6 MONITORING AND EVALUATION STRATEGY

Monitoring and evaluation is a key component of any CZMP for two purposes:

- To monitor, evaluate and report on the health of the Parramatta River estuary; and
- To determine if implementation of the Plan has been successful in meeting the management objectives.

Monitoring and evaluation permits adaptive management, whereby the adopted management approach can be modified in response to any changes in circumstances, or to provide improved management outcomes.

Section 6.1 provides an overview of how the implementation of the Plan will be measured against the management objectives, and Sections 6.2 and 6.3 provide further discussion on estuarine health monitoring requirements and coordination of the program. Section 6.4 contains the Parramatta River Estuary Health Monitoring Program.

6.1 Key Performance Indicators

To assist the Committee in measuring the success of implementation of the Plan, Key Performance Indicators (KPIs) have been developed for the Parramatta River estuary. The development of KPIs should ideally consider the SMART criteria, which means the measures should ideally be:

- Specific;
- Measurable (where possible);
- Achievable;
- Relevant; and
- Time phased, in this case the first period (5 to 10 years) of implementation of the Plan.

A series of KPIs have been developed to allow the Committee to measure whether the actions implemented under the Plan have been successful in working towards achievement of the management objectives (Table 6.1). Some more general KPIs have also been developed to assess the more procedural aspects of implementation of the Plan. Some KPIs would be informed by the estuarine health monitoring program, whereas others are either qualitative, or rely on other sources of information.

These KPIs should be assessed after a period of no more than five years, and a decision made by the Committee as to whether it is necessary to update the Plan. It may be beneficial to review the General KPIs listed at the bottom of Table 6.1 more regularly (e.g. annually). This process will assist the Committee in determining whether the actions list needs to be updated and additional actions incorporated for the forthcoming implementation period. This process should also be informed by the findings of the estuarine health monitoring program, particularly with respect to any emerging issues.

Table 6.1: Key Performance Indicators for Management Plan Objectives

Obj. ID	Management Objective(s)	Key Performance Indicator
Land Use Planning and Development		
1A	Ensure integration of the Parramatta River Estuary CZMP aims and objectives into other strategic planning and natural resource management activities, instruments and policies.	▪ Relevant Plans of Management and statutory and non-statutory instruments that have been updated since adoption of the CZMP make reference to the Plan.
Water and Sediments		
2A	Minimise incidences of illegal dumping of waste into the estuary.	▪ The reported incidences of illegal dumping as recorded by the Committee members are reduced. ▪ The quality of stormwater runoff from the catchment is improved. ▪ The incidence of reported sewer overflows as recorded by Sydney Water is reduced. ▪ There is increased compliance with the ANZECC (2000) guidelines for primary and secondary contact recreation at sites within the study area monitored under the Harbourwatch program. ▪ Estuarine water quality shows improved compliance with the ANZECC (2000) and OEH (2013) guidelines for aquatic ecosystem health. It may be necessary to validate the guideline values against baseline conditions for the estuary. ▪ Reference conditions for chlorophyll-a concentrations are established for the estuary in accordance with the requirements of the NSW MER Strategy (DECCW, 2010c).
2B	Reduce the level of contaminated sediment and other pollutant loads entering the estuary from catchment runoff.	
2C	Reduce the incidence of sewer overflows affecting the estuary and improve compliance with recreational water quality guidelines for all sites monitored under the Harbourwatch program.	
2D	Limit the mobilisation of pollutants from contaminated foreshore areas and bed sediments into the water column through minimising their disturbance.	
2E	Ensure all new developments do not have a negative impact on estuarine water quality.	
3A	Reduce sedimentation in the estuary, particularly where it affects vulnerable ecological communities such as seagrass.	
Ecology		
4A	Protect and enhance estuarine habitats (both aquatic and foreshore habitats), with a focus on providing ecological connectivity between core habitats.	▪ The net extent and percentage cover of estuarine aquatic and intertidal vegetation is maintained or improved. ▪ Net extent and percentage cover of riparian vegetation is maintained or improved. ▪ The characteristic suite of vegetation types found in and around the estuary, and along the riparian zones of the major tributaries, is maintained into the future.
4B	Naturalise existing concrete lined and highly modified creeks as opportunities arise.	

Obj. ID	Management Objective(s)	Key Performance Indicator
4C	Reduce the occurrence of weeds and pests in aquatic and terrestrial habitats in and around the estuary.	▪ Ecological connectivity is improved via the linking of discrete patches of core habitat. ▪ Reported incidences of vegetation vandalism are reduced. ▪ Environmental flows/tidal exchange is improved or restored (where possible) so as to permit fish passage. ▪ There is a decrease in the extent (linear length) of concrete lined channels/creeks. ▪ Occurrences of introduced animal species are reduced. ▪ Weed coverage in foreshore and riparian vegetation is reduced. ▪ Occurrences of aquatic pest species in the estuary and its tributaries are reduced.
4D	Incorporate additional aquatic habitat opportunities into existing areas of limited habitat.	
Bank Condition		
5A	Actively encourage the replacement of the current RiverCat with another vessel that has a lower environmental impact (i.e. particularly with respect to bank erosion).	▪ Increase in the extent (linear length) of environmentally friendly seawalls. ▪ Reduction in the extent (linear length) of artificial structures along the estuary foreshores. ▪ Reduction in the extent (linear length) of eroding natural shoreline. ▪ Increase in the extent of shoreline protected by natural vegetation (e.g. mangroves). ▪ The Committee enters into correspondence with Harbour City Ferries and initiates a dialogue on the RiverCat.
5B	Rehabilitate high priority sections of eroding shorelines.	
6A	Remove seawalls where feasible and restore a natural intertidal zone.	
6B	All seawalls, including those that are to be retained and new seawalls that are proposed, should where feasible incorporate the principals of environmentally friendly design features (after DECC and SMCMA, 2009).	
Human Usage and Recreation		
7A	Maintain and improve public access along the estuary foreshores and waterway.	▪ Opportunities to improve public access to the foreshore are realised through the planning and development process. ▪ The extent (linear length) of pathways for pedestrians and cyclists is increased and existing pathway sections are connected along the estuary foreshores. ▪ There is an increase in the extent (linear length) of publicly accessible estuary foreshore. ▪ The Committee members work together to promote within their organisations a strategic approach to management and planning for recreation, public access and transport linkages.
7B	Ensure that recreational facilities continue to be provided for a range of different user groups at strategic locations.	
7C	Achieve recognition of the iconic status of the Parramatta River and capitalise on foreshore and waterway linkages.	

Obj. ID	Management Objective(s)	Key Performance Indicator
Monitoring, Evaluation and Reporting		
8A	Implement a coordinated estuary health monitoring program in line with the NSW MER Strategy. This program should incorporate elements that assist in assessing the effectiveness of implementation of the Plan in achieving the stated aims and objectives. The program should also incorporate a reporting function to provide information to the community and key stakeholders.	▪ A centralised database is established and maintained to record all monitoring data. ▪ Estuarine health report cards are regularly produced. ▪ The Committee works with educational and research institutions to encourage scientific research and data sharing on the Parramatta River estuary. ▪ The community is involved in Plan implementation and monitoring activities. ▪ A web page is established to act as a centralised point for communication on the Plan and ongoing monitoring activities. ▪ The cultural heritage significance of the estuary is recognised, protected and (where appropriate) promoted.
9A	Promote public awareness of cultural heritage in and around the estuary.	
9B	Provide information to the community on the potential impacts of climate change on the Parramatta River estuary.	
Coastal Hazards		
10A	Plan for and mitigate (or increase the capacity to adapt to) the impacts of climate change and SLR on foreshore-based public infrastructure and ecological communities.	▪ The Committee members work together to promote within their organisations a strategic approach to biodiversity management and planning, taking into consideration the potential impacts of climate change. ▪ The Committee members work together to promote within their organisations a strategic approach to asset management that takes into account the potential impacts of climate change.
General KPIs		
▪ The Committee continues to meet several times during the year to progress the Plan. ▪ Committee members from local Government incorporate the initiatives and actions in the Plan into their strategic planning and reporting framework as required by the Department of Local Government. ▪ The Committee members are successful with grant applications to support implementation of actions identified in the Plan. ▪ A minimum of 75% of the management actions identified in the Plan have been initiated after a period of 5 years.		

6.2 Estuarine Health Monitoring Requirements

As previously identified, one of the requirements of a CZMP is to include a strategy for monitoring estuarine 'health'. The term estuarine health relates to the integrity and functioning of the estuarine ecosystem, and should consider whether it is in a 'natural' condition or a 'modified' condition (e.g. due to pollution or the impacts of other human activities).

It is difficult to define a baseline for a 'healthy' estuary, particularly in the context of the high rates of spatio-temporal variation in environmental parameters within an estuary (e.g. due to relative dominance of tidal and freshwater inflows), and differences between estuaries with different characteristics. It is therefore critical to collect data on indicators of estuarine health in each estuary as part of a comprehensive monitoring program to define a baseline condition, assess the range of natural variation in the system, and to track trends in the condition of the estuary. Estuarine health may be measured by a range of different variables. The Parramatta River estuary has historically been subject to significant impacts due to urbanisation of the catchment and use of the waterway, and is considered an extensively modified estuarine system.

The *New South Wales Natural Resources Monitoring, Evaluation and Reporting Strategy 2010-2015* (DECCW, 2010c) guides the Monitoring, Evaluation and Reporting (MER) of the status of natural resources in NSW. It presents a standard approach to coordinate the efforts of natural resource and land management agencies (including State Government agencies and the CMAs) to better understand whether the overall health of the natural resources of NSW are changing and to assess the effectiveness of remedial action in reversing observed negative trends. The state-wide natural resource condition targets in the Strategy (DECCW, 2010c) provide the structure for the MER program. The outcomes of the MER program also feed into the State of the Environment reporting prepared by OEH.

The MER Strategy aims to guide monitoring, evaluation and reporting efforts over the next five years to:

- Support continuous improvement of Natural Resources Management (NRM) and investment decisions;
- Inform evaluation and reporting on progress towards the NRM targets at the State and catchment level scales;
- Improve our knowledge of the condition of natural resources and the pressures on them, as well as on trends in the condition of our natural resources;
- Improve capacity to report on achievements of investments in NRM programs;
- Improve data management and sharing arrangements among MER partners; and
- Enhance collaborative partnerships with key NRM players to strengthen the MER effort.

The MER Strategy is supported by an Implementation Plan (DECCW, 2010a) that details the range of environmental indicators monitored under a series of 13 'themes'. The relevant theme for this Plan is the 'estuaries and coastal lakes' theme, under which a series of indicators are identified for monitoring (Table 6.2). OEH is the lead agency for this theme, with support provided by DPI (Fisheries). The 'current' program details activities that are currently undertaken using dedicated resources, however, the Implementation Plan (DECCW, 2010a) also details an 'essential' program which lists the activities that would need to be undertaken in order to meet the essential elements of the MER Strategy for 2010-2015 (DECCW, 2010c).

OEH provides guidance on implementation of the MER Strategy for estuaries in the document: *Assessing estuary ecosystem health: sampling, data analysis and reporting protocols* (2013). According to OEH (2013) monitoring as part of the estuaries theme of the MER Program focuses on estuarine biology to determine condition in preference to the stressors and pressures which are the external factors that cause changes in condition.

The estuarine ecosystem health indicators listed in OEH (2013) are summarised in Table 6.2. The MER water quality monitoring is scheduled to be undertaken approximately every 3 years, between mid-September and the end of March, in accordance with the sampling program outlined in Section 7.4 of OEH (2013). It is understood that the estuarine macrophytes and fish sampling would follow a similar cycle of sampling roughly every 3 years (DECCW, 2010a). The data collected is to be incorporated into the state-wide MER.

Table 6.2: Estuarine Ecosystem Health Indicators (after OEH, 2013)

Indicators	Method
Water quality indicators:	
Chlorophyll *a*	Filtration and extraction
Water clarity	Secchi disc; NTU
Other indicators:	
Estuarine macrophytes (saltmarsh, mangroves & seagrasses)	Areal extent
Fish assemblages	Estuarine Fish Community Index
Optional additional indicators:	
Macroalgae	Areal extent
Dissolved Oxygen	24hr in situ monitoring

OEH (2013) notes that these protocols do not address matters that reflect broader estuary uses, human health and community values such as the assessment of recreational water quality (see Beachwatch protocols), however, there may be opportunities to include additional indicators when reporting on estuary health or water quality more broadly.

In the event that the Committee obtains additional funding for implementation of the monitoring program under this CZMP, it is recommended they consider the recommendations provided in Appendix I. It is recommended that the Committee seek opportunities to introduce additional indicators (e.g. benthic assemblages) into their monitoring program for estuarine ecosystem health consistent with the advice of OEH (2013) as funding becomes available.

6.3 Program Coordination

The PRCG would be responsible for leading and coordinating the monitoring activities undertaken by each authority/organisation represented on the Committee. According to the *NSW MER Strategy* (DECCW, 2010c), data management, storage, sharing and dissemination standards and systems are the responsibility of the respective organisations carrying out the monitoring activity.

6.4 Parramatta River Estuary Health Monitoring Program

While a variety of stakeholders have in the past, and many continue to, monitor certain aspects of water quality and estuary health in discreet areas in the Parramatta River estuary, there has been no coordinated effort to monitor the health over the entire estuary.

Appendix H provides a brief overview of existing monitoring programs and activities conducted by a range of organisations within the Parramatta River, including details of indicative sampling locations and parameters monitored.

As part of developing this CZMP, the Committee agreed to adopt an Estuary Health Monitoring Program that will be used as a baseline to track how well the estuary is being managed over time, as well as whether implementation of the completed CZMP is contributing to improved estuary health.

The key objective of the monitoring is to look at how the overall health of the estuary changes over time. This monitoring program is consistent with the NSW MER Strategy (DECCW, 2010c) program principles. Other similar estuary health monitoring programs following the same principles also exist, including one for the Georges River, which will enable useful comparisons between estuaries.

It should be noted that while this section describes the monitoring program adopted at the time of preparing this CZMP, there may be changes over time to aspects such as indicators sampled, sites, sampling periods and analysis of data. This will allow for improvements to be made once more information becomes available, as well as to adopt changes to State-wide programs such as MER that may be rolled out and need to be complied with.

Appendix I also contains some additional guidance on estuarine health monitoring and additional parameters that could be incorporated into the Estuary Health Monitoring Program should additional funding become available in the future.

6.4.1 Indicators

The adopted estuary health monitoring program is based around using key indicators that are monitored at the State level under the MER Program. This includes monitoring:

- Chlorophyll *a*;
- Turbidity;
- Other supporting physico-chemical indicators such as salinity, dissolved oxygen, pH, and temperature;
- Estuarine macrophytes (seagrasses, saltmarsh, mangroves) distribution change; and
- Riparian vegetation distribution and condition.

6.4.2 Sampling Period and Effort

- Sampling monthly for chlorophyll a and turbidity (with fortnightly sampling of chlorophyll-a over the warmer months to be considered – roughly mid-September to end of March). Fortnightly sampling

over the warmer months is recommended as algal productivity is greatest over these months and as per MER methodology, will ensure that the chlorophyll a maxima is more likely to be accurately captured;

- Assessments of estuarine macrophyte distribution and condition every 5 to 10 years to compare with existing data to identify change in extent and condition over time; and
- Assessments of riparian vegetation distribution and condition every 5 to 10 years to compare with existing data to identify change in extent and condition over time.

6.4.3 Sampling Sites

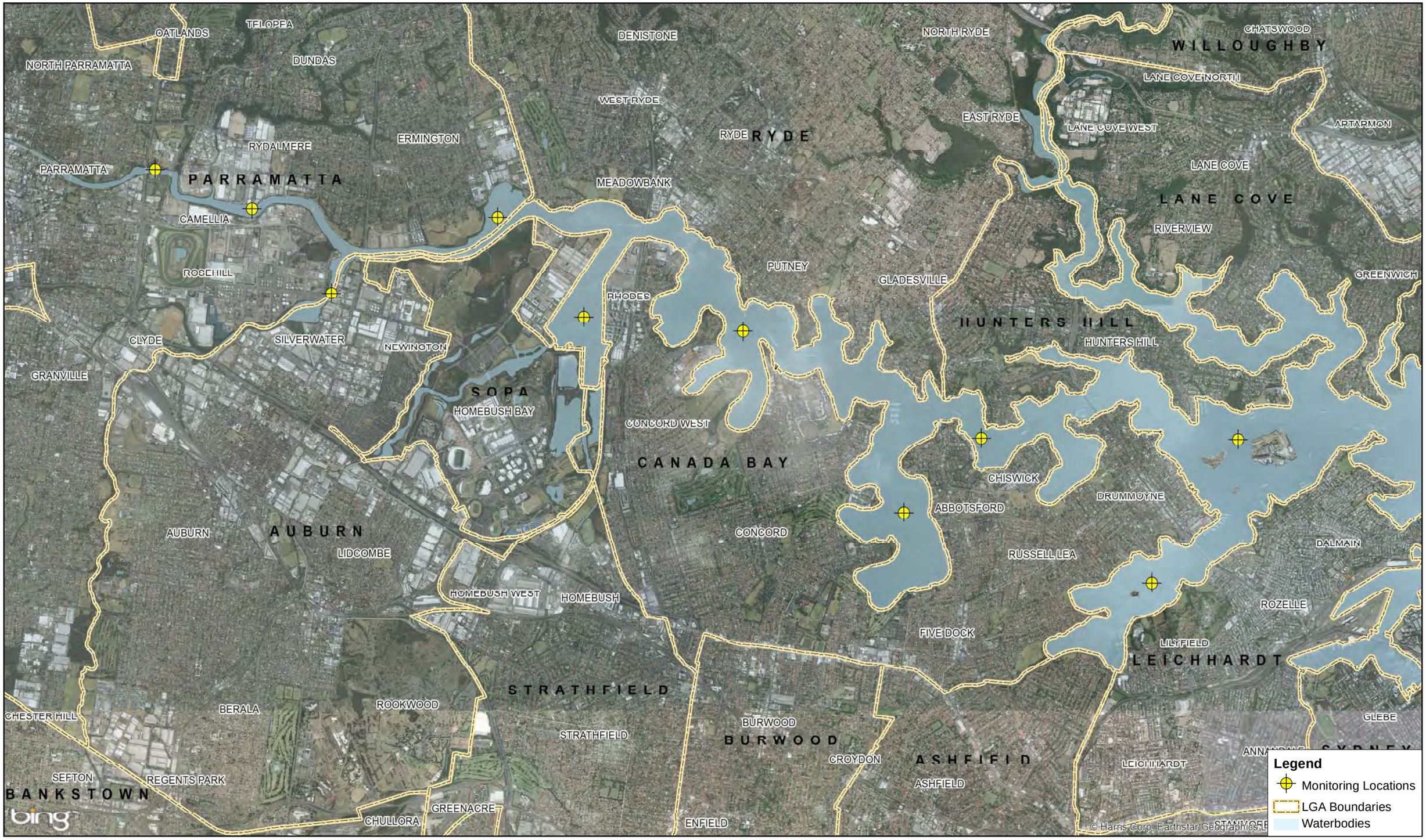
To gain a representative picture of the overall health of the Parramatta River estuary, it is recommended that ten sites are sampled (Figure 6.1). These include five sites along the main river channel that will capture the salinity gradient up the estuary from Cockatoo Island to the weir at Charles Street. The other four sites are located outside of the main river channel to ensure the major bays and tributaries of the Parramatta River are also included. These sites are located in Iron Cove, Hen and Chicken Bay, Homebush Bay and Duck River. For the site located upstream of Silverwater Bridge, boat access will need to be arranged with RMS (Maritime) and Harbour City Ferries.

Parramatta City Council have also initiated the installation of two continuous water quality monitoring stations located within their LGA, which will monitor the same suite of indicators. These stations will align with the locations of the two most upstream sites in the main channel. A third continuous monitoring station is proposed at the downstream end of the estuary, in the vicinity of Cockatoo Island, once additional funding is secured. These stations are part of a broader *Sydney Harbour Catchment Water Quality Improvement Plan* project coordinated by the HNCMA, which will also see installation of the monitoring stations in Sydney Harbour, Middle Harbour and Lane Cove River. The stations will also provide useful supporting information for this monitoring program and will allow cross calibration between chlorophyll a monitored continuously on each station using a fluorometer, with the chlorophyll a samples sent off to the laboratory.

6.4.4 Sampling Protocols

Sampling protocols for the monitoring program are as follows:

- Water quality parameters of pH, salinity, turbidity, dissolved oxygen and temperature will be sampled in-situ using a water quality logger. The logger should be calibrated before each use with the appropriate standards and buffer solutions. Chlorophyll a will be sampled in containers supplied by a NATA accredited laboratory and will broadly follow the MER sampling protocols (Scanes *et al*., 2009). Chlorophyll a will be sampled on a five minute boat drift whereby a 1L sample is taken every 30 seconds and poured into a bucket, a total of 10L of sample water will be drawn and homogenised in a bucket from which a 1L sample will be collected in supplied sample container;
- Monitoring of all sites will be undertaken by boat;
- Chlorophyll *a* samples will be covered in foil to block out the light, chilled and kept in an esky until dispatched to the laboratory, usually on the same day of collection, but no later than 48 hours after collection; and
- A duplicate and field blank sample will comprise 1 out of every 10 samples.



Legend

- Monitoring Locations
- LGA Boundaries
- Waterbodies

Note: Inaccuracies may be present in data provided by third parties. It is assumed that all GIS data provided by third party suppliers is sufficient and accurate for the purpose of this map.

1:44,000 Scale at A3

Metres

0 500 1000 1500 2000 2500

Estuary Monitoring Locations

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

FIGURE 6.1

N W E S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2013-06-05
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G6001_MonitoringLocations 03.mxd
Base Data Source: Land and Property Information NSW (LPI)
Imagery supplied by Bing and associated third party suppliers.

6.4.5 Analysis of Data

The assessment of chlorophyll *a* and turbidity data will be in accordance with the methodology used under the MER Program (OEH, 2013), including adoption of the trigger values derived from this program (Table 6.3). The methodology for assessing change in macrophyte distribution over time will also follow the MER methodology.

*Table 6.3: Trigger Values to be Used**

Indicator	Estuary Type	Estuary Zone (based on salinity)	Trigger Value
Chlorophyll *a*	River	Upper <10 ppt salinity	3.4 µg/L
		Middle 10-25 ppt salinity	2.9 µg/L
		Lower >25 ppt salinity	2.3 µg/L
Turbidity	River	Upper <10 ppt salinity	6.6 NTU
		Middle 10-25 ppt salinity	3.5 NTU
		Lower >25 ppt salinity	2.8 NTU

* Note: These trigger values were derived from data from reference estuaries sampled as part of the NSW MER.

6.4.6 Evaluation and Reporting

Evaluation and interpretation of the data is important for determining whether any priorities of the CZMP need to be amended or specific actions need to be taken. This should be an ongoing process.

Reporting of the data is important for highlighting to key stakeholders and the community in general how the health of the Parramatta River is changing over time, and how it compares to other estuaries. Reporting should be in the form of yearly report cards on estuary health/water quality.

7 CONCLUSIONS AND RECOMMENDATIONS

The Parramatta River Estuary CZMP has been prepared by Cardno on behalf of the Parramatta River Estuary Management Committee in accordance with the requirements of the *Coastal Protection Act 1979,* and with reference to the relevant guidelines, including the *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010b) and the *NSW Estuary Management Manual* (NSW Government, 1992; recently superseded).

The Plan includes an implementation strategy consisting of 67 prioritised actions proposed for execution within 10 years after the Plan is adopted. The strategy clearly identifies the responsible organisation for implementation of each management action, be it the Committee as a whole or by one of the 11 authorities that hold representation. The estimated capital cost of implementation is $19.4 million, with annually recurrent costs (assuming 10 years of implementation) of $1.6 million.

In addition to these 67 prioritised actions a further 16 management actions were identified as generic actions of significant benefit or high priority that may be implemented by any council or authority in the event the necessary resources become available. These generic actions have been provided as a stand-alone list.

The management actions within the implementation strategy (Section 5) have been prioritised to assist in allocating resources when carrying out the Plan, however, it is acknowledged that the resources required to progress the Plan are significant, and that a flexible approach to undertaking works should be adopted. For example, there may be grants or other funding opportunities that arise from time to time that will allow the Committee to select certain types of lower priority management actions for implementation before higher priority actions.

In order to measure the success of implementation of the Plan, a monitoring and evaluation strategy is also included (Section 6) that provides for regular assessment against a range of KPIs, as well as more regular monitoring of estuarine health. The Parramatta River Estuary CZMP should be regarded as a 'living document' that is reviewed and updated over time in accordance with the principles of adaptive management. The monitoring and evaluation strategy will be a key input into this process.

When the Plan is updated after the first period of implementation, the first activity that should be undertaken is a review of the key management issues, aims and objectives to confirm that they remain relevant. At this time the management options (and particularly their prioritisation) should also be reviewed. It may be that emerging issues have developed since adoption of this Plan and hence the list of high priority management options may require revision. Once these tasks have been undertaken, the list of management actions within the implementation strategy can then be reviewed. This will initially involve the removal from the strategy of any actions that have been completed. At this time, additional management actions that address the updated list of high priority management options can be considered for incorporation into the updated implementation strategy within the Plan. New management actions may be carried across from the management recommendations made in the *Estuary Processes Study* (AECOM, 2010) where they remain relevant. However, it may be necessary to consider developing new management actions that more adequately address the management priorities at that time.

The Parramatta River Estuary CZMP represents a comprehensive document that provides for the coordination of management initiatives by the Committee members. Successful implementation of the Plan

will require the continued cooperation of the many stakeholders under the guidance of the Parramatta River Estuary Management Committee.

8 QUALIFICATIONS AND ASSUMPTIONS

The following qualifications and assumptions apply to this Plan:

- The development of the Plan commenced prior to release of the new *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010b). Every effort has been made to meet the minimum requirements of the Guidelines in so far as is reasonably practical.
- The assessment of the potential impacts associated with the management options and management actions is preliminary in nature and is not intended as an exhaustive assessment. It has been assumed that the appropriate level of environmental impact assessment would be undertaken prior to the initiation of any on the ground works, and that appropriate mitigation measures and environmental safeguards will be put in place to minimise impacts associated with the works. The preliminary actions costings for on the ground works include a budgetary allowance for the required environmental impact assessment where indicated.
- It has also been assumed that any relevant approvals, permits or licences required under the legislation would be obtained for any works implemented under this Plan.
- The feasibility and sustainability of management actions identified in the implementation strategy have not been considered in detail during the preparation of this Plan, but have relied upon information presented in the *Parramatta River Estuary Processes Study* (AECOM, 2010) or provided by the Committee members. Where feasibility investigations were considered to be an important component of the implementation process for a particular management action, this has been identified in the implementation strategy. However, the need for further consideration of feasibility and sustainability should be assessed prior to initiation of any of the actions.
- The cost estimates shown in the implementation strategy are indicative and have been used for comparative purposes only. Detailed cost estimates should be obtained prior to initiation of any of the management actions.

9 REFERENCES

AECOM (2010) *Parramatta River Estuary Processes Study*. Prepared for the Parramatta River Estuary Committee. October 2010.

ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra. October 2000.

Applied Ecology (2010) *Lane Cove Estuary Saltmarsh Monitoring Manual.* Prepared for the Lane Cove River Estuary Management Committee. April 2010.

Bartlett, P. (2007) New Dawn for Harbour's Fish as Scales Tip in their Favour. *Sydney Morning Herald*: 28-29/07/07, pp. 3.

Birch, G.F., Eyre, B., and Taylor, S.E. (1999) The distribution of nutrients in bottom sediments of Port Jackson (Sydney Harbour), Australia. *Marine Pollution Bulletin*, 38 (12): pp. 1247-1251.

Birch, G.F., and Taylor, S.E. (2004) *The Contaminant Status of Sydney Harbour Sediments. A Handbook for the Public and Professionals*. Environmental, Engineering and Hydrogeology Specialist Group, Geological Society of Australia Public Education and Information Monograph No. 1, pp. 100.

Cardno (2008) *Parramatta River Estuary Data Compilation and Review Study*. Prepared for Parramatta City Council, the Department of Environment and Climate Change, and the Sydney Metropolitan Catchment Management Authority, on behalf of the Parramatta River Estuary Management Committee. July 2008.

Cardno (2010) *Working Together to Sustain the Parramatta River – Monitoring and Evaluation Report*. Prepared for Parramatta City Council. August 2010.

CCBC (2010) *Resourcing Strategy: Asset Management Plan.* City of Canada Bay. March 2010, pp. 51.

Chessman, B. (2003) *SIGNAL 2.iv A Scoring System for Macroinvertebrates ('Water Bugs') in Australian Rivers Users Manual.* Monitoring River Health Initiative Technical Report, Report No. 31. Commonwealth of Australia. September 2003, pp.: 34.

Creese, B., Glasby, T., West, G., and Gallen, C. (2009) *Mapping the Habitats of NSW Estuaries*. NSW Department of Industry and Investment NSW – Fisheries Final Report Series No. 113 ISSN 1837-2112.

CSE (2012) *Assessment of the Science Behind the NSW Government's Sea Level Rise Planning Benchmarks*. Prepared by the NSW Chief Scientist and Engineer, April 2012.

DEC (2004) *Waterwatch Australia National Technical Manual.* Waterwatch Australia Steering Committee, Australian Government Department of Environment and Heritage.

DECC and SMCMA (2009) *Environmentally Friendly Seawalls. A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries.* Prepared by the NSW Department of Environment and Climate Change and the Sydney Metropolitan Catchment Management Authority. June 2009, pp.: 27.

DECCW (2009) *NSW Sea Level Rise Policy Statement.* October 2009, pp.: 9.

DECCW (2010a) *NSW Natural Resources MER Strategy 2010-2015 Implementation Plan (Version 1.1)*. NSW Department of Environment, Climate Change and Water. October 2010, pp.: 66.

DECCW (2010b) *Guidelines for Preparing Coastal Zone Management Plans.* NSW Department of Environment, Climate Change and Water. December 2010.

DECCW (2010c) *New South Wales Natural Resources Monitoring, Evaluation and Reporting Strategy 2010-2015*. NSW Department of Environment, Climate Change and Water. December 2010.

DECCW (2010d). *Coastal Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments*. NSW Department of Environment, Climate Change and Water.

DLG (2010) *Planning a Sustainable Future. Planning and Reporting Guidelines for Local Government in NSW.* Division of Local Government, Department of Premier and Cabinet. January 2010, pp. 23.

DoP (2010) *NSW Coastal Planning Guideline: Adapting to Sea Level Rise*. NSW Department of Planning. August 2010.

EarthTech (2007) *Sydney Metropolitan Catchment Management Authority Waterways Health Strategy*. Prepared by EarthTech for SMCMA. June 2007, pp. 129.

EarthTech (2008) *City of Canada Bay Estuary Vegetation Management Plan*. City of Canada Bay. September 2008, pp. 78.

Geoscience Australia (2012) *OzCoasts: Australian Online Coastal Information – Sedimentation Rates*. Australian Government, Geoscience Australia. Accessed on 28/06/2012, at www.ozcoasts.gov.au/indicators/sediment_rates.jsp.

Green, R.H. (1979) *Sampling design and statistical methods for environmental biologists.* Cambridge University Press: Cambridge, England.

I&I NSW (2010) *NSW Weeds Action Program Guidelines for Applying for Funds 2010–2011*.

I&I NSW (2011) *Primefact 737: Sydney Harbour and Northern Beaches Recreational Fishing Guide*. January 2011.

McLoughlin, L. C. (2000) Estuarine Wetlands Distribution along the Parramatta River, Sydney, 1788-1940: Implications for Planning and Conservation. *Cunninghamia*, 6 (3): pp. 579-610.

NHMRC (2008) *Guidelines for Managing Risks in Recreational Waters*. National Health and Medical Research Council, Australian Government, February 2008.

NPWS and SOPA (2003) *Plan of Management for Newington Nature Reserve.* Jointly prepared by the NSW National Parks and Wildlife Service and the Sydney Olympic Park Authority. January 2003, pp.: 137.

NRMMC (2007) *National Protocol for Monitoring of Cyanobacteria and their Toxins in Surface Waters*. Natural Resource Management Ministerial Council. Draft (Under Review). Canberra.

NSW Government (1992) *Estuary Management Manual.* Prepared by the NSW Government. October 1992, pp. 198.

NSW Government (2009) *NSW Sea Level Rise Policy Statement.* NSW Department of Environment, Climate Change and Water. October 2009.

NSW Government (2010) *Metropolitan Plan for Sydney 2036*. NSW Department of Planning. December 2010.

NSW Natural Resources and Environment CEO Cluster Group (2006) *NSW Natural Resources Monitoring, Evaluation and Reporting Strategy*, August 2006.

NSW Water Resources Council (1993) *NSW Rivers and Estuaries Policy.* NSW Government. August, 1993, pp. 40.

OEH (2011) *Parramatta River*. Accessed on 13/09/2011, at: www.environment.nsw.gov.au/estuaries/stats/ParramattaRiver.htm.

OEH (2013) *Assessing Estuary Ecosystem Health: Sampling, Data Analysis and Reporting Protocols.* NSW Natural Resources Monitoring, Evaluation and Reporting Program. Prepared by NSW Office and Environment and Heritage, pp. 38.

PCC (2009*) The Parramatta River Foreshore Plan 2009-2016.* Parramatta City Council, pp. 70.

Roper, T., Creese, B., Scanes, P., Stephens, K., Williams, R., Dela-Cruz, J., Coade, G. and Coates, B. (2011). *Assessing the Condition of Estuaries and Coastal Lake Ecosystems in NSW Technical Report - NSW State of the Catchments 2010*. NSW Office of Environment and Heritage, Sydney.

Scanes, P., Coade, G. and Dela-Cruz, J. (2009) *Monitoring, Evaluation and Reporting Sampling Protocols*. Department of Environment, Climate Change and Water. November 2009, pp.: 24.

SHFT (2003) *The Plan*. Published by the Sydney Harbour Federation Trust, pp. 197.

SMCMA (2009) *Sydney Metropolitan Catchment Action Plan.* Sydney Metropolitan Catchment Management Authority, pp. 225.

SMCMA (2012a) *Botany Bay Water Quality Improvement Program*. Accessed on 27/06/2012, at: www.sydney.cma.nsw.gov.au/bbcci/.

SMCMA (2012b) *Draft Catchment Action Plan 2012 A Plan for Sydney's Liveability*. Sydney Metropolitan Catchment Management Authority, pp. 245.

SOPA (2010) *Parklands Plan of Management.* Prepared for the NSW Government by the Sydney Olympic Park Authority. November 2010, pp.: 62.

South Australian EPA (2007) *Community Estuarine Monitoring Manual*. Environment Protection Authority.

Standards Australia (1998a) *AS/NZS 5667.1:1998 Water Quality - Sampling - Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples*. Standards Australia, New South Wales.

Standards Australia (1998b) *AS/NZS 5667.6:1998 Water Quality - Sampling - Guidance on Sampling of Rivers and Streams*. Standards Australia, New South Wales.

Standards Australia (1999) *AS/NZS 5667.12:1999 Water Quality - Sampling - Guidance on Sampling of Bottom Sediments*. Standards Australia, New South Wales.

Sydney Ferries (2012) *Annual Report 2011-12*. Published by Sydney Ferries, pp. 104.

Total Earth Care (2009) *Weed Mapping in the Sydney Metropolitan CMA Region: Tussock Paspalum.* Report prepared for SMCMA, August 2009.

West, G. and Williams, R.J. (2008) *A Preliminary Assessment of the Historical, Current and Future Cover of Seagrass in the Estuary of the Parramatta River*. NSW Department of Primary Industries – Fisheries Final Report Series No. 98 ISSN 1449-9967.

West, G., Williams, R.J. and Laird, R. (2004) *Distribution of Estuarine Vegetation in the Parramatta River and Sydney Harbour, 2000*. Report Prepared for NSW Maritime and Australian Maritime Safety Authority. NSW Department of Primary Industries – Fisheries Final Report Series No. 70 ISSN 1449-9967, December 2004.

WRL (2011) *Sydney Harbour Catchment Water Quality Improvement Plan: Data Compilation and Review*. By D.S. Rayner, B.M. Miller, W.C. Glamore and G.P. Smith. Prepared by the Water Research Laboratory, UNSW, WRL Technical Report 2011/07, August 2011, pp.: 77.

Underwood, A.J. (1994) On Beyond-BACI: Sampling designs that might reliably detect environmental disturbances. *Ecological Applications*, 4 (1), pp. 3-15.

Underwood, A.J. (1992) Beyond BACI: The detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology*, 161, pp. 145-178.

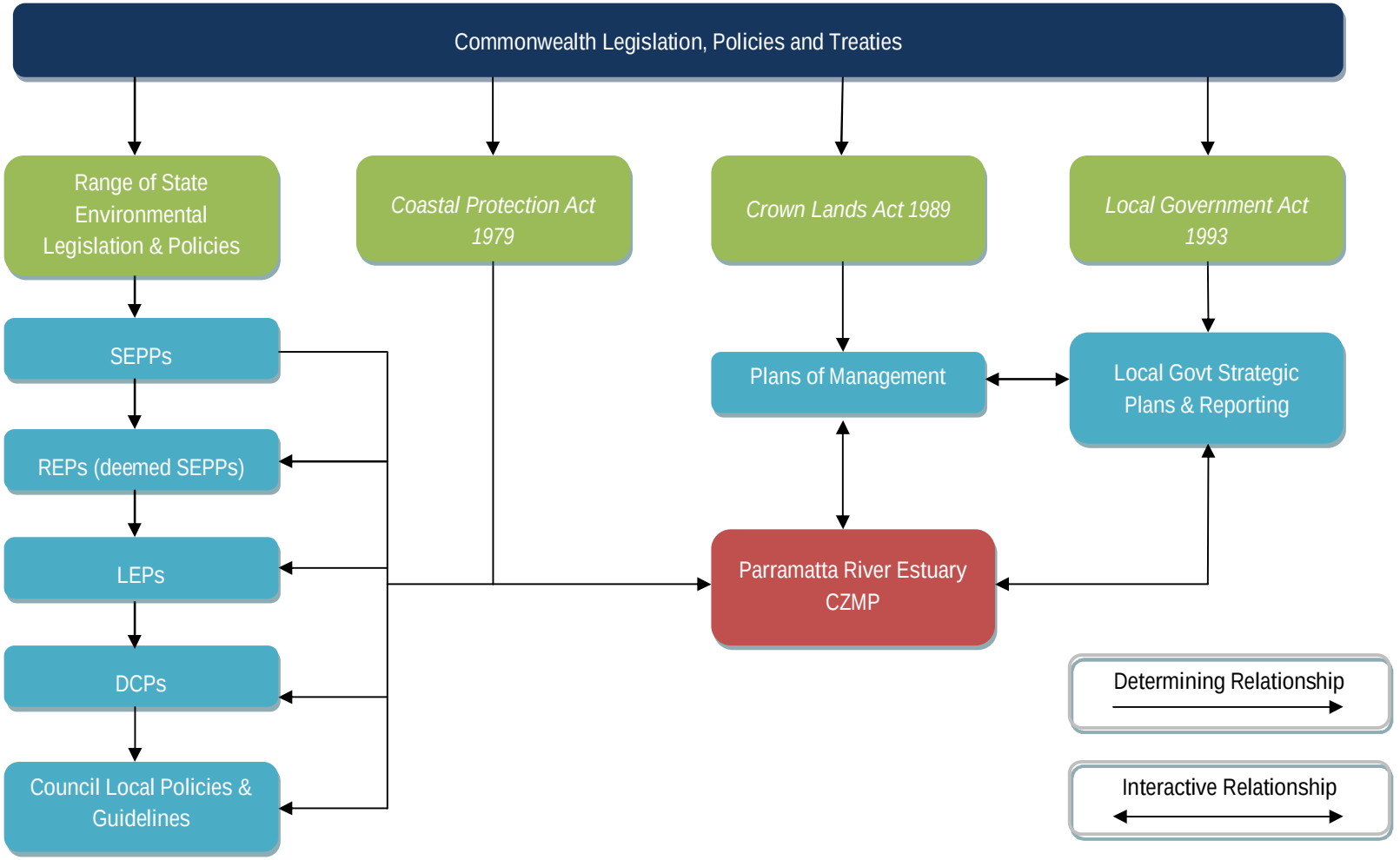
Underwood, A.J. (1991) Beyond BACI: Experimental designs for detecting human environmental impacts on temporal variations in natural populations. *Australian Journal of Marine and Freshwater Research*, 42, pp. 569-587.

You, Z.-J., Lord, D. and Watson, P. (2009) *Estimation of Relative Mean Sea Level Rise from Fort Denison Tide Gauge Data*. Coastal Unit, NSW Department of Environment, Climate Change and Water. Australian Coasts and Ports Conference Wellington, New Zealand, September 2009.

Appendix A

Relevant Legislation, Policies & Plans

This Appendix provides a brief overview of the statutory and non-statutory framework as it applies to the study area and to estuary management more generally. The hierarchy and relationships between the various legislation, policies and plans is illustrated in the flow chart below.



A.1 State and Regional Environmental Planning Policies

An overview of the key relevant state and regional planning policies is provided in Table A.1. It is noted that, as part of improvements to simplify the State's planning system, as of 1 July 2009, Regional Environmental Plans (REPs) are no longer part of the hierarchy of environmental planning instruments in NSW. All existing REPs are now deemed State Environmental Planning Policies (SEPPs).

