ulicifolia*
Shrub	Red Spider Flower	*Grevillea speciosa*
Shrub	River Lomatia	*Lomatia myricoides*
Shrub	Rough Guinea-flower	*Hibbertia aspera*
Shrub	Rusty Petals	*Lasiopetalum ferrugineum var. ferrugineum*

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Shrub	Sandfly Zieria	*Zieria smithii*
Shrub	Smooth Geebung	*Persoonia levis*
Shrub	Smooth Parrot-pea	*Dillwynia glaberrima*
Shrub	Snow Wreath	*Woollsia pungens*
Shrub	Sunshine Wattle	*Acacia terminalis*
Shrub	Swamp Banksia	*Banksia robur*
Shrub	Sweet Scented Wattle	*Acacia suaveolens*
Shrub	Sydney Golden Wattle	*Acacia longifolia*
Shrub	Tick Bush	*Kunzea ambigua*
Shrub	Tree Broom-heath	*Monotoca elliptica*
Shrub	Twining Guinea Flower	*Hibbertia dentata*
Shrub	Unknown	*Astrotricha floccosa*
Shrub	Unknown	*Baeckea imbricata*
Shrub	Unknown	*Clerodendrum tomentosum*
Shrub	Unknown	*Epacris crassifolia*
Shrub	Unknown	*Epacris pulchella*
Shrub	Unknown	*Epacris pulchella*
Shrub	Unknown	*Epacris pulchella*
Shrub	Unknown	*Grevillea longiflora*
Shrub	Unknown	*Hibbertia serpyllifolia*
Shrub	Unknown	*Hibbertia sp.*
Shrub	Unknown	*Maytenus silvestris*
Shrub	Unknown	*Omalanthus nutans*
Shrub	Unknown	*Omalanthus nutans*
Shrub	Unknown	*Omalanthus nutans*
Shrub	Unknown	*Omalanthus nutans*
Shrub	Unknown	*Petrophile sessilis*
Shrub	Unknown	*Phebalium dentatum*
Shrub	Unknown	*Phebalium dentatum*
Shrub	Unknown	*Phebalium dentatum*
Shrub	Unknown	*Phebalium squamulosum*
Shrub	Unknown	*Podocarpus spinulosus*
Shrub	Unknown	*Podocarpus spinulosus*
Shrub	Unknown	*Podocarpus spinulosus*
Shrub	Unknown	*Podocarpus spinulosus*
Shrub	Unknown	*Podocarpus spinulosus*
Shrub	Unknown	*Podocarpus spinulosus*
Shrub	Unknown	*Pomaderris ferruginea*
Shrub	Unknown	*Pomaderris intermedia*
Shrub	Unknown	*Styphelia triflora*
Shrub	White Spider Flower	*Grevillea linearifolia*
Shrub	Wikstroemia	*Wikstroemia indica*
Shrub	Wilkiea	*Wilkiea huegeliana*
Shrub	Willow-leaved Hakea	*Hakea salicifolia*
Shrub	Woody Pear	*Xylomelum pyriforme*
Shrub	Woolly Pomaderris	*Pomaderris lanigera*
Tree	Bangalay	*Eucalyptus botryoides*

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Tree	Black She-oak	*Allocasuarina littoralis*
Tree	Black Wattle	*Callicoma serratifolia*
Tree	Bloodwood	*Corymbia gummifera*
Tree	Blueberry Ash	*Elaeocarpus reticulatus*
Tree	Brush Muttonwood	*Rapanea howittiana*
Tree	Cheese Tree	*Glochidion ferdinandi var. ferdinandi*
Tree	Coachwood	*Ceratopetalum apetalum*
Tree	Coastal Banksia	*Banksia integrifolia ssp. integrifolia*
Tree	Corkwood	*Endiandra sieberi*
Tree	Dwarf Apple	*Angophora hispida*
Tree	Forest She-oak	*Allocasuarina torulosa*
Tree	Grey Mangrove	*Avicennia marina var. australasica*
Tree	Jackwood	*Cryptocarya glaucescens*
Tree	Lily Pilly	*Acmena smithii*
Tree	Magenta Lillypilly	*Syzygium paniculatum*
Tree	Muttonwood	*Rapanea variabilis*
Tree	Native Peach	*Trema aspera*
Tree	NSW Christmas Bush	*Ceratopetalum gummiferum*
Tree	Old Man Banksia	*Banksia serrata*
Tree	Parramatta Green Wattle	*Acacia parramattensis*
Tree	Port Jackson Fig	*Ficus rubiginosa*
Tree	Rough-fruit Pittosporum	*Pittosporum revolutum*
Tree	Sandpaper Fig	*Ficus coronata*
Tree	Scentless Rosewood	*Synoum glandulosum*
Tree	Scrub She-oak	*Allocasuarina distyla*
Tree	Smooth-barked Apple	*Angophora costata*
Tree	Spotted Gum	*Corymbia maculata*
Tree	Swamp Sheoak	*Casuarina glauca*
Tree	Sweet Pittosporum	*Pittosporum undulatum*
Tree	Sydney Blue Gum	*Eucalyptus saligna*
Tree	Sydney Peppermint	*Eucalyptus piperita*
Tree	Tuckeroo, Yowarro	*Cupaniopsis anacardiodies*
Tree	Unknown	*Acacia longissima*
Tree	Water Gum	*Trisaniopsis laurina*
Vine	Apple Berry, Dumplings	*Billardiera scandens*
Vine	Common Milk Vine	*Marsdenia rostrata*
Vine	Dusky Coral-pea	*Kennedia rubicunda*
Vine	False Sarsaparilla	*Hardenbergia violacea*
Vine	Golden Guinea Flower	*Hibbertia scandens*
Vine	Hairy Devil's Twine	*Cassytha pubescens*
Vine	Kangaroo Vine	*Cissus antarctica*
Vine	Love Creeper	*Glycine clandestina/microphylla*
Vine	Mistletoe	*Amyema congener ssp. congener*
Vine	Native Grape	*Cissus hypoglauca*
Vine	Native Sarsaparilla	*Smilax glyciphylla*
Vine	Scrambling Lily	*Geitonoplesium cymosum*
Vine	Smooth Devil's Twine	*Cassytha glabella*

Table B10 - Terrestrial Native Flora Species within the Study Area		
Habit	**Common Name**	**Scientific Name**
Vine	Snake Vine	*Stephania japonica var. discolor*
Vine	Sweet-scented Doubah	*Marsdenia suaveolens*
Vine	Unknown	*Cassytha sp.*
Vine	Wombat Berry	*Eustrephus latifolius*
Vine	Wonga Wonga Vine	*Pandorea pandorana*
Source: Skelton et al, 2004		

Table B11 - Terrestrial Exotic Flora Species within the Study Area			
Habit	**Common Name**	**Scientific Name**	**Status**
Fern	Fishbone Fern	*Nephrolepis cordifolia*	
Fern	Holly Fern	*Cyrtomium falcatum*	
Grass	Buffalo Grass	*Stenotaphrum secundatum*	
Grass	Clumping Bamboo	*Bambusa sp.*	
Grass	Giant Reed / Elephant Grass	*Arundo donax*	Noxious Class 4
Grass	Kikuyu	*Pennisetum clandestinum*	
Grass	Palm Grass	*Setaria palmifolia*	
Grass	Pampas Grass	*Cortaderia sp.*	Noxious Class 3
Grass	Parramatta Grass	*Sporobolus africanus*	
Grass	Paspalum	*Paspalum dilatatum*	
Grass	Pigeon Grass	*Setaria gracilis*	
Grass	Quaking Grass	*Briza maxima*	
Grass	Rhizomatous Bamboo	*Phyllostachys sp.*	Noxious Class 4
Grass	Shivery Grass	*Briza minor*	
Grass	Unknown	*Paspalum radiatium*	
Grass	Veldt Grass	*Ehrharta sp.*	
Grass	Whiskey Grass	*Andropogon virginicus*	
Herb	Agapanthus	*Agapanthus orientalis*	
Herb	Ageratum	*Ageratum houstonianum*	
Herb	Aluminium Plant	*Pilea cadeierei*	
Herb	American Cactus	*Agave americana*	
Herb	Arum Lilly	*Arum itallicum*	
Herb	Asparagus	*Asparagus officinalis*	
Herb	Asparagus Fern	*Asparagus densiflorus*	Noxious Class 4
Herb	Asthma Weed, Pellitory	*Parietaria judaica*	Noxious Class 4
Herb	Balsam	*Impatiens walleriana*	
Herb	Banana	*Musa sp.*	
Herb	Beefsteak Plant	*Acalypha wilkesiana*	
Herb	Black-berry Nightshade	*Solanum nigrum*	
Herb	Bromeliad	*Bromeliad*	
Herb	Canna Lily	*Canna indica*	
Herb	Cast Iron Plant	*Aspidistra elatior*	
Herb	Century Plant	*Agave attenuata*	
Herb	Climbing Asparagus	*Asparagus plumosus*	Noxious Class 4
Herb	Climbing Rose	*Rosa banskia var. banksiae*	
Herb	Cobbler's Pegs, Pitchforks	*Bidens pilosa*	
Herb	Common Verbena	*Verbena officinalis*	

Table B11 - Terrestrial Exotic Flora Species within the Study Area			
Habit	**Common Name**	**Scientific Name**	**Status**
Herb	Common Vetch	*Vicia sativa*	
Herb	Coreopsis	*Coreopsis lanceolata*	
Herb	Crofton Weed	*Ageratina adenophora*	Noxious Class 4
Herb	Crucifix Orchid	*Epidendrum ibaguense*	
Herb	Cud Weed	*Gnaphalium sp.*	
Herb	Diosma	*Coleonema sp.*	
Herb	Elephant's Ears	*Alocasia indica*	
Herb	Fairy Crassula	*Crassula multicava*	
Herb	Fat Hen	*Chenopodium album*	
Herb	Flatweed	*Hypochaeris radicata*	
Herb	Fleabane	*Conyza sp.*	
Herb	Freesia	*Freesia refracta*	
Herb	Gazania	*Gazania rigens*	
Herb	Geranium	*Geranium sp.*	
Herb	Ginger	*Zingiber officinale*	
Herb	Ginger Lily	*Hedychium gardnerianum*	
Herb	Ink Weed	*Phytolacca octandra*	
Herb	Japanese Knotweed	*Polygonum capitatum*	
Herb	Kaffir Lily	*Clivea miniata*	
Herb	Lamb's Tongues, Plantain	*Plantago lanceolata*	
Herb	Mistflower	*Ageratina riparia*	
Herb	Mother-of-millions	*Bryophyllum delagoense*	
Herb	Mouse Ear Chick Weed	*Cerastium glomeratum*	
Herb	Nasturtium	*Tropaeolum majus*	
Herb	New Zealand Christmas Bell	*Alstroemeria psittacina*	
Herb	New Zealand Flax	*Phormium tenax*	
Herb	Onion Weed	*Nothoscordum gracile*	
Herb	Ornamental Ginger	*Alpinia sp.*	
Herb	Paddy's Lucerne	*Sida rhombifolia*	
Herb	Paper Reed	*Cyperus papyrus*	
Herb	Petty Spurge	*Euphorbia peplus*	
Herb	Philodendron	*Philodendron bipinnatifidum*	
Herb	Pineapple Lily	*Eucomis comosa*	
Herb	Poinsettia	*Euphorbia pulcherrima*	
Herb	Potato Weed	*Galinsoga parviflora*	
Herb	Roadside Lilly	*Lilium formosum*	
Herb	Sailor Boy Daisy	*Dimorphotheca ecklonis*	
Herb	Seaside Daisy	*Erigeron karvinskianus*	
Herb	Smooth Cats Ear	*Hypochaeris glabra*	
Herb	Sow Thistle	*Sonchus oleraceus*	
Herb	Spider Plant	*Chlorphytum comosum*	
Herb	Swiss Cheese Plant	*Monstera deliciosa*	
Herb	Thickheads	*Crassocephalum crepidioides*	
Herb	Unknown	*Solanum sp.*	
Herb	Unknown	*Oxalis sp.*	
Herb	Unknown	*Oxalis sp.*	
Herb	Wandering Jew	*Tradescantia albiflora syn. fluminensis*	Noxious Class 4

Table B11 - Terrestrial Exotic Flora Species within the Study Area			
Habit	**Common Name**	**Scientific Name**	**Status**
Herb	Watercress	*Rorippa nasturtium-aquaticum*	
Herb	Wild Watsonia, Bugle Lily	*Watsonia meriana cv.bulbillifera*	
Herb	Yucca	*Yucca aloifolia*	
Palm	Bangalow Palm	*Archontophoenis cunninghamiana*	
Palm	Canary Island Palm	*Phoenix canariensis*	
Palm	Cocos Palm, Queen Palm	*Syagrus romanzoffiana*	
Reed	Unknown	*Isolepis prolifera*	
Scrambler	Blackberry	*Rubus fruticosus*	Noxious Class 4
Shrub	African Olive	*Olea europa ssp. africana*	
Shrub	Azalea	*Rhododendron sp.*	
Shrub	Bird of Paradise	*Strelitzia nicolaii*	
Shrub	Bitou bush/ Boneseed	*Chrysanthemoides monilifera ssp. rotundata*	Noxious Class 3
Shrub	Bottlebrush	*Callistemon sp.*	
Shrub	Brazilian Nightshade	*Solanum seaforthianum*	
Shrub	Butterfly Bush	*Buddleia davidii*	
Shrub	Cassia	*Senna floribunda*	
Shrub	Cassia / Senna	*Senna pendula*	Noxious Class 4
Shrub	Cootamundra Wattle	*Acacia baileyana*	
Shrub	Cotoneaster	*Cotoneaster pannosus*	
Shrub	Glossy Abelia	*Abelia X grandiflora*	
Shrub	Green Cestrum	*Cestrum parqui*	Noxious Class 3
Shrub	Grevillea	*Grevillea Hybrid*	
Shrub	Hebe	*Hebe sp.*	
Shrub	Hibiscus	*Hibiscus sp.*	
Shrub	Lantana	*Lantana camara*	Noxious Class 4
Shrub	Looking-glass Bush	*Coprosma repens*	
Shrub	Loquat	*Eriobotrya japonica*	
Shrub	May Bush	*Spiraea cantoniensis*	
Shrub	Ochna, Mickey Mouse Plant	*Ochna serrulata*	Noxious Class 4
Shrub	Oleander	*Nerium oleander*	
Shrub	Orange Firethorn	*Pyracantha angustifolia*	
Shrub	Polygala	*Polygala myrtifolia*	
Shrub	Privet - broad leaved	*Ligustrum lucidum*	Noxious Class 4
Shrub	Privet - narrow leaved	*Ligustrum sinense*	Noxious Class 4
Shrub	Rhus tree	*Toxicodendron succedaneum*	Noxious Class 4
Shrub	Silky Oak	*Grevillea robusta*	
Shrub	Tibouchina, Lasiandra	*Tibouchina sp.*	
Shrub	Umberella Tree	*Brassaia actinophylla*	
Shrub	Weigela	*Weigela florida*	
Shrub	Wild Tabacco Tree	*Solanum mauritianum*	
Tree	Albizzia	*Albizzia sp.*	
Tree	Black Bean	*Castanospermum australe*	
Tree	Camellia	*Camellia sasanqua*	
Tree	Camphora Laurel	*Cinnamomum camphora*	
Tree	Chinese Tallow Tree	*Sapium sebiferum*	
Tree	Coral Tree	*Erythrina X sykesii*	
Tree	Cypress	*Cupressus sp.*	