Table A.1: Relevant State and Regional Environmental Planning Policies

Environmental Planning Instrument	Notes
Sydney REP (Sydney Harbour Catchment) 2005	The Harbour REP covers the area of Sydney Harbour, including Parramatta River (and its tributaries) and the Lane Cove River. The plan aims to establish a balance between promoting a prosperous working harbour, maintaining a healthy and sustainable waterway environment and promoting recreational access to the foreshore and waterways. The Harbour REP covers all the waterways of the Harbour, the foreshores and the entire catchment. It establishes a set of planning principles to be used by councils for the preparation of planning instruments for the hydrological catchment of the Harbour. It also zones the waterways into nine different zones to suit the differing environmental characteristics and land uses of the harbour and its tributaries. The majority of the study area is zoned W1 – Maritime Water The Harbour REP includes a range of matters for consideration by consent authorities assessing development within the Foreshores and Waterways Area of the Plan. These are aimed at ensuring better and consistent development decisions, and include such issues as ecological and scenic quality, built form and design, maintenance of views, public access and recreation and working harbour uses. The REP includes provisions relating to heritage conservation and wetlands protection and provides planning controls for strategic foreshore sites.
SEPP – Infrastructure 2007	This Policy aims to facilitate the effective delivery of infrastructure across NSW. Key provisions include the following: ▪ Additional uses are permitted on certain State land (including some classes of Crown land) which would otherwise be prohibited under an LEP; ▪ Exempt development categories relevant to Crown reserves include access ramps, bush fire protection, car parks, fencing, landscaping, lighting, signage and boundary adjustments; ▪ Infrastructure planning provisions (including works and activities on Crown land) such as emergency services facilities, bushfire hazard reduction, parks and public reserves, flood mitigation works, port, wharf and boating facilities, waterway or foreshore management activities, etc.; ▪ Consultation requirements when undertaking development subject to the SEPP; ▪ Development for any purpose may be carried out without consent on a Crown reserve by or on behalf of the appointed trustee where the development relates to the implementation of a plan of management adopted under the *Crown Lands Act 1989*; ▪ Where local councils are Trust managers, they are permitted to carry out

Environmental Planning Instrument	Notes
	a range of works including roads, cycleways and outdoor recreation facilities; and ▪ The SEPP does not remove any existing requirements to obtain relevant approvals under other legislation such as the *National Parks and Wildlife Act 1974*, *Rural Fires Act 1997* etc.
SEPP No. 19 – Bushland in Urban Areas	This Policy is in place to protect and preserve bushland within urban areas in NSW. Several LGAs located in the study area are included in Schedule 1 of this SEPP. Under Sections 6 and 7 of the SEPP, consent is required for the disturbance of any bushland in urban areas zoned or reserved for public open space.
SEPP No. 55 – Remediation of Land	Introduces state-wide planning controls for the remediation of contaminated land. The policy states that land must not be developed if it is unsuitable for a proposed use because it is contaminated. If the land is unsuitable, remediation must take place before the land is developed. The policy makes remediation permissible across the State, defines when consent is required, requires all remediation to comply with standards, ensures land is investigated if contamination is suspected, and requires councils to be notified of all remediation proposals.
SEPP No. 71 – Coastal Protection	SEPP 71 aims to protect and manage the natural, cultural, recreational and economic attributes of the NSW coastal zone. The policy applies to land within the 'coastal zone' as defined in section 4A of the *Coastal Protection Act 1979* (CP Act). Statutory maps of the coastal zone published by DP&I indicate that the Parramatta River estuary is not located in the declared NSW Coastal Zone.
Sydney REP No. 24 – Homebush Bay Area	This REP applies to land generally bounded by Parramatta River, Homebush Bay Drive, the M4 and the Silverwater industrial area. It provides a planning framework to guide and coordinate the continued renewal of the Homebush Bay area. The plan acknowledges the principles of ecologically sustainable development. It identifies and protects environmental conservation areas, as well as heritage items, heritage conservation areas and potential archaeological sites. Note that from 1 July 2009 this plan is taken to be a SEPP.

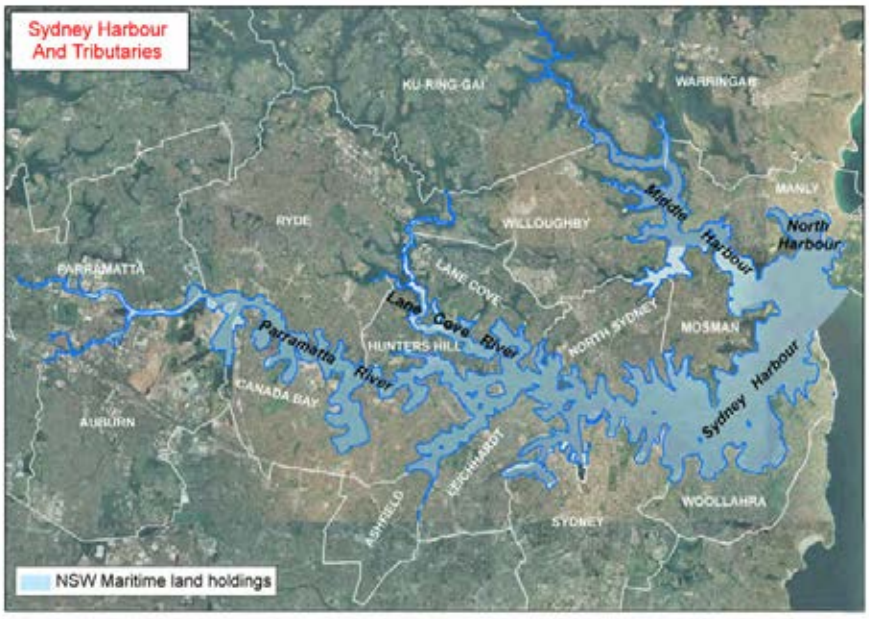
A.2 Key Relevant Legislation

Table A.2 summarises key legislation that has relevance to the management of the Parramatta River estuary.

Table A.2 Relevant Legislation

Statutory Instrument (Responsible Agency)	Notes
Coastal Protection Act 1979 (OEH)	This Act aims to provide for the protection of the coastal environment of the State for the benefit of both present and future generations. The *Coastal Protection Act 1979* (CP Act) is the principal legislation relating to coastal management in NSW. Key provisions of the Act include requirements relating to Ministerial concurrences for certain developments in the coastal zone, and requirements relating to preparing CZMPs. It also includes order powers relating to the unlawful dumping of material on beaches. Under the Act, CZMPs can address risks from coastal hazards, such as coastal erosion, as well as managing threats to estuary health. These plans also need to address the projected

Statutory Instrument (Responsible Agency)	Notes
	impacts on climate change, including projected SLR, on coastal erosion risks and estuary health. Statutory maps of the coastal zone published by DP&I indicate that the Parramatta River estuary is not located in the declared NSW Coastal Zone to which this Act applies.
Contaminated Land Management Act 1997 (OEH)	The *Contaminated Land Management Act 1997* outlines assessment criteria and delineates a management approach for contaminated lands where they pose a significant risk to human health or the environment. Under the Act, a person or public authority will be held responsible as an outcome of land contamination. OEH is responsible for declaring land as contaminated and requiring remediation, and will give notice to end the declaration, once satisfied that the land poses no further risk.
Crown Lands Act 1989 (DPI)	Crown land is land vested in the Crown and managed by Crown Lands Division within the DPI under the *Crown Lands Act 1989*. Under the Act, Crown lands may be: ▪ Held under tenure (lease, licence or permit) for public purposes; ▪ Community managed reserves; ▪ Reserved for environmental purposes; ▪ Crown public roads; or ▪ Managed reserved lands. The Act requires Crown land to be managed to the "benefit of the people of NSW". In accordance with S.11(f) of the Act, Crown land may be occupied, used, sold, leased, licensed or otherwise dealt with in the best interests of the State. The proposed use, development and management practices for Crown lands (or Crown Reserves) must be in accordance with the notified public purpose of the land and individual reserve purposes as applicable.
Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (SEWPAC)	The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the protection and conservation of aspects of the environment that are matters of national environmental significance.
Environmental Planning and Assessment Act 1979 (DP&I)	The NSW environmental planning system operates under the *Environmental Planning and Assessment Act 1979* (EP&A Act). It aims to encourage proper management, development and conservation of natural and artificial resources to ultimately promote the environment and the economic and social welfare of the community, and also seeks to promote the sharing of responsibility between state and local government and facilitate public involvement in the planning and assessment process. The EP&A Act is the primary legislation controlling development activity in the State of NSW and is administered by the DP&I, councils and other consent or determining authorities (such as RMS (Maritime) for Sydney Harbour). Under the Act, appropriate authorities must assess environmental impacts of new developments before development commences.
Fisheries Management Act 1994 (DPI)	The *Fisheries Management Act 1994* aims to conserve, develop and share the fisheries resources of NSW for the benefit of present and future generations. To protect key fish habitats and conserve threatened aquatic species, this Act requires approval to be obtained from DPI (Fisheries) for any works that involve obstruction of fish passage, removal or damage to aquatic vegetation, dredging or reclamation, and using explosive or electrical devices in a waterway. *Posidonia* seagrass beds in Sydney Harbour (including Parramatta River estuary) have been listed as an endangered population under Schedule 4 of the Act.

Statutory Instrument (Responsible Agency)	Notes
Fisheries Management (General) Regulation 2010 (DPI)	This regulation relates to a range of specifications for both recreational and commercial fishing practices, including prohibited fish size and bag limits, lawful fishing nets, protected fish species, etc.
Heritage Act 1977 (DP&I)	The *Heritage Act 1977* provides protection for natural and cultural heritage by providing for the listing of heritage items or places on the State Heritage Register and providing for the making of interim heritage orders for the protection of heritage items or places. Under the Act, it is an offence to harm relics protected by Interim Heritage Orders, the State Heritage Register or environmental planning instruments.
Marine Safety Act 1998 (RMS)	This Act aims to ensure the safe operation of vessels in ports and other waterways and to promote responsible operation of vessels so as to protect the safety and amenity of other users and the amenity of occupiers of adjoining land.
Maritime Services Act 1935 (RMS)	Under this Act and Regulation RMS (Maritime) is the consent authority and has a land owner consent role for any activities affecting RMS (Maritime) submerged lands in NSW ports, including Sydney Harbour. The RMS (Maritime) land holdings in Sydney Harbour are shown in the figure below. 
National Parks and Wildlife Act 1977 (OEH)	The Act aims to conserve the natural heritage of the State, including biological diversity, significant landforms or landscape features (including wilderness areas), objects or sites of significance to Aboriginal people and places of historical, architectural or scientific significance. A number of different permits and licences may be issued under the Act for various activities, including the undertaking of scientific studies (e.g. animal trapping) and archaeological investigations.
Protection of the Environment Operations Act 1997 (OEH)	The *Protection of the Environment Operations Act 1997* (POEO Act) ultimately aims to protect, enhance and restore the quality of the environment in NSW, to reduce risk to human health and promote mechanisms that minimise environmental degradation through a strong set of provisions and offences. A licence is required from OEH if any of the activities associated with the proposed works are determined to be a "scheduled activity" under Schedule 1 of the Act. Under Section 6(3) of the POEO Act, RMS (Maritime) is an appropriate regulatory authority in relation to vessels in navigable waters; and premises used in connection with vessels and

Statutory Instrument (Responsible Agency)	Notes
	situated adjacent to or over navigable waters. This means RMS (Maritime) is responsible for regulating marine pollution caused by vessels, including noise abatement and controls for vessels.
Threatened Species Conservation Act 1995 (OEH)	The Act is a key piece of legislation relating to the protection and management of biodiversity and threatened species. The purpose of this Act is to: ▪ Conserve biological diversity and promote ecologically sustainable development; ▪ Prevent the extinction of, and promote the recovery of, threatened species, populations and ecological communities; ▪ Protect the critical habitat of those species, populations and ecological communities that are endangered; ▪ Eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities; ▪ Ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed; and ▪ Encourage the conservation of threatened species, populations and ecological communities through co-operative management.
Water Management Act 2000 (NSW Office of Water)	The *Water Management Act 2000* controls the extraction of water, the use of water, the construction of works such as dams and weirs, and the carrying out of activities in or near water sources in NSW. The Act creates mechanisms for protecting and restoring water sources and their dependent ecosystems, improved access rights to water, and partnership arrangements between the community and the government for water management.

A.3 Sydney Metropolitan Catchment Action Plan

The SMCMA was a NSW Government agency that functioned to coordinate and deliver natural resource management for the Sydney region, covering eight major catchments, including the Parramatta River and Sydney Harbour catchments. The SMCMA has been merged with the Hawkesbury-Nepean Catchment Management Authority (HMCMA) as part of the changes to the regional service delivery model. The HNCMA engages with community groups, local Government and State Government agencies to integrate natural resource management planning. The HNCMA is responsible for preparing the *Sydney Metropolitan Catchment Action Plan* (CAP) (SMCMA, 2009). The CAP includes a series of overarching catchment targets under the key areas of Biodiversity, Water, Land and Community, under which are a series of more detailed management targets, including some specific targets for estuaries. The preparation of CZMPs is a specific key activity listed within the CAP, and there are a number of other activities listed that have relevance to estuary management planning. The HNCMA is, along with OEH, one of the key organisations with a role in the Coastal Management Process.

The HNCMA also has a State of the Catchment reporting program that identifies threats and pressures, and provides a discussion on the condition of different aspects of the catchment.

A.4 Local Environment Plans and Development Control Plans

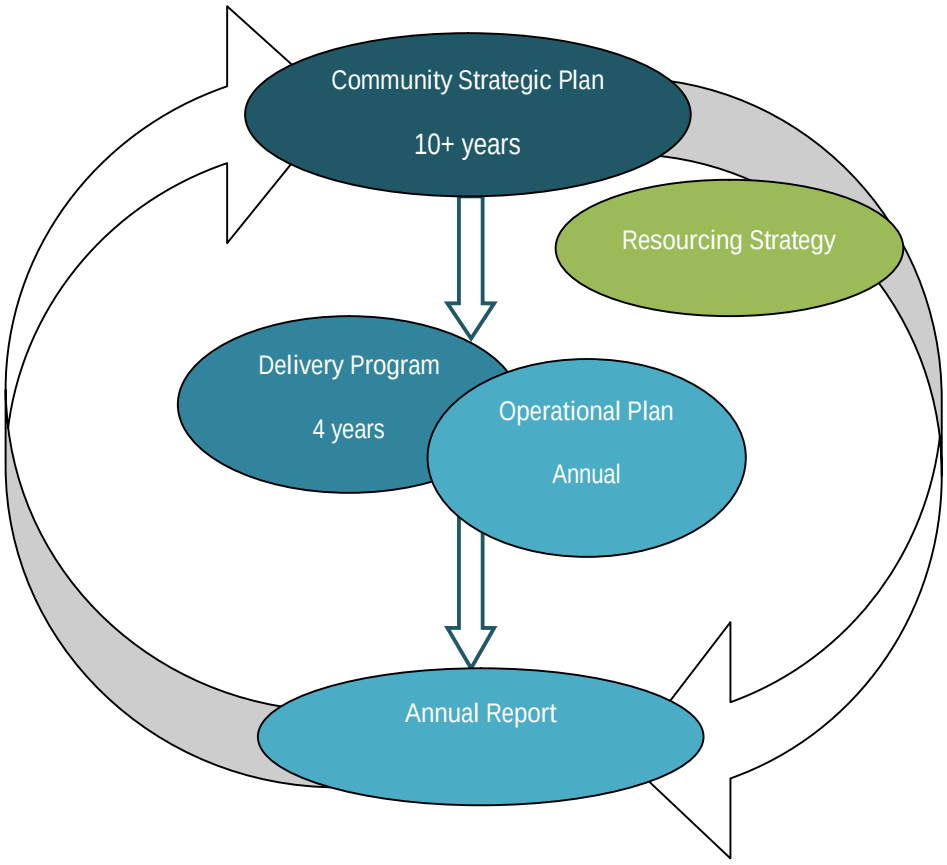
Each council undertakes strategic land use planning via the development of Local Environment Plans (LEPs), which are prepared in consultation with the NSW Department of Planning and Infrastructure (DP&I). LEPs identify which types of activities are permissible, permissible with consent, or prohibited in different land use

zonings applied within the LGA. LEPs also identify sites of local heritage significance. Supporting the LEPs are Development Control Plans (DCPs), which are prepared in accordance with the EP&A Act. DCPs are used to help achieve the objectives of the local plan by providing specific, comprehensive requirements for certain types of development or locations (e.g. for urban design, and heritage precincts and properties).

In July 2009 the then NSW Department of Planning (now DP&I) initiated a program of reform to standardise the planning framework in NSW, and all local councils have been required to prepare a standard instrument LEP and DCP. The local councils within the study area are at various stages in this process, with some having prepared draft standard instrument LEPs and DCPs. This requirement represents an opportunity to re-assess land use within each LGA and implement best practice environmental controls on development.

A.5 Strategic Planning and Reporting by Local Government

Recently the NSW Government introduced a new framework on the strategic and sustainable planning and reporting activities that local Governments must undertake to fulfil their requirements under the *Local Government Act 1993* and the *Local Government (General) Regulation 2005*. The framework is outlined in the Planning and Reporting Guidelines for Local Government (DLG, 2010). It includes a number of key elements that are illustrated in the flow chart below.



The overarching document is the Community Strategic Plan, which is prepared by council in consultation with the community, and identifies the community's main priorities and goals for their local areas, and the realistic and feasible strategies that will be undertaken to achieve these goals (DLG, 2010). The local council is the

custodian of the Plan, taking responsibility for development of the Plan, but is typically supported in the implementation of any strategies in the Plan by State Government agencies and community groups. It is required to cover a minimum period of 10 years.

The Plan is supported by the Resourcing Strategy, which clarifies roles and responsibilities for implementation, and provides detail on financial planning, workforce management planning and asset management planning (DLG, 2010).

The overarching strategic goals identified in the Community Strategic Plan are translated into a list or prioritised actions for implementation in the Delivery Program. All plans, projects, activities and funding allocations undertaken by council are required to be linked back to the Delivery Program, which is prepared every 4 years to coincide with the election cycle (DLG, 2010). The Delivery Program is supported by an Operational Plan that is prepared on an annual basis and outlines the activities to be undertaken in the forthcoming year that achieve the commitments outlined in the Program.

The Annual Report is the mechanism by which councils are required to review the success of implementation of the Operational Plan. The Report is also required to include a State of the Environment Report, which assesses progress towards achieving the objectives for the environment outlined in the Community Strategic Plan.

This framework for strategic planning and reporting is of particular relevance to the Parramatta River Estuary CZMP. Any actions identified for implementation by each council within this CZMP will need to be compatible with the respective council's Community Strategic Plan, and identified for implementation in the Delivery Program and Operational Plan. The monitoring and evaluation strategy contained within the Parramatta River Estuary CZMP (Section 6) will assist council in preparing their Annual Report and the State of the Environment Report in particular. There is, therefore, considerable interaction and linkages between the Parramatta River Estuary CZMP, and each of the council's strategic planning and reporting requirements.

Appendix B

Consultation Summary

B.1 Introduction

The *Estuary Management Manual* (NSW Government, 1992) and the new *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010b) identify the need to involve the community in the development of the Plan. This Appendix provides an overview of the community consultation activities undertaken as part of the Parramatta River Estuary CZMP and summarises the key findings of the consultation process.

B.2 Community Consultation Activities

There are two key mechanisms by which community members have had opportunity to become involved in the preparation of the *Parramatta River Estuary Coastal Zone Management Plan:*

- Via membership of the Parramatta River Estuary Management Committee. The members are identified in Table 1.2 of the main report – a total of four community representatives are included on the Committee, two individuals who represent the interests of the Aboriginal community and two from the wider community; and
- Through publicly advertised consultation activities, including an online survey, information evenings and by providing comments during public exhibition of the draft CZMP.

A discussion on activities involving the Committee (including the community representatives) is provided in Section 1.4 of the main report. This Appendix has focussed on the outcomes of the publicly advertised community consultation activities. The community consultation program involved:

- Public advertisement and notification of the commencement of the Plan;
- Provision of information on the study via the internet;
- An initial Community Information Session;
- A community survey; and
- Public exhibition of the draft CZMP and associated information evening.

Further details are provided below on each of these activities.

Public Notification of the Plan

The first activity after commencement of the project was to prepare a media release for distribution to media outlets and publication in local newspapers. The media release was issued in February 2011.

The eight foreshore council's also assisted in notifying their local residents of the commencement of the project via their own communications networks, such as in local newsletters, or via direct communication with local organisations such as a the volunteer Bushcare Groups.

Project Website and Email

In the initial stages of the project, project website was established (www.parramattaestuary.com.au; Figure B.1) and email address (parramatta.estuary@cardno.com.au), both of which went live on 23 February 2011. The website provides some general information on the P*arramatta River Estuary Coastal Zone Management Plan*, including:

- The context for the study within the NSW Estuary Management framework;
- A list of the stakeholders represented on the Committee;
- A summary of the key findings of the *Estuary Processes Study* (AECOM, 2010) and *Data Compilation and Review Study* (Cardno, 2008);
- An overview of what the CZMP includes and how it has been developed;
- Information on how to provide input, including information on the Community Information Session and a link to the online survey; and
- Project updates, such as provision of consultation materials presented at the information session.

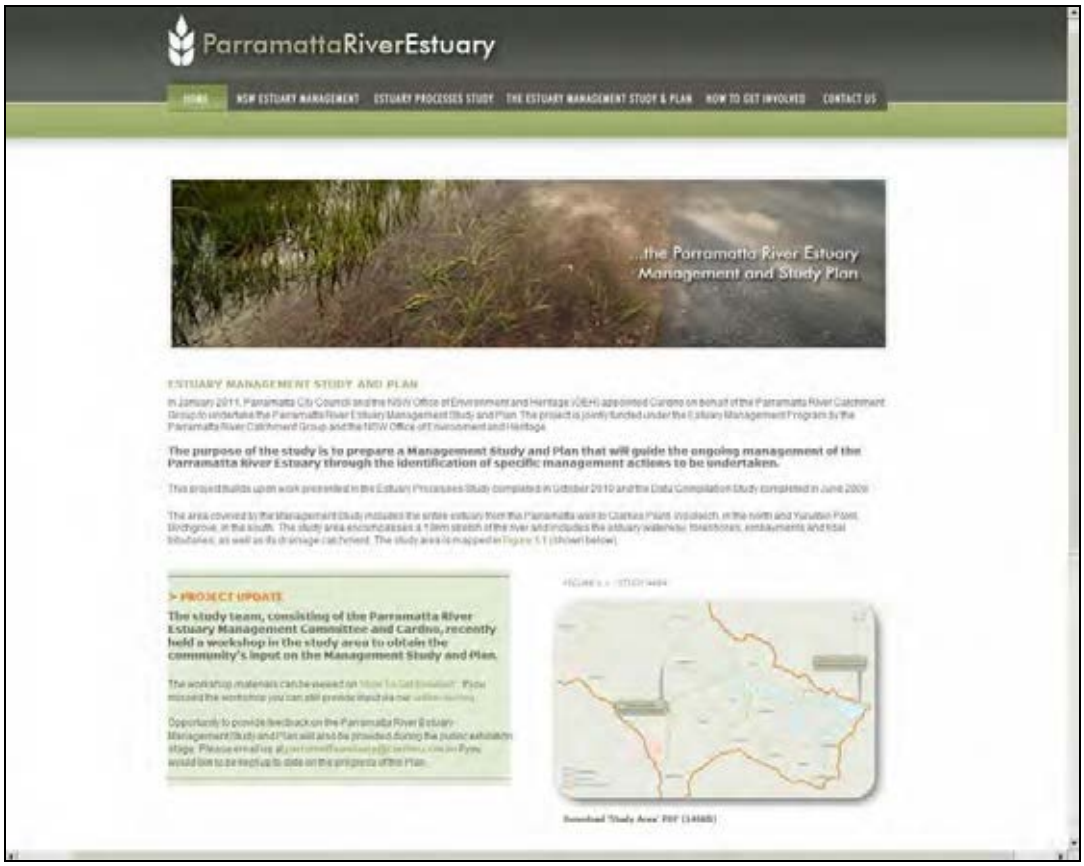


Figure B.1: Website Home Page

The project is also advertised on other websites, including the PRCG (http://parramattariver.org.au) and the City of Canada Bay (www.canadabay.nsw.gov.au) websites.

Community Survey

An online survey (https://www.surveymonkey.com/s/parramatta_estuary) was prepared in order to seek input from the community on:

- What features or uses of the estuary they valued; and
- What generic types of management options they preferred.

A copy of the survey is provided at the end of this Appendix. It was made available over the period 29 June to 26 August 2011.

A link to the survey was made available to members of the public via the project website, and was also made available:

- To each of the Committee members for issue to their contact databases;
- To representatives of local organisations using the Parramatta River for which up to date email addresses were available, including the:
  - Abbotsford 12ft Flying Squadron, Five Dock,
  - Balmain Rowing, Balmain,
  - Concord and Ryde Sailing Club, Putney,
  - Friends of Callan Park,
  - Leichhardt Rowing Club, Leichhardt,
  - Parramatta and District Local Historical Society,
  - Parramatta River Sailing Club, Gladesville,
  - Recreational Fishing Alliance of NSW,
  - Ryde District Historical Society,
  - Sydney Rowing Club, Abbotsford,
  - University of Technology Sydney Rowing Club, Haberfield; and
- To RiverCat passengers in the Parramatta River service area.

In addition, hard copies of the survey and details of the survey link were distributed at the community information evening (see below) and were made available at some of the council offices.

The results of the survey are discussed in Section B.3.

Community Information Session

A Community Information Session open to any interested members of the public was held from 5-7pm on 21 July 2011 at the Shepherds Bay Community Centre, Meadowbank. The information session was advertised via the:

- Project website, PRCG website, SMCMA website and the City of Canada Bay website;
- Parramatta Advertiser (22 June and 7 July 2011); and
- Inner Western Suburbs Courier (14 July 2011).

In addition, invitations were also issued by the foreshore councils, CMA and PRCG to their contact databases on behalf of the study team.

Materials presented on the evening included:

- Three large posters providing information on the project;
- A plain English PowerPoint presentation;
- Hard copies of the community survey (see above);
- The list of proposed management aims and objectives (see Section 4 of the main report);
- The full list of proposed management options, with high priority options highlighted (see Section 5 of the main report); and
- A map for each authority showing the location of any management actions proposed for implementation.

Copies of all these materials were subsequently made available on the project website, and were also distributed to each of the local councils. The three posters were taken by Parramatta City Council and placed on exhibition in the foyer of their Parramatta service centre. The outcomes of the information session are discussed in Section B.3.1.

Public Exhibition and Community Information Evening

The draft CZMP was placed on public exhibition over the period 19 February to 29 March 2013. The public exhibition period was advertised on the project website, on each of the Council websites, and via the placement of an advertisement in the Parramatta Advertiser on 6 March 2013.

Copies of the draft CZMP were made available:

- On the project website (www.parramattaestuary.com.au);
- On each of the eight foreshore Council's websites; and
- In the public libraries of each of the eight foreshore Council's.

In addition, to provide people with additional information on the draft CZMP, and to give them an opportunity to ask questions directly of the study team, a community information evening was held from 5:30-7:30pm on 12 March 2013 at Drummoyne Oval. The workshop was advertised via the Parramatta Advertiser on 6 March 2013 and via the project and Council websites. The public exhibition outcomes are discussed in Section B.3.3.

B.3 Outcomes of Consultation Activities

B.3.1 Community Information Evening

Two members of the Cardno project team were present, along with one representative each from Parramatta City Council, City of Ryde and OEH. An additional committee member (from Shell Refining) was also in attendance. Community attendance at the session was low, with only four members of the public present. It is thought that the poor weather conditions on the evening (heavy, persistent rain) were a contributing factor. It is recommended that any future workshops or communications on the *Parramatta River Estuary Coastal Zone Management Plan* be issued by each individual council and its relevance to the local community clearly articulated in order to attract interest.

The information session commenced with a half hour presentation from Cardno that summarised the key findings of the previous studies (AECOM, 2010; Cardno, 2008), provided an overview of the NSW Estuary Management Process, and an explanation of what the *Parramatta River Estuary Coastal Zone Management Plan* would include and how it was being developed. The session was then opened for informal discussion and questions (Figure B.2).

Key management issues identified by the community members present related to:

- The poor condition of seawalls;
- Pollution and littering;
- The need to maintain stormwater infrastructure along the shoreline, particularly where it is failing (e.g. cracked pipes);
- The poor condition of mangroves relative to their historical condition;
- The trampling of foreshore vegetation by members of the public; and
- Graffiti and vandalism.

Figure B.2: Community Information Evening

More generally speaking, the attendees were supportive of the overall process for developing the Plan, and felt that the key management issues, aims and objectives proposed by the Committee aligned well with issues they perceived to be of concern. The attendees were also able to comment on management actions that were proposed for their local area. Their feedback indicated that they were also supportive of the proposed actions and felt that they addressed the key management issues.

B.3.2 Community Survey

The community survey had two main components:

- A series of questions on features/uses of the estuary which were grouped under broad categories (Questions 1-3). Respondents were asked whether they rated the feature/use identified in the question as being of high, medium or low importance; and
- A series of questions (under Question 4) about generic types of management options, which respondents were asked to score on a continuous scale from 1 (most preferred) to 5 (least preferred) against their relative support for the option.

A total of 40 surveys were completed. The results are discussed in relation to each survey question below.

Community Values

Question 1: Recreation, access and amenity – how important are the following features to you?

1.01 The availability of recreational infrastructure such as BBQ areas, seating, public toilets, jetties and boat ramps.

1.02 Public access along the foreshore (e.g. cycle paths or walking tracks).

1.03 Water quality suitable for recreational purposes, such as swimming or boating.

1.04 Passive recreational opportunities in open spaces near the waterway, such as walking, jogging or picnicking.

1.05 Active recreational use opportunities for open spaces near the water (e.g. fishing or exercising).

1.06 Safe use of the waterways by residents and visitors (e.g. observing boating regulations).

1.07 Harmony between recreational users, commercial users and conservation of ecological values.

1.08 Boating facilities such as boat ramps, moorings and dinghy storage areas.

1.09 Pleasant views of Parramatta River estuary and foreshores.

1.10 Protecting public and private property in relation to wave inundation, flooding, erosion and/or sea level rise (e.g. via seawalls or flood control works).

Between two and three respondents did not complete each question. The responses to Question 1 are summarised below and in Figure B.3.

Those two features/values which were most consistently rated as being of high importance to the community were public access (1.02) and conflict between user groups and the environment (1.07), which 90% and 85% of respondents rated as being of high importance (respectively). Comments made in relation to Question 1 showed a high level of support for public access along the whole river for pedestrians and cyclists.

Passive recreational opportunities (1.04) were consistently rated as being of high importance (77% respondents), compared to active recreational opportunities (1.05), for which there was considerable variation in the responses provided (41% high, 41% medium, 21% low). One respondent feels that there is a need to ensure that adequate recreational infrastructure/open space areas are provided where people live in high densities, but other respondents considered that there were adequate recreational facilities in place at

present. The key issue appears to relate to the use of sail boats and other non-powered watercraft, which a number of respondents use (or would like to use), but they are concerned about safety and conflicts with powered watercraft users. The need for more enforcement and/or more locations subject to speed limits was mentioned in several responses, an issue which is also highlighted in the responses to question 1.06, which was rated as being of high importance by 79% of respondents. In addition, there is a desire for natural shorelines from which it is possible to launch small craft. In some locations this is difficult due to the presence of seawalls, or a lack of suitable infrastructure (e.g. boat ramps). There was a notable low level of support for boating infrastructure (1.08), which in combination with the responses to earlier questions (1.05 and 1.06) suggests that respondents favour low impact boating activities and are concerned about encouraging powered watercraft.

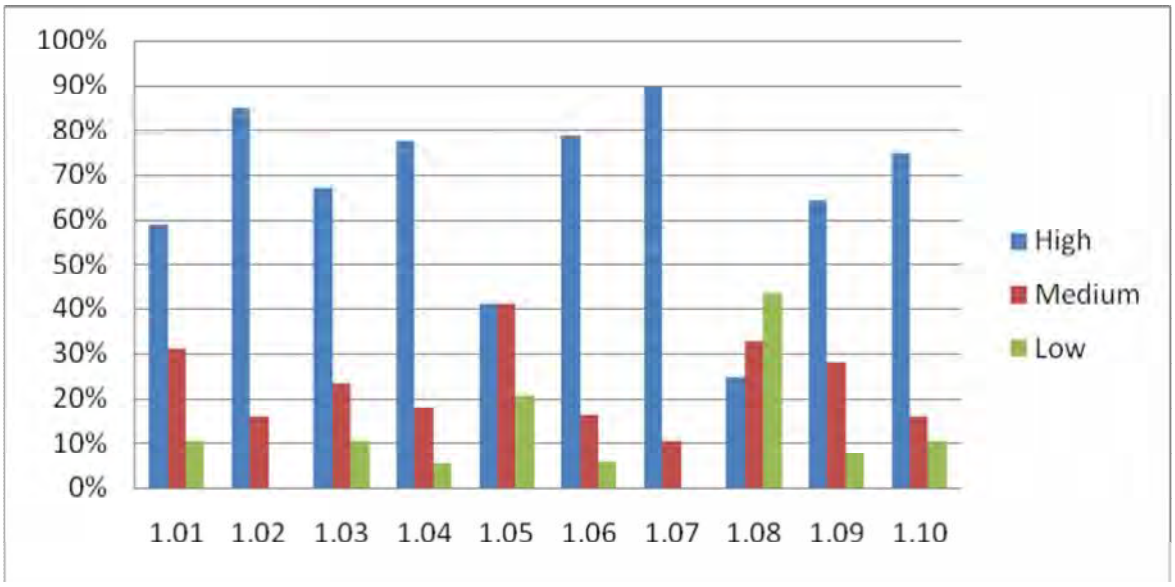


Figure B.3: Summary of Responses to Question 1

The negative impacts of boat wash, particularly from the RiverCat and ferries, was also highlighted in a number of comments provided in relation to the condition of seawalls, bank erosion and the loss of foreshore vegetation. Seawalls were typically noted as being in poor condition and in need of maintenance. A range of comments on their use for foreshore protection were provided, ranging from acknowledgement of the need to protect property, to concerns about loss of sandy areas in front of the seawalls and a preference for stabilisation with vegetation.

Water quality for recreational purposes did not consistently rate as being of high importance (1.03), although interestingly, this is due to a high level of awareness amongst respondents of the poor water and sediment quality in the Parramatta River. It is thought that swimming is not a popular activity for this reason, as well as the limited safe opportunities for swimming. One respondent did express concern about water quality in relation to boating activities, particularly for novice sailors, who are at higher risk of capsizing their vessels or otherwise ending up in the water.

Question 2: The natural environment – How important are the following features to you?

2.01 Water quality suitable for environmental conservation and aquatic health.

2.02 The presence of native animals (e.g. birds, fish etc.).

2.03 Natural vegetation (e.g. saltmarshes and mangroves) as habitat for animals.

2.04 Managing pollution and sedimentation associated with creeks and stormwater outlets.

2.05 European and Aboriginal heritage sites near or on the waterways.

One of the 40 respondents did not complete each question. The responses to Question 2 are summarised below and in Figure B.4.

Generally speaking, environmental values (2.01-2.04) were consistently rated as being of high importance by the community, indicating that the natural environment is highly valued and that there is concern about the current level of impact on the estuarine environment.

The need to manage stormwater pollution and sedimentation (2.04) was consistently rated as being of high importance (92% of respondents), as was water quality for ecological health (2.01, 90% of respondents). Comments provided acknowledged that water quality and stormwater management issues were difficult to manage due to the legacy of industrial activities (contaminated sites), the highly urbanised nature of the catchment, and limited resources of local councils for maintenance of stormwater infrastructure. However, the community remain very concerned about water quality and stormwater issues, and expressed a desire for best practice to be implemented (e.g. WSUD using natural features such as reed beds).

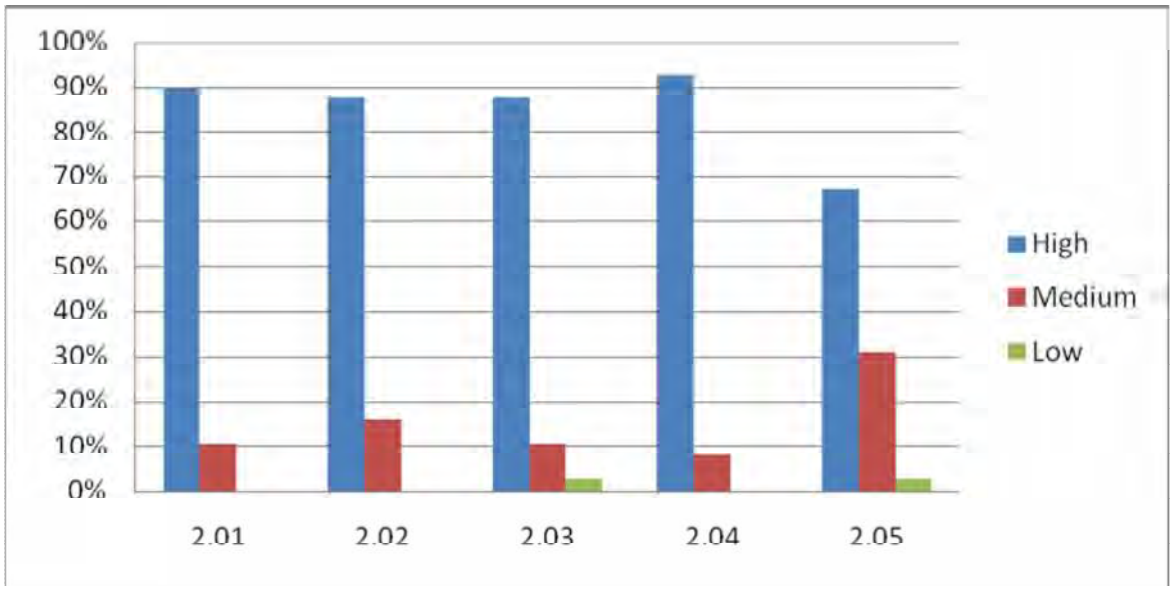


Figure B.4: Summary of Responses to Question 2

A total of 87% of respondents considered both native animals and vegetation (2.02 and 2.03) of high importance. Of note are comments relating to the need to manage biodiversity on a regional basis, coordinating efforts by the various authorities along the River. Other issues raised in relation to vegetation management, were the need for a balanced approach commensurate with access requirements, and the negative impacts of boat wake (particularly from the RiverCat) on foreshore vegetation. A moderate approach to weed management was also advocated that acknowledges the interim habitat value weeds may have in some locations while native vegetation is becoming established.

Heritage values associated with the estuary and its foreshores (2.05) were ranked as being of high importance to 67% of respondents and of medium importance by 31% of respondents. The poor promotion and education on Aboriginal heritage was noted by one respondent, and another identified the need to work with the Aboriginal community on this issue. The installation of interpretative signage was encouraged.

Also of interest were several comments on the need for monitoring and reporting on the state of the estuarine environment.

Question 3: Commercial activities – How important are the following features to you?

3.01 Transport operators and vessels providing public transport.

3.02 Foreshore businesses (e.g. marinas, restaurants, cafes, slipway services, etc.).

Two of the 40 respondents did not complete question 3.02 and one did not complete 3.01. The responses to Question 3 are summarised below and in Figure B.5.

The responses provided in relation to commercial activities on and along the Parramatta River estuary were more measured. Commercial public transport services along the River (3.01) were generally supported as an alternative form of public transport, and one that is more environmentally friendly than vehicular travel. There were, however, a number of comments on the economic viability, and environmental impacts of the current level of service, and particularly in relation to the RiverCat. One respondent suggested that the level of service could be reduced and the vessels travel at slower speeds so as to reduce these impacts. There was a general advocacy against the RiverCat and desire to replace this vessel with a lower impact craft.

Commercial development of the River foreshores also evoked a cautious response (3.02; see Figure B.3). One respondent felt it was beneficial for employment and that boating infrastructure would promote better linkages between the foreshore and waterway. However, the common response was that the amount or intensity of commercial development should be carefully managed and that boating services (e.g. marinas, slipways) should only be intensified in their current locations. This is due to concerns about the natural environment, and about conflicts with other users, such as users of non-powered watercraft. The need for sufficient parking to service any further commercial development was also highlighted. One interesting suggestion provided was to develop better signage to existing cafes and restaurants set back from the foreshore.

Swing moorings in particular were identified as being an issue for seagrasses, and for crowding out of other waterway users.

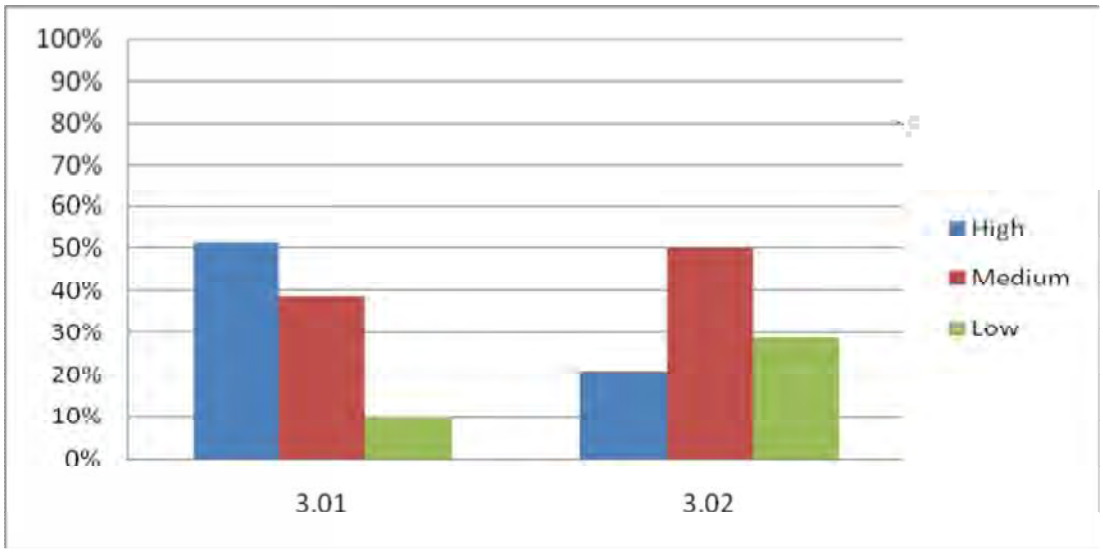


Figure B.5: Summary of Responses to Question 3

Generic Management Options

The respondents to the survey were also asked to indicate their preference for a range of generic types of management options based on a continuous scale ranging from 1 (strongly support / high importance) to 5 (low level of support / low importance). The responses to each of the 13 questions are summarised in Table B.1, which includes an average score and ranking of each of the management option.

Table B.1: Summary of Responses to Question 4

Question No.	Type of Option	Preference					Average	Rank
		1 Strongly Support	2	3	4	5 Low Level of Support		
4.01	Developing planning and development controls (e.g. LEPs and DCPs) to manage the strategic development of the estuary foreshores.	51%	28%	10%	5%	5%	1.8	5
4.02	Providing treatment of stormwater to improve water quality before it enters the Parramatta River.	72%	13%	5%	2%	8%	1.6	2
4.03	Works to stabilise the foreshore and control erosion.	54%	23%	10%	3%	10%	1.9	7
4.04	Habitat management, enhancement or restoration works (e.g. revegetation, weed control, creek naturalisation works).	72%	18%	0%	5%	5%	1.5	1

Question No.	Type of Option	Preference					Average	Rank
		1 Strongly Support	2	3	4	5 Low Level of Support		
4.05	Providing public access along the foreshores to improve connectivity for bikes and pedestrians through the area.	47%	37%	13%	3%	3%	1.8	5
4.06	Ensuring that infrastructure (such as seawalls, moorings, picnic tables and the like) are managed so as to minimise impacts on the environment.	64%	23%	3%	5%	5%	1.6	2
4.07	Seeking opportunities to involve the community in estuary management and raise awareness about estuary health.	49%	28%	13%	8%	3%	1.9	7
4.08	Strategic management of aspects such as recreational usage and estuarine biodiversity across administrative boundaries for the whole estuary.	41%	36%	13%	10%	0%	1.9	7
4.09	Understanding how climate change might impact on the estuary waterway and foreshores.	44%	26%	15%	8%	8%	2.1	11
4.10	Ongoing monitoring and reporting of estuarine health (e.g. water quality).	56%	28%	8%	5%	3%	1.7	4
4.11	Upgrading and/or providing additional recreational infrastructure to support land based and water based activities (such as BBQs, boat ramps, moorings, picnic tables and the like).	13%	32%	42%	8%	5%	2.6	13
4.12	Managing human impacts on estuarine vegetation (e.g. trampling).	46%	28%	13%	10%	3%	1.9	7
4.13	Undertaking activities to support strategic planning in relation to the potential future impacts of climate change.	39%	31%	15%	3%	8%	2.2	12

The average scores ranged from 1.5 to 2.6 (Table B.1), with all 13 generic management options attracting a high level of support. Based on the average scores calculated for each question, management options/actions relating to habitat management, enhancement and restoration (4.04) are consistently the most preferred activities as scored by respondents. This is consistent with the findings of the values survey (Questions 1-3), for which those attributes relating to the natural environment (Questions 2.01 – 2.04 and 2.06) were highly valued by respondents. Concern over the loss of habitat values over the years, and the need for biodiversity corridors were noted. The next highest ranking options were 4.02 relating to stormwater management and 4.06 relating to managing infrastructure and minimising impacts on the environment, followed by 4.10 on monitoring estuarine health.

The lowest ranking generic management option was 4.11, relating to the provision of infrastructure to support recreation, with most respondents (42%) allocating this option a score of three. Most of the comments provided centred on the issue of boating. The general tone was concern over opportunities for small watercraft such as sail boats and canoes, with difficulties launching being a common issue. Moorings are also a concern in relation to their impacts on seagrass and crowding of the waterway. Suggestions included the provision of improved infrastructure for visiting boaters (e.g. moorings and boat ramps), and the need for infrastructure to support small watercraft users. This concurs with the responses provided to the values survey. One respondent also highlighted the need to provide space and opportunity for organised recreational activities as a means to improve general public health.

The responses in relation to Question 4.13 on planning for climate change were also of interest. Several respondents highlighted the need to plan for hazards of any sort (e.g. flooding and SLR) so as to reduce the overall level of risk and vulnerability. There were some concerns expressed over the uncertainty of the climate change projections and the need to monitor indicators (e.g. water levels) was identified by a number of people. Also relevant was a comment that highlighted the importance of not restricting development too significantly now based on climate change projections for 100 years hence.

Additional Information Provided

Key recurring issues raised in the comments provided included:

- Impacts of boat wake, particularly from the RiverCat, on bank and seawall condition and foreshore vegetation;
- Need for stormwater management and maintenance of stormwater infrastructure;
- The desire to provide for improved public access along the foreshore, along with safety concerns about bikes and pedestrians using the same pathways;
- Conflicts between users of larger powered watercraft and smaller non-powered watercraft, and equity of provision of infrastructure for each group;
- Concern over the level of impact human activities have had on the environment, the need to address legacy sites (e.g. contaminated land/sediments) and to ensure that ongoing usage does not unduly impact on the environment;
- The need to recognise the heritage significance of the study area; and
- Improved connectivity for biodiversity corridors and public access.

Based on the feedback provided by the community during preparation of the draft CZMP, the key management issues, aims and objectives developed by the Committee appear to adequately and appropriately address the community's key concerns and values. The three key issues which both the Committee and the community ranked as being of a high priority to address were: stormwater management for water quality purposes, the need to reduce human impacts on the environment, and the need to undertake monitoring of estuarine health.

B.3.3 Public Exhibition Period

Over the six weeks that the Draft CZMP was on exhibition, a number of submissions were received, including:

- Three members of the general public;
- The Abbotsford 12 Foot Flying Squadron; and
- Concord and Ryde Sailing Club.

Comments were also received from the members of the Committee, including OEH and DPI.

The community information evening during the public exhibition period attracted a total of 24 attendees. A presentation was given to provide an overview of the draft CZMP contents and then the floor was opened to questions.

Figure B.6: Community Information Evening 12 March 2013 (Source: PCC)

Points of discussion included:

- Different techniques for environmental monitoring and general support for additional monitoring of water quality and ecosystem health;
- Acknowledgement of the limited resources for implementation and questions over potential funding sources;

- How community input has been incorporated into the study and selection of management actions for the implementation strategy;
- Concern over the impacts of powered watercraft (the RiverCat and Fantasea vessels in particular) on foreshore condition;
- Concern over conflicts between powered and non-powered watercraft and safety;
- Desire to implement more speed restrictions; and
- Opportunities for greater involvement by sporting clubs in management.

The key issue raised by attendees was the need for equity between users and ensuring the safety of rowers and sailors associated with the numerous small sports clubs along the river. There are concerns that the safety issues are negatively impacting on the club membership, particularly children's events and classes.

The Committee subsequently discussed extending an invitation to a sporting club to have representation on the Committee.

In addition to the formal consultation, there was also media coverage of the Draft CZMP and discussion of issues raised in the Plan. This included the following:

- '*Call to Axe Ferries Ravaging River*' – published 30 October 2012 in the Sydney Morning Herald. The article discussed the increase in services to Parramatta and also the AECOM (2010) findings regarding the impacts of the RiverCat on the river banks and mangroves. Calls to replace the RiverCat vessels for lower impact vessels were also presented;
- '*Lovely Trip but RiverCats Destroy*' – published 1 November 2012 in the Parramatta Sun. The article discussed the patronage of the service and also the AECOM (2010) findings regarding the impacts of the RiverCat on the river banks;
- Interview with Dr Melanie Bishop of Macquarie University - Broadcast 1 November 2012 on ABC Radio 702, Sydney. Discusses the impacts of RiverCats on bank condition and sediment transport processes as presented in AECOM (2010) and this CZMP. The discussion was supported by listener observations;
- '*Rising Sea a Threat to Riverside Homes'* – published 3-4 November 2012 in the Sydney Morning Herald. The article re-produced mapping from the CHA prepared by Cardno and discussed the study findings in the context of the recent repeal of the SLR planning benchmarks; and
- *'RiverCat Adding to Erosion Service Threatened Further*' – published 19 December 2012 in the Northern District Times. The article discussed AECOM's (2010) findings regarding the RiverCat on bank erosion and discussed the draft CZMP with a representative of City of Ryde.

Appendix C

Coastal Hazard Assessment Report

Cardno
Shaping the Future

Parramatta River Estuary Coastal Hazard Assessment

LJ2929/Rep2752

Prepared for Parramatta River Estuary Management Committee*

7 June 2013

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Level 9, The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia

Telephone: 02 9496 7700
Facsimile: 02 9439 5170
International: +61 2 9496 7700

sydney@cardno.com.au
www.cardno.com.au

Cover Photograph shows Iron Cove from Henley Marine Drive, Drummoyne looking south-west towards Rodd Point (8 February 2011).

* The Parramatta River Estuary Management Committee has prepared this document with financial assistance from the NSW Government through the Office of Environment and Heritage. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

Document Control:

Version	Status	Date	Author		Reviewer	
			Name	Initials	Name	Initials
1	Draft	20 July 2012	Tanja Mackenzie & Shani Archer	TJM SCA	Doug Treloar	PDT
2	Final	17 August 2012	Shani Archer	SCA	Tanja Mackenzie	TJM
3	Final	24 June 2013	Tanja Mackenzie	TJM	Emma Maratea	ERM

TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Policy Context 1
1.2 Physical Processes 3
1.3 Inundation Mechanisms 6
1.4 Objectives 7

2 METHODOLOGY 9
2.1 Overview 9
2.2 Data Inputs 10
2.3 Digital Elevation Model 12
2.4 Inundation Extents 17
2.5 Outputs 19
2.6 Limitations of the Data 19

3 RESULTS 20
3.1 Inundation Extents 20
3.1.1 Existing Scenario (no SLR) 20
3.1.2 0.4m SLR Scenario 21
3.1.3 0.9m SLR Scenario 21
3.1.4 Comparison of Inundation Extents 31
3.2 Key Areas at Risk from Coastal Hazards 31

4 DISCUSSION 36
4.1 Potential Effects on Estuarine Processes 36
4.2 Potential Impacts on the Built Environment 37
4.3 Management Recommendations 39
4.4 Concluding Remarks 40

5 QUALIFICATIONS AND ASSUMPTIONS 41

6 REFERENCES 42

7 GLOSSARY & ABBREVIATIONS 43

TABLES

Table 1.1: Key Influences on Estuarine Water Levels 3
Table 1.2: Inundation Mechanisms in the Parramatta River Estuary 6
Table 2.1: Design Still Water Levels for Fort Denison (after DECCW, 2010b) 9
Table 2.2: Details of Data Inputs 10
Table 2.3: Details of Data Pre-Processing 11
Table 2.4: Details of Data Limitations 19
Table 3.1: Area of Land Affected by Inundation 31
Table 3.2: Number of Cadastral Lots Affected by Inundation 31
Table 4.1: Summary of Effects on the Built Environment 38

FIGURES

Figure 1.1: Study Area 2
Figure 1.2: Schematic – Coastal Inundation 7
Figure 1.3: Schematic – Tidal Inundation 7
Figure 2.1: Shoreline Cross-Section Schematic with Data Inputs 11
Figure 2.2: LiDAR Coverage 13
Figure 2.3: Bathymetric Survey Coverage 14
Figure 2.4: Seawalls Data 15
Figure 2.5: Digital Elevation Model 16
Figure 2.6: Areas Excluded from Assessment 18
Figure 3.1: Existing Scenario (No SLR) – 1-Year and 100-Years ARI Inundation Extents, Upper Estuary 22
Figure 3.2: Existing Scenario (No SLR) – 1-Year and 100-Years ARI Inundation Extents, Mid Estuary 23
Figure 3.3: Existing Scenario (No SLR) – 1-Year and 100-Years ARI Inundation Extents, Lower Estuary 24
Figure 3.4: 0.4m SLR Scenario – 1-Year and 100-Years ARI Inundation Extents, Upper Estuary 25
Figure 3.5: 0.4m SLR Scenario – 1-Year and 100-Years ARI Inundation Extents, Mid Estuary 26
Figure 3.6: 0.4m SLR Scenario – 1-Year and 100-Years ARI Inundation Extents, Lower Estuary 27
Figure 3.7: 0.9m SLR Scenario – 1-Year and 100-Years ARI Inundation Extents, Upper Estuary 28
Figure 3.8: 0.9m SLR Scenario – 1-Year and 100-Years ARI Inundation Extents, Mid Estuary 29
Figure 3.9: 0.9m SLR Scenario – 1-Year and 100-Years ARI Inundation Extents, Lower Estuary 30
Figure 3.10: Example Risk Areas - Existing Scenario (No SLR) 33
Figure 3.11: Example Risk Areas - 0.4m SLR Scenario 34
Figure 3.12: Example Risk Areas - 0.9m SLR Scenario 35

1 INTRODUCTION

This Coastal Hazard Assessment (CHA) of the Parramatta River estuary has been prepared for the Parramatta River Estuary Management Committee. It describes the results of an assessment of hazard from coastal inundation on the estuary foreshores. The assessment was conducted for the present day, and also under projected climate change conditions when sea level rise (SLR) is likely to be a significant contributor to a change in the risk profile for the study area foreshores.

The study area is shown in Figure 1.1 and comprises the whole of the Parramatta River estuary, including the waterway, bays, foreshores and adjacent lands of the Parramatta River and its tidal tributaries, extending from the Charles Street weir at Parramatta to Clarkes Point, Woolwich, in the south and Yurulbin Point, Birchgrove, in the north. This includes a total of around 135km of foreshore (AECOM, 2010). The Parramatta River estuary comprises the western portion of Port Jackson.

This discussion paper is a companion document to the *Parramatta River Estuary Coastal Zone Management Plan* (Cardno, 2013).

1.1 Policy Context

The NSW Government *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010a) require the assessment of risks to public safety and built assets from coastal hazards, to include consideration of climate change. This involves estimation of areas subject to coastal inundation due to the 1-year, 50-years and 100-years Average Recurrence Interval (ARI) still ocean water levels. Guidelines on the incorporation of SLR planning benchmarks into CHAs are found in the *Coastal Risk Management Guide* (DECCW, 2010b). Assessments should be conducted for the present day, and also adopt the projections provided in the *Sea Level Rise Policy Statement* (DECCW, 2009) of 0.4m by 2050 and 0.9m by 2100.

It should be acknowledged that the NSW Government announced its Stage One Coastal Management Reforms on 8 September 2012. As part of these reforms, the NSW Government no longer recommends state-wide SLR benchmarks for use by local councils, with councils having the flexibility to consider local conditions when determining local future hazards. Accordingly councils should consider information on historical and projected future SLR that is widely accepted by competent scientific opinion. This may include information in the NSW Chief Scientist and Engineer's Report entitled *Assessment of the Science behind the NSW Government's Sea Level Rise Planning Benchmarks* (CSE, 2012).

The NSW Chief Scientist and Engineer's Report noted the evolving nature of the science, which will provide a clearer picture of the changing sea levels into the future. The report identified that:

- The science behind SLR benchmarks from the NSW *Sea Level Rise Policy Statement* (DECCW, 2009) was adequate;
- Historically, sea levels have been rising since the early 1880s;
- There is considerable variability in the projections for future SLR;

BAULKHAM HILLS
TELOPEA
DUNDAS VALLEY
EASTWOOD
DENISTONE
NORTH RYDE
CHATSWOOD
WILLOUGHBY
OATLANDS
NORTH PARRAMATTA
DUNDAS
LANE COVE NORTH
WEST RYDE
EAST RYDE
ARTARMON
RYDE
LANE COVE WEST
RYDALMERE
ERMINGTON
PARRAMATTA
LANE COVE
MEADOWBANK
CAMELLIA
RIVERVIEW
GREENWICH
ROSEHILL
PUTNEY
GLADESVILLE
HOLROYD
RHODES
HUNTERS HILL
NORTH SYDNEY
CLYDE
SILVERWATER
NEWINGTON
HUNTERS HILL
GRANVILLE
HOMEBUSH BAY
SOPA
CONCORD WEST
CANADA BAY
CHISWICK
DRUMMOYNE
ABBOTSFORD
AUBURN
CONCORD
BALMAIN
LIDCOMBE
RUSSELL LEA
HOMEBUSH WEST
HOMEBUSH
ROZELLE
FIVE DOCK
LEICHHARDT
LILYFIELD
STRATHFIELD
BERALA
ROOKWOOD
GLEBE
CHESTER HILL
BURWOOD
STRATHFIELD
CROYDON
ASHFIELD
LEICHHARDT
SEFTON
REGENTS PARK
ASHFIELD
BANKSTOWN
GREENACRE
CHULLORA
ENFIELD
SUMMER HILL

Legend
- LGA Boundaries
- Tidal Waterbody
- Parramatta River Catchment
- Other Waterbodies

Study Area

PARRAMATTA RIVER ESTUARY
COASTAL HAZARD ASSESSMENT

FIGURE 1.1

1:45,000 Scale at A4

Metres

0 500 1000 1500 2000 2500

N W E S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GCS GDA 1994
Project: LJ2929
Map: G1001_StudyArea.mxd 02
Base Data Source: Land and Property Information NSW (LPI)
Imagery supplied by Sydney Metropolitan Catcnment Management Authority, Google and associated third party suppliers.

- The science behind future SLR projections is continually evolving and improving.

As this CHA was completed prior to the announcement of the NSW Government's Coastal Management Reforms in September 2012, the potential impacts of estuarine water levels have been based on SLR projections from the 2009 *NSW Sea Level Rise Policy Statement*. Given that the Chief Scientist and Engineer's Report identifies the science behind these SLR projections is adequate, the Committee is satisfied that the potential impacts of SLR for the Parramatta River estuary have been based on the best available information at the time of preparation of this report.

The high development intensities along the Parramatta River estuary justify the need for the assessment to be undertaken, particularly in relation to future risk under SLR conditions. It is understood that no such hazard study has previously been conducted for the Parramatta River estuary, although some smaller studies have been conducted using slightly different approaches, such as the *Estuarine Planning Levels Study – Foreshore Region of Leichhardt Local Government Area* (Cardno, 2010), which also included wave run-up and overtopping of shoreline edges (a shorter duration hazard).

1.2 Physical Processes

In large estuarine systems such as the Parramatta River, the primary controls on water levels on a day to day basis are ocean water levels and catchment inflows. The timing and volume of catchment inflows is determined by a range of processes, such as individual rainfall events or storms, as well as longer term drought/wet cycles. The impact of catchment inflows on estuarine water levels is not considered in this study.

Ocean water levels, and consequently estuarine water levels, can vary as a result of:

- Coastal trapped waves (shelf waves);
- Global changes in meteorological conditions;
- Wind set-up and the Inverse Barometer Effect (IBE);
- Wave set-up and wave run-up;
- Astronomical tides;
- Ocean circulation (e.g. East Australian Current); and
- Climate change (projected SLR).

The time scales over which these processes can operate are listed in Table 1.1.

Table 1.1: Key Influences on Estuarine Water Levels

Phenomena	Timeframe	Magnitude of Change
Coastal trapped waves	4-7 days	~±0.3 m
Changes in meteorological conditions: Southern Oscillation (El Niño, La Niña) Interdecadal Pacific Oscillation	 3-7 years >10 years	~ ±0.1 m
Wind set-up and IBE	1-7 days	0.3 m

Phenomena	Timeframe	Magnitude of Change
Wave set-up	hours	0.05-0.1 m
Wave run-up	hours	0.2-1 m
Tides	6 hours – 18.6 years	±1 m
Climate change	10,000 years	>100m

Meteorological Conditions

Global meteorological and oceanographic variability associated with phenomena such as the El Niño Southern Oscillation (ENSO) in the Pacific Ocean, and coastal trapped waves that propagate up the east Australian coast and shelf, cause medium term variations in sea level. Sea level changes associated with ENSO events may persist for a year or more.

Coastal Trapped Waves

Common consensus is that the coastal trapped waves experienced along the NSW coastline are mainly a result of large wind events in the Bass Strait. Analyses of long term data from Australian tide gauges indicate that annual mean sea level may vary up to 0.1 m from the long term trend, whilst mean sea level may vary by more than ±0.3 over the time scale of weeks as a result of coastal trapped wave activity.

Wind Set-up

Wind set-up is caused by regional meteorological conditions (passage of high/low pressure systems across a region). When the wind blows over an open body of water, drag forces develop between the air and the water surface. These drag forces are proportional to the square of the wind speed. The result is that a wind drift current is generated. This current may transport water towards the coast upon which it piles up causing wind set-up of the water surface. Wind set-up is inversely proportional to depth.

Inverse Barometer Effect

Severe meteorological events are accompanied by a drop in atmospheric pressure and this causes water to flow from high pressure areas on the periphery of the meteorological formation to the low pressure area. The inverse barometer effect (IBE) results in water level increases up to 1cm for each hecta-Pascal (hPa) drop in central pressure below the average sea level atmospheric pressure in the area for the particular time of year, which is typically about 1,010 hPa. The actual increase in water level depends on the speed of the meteorological system and 1cm is only achieved if it is moving slowly. The phenomenon causes daily variations from predicted tide levels of up to 0.05m. Higher water level rises may occur if the meteorological system travels over the water body at the speed of long waves in the underlying water depth.

Waves

Wave run-up is the vertical distance between the maximum height a wave runs up the beach or a coastal structure and the still water level, comprising tide, storm surge and wave set-up. Additionally, run-up level varies with surf-beat, which arises from wave grouping effects. Wave set-up is included implicitly in wave run-up. Neither is directly important to this study.

Tides

Tides are caused by the gravitational attractions of the Earth, Moon and Sun acting on the ocean water body. While the vertical tidal fluctuations are generated by the gravitational forces, the distribution of land masses, ocean bathymetric variations and the Earth's rotation (Coriolis effect) determine the local tidal characteristics. The Parramatta River estuary is connected to the ocean via Port Jackson, which is a drowned river valley. Moving upstream, away from Fort Denison and along the Parramatta River, the estuary becomes narrower and water depths tend to decrease due to siltation. These changes in the channel dimensions affect the tide as it propagates into the estuary. The tidal characteristics are described as mixed diurnal (once per day) and semidiurnal (twice per day) with a strong spring-neap (15 days) cycle, but are predominantly semi-diurnal. In the Parramatta River estuary, the tidal range is not significantly modified from the ocean tidal range (as measured at Fort Denison). An analysis of water level data provided by Manly Hydraulics Laboratory (MHL) shows that there is a slight amplification in the tidal range moving upstream, resulting in a 6cm increase in the Mean High Water Springs (MHWS) tidal range at the Charles Street weir, when compared to Fort Denison (approximately a 10% increase above Fort Denison value).

Currents

Currents can also impact water levels, although the effect on estuarine water levels in the study area is likely to be very small (a few centimetres). Currents such as the East Australian Current (EAC) can influence water levels by bringing warm water down the NSW coastline and increasing water levels due to thermal expansion. It is noted that currents such as the EAC are typically located well offshore and are therefore unlikely to impact on estuarine water levels, as indicated above.

Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has recorded a global trend in average SLR over the period 1961-2003 of 1.8mm/yr (the range being 1.3 to 2.3mm/yr), with more accelerated SLR occurring over the period 1993-2003 with an average global rate of rise of 3.1mm/yr (2.4 to 3.8mm/yr) (Bindoff and Willebrand, 2007). SLR benchmarks were outlined by the NSW Government in their *Sea Level Rise Policy Statement* (DECCW, 2009) and include a SLR of 0.4m by 2050 and 0.9m by 2100.

An analysis undertaken by Watson (2011) for four long term, continuous tide gauge records in Australia (including Fort Denison) showed that whilst mean sea level was showing an ongoing upward trend, there was a consistent trend of weak deceleration in the rate of SLR over the period from 1940 to 2000. Watson (2011), however, highlights the importance of ground movement measurements when monitoring changes in sea levels, since the land surface underneath a gauge may be subject to a range of complex factors including tectonic movements, glacial isostatic adjustment, compaction of reclaimed land and subsidence. Another investigation by Watson *et al.* (2009) has local significance as it considers the vulnerability of several islands in Sydney Harbour with respect to NSW 2050 and 2100 SLR projections. These studies highlight the importance of ongoing monitoring and data analyses in assessing long term trends in water levels. This is an important consideration for the Parramatta River estuary due to the high development intensities.

Tidal exchange is the most dominant process that contributes to water level variations in the Parramatta River estuary. SLR is therefore likely to have a direct effect on water levels in the estuary, and have consequent impacts on natural estuarine processes in addition to human uses of the estuary.

1.3 Inundation Mechanisms

The information provided in Section 1.2 gives an indication of the types of processes that cause elevated water levels within in the estuary. Joint occurrence of several of the above processes is particularly likely to cause elevated water levels, for example, severe wind set-up and IBE can cause storm surge. Most high water levels in the estuary will have underlying spring tide levels. In this assessment we are concerned with oceanic still water levels as defined by DECCW (2010b).

Elevated estuarine water levels are typically described using a probability of recurrence, e.g. a 100-years ARI event indicates an event of a particular magnitude that has a 1 in 100 (1%) chance of occurring in any given year.

This CHA considers the effects of:

- Coastal inundation which can occur at present due to a combination of phenomena as outlined in Section 1.2, and;
- The combined effect of coastal inundation and projected future SLR, which is likely to have impacts on some sections of the foreshore of the estuary.

Comparison of Inundation Mechanisms

To provide clarity, Table 1.2 describes the ocean/tide inundation mechanisms present within the Parramatta River estuary, as illustrated in Figure 1.2 and Figure 1.3. Recognising the difference between these inundation mechanisms may assist in understanding the objectives and key findings of this investigation.

Table 1.2: Inundation Mechanisms in the Parramatta River Estuary

Mechanism	Schematic	Scenario	Description	Considered in this CHA?
Coastal inundation	See Figure 1.2	Existing	▪ Elevated ocean levels, which cause elevated estuary levels (within tidal limits); ▪ Caused by significant coastal events, especially a combination of phenomena including severe ocean storm surges, high tides, waves etc.; ▪ Generally characterised by large, infrequent events (e.g. 1 in 100-years ARI).	Yes (SWL only)*
		With SLR	▪ As above, but including the additional contribution of SLR due to climate change, which is projected to result in more significant increases in water levels and therefore an increase in inundation extents.	
Tidal inundation	See Figure 1.3	Existing	▪ This type of inundation does not really occur in the existing case since people are unlikely to tolerate day to day inundation; however, it may occur with an approximately biannual frequency (king tides);	No
		With SLR	▪ Likely to occur more frequently in the future once sea levels rises to a level sufficient to surcharge the stormwater system and/or overtop the foreshore and seawalls on a regular basis (e.g. daily inundation); ▪ Highly influenced by tides;	

Mechanism	Schematic	Scenario	Description	Considered in this CHA?
			▪ Likely to occur in the future if no SLR mitigation measures are undertaken.	

* The effect of waves is not considered in this assessment.

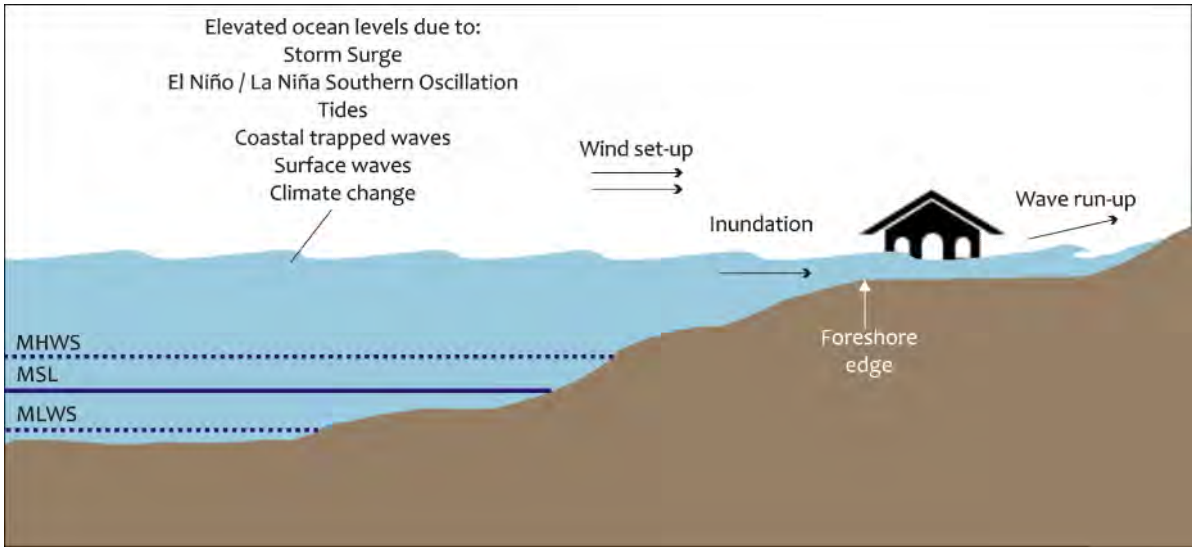


Figure 1.2: Schematic – Coastal Inundation

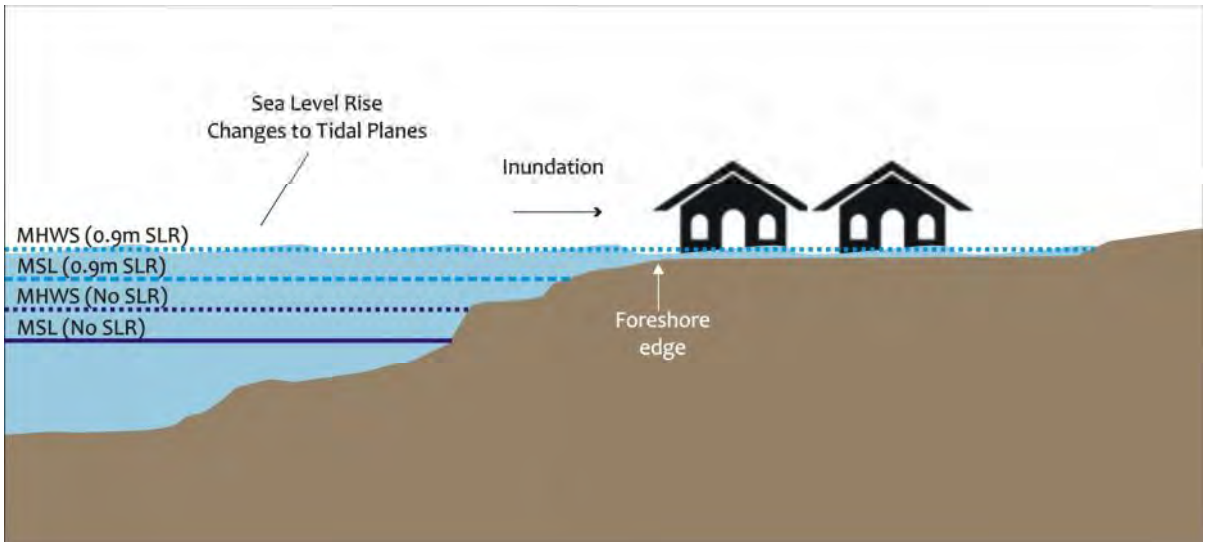


Figure 1.3: Schematic – Tidal Inundation

1.4 Objectives

This CHA has the following broad objectives:

- Incorporate SLR projections into an assessment of coastal hazards for the Parramatta River estuary;
- Identify areas of impact on the foreshores of the Parramatta River estuary that are most at risk from coastal hazards over the defined planning periods;

- Provide broad recommendations for the integration of the results of this investigation into planning mechanisms for the Parramatta River estuary foreshores.

2 METHODOLOGY

2.1 Overview

This CHA was undertaken in two key parts:

- Stage 1, which involved a review of available data and an assessment of data gaps and limitations; and
- Stage 2, which involved the preparation of the CHA, including the delineation of inundation extents under ocean still water levels in accordance with projected SLR.

The following provides a summary of the Stage 2 methodology:

- Collate and review data inputs to the study;
- Create a digital elevation model (DEM) from available data inputs, namely LiDAR (Light Detection and Ranging) data, bathymetric survey data and seawall data;
- Generate a water level surface and map inundation extents using GIS for the following scenarios:
  - Existing Scenario (no SLR) for the 1-year ARI event, 50-years ARI event and 100-years ARI event;
  - 2050 Planning Horizon Scenario (0.4m SLR) for the 1-year ARI event, 50-years ARI event and 100-years ARI event;
  - 2100 Planning Horizon Scenario (0.9m SLR) for the 1-year ARI event, 50-years ARI event and 100-years ARI event;
- Consider the results of the assessment in the context of both natural estuarine processes and the built environment;
- Provide strategic recommendations based on the results of this CHA.

It has been assumed for the purposes of this assessment that the future tidal range along the whole estuary would remain the same as observed under the existing tidal planes. Although there is amplification of the tidal range in the upper estuary compared to the lower estuary, it has been assumed the tidal planes are flat over the entire estuary as hydrodynamic modelling was not proposed for this study. As such, the still water level extents were prepared in accordance with the design still water levels for Fort Denison provided in DECCW (2010b) (Table 2.1).

Table 2.1: Design Still Water Levels for Fort Denison (after DECCW, 2010b)

ARI (years)	Existing Scenario (No SLR) Design Still Water Levels (mAHD)	2050 Scenario (0.4m SLR) Design Still Water Levels (mAHD)	2100 Scenario (0.9m SLR) Design Still Water Levels (mAHD)
1	1.24	1.58	2.08
50	1.41	1.75	2.25
100	1.44	1.78	2.28

2.2 Data Inputs

This assessment draws on available data provided by Sydney Metropolitan Catchment Management Authority (SMCMA; now amalgamated with the Hawkesbury Nepean CMA), spatial data and aerial imagery provided by Parramatta City Council and NSW Land and Property Information (LPI), and the SLR benchmarks outlined in the *NSW Government Sea Level Rise Policy Statement* (DECCW, 2009).

The final dataset used in the DEM creation was provided to Cardno by the SMCMA. This data was made up of a series of tiles that included the following data types:

- LiDAR data;
- Bathymetric data; and
- Interpolated seawall crest and toe levels.

Table 2.2 provides more details, including the sources and dates for each of the above data types. The coverage of each dataset is shown schematically in Figure 2.1.

Table 2.2: Details of Data Inputs

Data Type	Layer Names	Date	Primary Data Source	Positional Accuracy	Vertical Accuracy
LiDAR	LiDAR	2006, 2007, 2008	Geoscience Australia	0.3m	0.15m
Bathymetric data	Sydney_Harbour_soundings	Various	NSW Maritime	0.3m	0.1m (subject to date of survey)
	LPR_bathymetry	April 2012	Catchment Research Pty Ltd	0.3m	0.1m (subject to date of survey)
Seawall crest levels	Seawalls_SHC	April 2012	SMCMA – interpolated values (from LiDAR)	+/-0.2m	SMCMA – interpolated values (from LiDAR)
Seawall toe levels	Base_Seawalls_SHC	April 2012	SMCMA – interpolated values (from bathymetric data)	+/-0.2m	SMCMA – interpolated values (from bathymetric data)

In order to prepare the data inputs for integration into a DEM, a series of data pre-processing tasks was undertaken. Stage 1 of the CHA (review of available data) identified a number of data limitations and an effort was made to address those limitations and data gaps where possible.

Stage 1 of the CHA identified a data gap between the landward boundary of LiDAR data points and the seaward edge of the bathymetric survey data near the land-water interface. It was resolved that additional data at the land-water interface would allow for increased DEM accuracy in these locations – in particular, seawall data. Unfortunately, seawall crest and toe levels were not available because they have not been surveyed around the estuary, so an alternative method was applied. This method involved the digitising lines of seawall crests and toes from recent aerial photographs and then conversion of seawall lines to points (at intervals of 2m). The levels of these seawall points were then interpolated. Seawall crest levels for each

point were interpolated from the nearest LiDAR points and seawall toe levels were interpolated from the nearest bathymetry points.

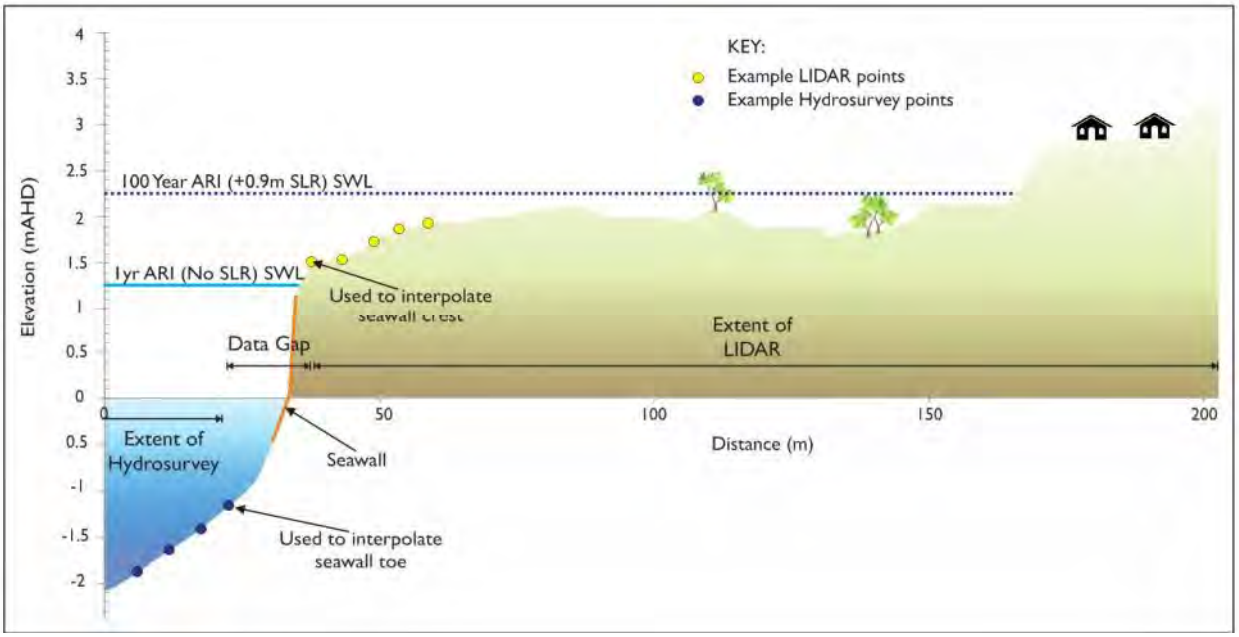


Figure 2.1: Shoreline Cross-Section Schematic with Data Inputs

A summary of the tasks undertaken to prepare the data inputs for incorporation into the DEM is described in Table 2.3.

Table 2.3: Details of Data Pre-Processing

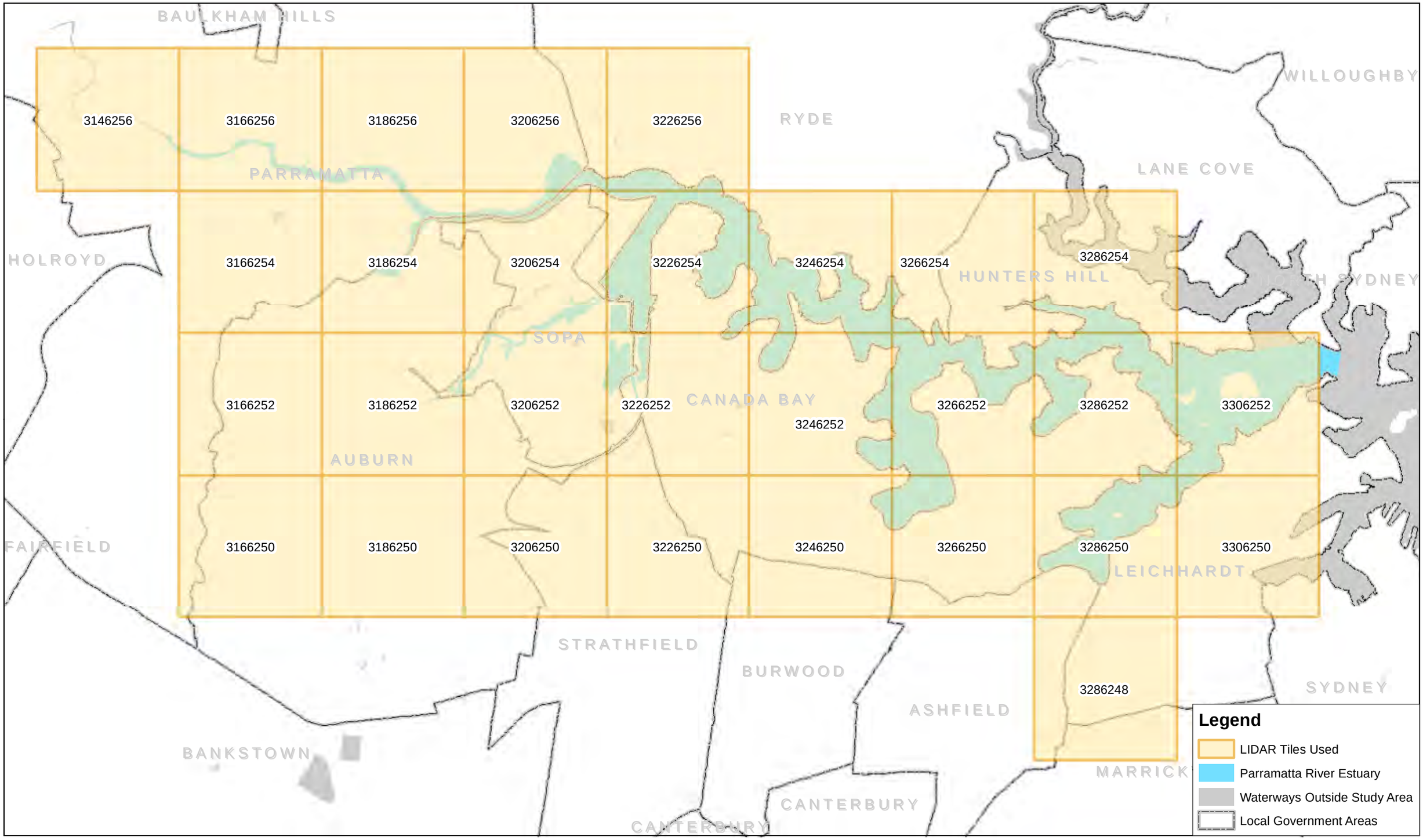
Data Type	Processing Summary	Details
LiDAR	Converted from XYZ data to shape files	LiDAR was imported from XYZ text files in 2km tiles and converted to shape files for viewing in GIS. The LiDAR data required for the assessment comprised 29 data tiles (shape files), each 2km by 2km. The distribution and coverage of these tiles are shown in Figure 2.2.
Bathymetric Survey	None required	Bathymetry data had already been translated into shape file format. The extent of the bathymetric survey data is shown in Figure 2.3.
Seawalls	Digitising, conversion from lines to points, interpolation of seawall levels.	Seawall toe and crest layers were digitised using 2009 aerial photography. The extent of these seawall layers is shown in Figure 2.4. These line features were converted to points (using a 2m interval) and elevation values for resulting point features were interpolated in GIS using a custom-made tool. LiDAR data and bathymetry data were used to interpolate seawall crest data and seawall toe data respectively.
LiDAR, Bathymetric Survey and Seawalls	Merging of data, clipping to 2km by 2km data tiles	LiDAR, bathymetric data and interpolated seawall data points were merged and subsequently clipped to 2km by 2km tiles to facilitate ease of viewing.
LiDAR, Bathymetric Survey and Seawalls	Quality assurance and checking	Data quality assurance checking was undertaken. Where the separate data layers converged, elevation values were visually checked for logical distribution. Non-conforming points were removed, including points that coincided with jetties as identified via aerial photography. The data points from various sources were prioritised depending on the date of the data (with priority given to more recent data points).