Table B11 - Terrestrial Exotic Flora Species within the Study Area			
Habit	**Common Name**	**Scientific Name**	**Status**
Tree	Flame Tree	*Brachychiton acerifolius*	
Tree	Grapefruit	*Citrus X paradisi*	
Tree	Jacaranda	*Jacaranda mimosifolia*	
Tree	Lombardy Poplar	*Populus sp.*	
Tree	Morton Bay Fig	*Ficus macrophylla*	
Tree	Pine	*Pinnus sp.*	
Tree	Senna	*Senna coluteoides var. glabrata*	
Tree	Stonefruit	*Prunus sp.*	
Tree	White Mulberry	*Morus alba*	
Tree	Willows	*Salix sp.*	Noxious Class 5
Vine	Balloon Vine	*Cardiospermum grandiflorum*	Noxious Class 4
Vine	Cape Ivy	*Delairea odorata*	Noxious Class 4
Vine	Climbing Asparagus Fern	*Protoasparagus plumosus*	Noxious Class 4
Vine	English Ivy	*Hedera helix*	
Vine	Japanese Honeysuckle	*Lonicera japonica*	
Vine	Jasmine	*Jasminum sp.*	
Vine	Madeira Vine	*Anredera cordifolia*	Noxious Class 4
Vine	Morning Glory	*Ipomea cairica*	Noxious Class 4
Vine	Moth Vine	*Araujia sericifera*	
Vine	Passionfruit	*Passiflora edulis*	
Vine	Star Jasmine	*Trachelospermum jasminoides*	
Vine	Turkey Rhubarb	*Acetosa sagittata*	
Source: Skelton et al, 2004			

Status Definitions	
Noxious Class 1	State Prohibited Weeds - The plant must be eradicated from the land and the land must be kept free of the plant.
Noxious Class 2	Regionally Prohibited Weeds - The plant must be eradicated from the land and the land must be kept free of the plant.
Noxious Class 3	Regionally Controlled Weeds - The plant must be fully and continuously suppressed and destroyed.
Noxious Class 4	Locally Controlled Weeds - The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed.
Noxious Class 5	Restricted Plants - The requirements in the Noxious Weed Act 1993 for a notifiable weed must be complied with.

APPENDIX C
STORMWATER QUALITY DESKTOP STUDY

Stormwater Quality Desktop Study:

Clontarf / Bantry Bay Estuary Catchments

Manly Council

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SUMMARY

Maintaining water quality is crucial to protect the health of the Middle Harbour Estuary environment. Stormwater from surrounding urban areas is a primary source of pollution inflows into the Middle Harbour Estuary, exerting control over water quality and environmental health. Six urban catchments exist in Manly Council to the eastern side of Middle Harbour in the Clontarf / Bantry Bay area. These deliver stormwater directly into Middle Harbour, via both artificial stormwater drainage structures and natural creek channels. This document estimates current net stormwater pollutant loads delivered into the estuary from these six Clontarf / Bantry Bay catchments. Net stormwater pollutant loads delivered into the estuary are estimated here from: (1) modelling of stormwater pollutant loads currently generated in the six urban catchments, and (2) review of current pollutant reduction measures implemented by Council in these catchments, (and subtraction of these from modelled loads to estimate net pollutant loads).

Modelling of stormwater pollutant loads currently generated by the six catchments was commissioned, using standard techniques. Modelling was based on present land-uses found in the six catchments, drainage connectivity, adopted annual rainfall, and estimated average stormwater pollutant concentrations. For each catchment, six key stormwater pollutants were modelled: Total Nitrogen (TN), Total Phosphorus (TP), Copper (Cu), Lead (Pb), Zinc (Zn) and Sediment. Substantial annual loads of all pollutants from all catchments were estimated. However, loads are consistent with other urban areas. In all catchments, 'roads' and 'residential' land-uses (rather than other land-uses) were estimated to generate the majority of pollutants. This is due to these land-uses': (1) high imperviousness (transforming a large percentage of rainfall falling in the catchments into stormwater); (2) substantial surface area; and (3) wide range of pollutant sources. Suggested pollutant sources include vehicle traffic and road corrosion (delivering heavy metals, sediment), deciduous trees (delivering nutrients) and vegetation matter (delivering nutrients and sediment).

Current measures implemented by Council in the Clontarf / Bantry Bay catchments to reduce pollutant transportation into Middle Harbour are reviewed, and include street sweeping and Gross Pollutant Traps (GPTs). Pollutant reduction by these treatments is estimated based on research on street sweeping and GPTs in other areas in Manly, and substantial reductions are estimated in loads of all pollutants. However, for all stormwater pollutants, high net loads are predicted to remain in stormwater to enter Middle Harbour, requiring further management. This report provides recommendations for future management of these pollutants from the Clontarf / Bantry Bay catchments, and appropriate interventions for consideration.

1 CATCHMENTS DEFINITION

1.1 Middle Harbour Estuary receiving waters and catchments

Middle Harbour Estuary is a major harbour estuary located to the north-west of Sydney Harbour. It is bordered to its eastern extent by Manly Council (Figure 1), and is partially protected from the Pacific Ocean by Sydney Harbour's North and South Heads.

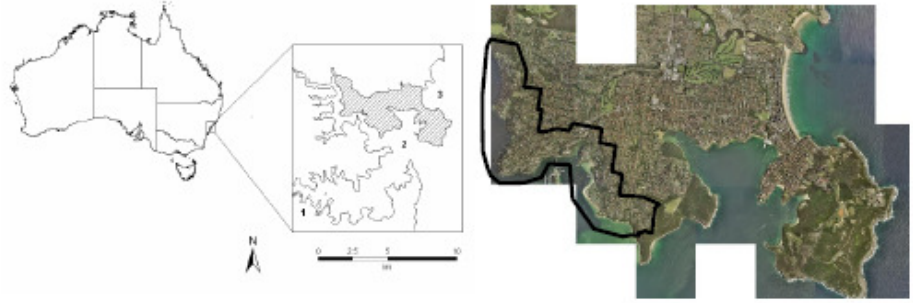

Figure 1: (Left) Location of Manly Local Government Area (LGA) (shaded), on the northern shore of Sydney Harbour (1-Sydney CBD, 2-Sydney Harbour, 3-Manly Beach). Middle Harbour Estuary is located to the immediate west of Manly Council. (Right) Aerial Photo of Manly LGA, showing Manly Council Catchments bordering Middle Harbour (outlined).

During rainfall, the Middle Harbour Estuary receives large inflows of freshwater from urbanised catchments surrounding the estuary. To the east of the estuary, in the Manly Local Government Area, this consists of six urban catchments (Figure 2), in the Clontarf / Bantry Bay area. Stormwater flows into Middle Harbour from these catchments through both extensive artificial drainage networks and natural creek channels. Artificial drainage networks and stormwater outfall locations are marked on Figure 2. The next section reviews these six catchments.

1.2 Clontarf / Bantry Bay Catchments and Land-Uses Present

The six Clontarf / Bantry Bay Catchments in the Manly LGA, which transport stormwater into Middle Harbour, are displayed below (Table 1), based on Manly Council zoning. The catchment areas as defined for this desktop study were determined based on: (1) Manly Council drainage catchment boundaries (previously defined), and (2) restriction of stormwater modelling to within the boundary of the Clontarf / Bantry Bay Estuary Management Plan (as previously defined in that Plan). **Addendum A** includes further information on the process of catchment definition undertaken.

The Clontarf / Bantry Bay Catchments in Manly LGA, as identified (Table 1), occupy a total of 230.55 hectares (ha). Residential land-uses occupy the greatest proportion of this area at 65.5%, followed by road surfaces (22.0%). The urbanised catchments contain approximately 16.03 km in total of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The remainder of **Section 1.2** reviews the land-use conditions in the six Clontarf / Bantry Bay Catchments individually.

Table 1: Land-use breakdown in the six Clontarf / Bantry Bay Catchments in Manly Council (^ includes both Open Space and National Parks; * includes Commercial, Special Use Property, and Unzoned).

Catchment Name	Area (sq m)	Land-use Breakdown (Percent)			
		Residential	Open-Space^	Roads	Other*
Gurney Crescent	319,923	62.4%	15.1%	18.4%	4.2%
Bligh Crescent	179,511	55.3%	13.2%	17.9%	13.6%
Sangrado Street	428,540	75.6%	4.3%	20.1%	0.0%
The Spit	474,719	62.4%	10.5%	26.1%	1.0%
Clontarf	610,506	65.2%	10.6%	22.5%	1.7%
Castle Rock Reserve	292,324	65.9%	10.3%	23.8%	0.0%
Combined Total	**2,305,524**	**65.5%**	**10.2%**	**22.0%**	**2.3%**

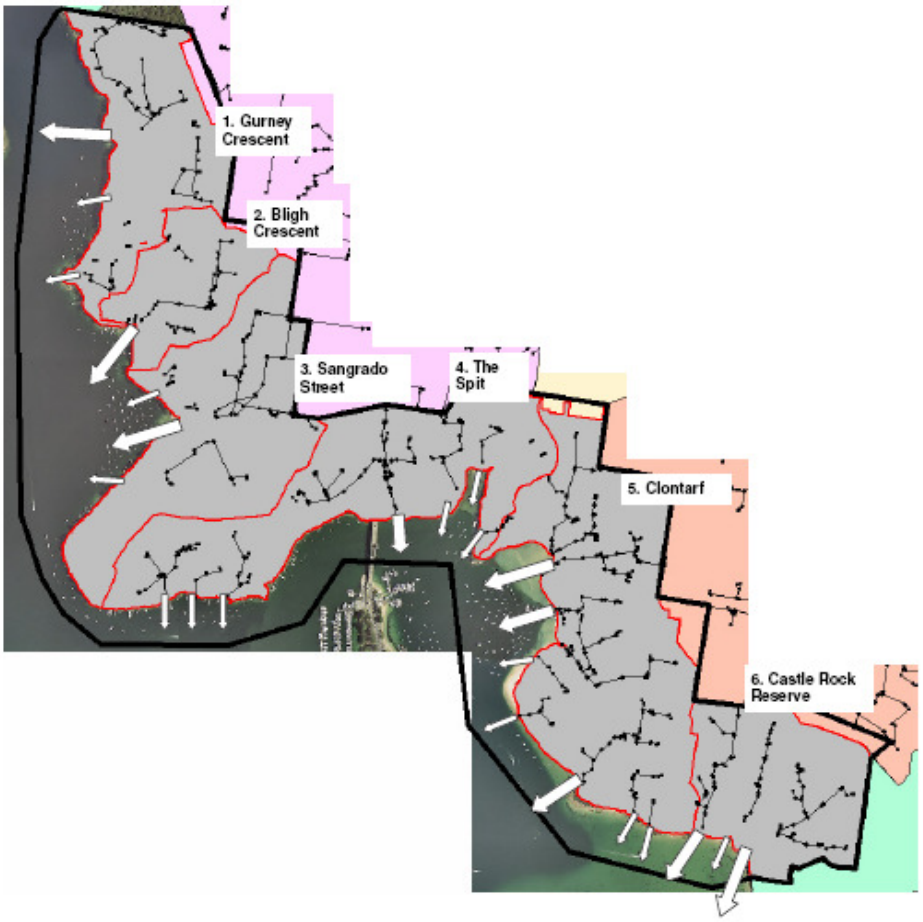

Figure 2: The six Clontarf / Bantry Bay Catchments in Manly Council (shaded grey with red boundaries). Top-to-bottom: 1. Gurney Crescent; 2. Bligh Crescent; 3. Sangrado Street; 4. The Spit; 5. Clontarf; 6. Castle Rock Reserve. Artificial stormwater drainage networks are shown by black lines within the catchments. Black dots indicate locations of pits. Arrows indicate stormwater outfall locations; major outfalls are indicated by larger arrows. The Spit Bridge is visible on the centre-bottom.

1.2.1 Gurney Crescent Catchment and Land-Uses Present

The first of the six catchments, Gurney Crescent, occupies approximately 31.99 ha, and contains approximately 2.09 km of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The artificial drainage network in Gurney Crescent, and land-use distribution is shown in Figure 3A below. The predominant land-use in the catchment is residential at 62.4% (Table 1).

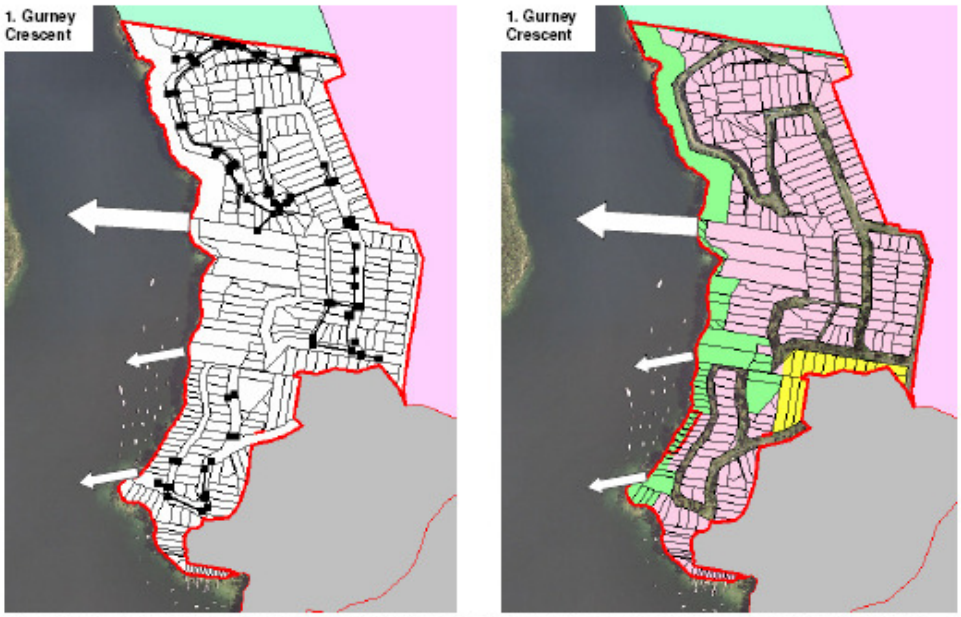

Figure 3A: Gurney Crescent Catchment. (Left) artificial stormwater drainage network. Arrows indicate stormwater outfall locations. (Right) land-use breakdown (Pink: residential; Green: open space; Clear: roads; Yellow: special use).