Data Type	Processing Summary	Details
LiDAR, Bathymetric Survey and Seawalls	Clipping to 10m contour line	The dataset was clipped to the 10m contour line to further facilitate ease of viewing and to reduce computer processing times in preparation for DEM creation (Section 2.3).

2.3 Digital Elevation Model

Once the data inputs had been converted to point features and had been quality checked, a DEM was created from the dataset. A DEM is a 2.5D digital representation of a terrain surface that is represented in a GIS as a raster dataset (a grid of pixels of equal length and width, with one elevation value assigned to each pixel).

A series of DEM tiles was created from the 29 point feature tiles at a resolution of 1m, which was considered sufficient given the data input accuracies and the proposed objectives of the investigation and data outputs. The 29 DEM tiles were then merged to create a single DEM. Figure 2.5 provides a visual indication of the final DEM (which has been clipped to the 10m contour to show the study area more prominently). Several straight lines delineating the boundary of the DEM are noticeable in Figure 2.5 – these indicate the edges of the data tiles (i.e. data outside this extent was not required for the study area).



LiDAR Coverage

PARRAMATTA RIVER ESTUARY
COASTAL HAZARD ASSESSMENT

FIGURE 2.2

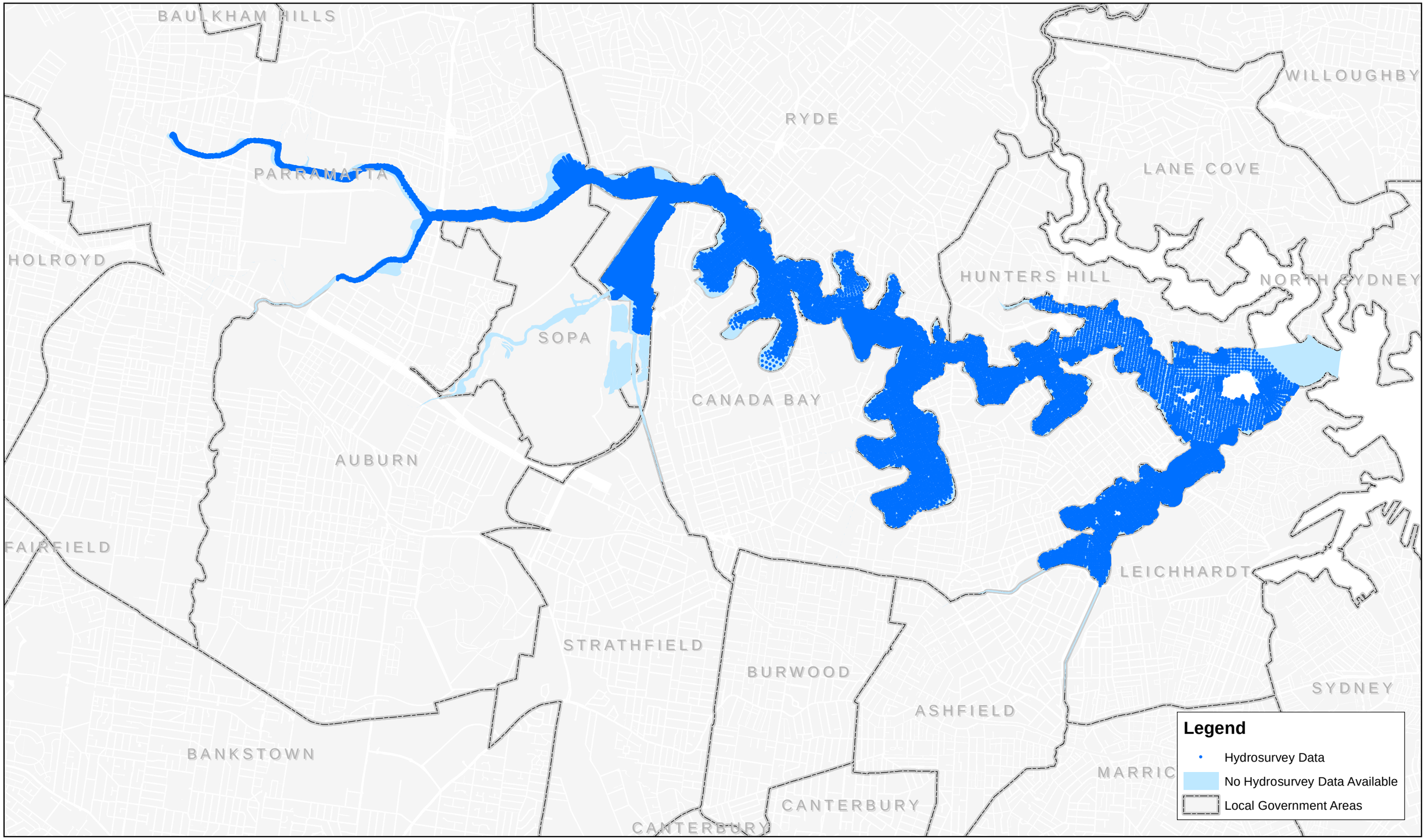
1:50,000 Scale at A4

Metres
0 500 1000 1500 2000 2500

N
W E
S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G2002_LIDARCoverage.mxd 01
Data Sources: NSW Land and Property Information (LPI) and Sydney Metropolitan Catchment Management Authority (SMCMA)



Bathymetric Survey Data Coverage

PARRAMATTA RIVER ESTUARY
COASTAL HAZARD ASSESSMENT

FIGURE 2.3

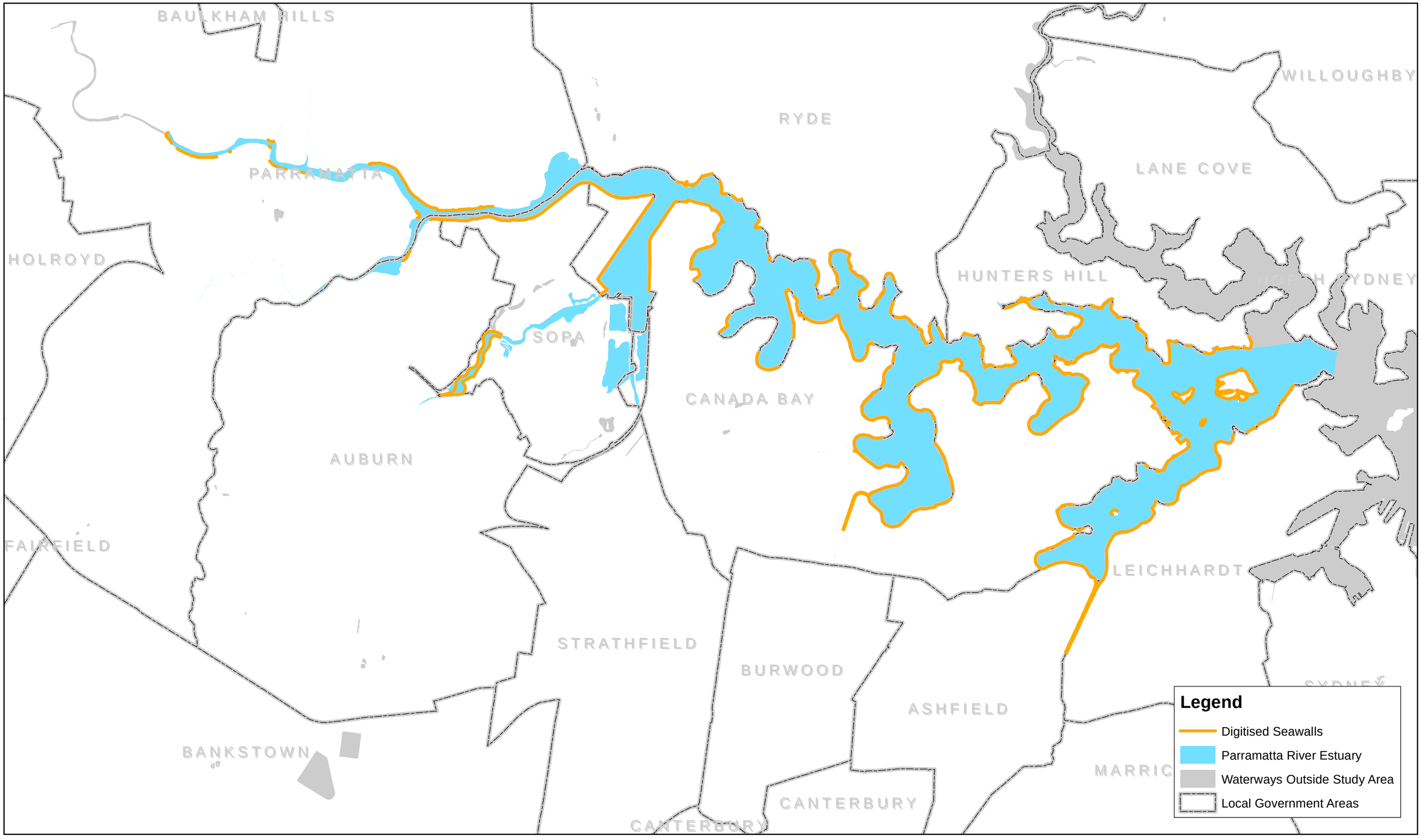
1:50,000 Scale at A4

Metres
0 500 1000 1500 2000 2500

N
W E
S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G2003_BathymetryCoverage.mxd 01
Data Sources: NSW Land and Property Information (LPI) and Sydney Metropolitan Catchment Management Authority (SMCMA)



Seawall Data

PARRAMATTA RIVER ESTUARY
COASTAL HAZARD ASSESSMENT

FIGURE 2.4

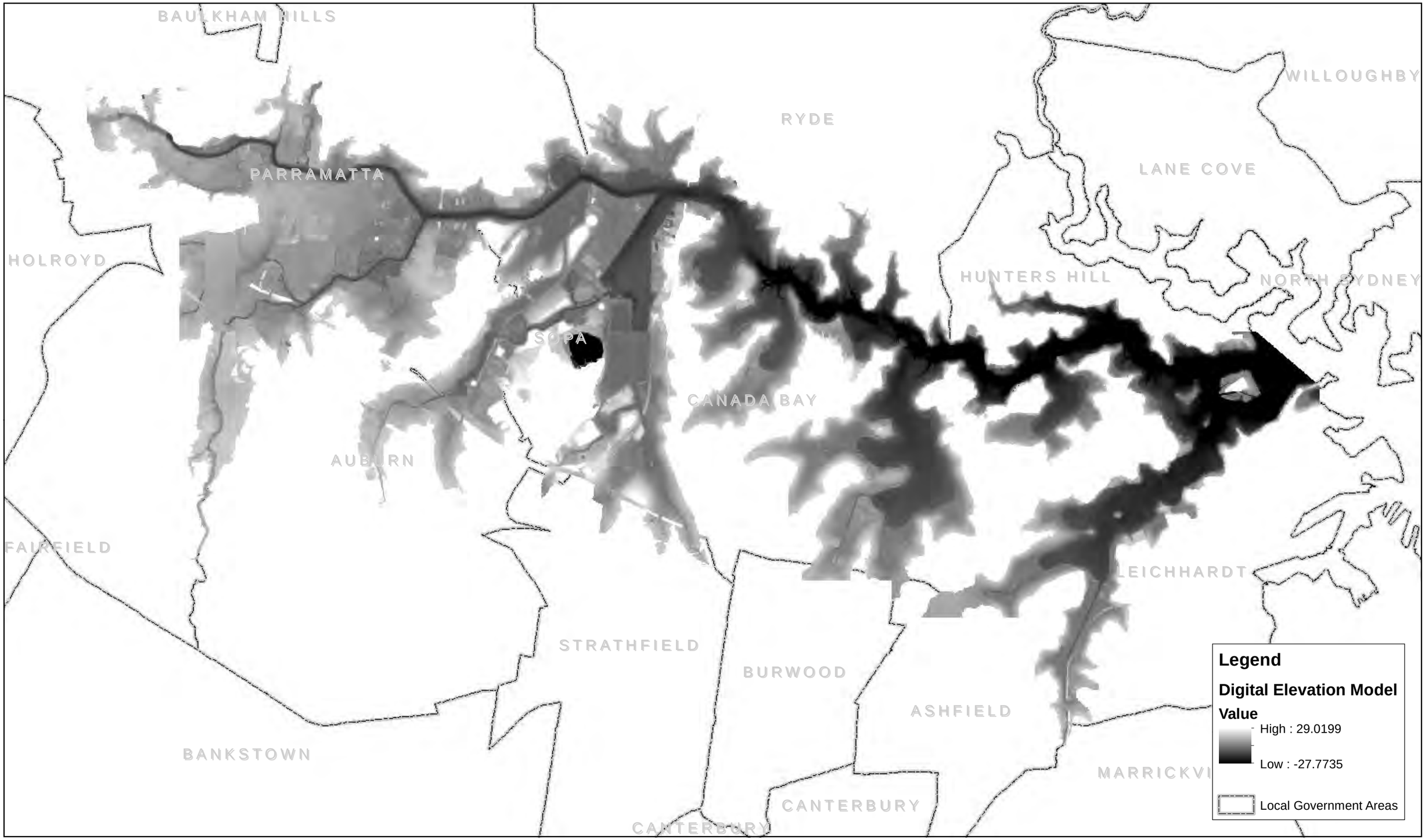
1:50,000 Scale at A4

Metres
0 500 1000 1500 2000 2500

N
W E
S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G2004_SeawallData.mxd 01
Data Sources: NSW Land and Property Information (LPI) and Sydney Metropolitan Catchment Management Authority (SMCMA)



Digital Elevation Model

PARRAMATTA RIVER ESTUARY
COASTAL HAZARD ASSESSMENT

FIGURE 2.5

1:50,000 Scale at A4

Metres
0 500 1000 1500 2000 2500

N
W E
S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G2005_DEM.mxd 01
Data Source: NSW Land and Property Information (LPI)

2.4 Inundation Extents

Inundation extents were mapped by producing a series of contours based on the DEM. These contours were produced as regions (polygons) rather than contour lines for ease of analysis. Since region contours are not the default in ArcGIS, this involved the following additional "work-around" steps:

- The raster calculator was used to multiply all DEM values by 100 (so that values were not truncated as per next step);
- The raster calculator was used to convert all DEM values to Integers (in order to be compatible with the tool used in the next step);
- The DEM was reclassified from continuous to discrete, using the values required for the contours multiplied by 100, for example, for the existing scenario, all values from 0 to 124 were reclassified as 124, all values from 124 to 141 were reclassified as 141 and all values from 141 to 144 were reclassified 144;
- The raster dataset was converted to polygons and labelled according to original values (that is, current raster values divided by 100).

As described above, the inundation extents were mapped using a raster dataset. Although smoothing of polygons was undertaken though anti-aliasing, the extents still appear pixelated due to the nature of the original raster dataset. This characteristic is not noticeable at small scales, however, it is much more noticeable when viewing the extents at larger scales.

Once the inundation extents had been created for each of the nine scenarios, a process was undertaken to quarantine a number of areas that were outside of the study area, or otherwise considered to have low data accuracy. This process involved the following:

- The extents were clipped at the upstream extent (Charles Street weir) and the downstream extent (using the adopted study area boundary);
- The four estuary islands (Cockatoo Island, Spectacle Island, Snapper Island and Rodd Island) were removed from the extents, as agreed with Council and OEH;
- All polygons that were disjunct from the main inundation extent were considered not to be affected (by overland flow) and were therefore removed from the extents; and
- Wetland areas within the Sydney Olympic Park Authority (SOPA) boundary were excluded from the assessment as the available data for these wetland areas was not considered to be sufficiently accurate for the purposes of this exercise, noting also that tidal inundation is artificially managed in these areas.

Figure 2.6 shows those areas excluded from the assessment due to accuracy or other reasons, as outlined above.

Excluded Areas

PARRAMATTA RIVER ESTUARY
COASTAL HAZARD ASSESSMENT

FIGURE 2.6

1:50,000 Scale at A4

Metres
0 500 1000 1500 2000 2500

N
W E
S

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G2006_ExcludedAreas.mxd 01
Data Source: NSW Land and Property Information (LPI)

2.5 Outputs

Key outputs of this assessment include 1-year, 50-years and 100-years ARI inundation extents for each of the three scenarios – existing scenario (no SLR), 0.4m SLR scenario and 0.9m SLR scenario (that is, nine inundation extents in total). These extents have been included in the assessment mapping (see Section 3).

2.6 Limitations of the Data

Inherent to any dataset are limitations based on various factors including the type, source, date and method of collection of the data. Data used in this assessment have a number of limitations (Table 2.4), which need consideration in drawing conclusions from the results of this investigation.

Table 2.4: Details of Data Limitations

Task	Limitations
Water levels	Although there is amplification of the tidal range in the upper estuary compared to the lower estuary, the tidal planes were assumed to be flat over the entire estuary, as hydrodynamic modelling was not undertaken for the purposes of this study. Still water level extents were prepared using design still water levels for Fort Denison provided in DECCW (2010b).
LIDAR	There is a range of limitations that may occur in the collection of LiDAR data. In the first instance there is potential for issues associated with data capture, including potential errors inherent to the instruments used, calibration of instruments, and sensor altitude. Secondly, there is potential for issues relating to the pre-processing of LiDAR data once collected, such as filtering of "noise", data correction etc.
Incorporation of seawalls	Interpolated levels for seawalls were the best data available; however this method may not optimally represent the actual local surface variation in these foreshore areas. Final data tiles that were used in creating the DEM comprised some LiDAR points that overlapped the seawalls. Surveys of seawall crest and toe levels have not been undertaken and were therefore unavailable for use.
DEM creation	LiDAR data in the vicinity of the land-water interface is likely to have greater inaccuracy than in other locations. The laser instrumentation used in LiDAR data collection cannot always accurately record LiDAR reflectance where water is present. However, the mapped inundation extents should generally lie landward of the interface (especially for higher water levels).
DEM creation	A number of different datasets from different time periods were used in the assessment (e.g. LiDAR from 2006 to 2008 and bathymetric survey from 1958 onwards) meaning that data in adjacent spatial locations may have different elevation/depth values.

3 RESULTS

3.1 Inundation Extents

This section provides the results of the assessment, including the mapping of inundation extents for the estuary, namely:

- 1-year ARI and 100-years ARI extent for the existing scenario (no SLR);
- 1-year ARI and 100-years ARI extent for the 0.4m SLR scenario;
- 1-year ARI and 100-years ARI extent for the 0.9m SLR scenario.

Although mapped in GIS, the 50-years ARI extents have been excluded from the discussion in this document since they were very similar to the 100-years ARI extents. Similarly, the 50-years ARI extents have not been mapped in the accompanying figures (Figures 3.1 to 3.9) due to difficulties differentiating them from the 100-years ARI extents at the relevant map scale.

3.1.1 Existing Scenario (no SLR)

Figures 3.1, 3.2 and 3.3 show the 1-year and 100-years ARI events in the upper, middle and lower estuary regions, respectively representing the area of land subject to coastal hazards associated with coastal inundation for the existing case. The 1-year ARI inundation extent is confined primarily to the immediate foreshore areas including parks and other open space areas (such as at Homebush Bay and Homebush). Parkland and open space areas are particularly vulnerable to inundation as they are often located at lower elevations along the foreshore or along the tributaries. Some freehold properties are also inundated, although typically only the undeveloped portions of land appear to be impacted. Inundation occurring on an approximately annual basis (i.e. the 1-year ARI event) is unlikely to be tolerated by residents or commercial/industrial activity unless the effects are minor. In general, the lower estuary is not as significantly affected by inundation, due to generally high river banks and seawall crest levels. Some localised impacts on utilities may occur, and some foreshore structures (such as jetties) may not be accessible if overtopped during an event.

In the 100-years ARI event, inundation extents are larger, with some areas of industrial/commercial land and small areas of residential land being inundated. Key areas that are currently at risk of inundation during the 100-years ARI include Haberfield (roads) and Drummoyne (residential properties). Whilst the main developed portion of these residential and commercial/industrial lands are unlikely to be inundated, there may be localised areas of impact, particularly in relation to ancillary structures such as garden sheds or storage areas.

Some roads are affected, particularly along tributaries of the main waterway. Areas at risk in Rydalmere, Rosehill, Silverwater, Newington, Homebush Bay, Homebush and Concord are located along tributaries of the main estuary waterbody and/or are mostly comprised of open space areas, parklands or wetlands. Boatsheds, jetties and other foreshore structures would also be overtopped during this event.

3.1.2 0.4m SLR Scenario

Figures 3.4, 3.5 and 3.6 show the 1-year and 100-years ARI events in the upper, middle and lower estuary respectively for the 0.4m SLR scenario. As anticipated, under SLR conditions a larger area of land is inundated when compared to the existing scenario (450% increase in extent).

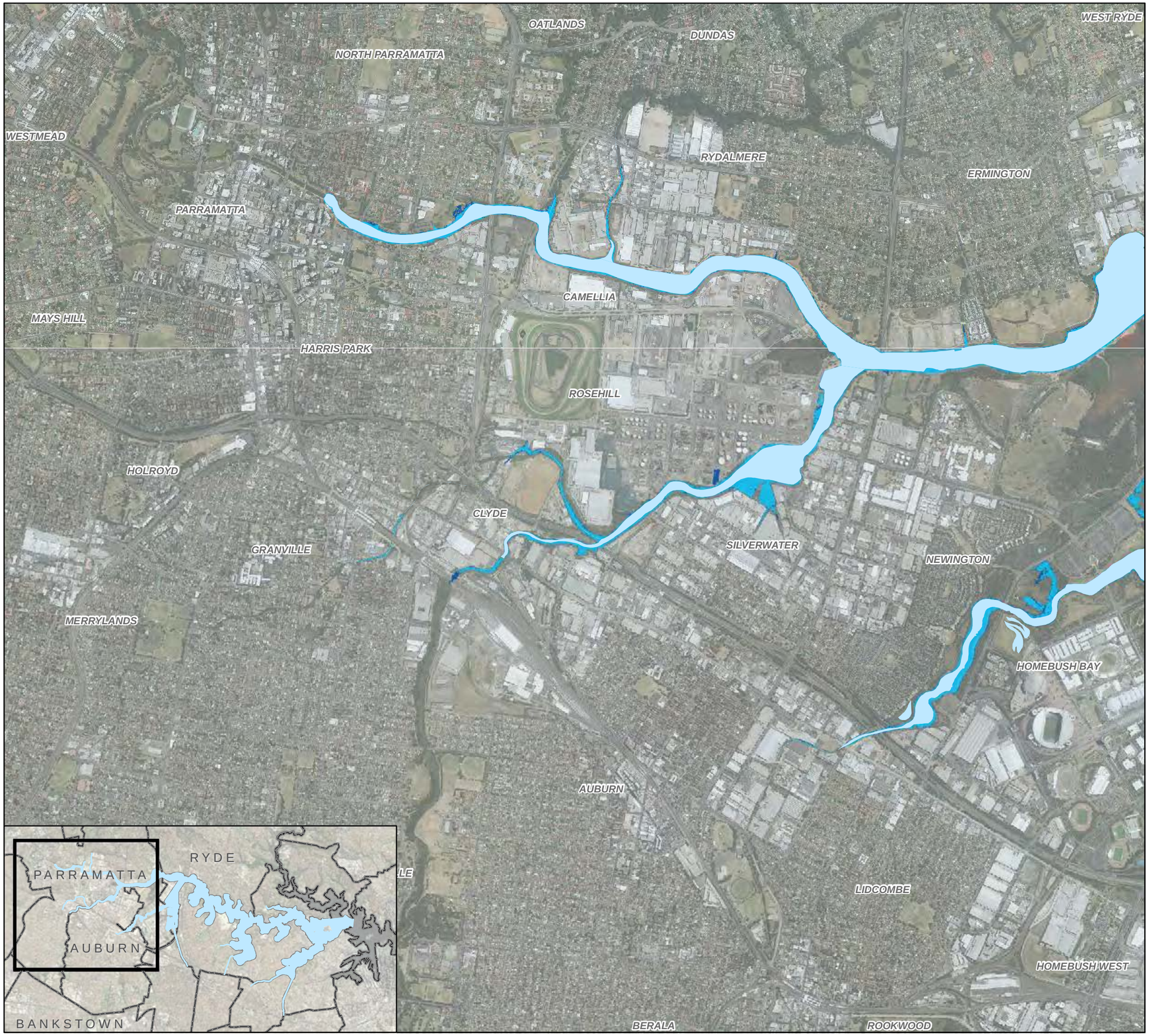
The mapped inundation extents include an increasing number of residential allotments, with potential for the main dwelling located on the lot to be inundated, particularly under the 100-years ARI event (+0.4m SLR). Locations subject to relatively larger inundation extents include Haberfield (roads, residential areas and some industrial land), Drummoyne (residential land) and also new areas such as Concord (golf course). Industrial/commercial land and buildings would be affected, albeit to a limited extent (as for the existing scenario). Other areas falling within the inundation extent include roads in Haberfield, Chiswick and Five Dock, and open space areas and wetlands in a number of suburbs including Lilyfield and Five Dock.

3.1.3 0.9m SLR Scenario

Figures 3.7, 3.8 and 3.9 show the 1-year and 100-years ARI events in the upper, middle and lower Parramatta River estuary, respectively, for the future (0.9m SLR) scenario.

Areas subject to inundation are larger in the 0.9m SLR scenario. In the 1-year ARI event, affected areas in the lower estuary tend to be dominated by residential lands, with areas of commercial/industrial land being impacted in the middle and upper estuary. Open space and parkland areas are also increasingly affected, including several golf courses. Foreshore roads and areas surrounding the tributaries of the main estuary waterbody are also significantly affected in some locations.

In the 100-years ARI event, the inundation risk to residential land and dwellings increase in some areas, particularly in parts of the lower and middle estuary, whilst industrial/commercial land and buildings become more affected in sections of the upper estuary. Homebush Bay (industrial) is likely to become significantly affected by inundation under a 0.9m SLR scenario. Haberfield and Drummoyne would also become substantially more affected, with primarily residential properties at risk. Additional affected areas include Rydalmere (industrial), Canada Bay (residential), Homebush (industrial), Meadowbank (open space and some residential), and Rosehill (industrial). Golf courses in several suburbs (for example, Concord and Five Dock) are significantly inundated, and open space, parklands and wetland areas in a number of these and other suburbs are also affected.



SWL Inundation Extents (Existing Scenario) Upper Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2010 (1.24mAHD)
- 100-Years ARI Still Water Level - 2010 (1.44mAHD)

N
W E
S

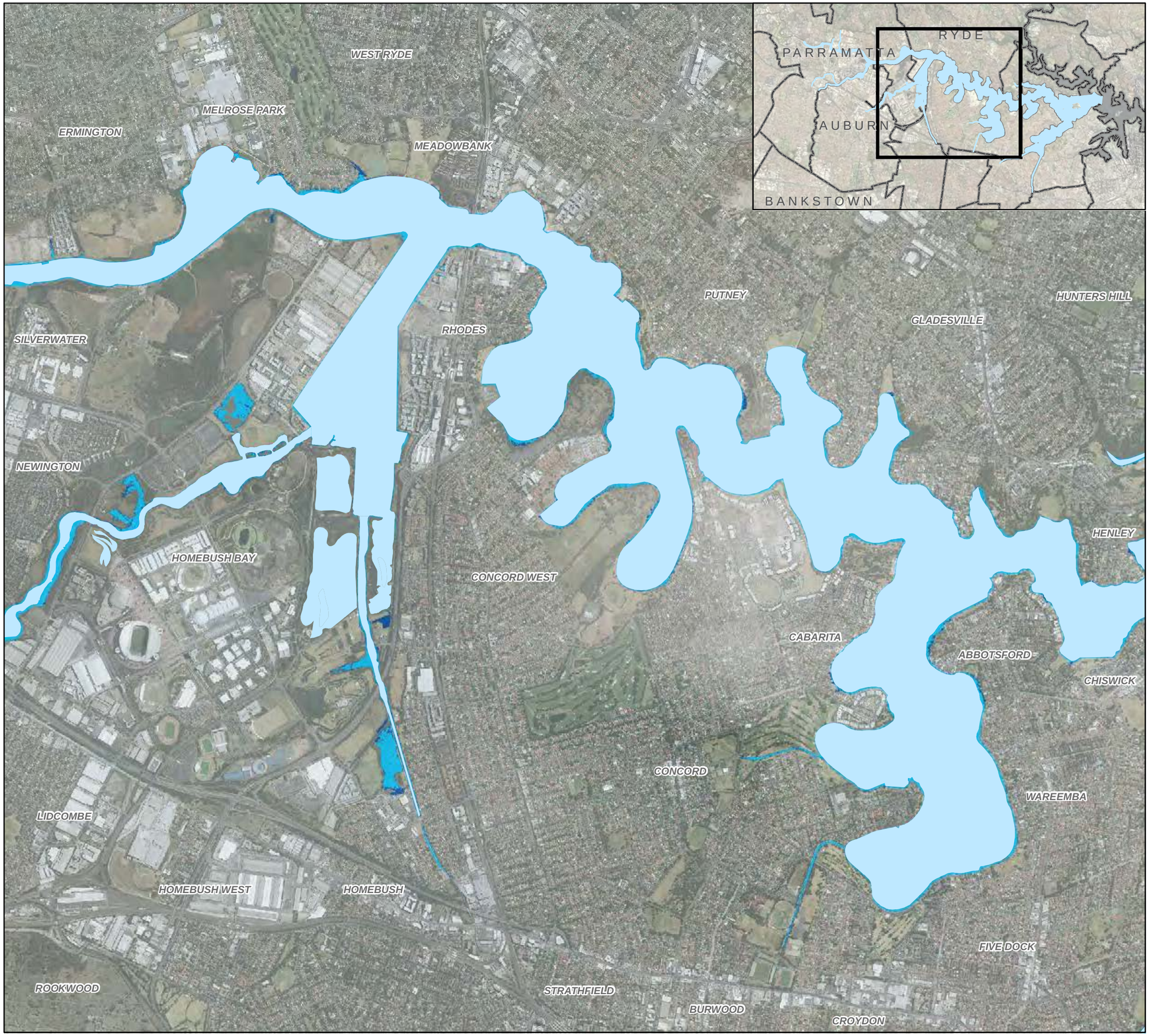
FIGURE 3.1

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3001_2010ExtentsUpper.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (Existing Scenario) Middle Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2010 (1.24mAHD)
- 100-Years ARI Still Water Level - 2010 (1.44mAHD)

N
W E
S

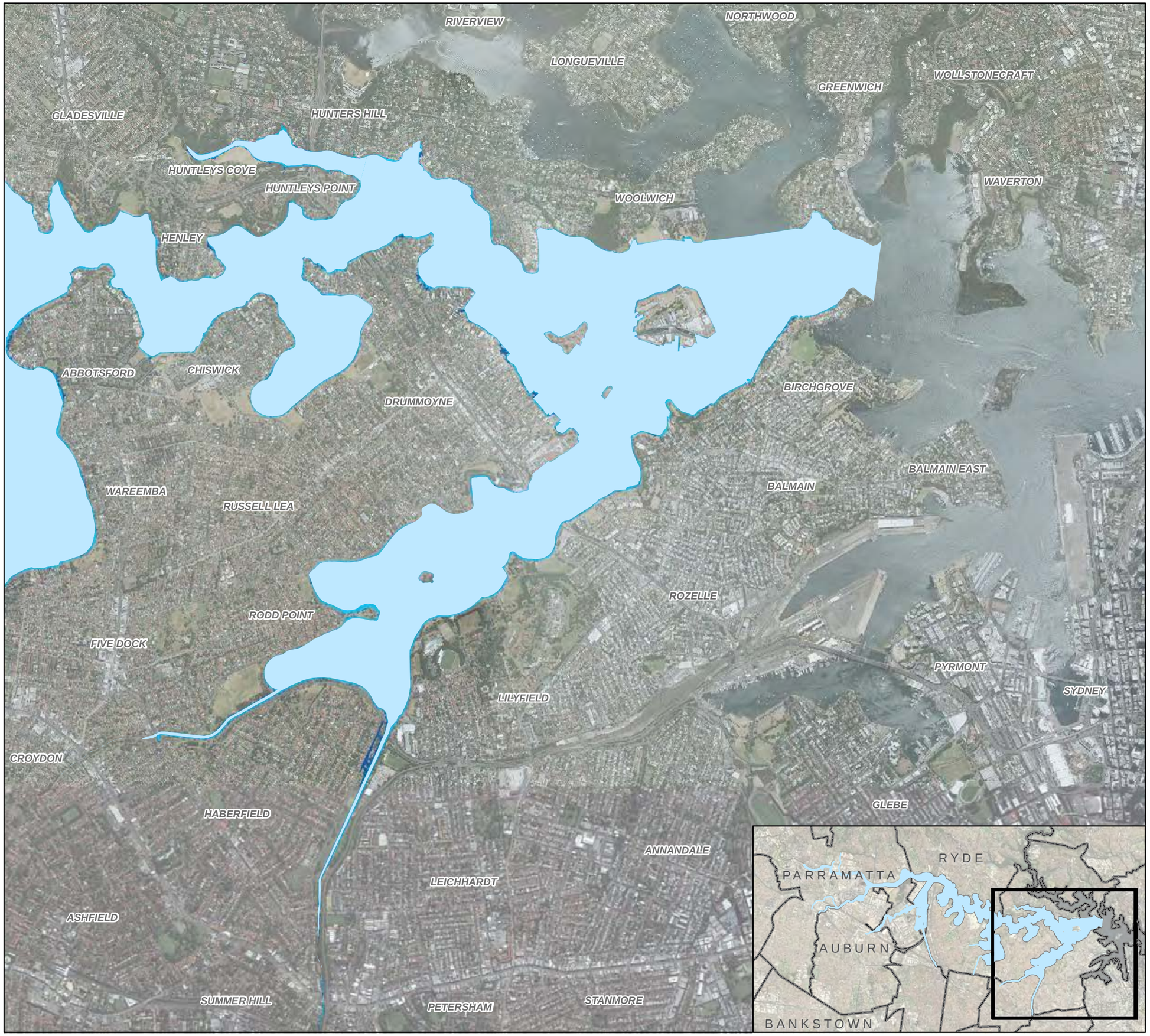
FIGURE 3.2

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3002_2010ExtentsMid.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (Existing Scenario) Lower Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2010 (1.24mAHD)
- 100-Years ARI Still Water Level - 2010 (1.44mAHD)

N
W E
S

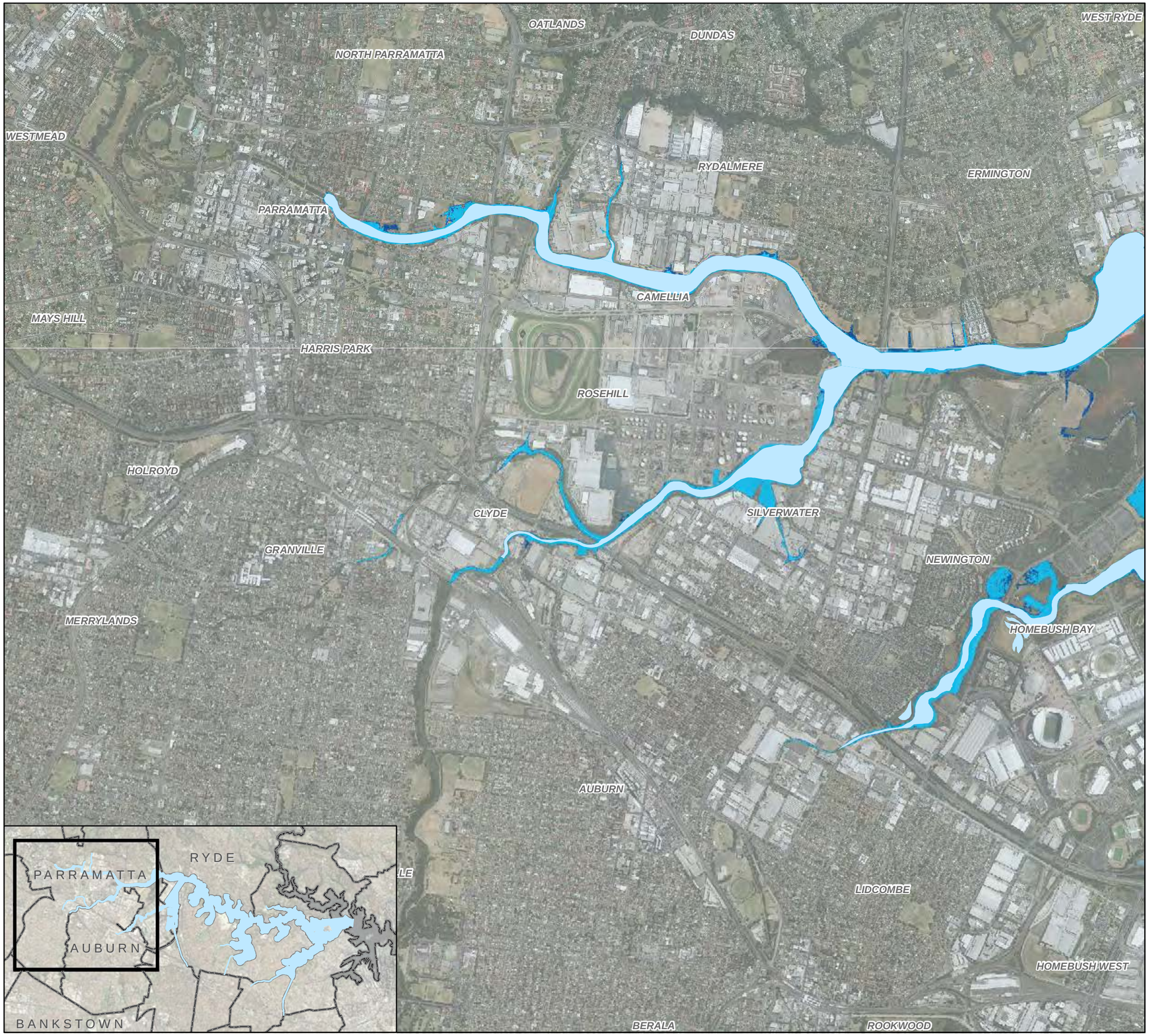
FIGURE 3.3

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3003_2010ExtentsLower.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (0.4m SLR Scenario) Upper Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2050 (1.58mAHD)
- 100-Years ARI Still Water Level - 2050 (1.78mAHD)

N
W E
S

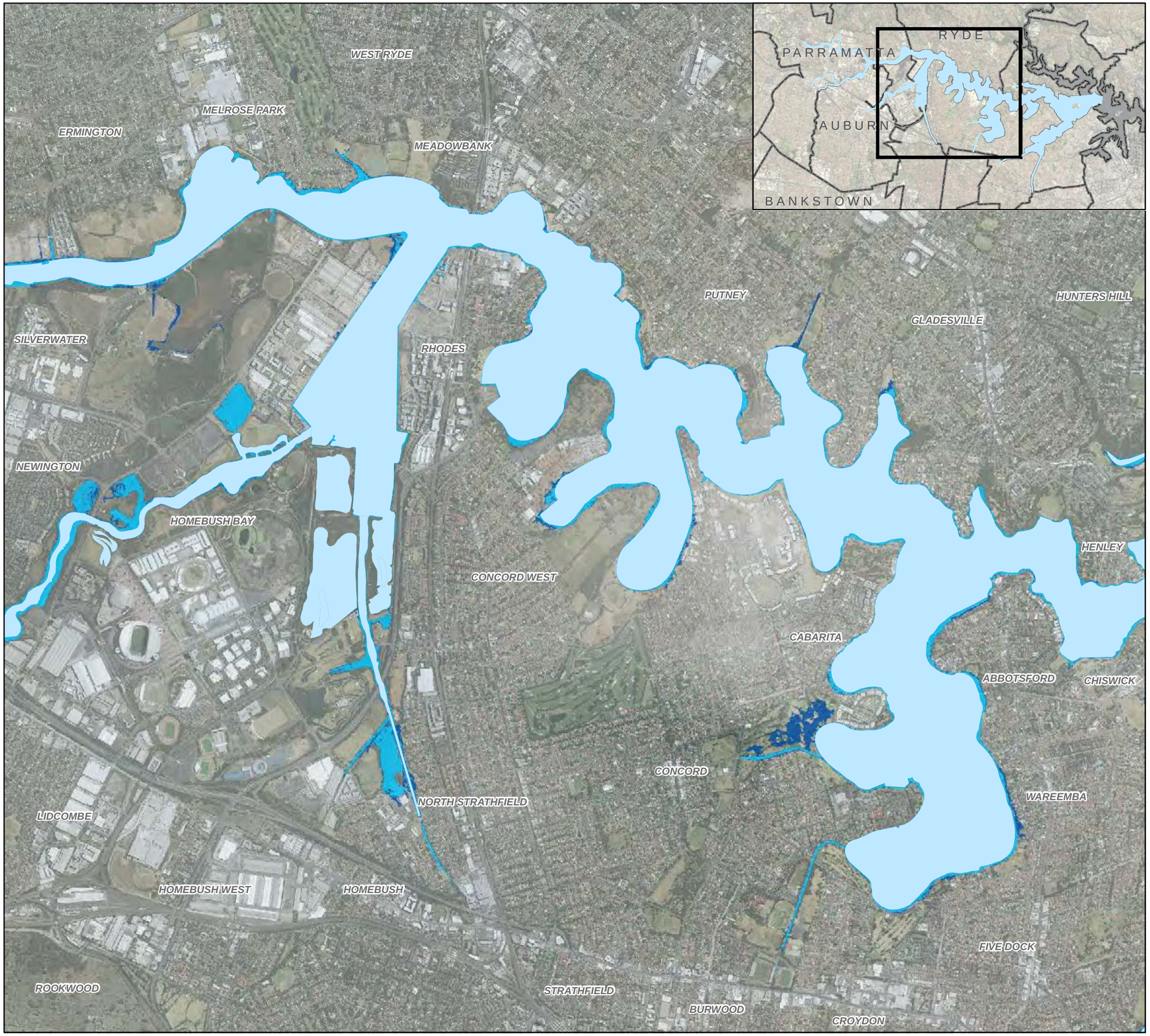
FIGURE 3.4

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3004_2050ExtentsUpper.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (0.4m SLR Scenario) Middle Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2050 (1.58mAHD)
- 100-Years ARI Still Water Level - 2050 (1.78mAHD)

N
W E
S

FIGURE 3.5

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

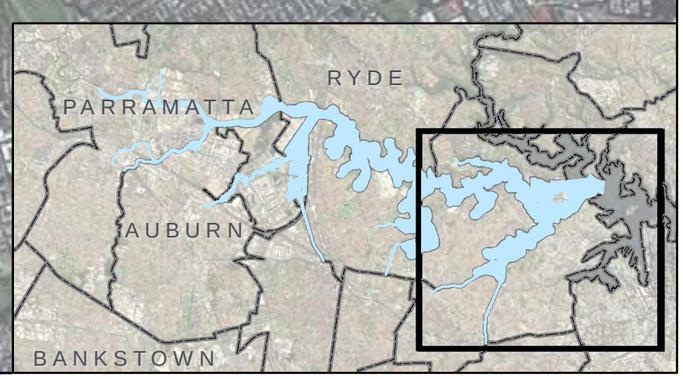
Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3005_2050ExtentsMid.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers

SWL Inundation Extents (0.4m SLR Scenario) Lower Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

RIVERVIEW
NORTHWOOD
LONGUEVILLE
WOLLSTONECRAFT
GREENWICH
GLADESVILLE
HUNTERS HILL
HUNTLEYS COVE
HUNTLEYS POINT
WOOLWICH
WAVERTON
HENLEY
ABBOTSFORD
CHISWICK
DRUMMOYNE
BIRCHGROVE
BALMAIN EAST
BALMAIN
WAREEMBA
RUSSELL LEA
ROZELLE
RODD POINT
FIVE DOCK
PYRMONT
SYDNEY
LILYFIELD
CROYDON
GLEBE
HABERFIELD
ANNANDALE
LEICHHARDT
ASHFIELD
SUMMER HILL
PETERSHAM
STANMORE



Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2050 (1.58mAHD)
- 100-Years ARI Still Water Level - 2050 (1.78mAHD)

N
W E
S

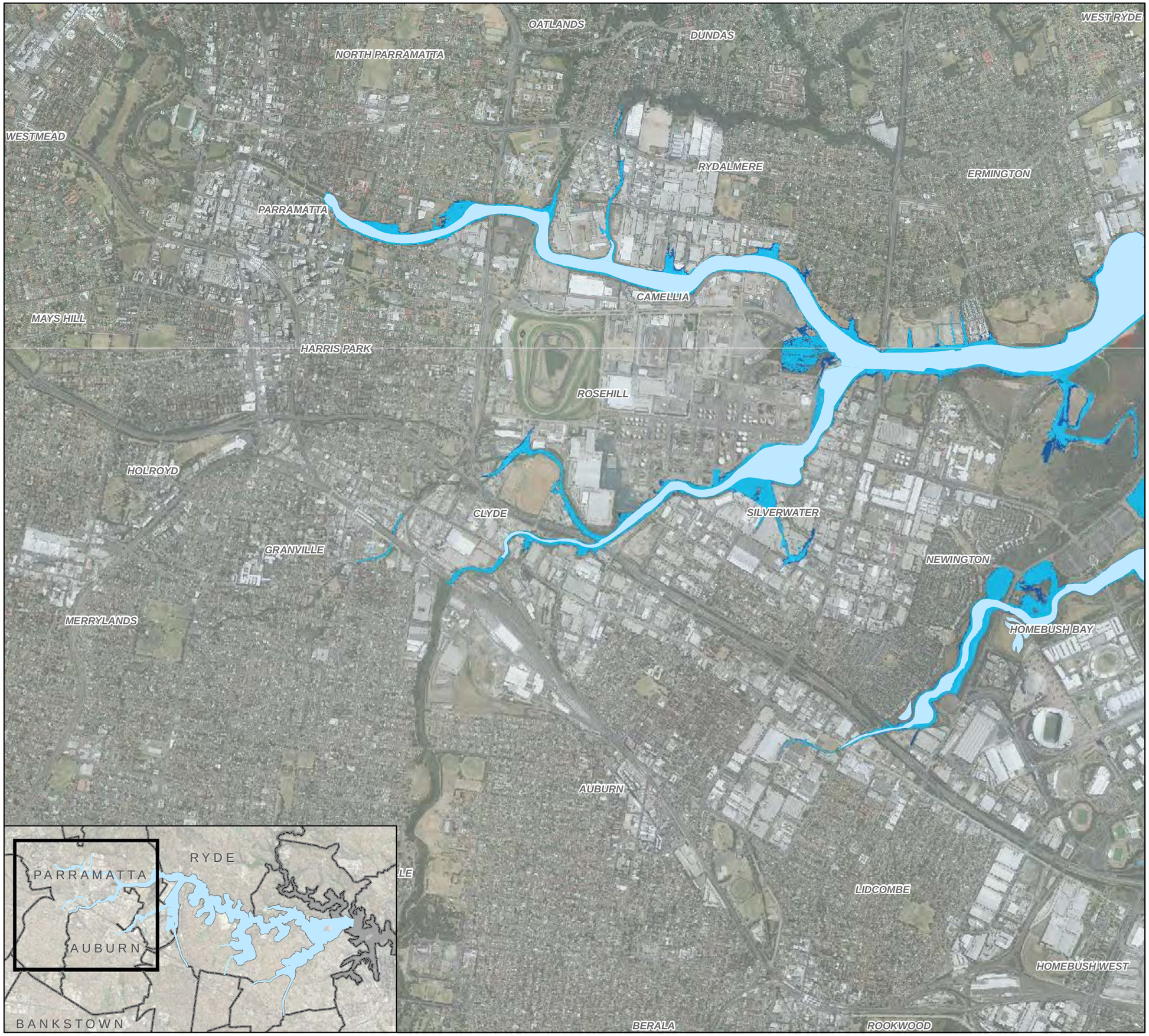
FIGURE 3.6

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3006_2050ExtentsLower.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (0.9m SLR Scenario) Upper Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2100 (2.08mAHD)
- 100-Years ARI Still Water Level - 2100 (2.28mAHD)

N
W E
S

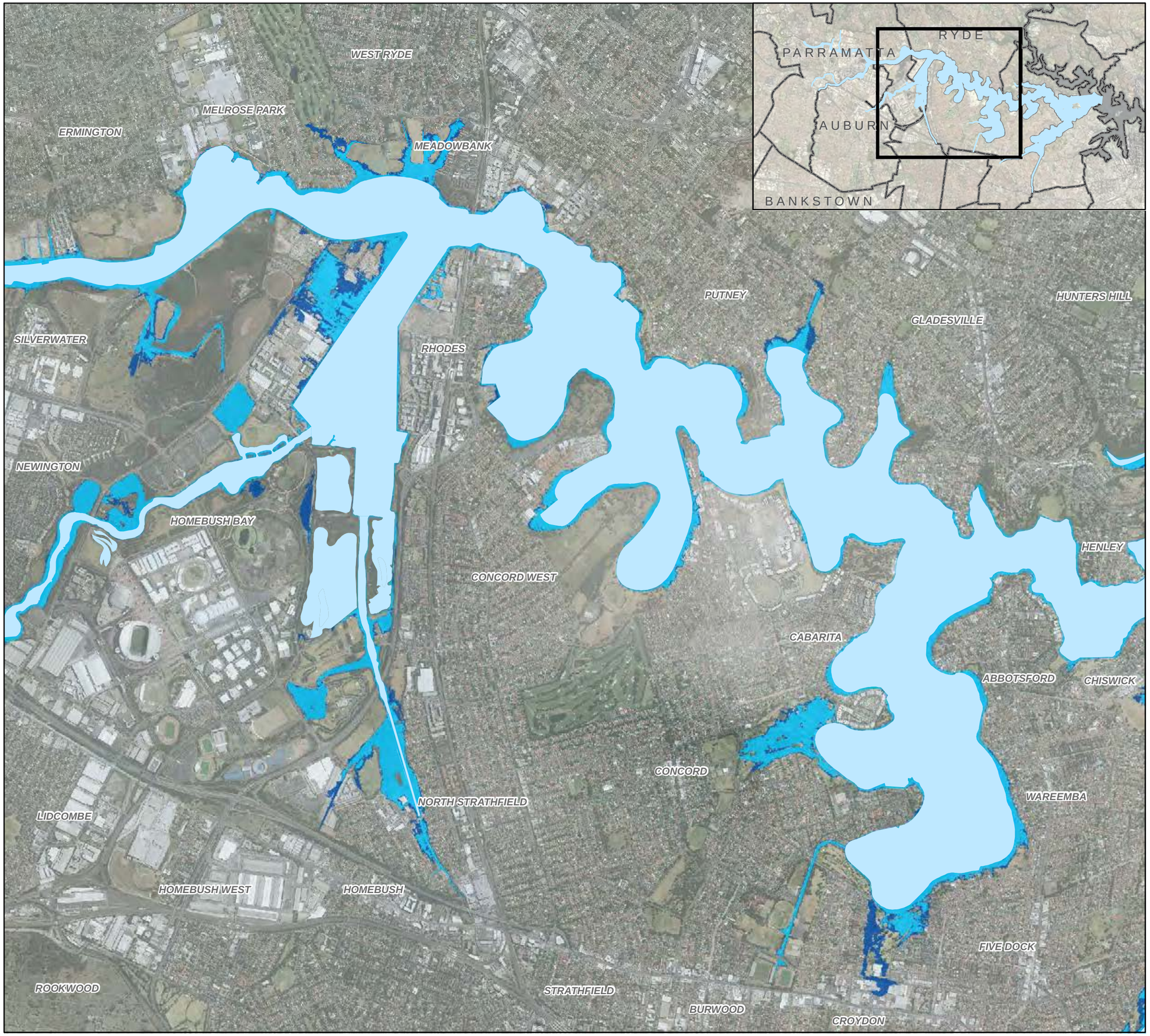
FIGURE 3.7

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3007_2100ExtentsUpper.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (0.9m SLR Scenario) Middle Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2100 (2.08mAHD)
- 100-Years ARI Still Water Level - 2100 (2.28mAHD)

N
W E
S

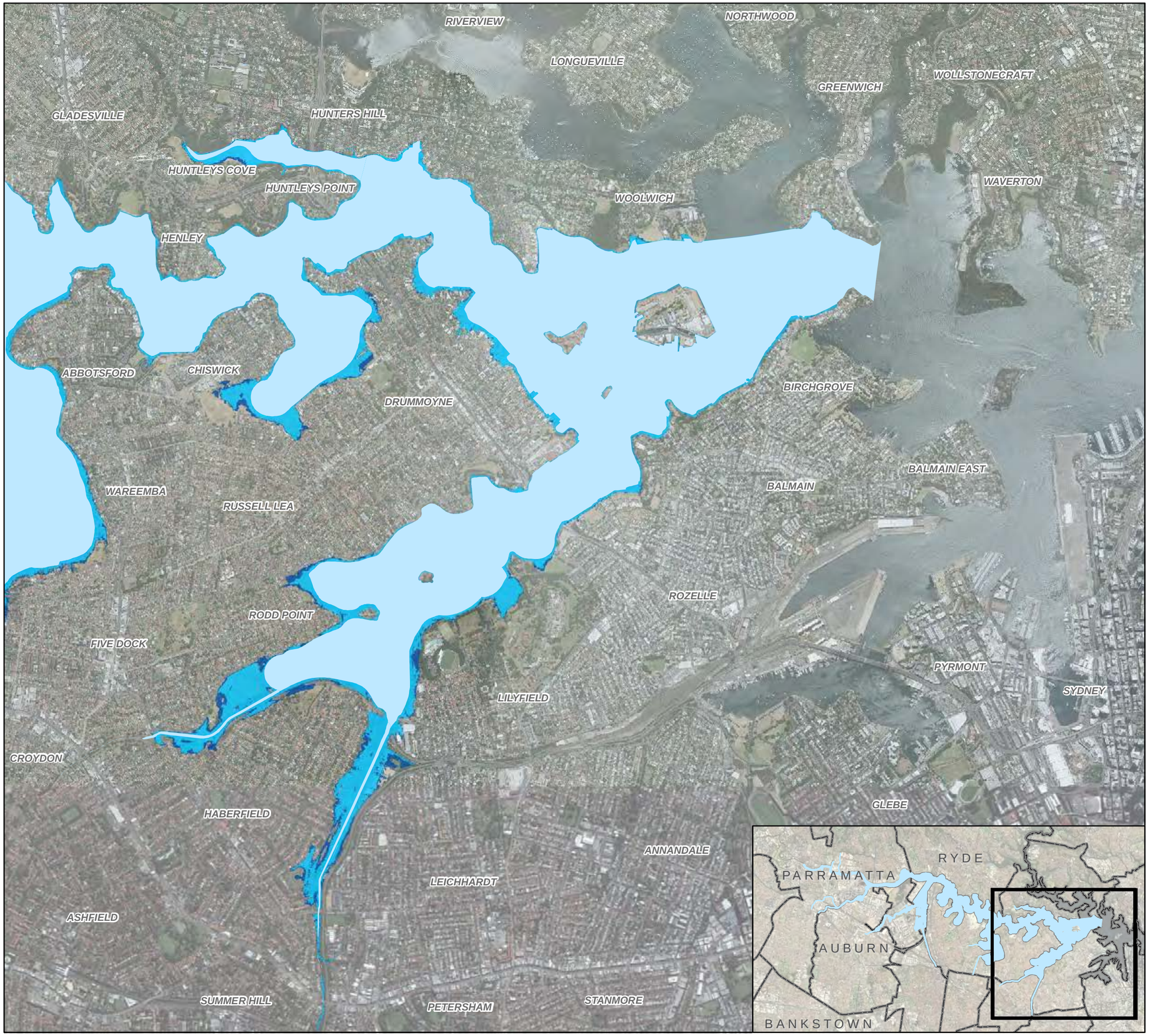
FIGURE 3.8

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3008_2100ExtentsMid.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers



SWL Inundation Extents (0.9m SLR Scenario) Lower Estuary

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Parramatta River Tidal Limits
- 1-Year ARI Still Water Level - 2100 (2.08mAHD)
- 100-Years ARI Still Water Level - 2100 (2.28mAHD)

N
W E
S

FIGURE 3.9

1:25,000 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3009_2100ExtentsLower.mxd 01
Imagery Source: Sydney Metropolitan Catchment Management Authority (SMCMA) and associated third party suppliers

3.1.4 Comparison of Inundation Extents

Table 3.1 shows the area of land falling within the inundation extents under the existing (2010) and SLR scenarios for the 1-year and 100-years ARI events. As anticipated, the inundation extents under the SLR scenarios are larger for the existing scenario, with the greatest increase occurring between the 0.4m SLR and 0.9m SLR scenarios. This may be due to overtopping of existing seawalls.

Table 3.1: Area of Land Affected by Inundation

Scenario	1-Year ARI - Inundation Extent (ha)	100-Years ARI - Inundation Extent (ha)
Existing Scenario (no SLR)	11.32	37.00
0.4m SLR Scenario	62.35	114.16
0.9m SLR Scenario	234.63	315.97

Notes: Inundation on the four islands (Cockatoo Island, Spectacle Island, Snapper Island and Rodd Island) and in the SOPA wetlands is not included in the assessment (see Section 2.4).
The area of tidal waterway is assumed to be 1,404.74ha.

Table 3.2 shows number of cadastral lots falling within each inundation extent.

Table 3.2: Number of Cadastral Lots Affected by Inundation

Scenario	1-Year ARI - Number of Lots	100-Years ARI - Number of Lots
Existing Scenario (no SLR)	1,181	1,357
0.4m SLR Scenario	1,535	1,804
0.9m SLR Scenario	2,270	2,653

Notes: The above numbers refer to all cadastral lots, including open space/parkland.
The above numbers are likely to be conservative and correspond to every property that intersects either partially or fully with the inundation extent. This is particularly relevant for waterfront properties where the property boundary may extend into the waterway.

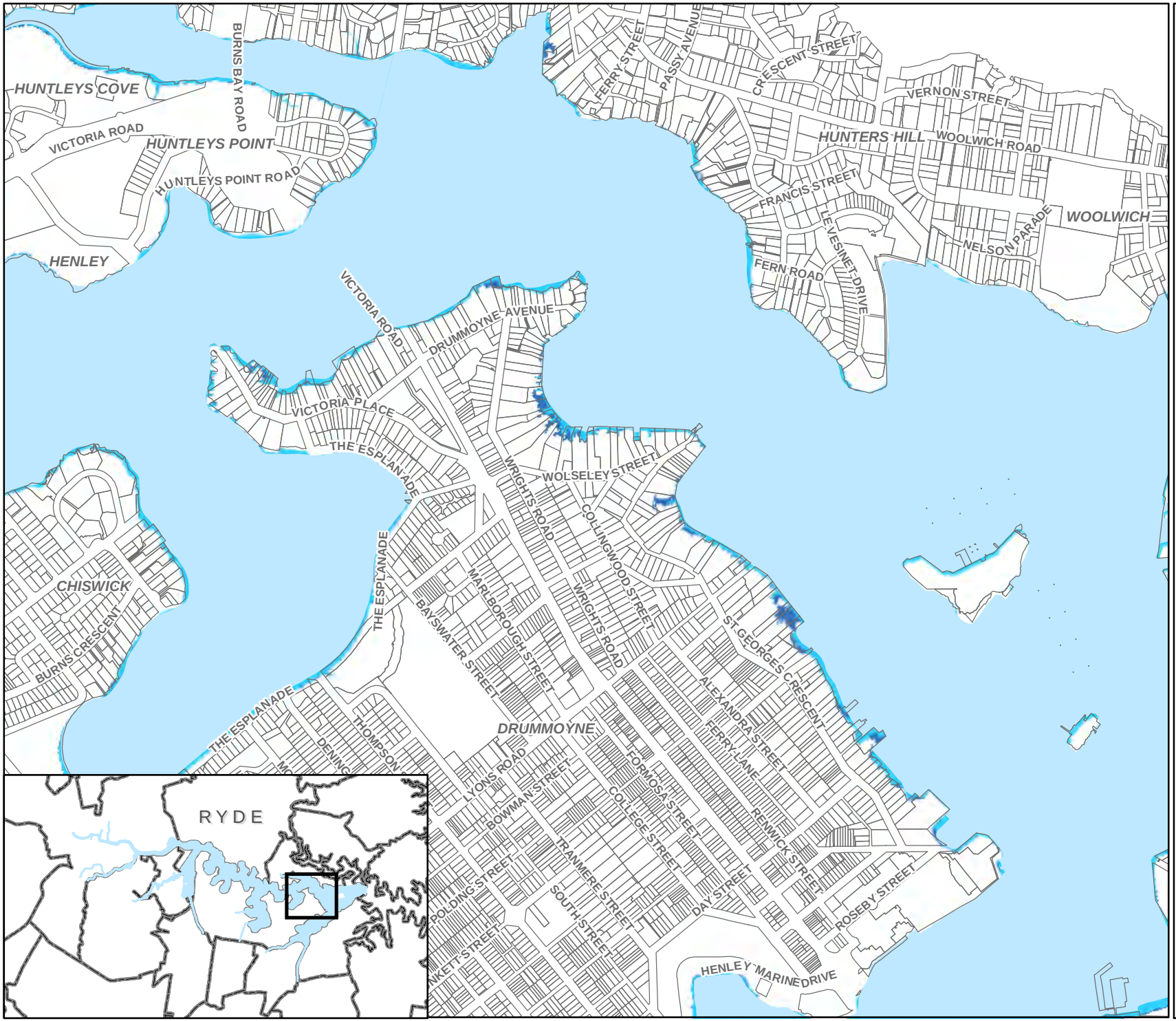
3.2 Key Areas at Risk from Coastal Hazards

A number of key areas have been identified that are more likely to be at risk from the coastal inundation hazard, with the level of risk increasing under SLR conditions. When compared to the existing scenario (no SLR), the results of this assessment indicate that areas at risk of inundation under a 0.4m SLR and 0.9m SLR scenario tend to be greater in extent due to higher mean water levels.

It is noted that these SLR scenarios assume the maintenance of the present day foreshore position and ground/seawall levels. In reality, this may not be the case and it is possible that inundation extents may change in the future due to land reclamation or filling, the installation of tidal gates and/or retrofitting of seawalls for higher crest levels.

To demonstrate the types of hazard experienced across spatial and temporal scales, an example figure has been prepared for each inundation scenario:

- Existing Scenario (No SLR) – Figure 3.10 shows a zoomed-in example of an area of Drummoyne which is currently at risk of relatively minor inundation. Inundation risk predominately affects garden areas of residences (rather than dwellings) and this is likely due to current planning controls, which generally specify zero or very limited development on land subject to inundation.
- 0.4m SLR Scenario – Figure 3.11 shows a zoomed-in example of an area of Haberfield that is at risk of experiencing inundation under SLR conditions. This area lies in close proximity to a tidal tributary of the estuary (Hawthorne Canal).
- 0.9m SLR Scenario – Figure 3.12 shows a zoomed-in example of an area of Homebush Bay that would be substantially affected by inundation risk. This inundation extent covers commercial/industrial land, buildings and roads. When considering Figure 3.12, please note the data exclusions described in Section 2.4 and shown in Figure 2.6.



Example of Key Areas At Risk (Existing Scenario)

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Cadastre (Property Boundaries)
- Parramatta River Tidal Limits
- 1-Year ARI SWL - 2010 (1.24mAHD)
- 100-Years ARI SWL - 2010 (1.44mAHD)

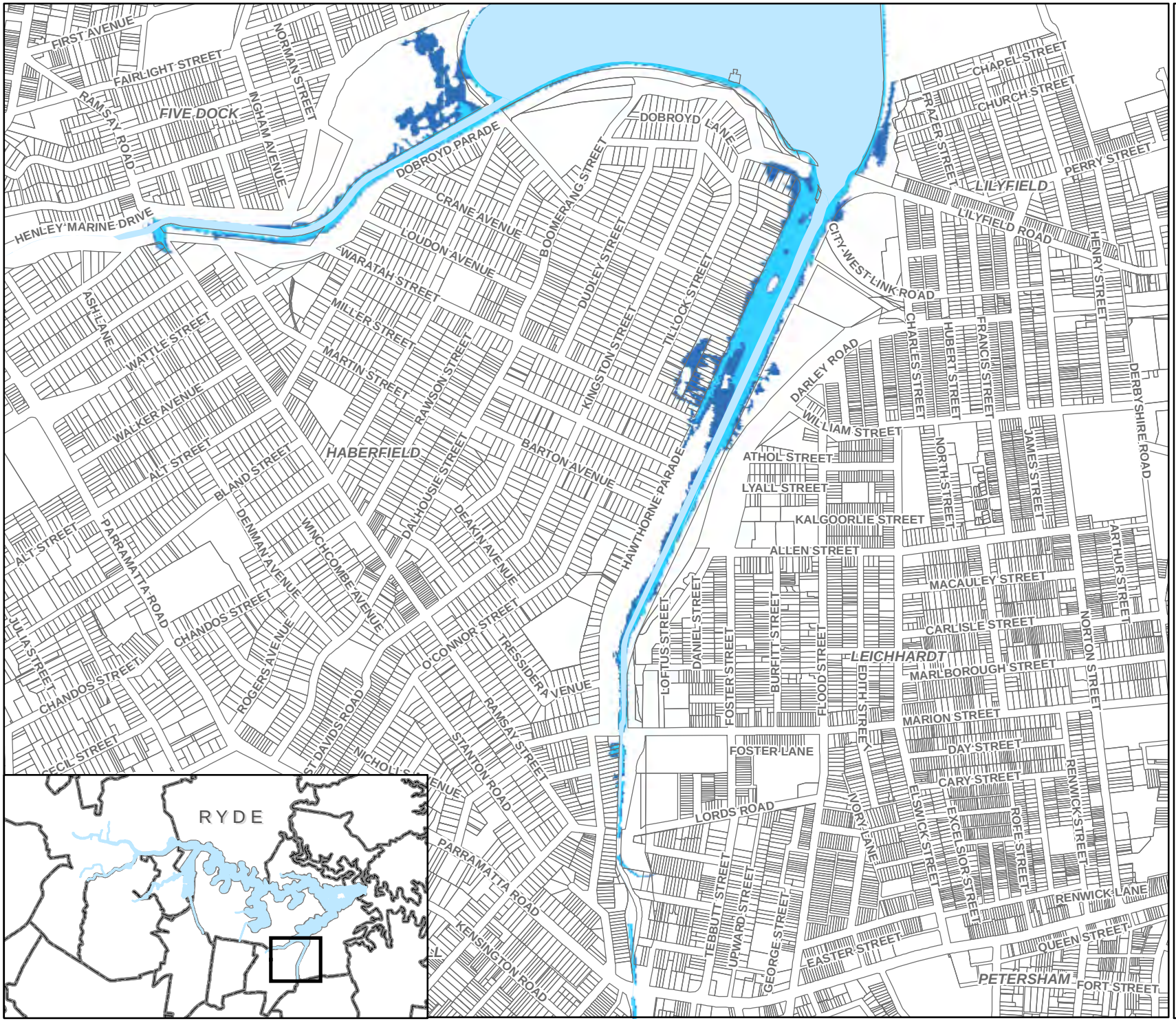
FIGURE 3.10

1:12,500 Scale at A4

Metres
0 50 100 200 300 400

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3010_2010_ExampleRiskArea.mxd 01
Base Data Source: NSW Land and Property Information (LPI)



Example of Key Areas at Risk (0.4m SLR Scenario)

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Cadastre (Property Boundaries)
- Parramatta River Tidal Limits
- 1 Year ARI SWL - 2050 (1.58mAHD)
- 100 Year ARI SWL - 2050 (1.78mAHD)

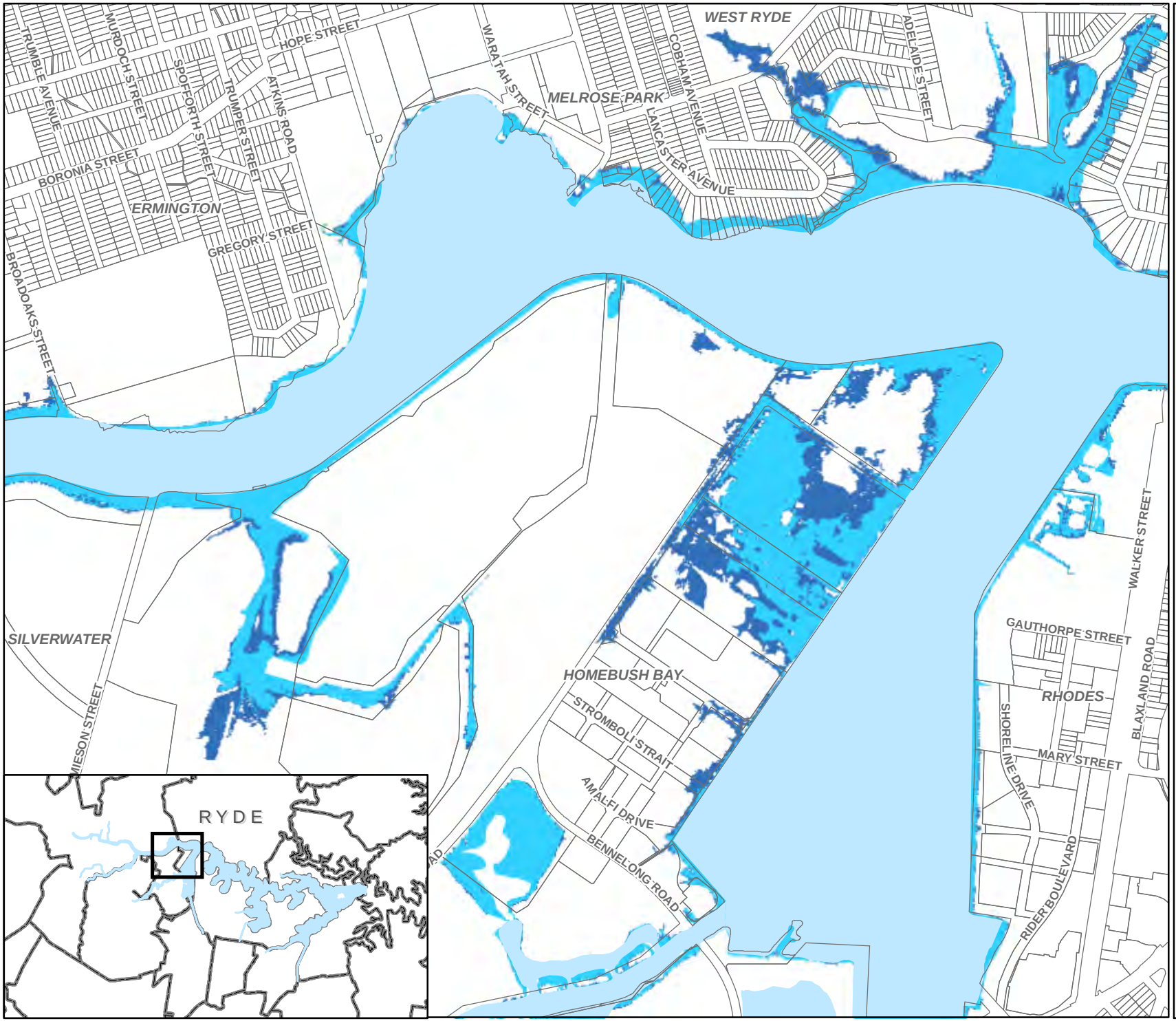
FIGURE 3.11

1:12,500 Scale at A4

Metres
0 50 100 200 300 400

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3011_2050_ExampleRiskArea.mxd 01
Base Data Source: NSW Land and Property Information (LPI)



Example of Key Areas at Risk (0.9m SLR Scenario)

PARRAMATTA RIVER
COASTAL HAZARD ASSESSMENT

Legend

- Cadastre (Property Boundaries)
- Parramatta River Tidal Limits
- 1 Year ARI SWL - 2100 (2.08mAHD)
- 100 Year ARI SWL - 2100 (2.28mAHD)

FIGURE 3.12

1:12,500 Scale at A4

Metres
0 50 100 200 300 400

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: G3012_2100_ExampleRiskArea.mxd 01
Base Data Source: NSW Land and Property Information (LPI)

4 DISCUSSION

This CHA has investigated the potential effects of storm surge events, both now and under projected SLR conditions, in accordance with the *Coastal Risk Management Guide* (DECCW, 2010b). Under SLR conditions, storm surge events will continue to occur infrequently, but when they do occur, higher water levels are likely to be experienced and larger areas are likely to be affected, when compared to the existing case.

In terms of likelihood and consequence, the existing 100-years ARI event has a probability of occurrence of 1 event every 100 years, on average. Hence, the likelihood of such an event is relatively low. The potential consequences of coastal inundation include human injury or stress, damage to land and dwellings/buildings, economic losses, loss of land and foreshore erosion. Loss of life is unlikely given the rate of water level rise (controlled by the tide), which makes evacuation relatively easy. When assessing the risk associated with inundation under SLR conditions, the adoption of trigger levels (a specified amount of SLR), may prove to be more useful than using specific planning horizons.

4.1 Potential Effects on Estuarine Processes

This investigation has considered the impacts of SLR during larger storm surge events that do not tend to occur regularly. However, the 1-year ARI inundation extents provide an indication of the magnitude of inundation that is likely to occur on a more regular basis (i.e. on average once every year). The 1-year ARI water levels therefore provide a reasonable indication of the impacts of the biannual king tide which is typically around 2m LAT (around 1.1m AHD). A recent high water level event on 5-6 June 2012 produced a water level of 2.19m Zero Camp Cove (ZCC) (which equates to approximately -0.925m AHD) measured at Middle Head. This is an example of the type of event likely to arise due to a combination of factors that contribute to coastal inundation. The same event produced a water level of 2.29m ZCC at the Silverwater Bridge gauge, which demonstrates the amplification (0.1m) that typically occurs in the upper Parramatta River estuary compared to lower estuary for large spring tides.

Estuarine processes represent a complex interplay of a range of biotic and abiotic factors. These processes are unlikely to be substantially affected by the relatively infrequent events assessed in this investigation. More significant impacts are likely to be experienced over the long term in relation to the gradual increase in mean sea levels and the resultant daily tidal inundation of areas that are currently supra-tidal. This is particularly significant for intertidal estuarine habitats.

There are a number of potential impacts of SLR that may have an impact on estuarine processes, including:

- Changes in the position of unconsolidated shorelines at higher estuarine water levels;
- Changes to the tidal prism due to increasing sea levels (and associated impacts on tidal flushing/water quality);
- Increases in storm intensity and frequency (and therefore increased storm surge levels);
- Changes in seasonal rainfall patterns;
- Changes in water balance and baseflows;

- Increases in average and maximum air temperatures; and
- Increases in the frequency of drought.

One key impact on ecological processes in the estuary is the potential for vertical migration of estuarine vegetation species and/or colonization of the future intertidal zone. A range of variables are likely to influence this process, most importantly, the presence of existing development immediately behind intertidal areas. Other variables include the existing assemblage structures, substrate type (soil type, etc.), catchment hydrology, interspecific competition, herbivory and solar radiation/shading that is present in any particular area. The spatial and temporal variation in these factors is likely to influence the composition of intertidal vegetation communities.

Irrespective of these ecological processes, the presence of human constructs (e.g. infrastructure) and the ongoing use of the intertidal zone by humans will likely continue into the future, and therefore the pressures on intertidal ecosystems will probably intensify.

4.2 Potential Impacts on the Built Environment

Impacts on the built environment are likely to increase in magnitude and extent as sea levels rise, particularly in vulnerable foreshore areas. This CHA has considered the impacts of SLR during larger storm surge events that do not tend to occur regularly. For the Parramatta River estuary, everyday tidal inundation due to SLR may have more significant impacts on residential, industrial/commercial and parkland land uses than these irregularly occurring events. Open space areas are particularly vulnerable to SLR being generally located in lower lying areas closer to the foreshore, with potential for impacts on the condition of turf and recreational infrastructure such as playground equipment, seating, barbeques, toilets etc. Inundation of this built infrastructure would probably be classed as a nuisance event, and would be unlikely to represent substantial risk to life or incur much damage. However, should inundation occur regularly enough, or for longer durations, the affected open space and parkland areas may no longer be viable for public use.

Roads in low-lying foreshore areas are also likely to be vulnerable to inundation. Depending on the depth, frequency and duration of inundation, public access along roads may be impeded. One issue of concern is the potential for access by emergency vehicles to be impacted, or to impact the egress of people from inundated land during an event. Potential impacts on services and utilities, particularly those that lie underground, may also present an issue and this is of significant concern to asset managers such as the local Councils and other utilities providers.

Impacts on residences and commercial/industrial property are also likely to be of significant concern due to the generally higher risks to life, in addition to the socio-economic impacts. Those areas currently subject to inundation risk in the 1-year and 100-years ARI events are likely to be subject to worsening risks under SLR conditions due to both an increase in inundation extents (and depths).

Inundation extents mapped in this investigation do not consider the potential for inundation due to the ingress of estuarine water back up the stormwater system (stormwater surcharge) and onto properties during a storm surge event. This may occur in areas connected to the stormwater system that are protected by a higher foreshore crest but are situated on land that is lower than the estuarine water level. This process may affect the foreshores of the estuary in some (generally low-lying) locations. With intense rainfall events, the capacity of the stormwater system is likely to be substantially reduced, since more water is flowing through the pipes.

When stormwater pipes are at or near capacity, more force is required for flushing to occur, and hence backing up of the stormwater system is more likely. Joint occurrence of both a large rainfall event and coastal inundation event would further reduce the capacity of the stormwater system, and hence stormwater surcharge during these times would be even more likely. In the case of joint occurrence, rainfall may cause localised flooding, with areas of inundation not necessarily being limited to areas that lie lower than the estuary water level. This is of course a catchment-driven process, rather than an estuary-driven process, which is not considered in coastal hazard assessments.

Although not directly related to the type of event-based coastal inundation considered in this CHA, if water levels are consistently higher (i.e. on a day to day basis) due to SLR, then sediment from the estuary may intrude into stormwater pipes on a regular (e.g. daily basis). This would likely to cause sedimentation inside stormwater pipes and may therefore lead to increased maintenance requirements (i.e. sediment removal) from the pipes so as to allow adequate flushing. This in turn would lead to increased costs of maintenance of the stormwater system. The installation of tide-flaps on the end of stormwater pipes could assist in allowing the egress of stormwater flows, while at the same time reducing water and sediment inflows from the estuary back into the stormwater system.

Table 4.1 provides a generalised summary of the impacts of inundation on the built environment for each scenario.

Table 4.1: Summary of Effects on the Built Environment

Scenario	1-Year ARI – Effects on Built Environment	100-Years ARI – Effects on Built Environment
Existing (no SLR)	Negligible impacts. Some localised impacts on utilities may be present in foreshore locations. Some impacts on parkland infrastructure may occur. Some foreshore structures (e.g. jetties) may not be accessible.	Residential dwellings and commercial/industrial buildings and structures unlikely to be affected, but there may be localised areas of inundation. Structures in residential gardens, or commercial/industrial stockpiles or storage areas, may be affected. Roads may be inundated in some locations, particularly along the foreshore and adjacent to tributaries of the main waterway. Boatsheds, jetties and other foreshore structures likely to be affected.
0.4m SLR Scenario	Larger impacts on roads, utilities and foreshore/parkland structures. Several areas of residential land likely to be inundated. Residential dwellings in some locations also likely to be affected. Some industrial/commercial land likely to be affected, however only a few industrial/commercial buildings likely to be impacted.	Larger areas of residential land and dwellings inundated. Industrial/commercial land likely to be impacted, but still only a few buildings of this land use likely to be affected. Roads inundated in several locations. In the upper estuary, 100-years ARI event has similar impacts to the 1-year ARI event.
0.9m SLR Scenario	Industrial/commercial land and buildings affected in several locations (mainly upper estuary). Residential land and dwellings, particularly waterfront properties, are likely to be at risk in several areas (mainly lower estuary). Inundation of roads likely to occur in several locations.	Industrial/commercial land and buildings inundated in many locations. Risk to residential land and dwellings are increased in the lower and middle estuary.

It is noted that this assessment of potential hazard under SLR conditions assumes that the current patterns of land development and the existing foreshore protection works do not change in future. This may not be the

case, and it is reasonable to assume that there may be efforts to adapt to rising sea levels by retrofitting existing defences. Conversely, increasing urban development intensities along the foreshore could result in a net increase in risk from coastal inundation.

4.3 Management Recommendations

The results of this CHA should be incorporated into the *Parramatta River Estuary Coastal Zone Management Plan* (Cardno, 2013). Monitoring of the effects of SLR and subsequent impacts on water levels and the estuarine ecosystem will have a bearing on future CZMP updates.

Although considering the broad-scale management of, and adaptation to, projected SLR and the increased exposure to coastal hazards, management focus is perhaps best applied to the existing case inundation scenario, i.e. the inundation risk that *currently* affects the Parramatta River foreshores. The management of current risks (to life and property) is clearly a higher priority than risks that may occur in the future. However, it is still important to start planning for SLR now to enable implementation of adaptive measures at particular trigger levels or events where the inundation risk is no longer considered acceptable. For these reasons, the management options and actions included in the CZMP are limited to those activities that relate to the first 5-10 years of management and have therefore focused on priority short term actions, noting however that Action 39_COM21 acts as prompt for that process when next updating the CZMP.

This CHA provides an indication of the impacts of less frequent, but larger, coastal hazard events. If further information is required regarding the impacts associated of regular tidal inundation, further investigations could be undertaken. The impacts associated with a 1-year ARI event, as discussed in this assessment, provide a reasonable indication of the impacts that would be associated with a biannual king tide event that occurs in the present day.