1.2.2 Bligh Crescent Catchment and Land-Uses Present

The second of the six catchments, Bligh Crescent, occupies approximately 17.95 ha, and contains approximately 0.99 km of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The artificial drainage network in Bligh Crescent, and land-use distribution is shown in Figure 3B below. The predominant land-use in the catchment is residential at 55.3% (Table 1).

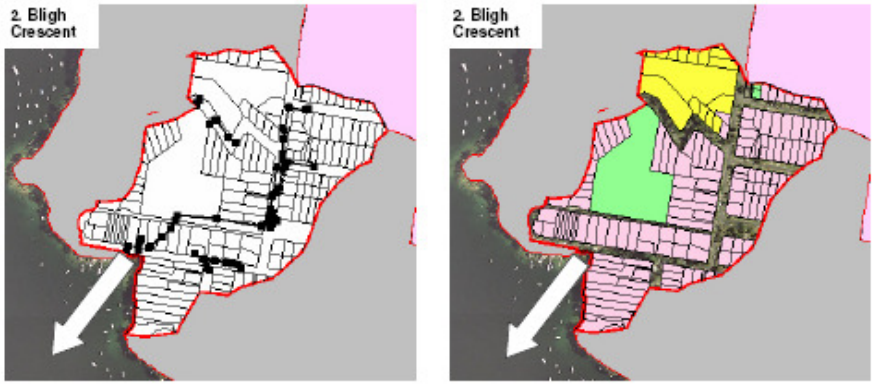

Figure 3B: Bligh Crescent Catchment. (Left) artificial stormwater drainage network. Arrows indicate stormwater outfall locations. (Right) land-use breakdown (Pink: residential; Green: open space; Clear: roads; Yellow: special use).

1.2.3 Sangrado Street Catchment and Land-Uses Present

The third of the six catchments, Sangrado Street, occupies approximately 42.85 ha, and contains approximately 2.35 km of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The artificial drainage network in Sangrado Street, and land-use distribution is shown in Figure 3C below. The predominant land-use in the catchment is residential at 75.6% (Table 1).

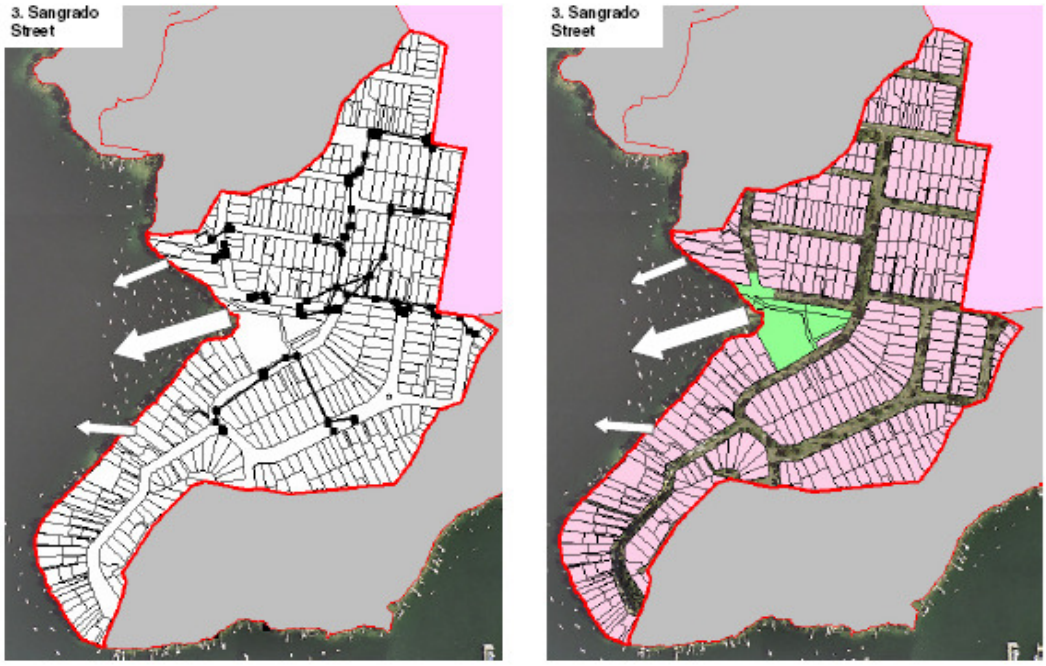

Figure 3C: Sangrado Street Catchment. (Left) artificial stormwater drainage network. Arrows indicate stormwater outfall locations. (Right) land-use breakdown (Pink: residential; Green: open space; Clear: roads).

1.2.4 The Spit Catchment and Land-Uses Present

The fourth of the six catchments, The Spit, occupies approximately 47.47 ha, and contains approximately 3.71 km of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The artificial drainage network in The Spit, and land-use distribution is shown in Figure 3D below. The predominant land-use in the catchment is residential at 62.4% (Table 1).

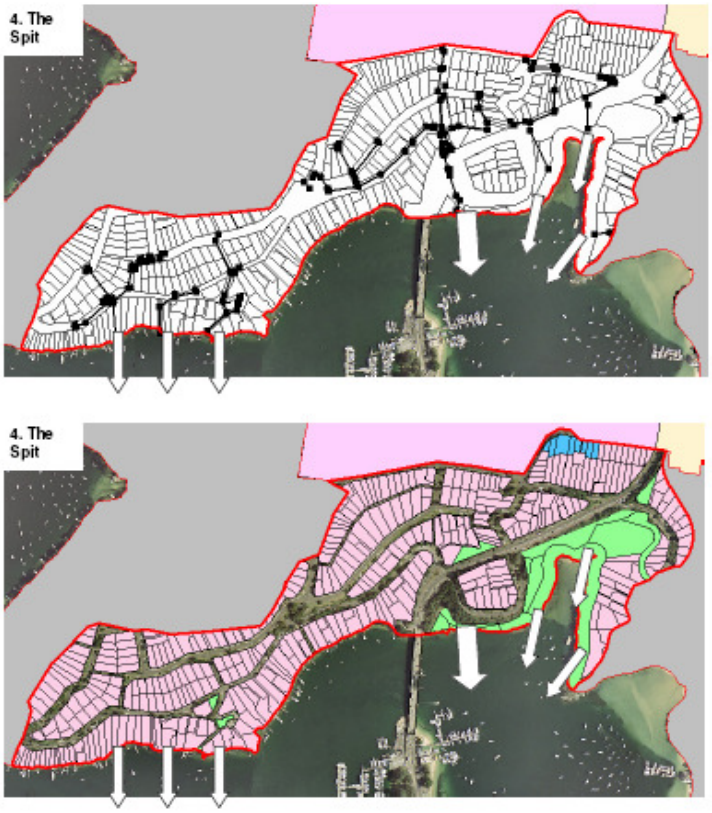

Figure 3D: The Spit Catchment. (Top) artificial stormwater drainage network. Arrows indicate stormwater outfall locations. (Bottom) land-use breakdown (Pink: residential; Green: open space; Clear: roads; Blue: commercial).

1.2.5 Clontarf Catchment and Land-Uses Present

The fifth of the six catchments, Clontarf, occupies approximately 61.05 ha, and contains approximately 4.90 km of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The artificial drainage network in Clontarf, and land-use distribution is shown in Figure 3E below. The predominant land-use in the catchment is residential at 65.2% (Table 1).

Figure 3E: Clontarf Catchment. (Left) artificial stormwater drainage network. Arrows indicate stormwater outfall locations (Right) land-use breakdown (Pink: residential; Green: open space; Clear: roads; Blue: commercial; Yellow: special use).

1.2.6 Castle Rock Reserve Catchment and Land-Uses Present

The last of the six catchments, Castle Rock Reserve, occupies approximately 29.03 ha, and contains approximately 1.99 km of artificial drainage network, directing stormwater into the Middle Harbour Estuary. The artificial drainage network in Castle Rock Reserve, and land-use distribution is shown in Figure 3F below. The predominant land-use in the catchment is residential at 65.9% (Table 1).

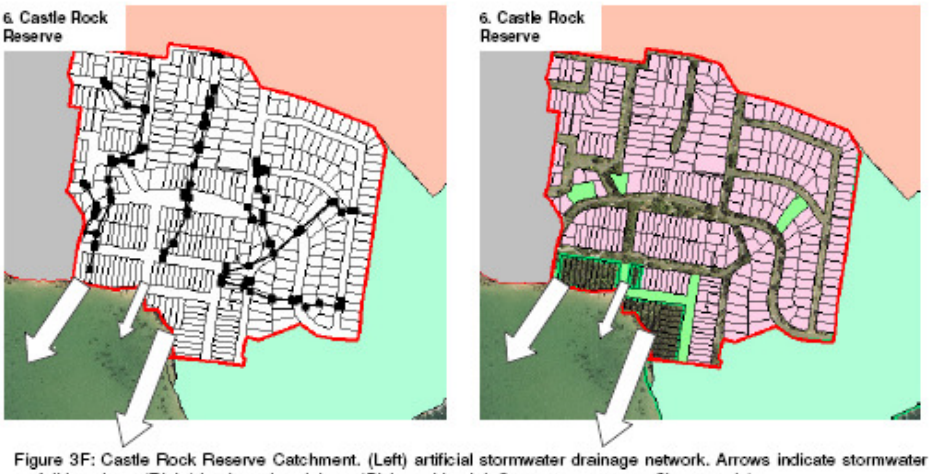

Figure 3F: Castle Rock Reserve Catchment. (Left) artificial stormwater drainage network. Arrows indicate stormwater outfall locations. (Right) land-use breakdown (Pink: residential; Green: open space; Clear: roads).

2 EXPECTED POLLUTANT LOADS IN STORMWATER FROM CLONTARF / BANTRY BAY CATCHMENTS

2.1 Modelling methodology adopted

Estimation of annual pollutant loads generated by land-uses in the six Clontarf / Bantry Bay Catchments was undertaken for the most frequently identified and highest priority pollutants typically identified to occur in urban stormwater. These were identified from local research undertaken in the Manly local government area (Smith, P.G., 2006; Galloway, M.J., 2005a), and through literature review of national and international studies (USEPA, 1983; Galloway, M.J., 2005b). The six pollutants identified were: Total Nitrogen (TN), Total Phosphorus (TP), Copper (Cu), Lead (Pb), Zinc (Zn), and Sediment.

Modelling was commissioned to estimate the total annual loads (expressed as kg per year) of these pollutants generated from the six catchments. Standard techniques were used in this modelling. Key steps included: 1) assigning a "rainfall-runoff coefficient" to land-use classes in each catchment (the percentage of rainfall that is expected to become "runoff" and enter the stormwater drainage network), 2) adopting a figure for the annual rainfall in Manly, and 3) adopting estimated average stormwater pollutant concentrations for stormwater runoff for each land-use found within the catchments. Values selected for all the parameters were selected to be as site-specific to the Clontarf / Bantry Bay Catchment conditions as possible, based on monitoring undertaken in similar urban areas. Assumptions used in assigning these values, and sources cited are further outlined in **Section 2.2** (below).

2.2 Modelling components and sources

This section reviews values used for the three steps outlined in **Section 2.1** as comprising the modelling process. First, land-use classes in each catchment were each assigned a runoff coefficient (Table 2, left). Runoff coefficients commonly vary between land-uses, individual sites, and research publications. In this study, runoff coefficients adopted for land-uses were derived from ASCE (1969). These were believed to be representative of land-uses in the Clontarf / Bantry Bay Catchments, and are reproduced in **Addendum B**.

Second, the long term average rainfall for the region was adopted (Table 2, right). This was average annual rainfall recorded at the Manly Dam rainfall station between 1907-2002 (Source: Bureau of Meteorology). The long term average rainfall for the region was adopted for this modelling (rather than lower recorded rainfalls in the most recent 2005/06 year), so that any stormwater pollutant reduction measures subsequently taken are adequately sized to suit average long-term flows.

Table 2: (Left) Runoff coefficients assigned to the land-use classes in all Clontarf / Bantry Bay Catchments (^ : includes Open Space and National Parks; * : includes Commercial, Special Use Property, and Unzoned Property) (Source: ASCE, 1969). (Right) Long term average annual rainfall (1907-2002) at Manly Dam (Source: BOM).

	Runoff Coefficient
Residential	0.35
Open Space^	0.08
Roads	0.85
Other*	0.60

Long Term Average Rainfall	
Manly Dam (mm/year)	1201.1

Third, average stormwater pollutant concentrations for runoff for each of the land-uses found in the Clontarf / Bantry Bay Catchments was assigned (Table 3). These were derived from previous stormwater monitoring studies undertaken throughout Sydney by the NSW EPA; stormwater monitoring research conducted in a variety of residential and commercial catchments in Manly; and adopted values in other stormwater modelling undertaken on Sydney's Northern Beaches. Values adopted are Event Mean Concentrations (EMCs) (Table 3), a typical measure of the average flow-weighted concentration of pollutants in stormwater, and widely used in stormwater research.

Table 3: Adopted average stormwater pollutant concentrations (Mean EMCs) for stormwater from land-use classes in the Clontarf / Bantry Bay Catchments. Values chosen were those considered to best represent conditions in the Catchments (^ : includes Open Space and National Parks; * : includes Commercial, Special Use Property, and Unzoned Property)

Stormwater Pollutant Mean EMCs (Event Mean Concentations). All units mg/L						
	TN	TP	Cu	Pb	Zn	Sediment
Residential	1.90***	0.31***	0.035[&]	0.041[&]	0.186[&]	75^^
Open Space^	0.90^^	0.22^^	0.010**	0.020^^	0.010**	200^^
Roads	1.80^^	0.03^^	0.300**	0.400^^	0.700**	142^^
Other*	3.99[&]	1.16[&]	0.051[&]	0.025[&]	0.341[&]	75^^

***Derived from EPA Managing Urban Stormwater: Strategic Framework (1997): Appendix C, Table 2, p139
[&]Derived from detailed stormwater quality monitoring undertaken in Manly by Galloway, M.J. (2005)
^^Derived from Northern Beaches Stormwater Management Plan (1999): p22
**Derived from detailed stormwater quality monitoring undertaken in Manly by Smith, P.G. (2006)

2.3 Clontarf / Bantry Bay Catchments: annual stormwater pollution loads

This section displays modelled stormwater pollutant loads estimated to be generated by the six Clontarf / Bantry Bay Catchments.

Stormwater pollutant loads are expressed as a total kg of each pollutant expected to be delivered into the Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollutant management. A total of **1,214 ML of stormwater** / year (1.214 billion litres) were predicted to be generated in the six catchments and to enter stormwater drainage and Middle Harbour.

Figure 4 displays the modelled combined total annual pollutant load from all six Manly Council Clontarf / Bantry Bay Catchments. The remainder of **Section 2.3** reviews modelled annual loads from each of the six catchments individually.