The following are general recommendations that the Committee may wish to consider in future in relation to coastal hazards and the potential impacts of SLR hazard extents:

- It is recommended that any triggers for the implementation of adaptive action be based on SLR increments at which the level of risk from coastal hazards becomes unacceptable, as opposed to planning horizons (years). This is due to the uncertainty associated with the SLR projections.
- It is recommended that an assessment of the potential for day-to-day inundation under SLR conditions be considered. However, given the limitations of LiDAR and other data (as discussed in Section 2.6), the delineation of lower water level events such as MHWS and MLWS would be likely to be even more challenging.
- It is recommended that ground-truthing be undertaken to verify the results of this assessment, particularly in areas identified as having a high impact from SLR.
- The potential effects of SLR on groundwater quality and levels should also be considered. This has the potential to impact on soil condition, vegetation management, irrigation and below ground services.
- Asset managers should assess the vulnerability of utilities and services to both coastal hazards for the present day and under SLR conditions, as well as day-to-day tidal inundation under SLR conditions.

- The potential for inundation of key roads and access ways during a storm surge event should be considered with respect to emergency management.
- Given the limitations inherent in the data and the assumptions made in the assessment process, small-scale (e.g. lot-based) applications of the results of this CHA are not advised. Broader planning and assessment outcomes, however, could be facilitated through consideration of the results on a larger scale.
- The results of this assessment should be incorporated into the floodplain risk management process and any upcoming investigations regarding flooding in the Parramatta River estuary.

4.4 Concluding Remarks

This investigation has assessed the potential impacts of storm surge under SLR conditions on the Parramatta River estuary, in accordance with the *Coastal Risk Management Guide* (DECCW, 2010b). This investigation has provided a visual representation and a discussion of the potential effects of SLR on ocean still water levels in the estuary and it is anticipated that the results can be utilised in various strategic and land use planning and management frameworks for the estuary.

5 QUALIFICATIONS AND ASSUMPTIONS

Several assumptions have been made in this investigation in order to complete the assessment. It is integral that these assumptions be considered when viewing the results of the analysis and when drawing conclusions from the assessment. In addition, study results should not be used for purposes other than those for which they were prepared.

The report relies on the accuracy of the data provided to Cardno from various sources, including SMCMA and Councils. The investigation and mapping procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, data outputs depend on the quality of the input data available. Hence there will be a level of uncertainty in the results and this should be kept in mind in the application of study results.

The inundation mapping provided in this document has been based on regional land survey data captured via aerial laser survey (LiDAR) over 2006 to 2008 that was provided to Cardno by SMCMA. If inundation extents for individual properties are required, a more accurate and detailed representation of inundation could be achieved by obtaining an independent property ground level survey.

Although there is amplification of the tidal range in the upper Parramatta River compared to the lower estuary, it has been assumed the tidal planes are flat over the entire estuary, and results have been based on SWL's for Fort Denison because hydrodynamic modelling was not conducted as part of the assessment.

The depth of inundation has not been considered in this assessment. In addition, inundation extents for the estuary do not include the potential for inundation due to the ingress of estuarine water back up the stormwater system (surcharge) and onto properties during a storm surge event.

It is acknowledged that legislation and planning policies are correct at the time of report issue, but are subject to change.

6 REFERENCES

AECOM (2010) *Parramatta River Estuary Processes Study*. Prepared for Parramatta River Estuary Management Committee.

Bindoff, N.L., Willebrand, J., Artale, V., Cazenave, A., Gregory, J., Gulev, S., Hanawa, K., Le Quéré, C. *et al.* (2007) "Observations: Oceanic Climate Change and Sea Level". In Solomon, S.; Qin, D., Manning, M. *et al*. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Cardno (2013) *Parramatta River Estuary Coastal Zone Management Study*. Prepared for Parramatta River Estuary Management Committee.

Cardno, (2010) *Estuarine Planning Levels Study – Foreshore Region of Leichhardt Local Government Area*. Prepared for Leichhardt Municipal Council.

CSE (2012) *Assessment of the Science Behind the NSW Government's Sea Level Rise Planning Benchmarks*. Prepared by the NSW Chief Scientist and Engineer, April 2012.

DECCW (2009) *NSW Sea Level Rise Policy Statement.* NSW Department of Environment, Climate Change and Water.

DECCW (2010a) *Guidelines for Preparing Coastal Zone Management Plans*. Department of Environment, Climate Change and Water.

DECCW (2010b). *Coastal Risk Management Guide*. Department of Environment, Climate Change and Water.

Watson, P.J. (2011) Is there evidence yet of acceleration in mean sea level rise around mainland Australia? *Journal of Coastal Research*, 27(2), 368–377. West Palm Beach (Florida).

Watson, P.J., Lord, D., and Snelgrove, C. (2009) *Sydney Harbour Sea Level Rise Vulnerability Studies*. Department of Environment, Climate Change and Water, September 2009.

7 GLOSSARY & ABBREVIATIONS

ArcGIS	A common GIS software program developed by the Environmental Systems Research Institute (ESRI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of an inundation event as big as or larger than the selected event. For example, the 20 year ARI inundation event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of an inundation event.
Barometric Setup	Mean sea level (MSL) rises in areas of low atmospheric pressure. This may be more generally referred to as the Inverse Barometer Effect.
Bathymetric survey / bathymetry data	Survey of ocean or river beds using depth soundings (SONAR).
Benchmarks	A standard by which something can be measured or judged. For example, predicted amounts of sea level rise to incorporate into planning considerations.
Cadastre	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
CHA	Coastal Hazard Assessment
Coastal inundation	See inundation
Coastal processes	The set of mechanisms that affect the land-water interface. These processes incorporate sediment transport and are governed by factors such as tide, wave and wind energy.
Crest level	The level in m AHD of the top of a feature (e.g. a seawall).
CZMP	Coastal Zone Management Plan
DECC	New South Wales Department of Environment and Climate Change (now OEH).
DECCW	New South Wales Department of Environment, Climate Change and Water (now OEH)
Design event	A significant event to be considered in the planning process.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
ENSO (El Niño and La Niña)	El Niño Southern Oscillation. A climatic cycle that oscillates between El Niño and La Niña conditions. It occurs due to changes in the strength of the Walker Circulation over the equatorial south Pacific. During El Niño conditions, which occur every three to seven years, drier conditions prevail, and average sea surface temperatures and sea levels are both lower. La Niña conditions in Australia are generally wetter, and sea surface temperatures and average sea levels are both higher.
Fetch	The horizontal distance over which a wind blows in generating waves.
Foreshore	The area of land at the land-water interface that is likely to be affected by coastal processes.
Geographical Information System (GIS)	A system of hardware, software, data, and procedures designed to support the management, manipulation, analysis and display of spatially referenced data by trained personnel.
Hazard	A situation that poses a level of threat to life, health, property, or the environment.
High Tide	The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions.
Highest astronomical tide (HAT)	The highest level of water which can be predicted to occur under any combination of astronomical conditions which occurs once every 18 years (however water levels can often exceed HAT values because of the influence of wind and waves).

Interdecadal Pacific Oscillation	A climatic cycle affecting both the north and south Pacific that oscillates on at least inter-decadal time scale, usually about 15 to 20 years.
Interpolation	A method of estimating the attributes of data through the utilisation of surrounding data. Interpolation of data points is common when creating surfaces in GIS.
Inundation	There are several types: Coastal inundation: A natural process whereby elevated ocean water levels combined with wave run-up along beaches result in seawater overtopping estuarine foreshores during storm events. This process is generally rare and episodic, occurring principally around the peak of a high tide, creating a hazard particularly in areas below about 5m AHD. *This term is used instead of oceanic inundation in this report (see below).* Oceanic inundation: A natural process whereby elevated ocean water levels combined with wave run-up along beaches result in seawater overtopping frontal dune systems and coastal barriers during storm events. This process is generally rare and episodic, occurring principally around the peak of a high tide, creating a hazard mainly where frontal dunes or coastal barriers along the NSW coastline are crested below about 5m AHD. *This term is not used in this report as the Parramatta River is an estuary rather than a dune system or coastal barrier, however the mechanism of inundation is comparable.* Tidal inundation: The submergence of land by seawater due mainly to the action of very high tides. This process is predominantly a hazard for low-lying estuarine foreshores. *This term is used in this report to describe inundation that occurs on a more regular basis (but with lower water levels), and is likely to worsen with projected sea level rise.*
Inverse Barometer Effect (IBE)	Mean Sea level (MSL) rises in areas of low atmospheric pressure and falls in areas of high pressure.
IPCC	Intergovernmental Panel on Climate Change
Joint Occurrence	The occurrence of two or more processes at any given point in time. With respect to coastal processes, joint occurrence could include the simultaneous occurrence of high astronomical tides, storm surges and wind-waves which would lead to highly elevated water levels.
LGA	Local Government Area
LiDAR	Light Detection and Ranging – remote sensing technology that measures distances using instrumentation including a laser. LiDAR data in this project refers to data collected to provide a surface of local topography for the study area.
LPI	New South Wales Land and Property Information
MHL	Manly Hydraulics Laboratory
Mean High Water Springs (MHWS)	The MHWS is the highest level which spring tides reach on the average over a period of time (usually several years).
Mean Low Water Springs (MLWS)	The MLWS is the lowest level which spring tides reach on the average over a time period (usually several years).
Mean Sea Level (MSL)	MSL is a measure of the average height of the ocean's surface such as the halfway point between the mean high tide and the mean low tide. At present, mean sea level is approximately equivalent to 0mAHD.
Oceanic inundation	See inundation.
OEH	Office of Environment and Heritage (formerly DECCW)
Probability	A statistical measure of the expected frequency or occurrence of inundation.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of inundation, communities and the environment.
Sea level rise (SLR)	A rise in the level of the ocean surface that is projected to occur in the future.
Sea wall	Wall built parallel to the shoreline to assist in protecting the shoreline from erosion.
Shapefile	Spatial vector data format for geographic information systems software, namely ESRI ArcGIS.

SMCMA	Sydney Metropolitan Catchment Management Authority; now amalgamated with the Hawkesbury Nepean Catchment Management Authority.
SONAR	SOund Navigation And Ranging – a technique that utilises sound waves to detect objects or measure distances on or under the surface of the water.
Still Water Level (SWL)	Average water-surface elevation at any instant including the effects of tides and storm surge, but excluding local variation due to waves and wave set-up.
Storm surge	The increase in coastal water level caused by the effects of storms. Storm surge consists of two components: the increase in water level caused by the reduction in barometric pressure (barometric set-up) and the increase in water level caused by the action of wind blowing over the sea surface (wind set-up).
Tidal inundation	See inundation.
Tides	The regular rise and fall of the sea level in response to the gravitational attraction between the sun, moon and Earth.
Toe level	The level in metres Australian Height Datum (m AHD) of the base of a feature (e.g. a seawall).
Topography	A surface which defines the ground level of a chosen area.
Wave breaking	As waves increase in height through the shoaling process, the crest of the wave tends to speed up relative to the rest of the wave. Waves break when the speed of the crest exceeds the speed of the advance of the wave as a whole. Waves can break in three modes: spilling, surging and plunging.
Wave run-up	The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.
Wave set-up	The increase in water level within the surf zone above mean still water level caused by the breaking action of waves.

Appendix D

Issues List

A total of over 100 management issues were identified by the study team in consultation with the Committee and the community during the preparation of the *Data Compilation and Review Study* (Cardno, 2008) and the *Estuary Processes Study* (AECOM, 2010). This larger list was then consolidated by combining recurrent issues into a list of 70 management issues for presentation at Committee Workshop 1 for discussion and review with the Committee. Based on review of this list, the Committee identified the top 10 broad management issues that they consider a priority for management at the present time (see Section 2.8).

The 70 management issues in Table D.1 have been grouped based on the following key estuarine processes:

- Catchment Characteristics (CP);
- Urban Stormwater, Hydrology and Flood Behaviour (SF);
- Geomorphology, Bathymetry and Estuary Sediments (GS);
- Hydrodynamics and Water Quality (HD);
- Ecology (EC);
- Human Usage and Recreation (HR); and
- Cultural Heritage, Values and Significance (CH).

Table D.1: Consolidated List of Identified Management Issues

Issue No.	General / Site Specific	Management Issue
CP01	General	Development and strategic planning within the Parramatta River estuary catchment does not always consider the downstream impacts on the estuary.
CP02	General	The combination of private and public land ownership within the catchment poses conflicting management initiatives.
CP04	General	Development has resulted in a significant reduction in the extent of natural vegetation in the catchment. Very few areas of natural vegetation still remain. This has contributed to a reduction of infiltration, increasing flow velocities and declines in water quality entering the estuary and its tributaries.
CP05	General	There has been a decline in water quality in the catchment since European settlement due to the industrialisation and urbanisation of the catchment. This has contributed to poor water quality within Parramatta River estuary.
CP06	General	Urbanisation in the catchment has likely contributed to increased local air temperatures, an effect known as the Urban Heat Island effect. This effect can impact on air quality by increasing the production of ozone, and can also result in increases in water temperature in tributaries or other shallow parts of the estuary.
CP07	General	Climate change has the potential to impact on the catchment and estuary through changes in hydrology, evaporation and SLR.
CP08	General	Poor erosion and sediment control on construction sites in the catchment contributes to poor water quality in the estuary.
SF01	Site specific	Flooding periodically impacts on access and use of ferry wharves.
SF02	General	The catchment hydrology has been altered to include pit and pipe stormwater systems. The changes in stormwater hydrology that have resulted are leading to in erosion of local creeks.
SF03	Floodplains	Significant flooding of urban areas occurs within the catchment. Inadequate funding is available for the maintenance and creation of stormwater assets, which exacerbates this issue.
SF04	General	There is a reported lack of general understanding of catchment issues by the multicultural community and this is considered to both hinder management initiatives and contribute to the stormwater issues.

Issue No.	General / Site Specific	Management Issue
SF05	General	Gross pollutants from the catchment and runoff from roads are contributing to poor water quality in the estuary.
SF06	General	There is a lack of information on stormwater assets in relation to the size of outlets to the estuary, and GPT types, location and maintenance regimes.
SF07	Site specific	Extremely high levels of pollution have been observed in both Dobroyd and Hawthorne Canals, including sewage contamination.
SF08	Site specific	Frequent sewer overflows occur at Bremner Park and in the Hunters Hill area.
SF10	General	The coordination of stormwater management initiatives in the catchment is hindered due to the lack of knowledge on the status of existing stormwater management plans, and the non-uniform means by which stormwater management activities are collated and reported on.
SF11	General	Foreshore flood extents are likely to increase as a result of SLR.
GS01	General and site specific	Contamination poses a major challenge for future development and for ongoing water quality management due to leachate. In addition, the extent and type of contamination is not known for many locations, particularly for reclaimed lands. Areas thought likely to be most adversely affected by leachate from contaminated land are located in Parramatta and Auburn LGAs, as well as several bays in the City of Canada Bay.
GS02	General	Sedimentation is thought to have accelerated since European settlement and continues today, affecting the amenity of the waterways.
GS03	Site specific	Historic dredging activities have altered the hydrodynamics of the estuary in some locations. Dredging activities are also likely to contribute to the disturbance of benthic organisms, to remobilisation of contaminated sediments, and to increased turbidity.
GS04	General	Contamination of estuarine sediments has resulted from the industrialisation and urbanisation of the catchment. This is thought to have significant impacts on both ecological and human health, however, the full impact is not at this time fully understood and the cost of remediation is prohibitive. In addition, processes governing partitioning of contaminants and the potential for mobilisation of contaminants to the water column are not adequately understood.
GS05	General	Acid sulfate soils occurring in some locations have the potential to impact on water and sediment quality, infrastructure and the estuarine ecology.
GS06	Seawalls	Foreshore erosion and seawall collapse is occurring at a number of locations along the estuary. This affects foreshore amenity, posing a risk to public safety, and can also lead to environmental degradation. Issues with seawalls in the study area include: ▪ inadequate drainage, ▪ overtopping, ▪ toe scour, ▪ differential settlement, and/or ▪ unit failure. Efforts to address foreshore erosion and seawall collapse are hampered by poorly delineated lines of responsibility for maintenance and remediation, as well as a lack of funds.
GS07	Upstream of Silverwater Road	The RiverCat bow wave has negative impacts on bank stability, undermining mangroves and increasing turbidity in the waterway. The economic and social benefits associated with the RiverCat need to be weighed against the environmental impacts.
HD02	General	Extensive alteration of the foreshores, both within the Parramatta River and its tributaries, has impacted on tidal processes and mixing of the water column. This can affect aquatic flora and fauna through changes to the natural range of variation in parameters such as pH, salinity and water temperature.
HD03	General	SLR as a result of climate change has the potential to impact upon the hydrodynamic processes of the estuary (such as the tidal prism).

Issue No.	General / Site Specific	Management Issue
HD04	General	Based on data collected under OEH's Harbourwatch program, the waters of the estuary are often unsuitable for primary contact recreation due to high faecal coliform counts. Also of concern is the presence of organic chemical and heavy metal contaminants.
HD05	General	Water quality in the Parramatta River estuary is also unsuitable for secondary contact recreation in many locations. There are numerous boat ramps around the Parramatta River estuary and these locations should be targeted for monitoring programs and management.
HD06	General	Human activities within the catchment have significantly altered nutrient inputs to the estuary and nutrient flux within the water body. Nutrient enrichment can lead to accelerated algal growth. Where algal growths occur, this can lead to low dissolved oxygen levels and/or flow restrictions.
HD08	General	The high levels of gross pollutants observed in the estuary indicate that the existing network of GPTs is insufficient. Urbanised catchments produce large amounts of litter, which can blow directly into the estuary or be entrained in stormwater runoff flowing into tributaries. Gross pollutants can be unsightly and dangerous to many aquatic species.
HD09	General	Dumping and accidental spills significantly contribute to the total amount of pollution within the Parramatta River estuary. However, there is little publicly available information on this issue. Catchment monitoring at a local council scale may assist in reducing the extent of illegal discharges to the estuary.
EC01	Site specific	Dumping of rubbish and green waste can impact on water quality and estuarine ecology. Locations observed to be particularly affected by dumping include Duck River, Melrose Park, Half Moon Bay and Yaralla Bay.
EC02	General	Obstructions to fish passage.
EC03	General	Conservation and management of threatened species/communities appears to be largely uncoordinated throughout the study area, and corridors linking important habitats are lacking. Habitat management for biodiversity conservation needs to be coordinated across the entire study area.
EC04	General	Mangrove areas are expanding in some locations at the expense of other habitats (i.e. saltmarsh). This may require active management in some cases.
EC05	General	The extensive development and reclamation along the estuary foreshores has resulted in large declines in the extent of natural foreshore and intertidal habitats.
EC06	General	Introduced species are prevalent throughout the study area. Whilst few targeted studies have investigated their impacts on native species, it is thought that they are having a significant negative impact on native flora and fauna, be it through simple displacement or more complex processes such as competition for resources.
EC07	General	Historic and ongoing seagrass loss and degradation.
EC08	General	The bioaccumulation of toxic contaminants in aquatic organisms is known to be an issue for the health of estuarine flora and fauna, as well as human health. However, other impacts of poor water and sediment quality on the estuarine ecology are not fully understood.
EC09	General	Sedimentation has been observed to have resulted in smothering of aquatic habitats.
EC10	General	Inappropriate mowing practices, trampling and other damaging activities on private and public land are impacting on native vegetation.
EC11	General	The unauthorised removal of native vegetation, such as lopping of tree limbs or poisoning, has been observed. Such activities are typically undertaken where vegetation inhibits water views from private property.
EC12	General	Direct impacts on seagrasses have been attributed to human activities, for example, from propellers/anchors, boat launching and shading from jetties.
EC13	General	Stormwater has negative impacts on seagrasses, including reduced light penetration, sedimentation, macroalgal growth due to elevated nutrient concentrations, and excessive amounts of leaf litter and/or other gross pollutants.

Issue No.	General / Site Specific	Management Issue
EC14	General	Negative impacts of stormwater on mangroves include: ▪ changes in pH, DO (redox potential) and salinity can mobilise contaminants from sediments, ▪ heavy metals can inhibit photosynthesis and respiration, ▪ floating oil deposited on mangrove roots can suffocate mangroves and/or have toxic effects, and ▪ smothering of pneumatophores and suffocation due to sedimentation.
EC15	General	The potential impacts of climate change on the estuarine ecology are largely unknown. Given the pressure estuarine ecosystems are currently experiencing, adaptation to climate change impacts may be difficult (e.g. vertical migration of vegetation may not be possible in some locations).
EC16	General	There is a need to consider conservation of *Wilsonia backhousei* in the context of an individual species, rather than at the level of the saltmarsh community as a whole.
EC17	General	Terrestrial and aquatic weed infestations are affecting floodplain, riparian and estuarine vegetation.
HR01	General	The tourism potential of the estuary is not being realised.
HR02	General	Sign posting is not adequately implemented throughout the estuary (e.g. no signage on Victoria Road announcing George Kendall Reserve). Existing signage is often vandalised.
HR03	General	There is a lack of continuity of walking tracks and open space along the foreshore, primarily due to the presence private land.
HR04	General	Development adjacent to the estuary should consider the impacts associated with building height and maximising estuary access and views through building orientation.
HR05	General	There is a need to ensure that the open spaces and facilities are appropriately configured to the needs of the users (e.g. larger families and groups, sporting preferences, youth entertainment and passive recreation).
HR06	Site specific	Mosquitoes are a problem around George Kendall Reserve and Meadowbank Park.
HR07	General	The lack of formal access and walkways has led to the degradation of foreshore vegetation and creek banks. The incorporation of boardwalks may assist in managing this issue.
HR08	Site specific	Better pedestrian links are required on the southern side of the River and across Duck River, connecting Parramatta with Homebush Bay.
HR09	General	There is a lack of appropriate lighting along foreshore areas.
HR10	General	Poor public transport is a key constraint to accessing the estuary.
HR11	Site specific	Housing developments (medium density) around Homebush Bay will increase the demand for public spaces and facilities.
HR12	General	There are conflicts between waterway users, in particular the RiverCat and rowing sculls.
HR13	General	There is a need to rationalise boat ramps and associated facilities (such as car parks).
HR14	General	The inappropriate storage of dinghies occurs along the foreshores.
HR15	General	Some foreshore facilities are currently in poor condition.
HR16	General	There is potential for a loss of foreshore recreational facilities, loss of open space and increased maintenance costs associated with projected SLR.
HR17	General	Where formal parking bays are not present, parking of vehicles along the foreshore had led to vegetation degradation/loss and erosion.
CH01	General	Integration of data on heritage items is lacking, particularly for foreshore items/infrastructure. This is an issue given the complicated management framework for the study area.
CH02	General	Loss of heritage items is thought to be a significant issue in the study area. While it is anticipated that a number of items have been lost during the process of urbanisation of the catchment, ongoing impacts are also occurring.

Issue No.	General / Site Specific	Management Issue
CH03	General	There are likely a number of as yet unidentified heritage items present in the study area.
CH04	General	The cultural heritage of the Parramatta River estuary is inadequately promoted, particularly with respect to Aboriginal cultural heritage.
CH05	General	Lack of linkages between open space areas and heritage items.

Appendix E

Assessment Criteria

Table E.1: Options Assessment Criteria Used to Determine Benefit Index

	Likely Outcome (Qualitative Assessment)							
	-3	-2	-1	0	1	2	3	Notes
Public Access	Significant reduction in public access for a large proportion of the estuary and its foreshores. Results in a fragmented and poorly coordinated approach to providing public access on an estuary-wide basis.	Reduction in public access for a large number of sites, lack of coordinated planning.	There is a minor reduction in public access; for options negatively impacting on a limited number of sites and/or limited range of user groups.	No impact on public access.	Public access is subject to minor improvements; for options that provide access to only a small portion of the study area.	Public access is improved via coordination of initiatives across a larger portion of the study area.	Significant improvement in public access via improved connectivity throughout the entire study area that also considers links with areas beyond the study area.	
Recreational Amenity	Recreational amenity across the study area is poorly coordinated and fails to reflect the needs of the different user groups. There is a significant reduction/deterioration in recreational facilities/infrastructure/activities across the study area.	Recreational amenity is reduced through a decline or deterioration in the number, variety or condition of recreational facilities, infrastructure or activities. This impacts a large part of the study area and/or a range of user groups.	Recreational amenity is reduced through a deterioration in the condition of recreational facilities, infrastructure or activities at a limited number of sites, or impacting on a limited number of recreational users.	No impact on recreational amenity.	Recreational amenity is improved through the provision of enhanced/additional facilities, infrastructure or activities at a limited number of sites, or for a limited number of recreational users.	Recreational amenity is improved through the strategic provision of additional/upgraded facilities, infrastructure or activities across a large part of the study area and/or targeting a range of user groups.	Plans for the strategic provision of recreational amenity on an estuary-wide basis. Recreational amenity is significantly improved via enhanced/additional facilities across the study area and for a large range of user groups.	
Cultural Heritage	Permanent loss or deterioration of a number of heritage sites; current levels of access to heritage sites is significantly reduced; existing activities to promote cultural heritage are significantly reduced in scope.	Loss or deterioration of some heritage sites; existing levels of access to heritage sites are impacted/reduced; existing activities promoting cultural heritage are reduced in scope.	Minor negative impacts on cultural heritage values would result due to the loss or deterioration of a small number of culturally significant sites.	No impact on cultural heritage values.	Cultural heritage values are promoted or heritage sites are conserved; focuses on a small subset of sites or particular aspects of cultural heritage.	Cultural heritage values are promoted; heritage sites are conserved and made accessible to the public; provides an improved appreciation of the heritage context by capturing a larger area or broader scope.	Results in a more strategic approach to the promotion of cultural heritage values for the estuary as a whole; provides for conservation and ongoing management of heritage sites over the longer term.	
Economic	N/A	The relative cost of works is very high (>$300,000).	The relative cost of works is high ($100,000 - $300,000).	The relative cost of works is medium ($50,000 - $100,000).	The relative cost of works is low ($10,000 - $50,000).	The relative cost of works is very low (<$10,000).	N/A	Note that this is a crude first pass estimate that relates to relative cost of implementation. Where there is not enough detail to estimate costs, a standard 'medium' cost has been assigned.
Water and Sediments	Results in a significant decline in water or sediment quality and / or increase in sediment quantity via direct impacts on the estuary as a whole.	Results in a direct decline in water or sediment quality and / or increase in sediment quantity in the estuary, but for a limited number of locations and/or contaminants.	Results in an indirect decline in water or sediment quality and / or increase in sediment quantity in the estuary.	No impact on water or sediment quality or quantity.	Results in an indirect improvement in water or sediment quality and / or decrease in sediment quantity in the estuary.	Results in a direct improvement in water or sediment quality and / or decrease in sediment quantity in the estuary, but for a limited number of locations and/or contaminants.	Results in a significant improvement in water or sediment quality and / or decrease in sediment quantity via direct impacts for the estuary as a whole.	
Estuarine Ecology	Results in direct negative impacts on estuarine ecosystems over the medium-long term, possibly resulting in the permanent loss of a species or habitat for at least one site.	Direct negative impacts on at least one species, habitat or site in the short-medium term.	Results in either indirect negative impacts on estuarine ecosystems, or direct negative impacts on a limited number of sites and/or a particular species/habitat.	No impact on estuarine ecosystems.	Results in either indirect positive impacts on estuarine ecosystems, or direct positive impacts for a small number of sites and/or a particular species/habitat.	Results in an improved understanding of ecosystem function; direct positive impacts for at least one species, habitat or site; short-medium term focus.	Significantly enhances understanding of ecosystem function; results in a more strategic approach to the protection of estuarine ecosystems for the estuary as a whole; provides for the medium to long term conservation, management and rehabilitation of a number of sites, species or habitats.	

	Likely Outcome (Qualitative Assessment)							
Climate Change	Significant negative interaction with climate change impacts; option not feasible under climate change conditions.	Negative interaction with climate change impacts for a number of locations or for specific scenarios.	Minor negative interaction with climate change impacts; limited to a particular location.	No impact on sustainability under climate change conditions.	Minor benefit under climate change conditions; limited to a particular location.	Additional benefit under climate change conditions for a number of locations or for specific scenarios (e.g. benefit only conferred under 0.4m SLR conditions, then lost for higher SLR amounts); provides for an improved understanding of the potential impacts of climate change in relation to a particular estuary process.	Significant added benefit in terms of climate change adaptation for a large area or for a range of scenarios (e.g. benefit conferred under both 0.4m and 0.9m SLR); provides for an improved understanding of the potential impacts of climate change for the entire estuary.	
Do Nothing	Potential Impacts of not Implementing the Option (i.e. 'Business as Usual'). Notes provided on the potential impact of not implementing the option; no scoring required.							

Table E.2: Actions Assessment Criteria

	Likely Outcome (Qualitative Assessment)					
	-2	-1	0	1	2	Notes
Statutory Framework Compatibility	Action would be illegal or in direct contravention with Government policy - Knock out factor.	Action inconsistent with the relevant policies/guidelines: LEP Zoning, State and Federal legislation considered.	N/A	Action consistent with the relevant policies/guidelines: LEP Zoning, State and Federal legislation considered.	Action reinforces or provides support for existing policies/guidelines (LEP Zoning, State and Federal legislation); results in the creation of a new policy.	If not permissible – knock out factor. Scores were allocated based on consideration of the key relevant State and Commonwealth legislation as current at time of preparation, including those instruments listed in Table A.2 of Appendix A, and the information on each action provided by the Committee members.
Tenure Constraints	N/A	Tenure constraints are such that additional negotiation between stakeholders, funding or resources may be required to implement the option.	There are no significant tenure constraints relevant to the subject site.	N/A	N/A	There are no known instances in which tenure actively facilitates implementation of an action and therefore no positive scores are provided. Tenure was assessed in GIS based on consideration of the following GIS layers: - CrownTenure.shp and Estate_2011_V1.shp provided by OEH and understood to show all Crown land and National Parks land respectively; and - nsw_maritime_title_boundary.shp, premises.shp and reclamations.shp provided by RMS (Maritime), understood to show the extent of land managed by that authority. In some instances, tenure information was provided by the authority that developed the management action. No other information was available on the land tenure status where management actions are proposed and in some cases assumptions have been made in allocating a score.
Likely Community Acceptance	Widespread disagreement with the intent of this action.	Majority of the community does not accept/support the action.	Neutral.	Majority of the community accepts/supports the action.	Widespread acceptance/support for the action.	These scores were applied qualitatively based on a review of the feedback provided in the community survey (Appendix B).

Table E.3: Options Assessment for Preliminary Benefit Index

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
Land Use Planning and Development																
1	New and revised Plans of Management should be compatible and consistent with the recommendations of the Parramatta River Estuary CZMP.	1	May result in indirect benefit by encouraging coordination of activities relating to access within each LGA.	1	May result in indirect benefit by encouraging coordination of activities relating to recreation within each LGA.	1	May result in indirect benefit by encouraging coordination of activities relating to cultural heritage management within each LGA.	0	-	1	May result in indirect benefit by encouraging coordination of activities relating to water and sediment quality within each LGA.	1	May result in indirect positive impact by encouraging coordination of activities relating to management of biodiversity, vegetation or other estuarine habitats within each LGA.	1	May result in indirect positive impact by encouraging coordination of activities relating to climate change.	6
2	When undertaking reviews of planning instruments or engaging in strategic land use planning, seek consistency with the Parramatta River Estuary CZMP and, where possible, update the relevant instrument as required.	1	May result in indirect benefit via improved provision for public access within the planning framework.	1	May result in indirect benefit via improved provision for recreational amenity within the planning framework.	1	May result in indirect benefit by providing for the listing of additional sites with local heritage significance within each LGA.	1	Costs to simply review documents are generally relatively low.	1	May result in indirect benefit via improved provision for water quality controls in the catchment.	1	May result in indirect benefit via improved provision for ecological conservation.	3	Would result in the provision of planning mechanisms that consider coastal hazards, such as foreshore inundation. Mechanisms could include adaptive measures.	9
3	Work with relevant Aboriginal community groups along the Parramatta River to determine management options for identified Aboriginal heritage sites.	0	-	1	May result in indirect benefit via improved awareness & education of Aboriginal sites.	3	Direct benefit to long term management and conservation of identified Aboriginal sites for the estuary as a whole.	0	-	0	-	0	-	0	-	4
4	Develop provisions under Development Control Plans that provide for the incorporation of best practice WSUD and ecological connectivity along the estuary foreshores for sites subject to redevelopment.	1	Potential for value-added benefits for public access where incorporated into ecological corridor.	1	Potential for value-added benefits for recreational amenity where incorporated into ecological corridor & through an improvement in water quality.	0	-	0	-	2	Direct benefit via a reduction in pollutant loads being delivered to the estuary from stormwater from a limited number of re-development sites.	2	Direct, long term benefit via improved connectivity and a potential increase in the extent of estuarine habitat.	2	Direct benefit in terms of facilitating migration of flora and fauna both in the present and under a climate change scenario.	8
Water and Sediments																
5	Promote the reporting and enforcement of illegal dumping on the estuary foreshores and waterway.	0	-	0	-	0	-	0	-	1	May result in indirect benefits where dumped materials may impact on water and/or sediment quality.	1	May benefit sites where dumped material is impacting on estuarine habitats, or introducing weed species or other contaminants to the environment.	0	-	2
6	Ensure the prompt removal of waste materials dumped in the estuary or along its foreshores for disposal at a suitably licensed waste management facility.	0	-	0	-	0	-	0	-	1	Direct benefit for specific locations where dumped material is impacting on water quality.	1	Direct benefit for specific locations where dumped material is impacting either directly or indirectly on estuarine ecology.	0	-	2

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
7	Retrofit appropriate WSUD features in existing urban areas of the catchment targeting locations upstream from where stormwater runoff and associated pollutants are impacting sensitive estuary locations.	0	-	2	Indirect benefit for recreational amenity via improved water quality.	0	-	0	-	2	Direct benefit via a reduction in pollutant loads being delivered to the estuary from the stormwater system.	2	Indirect benefit via a reduction in pollutant loads being delivered to the estuary.	0	-	6
8	Modify, upgrade or repair existing SQIDs, stormwater infrastructure and management practices as required to maintain or improve their effectiveness. This should include development of maintenance schedules for existing infrastructure where they are not currently in place.	0	-	2	Indirect benefit for recreational amenity via improved water quality.	0	-	0	-	2	Direct benefit via a reduction in pollutant loads being delivered to the estuary.	2	Indirect benefit via a reduction in pollutant loads being delivered to the estuary.	0	*	6
9	Work with Sydney Water to prioritise maintenance and upgrade of the sewerage network within the catchment on an ongoing basis to reduce sewage overflows. This activity should include investigations into the incidence of illegal private connections to the sewerage and / or stormwater network.	0	-	1	Indirect improvement in recreational amenity through improved water quality.	0	-	0	-	2	Direct benefit via a reduction in pollutant loads.	1	Potential indirect benefits via a reduction in loads of some pollutants delivered to the estuary.	0	-	4
10	Reduce sediment inputs through bank stabilisation works in estuary tributaries.	0	-	1	Indirect improvement in recreational amenity via improved water quality.	0	-	0	-	2	Positive impact via reduction of sediment inputs from targeted locations.	2	Direct benefit where sedimentation is impacting on estuarine habitats at targeted locations.	0	-	5
Estuarine Ecology																
11	Develop and implement a strategy for the coordinated management of estuarine and riparian biodiversity across administrative boundaries for the estuary as a whole. The strategy should incorporate biodiversity corridors and SLR considerations, to ensure the ongoing provision of habitat and connectivity between habitat areas.	1	Activity may inform planning for ongoing provision of public access, in consideration of biodiversity corridors.	0	-	0	-	0	-	0	-	3	Long term, estuary-wide, direct benefit to estuarine ecology.	3	One component of the strategy would be planning for a climate change scenario.	7
12	Minimise impacts of moorings and boating on seagrass.	0	-	1	Potential for value-added benefits for recreational amenity where ecological features incorporated in moorings.	0	-	0	-	1	Indirect benefits may be accrued through the treatment of stormwater runoff via seagrass.	3	Long term, estuary-wide, direct benefit to estuarine ecology.	-2	Some seagrass may be lost with long term climate change, so would need to prioritise sites for long term conservation.	3

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
13	Manage public access at environmentally sensitive foreshore locations. Priority areas may include key habitat and vegetation communities located in areas that are frequented by the public.	-1	May result in reduced access at some specific sites.	1	Potential for value-added benefits for recreational amenity where ecological areas are enhanced.	0	-	0	-	1	Indirect benefits may be accrued through the treatment of stormwater runoff by the protected estuarine vegetation.	3	Benefit provided for a number of specific locations.	1	Considerations would be given to SLR in the long term.	5
14	Reduce the unauthorised clearing of riparian and estuarine vegetation.	-1	May result in reduced access at some specific sites if illegal clearing of estuarine vegetation is reduced or stopped in the long term.	1	May result in an increase in recreational amenity at specific locations if illegal clearing of estuarine vegetation is reduced or stopped in the long term.	0	-	0	-	1	Indirect benefits may be accrued through the treatment of stormwater runoff via estuarine vegetation that are retained in the long term.	3	Long term, estuary-wide, direct benefit to estuarine ecology if illegal clearing of estuarine vegetation can be reduced or stopped.	0	-	4
15	Work with private landholders and bush care groups to encourage and assist in the re-vegetation of foreshore areas, and the management and conservation of existing vegetation. As a priority, target landholders with ecologically significant vegetation present on their land.	0	May reduce private access but would not affect public access, assuming tenure does not provide public access.	1	May result in an increase in recreational amenity at specific foreshore locations via revegetation works.	0	-	0	-	1	Indirect benefits may be accrued through the treatment of stormwater runoff via estuarine vegetation.	2	Benefit provided for a limited number of specific locations.	0	-	4
16	Undertake improvements to foreshore infrastructure where possible to reduce their impacts on aquatic habitats. Consider the need, where feasible, to relocate or decommission infrastructure where it is impacting on environmentally sensitive locations.	1	Potential for value-added benefits for public access where infrastructure is improved.	3	Direct benefit via the coordination of recreational usage of the study area for a range of user groups.	0	-	0	-	0	-	3	Benefit provided for a number of specific locations where infrastructure is decommissioned or relocated and improvements are made.	0	-	7
17	Undertake works to provide for the ongoing preservation of estuarine and riparian habitats under climate change conditions. This should include the enhancement of existing habitats where there is possibility of retreat, or establishing additional habitat areas as required, to maximise habitat under SLR conditions.	-1	May result in reduced access at some specific sites.	-1	May impact on a limited number of recreational areas in terms of their potential for expansion in the future.	0	-	1	Costs required to plan for SLR in the 5 to 10 year timeframe of this current CZMP are considered relatively low.	1	Indirect benefits may be accrued through the treatment of stormwater runoff via estuarine vegetation in the long term, where this vegetation may otherwise be lost if it cannot retreat in response to SLR.	3	Long term, direct benefit at a site specific scale; potential for improved connectivity along the estuary.	3	Direct benefit in terms of facilitating migration and climate change adaptation of estuarine vegetation at key sites under climate change scenarios.	6

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
18	Manage identified public foreshore areas where they are required for the retreat of estuarine vegetation in response to SLR.	-1	May result in reduced access at some specific sites.	-1	May impact on a limited number of recreational areas in terms of their potential for expansion in the future.	0	-	1	Costs required to plan for SLR in the 5 to 10 year timeframe of this current CZMP are considered relatively low.	1	Indirect benefits may be accrued through the treatment of stormwater runoff via estuarine vegetation in the long term, where this vegetation may otherwise be lost if it cannot retreat in response to SLR.	3	Long term, estuary-wide, direct benefit to estuarine ecology.	3	Significant benefit in terms of facilitating migration and climate change adaptation of estuarine vegetation under climate change scenarios.	6
19	Undertake creek naturalisation works of existing channelised creeks, focusing as a priority on channels coming to the end of their design life.	0	-	0	-	0	-	0	-	3	May provide some additional treatment of stormwater runoff via the use of vegetation, etc.	3	Where implemented for more than one tributary, provides for long term direct benefits.	0	-	6
20	Undertake ongoing monitoring and management of aquatic and terrestrial weeds (incl. noxious weeds) and introduced species (both flora and fauna).	0	-	1	May result in the provision of improved recreational amenity through the removal of weeds.	0	-	0	-	1	May indirectly improve water quality through the promotion of native species.	3	Direct benefit for specific locations affected by weed infestations.	1	Control of exotic species is important when considering climate change as many introduced species are able to more quickly adapt and/or migrate, and may displace native species without careful management.	6
21	Improve the environmental value of existing seawalls through the addition of habitat, where feasible.	0	-	1	May result in the provision of improved recreational amenity through the design of any upgraded seawalls.	1	There are a number of heritage listed seawalls within the study area and some of these may require improvement with habitat.	0	-	1	May provide some additional treatment of stormwater runoff via the use of vegetation as additional habitat on the seawalls.	3	Potential for direct benefit at sites where opportunities to incorporate additional habitat in design are realised.	1	Potential direct benefit where the upgrade considers SLR under climate change.	7
Bank Condition																
22	Formally negotiate with Harbour Ferries for a change in vessel (from the RiverCat) that would have less wake impacts.	0	-	0	-	0	-	2	Relative cost of negotiations is very low; however further costs of actually replacing or retiring the RiverCat would be greater.	1	Potential indirect benefit via allocation of liability - resources may be made available to address impacts.	2	Potential indirect benefit via allocation of liability - resources may be made available to address impacts.	1	Potential direct benefit where the upgrade considers SLR under climate change.	6
23	Encourage bank and foreshore erosion control techniques that maximise the use of riparian and estuarine vegetation.	0	-	1	May result in an increase in recreational amenity at specific foreshore locations via revegetation works.	0	-	0	-	2	Direct benefit by reducing sediment in runoff from specific sites, assuming a number of sites are redeveloped in the catchment.	2	Potential for direct benefit at sites where opportunities to incorporate riparian and estuarine vegetation in erosion control are realised.	0	-	5