Six Clontarf / Bantry Bay Catchments (kg/year)	TN	TP	Cu
Residential	1142.25	196.72	21.93
Open Space^	20.31	4.97	0.23
Roads	933.96	15.57	155.66
Other*	151.90	44.12	1.92
Total	**2248.43**	**261.37**	**179.74**

	Pb	Zn	Sed.
Residential	25.69	117.79	47594
Open Space^	0.45	0.23	4514
Roads	207.55	363.21	73679
Other*	0.95	12.98	2858
Total	**234.64**	**494.21**	**128645**

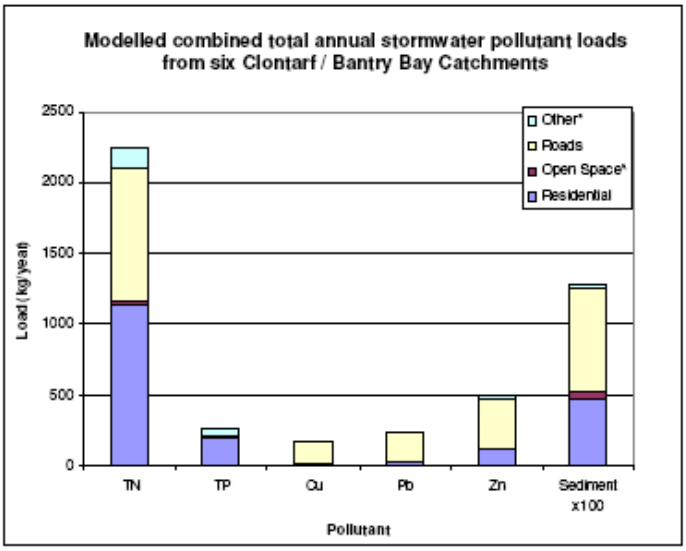

Figure 4: Combined total modelled stormwater pollutant loads from the six Clontarf / Bantry Bay Catchments, for the six stormwater pollutants (expressed as kg/year), expected to enter Middle Harbour in the absence of any stormwater treatment. Modelling estimates over 2250 kg of TN; 490 kg of Zn; and 128,000 kg of Sediment to be generated in stormwater. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of most pollutants.

2.3.1 Gurney Crescent Catchment: annual stormwater pollution loads

Results from modelling for Gurney Crescent Catchment, for the six stormwater pollutants adopted, is shown in Figure 5A. Results are expressed as total kg of each pollutant estimated to be generated by land-uses in the catchment, and delivered into Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollution management. A total of **158 ML of stormwater** / year (158 million litres) were predicted to be generated in the Gurney Crescent catchment and to enter stormwater drainage and Middle Harbour.

Gurney Crescent	(kg/year)		
	TN	TP	Cu
Residential	151.04	26.01	2.90
Open Space^	4.17	1.02	0.05
Roads	108.00	1.80	18.00
Other*	38.25	11.11	0.48
Total	**301.46**	**39.94**	**21.43**

	Pb	Zn	Sed.
Residential	3.40	15.58	6293.51
Open Space^	0.09	0.05	926.82
Roads	24.00	42.00	8520.20
Other*	0.24	3.27	719.60
Total	**27.73**	**60.89**	**16460.12**

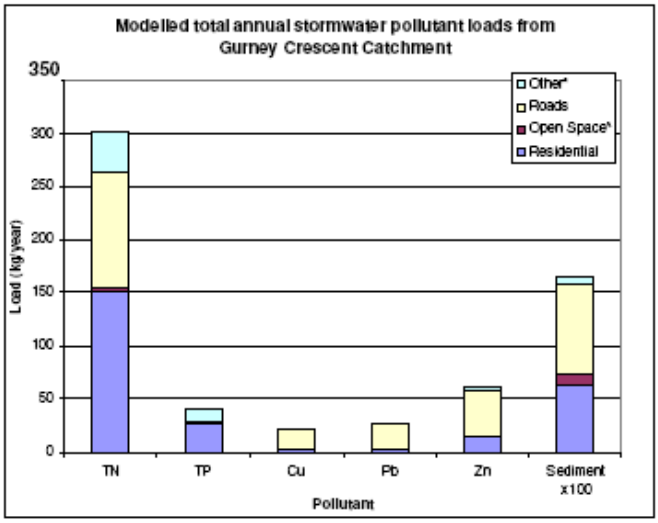

Figure 5A: Annual stormwater pollutant loads (expressed as kg/year) from the Gurney Crescent catchment, for the six stormwater pollutants modelled. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of most pollutants.

2.3.2 Bligh Crescent Catchment: annual stormwater pollution loads

Results from modelling for Bligh Crescent Catchment, for the six stormwater pollutants adopted, is shown in Figure 5B. Results are expressed as total kg of each pollutant estimated to be generated by land-uses in the catchment, and delivered into Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollution management. A total of **94 ML of stormwater** / year (94 million litres) were predicted to be generated in the Bligh Crescent catchment and to enter stormwater drainage and Middle Harbour.

Bligh Crescent	(kg/year)		
	TN	TP	Cu
Residential	75.15	12.94	1.44
Open Space^	2.04	0.50	0.02
Roads	59.15	0.99	9.86
Other*	70.09	20.36	0.89
Total	**206.43**	**34.78**	**12.21**

	Pb	Zn	Sed.
Residential	1.69	7.75	3131.45
Open Space^	0.05	0.02	453.67
Roads	13.14	23.00	4665.97
Other*	0.44	5.99	1318.75
Total	**15.32**	**36.77**	**9569.84**

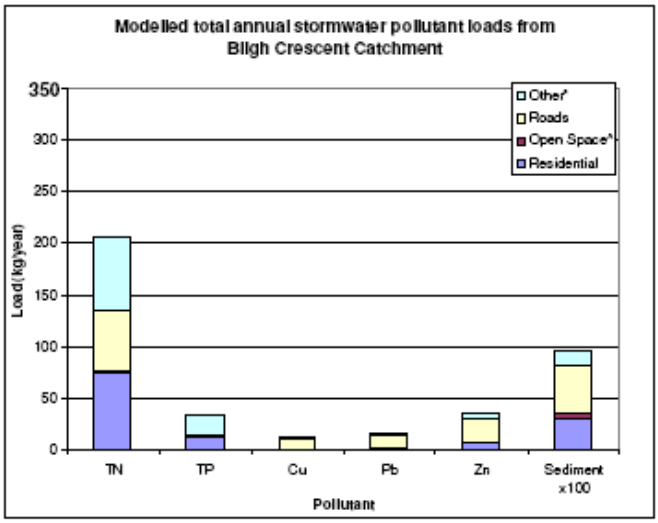

Figure 5B: Annual stormwater pollutant loads (expressed as kg/year) from the Bligh Crescent catchment, for the six stormwater pollutants modelled. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of most pollutants.

2.3.3 Sangrado Street Catchment: annual stormwater pollution loads

Results from modelling for Sangrado St Catchment, for the six stormwater pollutants adopted, is shown in Figure 5C. Results are expressed as total kg of each pollutant estimated to be generated by land-uses in the catchment, and delivered into Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollution management. A total of **226 ML of stormwater** / year (226 million litres) were predicted to be generated in the Sangrado St catchment and to enter stormwater drainage and Middle Harbour.

Sangrado Street	(kg/year)		
	TN	TP	Cu
Residential	244.99	42.19	4.70
Open Space^	1.60	0.39	0.02
Roads	158.46	2.64	26.41
Other*	0.18	0.05	0.00
Total	**405.23**	**45.28**	**31.13**

	Pb	Zn	Sed.
Residential	5.51	25.26	10207.94
Open Space^	0.04	0.02	355.25
Roads	35.21	61.62	12500.62
Other*	0.00	0.02	3.37
Total	**40.76**	**86.92**	**23067.18**

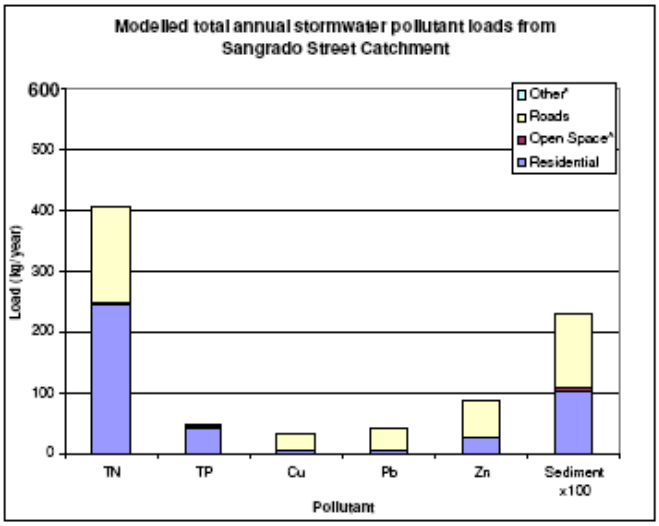

Figure 5C: Annual stormwater pollutant loads (expressed as kg/year) from the Sangrado Street catchment, for the six stormwater pollutants modelled. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of all pollutants.

2.3.4 The Spit Catchment: annual stormwater pollution loads

Results from modelling for The Spit Catchment, for the six stormwater pollutants adopted, is shown in Figure 5D. Results are expressed as total kg of each pollutant estimated to be generated by land-uses in the catchment, and delivered into Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollution management. A total of **259 ML of stormwater** / year (259 million litres) were predicted to be generated in the Spit catchment and to enter stormwater drainage and Middle Harbour.

The Spit	(kg/year)		
	TN	TP	Cu
Residential	224.30	38.63	4.31
Open Space^	4.30	1.05	0.05
Roads	227.93	3.80	37.99
Other*	13.00	3.78	0.16
Total	**469.53**	**47.26**	**42.51**

	Pb	Zn	Sed.
Residential	5.04	23.13	9345.78
Open Space^	0.10	0.05	955.94
Roads	50.65	88.64	17981.04
Other*	0.08	1.11	244.62
Total	**55.87**	**112.93**	**28527.38**

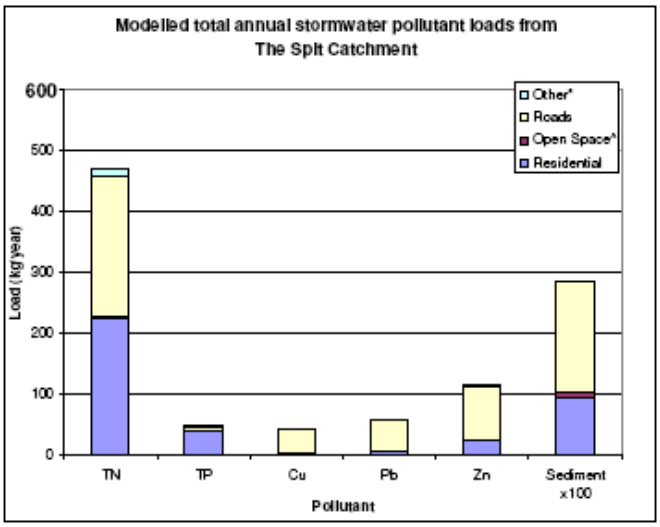

Figure 5D: Annual stormwater pollutant loads (expressed as kg/year) from The Spit catchment, for the six stormwater pollutants modelled. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of all pollutants.

2.3.5 Clontarf Catchment: annual stormwater pollution loads

Results from modelling for the Clontarf Catchment, for the six stormwater pollutants adopted, is shown in Figure 5E. Results are expressed as total kg of each pollutant estimated to be generated by land-uses in the catchment, and delivered into Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollution management. A total of **321 ML of stormwater** / year (321 million litres) were predicted to be generated in the Clontarf catchment and to enter stormwater drainage and Middle Harbour.

Clontarf	(kg/year)		
	TN	TP	Cu
Residential	301.08	51.85	5.78
Open Space^	5.58	1.36	0.06
Roads	252.63	4.21	42.11
Other*	30.38	8.82	0.38
Total	**589.68**	**66.25**	**48.33**

	Pb	Zn	Sed.
Residential	6.77	31.05	12545.01
Open Space^	0.12	0.06	1240.86
Roads	56.14	98.25	19929.72
Other*	0.19	2.60	571.61
Total	**63.23**	**131.95**	**34287.20**

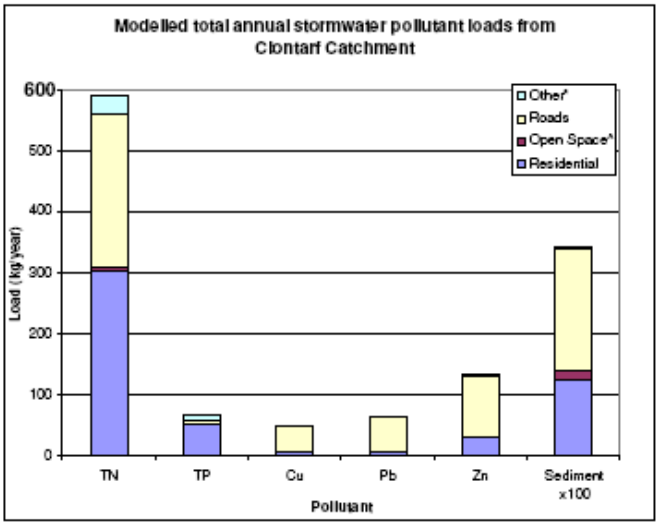

Figure 5E: Annual stormwater pollutant loads (expressed as kg/year) from Clontarf catchment, for the six stormwater pollutants modelled. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of most pollutants.

2.3.6 Castle Rock Reserve Catchment: annual stormwater pollution loads

Results from modelling for the Castle Rock Reserve Catchment, for the six stormwater pollutants adopted, is shown in Figure 5F. Results are expressed as total kg of each pollutant estimated to be generated by land-uses in the catchment, and delivered into Middle Harbour Estuary per year, in the absence of any pollutant reduction measures. Total annual loads are broken down by contributing land-uses based on the modelling, to inform land-use and pollution management. A total of **155 ML of stormwater** / year (155 million litres) were predicted to be generated in the Castle Rock Reserve catchment and to enter stormwater drainage and Middle Harbour.