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
24	All management authorities involved in the building, design and approval of new seawalls, or major upgrades of existing seawalls, should promote their compliance with the Environmentally Friendly Seawalls Guidelines (DECC and SMCMA, 2009) within legislative constraints.	1	May result in the provision of improved access through design of any upgraded seawalls (e.g. by incorporating a stepped revetment to access the water).	1	May result in the provision of improved recreational amenity through the design of any upgraded seawalls (e.g. via the incorporation of seating).	1	There are a number of heritage listed seawalls within the study area and some of these may require upgrading / stabilisation.	0	-	0	-	2	Potential for direct benefit where opportunities to incorporate environmentally sensitive design are realised.	1	Potential direct benefit where the upgrade considers SLR under climate change.	6
Human Usage and Recreation																
25	Maintain and improve existing public access (i.e. bike and walking paths) for the Parramatta River estuary to provide transport linkages throughout the LGAs, giving consideration to sensitive environmental locations.	3	Provides a coordinated approach that benefits a large number of users.	2	Will result in the provision of improved recreational amenity through improved access to the waterway.	0	-	0	-	0	-	1	Potential for direct benefit where environmentally sensitive locations are conserved.	1	Potential direct benefit where the access considers SLR under climate change.	7
26	Repair or upgrade existing foreshore facilities identified as failing or as being in poor condition in the Estuary Processes Study (AECOM, 2010) as funding opportunities allow.	2	This may include facilities that facilitate access, such as pathways, jetties or wharves. A number have been identified as representing safety risk by AECOM (2010).	3	Would directly benefit a large range of recreational users across the estuary as a whole.	0	-	0	-	0	-	0	-	0	-	5
27	Continue to conduct surveillance and compliance monitoring with a view of removing or regularising unauthorised foreshore structures / uses.	0	-	1	May result in an improvement in recreational facilities at specific locations.	0	-	0	-	0	-	0	-	0	-	1
28	Strategically provide foreshore infrastructure to support boating in the Parramatta River estuary, with due consideration of any potential impacts on the estuary.	2	Would improve connectivity between the waterway and foreshores, improving boating access.	2	Would provide for improved recreational amenity for the boating public.	1	This option could include interpretive signage to promote heritage sites.	0	-	0	-	1	Potential for direct benefit where environmentally sensitive locations are conserved.	0	-	6
29	Develop and implement an integrated approach to the provision of recreational amenity for the estuary as a whole.	2	Would likely have a positive impact where implementation includes access.	3	Would provide a coordinated approach that addresses recreational requirements within the study area.	1	This option could include interpretive signage to promote heritage sites.	0	-	0	-	0	-	1	Potential direct benefit where the recreational amenity is improved with consideration given to SLR under climate change.	7

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
30	Provide viewing points and interpretive signage at appropriate locations to promote an appreciation of the estuary and enhance the visitor experience.	0	-	1	Potential indirect benefit via promotion of these features and incorporation into recreational trails etc.	2	This option could include interpretive signage to promote heritage sites.	0	-	1	Potential for indirect benefit via community education on water quality issues.	1	Potential indirect benefit via community education on estuarine ecology.	1	On a site specific basis, may include information about any projects that have value added benefits under climate change conditions (e.g. interpretive signage about facilitated migration of intertidal vegetation).	6
31	Work with the key stakeholders to develop and implement a vision for the Parramatta River estuary that delivers world-class facilities for both residents and visitors. The vision should recognise the regional, State and Federal significance of the Parramatta River as an iconic waterway.	2	May result in the provision of improved access.	2	May result in significant improvement in recreational amenity within the study area.	0	-	1	Considered relatively low cost to achieve.	0	-	0	-	0	-	5
32	Work together to develop and implement a program for industry and the community to raise awareness of issues relating to estuary management and estuarine health. Key elements of the program could include: - Good catchment management practices; - The heritage significance of the estuary and its foreshores; - The types of activities that are permitted, or are not permitted, in different parts of the foreshore or waterway; - The use of vegetation for bank and foreshore protection works; - The potential impacts of climate change on the estuary; and - How individuals can reduce their impact on the estuary.	0	-	1	Indirect benefit for recreational amenity via improved water quality.	2	This option could include interpretive signage to promote heritage sites and may increase heritage values through education.	0	-	2	Potential direct benefit via net reduction in loadings of some pollutants and dumping into the estuary through community education on water quality issues.	2	Potential indirect benefits via a reduction in loads of some pollutants delivered to the estuary and protection of estuarine vegetation through education.	1	Provides community with climate change impacts on the estuary as a whole.	8
Monitoring, Evaluation and Reporting																
33	Develop and implement a communication strategy for the implementation stage of the Parramatta River Estuary CZMP.	1	Indirect benefit via promotion / education on objectives and actions relating to improved public access.	1	Indirect benefit via promotion/education on objectives and actions relating to management of recreational usage.	1	Indirect benefit via promotion/education on objectives and actions relating to cultural heritage.	1	Costs are considered to be relatively low to inform the community on progress of the CZMP.	1	Indirect benefit via promotion/education on objectives and actions relating to water quality.	1	Indirect benefit via promotion/education on objectives and actions relating to estuarine ecology.	0	-	6

Option ID	Option Description	Public Access	Public Access Comments	Recreational Amenity	Recreational Amenity Comments	Cultural Heritage	Cultural Heritage Comments	Economic	Economic Comments	Water and Sediments	Water and Sediments Comments	Estuarine Ecology	Estuarine Ecology Comments	Climate Change	Climate Change Comments	Preliminary Benefit Index
34	Develop and implement a holistic and rigorous monitoring program that coordinates the efforts of the various stakeholders responsible for management of the Parramatta River estuary and includes monitoring of climate change impacts.	0	-	1	Indirect benefit provided by reporting water quality at key recreational sites.	0	-	0	-	3	Direct benefit in establishing a baseline and identifying trends in water quality over the long term; this would inform adaptive management.	3	Direct benefit in establishing a baseline and identifying trends in ecological parameters over the long term; this would inform adaptive management.	0	-	7
35	Encourage DPI (Fisheries) to periodically map the distribution of estuarine vegetation (seagrass, saltmarsh and mangroves) for the estuary.	0	-	0	-	0	-	0	-	0	-	1	Potential to highlight areas where seagrasses are being lost and conservation efforts can be targeted here.	1	Potential to highlight seagrasses areas into the future that are being lost with climate change.	2
Coastal Hazards																
36	Within the regular program of upgrades, provide additional capacity in the stormwater network to account for changes in rainfall patterns and elevated estuary water levels under climate change conditions.	0		0	-	0		0		0		0		2	Projected increase in storm intensities under climate change will increase the volume of stormwater. This option provides for increased capacity to accommodate the higher stormwater flows.	2
37	Restrict new foreshore developments in areas where tidal inundation hazards under current and future SLR scenarios are quantified.	-1	May result in a minor reduction to future public access in some areas.	-1	May result in a minor reduction in recreational facilities in some areas.	0	-	1	Costs are considered to be relatively low to restrict developments.	0	-	0	-	3	Significant benefit in terms of climate change adaptation of developments.	2
38	Manage foreshore infrastructure with likely tidal inundation risk in such a way as to allow adaptation to SLR.	-1	May result in a minor reduction to future public access in some areas.	-1	May result in a minor reduction in recreational facilities in some areas.	0	-	0	-	0	-	1	Potential for direct benefit where areas for retreat of estuarine vegetation are also identified and conserved.	3	Significant benefit in terms of climate change adaptation of developments.	2
39	Assess the potential impacts of SLR on the estuary foreshores.	0	-	1	Indirect benefit in that it may assist in management of recreational facilities at SLR affected locations into the future.	2	This information could be used to identify heritage sites that may be affected by SLR.	0	-	0	-	2	Potential direct benefit in the future by informing current and future planning for estuarine habitats (e.g. via strategic land acquisition).	2	Provides an improved understanding of one aspect of climate change for the entire estuary.	7
40	Identify cultural heritage sites that are currently affected by coastal hazards, or that may be affected by coastal hazards under climate change conditions, and develop appropriate management responses to address these issues.	0	-	0	-	3	Direct benefit to long term management and conservation of identified Aboriginal sites for the estuary as a whole.	0	-	0	-	0	-	1	Potential to highlight cultural heritage sites that may be lost with climate change.	4

Table E.4: Options Assessment Final Outcomes

Option ID	Option Description	Primary Objective Addressed	Additional Objective(s) Addressed	Potential Impacts of Not Implementing the Option (i.e. 'Business as Usual')	Key Advantages of Implementation	Preliminary Benefit Index (Table E.3)	Objective Prioritisation (High = 3, Medium = 2, Low = 1)	Adjusted Benefit Index	Option Rank (Blue = HIGH PRIORITY)
Land Use Planning and Development									
1	New and revised Plans of Management should be compatible and consistent with the recommendations of the Parramatta River Estuary CZMP.	1A	-	Potentially conflicting/contradictory management actions within existing LGA management plans. This could lead to negative impacts on estuarine health at locations subject to the CZMP.	Promotes good governance, and coordinated and holistic management.	6	3	9	7
2	When undertaking reviews of planning instruments or engaging in strategic land use planning, seek consistency with the Parramatta River Estuary CZMP and, where possible, update the relevant instrument as required.	1A	-	There may be planning controls within the existing instruments that either fail to promote sustainable management of estuarine resources or cause negative impacts on the estuary. Should land use planning/zoning decisions not consider estuarine health, there is potential for these impacts to be ongoing, or to increase in magnitude or extent.	Opportunity to incorporate specific planning controls that promote estuarine health and would be required to be implemented for all new development.	9	3	12	1
3	Work with relevant Aboriginal community groups along the Parramatta River to determine management options for identified Aboriginal heritage sites.	1A	9A	Identified Aboriginal heritage sites are currently protected under the *National Parks and Wildlife Act 1977, and therefore 'doing nothing' will not necessarily result in a significant impact*. However, failure to provide for their ongoing management/maintenance may lead to a decline in cultural heritage values and lead to degradation of the sites, particularly under climate change conditions. Failure to raise awareness of and/or promote the sites may also lead to a decline in cultural heritage values.	Promotes the involvement of Aboriginal people in the management of their cultural heritage.	4	3	7	24
4	Develop provisions under Development Control Plans that provide for the incorporation of best practice WSUD and ecological connectivity along the estuary foreshores for sites subject to redevelopment.	2E	4A, 3A, 2B	Development will continue in accordance with the relevant guideline documents and other requirements (e.g. BASIX), however, these do not always have the statutory weight of a DCP. There is potential that sites subject to (re)development fail to opportunise best practice WSUD and impacts of stormwater on the estuarine water quality will continue.	Provides an opportunity for improved biological connectivity and WSUD on sites subject to redevelopment. Where the controls apply to a number of sites for redevelopment, this could improve conditions for a large proportion of the estuary.	8	3	11	2
Water and Sediments									
5	Promote the reporting and enforcement of illegal dumping on the estuary foreshores and waterway.	2A	-	As there is currently in place a framework for reporting (EPA Pollution Hotline 131 555), ensuring compliance on and removing illegally dumped materials, there is not likely to be any significant impacts of 'doing nothing'. However, the opportunity to increase community awareness and this system is unlikely to dramatically increase.	Raises community awareness, and may also promote the more prompt enforcement of legislation and removal of dumped materials.	2	2	4	36
6	Ensure the prompt removal of waste materials dumped in the estuary or along its foreshores for disposal at a suitably licensed waste management facility.	2A	-	There is currently in place a system to enforce the removal of dumped material, however, there are difficulties in ensuring prompt removal and in allocating responsibility to do so. 'Doing nothing' would likely primarily impact only the timeframe upon which waste removal takes place.	Minimises the risk of negative impacts on sediment and water quality through prompt removal of material.	2	2	4	36
7	Retrofit appropriate WSUD features in existing urban areas of the catchment targeting locations upstream from where stormwater runoff and associated pollutants are impacting sensitive estuary locations.	3A	2B	Some parts of the catchment currently have WSUD features in place. However, there exists significant opportunity to implement additional WSUD/stormwater controls that could benefit water quality in the estuary and its tributaries. This would not be realised under a 'do nothing' scenario and the current level of impact on water quality would persist.	Opportunity to promote good catchment management and to reduce the magnitude of stormwater impacts on the estuary and its tributaries.	6	3	9	7
8	Modify, upgrade or repair existing SQIDs, stormwater infrastructure and management practices as required to maintain or improve their effectiveness. This should include development of maintenance schedules for existing infrastructure where they are not currently in place.	2B	-	Some SQIDs and other stormwater infrastructure are currently negatively impacting on the estuary due a failure to provide effective treatment of stormwater flows. 'Doing nothing' would result in an ongoing impact on water quality.	Potential to improve water quality in the estuary and its tributaries. Potential to reduce stormwater impacts on bank condition, or where it is causing erosion.	6	3	9	7

Option ID	Option Description	Primary Objective Addressed	Additional Objective(s) Addressed	Potential Impacts of Not Implementing the Option (i.e. 'Business as Usual')	Key Advantages of Implementation	Preliminary Benefit Index (Table E.3)	Objective Prioritisation (High = 3, Medium = 2, Low = 1)	Adjusted Benefit Index	Option Rank (Blue = HIGH PRIORITY)
9	Work with Sydney Water to prioritise maintenance and upgrade of the sewerage network within the catchment on an ongoing basis to reduce sewage overflows. This activity should include investigations into the incidence of illegal private connections to the sewerage and / or stormwater network.	2C	-	Sydney Water currently has in place a program to reduce the incidence of sewage overflows from their network called SewerFix. As this option provides only for liaison with Sydney Water on prioritising works in problem areas within the study area and therefore, despite the fact that sewage overflows can have a big impact on water quality, 'doing nothing' would not likely result in a significantly different outcome over the long term.	Potential to target SewerFix activities to problem locations along the Parramatta River or its tributaries, thereby reducing risk to ecological and public health.	4	3	7	24
10	Reduce sediment inputs through bank stabilisation works in estuary tributaries.	2B	3A	Banks will continue to erode, continuing to contribute sediment loads to the estuary and potentially impacting on other estuarine assets (e.g. vegetation).	Reduces risk of erosion and sedimentation, and consequently reduces level of threat to estuarine water quality and ecology.	5	3	8	14
Estuarine Ecology									
11	Develop and implement a strategy for the coordinated management of estuarine and riparian biodiversity across administrative boundaries for the estuary as a whole. The strategy should incorporate biodiversity corridors and SLR consideration, to ensure the ongoing provision of habitat and connectivity between habitat areas.	4A	10A	Biodiversity should ideally be managed on a regional scale. Without coordinated management, there is a risk of conflicting activities by different authorities or of declines in local biodiversity values, particularly under a climate change scenario when there may be a need to accommodate biological exchange across the region.	Opportunity to undertake strategic planning as an investment in both current and future biodiversity. Provides improved capacity for ecological adaptation.	7	3	10	4
12	Minimise impacts of moorings and boating on seagrass.	4A	-	The current level of impact of moorings and boating on seagrasses will not be reduced, potentially resulting in an ongoing decline in the extent and condition of seagrasses.	Potential to promote improved condition and extent of seagrasses.	3	3	6	31
13	Manage public access at environmentally sensitive foreshore locations. Priority areas may include key habitat and vegetation communities located in areas that are frequented by the public.	4A	-	Without clearly defined public access, particularly in sensitive areas, vegetation and habitat could potentially be subject to loss or damage. This may result in a net decrease in the extent of vegetation across the estuary as a whole.	Reduces risk of impacts on foreshore ecology, with added benefit where public access is also compromising bank condition or causing erosion and sedimentation.	5	3	8	14
14	Reduce the unauthorised clearing of riparian and estuarine vegetation.	4A	-	The unauthorised clearing of riparian and estuarine vegetation is currently monitored and enforced by a number of authorities, including DPI (Fisheries), OEH and councils. The levels of unauthorised riparian and estuarine vegetation clearing are unlikely to decrease without additional effort on compliance.	Increase extent of estuarine and riparian vegetation. Opportunity to raise public awareness.	4	3	7	24
15	Work with private landholders and bush care groups to encourage and assist in the re-vegetation of foreshore areas, and the management and conservation of existing vegetation. As a priority, target landholders with ecologically significant vegetation present on their land.	4A	5B	There are currently a number of active bush care groups in the study area. However, the amount of vegetation in foreshore areas is unlikely to significantly increase without re-vegetation, and without proper management and conservation, there is a risk that the amount of existing native vegetation will decrease in extent over time.	Potential to increase extent and condition of estuarine and riparian vegetation. Opportunity to raise public awareness.	4	3	7	24
16	Undertake improvements to foreshore infrastructure where possible to reduce their impacts on aquatic habitats. Consider the need, where feasible, to relocate or decommission infrastructure where it is impacting on environmentally sensitive locations.	4A	6A, 4D, 7B	Existing recreational infrastructure remains as is, including those having a detrimental impact on the estuary.	Opportunity to strategically manage recreational infrastructure, while at the same time improving the condition of the natural environment.	7	3	10	4
17	Undertake works to provide for the ongoing preservation of estuarine and riparian habitats under climate change conditions. This should include the enhancement of existing habitats where there is possibility of retreat, or establishing additional habitat areas as required, to maximise habitat under SLR conditions.	4A	10A	Failure to implement this option is unlikely to have a significant impact in the short term. 'Doing nothing' will become more an issue in the future, particularly if areas suitable for retreat are subject to development or management such that they would be unavailable for environmental use under SLR.	Long term benefit in maintaining and potentially improving extent of estuarine vegetation; provides for maintenance of estuarine biodiversity and ecosystem services.	6	3	9	7

Option ID	Option Description	Primary Objective Addressed	Additional Objective(s) Addressed	Potential Impacts of Not Implementing the Option (i.e. 'Business as Usual')	Key Advantages of Implementation	Preliminary Benefit Index (Table E.3)	Objective Prioritisation (High = 3, Medium = 2, Low = 1)	Adjusted Benefit Index	Option Rank (Blue = HIGH PRIORITY)
18	Manage identified public foreshore areas where they are required for the retreat of estuarine vegetation in response to SLR.	4A	10A	Failure to implement this option is unlikely to have a significant impact in the short term. 'Doing nothing' will become more an issue in the future, particularly if areas suitable for retreat are subject to development or management such that they would be unavailable for environmental use under SLR.	Long term benefit in maintaining and potentially improving extent of estuarine vegetation; provides for maintenance of estuarine biodiversity and ecosystem services.	6	3	9	7
19	Undertake creek naturalisation works of existing channelised creeks, focusing as a priority on channels coming to the end of their design life.	4B	-	Many of the creeks in the lower catchment have been channelised and have low environmental value. 'Doing nothing' would mean that the opportunity to naturalise the creeks would not be realised and these potential opportunities to create habitat and improve visual amenity would be lost.	Opportunity to provide improved ecological value and incorporate WSUD features.	6	2	8	14
20	Undertake ongoing monitoring and management of aquatic and terrestrial weeds (incl. noxious weeds) and introduced species (both flora and fauna).	4C	-	There are many areas around the estuary that are affected by introduced terrestrial and aquatic species. If these areas are not subject to ongoing management, there may be a proliferation of these areas at the expense of native species, resulting in a net decline in biodiversity values.	Reduces risk to estuarine biodiversity; potential to increase extent and condition of habitat areas.	6	2	8	14
21	Improve the environmental value of existing seawalls through the addition of habitat, where feasible.	4D	4A	The current low level of habitat availability within the existing seawalls would persist.	Potential to increase the extent of estuarine habitat.	7	1	8	14
Bank Condition									
22	Formally negotiate with Harbour City Ferries for a change in vessel (from the RiverCat) that would have less wake impacts.	5A	2D	The RiverCat will continue to cause significant bank erosion through its wake impacts.	Reduction in extent/magnitude of bank erosion resulting in improved bank condition. Reduction in the rate of loss/damage to intertidal vegetation and seawalls.	6	2	8	14
23	Encourage bank and foreshore erosion control techniques that maximise the use of riparian and estuarine vegetation.	5B	4B	Bank and foreshore erosion control techniques utilising hard engineered structures may prevail, potentially leading to a net decline in habitat values.	Potential to increase the condition and extent of estuarine vegetation; improves ecological connectivity along the estuary.	5	3	8	14
24	All management authorities involved in the building, design and approval of new seawalls, or major upgrades of existing seawalls, should promote their compliance with the *Environmentally Friendly Seawalls Guidelines* (DECC and SMCMA, 2009) within legislative constraints.	6B	4D	Seawall maintenance and upgrades will be conducted as it had previously, without realising habitat creation opportunities identified in the Environmentally Friendly Seawalls Guidelines (DECC and SMCMA, 2009). This has the potential to contribute to an ongoing decline in the extent of some habitats.	Potential to increase the extent estuarine habitat, or at least reduce the rate of loss of intertidal habitat.	6	2	8	14
Human Usage and Recreation									
25	Maintain and improve existing public access (i.e. bike and walking paths) for the Parramatta River estuary to provide transport linkages throughout the LGAs, giving consideration to sensitive environmental locations.	7A	7C	At best, the network will remain as is, with the condition of paths likely to deteriorate over time without maintenance. Failure to provide alternative transport/access options (e.g. walking or bike paths) may place increased pressure on less sustainable forms of transport, such as private vehicles. 'Doing nothing' may also have implications for public health, through a failure to promote healthy exercise or reduce vehicle emissions.	Primary benefit via improved connectivity and public access and amenity. Value added benefits via reduced vehicle emissions and improved public health.	7	1	8	14
26	Repair or upgrade existing foreshore facilities identified as failing or as being in poor condition in the Estuary Processes Study (AECOM, 2010) as funding opportunities allow.	7B	-	Failing facilities can be a deterrent for human usage of the foreshore facility and its surrounds, as well a potentially a public hazard. 'Doing nothing' may result in an increase in the risk to the public and the environment from these structures over time.	Provides for improved public access and recreational amenity. Opportunity to reduce environmental impacts where they are occurring.	5	1	6	31
27	Continue to conduct surveillance and compliance monitoring with a view of removing or regularising unauthorised foreshore structures / uses.	7B	-	There is currently a range of mechanisms in place to monitor and control development along the foreshore. 'Doing nothing' will therefore not necessarily have a significant negative impact on the estuary.	Opportunity to ensure compliance with the relevant environmental controls.	1	1	2	41

Option ID	Option Description	Primary Objective Addressed	Additional Objective(s) Addressed	Potential Impacts of Not Implementing the Option (i.e. 'Business as Usual')	Key Advantages of Implementation	Preliminary Benefit Index (Table E.3)	Objective Prioritisation (High = 3, Medium = 2, Low = 1)	Adjusted Benefit Index	Option Rank (Blue = HIGH PRIORITY)
28	Strategically provide foreshore infrastructure to support boating in the Parramatta River estuary, with due consideration of any potential impacts on the estuary.	7B	7A, 7C	Without strategically planning boating infrastructure, the boasting infrastructure may be poorly designed, deterring boat usage in the Parramatta River estuary, or detrimentally impacting the estuary health. In addition, the opportunities to promote sustainable development of the estuary for a wide range of users would not be realised.	Potential to improve recreational access and amenity. Potential to capitalise on commercial opportunities.	6	1	7	24
29	Develop and implement an integrated approach to the provision of recreational amenity for the estuary as a whole.	7B	7A, 7C	There are a large number of residents living around the estuary, in addition to which a large number of visitors are also attracted to the area. There is therefore a need to manage recreation on a regional basis. If this is not undertaken, the recreational needs of the community may not be met, which could result in increasing levels of conflict between users, lost opportunity for sustainable development, and increasing pressure on the environment.	Potential to improve recreational amenity while also reducing any negative impacts on the environment.	7	1	8	14
30	Provide viewing points and interpretive signage at appropriate locations to promote an appreciation of the estuary and enhance the visitor experience.	7B	7C	Public enjoyment and awareness of the estuary and the natural environment will not be improved. Opportunities to promote the estuary or educate the community will not be realised.	Potential to improve public enjoyment and awareness of the estuary and the natural environment.	6	1	7	24
31	Work with the key stakeholders to develop and implement a vision for the Parramatta River estuary that delivers world-class facilities for both residents and visitors. The vision should recognise the regional, State and Federal significance of the Parramatta River as an iconic waterway.	7C	-	There is a need for a regional approach to management of the estuary as a resource for both the local community and visitors. This will require significant resources to implement and if not supported by all stakeholders, may not be realised.	Being situated within Port Jackson, one of the most populous and heavily visited harbours in Australia, there is significant opportunity to promote sustainable development.	5	1	6	31
32	Work together to develop and implement a program for industry and the community to raise awareness of issues relating to estuary management and estuarine health. Key elements of the program could include: - Good catchment management practices; - The heritage significance of the estuary and its foreshores; - The types of activities that are permitted, or are not permitted, in different parts of the foreshore or waterway; - The use of vegetation for bank and foreshore protection works; - The potential impacts of climate change on the estuary; & - How individuals can reduce their impact on the estuary.	2B	4A, 9B	Community awareness will not be increased, and the current level of impact from activity in the catchment will continue.	Opportunity to raise community awareness and promote good practice. Potential to reduce impacts on estuarine health.	8	3	11	2
Monitoring, Evaluation and Reporting									
33	Develop and implement a communication strategy for the implementation stage of the Parramatta River Estuary CZMP.	8A	-	The opportunity to raise awareness about estuary management processes and issues would not be realised. There would potentially be a lack of accountability for resources directed to estuary management.	Opportunity to promote estuary management, educate the community about estuary issues, and attract people to the estuary.	6	3	9	7
34	Develop and implement a holistic and rigorous monitoring program that coordinates the efforts of the various stakeholders responsible for management of the Parramatta River estuary and includes monitoring of climate change impacts.	8A	-	It will be difficult to quantitatively represent the estuarine health/condition, establish baseline conditions, or make comparisons of changes over time. Without this information it may not be possible to assess the success of implementation of the CZMP, measured against the management objectives.	Opportunity to establish a baseline and track trends in estuarine health. This may also enable comparison against similar systems. Promotes holistic and coordinated adaptive management.	7	3	10	4
35	Encourage DPI (Fisheries) to periodically map the distribution of estuarine vegetation (seagrass, saltmarsh and mangroves) for the estuary.	8A	4A	Mapping of estuarine vegetation has previously been undertaken by DPI (Fisheries), and will likely continue in the future. However, if not encouraged by the Committee, the frequency that this monitoring occurs may not be sufficient to inform management.	Opportunity to track trends in estuarine vegetation and promote adaptive management.	2	3	5	34

Option ID	Option Description	Primary Objective Addressed	Additional Objective(s) Addressed	Potential Impacts of Not Implementing the Option (i.e. 'Business as Usual')	Key Advantages of Implementation	Preliminary Benefit Index (Table E.3)	Objective Prioritisation (High = 3, Medium = 2, Low = 1)	Adjusted Benefit Index	Option Rank (Blue = HIGH PRIORITY)
Coastal Hazards									
36	Within the regular program of upgrades, provide additional capacity in the stormwater network to account for changes in rainfall patterns and elevated estuary water levels under climate change conditions.	10A	-	This is unlikely to have a significant impact in the short term. It will become more of a problem into the future under climate change conditions.	Provides for ongoing functionality of the stormwater system under climate change. It may be more economical and efficient to do these works progressively over time.	2	2	4	36
37	Restrict new foreshore developments in areas where tidal inundation hazards under current and future SLR scenarios are quantified.	10A	-	This is unlikely to have a significant impact in the short term. However, 'doing nothing' will become more of a problem into the future, particularly if development is undertaken in areas likely to be impacted by SLR, which would represent a risk to public safety and infrastructure.	Reduces risk to development from coastal hazards, but primarily in the long term. Provides for accommodation of intertidal communities.	2	2	4	36
38	Manage foreshore infrastructure with likely tidal inundation risk in such a way as to allow adaptation to SLR.	10A	7B	This is unlikely to have a significant impact in the short term. However, 'doing nothing' will become more of a problem into the future, particularly if infrastructure is provided in unsuitable locations, or is not sufficiently flexible to be adapted to climate change impacts, which would represent a risk to public safety and environmental health (i.e. if the structure fails).	Reduces long term risk to public and environmental health and safety. Promotes sustainable and adaptive development.	2	2	4	36
39	Assess the potential impacts of SLR on the estuary foreshores.	10A	9B	This is unlikely to have a significant impact in the short term. However, 'doing nothing' will mean that there is not sufficient information available to inform long term planning.	Provides information to assist strategic, long term planning of the estuary foreshores and waterway.	7	2	9	7
40	Identify cultural heritage sites that are currently affected by coastal hazards, or that may be affected by coastal hazards under climate change conditions, and develop appropriate management responses to address these issues.	9A	-	Impacts are limited in the short term impact. Under climate change conditions, however, 'doing nothing' may result in the deterioration or loss of heritage sites.	Provides for ongoing protection of heritage sites/values.	4	1	5	34

.

Appendix F

Action List Grouped Under Options

This Appendix provides an unranked list of all the actions grouped according to the relevant option in Tables F.1 and F.2. Note that only the 67 prioritised management actions are included here, as the 16 generic actions have not been prioritised and costed in the same manner.

Table F.1: Actions Grouped According to Relevant Option (Actions Assessment for Benefit Index)

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
Land Use Planning and Development: New and revised Plans of Management should be compatible and consistent with the recommendations of the Parramatta River Estuary CZMP. Primary Objective Addressed: 1A												
1_COM01	Encourage the development or review of Plans of Management for all fresh water and saltwater wetlands in the PRCG area, focusing initially on high and medium priority wetlands identified in the HNCMA Wetlands Prioritisation process in the PRCG area, specifically: - Newington Nature Reserve Wetland (*Plan of Management for Newington Nature Reserve*, 2003), - Bicentennial Park (*Plan of Management for The Parklands at Sydney Olympic Park*, 2010), and - Upper Duck River 1 and 2 (*Upper Duck River Riparian and Wetland Plan of Management* - funded by HNCMA and to be completed 2012).	Committee SOPA, Auburn City Council	Catchment-wide	Planning	1	-	0	Action relates to updating a Plan and no on the ground works proposed, therefore, no tenure constraints.	1	Habitat protection and management identified as a high priority in the community survey.	3	5
1_HUN1	Implement the *Stormwater Management Action Plan* currently being prepared for Hunter's Hill Council consistent with the Parramatta River Estuary CZMP and review the maintenance regimes for stormwater infrastructure to ensure existing infrastructure is maintained regularly. This Action Plan will identify sites for stormwater infrastructure improvements / upgrades, additional GPTs and/or other stormwater quality controls in various locations, including Tarban Creek.	Hunters Hill Council	Hunters Hill LGA	Works	1	-	-1	Approvals and/or landowner consent, licenses and permits required from various stakeholders. Located in an RNE area.	2	Stormwater management activities strongly supported in survey.	3	5
1_STR1	Review and update the Plans of Management for Mason and Bressington Park to incorporate consideration of the impacts of SLR on vegetation.	Strathfield Council	Strathfield LGA	Planning	1	-	0	Involves development of a Plan. No on the ground works involved.	0	Survey respondents support habitat management/protection, but also highly value public access.	3	4
Land Use Planning and Development: When undertaking reviews of planning instruments or engaging in strategic land use planning, seek consistency with the Parramatta River Estuary CZMP and, where possible, update the relevant instrument as required. Primary Objective Addressed: 1A												
2_COM02	Consult with the NSW Department of Planning and Infrastructure to develop a model LEP clause for inclusion into the statutory planning framework that provides for consideration of issues such as foreshore building lines, riparian setbacks and public access. Encourage inclusion by Councils into their standard instrument LEPs.	Committee	Catchment-wide	Planning	2	Has potential to provide significantly improved outcomes.	0	-	0	Survey indicates support by wider community, but affected landowners may be less supportive.	3	5
2_CAN1	Liaise with the NSW Government to progress the remediation of Kendall Bay and others and seek appropriate rezoning to W2 - Environmental Protection Zone.	City of Canada Bay	Kendall Bay	Comms	1		-1	Maritime land - Landowner consent required from RMS (Maritime)	1	Contamination issues are of significant concern to the community.	3	4
Land Use Planning and Development: Develop provisions under Development Control Plans that provide for the incorporation of best practice WSUD and ecological connectivity along the estuary foreshores for sites subject to re-development. Primary Objective Addressed: 2E												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
4_COM03	In consultation with the NSW Department of Planning and Infrastructure, develop model DCP clauses for more specific aspects of estuarine management, such as: - Environmentally friendly seawalls; - Site-based WSUD; - Stormwater retention, harvesting and re-use; - Foreshore inundation/flooding (including from SLR); - Biodiversity corridors and habitat conservation; - Public access; and - Riparian setbacks. Encourage inclusion by local Councils in their DCPs.	Committee OEH, HNCMA	Catchment-wide	Planning	2	-	0	-	0	Survey indicates support by wider community, but affected landowners may be less supportive.	3	5
Water and Sediments: Retrofit appropriate WSUD features in existing urban areas of the catchment targeting locations upstream from where stormwater runoff and associated pollutants are impacting sensitive estuary locations. Primary Objective Addressed: 3A												
7_SYD1	Investigate the potential for installing additional stormwater quality improvement devices (SQIDs) to provide improved treatment of stormwater flows entering the estuary at the 11 locations indicated, within the following stormwater channels: - SWC 92 Tarban Creek - SWC 55 Johnsons Creek - SWC 62 Hawthorne Canal - SWC 53 Dobroyd - SWC 50 Powells Creek - SWC 13 Haslams Creek - SWC 86 Sefton Park - SWC 27 Clay Cliff Creek - SWC 42 Finalysons Creek.	Sydney Water	Catchment-wide	Works	1	-	-1	Landowner consent likely to be required.	2	Stormwater management activities strongly supported in survey.	3	5
7_RYD1	Investigate the potential for installing irrigation and bioretention systems at Anzac Park in West Ryde to provide improved treatment of stormwater flows entering the estuary from the site.	City of Ryde	West Ryde	Works	1	-	-1	Crown land - landowner consent required.	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	4
7_RYD2	Investigate the potential for installing irrigation and bioretention systems at Peel Park in Gladesville to provide improved treatment of stormwater flows entering the estuary from the site.	City of Ryde	Gladesville	Works	1	-	0	Council owned land?	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	5
7_AUB1	Investigate the installation of a GPT or WSUD feature within Mona Park, Auburn, to treat stormwater discharging into Duck River.	Auburn City Council	Auburn	Works	1	-	-1	Partially Crown land - landowner consent may be required.	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	4
7_LEI1	Improve the quality of stormwater flows by providing GPTs or other WSUD features as part of stormwater harvesting schemes, to include the installation of a GPT at Birchgrove Oval.	Leichhardt Municipal Council	Leichhardt LGA	Works	1	-	-1	Landowner consent likely to be required.	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	4

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
7_LEI2	Improve the quality of stormwater flows by converting a stormwater detention basin collecting runoff from the City West Link into a constructed wetland system at Blackmore Park.	Leichhardt Municipal Council	Leichhardt LGA	Works	1	-	-1	RMS land - Landowner consent required.	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	4
7_RYD3	Investigate the potential for installing a SQID at Meadowbank Lane, Meadowbank.	City of Ryde	Meadowbank	Works	1	-	1	Council owned land.	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	6
Water and Sediments: Modify, upgrade or repair existing SQIDs, stormwater infrastructure and management practices as required to maintain or improve their effectiveness. This should include development of maintenance schedules for existing infrastructure where they are not currently in place. Primary Objective Addressed: 2B												
8_PAR1	Investigate the efficacy of existing water quality controls and review maintenance regimes for stormwater infrastructure across the Parramatta LGA.	Parramatta City Council	Parramatta LGA	Investigation	1	-	0	-	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits. In addition, doesn't provide for construction of new features.	3	5
8_COM04	Liaise with RMS (Maritime) to encourage the ongoing collection of gross pollutants from the estuary waterway.	Committee	Waterway-wide	Comms	1	-	0	-	2	Stormwater management activities strongly supported in survey.	3	6
8_ASH1	In conjunction with Leichhardt Municipal Council, City of Canada Bay and Sydney Water undertake a critical review of existing stormwater management practices to determine: - The efficacy of maintenance regimes of existing GPTs, and - Identify locations where additional gross pollutant trapping is required. Include a review of current street sweeping activities in catchment areas draining to Iron Cove Bay, given that the dominant gross pollutant evident is leaf litter. Reference should be made to AECOM (2010) for further discussion of the issues relevant to this action.	Ashfield Council Leichhardt Municipal Council, City of Canada Bay, Sydney Water	Iron Cove Catchment	Investigation	1	-	-1	Likely to require negotiation with asset owners and landowner consent, as well as coordination with other LGAs that drain to Iron Cove Bay.	1	Stormwater management activities strongly supported in survey, however, this action has more localised benefits.	3	4
8_SOP1	Provide support to the relevant asset owner(s) in prioritising stormwater maintenance and upgrade works, including gross pollutants and sediment control measures, so as to reduce impacts on sensitive habitats within Sydney Olympic Park.	SOPA	Sydney Olympic Park	Comms	1	-	0	-	1	Survey identified support for stormwater and habitat management activities, however, the benefits of this action are more localised.	3	5
8_CAN2*	Develop and commence a staged implementation program from the City of Canada Bay Stormwater Drainage Asset Management Plan. The implementation program should incorporate activities that aim to reduce the potential impacts of climate change and SLR on stormwater drainage.	City of Canada Bay	City of Canada Bay	Planning	1	-	-1	Approvals and/or landowner consent, licenses and permits required from various stakeholders. May fall in RNE area.	2	Stormwater management activities supported in survey.	3	5
Water and Sediments: Work with Sydney Water to prioritise maintenance and upgrade of the sewerage network within the catchment on an ongoing basis to reduce sewage overflows. This activity should include investigations into the incidence of illegal private connections to the sewerage and / or stormwater network. Primary Objective Addressed: 2C												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
9_SOP2*	Provide support to Sydney Water in prioritising works to address sewer overflows affecting estuarine wetlands within Bicentennial Park.	SOPA Sydney Water	Bicentennial Wetlands	Comms	1	-	0	-	1	Survey identified support for stormwater and habitat management activities, however, the benefits of this action are more localised.	3	5
Water and Sediments: Reduce sediment inputs through bank stabilisation works in estuary tributaries. Primary Objective Addressed: 2B												
10_COM05	Councils and the Committee should liaise with the HNCMA to prioritise and implement bank stabilisation works, focusing on upper catchment areas, based on the findings of the HNCMA's *Waterways Health Strategy* (EarthTech, 2007). The following recommendations from the Strategy are based on a desktop study only and must be ground-truthed prior to implementation: 1) Revegetate riparian zone, particularly focusing on riverbank stabilisation through revegetation for the Parramatta River main channel left hand bank between the confluence with Duck River downstream to the eastern extent of George Kendall Riverside Park, 2) Revegetate riverbanks and riparian zone on both banks of the Girraween Creek (between Great Western Highway and the western Railway line), 3) Revegetate riverbanks and riparian zone on both banks of the Lalor Creek (between M7 to confluence with Blacktown Creek), and 4) Revegetate riverbanks and riparian zone along the whole creek length of Archer Creek.	Committee	Catchment-wide	Works	1	-	-1	Likely to require landowner consent and liaison with various authorities.	1	Survey indicates moderate level of support for bank stabilisation works.	3	4
10_AUB2	Undertake bank stabilisation works with natural materials and vegetation in Duck River, along approximately a 20-30m reach adjacent to the Auburn Botanic Gardens and approximately a 50m reach adjacent to Mona Park.	Auburn City Council	Duck River	Works	1	-	-1	Part of park is Crown land - landowner consent may be required.	1	Survey indicates moderate level of support for bank stabilisation works; localised action.	3	4
Estuarine Ecology: Develop and implement a strategy for the coordinated management of estuarine and riparian biodiversity across administrative boundaries for the estuary as a whole. The strategy should incorporate biodiversity corridors and SLR consideration, to ensure the ongoing provision of habitat and connectivity between habitat areas. Primary Objective Addressed: 4A												
11_COM06	Support the PRCG Biodiversity Sub-Committee to develop a biodiversity corridors strategy for the Parramatta River catchment area. Work with State agencies and other stakeholders for this Strategy to be recognised within planning and development frameworks including LEPs and DCPs, DA assessments and Plans of Management. Encourage on-ground rehabilitation works undertaken within these areas to support the biodiversity corridors concept.	Committee	Catchment-wide	Planning	2	-	0	Involves development of a Plan. No on the ground works involved.	0	Survey indicates support by wider community, but affected landowners may be less supportive.	3	5
Estuarine Ecology: Minimise impacts of moorings and boating on seagrass. Primary Objective Addressed: 4A												
12_MAR1*	Subject to further investigation, consider the reconfiguration of moorings where they are impacting on (or have the potential to impact on) seagrass beds. This action should be informed by the *Estuary Processes Study* (AECOM, 2010).	RMS (Maritime)	Waterway-wide	Works	1	-	0	-	0	Some survey respondents are concerned about impacts on seagrass, but others may be concerned about impacts on access on the waterway.	3	4
Estuarine Ecology: Manage public access at environmentally sensitive foreshore locations. Priority areas may include key habitat and vegetation communities located in areas that are frequented by the public. Primary Objective Addressed: 4A												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
13_STR2	Manage public access and/or off-leash dog walking near the Mason Park wetlands. Managing public access may involve formalising a walking trail, prohibiting access or installing signage to indicate appropriate activities.	Strathfield Council	Mason Park	Works	1	-	-1	May require landowner consent, depending upon the final proposal.	0	Survey respondents support habitat management/protection, but also highly value public access.	3	3
Estuarine Ecology: Undertake improvements to foreshore infrastructure where possible to reduce their impacts on aquatic habitats. Consider the need, where feasible, to relocate or decommission infrastructure where it is impacting on environmentally sensitive locations. Primary Objective Addressed: 4A												
16_SYD2	Ensure that new stormwater infrastructure is designed to appropriately mitigate the impacts of scour on estuarine habitats.	Sydney Water	Catchment-wide	Comms	1	-	0	-	1	Survey respondents support habitat management/protection, but benefits likely to be fairly localised.	3	5
16_MAR2	Endorse the use of environmentally friendly moorings in the Parramatta River estuary.	RMS (Maritime)	Waterway-wide	Comms	1	-	0	-	0	Some survey respondents are concerned about impacts on seagrass, but others may be concerned about impacts on access on the waterway.	3	4
16_SOP3	Seek external funding for priority works to restore tidal exchange and stormwater flows within Sydney Olympic Park sections of Haslams Creek and Powells Creek.	SOPA	Sydney Olympic Park	Works	1	-	-1	Likely to require landowner consent.	1	Survey identified support for habitat enhancement activities, however, the benefits of this action are more localised.	3	4
Estuarine Ecology: Undertake works to provide for the ongoing preservation of estuarine and riparian habitats under climate change conditions. This should include the enhancement of existing habitats where there is possibility of retreat, or establishing additional habitat areas as required, to maximise habitat under SLR conditions. Primary Objective Addressed: 4A												
17_COM07	Work with local Councils and other land managers that are responsible for developing and implementing Plans of Management to ensure that they provide for the landward retreat (where feasible) of all significant saltmarsh, swamp oak floodplain forest and mangrove communities. Issues to be addressed in the Plans of Management include the protection and enhancement of the communities, and provision for areas for landward retreat.	Committee	Catchment-wide	Planning	2	-	0	Involves development of a Plan. No on the ground works involved.	0	Some division over climate change, primarily in relation to impacts on development and whether it needs to be addressed now or not.	3	5
17_HUN2	Provide for the ongoing monitoring, conservation and management of estuarine vegetation and adequately address stormwater / sewage issues in Tarban Creek (in Riverglade Reserve).	Hunters Hill Council	Tarban Creek	Monitoring	1	-	-1	Crown land - landowner consent required. Within RNE area.	1	Survey identified support for stormwater and habitat management activities, however, the benefits of this action are more localised.	3	4
17_HUN3	Undertake management of estuarine vegetation within Gladesville Reserve and Riverglade Reserve to enhance saltmarsh habitats in these areas and allow for future landward migration with SLR.	Hunters Hill Council	Gladesville Reserve, Riverglade Reserve	Works	1	-	-1	Crown land - landowner consent required. Within RNE area.	1	Survey respondents support habitat enhancement; the benefits of this action are fairly localised.	3	4
17_STR3	Provide for the ongoing monitoring, conservation and management of saltmarsh, swamp oak floodplain forest and mangrove communities in the Mason Park wetlands to enhance estuarine habitats in these areas and allow for their future landward migration with SLR (e.g. weed control).	Strathfield Council	Mason Park	Planning	1	-	0	Unlikely to require landowner consent.	1	Survey respondents support habitat enhancement; the benefits of this action are fairly localised.	3	5