Castle Rock Reserve	(kg/year)		
	TN	TP	Cu
Residential	145.68	25.09	2.80
Open Space^	2.62	0.64	0.03
Roads	127.80	2.13	21.30
Other*	0.00	0.00	0.00
Total	**276.10**	**27.86**	**24.13**

	Pb	Zn	Sed.
Residential	3.28	15.02	6070.13
Open Space^	0.06	0.03	581.42
Roads	28.40	49.70	10081.88
Other*	0.00	0.00	0.00
Total	**31.73**	**64.75**	**16733.43**

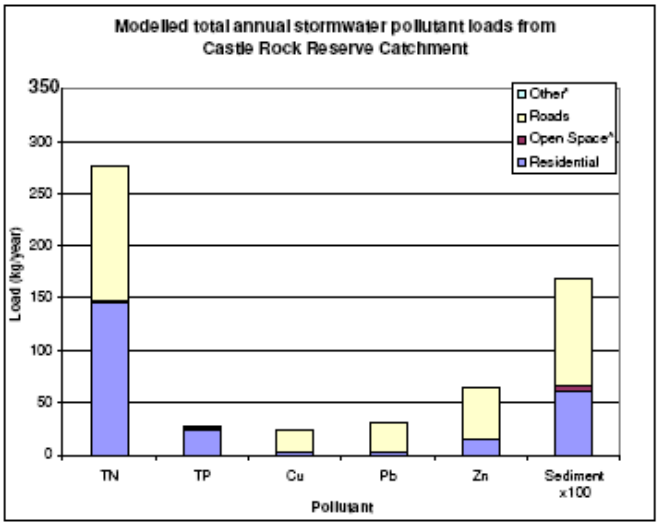

Figure 5F: Annual stormwater pollutant loads (expressed as kg/year) from The Castle Rock Reserve catchment, for the six stormwater pollutants modelled. Pollutants are separated into contributing land-use sources to inform management. 'Roads' and 'residential' land-uses are estimated to provide the greatest loads of all pollutants.

2.4 Discussion of results

2.4.1 Total annual pollutant loads, and contributing land-uses / likely sources

The combined total load of pollutants in stormwater estimated to be generated by the six Clontarf / Bantry Bay Catchments based on the modelling exercise undertaken, was approximately **2250 kg/year of Total Nitrogen; 260 kg/year of Total Phosphorus; 180 kg/year of Copper, 230 kg/year of Lead, 490 kg/year of Zinc, and 128,000 kg/year of Sediment** (Figure 4). In the absence of pollutant reduction measures, this would be expected to be delivered into the Middle Harbour Estuary each year.

The greatest contributing land-uses emergent from modelling were roads and residential land-use classes. Roads were estimated to produce highest loads for Copper, Lead, Zinc and Sediment, while residential land-uses were estimated to produce the highest overall loads of nutrients (TN and TP). Suggested sources include vehicle traffic and corrosion of road surfaces (delivering heavy metals, and sediment into stormwater); deciduous trees (delivering nutrients); residential buildings (delivering heavy metals including Cu, Pb, Zn from corrugated roof surfaces into stormwater), construction sites and disturbed sites (delivering high levels of sediment), and residential gardens and vegetative matter from deciduous trees and lawn mowing (delivering nutrients and sediment).

Of the six land-use catchments, pollutant load was generally found to be highly related to catchment size. The highest three catchment loads/year for all pollutants (TN, TP, Cu, Pb, Zn, Sediment), were those from the three largest catchments (Clontarf, The Spit, and Sangrado St Catchments; Figures 5A-F). Only in the Bligh Crescent Catchment was significant pollutant loads found to be derived from land-uses other than residential or roads, with "Other" providing a substantial percentage of TN, TP, Zn and Sediment. This was expected due to the presence of a large Special Use zone in the catchment (Figure 3B, and Figure 5B).

All results were broadly comparable with loads predicted for Middle Harbour catchments in general by Willing and Partners (1999). It is noted that the modelling undertaken is investigative only and should be refined with site specific monitoring during storm events to gain a better insight into the nature of stormwater pollution. Furthering of this storm based monitoring would greatly assist calibration of the modelling in this report.

The Clontarf / Bantry Bay catchments draining into Middle Harbour comprise approximately 2.8% of the entire Middle Harbour catchment area. According to the figures modelled (Figure 4 – above), and the figures provided in Willing and Partners (1999), the Clontarf / Bantry Bay study area contributes approximately 7.5% of the Total Nitrogen; 6.1% of the Total Phosphorus; & 1.5% of the Sediment transported into the entire Middle Harbour estuary annually. These figures suggest that the modelling undertaken in this report is consistent with the modelling undertaken in Willing and Partners (1999) for the entire Middle Harbour catchment, due to the similarity between the relative catchment size and the relative pollutant loads predicted.

Two parameters in the modelling predominantly influence the modelling results. The first is adopted rainfall-runoff coefficients (Table 2, Left). The second is adopted stormwater pollutant concentrations (Table 3). Consideration of research undertaken in other Manly sub-catchments to date, site-specific considerations in the Clontarf / Bantry Bay Catchments; and recent research publications in other urban catchments was made in determination of these values. Thus, while some margin of error in modelling of annual pollutant loads is possible, results are likely to be generally representative of current pollutant loads generated by land-uses in the catchment, and likely to be delivered into Middle Harbour Estuary, in the absence of any pollutant reduction measures.

It is suggested that in-stream monitoring in the Clontarf / Bantry Bay Catchments be undertaken to calibrate monitoring results here. Because the broader urban area surrounding Middle Harbour is significantly larger than just those Manly Council Clontarf / Bantry Bay Catchments evaluated in this document, it is suggested a holistic approach should be undertaken whereby a survey be conducted of in-stream monitoring currently undertaken in other areas of Middle Harbour of wet-weather stormwater flows. Monitoring designs should accommodate synergies and common methodologies with existing programs.

→ **Recommendation (1):** That further on-site stormwater monitoring be undertaken to confirm stormwater quality entering the Middle Harbour Estuary from catchments examined here, through commissioning of an automated stormwater sampling machine at the base of appropriate catchments.

→ **Recommendation (2):** That the relevant precincts continue to report dry and wet weather sewage incidents immediately to Sydney Water on 132 092 or at sydneywater.com.au

2.4.2 Other pollutants not considered (litter, sewage ex-filtration / in-filtration)

Stormwater from the Clontarf / Bantry Bay Catchments is also likely to transport other pollutants not considered in this study into Middle Harbour. This includes high loads of litter and rubbish swept from gutters. It also includes sewage delivered through: (1) sewage ex-filtration into stormwater pipes, due to cracked and aging stormwater and sewerage pipes, (2) stormwater in-filtration into sewerage pipes - forcing sewage into the environment through sewage pipe incapacity, and (3) release from designed sewerage overflow points within Clontarf / Bantry Bay Catchments.

With regards to sewage, the extent of factors (1) and (2) in the Clontarf / Bantry Bay Catchments is not known. However, five registered sewage overflow points are currently located within the Clontarf / Bantry Bay Catchments, and are shown in **Addendum C**. All of these may cause serious impacts on the health of the Middle Harbour estuary. However, unlike the other pollutants modelled in this exercise, both litter and rubbish accumulation; sewage ex-filtration / in-filtration; and sewage overflows; are highly sporadic, site-specific, and dependent on conditions found locally and on stormwater and sewage network engineering. This presents modelling difficulties, requiring further direct on-site monitoring in particular locations.

It is worth noting that sewage has been frequently identified as an issue at Sangrado Baths in the Sangrado St catchment. Sangrado Baths was registered as the second worst of eight Middle Harbour monitoring locations reported in the 2005-06 Harbour Watch Report (Table 4), with only 84% compliance with guideline levels of Enterococci, and 97% compliance with guideline levels of Faecal Coliforms, amongst samples taken at the location over the 2005-06 year. Both Enterococci and Faecal Coliforms are indicators of sewage ingress in the waterway. This may be due to the designed sewer overflow registered to exist in the catchment (Addendum C), but requires further monitoring.

Table 4: Harbour Watch Data in Summer 2005-06 – Middle Harbour. Sangrado Baths performed second-worst of the eight Middle Harbour Estuary sites monitored, suggesting sewage ingress in the Sangrado St Catchment. Source: DEC, 2006.

Site	**Compliance (%)**	
	Faecal Coliforms	**Enterococci**
Davidson Reserve	81	78
Gurney Crescent Baths	100	100
Sangrado Baths	97	84
Northbridge Baths	100	100
Clontarf Pool	100	100
Chinamans Beach	100	100
Edwards Beach	100	100
Balmoral Baths	100	100

→ **Recommendation (3):** That Sydney Water be contacted to confirm the presence of the five sewerage overflow points documented in this report, and any additional designed overflow points within the Clontarf / Bantry Bay Catchments in this report. That Sydney Water's Wet Weather Overflow Abatement Program (WWOAP) division be contacted to request results of any sewerage network capacity modelling undertaken in the Clontarf / Bantry Bay Catchments, in particular seeking the expected frequency and volume of sewage overflows modelled from the designed overflows documented in this report. That this information be used to prioritise sewerage overflows for further controls, as appropriate.

→ **Recommendation (4):** That on-site stormwater monitoring be undertaken to determine sewage ex-filtration / in-filtration (through monitoring stormwater for bacteria) from Clontarf / Bantry Bay Catchments, through commissioning of an automated stormwater sampling machine at the base of appropriate catchments. This could be done in conjunction with Recommendation 1.

→ **Recommendation (5):** That an assessment of litter levels transported into the Middle Harbour Estuary from the Clontarf / Bantry Bay catchments be undertaken.

→ **Recommendation (6):** That poor Harbour Watch compliance in Sangrado Baths be investigated through assessment of the registered sewer overflow point within the catchment (see Addendum C), and assessment of possible sources of Faecal Coliforms and Enterococci.

2.4.3 Likely impacts on aquatic health

This section reviews the likely impacts of stormwater pollution on the Middle Harbour Estuary. The impacts of the pollutants Total Nitrogen and Total Phosphorus are likely to be serious, and include increased promotion of algal growth, decreased dissolved oxygen in water, and impacts on flora and fauna.

Algal growth can impact waterways dramatically through decreasing light penetration through the water column, and hence photosynthesis for aquatic vegetation. Certain types of algae (eg- blue green) can also become toxic to aquatic fauna. In general, one gram of Total Phosphorus entering a waterway from a catchment has been shown to promote growth of up to 30 grams of algae (1:30). Through preventing nutrients such as Total Phosphorus entering the Middle Harbour Estuary, significant volumes of algal growth could thus potentially be prevented.

The impacts of sewage ex-filtration / in-filtration, entering stormwater and the Middle Harbour Estuary is likely to be similar to those impacts arising from the nutrients Total Nitrogen and Total Phosphorus. Sewage causes a general increase in nutrient levels in the water column, and is known to cause increased phytoplankton growth, and enhanced growth of macroscopic and microscopic algae on seagrasses, causing changes in natural ecosystem structure and function. The bacteria in sewage also create risks for humans undertaking recreational activities in the estuary, with the possibility of infection.

The impacts of the heavy metals Copper, Lead, and Zinc are likely to be more cumulative, through accumulation of metals in sediment in Middle Harbour, and chronic impacts on flora and fauna. Impacts of sediment are likely to be both acute and chronic, through increased smothering of aquatic flora and habitat sedimentation, impeding ecosystem health (Bickford *et. al.*, 1999). This may result in a decline in seagrass beds due to competition for space and light, which would have flow-on effects for other ecosystem functions.

The impact of litter and rubbish transported into Middle Harbour with stormwater is likely to include smothering of aquatic habitat, habitat degradation, and death of fish and other fauna which consume this litter.

However, due to the exposed nature of the Middle Harbour Estuary to tidal flushing and ocean swells, it is likely that many of these impacts are minimised relative to other Sydney Harbour embayments, due to pollutant dilution, and re-distribution.

→ **Recommendation (7):** That the impacts on aquatic health in the Middle Harbour Estuary of stormwater inflows from the Clontarf / Bantry Bay Catchments be greater understood, through consideration of ecological impacts and interactions with other elements of the water cycle.

→ **Recommendation (8):** That application of appropriate treatment measures or range of treatment measures be undertaken to minimise stormwater pollution, as possible. That actions undertaken are undertaken in consideration of recommendations outlined for the broader Middle Harbour Estuary catchments in Willing and Partners (1999).

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3 CURRENT MANLY COUNCIL STORMWATER QUALITY IMPROVEMENT MEASURES IN CLONTARF / BANTRY BAY CATCHMENTS

3.1 Street Sweeping treatment reduction

Street sweeping (Figure 6) is currently conducted in the six Clontarf / Bantry Bay Catchments at a frequency of at least once of every twelve weeks, in each catchment. Street sweeping captures sediments, nutrients, metals and gross pollutant loads (to a finer size range than some other treatments, such as GPTs), by targeting accumulations of these pollutants on street surfaces within the catchments. Street sweeping has been shown through scientific research to capture large loads of sediment, gross pollution, and nutrient and metal loads throughout the Manly LGA. In the 2005/06 financial year street sweeping in Manly LGA was estimated to prevent 580 tonnes of sediment, and 4.5 tonnes of nutrients from entering Manly waterways. This has been estimated to have prevented 25 tonnes of algal growth (Table 5).

Scientific research in other areas of the Manly LGA has also demonstrated street sweeping to be capable of capturing on average 27% of sediment and 14% of nutrients and heavy metals in stormwater, dependent on conditions. Based on pollutant loads modelled to enter Middle Harbour from the six Clontarf / Bantry Bay Catchments in this report (see Figure 4), this suggests street sweeping may capture up to **303 kg/year of TN, 35 kg/year of TP, 23 – 66 kg/year each of Copper, Lead and Zinc, and 35 tonnes of sediment** from the six Clontarf / Bantry Bay Catchments, which is prevented from entering Middle Harbour (data summarised in **Section 3.4**). Street sweeping is also particularly likely to be effective in pollutant prevention because "roads" were modelled to produce the highest loads of Cu, Pb, Zn and Sediment (Figure 4) and second-highest loads of TN and TP (Figure 4). Regular sweeping of road surfaces would thus significantly reduce the percentage of loads generated entering stormwater.

In addition, beach raking is currently carried out daily on Clontarf beach. This is estimated to provide further capture of gross pollutants not prevented by street sweeping or other pollutant reduction measures.

Figure 6: Schematic of a typical Schwartz regenerative air street sweeping vehicle used in the Manly LGA.

Table 5: Estimated street sweeping performance in Manly Council in the 2005/06 financial year (total kg of pollutants captured). Figures derived from detailed quantification and analysis of captured loads from a number of street sweeping operations in Manly.

Street Sweeping estimated pollutant prevention in Manly Council (2005/06) (kg)	
TN	**4,463.7**
TP	**847.8**
Cu	**81.1**
Pb	**62.1**
Zn	**232.4**
Sediment	**580,840.6**
Algal growth prevented	**25,434.1**

→ **Recommendation (9):** Pending monitoring, that street sweeping in the Clontarf / Bantry Bay Catchments be increased in frequency, and target key pollutants.

3.2 Gross Pollutant Traps treatment reduction

Four Gross Pollutant Traps (GPTs) are currently installed in the Clontarf / Bantry Bay Catchments. These capture gross pollution and litter, sediment, and a limited percentage of nutrients and metals present in stormwater, improving the quality of catchment-generated stormwater entering Middle Harbour. All four GPTs are located within the popular swimming and recreation catchment, Clontarf (also the catchment) (see Figures 7, 8, Table 6). GPTs are not present in any other Clontarf / Bantry Bay Catchments.

GPTs are all currently maintained (cleaned out) at least once every 8 weeks, and additionally, immediately after heavy rainfall (inspection automatically occurs following 20 mm or greater rainfall to determine cleaning needs) as required. This is carried out to remove pollutants re-captured from stormwater, minimising pollutant decomposition, and minimising re-suspension of pollutants into Middle Harbour in subsequent rainfall events.

GPTs have been shown through scientific research to capture large loads of sediment, gross pollution, and nutrients and metal loads throughout the Manly LGA (Table 7). In the 2005/06 financial year GPTs were estimated to prevent 108 tonnes of sediment, and 625 kg of nutrients from entering Manly waterways. This has been estimated to have prevented 2.4 tonnes of algal growth in Manly's waterways (Table 7).

Figure 7: GPT locations in Clontarf / Bantry Bay Catchments. Four GPTs are located in the Clontarf / Bantry Bay Catchments, all in Clontarf.

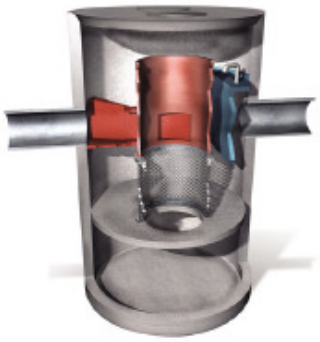

Figure 8: Schematic of a typical gross pollutant trap (GPT). Inflow is from the left and outflow to the right, over the sedimentation / gross pollutant capture grate and retention well (Source: CDS Technologies, 2006). Note: different models differ in design.

Table 6: GPT Locations in Clontarf / Bantry Bay Catchments. All GPTs are located in Clontarf.

GPT Model	Location in Clontarf
CDS P1512	Sandy Bay Reserve, opp. 12 Sandy Bay Rd
CDS P1512	Sandy Bay Reserve, opp. 11 Sandy Bay Rd.
CDS P1512	Clontarf Reserve, opp. 4 Sandy Bay Rd
CDS F0908	Clontarf Reserve, opp. 2A Sandy Bay Rd

Table 7: Estimated GPT performance in Manly Council in the 2005/06 financial year (total kg of pollutants captured). Figures derived from detailed quantification and analysis of captured loads from a number of GPTs in Manly.

GPT estimated pollutant prevention in Manly Council (2005/06) (kg)	
TN	**625.7**
TP	**80.0**
Cu	**9.9**
Pb	**10.4**
Zn	**54.6**
Sediment	**108,550.7**
Algal growth prevented	**2,399.2**

Scientific research in other areas of the Manly LGA has also demonstrated GPTs to be capable of capturing on average 23% of nutrients and metals, and 56% of sediment in stormwater generated in the catchments. Based on pollutant loads modelled to enter Middle Harbour from the *Clontarf* Catchment only (Figure 5E), and the percentage of that catchment's stormwater flows estimated to flow through the four GPTs installed in that catchment, the GPTs are estimated to capture up to **74.2 kg/year of TN, 8.3 kg/year of TP, 6.1 – 16.6 kg/year each of Copper, Lead and Zinc, and up to 10.5 tonnes of sediment** from the six Clontarf / Bantry Bay Catchments, which is prevented from entering Middle Harbour (summarised in **Section 3.4**).

Litter loads from the Clontarf catchment are suggested to be well controlled by the existing suite of four GPTs. However, in other catchments, minimal or zero litter re-capture from stormwater is currently provided by GPTs or other devices.

→ **Recommendation (10):** That maintenance of existing gross pollutant traps in the Clontarf catchment be maintained at a high frequency to achieve maximum pollutant captured, and minimise pollutant re-suspension, and anaerobic decomposition, by existing GPTs.

→ **Recommendation (11):** That investigation be progressed for installation of further GPTs in Clontarf / Bantry Bay catchments other than Clontarf in priority locations. That appropriate research be conducted into current best practice GPT technologies.

3.3 Community Education Programs

Education campaigns to target behaviour in individual residences have been conducted in the past in many precincts in Manly Council. In particular the SeaChange education program has targeted residents in the major central business district precincts to achieve behavioural outcomes including reductions in nutrients, sediment, and litter pollutants in stormwater from individual premises.

This is important because the greatest source of TN and TP in many urban areas, including the Clontarf / Bantry Bay Catchments (Figure 4) is estimated to be residential land-uses. Residents in the Clontarf / Bantry Bay Catchments play a crucial role in preventing these pollutants from entering the stormwater system, and achieving real improvements in water quality.

The Bricks and Water stormwater education program for construction sites has taken place throughout the Manly LGA, including the Clontarf / Bantry Bay study area. This program targets sediment and nutrient runoff from construction sites, which have both been determined as significant pollutants within the study area. Councils 'Hill to Harbour' walks program also includes two walk routes within the study area. The walks discuss a variety of environmental issues with participants, with a focus on catchment / stormwater related issues.

Stormwater education messages emergent from education programs undertaken in other precincts were reasonably expected to have disseminated to residents in the Clontarf / Bantry Bay Catchments, enacting some behavioural change and water quality improvements. Further, extension of such community stormwater education programs (eg- SeaChange) to areas of the Clontarf / Bantry Bay Catchment in the immediate future is relatively simple (compared with more structural engineering treatment solutions, reviewed further in **Section 4**). As a result of existing programs, some water quality benefits from Manly Council's general stormwater education are considered to have occurred in the Clontarf / Bantry Bay Catchments. This would be believed to represent a maximum 10% improvement / reduction in stormwater pollutant loads for the purposes of modelling in this report (summarised in **Section 3.4**). Community education and responsible community behaviour was thus estimated to have prevented generation of **225 kg/year of TN, 26 kg/year of TP, 18 – 49 kg/year of Cu, Pb, and Zn, and up to 12.8 tonnes of sediment** in the six Clontarf / Bantry Bay catchments, which is prevented from entering Middle Harbour (summarised in **Section 3.4**).

Sources for residential education targeting include those in residential areas predicted to generate the greatest pollutant loads and those areas with relatively easy capacity for improvement (eg deciduous trees management; materials used in residential building and roof design; construction site controls; disturbed site controls; residential garden management and lawn mowing; drain stencil education).

Full outcomes emergent from Manly Council's SeaChange program are available at the SeaChange website: www.manly.nsw.gov.au/seachange/.

➔ **Recommendation (12):** That Council's education team work with residents in the Clontarf / Bantry Bay Catchments to assist in the uptake of best practice in stormwater management at a residential scale.

3.4 Current Clontarf / Bantry Bay Combined Catchment Pollutant Load Reduction: All Treatments

This section summarises the combined benefits of stormwater quality improvement measures currently applied in the Clontarf / Bantry Bay Catchments by Manly Council (street sweeping, GPTs, and community education), and net pollutant loads remaining to enter Middle Harbour. In addition, Manly Council continually reviews new and emergent treatment options available, and further treatment options appropriate for future management are outlined in **Section 4**.

Total reductions in stormwater pollutant loads from Clontarf / Bantry Bay Catchments in Manly Council due to Council treatments are displayed in Figure 9 (Street Sweeping (SS), GPTs, community education). These are compared with initial total modelled stormwater pollutant loads estimated to be generated by the Clontarf / Bantry Bay Catchments, which would be expected to enter Middle Harbour in the absence of any treatments. This demonstrates the significant water quality improvements achieved to date. However, continued responsible community behaviour in and around the home to reduce pollutants entering the stormwater system is critical to maintain these achievements.

Treatment reduction	TN	TP	Cu
GPT	74.25	8.342	6.086
SS	303.5	35.28	23.42
Responsible Community Behaviour	224.8	26.14	17.97
Total Remaining	**1646**	**192**	**132**

Treatment reduction	Pb	Zn	Sed.
GPT	7.961	16.61	10528
SS	31.1	66.72	35163
Responsible Community Behaviour	23.46	49.42	12865
Total Remaining	**172**	**361**	**70089**

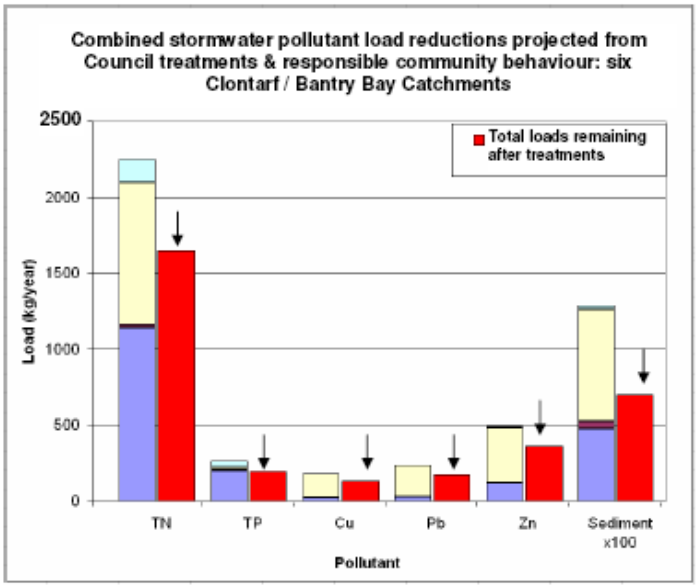

Figure 9: (Left Table) Total reductions in annual stormwater pollutant loads (kg/year) in the six Clontarf / Bantry Bay Catchments by Manly Council treatments (SS, GPTs) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the modelled catchment loads (Figure 4). (Right Graph) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

The pollutant loads expected to be generated in the Clontarf / Bantry Bay Catchment (Figure 9, right), are typical of pollutant generation in low intensity residential catchments in Manly. Since implementing additional street sweeping and GPT maintenance, loads have been reduced substantially (Figure 9, right, *red columns*). Cost-effectively maintaining these load reductions requires continued Council engagement with the community to target behaviours and create a community stewardship within the catchment. The total net reduction of Council and community working together results in a much greater outcome than Council taking action in isolation. The outcome of these actions will result in stormwater that is of significantly greater quality for discharge into the Middle Harbour Estuary. Further actions that could be taken, are outlined in **Section 4**, subject to further monitoring.

The remainder of **Section 3.4** reviews projected (reduced) total annual stormwater pollutant loads achieved in each of the six Clontarf / Bantry Bay Catchments individually through application of Council treatments and education.

3.4.1 Gurney Crescent Catchment

Projected reductions in annual stormwater pollutant loads achieved through application of street sweeping (SS) and emergent from community education, in the Gurney Crescent Catchment, is shown in Figure 10A. Results are expressed as reduction in total kg/year of each of the six pollutants by individual treatments (Left Table), and estimated to remain in stormwater and enter Middle Harbour despite treatments (Right, red collumns).

Treatment reduction	TN	TP	Cu
SS	40.7	5.392	2.893
Responsible Community Behaviour	30.15	3.994	2.143
Total Remaining	**231**	**31**	**16**

Treatment reduction	Pb	Zn	Sed.
SS	3.743	8.221	4499
Responsible Community Behaviour	2.773	6.089	1646
Total Remaining	**21**	**47**	**10315**

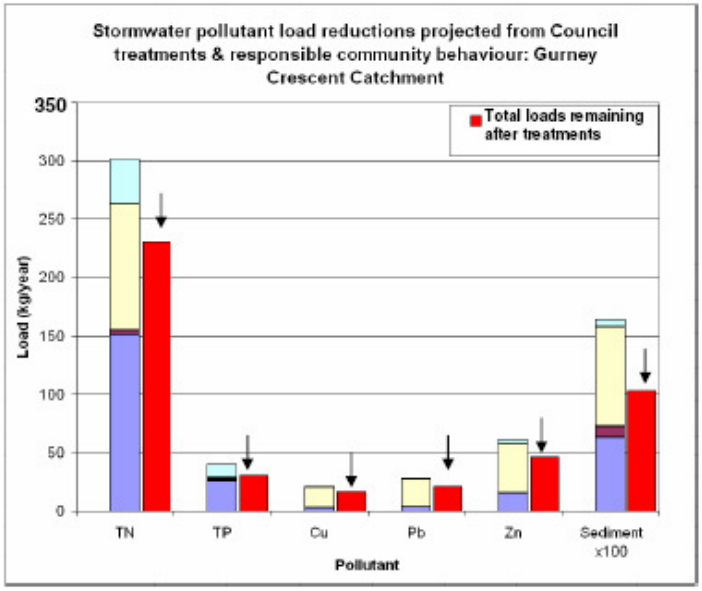

Figure 10A: (Left) Total reductions in annual stormwater pollutant loads (kg/year) in Gurney Crescent catchment by Manly Council treatments (SS) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the original modelled catchment load (Figure 5A). (Right) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

3.4.2 Bligh Crescent Catchment

Projected reductions in annual stormwater pollutant loads achieved through application of street sweeping (SS) and emergent from community education, in the Bligh Crescent Catchment, is shown in Figure 10B. Results are expressed as reduction in total kg/year of each of the six pollutants by individual treatments (Left Table), and estimated to remain in stormwater and enter Middle Harbour despite treatments (Right, red collumns).

Treatment reduction	TN	TP	Cu
SS	27.87	4.696	1.649
Responsible Community Behaviour	20.64	3.478	1.221
Total Remaining	**158**	**27**	**9**

Treatment reduction	Pb	Zn	Sed.
SS	2.068	4.963	2616
Responsible Community Behaviour	1.532	3.677	957
Total Remaining	**12**	**28**	**5997**

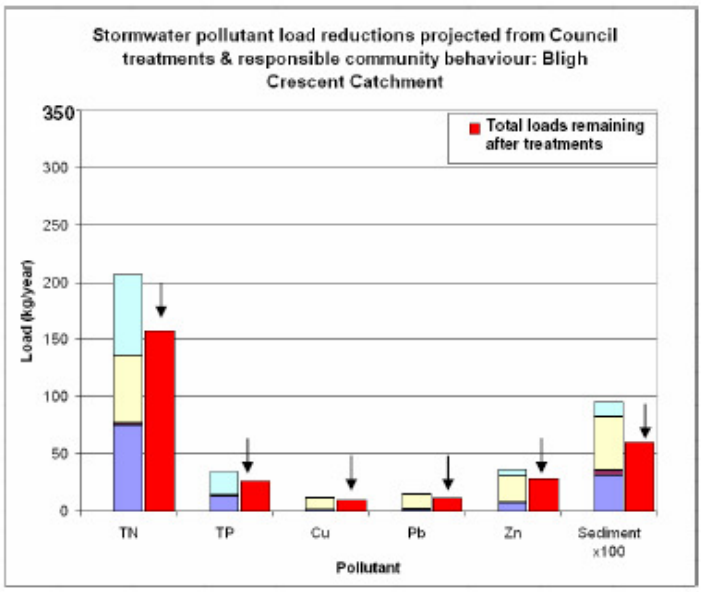

Figure 10B: (Left) Total reductions in annual stormwater pollutant loads (kg/year) in Bligh Crescent catchment by Manly Council treatments (SS) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the original modelled catchment load (Figure 5B). (Right) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

3.4.3 Sangrado Street Catchment

Projected reductions in annual stormwater pollutant loads achieved through application of street sweeping (SS) and emergent from community education, in the Sangrado Street Catchment, is shown in Figure 10C. Results are expressed as reduction in total kg/year of each of the six pollutants by individual treatments (Left Table), and estimated to remain in stormwater and enter Middle Harbour despite treatments (Right, red collumns).

Treatment reduction	TN	TP	Cu
SS	54.71	6.112	4.203
Responsible Community Behaviour	40.52	4.528	3.113
Total Remaining	**310**	**35**	**24**

Treatment reduction	Pb	Zn	Sed.
SS	5.502	11.73	6305
Responsible Community Behaviour	4.076	8.692	2307
Total Remaining	**31**	**66**	**14455**

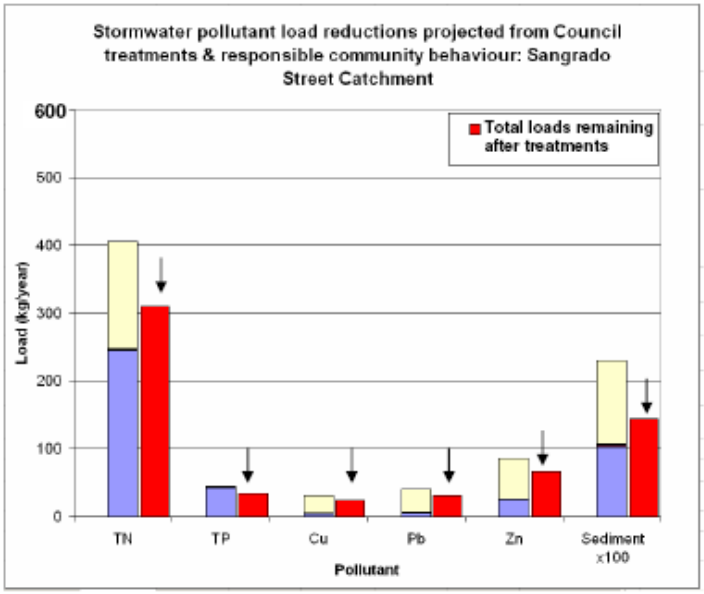

Figure 10C: (Left) Total reductions in annual stormwater pollutant loads (kg/year) in Sangrado Street catchment by Manly Council treatments (SS) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the original modelled catchment load (Figure 5C). (Right) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

3.4.4 The Spit Catchment

Projected reductions in annual stormwater pollutant loads achieved through application of street sweeping (SS) and emergent from community education, in The Spit Catchment, is shown in Figure 10D. Results are expressed as reduction in total kg/year of each of the six pollutants by individual treatments (Left Table), and estimated to remain in stormwater and enter Middle Harbour despite treatments (Right, red collumns).

Treatment reduction	TN	TP	Cu
SS	63.39	6.379	5.738
Responsible Community Behaviour	46.95	4.726	4.251
Total Remaining	**359**	**36**	**33**

Treatment reduction	Pb	Zn	Sed.
SS	7.543	15.25	7797
Responsible Community Behaviour	5.587	11.29	2853
Total Remaining	**43**	**86**	**17877**

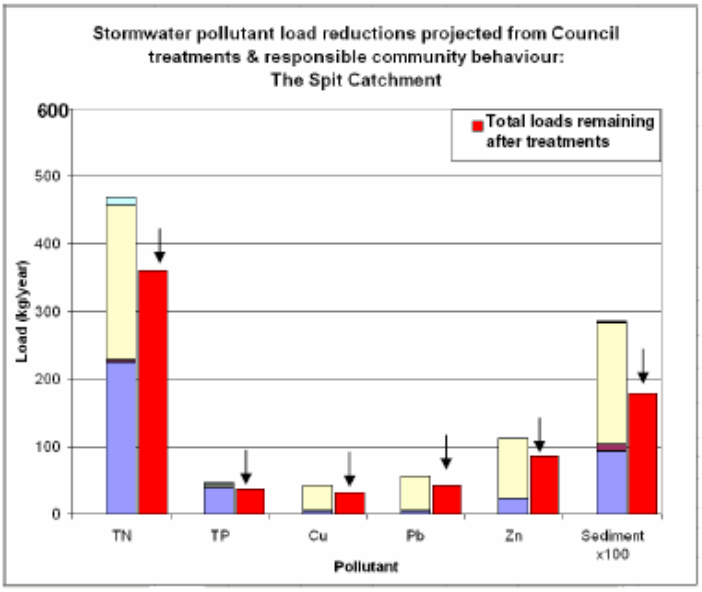

Figure 10D: (Left) Total reductions in annual stormwater pollutant loads (kg/year) in The Spit catchment by Manly Council treatments (SS) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the original modelled catchment load (Figure 5D). (Right) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

3.4.5 Clontarf Catchment

Projected reductions in annual stormwater pollutant loads achieved through application of street sweeping (SS) and emergent from community education, in the Sangrado Street Catchment, is shown in Figure 10E. Results are expressed as reduction in total kg/year of each of the six pollutants by individual treatments (Left Table), and estimated to remain in stormwater and enter Middle Harbour despite treatments (Right, red collumns).

Treatment reduction	TN	TP	Cu
GPT	74.25	8.342	6.086
SS	79.61	8.944	6.525
Responsible Community Behaviour	58.97	6.625	4.833
Total Remaining	**377**	**42**	**31**

Treatment reduction	Pb	Zn	Sed.
GPT	7.961	16.61	10528
SS	8.535	17.81	9372
Responsible Community Behaviour	6.323	13.2	3429
Total Remaining	**40**	**84**	**10958**

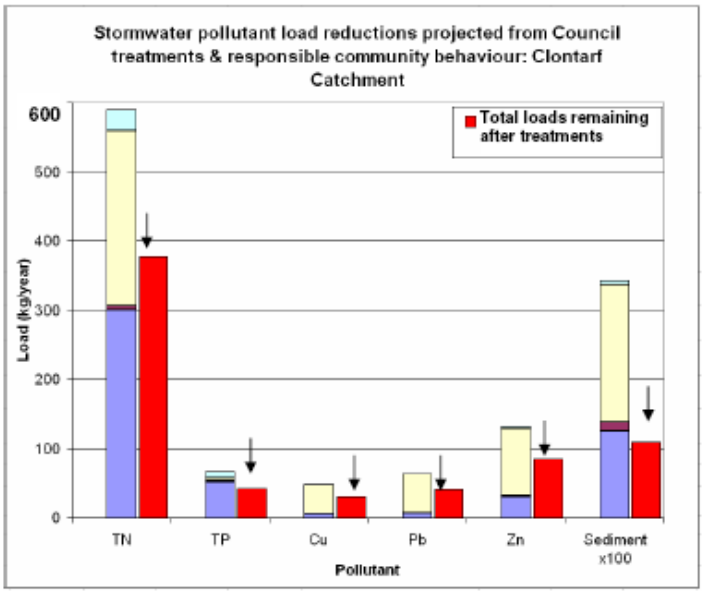

Figure 10E: (Left) Total reductions in annual stormwater pollutant loads (kg/year) in Sangrado Street catchment by Manly Council treatments (SS, GPTs) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the original modelled catchment load (Figure 5E). (Right) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

3.4.6 Castle Rock Reserve Catchment

Projected reductions in annual stormwater pollutant loads achieved through application of street sweeping (SS) and emergent from community education, in the Sangrado Street Catchment, is shown in Figure 10F. Results are expressed as reduction in total kg/year of each of the six pollutants by individual treatments (Left Table), and estimated to remain in stormwater and enter Middle Harbour despite treatments (Right, red collumns).

Treatment reduction	TN	TP	Cu
SS	37.27	3.761	3.257
Responsible Community Behaviour	27.61	2.786	2.413
Total Remaining	**211**	**21**	**18**

Treatment reduction	Pb	Zn	Sed.
SS	4.284	8.741	4574
Responsible Community Behaviour	3.173	6.475	1673
Total Remaining	**24**	**50**	**10486**

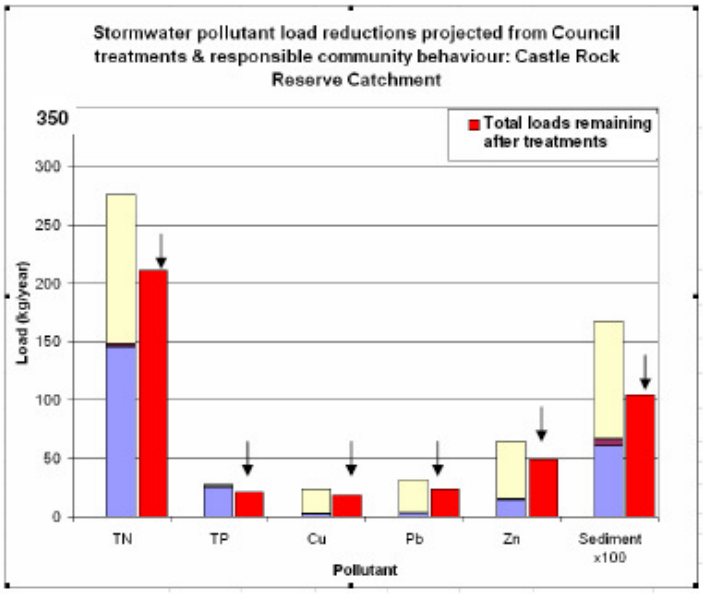

Figure 10F: (Left) Total reductions in annual stormwater pollutant loads (kg/year) in Castle Rock Reserve catchment by Manly Council treatments (SS) and by education (responsible community behaviour). Totals remaining to enter the Middle Harbour Estuary are calculated by subtraction from the original modelled catchment load (Figure 5F). (Right) Graphical representation of reduced loads due to treatments remaining to enter the Estuary (in red).

3.5 Discussion of results

Through a combination of treatments (treatment train approach), Manly Council has been successful in reducing loads of all pollutants, in all catchments, in stormwater entering the Middle Harbour Estuary. Figure 9 displays overall reductions by each component in the treatment train.

However, the combined total load of pollutants estimated to *remain* in stormwater following generation in the six Clontarf / Bantry Bay Catchments, and application of the treatment train approach, was approximately **1646 kg/year of Total Nitrogen; 192 kg/year of Total Phosphorus; 132 kg/year of Copper, 172 kg/year of Lead, 361 kg/year of Zinc, and 70,089 kg/year of Sediment** (Figure 9). This amount is the net pollutant load expected to be currently delivered into Middle Harbour Estuary each year, despite treatments.

Further treatments are recommended to reduce these pollutant loads further, in combination with water quality monitoring to validate improvements as they occur.

Because the greatest contributing land-uses emergent from the modelling were roads and residential activities, these are recommended for further treatment targeting. Roads were estimated to produce highest loads for Copper, Lead, Zinc and Sediment, while residential land-uses were estimated to produce the highest overall loads of nutrients (TN and TP). Substantial reductions could likely be made through residential uptake of infrastructure such as rainwater tanks, on-site detention and re-use, and other technologies to reduce polluted stormwater generation in residential areas in the first place. Further, structural measures may also be possible to be implemented by Council to further reduce pollutant loads or stormwater volumes. These are reviewed in **Section 4.**

4 FUTURE IDENTIFIED MANLY COUNCIL STORMWATER QUALITY IMPROVEMENT MEASURES IN CLONTARF / BANTRY BAY CATCHMENTS

4.1 Increased residential uptake of rainwater tanks, and on-site detention and re-use to reduce stormwater flow volumes

Increased community installation of rainwater tanks at an individual residential scale, would greatly reduce the volume of polluted stormwater entering Middle Harbour, through disconnecting the large roof areas of residential properties' from the stormwater network. This would decrease the proportion of stormwater swept off-site from residential properties, and the capacity of stormwater to entrain and transport pollution into the Middle Harbour estuary. In particular it would also decrease the pollution load from residential land-uses in the catchment through containing nutrient and other pollution on-site. Residential land-uses were estimated to be the greatest source of nutrients and the second-greatest source of heavy metals and sediment in Middle Harbour (see Table 4, page 5).

Further, installation of rainwater tanks throughout the catchment would also decrease stormwater flows onto the Middle Harbour foreshores, minimising the likelihood of beach erosion at each outlet. This would better mimic the natural volume of rainwater that flowed onto the foreshore during rain events in pre-European times, and assist in restoring the natural beach / sediment processes.

Manly Council would encourage residents to consider installation of residential rainwater tanks as a means to reduce stormwater flows into Middle Harbour, and establish an alternate water source for their gardens and/or properties.

Manly Council's Guidelines on the Installation of Rainwater Tanks are available at Council's website: www.manly.nsw.gov.au under "DA Fact Sheets" in the "Planning and Development" menu.

→ **Recommendation (13):** That local precincts within the Middle Harbour Estuary catchment discuss the merit of disseminating best practice messages in regard to residential rainwater harvesting and the associated benefits for pollution prevention. That Manly Council examine ways to make rainwater tank purchases and associated infrastructure purchases by residents more attractive in recognition of their environmental benefit through reduced stormwater generation.

→ **Recommendation (14):** That a flood hotspot survey and demand management be undertaken to facilitate re-use potential of stormwater in the Clontarf / Bantry Bay catchments, to reduce stormwater volumes entering Middle Harbour.

4.2 Pit Inserts in Stormwater Drains

Pit inserts are a very effective method of capturing gross pollutants before they enter the stormwater system and receiving waterways. Consisting of a fine mesh, they can be installed inside stormwater pits throughout each catchment to filter gross pollutants before they enter the stormwater system, where they will become more difficult and costly to treat. The captured pollutants are stored in the mesh in a dry state, and their location at street level means that pollutants are easily removed by hand for disposal. Pit inserts are also relatively cheap to install compared to other engineering methods of stormwater treatment, although the limited storage of each unit means that they need to be installed at many locations throughout each catchment. Pit inserts do require regular ongoing maintenance, as their effectiveness means that they can fill quickly during a storm event and contribute to the chance of localised flooding.

→ **Recommendation (15):** Use the results from the litter survey (Recommendation 6) to determine litter hotspots within the study area catchments. Install trial pit inserts into selected stormwater pits, and monitor

their success and practicality (cost and ease of maintenance) for ongoing use. If successful and practical, install pit inserts in litter hotspots throughout the study area.

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5 FURTHER INVESTIGATION AND SUMMARY OF RECOMENDATIONS

In light of: 1) pollutant loads emergent from modelling undertaken; 2) current treatments carried out in Manly Council Clontarf / Bantry Bay Catchments; and 3) further available treatment options, the following further investigations and actions were recommended by this desktop study.

→ **(1)** That further on-site stormwater monitoring be undertaken to confirm stormwater quality entering the Middle Harbour Estuary from catchments examined here, through commissioning of an automated stormwater sampling machine at the base of appropriate catchments.

→ **(2)** That the relevant precincts continue to report dry and wet weather sewage incidents immediately to Sydney Water on 132 092 or at sydneywater.com.au

→ **(3)** That Sydney Water be contacted to confirm the presence of the five sewerage overflow points documented in this report, and any additional designed overflow points within the Clontarf / Bantry Bay Catchments in this report. That Sydney Water's Wet Weather Overflow Abatement Program (WWOAP) division be contacted to request results of any sewerage network capacity modelling undertaken in the Clontarf / Bantry Bay Catchments, in particular seeking the expected frequency and volume of sewage overflows modelled from the designed overflows documented in this report. That this information be used to prioritise sewerage overflows for further controls, as appropriate.

→ **(4)** That on-site stormwater monitoring be undertaken to determine sewage ex-filtration / in-filtration (through monitoring stormwater for bacteria) from Clontarf / Bantry Bay Catchments, through commissioning of an automated stormwater sampling machine at the base of appropriate catchments. This could be done in conjunction with Recommendation 1.

→ **(5)** That an assessment of litter levels transported into the Middle Harbour Estuary from the Clontarf / Bantry Bay catchments be undertaken.

→ **(6)** That poor Harbour Watch compliance in Sangrado Baths be investigated through assessment of the registered sewer overflow point within the catchment (see Addendum C), and assessment of possible sources of Faecal Coliforms and Enterococci.

→ **(7)** That the impacts on aquatic health in the Middle Harbour Estuary of stormwater inflows from the Clontarf / Bantry Bay Catchments be greater understood, through consideration of ecological impacts and interactions with other elements of the water cycle.

→ **(8)** That application of appropriate treatment measures or range of treatment measures be undertaken to minimise stormwater pollution, as possible. That actions undertaken are undertaken in consideration of recommendations outlined for the broader Middle Harbour Estuary catchments in Willing and Partners (1999).

→ **(9)** Pending monitoring, that street sweeping in the Clontarf / Bantry Bay Catchments be increased in frequency, and target key pollutants.

→ **(10)** That maintenance of existing gross pollutant traps in the Clontarf catchment be maintained at a high frequency to achieve maximum pollutant captured, and minimise pollutant re-suspension, and anaerobic decomposition, by existing GPTs.

→ **(11)** That investigation be progressed for installation of further GPTs in Clontarf / Bantry Bay catchments other than Clontarf in priority locations. That appropriate research be conducted into current best practice GPT technologies.

→ **(12)** That Council's education team work with residents in the Clontarf / Bantry Bay Catchments to assist in the uptake of best practice in stormwater management at a residential scale.

→ **(13)** That local precincts within the Middle Harbour Estuary catchment discuss the merit of disseminating best practice messages in regard to residential rainwater harvesting and the associated benefits for pollution prevention. That Manly Council examine ways to make rainwater tank purchases and associated infrastructure purchases by residents more attractive in recognition of their environmental benefit through reduced stormwater generation.

→ **(14)** That a flood hotspot survey and demand management be undertaken to facilitate re-use potential of stormwater in the Clontarf / Bantry Bay catchments, to reduce stormwater volumes entering Middle Harbour.

→ **(15):** Use the results from the litter survey (Recommendation 6) to determine litter hotspots within the study area catchments. Install trial pit inserts into selected stormwater pits, and monitor their success and practicality (cost and ease of maintenance) for ongoing use. If successful and practical, install pit inserts in litter hotspots throughout the study area.

6 REFERENCES

ASCE (1969), *Design and Construction of Sanitary and Storm Sewers, American Society of Civil Engineers,* p332. See also Addendum B for summary table.

Bickford, G., Toll, J., Hansen, J., Baker, E. and Keessen, R., (1999). Aquatic Ecological and Human Health Risk Assessment of Chemicals in Wet Weather Discharges in the Sydney Region, New South Wales, Australia, *Marine Pollution Bulletin, 39* (1-12), 335-345

CDS Technologies, (2006) [online] http://www.cdstech.com/stormwater/inlineunit.htm. [Accessed] 13 Dec 2006

DEC (2006), Harbour Watch 2005-2006, Sydney Harbour – Middle Harbour. [online] http://www.environment.nsw.gov.au/beach/ar2006/sydneyharbour-17.asp [Accessed] 21 Dec 2006. NSW Department of Environment and Conservation.

Galloway, M.J. (2005a) Stormwater Pollutant Concentrations and the Success of Current Treatment Trains in three Urban Sub-catchments in Sydney, Australia. (Research Thesis, UNSW).

Galloway, M.J. (2005b) Pollutant Loads in Stormwater From Urban Sub-catchments (Literature Review, UNSW).

Smith, P.G. (2006), *A Systems Approach to Integrated Watercycle Science, Action and Institutional Change*, PhD Thesis, University of Western Sydney, Richmond, NSW.

U.S. EPA (1983). Results of the Nationwide Urban Runoff Program. Water Planning Division of U.S. Environmental Protection Agency, United States.

Willing and Partners (1999). Middle Harbour Catchment Stormwater Management Plan. Project No. 3963. Willing and Partners Consulting Engineers, in association with Clouston. Ku-ring-gai Municipal Council, Willoughby City Council, Warringah Council, North Sydney Council, Mosman Council, Manly Council, Middle Harbour Catchment Management Committee, Roads and Traffic Authority, Sydney Water Corporation, NPWS-Garigal, Stormwater Trust. July 1999.

ADDENDUM A: Further Information On Catchment Definition Process

The catchment areas as defined for this desktop study were determined based on: (1) Manly Council drainage catchment boundaries, and (2) restriction of modelling to within the boundary of the Clontarf / Bantry Bay Estuary Management Plan study area (as defined in that Plan).

Definition of Manly Council drainage catchment boundaries (1) was conducted previous to this desktop study through in depth analysis of topography and artificial stormwater drainage in Council's GIS, through field validation of flow directions, and through modelling of catchment flows.

For the purposes of this desktop study, land areas *outside* the Clontarf / Bantry Bay Estuary Management Plan boundary (2) (as defined in that Plan), which may also drain stormwater indirectly or directly into Middle Harbour Estuary were not included in desktop modelling here. These were beyond the scope of this desktop study.

Additionally, for the purposes of this desktop study, land areas *within* the Clontarf / Bantry Bay Estuary Management Plan boundary (as defined in that Plan), but *also* found to not drain stormwater to the Middle Harbour Estuary (for example, due to an artificial drainage pipe directing drainage *away* from the Middle Harbour Estuary), these areas were also excluded from desktop modelling here.

Final catchment boundaries as used for this desktop modelling area are shown in **Section 1.2** of this report.

ADDENDUM B: Runoff Coefficient Guidelines

Below: Runoff Coefficient Table derived from ASCE (1969), adopted for stormwater catchment modelling in this report (Table 2).

Description of Area	Range of Runoff Coefficients	Recommended Value*
Business		
Downtown	0.70–0.95	0.85
Neighborhood	0.50–0.70	0.60
Residential		
Single-family	0.30–0.50	0.40
Multiunits, detached	0.40–0.60	0.50
Multiunits, attached	0.60–0.75	0.70
Residential (suburban)	0.25–0.40	0.35
Apartment	0.50–0.70	0.60
Industrial		
Light	0.50–0.80	0.65
Heavy	0.60–0.90	0.75
Parks, cemeteries	0.10–0.25	0.20
Playgrounds	0.20–0.35	0.30
Railroad yard	0.20–0.35	0.30
Unimproved	0.10–0.30	0.20

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surface in the drainage area. This procedure often is applied to a typical sample block as a guide to the selection of reasonable values of the coefficient for an entire area. Coefficients with respect to surface type currently in use are listed below.

Character of Surface	Range of Runoff Coefficients	Recommended Value*
Pavement		
Asphaltic and concrete	0.70–0.95	0.85
Brick	0.75–0.85	0.80
Roofs	0.75–0.95	0.85
Lawns, sandy soil		
Flat, 2%	0.05–0.10	0.08
Average, 2 to 7%	0.10–0.15	0.13
Steep, 7%	0.15–0.20	0.18
Lawns, heavy soil		
Flat, 2%	0.13–0.17	0.15
Average, 2 to 7%	0.18–0.22	0.20
Steep, 7%	0.25–0.35	0.30

The coefficients in these two tabulations are applicable for storms of 5- to 10-year frequencies. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff. The coefficients are based on the assumption that the design storm does not occur when the ground surface is frozen.

* Recommended value not included in original source.

Source: American Society of Civil Engineers. *Design and Construction of Sanitary and Storm Sewers*. New York, 1969. 332.

ADDENDUM C: Known Designed Sewer Overflow Locations In Clontarf / Bantry Bay Catchments

Above: Known designed sewage overflow points in the Clontarf / Bantry Bay Catchments currently registered in Council's GIS system.

Below: Details of known designed sewage overflow points in the Clontarf / Bantry Bay Catchments currently registered in Council's GIS system.

Overflow No.	Catchment	Address	Location	Suburb
SN436OF01	Bligh Crescent	BLIGH CR	IN-ROAD	SEAFORTH
SMSE1OF02	Sangrado Street	SANDGRADO ST	BUSH-NP	SEAFORTH
SMSE1OF01	The Spit	BATTLE BVD	PRIVATE	SEAFORTH
SMCL5OF01	Clontarf	AMIENS RD/HOLMES AVE	IN-ROAD	CLONTARF
SMCL5OF02	Castle Rock Reserve	OGILVY/WEEKES RD		CLONTARF

APPENDIX D
PHOTOGRAPHS

Historical photographs are from Manly Council Library (Local Studies)

Spit Punt, c1880s

The Spit, looking towards Seaforth prior to the Bridge, c1905

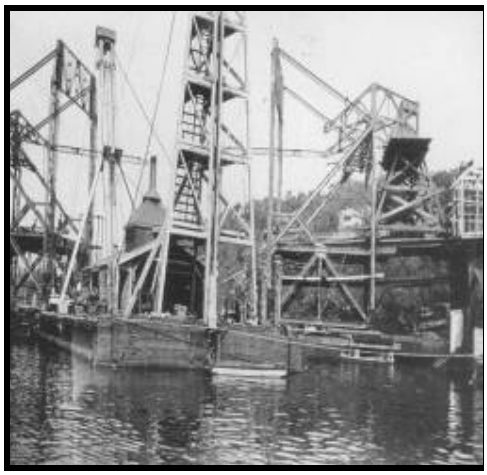
Seaforth, looking toward Middle Head prior to development, c1906

Slipway & Boatshed at Clontarf, year unknown

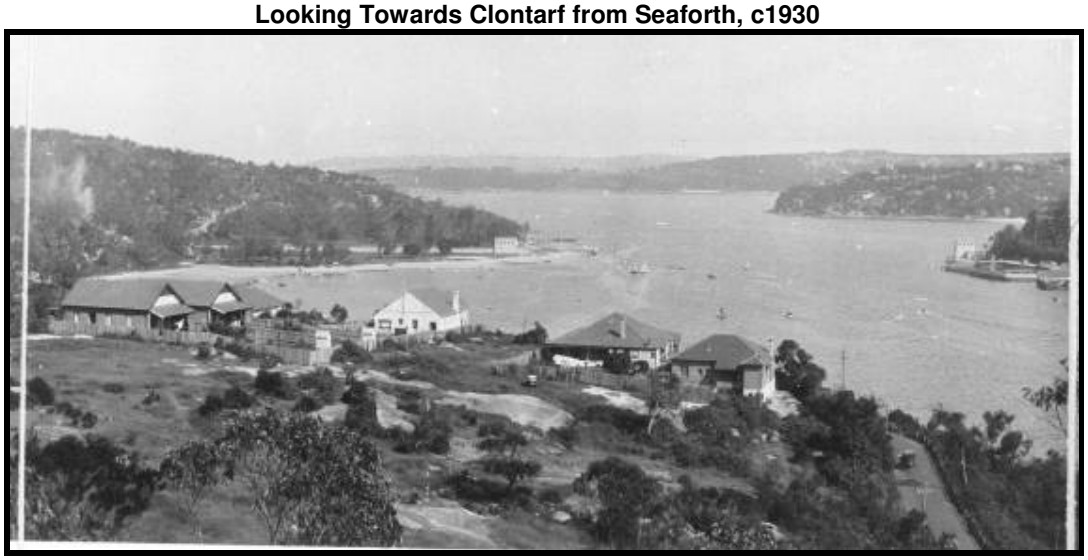
Clontarf Reserve Prior to Landscaping, year unknown

First Spit Bridge Under Construction, c1923

The Spit Tram Afloat, year unknown



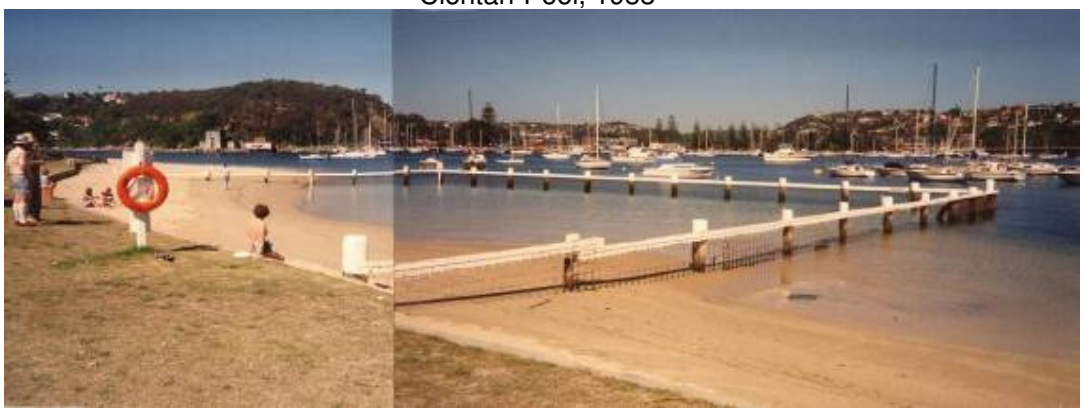
Looking Towards Clontarf from Seaforth, c1930



Aerial Photo of Clontarf & The Spit, 1952

Aerial Photo of Powderhulk Bay, 1979

Clontarf Pool, 1988



Aboriginal middens

Castle Rock

Private moorings

Boat garage

Elloroy Reserve

Old Seawalls

House Boat

Sandy Bay

Clontarf Reserve

Private access to shoreline

Shore front residences near Spit Bridge

Estuary front near Spit bridge: Residential properties & boats

Stormwater being discharged into

Stormwater pipe outflow on the beach

estuary, Clontarf

Pickering Point Swimming Enclosure: Note dinghi storage

Powdery Hulk Swimming Enclosure

Clontarf Swimming enclosure: marine growth

Clontarf Swimming enclosure: sand filled

Recreational Fishing

Kayaking

Dog walking on Sandy Bay

Windsurfing

Clontarf Reserve; picnic area

Beach racking on Clontarf beach

Dinghi storage near Gurney Crescent

Dinghi storage near Sandy Bay

Dinghi storage near Sandy Bay

Clontarf Merina

The Spit Bridge

Old platform for the punt, the Spit

Opening of the Spit Bridge