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
17_SOP4	Undertake management of swamp oak floodplain forest and mangroves within Sydney Olympic Park to enhance respective habitats, including saltmarsh habitats, and allow for their future landward migration with SLR.	SOPA	Sydney Olympic Park	Planning	1	-	0	Unlikely to require landowner consent.	1	Survey respondents support habitat enhancement; the benefits of this action are fairly localised.	3	5
17_LEI3	Liaise with the State Government to identify potential rehabilitation and habitat management opportunities for incorporation in the re-development of Callan Park, including provision for potential impacts of climate change.	Leichhardt Municipal Council	Callan Park	Comms	1	-	0	No on the ground works proposed.	1	Some division over climate change, however, local community likely to be supportive of any initiatives that enhance habitat, access and recreational opportunities.	3	5
17_CAN3	Undertake enhancement of estuarine vegetation as a stabilisation method in areas of erosion, and to protect existing seawalls from further erosion. Locations as identified in the *Estuary Processes Study* (AECOM, 2010) include: Hen and Chicken Bay, Sisters Bay, Half Moon Bay, Five Dock Bay and Iron Cove Bay.	City of Canada Bay	City of Canada Bay	Works	1	Falls in RNE area.	0	Unlikely to requite landowner consent. Some minimal liaison may be required.	1	Survey respondents support habitat enhancement and are concerned about erosion; the benefits of this action are likely to be fairly localised.	3	5
Estuarine Ecology: Manage identified public foreshore areas where they are required for the retreat of estuarine vegetation in response to SLR. Primary Objective Addressed: 4A												
18_PAR2	If possible, purchase land upslope of the Baludarri Wetlands and Eric Primrose Reserve, to allow for landward migration of the ecosystems at this location caused by the long term effects of SLR.	Parramatta City Council	Parramatta LGA	Planning	1	-	-1	Both located on Reserves (Crown land) and require landowner consent.	0	Survey respondents divided over climate change, although response would be more positive if there are value added benefits for access and recreation.	3	3
Estuarine Ecology: Undertake creek naturalisation works of existing channelised creeks, focusing as a priority on channels coming to the end of their design life. Primary Objective Addressed: 4B												
19_STR4	Undertake naturalisation of approximately 150m of the western wall of Boundary Creek, south from the end of Mandemar Avenue, Homebush West, if investigations indicate this is feasible.	Strathfield Council	Homebush West	Works	1	-	-1	May require landowner consent.	1	Survey respondents support naturalisation works; relatively localised in extent.	2	3
19_SYD3	Investigate the potential for channel naturalisation of the following five channels as they require asset renewal and/or replacement: - SWC 50 Powells Creek - SWC 18 Brickfield Creek - SWC 53 Dobroyd - SWC 90 St Lukes Park - SWC 95 Whites Creek. Any future channel naturalisation projects would be subject to feasibility studies and landowner consent.	Sydney Water	Catchment-wide	Works	1	-	-1	Landowner consent likely to be required.	2	Survey respondents supportive of naturalisation works.	2	4
19_SYD4	In consultation with Strathfield Council and the City of Canada Bay, consider the addition of tide gates along Powells Creek to increase the flushing of the Mason Park wetlands, subject to feasibility studies. If Powells Creek stormwater channel (SWC 50) is to be naturalised these works should occur concurrently, if possible and subject to feasibility studies.	Sydney Water Strathfield Council, City of Canada Bay	Mason Park	Works	1	-	-1	Landowner consent likely to be required.	1	Survey identified support for habitat enhancement activities, however, the benefits of this action are more localised.	2	3
Estuarine Ecology: Undertake ongoing monitoring and management of aquatic and terrestrial weeds (incl. noxious weeds) and introduced species (both flora and fauna). Primary Objective Addressed: 4C												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
20_HUN4	Continue bush regeneration in all reserves of the Parramatta River estuary catchment located within Hunters Hill LGA, including undertaking the following recommendations made in the *Estuary Processes Study* (AECOM, 2010): - Targeted vine control and removal of young Phoenix palms, Coral trees and Green Cestrum within the upper tidal reach of Tarban Creek; - Control of emerging mangrove saplings in saltmarsh located within Gladesville Reserve; - Ongoing monitoring and management of Alligator Weed in Betts Park and Gladesville Reserve; and - Gradual removal of large Camphor Laurels in Betts Park and replacement with native species.	Hunters Hill Council	Hunters Hill LGA	Works	1	Action lies within a RNE area.	-1	Crown land - landowner consent required.	2	Survey indicates support for habitat enhancement, provided it is implemented strategically.	2	4
Estuarine Ecology: Improve the environmental value of existing seawalls through the addition of habitat, where feasible. Primary Objective Addressed: 4D												
21_PAR3	As seawalls in the Parramatta LGA need to be repaired or upgraded this should be done in compliance with the DECC and SMCMA (2009) *Guidelines for Environmentally Friendly Seawalls* and should incorporate habitat creation opportunities wherever possible. Note: at the time of writing of this report all Parramatta Council owned seawalls have been repaired to "good" standard. However, some funds will be required annually to inspect and repair these seawalls into the future.	Parramatta City Council	Parramatta LGA	Works	1	-	-1	Likely to require landowner consent.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; localised in extent.	1	2
21_ASH2	Utilise data collected for all seawalls, including referenced site photographs, as a benchmark for ongoing monitoring and in particular continue to monitor the seawall identified in AECOM (2010) as ASH_S03 for any decrease in structural stability. Include intertidal habitat, such as artificial reefs, in the eventual repair and / or replacement of seawalls.	Ashfield Council	Haberfield	Monitoring	1	Action lies within a RNE area.	-1	Works footprint will incorporate RMS (Maritime) land - Landowner consent required.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; localised in extent.	1	2
21_LEI4	Upgrade and/or repair the sections of seawall identified as being poor condition and of high priority in the *Estuary Process Study* (AECOM, 2010). Continue to monitor the condition of other seawall sections identified in the *Estuary Process Study* (AECOM, 2010) for any decrease in structural stability. Incorporate potential habitat opportunities into seawall designs and/or upgrades. This will include the advancement of knowledge through: -Contributing research into seawall habitat and -Carrying out further research into retrofitting habitat to seawalls.	Leichhardt Municipal Council	Leichhardt LGA	Works	1	-	-1	Landowner consent likely to be required.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; localised in extent.	1	2
21_CAN4	Develop and commence a staged implementation program from the *City of Canada Bay Estuary Foreshore Management Strategy* to include environmentally friendly seawalls as key options for seawall and foreshore management, where reasonable and feasible. Continue to monitor the condition of seawall sections identified in the *Estuary Processes Study* (AECOM, 2010) and prioritise in accordance with the *City of Canada Bay Asset Management Plan* (2010) to ensure structural integrity. As a priority, repair and/or upgrade existing seawall sections along Abbotsford Bay (CAN_S28) and Five Dock Bay (CAN_S23).	City of Canada Bay	City of Canada Bay	Works	1	Falls in RNE area.	-1	Likely to require landowner consent for some works.	2	Survey indicates support for improving quality of infrastructure and habitat enhancement; larger extent of foreshore.	1	3

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
21_RYD4	Upgrade and / or repair the following four sections of seawall identified as being in poor condition and of a high priority in the *Estuary Processes Study* (AECOM, 2010) and seek to incorporate additional vegetated habitat in the design, subject to available funding: RYD-S06, RYD-S11, RYDS03 and RYD-S23. Continue to monitor the condition of other seawall sections identified in the *Estuary Processes Study* (AECOM, 2010) for any decrease in structural stability.	City of Ryde	City of Ryde	Works	1	-	-1	Seawall section falls on the boundary on RMS (Maritime) land - Landowner consent required.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; localised in extent.	1	2
Bank Condition: Formally negotiate with Harbour City Ferries for a change in vessel (from the RiverCat) that would have less wake impacts. Primary Objective Addressed: 5A												
22_COM08	In order to mitigate the impacts of the RiverCat on seawalls, bank condition and fringing vegetation along large sections of the shoreline, open the dialogue and formally negotiate with Harbour City Ferries for a change in vessel that has lower vessel wake impacts.	Committee	Waterway-wide	Comms	1	-	0	No on the ground works proposed.	2	This was a particular issue that was raised repeatedly by respondents to the survey.	2	5
22_COM09	Liaise with Harbour City Ferries on opportunities to mitigate the impact of RiverCat wash on the foreshore and, where feasible, rehabilitate impacted areas.	Committee	Waterway-wide	Comms	1	-	0	No on the ground works currently proposed.	2	This was a particular issue that was raised repeatedly by respondents to the survey.	2	5
Bank Condition: Encourage bank and foreshore erosion control techniques that maximise the use of riparian and estuarine vegetation. Primary Objective Addressed: 5B												
23_COM10	Collate and distribute guidelines to Councils and foreshore landowners on best practice bank and foreshore erosion control and rehabilitation techniques that promote the use of riparian and estuarine vegetation.	Committee	Catchment-wide	Comms	1	-	0	No on the ground works proposed.	0	Some division over climate change, but may be supported where it provides value added benefits for access and recreation.	3	4
23_CAN5	Repair and/or upgrade sections of seawall, natural shoreline and adjacent affected infrastructure around Iron Cove, including the following sections identified in the *Estuary Processes Study* (AECOM, 2010), avoiding the use of artificial structures where reasonable and feasible: CAN_S03, CAN_S04, CAN_S06, CAN_NS01 and CAN_NS02. Seawall upgrades should, where possible, be designed in accordance with the DECC and SMCMA (2009) *Guidelines for Environmentally Friendly Seawalls*.	City of Canada Bay	Iron Cove Bay	Works	1	Falls in RNE area.	-1	Likely to require landowner consent for some works.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; localised in extent.	3	4
23_RYD5	Rehabilitate the following two sections of eroding foreshore identified as being of a high priority and in poor condition in the *Estuary Processes Study* (AECOM, 2010), subject to available funding: - RYD-NS07 (Kissing Point Park, Putney), and - RYD-NS13 (Meadowbank, adjacent to rail bridge).	City of Ryde	City of Ryde	Works	1	-	-1	Landowner consent likely to be required.	1	Survey indicates support for improving foreshore condition; localised in extent.	3	4
Bank Condition: All management authorities involved in the building, design and approval of new seawalls, or major upgrades of existing seawalls, should promote their compliance with the Environmentally Friendly Seawalls guideline (DECC and SMCMA, 2009) within legislative constraints. Primary Objective Addressed: 6B												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
24_HUN5	Disseminate the *Guidelines for Environmentally Friendly Seawalls* (DECC and SMCMA, 2009) to council staff, particularly those involved in the assessment of Development Applications, to encourage the promotion of the guidelines. This should be undertaken on a regular basis so as to ensure new staff are familiar with the guidelines. Make sure the planned repairs to the following seawalls comply with the guidelines wherever possible: HUN_S01, HUN_S04 and HUN_S07.	Hunters Hill Council OEH	Hunters Hill LGA	Comms	1	Action lies within a RNE area.	-1	RMS (Maritime) land - Landowner consent required.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; however, may impact some property owners.	2	3
24_MAR3	Liaise with the Department of Planning and Infrastructure to include reference to the *Guidelines for Environmentally Friendly Seawalls* (DECC and SMCMA, 2009) as part of the *Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005* review.	RMS (Maritime) OEH	Waterway-wide	Planning	2	-	0	-	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; however, may impact some property owners.	2	5
24_LEI5	Provide information to Council staff on the DECC and SMCMA (2009) *Guidelines for Environmentally Friendly Seawalls* to promote their usage within the LGA.	Leichhardt Municipal Council OEH, HNCMA	Leichhardt LGA	Comms	1	-	0	No on the ground works proposed.	1	Survey indicates support for improving quality of infrastructure and habitat enhancement; however, may impact some property owners.	2	4
Human Usage and Recreation: Maintain and improve existing public access (i.e. bike and walking paths) for the Parramatta River estuary to provide transport linkages throughout the LGAs, giving consideration to sensitive environmental locations. Primary Objective Addressed: 7A												
25_COM11	Liaise with Harbour City Ferries and the RMS to encourage them to incorporate environmentally friendly features into their designs for new (or upgraded) ferry wharf access ways and bike paths (respectively). As part of the design and site selection process, due consideration should be given to the protection and enhancement of riparian zones, biodiversity corridors and estuarine vegetation.	Committee	Catchment-wide	Comms	1	-	0	No on the ground works proposed.	2	Survey indicates support for improving quality of infrastructure and habitat enhancement.	1	4
25_COM12	Coordinate the efforts of the relevant local Councils (Parramatta, City of Ryde and Hunters Hill) to extend the Parramatta Valley Cycleway Shared Path to the end of the Parramatta River estuary (near Cockatoo Island).	Committee Parramatta City Council, City of Ryde, Hunters Hill Council	Catchment-wide	Comms	1	-	0	No on the ground works proposed.	2	Survey results indicate access is highly valued.	1	4
25_PAR4	Improve public access along the foreshore by investigating the feasibility of Shared Paths. A shared pedestrian and cycle bridge connecting Morton St and Alfred St, Parramatta, and a Shared Path from Pike St to South St have been previously identified as being high priority.	Parramatta City Council	Parramatta LGA	Works	1	-	-1	Likely to require landowner consent.	1	Survey results indicate access is highly valued; however, limited in extent.	1	2
25_PAR5	Facilitate the incorporation of public access into new and existing developments with due consideration of sensitive estuarine environments and ecological values.	Parramatta City Council	Parramatta LGA	Planning	1	-	0	-	1	Survey results indicate access is highly valued; somewhat localised in extent.	1	3
25_STR5	Seek to improve public access linkages to and along the estuary foreshores by preparing a draft pedestrian / cycleway plan that takes into consideration existing and proposed infrastructure in the Strathfield LGA. As a priority activity under the CZMP, undertake works along Powells Creek to improve cycleway connectivity with public transport.	Strathfield Council	Strathfield LGA	Works	1	-	-1	Likely to require landowner consent.	1	Survey results indicate access is highly valued; somewhat localised in extent.	1	2
Human Usage and Recreation: Develop and implement an integrated approach to the provision of recreational amenity for the estuary as a whole. Primary Objective Addressed: 7B												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
29_COM13	Address recreational needs across the catchment in a two-step process as follows: 1) Conduct a recreational needs analysis that incorporates the DP&I's Accessing Sydney Harbour Policy and RMS (Maritime)'s Better Boating Policy, and 2) Develop and implement a strategy for the integrated management of recreational amenity across administrative boundaries for the estuary as a whole, giving consideration to: - The need to maintain and improve access and address safety issues (e.g. installation of safety barriers where appropriate); - Liaison between local Councils; and - Identification of priorities for management.	Committee	Catchment-wide	Planning	1	-	0	No on the ground works proposed.	2	Equity and quality of recreational amenity is of high importance to the community.	1	4
29_MAR4	Continue to encourage infrastructure improvements for recreational boating facilities through the Better Boating Program.	RMS (Maritime)	Waterway-wide	Planning	1	-	0	-	0	Survey indicates there is some division over the level of service for the boating community.	1	2
Human Usage and Recreation: Work together to develop and implement a program for industry and the community to raise awareness of issues relating to estuary management and estuarine health. Key elements of the program could include: - Good catchment management practices; - The heritage significance of the estuary and its foreshores; - The types of activities that are permitted, or are not permitted, in different parts of the foreshore or waterway; - The use of vegetation for bank and foreshore protection works; - The potential impacts of climate change on the estuary; and - How individuals can reduce their impact on the estuary. Primary Objective Addressed: 2B											
32_COM14	Develop and implement an education strategy targeting key groups, such as school groups and foreshore landowners. Where possible use existing educational materials, such as the: - PRCG's program *Growers for Greenspace,* which aims to promote the protection and enhancement of biodiversity corridors; or the - *Guidelines for Environmentally Friendly Seawalls* (DECC and SMCMA, 2009), which could be provided to foreshore landowners submitting applications for new seawalls or seawall upgrades.	Committee	Catchment-wide	Comms	1	-	0	No on the ground works proposed.	1	Community generally supportive of habitat enhancement.	3	5
32_COM15	Continue to coordinate the provision and maintenance of educational and prohibited activities signage at appropriate locations around the estuary by the local councils.	Committee	Catchment-wide	Comms	1	-	0	No on the ground works proposed.	1	Community generally supportive of habitat enhancement and identified signage as an opportunity to promote estuarine features.	3	5
Monitoring, Evaluation & Reporting: Develop and implement a communication strategy for the implementation stage of the Parramatta River Estuary CZMP. Primary Objective Addressed: 8A												

Action ID	Action Description	Primary Responsibility Supporting Organisation	Location(s)	Management Category	Statutory Framework Compatibility	Statutory Framework Compatibility Comments	Tenure Constraints	Tenure Constraints Comments	Likely Community Acceptance	Likely Community Acceptance Comments	Management Option Score	Benefit Index
33_COM16	Develop and implement a communication strategy utilising the PRCG website for the implementation stage of the Parramatta River Estuary CZMP to update the general public each time an action is being progressed or is completed. Encourage all organisations on the Committee to provide links on their web pages and in regular publications (i.e. newsletters) to the PRCG website, with a view to promoting the estuary and disseminating information about the progress of the CZMP.	Committee	N/A	Comms	1	-	0	No on the ground works proposed.	2	The community has expressed interest in the study and a desire to obtain more information.	3	6
Monitoring, Evaluation and Reporting: Develop and implement a holistic and rigorous monitoring program that coordinates the efforts of the various stakeholders responsible for management of the Parramatta River estuary and includes monitoring of climate change impacts. Primary Objective Addressed: 8A												
34_COM17	Implement an estuarine health monitoring program for the Parramatta River estuary in accordance with the recommendations of the CZMP, and the requirements of the NSW MER Strategy, that coordinates the monitoring activities undertaken by the various stakeholders, including the *Sydney Harbour Catchment Water Quality Improvement Plan* data coordinated by the HNCMA.	Committee OEH	Catchment-wide	Monitoring	1	Requirement under the guidelines.	0	No on the ground works proposed.	2	The community has expressed concern over estuarine health and a desire to obtain more information. The need for monitoring was highlighted several times.	3	6
34_COM18	Undertake annual reporting to the PRCG and the community on trends in estuarine health for the Parramatta River. Estuarine health report cards should be prepared quarterly and published on the PRCG website. Reporting on trends in estuarine health should be undertaken in accordance with the recommendations made with respect to monitoring and evaluation within the Parramatta River Estuary CZMP.	Committee OEH	N/A	Monitoring	1	Requirement under the guidelines.	0	No on the ground works proposed.	2	The community has expressed interest in the study and a desire to obtain more information.	3	6
34_COM19	Undertake a review of the Parramatta River Estuary CZMP every 5 to 10 years.	Committee	N/A	Planning	1	Requirement under the guidelines.	0	No on the ground works proposed.	1	Likely to be supported for purposes of responding to emerging issues and to reflect community preferences.	3	5
34_COM20	Liaise with OEH about opportunities for installation and operation of permanent automatic water level gauges on the Parramatta River estuary.	Committee OEH	Waterway-wide	Monitoring	1	-	0	No on the ground works proposed.	1	Likely to be supported as part of a suite of monitoring activities and as a source of information on observed climate change impacts.	3	5
Coastal Hazards: Assess the potential impacts of SLR on the estuary foreshores. Primary Objective Addressed: 10A												
39_COM21	When updating the CZMP, consider the implications of the coastal hazard assessment (Section 2.5 and Appendix C) for management.	Committee	Catchment-wide	Planning	1	-	0	No on the ground works proposed.	0	Some division over climate change, primarily in relation to impacts on development and whether it needs to be addressed now or not.	2	3

Table F.2: Actions Grouped According to Relevant Option (Actions Assessment Outcomes)

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
Land Use Planning and Development: New and revised Plans of Management should be compatible and consistent with the recommendations of the Parramatta River Estuary CZMP. Primary Objective Addressed: 1A											
1_COM01		- Improved condition and extent of wetland areas. - Improved ecosystem function of wetland areas (e.g. stormwater treatment). - Provides for management of mosquitoes.	- Improved visual amenity. - Improved public & environmental health via stormwater treatment and mosquito control. - Promotes improved management of recreational access and amenity. - Promotes good governance.	5	$88,000		$4,000	Encourage councils to undertake/update PoMs for wetlands in the PRCG area.	$116,094	0.99	32
1_HUN1	Relies on completion of the Action Plan for implementation.	- Outcomes include improved effectiveness of stormwater treatment. - Improved stormwater quality.	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	5	$50,000	For review of existing maintenance regimes.	$250,000	Budget for implementation will depend on the strategy defined in the Action Plan. Current costings provide an indicative annual budget for implementation.	$1,805,895	0.80	51
1_STR1	Outcomes of implementation will be dependent on ongoing commitment over a long period of time. Those elements of the Plans relating to accommodating SLR should provide some capacity to adapt to changes in SLR projections/observations.	- Provides for improvement of existing condition and extent of vegetation. - Promotes ongoing provision of vegetation and associated habitat into the future via adaptation.	- Opportunity to raise awareness in the community about potential impacts of climate change. - Negative impacts may include small reduction in recreational access.	4	$26,000	Assumes GIS based analysis of potential inundation extents and review of action plans/lists.	$ -		$26,000	0.91	25
Land Use Planning and Development: When undertaking reviews of planning instruments or engaging in strategic land use planning, seek consistency with the Parramatta River Estuary CZMP and, where possible, update the relevant instrument as required. Primary Objective Addressed: 1A											
2_COM02		- Opportunity to provide improved ecological connectivity in both the short and long terms. - Reduces net impact on foreshore habitats. - Reduces future exposure to coastal hazards.	- Opportunity to promote good governance and strategic planning (intergenerational equity). - Results in improved public access to foreshore areas in both the short and long term. - Improved public health. - May provide long term economic benefits through attraction of people to the area, or if public foreshore lands are leased for commercial purposes.	5	$ -		$1,200	Assumes 0.05 FTE hours per week over three years.	$8,428	1.27	2

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
2_CAN1		- Reduction in extent of sedimentary contamination. - Improved water quality. - Short term negative impacts on aquatic ecology. - Long term benefit for aquatic ecology.	- Reduced risk to human health from contaminated sediments. - Short term impacts associated with remediation works (e.g. visual, noise, etc.).	4	$ -		$400	Assumes 0.05 FTE hours per week for 6 months.	$2,809	1.16	1
Land Use Planning and Development: Develop provisions under Development Control Plans that provide for the incorporation of best practice WSUD and ecological connectivity along the estuary foreshores for sites subject to re-development. Primary Objective Addressed: 2E											
4_COM03		- Opportunity to provide improved ecological connectivity in both the short and long terms. - Reduces net impact on foreshore habitats and promotes habitat creation opportunities. - Reduces net impact on environmental flows and water quality. - Reduces future exposure to coastal hazards.	- Opportunity to promote good governance and strategic planning (intergenerational equity). - Results in improved public access to foreshore areas in both the short and long term. - Improved public health. - May provide long term economic benefits through attraction of people to the area, or if public foreshore lands are leased for commercial purposes.	5	$ -		$1,200	Assumes 0.05 FTE hours per week over three years.	$8,428	1.27	3
Water and Sediments: Retrofit appropriate WSUD features in existing urban areas of the catchment targeting locations upstream from where stormwater runoff and associated pollutants are impacting sensitive estuary locations. Primary Objective Addressed: 3A											
7_SYD1	The installation of any future SQIDs would be subject to feasibility studies and landowner consent.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows).	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	5	$457,500	Investigation into options, design, EIA, tender, project management, site establishment, buy and install SQID, site restoration.	$110,000	Annual maintenance of structure.	$1,230,094	0.82	46
7_RYD1	Works would be subject to feasibility studies and available funding. Anzac Park has a potential bioretention system catchment area of 3,100m^2 and treatment area of 67m^2. There is also a potential underground tank catchment area of 14,000m^2 and treatment area of 20m2 for irrigation purposes.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows).	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	4	$83,438	Feasibility, design, EIA, tender, project management, site establishment, construction bioretention treatment area, excavate and construct below ground tank.	$3,008	Annual maintenance of features.	$104,565	0.80	40
7_RYD2	Works would be subject to feasibility studies and available funding. Peel Park has a potential treatment area of 150m2.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows).	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	5	$114,375	Feasibility, design, EIA, tender, project management, site establishment, construct bioretention treatment area.	$4,575	Annual maintenance of features.	$146,508	0.97	33

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
7_AUB1	For purposes of including a realistic budgetary estimate within the Plan, this has been costed assuming installation of a GPT.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows).	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	4	$52,500	Feasibility, design, EIA, tender, project management, site establishment. Supply and install GPT, including connection to existing drainage, and discharge erosion protection as required.	$10,000	Annual maintenance of GPT.	$122,736	0.79	42
7_LEI1	Based on an average project cost as reported for the Sustaining the Parramatta River project.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows).	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	4	$705,000	Investigation into options, design, EIA, tender, project management, site establishment, implement water quality system.	$28,200	Annual maintenance of features.	$903,065	0.67	53
7_LEI2	Works located on RMS Land. Approval and MOUs required. RMS have provided in principle support.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows).	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	4	$283,150	Detailed design and construction.	$10,000	Annual maintenance	$353,386	0.72	49
7_RYD3	Works would be subject to available funding. Potential treatment area of 40,000m^2.	- Improved stormwater quality.	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	6	$220,000	Design, EIA, tender, project management, site establishment, construction.	$3,000	Annual maintenance	$241,071	1.11	29
Water and Sediments: Modify, upgrade or repair existing SQIDs, stormwater infrastructure and management practices as required to maintain or improve their effectiveness. This should include development of maintenance schedules for existing infrastructure where they are not currently in place. Primary Objective Addressed: 2B											
8_PAR1	This action is likely to require the collation of data and potentially the acquisition of additional data. It is recommended that the analysis and reporting be linked to mapping in GIS.	- Potential to improve stormwater quality. - Potential to improve management of stormwater releases (i.e. in relation to environmental flows).	- Potential positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Promotes adaptive management.	5	$75,000		$ -		$75,000	1.03	26
8_COM04		- Improved estuarine water quality. - Improved aquatic ecosystem health.	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good catchment management.	6	$ -		$1,500	Assumes total of one week of a staff member's time over a year.	$10,535	1.49	4

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
8_ASH1		- Potential to improve stormwater quality. - Potential to improve management of stormwater releases (i.e. in relation to environmental flows). - Potential to reduce existing level of impact on sensitive habitats in Iron Cove (e.g. seagrasses).	- Potential positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Promotes adaptive management and good governance.	4	$40,000		$ -		$40,000	0.87	31
8_SOP1		- Potential to improve stormwater quality. - Potential to improve management of stormwater releases (i.e. in relation to environmental flows). - Potential to improve management of any erosion and sedimentation issues. - Potential to reduce existing level of impact on sensitive habitats in Olympic Park (e.g. wetlands).	- Potential positive impact on visual and recreational amenity of the Park. - Promotes adaptive management and good governance.	5	$ -		$3,000	Assumes total of two weeks of a staff member's time over a year.	$21,071	1.16	13
8_CAN2*	Opportunities to reduce vulnerability of the stormwater drainage system to climate change impacts may be achieved more cost effectively in a progressive fashion, although some activities may be more suitable for implementation once a trigger has been reached.	- Potential to improve stormwater quality. - Potential to improve management of stormwater releases (i.e. in relation to environmental flows). - Reduces vulnerability to climate change impacts.	- Potential positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Promotes adaptive response to climate change. - Good strategic planning.	5	$50,000		$ -		$50,000	1.06	23
Water and Sediments: Work with Sydney Water to prioritise maintenance and upgrade of the sewerage network within the catchment on an ongoing basis to reduce sewage overflows. This activity should include investigations into the incidence of illegal private connections to the sewerage and / or stormwater network. Primary Objective Addressed: 2C											
9_SOP2*		- Potential to improve stormwater quality. - Potential to reduce existing level of impact on sensitive habitats in Olympic Park (e.g. wetlands).	- Potential positive impact on visual and recreational amenity of the Park. - Potential to reduce risk to human health.	5	$ -		$1,500	Assumes total of one week of a staff member's time over a year.	$10,535	1.24	27
Water and Sediments: Reduce sediment inputs through bank stabilisation works in estuary tributaries. Primary Objective Addressed: 2B											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
10_COM05	Feasibility investigations, including ground-truthing required prior to implementation.	- Improved stormwater quality. - Improved management of stormwater releases (i.e. in relation to environmental flows). - Opportunity to address any erosion and sedimentation issues. - Stabilises banks and improves ecological connectivity and health.	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Reduced risk to members of the public from any unstable banks. - Opportunity for awareness raising in the community on good riparian management.	4	$2,000,000	Investigation into options (feasibility studies), design, EIA, tender, project management, site establishment, and revegetate sites.	$100,000	Maintenance requirements will reduce over time as plants become established.	$2,702,358	0.62	63
10_AUB2		- Opportunity to address any erosion and sedimentation issues. - Stabilises banks.	- Reduced risk to members of the public from any unstable banks.	4	$26,250	Design, EIA, tender, project management, site establishment. Install sandstone bank protection (200mm high, 50m long retaining wall) including footings, and restoration as required to surrounding area.	$525		$29,937	0.89	39
Estuarine Ecology: Develop and implement a strategy for the coordinated management of estuarine and riparian biodiversity across administrative boundaries for the estuary as a whole. The strategy should incorporate biodiversity corridors and SLR consideration, to ensure the ongoing provision of habitat and connectivity between habitat areas. Primary Objective Addressed: 4A											
11_COM06	This action will require consultation with the NSW Department of Planning and Infrastructure on development of standard clauses for LEPs and DCPs. Reference should be made to linked actions 2_COM02 and 4_COM04.	- Potential for improved biological connectivity, both now and under climate change conditions. - Potential for increase in extent and condition of existing habitat.	- Potential for improved opportunities for access, recreation and scientific study.	5	$ -		$8,000	Assume 0.1 FTE hours for staff member.	$56,189	1.05	14
Estuarine Ecology: Minimise impacts of moorings and boating on seagrass. Primary Objective Addressed: 4A											
12_MAR1*	This action may be undertaken opportunistically or in a targeted fashion.	- Reduction in current level of impact on seagrasses. - Improved condition and extent of seagrasses.	- May be potential to alter current access arrangements.	4	$285,000	Identification, project management, site establishment, relocate moorings. Assumes 5% of 1,764 moorings require relocation.	$ -		$285,000	0.73	67
Estuarine Ecology: Manage public access at environmentally sensitive foreshore locations. Priority areas may include key habitat and vegetation communities located in areas that are frequented by the public. Primary Objective Addressed: 4A											
13_STR2	Consultation with the community may be required as to selection of a preferred option.	- Reduction in level of threat from human activities on habitats. - Reduction in disturbance of birds and other fauna by humans or dogs. - Potential for improved condition and extent of vegetation.	- May result in some decrease in public access. - Good opportunity for public awareness raising.	3	$1,290,000	Design, EIA, tender, project management, site establishment. Construct path, reinstating surrounding disturbed area as required. Install fencing as required around sensitive areas to prevent access. Provide signage.	$22,501		$1,448,038	0.49	66
Estuarine Ecology: Undertake improvements to foreshore infrastructure where possible to reduce their impacts on aquatic habitats. Consider the need, where feasible, to relocate or decommission infrastructure where it is impacting on environmentally sensitive locations. Primary Objective Addressed: 4A											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
16_SYD2	This action will likely require some internal communications/education activities to ensure implementation.	- Reduction in erosion and sedimentation. - Positive water quality impacts. - Potential for improved condition/extent of sensitive estuarine habitats (e.g. seagrasses).	- Potential to reduce risk to public safety from erosion around stormwater outlets. - Improved visual amenity.	5	$5,000	Develop an internal guidance note.	$3,000	Review of designs, assume 2 weeks of a staff member's time per year.	$26,071	1.13	9
16_MAR2	This action will likely require some internal communications/education activities to ensure implementation.	- Potential for reduction in current level of impact on seagrasses. - Potential for improved condition and extent of seagrasses.	- Potential for value-added benefits for public access where infrastructure is improved. - Opportunity for public awareness raising.	4	$5,000	Develop a guidance note.	$1,500	Assumes total of one week of a staff member's time over a year to promote seagrass friendly moorings.	$15,535	0.95	11
16_SOP3	Feasibility investigations should consider impacts on catchment flooding and potential future SLR impacts.	- Restoration of tidal exchange and promotion of flushing. - Improved water quality. - Improved ecological connectivity (fish passage). - Restoration of habitat. - Potential to change (possibly increase) level of risk from coastal hazards.	- Potential positive impact on visual and recreational amenity of the Park.	4	$10,000	Prepare funding applications, liaison with relevant organisations.	$ -		$10,000	1.00	5
Estuarine Ecology: Undertake works to provide for the ongoing preservation of estuarine and riparian habitats under climate change conditions. This should include the enhancement of existing habitats where there is possibility of retreat, or establishing additional habitat areas as required, to maximise habitat under SLR conditions. Primary Objective Addressed: 4A											
17_COM07	The Committee's role in implementation will likely involve technical advice and review, and should be supported by SMCMA and OEH.	- Improved condition and extent of wetland and intertidal areas. - Potential long term benefit under climate change conditions.	- Potential for positive and/or negative impacts on visual amenity and public access. - Promotes improved management of recreational access and amenity. - Promotes strategic planning/adaptive management for climate change.	5	$ -		$4,000	Assumes 0.05 FTE hours for staff member	$28,094	1.12	16
17_HUN2	Reference is made to AECOM (2010) for a discussion on issues currently impacting Tarban Creek and management recommendations.	- Improved stormwater management and resultant water quality improvements. - Improved condition and extent of vegetation and associated habitat.	- May result in reduced access at some specific sites. - May restrict expansion of recreational activities.	4	$345,000	Design, EIA, tender, project management, site establishment. Install leaf traps and GPTs, provide erosion protection as required. Bank rehabilitation upstream of pedestrian bridge. Remediation of weir controlling flows to the wetland.	$64,625	Includes 0.05 FTE hours for one staff member and annual maintenance/monitoring/works costs.	$798,899	0.68	52

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
17_HUN3	This action may require assessment of potential SLR impacts on the Reserves. Reference is made to linked actions 34_COM22 and 39_COM23.	- Provides for improvement of existing condition and extent of saltmarsh. - Improved ecosystem function of wetland areas (e.g. stormwater treatment). - Promotes ongoing provision of saltmarsh habitat into the future via adaptation.	- Opportunity to raise awareness in the community about potential impacts of climate change. - Negative impacts may include small reduction in recreational access.	4	$ -		$50,000	Assumed annual budget for implementation of activities identified in the relevant Estuary Vegetation Rehabilitation and Management Plans.	$351,179	0.72	47
17_STR3	It has been assumed that this action provides for strategic support and management planning to support the existing works program. Reference should be made to AECOM (2010) for a discussion on vegetation management relating to Mason Park.	- Improved condition and extent of wetland and intertidal areas. - Potential long term benefit under climate change conditions.	- Potential for positive and/or negative impacts on visual amenity and public access. - Promotes strategic planning/adaptive management for climate change.	5	$ -		$50,000	Assumed annual budget based on allowance for control of weeds and mangrove seedlings, monitoring vegetation extents, propagation and transplantation of saltmarsh species.	$ 351,179	0.90	41
17_SOP4	It has been assumed that this action provides for strategic support and management planning to support the existing works program.	- Improved condition and extent of wetland and intertidal areas. - Potential long term benefit under climate change conditions.	- Potential for positive and/or negative impacts on visual amenity and public access. - Promotes strategic planning/adaptive management for climate change.	5	$ -		$130,000	Assume 1.0 FTE staff member and operational budget of $50,000 p.a.	$913,066	0.84	45
17_LEI3	This may include the incorporation of habitat features within seawalls proposed for upgrading, as well as other activities relating to management of open space.	- Potential for habitat protection, enhancement and creation opportunities. - Potential for reduction in existing level of risk from coastal hazards.	- Promotes good governance and strategic planning.	5	$ -		$4,000	Assume 0.1 FTE hours for a staff member for five years.	$28,094	1.12	17
17_CAN3		- Potential for habitat protection, enhancement and creation opportunities. - Potential to reduce water quality impacts resulting from erosion and sedimentation. - Potential for reduction in extent of erosion and protection from coastal hazards.	- Potential to reduce impacts of erosion on public safety and use of the area. - Improved visual amenity. - Potential opportunity for community education, particularly in relation to illustrating approaches that owners of private foreshore properties may also wish to consider.	5	$ -		$2,500	Assumed annual budget for vegetation management activities (noting that the effort will decrease over time as the vegetation becomes established).	$17,559	1.18	12
Estuarine Ecology: Manage identified public foreshore areas where they are required for the retreat of estuarine vegetation in response to SLR Primary Objective Addressed: 4A											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
18_PAR2	Potential for migration should be confirmed prior to implementation via ground-truthing and supported by SLR mapping.	- Potential for improved condition and extent of wetland and intertidal areas. - Potential long term benefit under climate change conditions.	- Potential for positive impacts on visual amenity, recreation and public access. - Promotes strategic planning/adaptive management for climate change.	3	$400,000		$ -		$400,000	0.54	55
Estuarine Ecology: Undertake creek naturalisation works of existing channelised creeks, focusing as a priority on channels coming to the end of their design life. Primary Objective Addressed: 4B											
19_STR4	Detailed design should consider potential flood impacts. Ongoing maintenance will be critical to the long term success of these projects.	- Potential for improved stormwater quality. - Potential for improved management of stormwater releases (i.e. in relation to environmental flows). - Opportunity to address any erosion and sedimentation issues. - Stabilises banks and improves ecological connectivity and health.	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Reduced risk to members of the public from any unstable banks. - Opportunity for awareness raising in the community on good riparian management.	3	$101,250	Design, EIA, tender, project management, site establishment. Naturalisation of creek incl. removal of existing channel if required, weed control, preparation or soil for planting, planting & establishment of selected species.	$3,375		$124,955	0.59	50
19_SYD3	Detailed design should consider potential flood impacts. Ongoing maintenance will be critical to the long term success of these projects.	- Potential for improved stormwater quality. - Potential for improved management of stormwater releases (i.e. in relation to environmental flows). - Opportunity to address any erosion and sedimentation issues. - Improves ecological connectivity and health.	- Positive impact on visual and recreational amenity of the waterway via reduced pollutant loadings. - Opportunity for awareness raising in the community on good riparian management.	4	$1,426,875	Design, EIA, tender, project management, site establishment. Removal of existing channel if required, removal of foreign species, preparation or soil for planting, planting of selected species, and upkeep and protection during establishment.	$47,563		$1,760,938	0.64	57
19_SYD4	Feasibility investigations should consider impacts on catchment flooding and potential future SLR impacts.	- Restoration of tidal exchange and promotion of flushing. - Improved water quality. - Improved ecological connectivity (fish passage). - Restoration of habitat. - Potential to change (possibly increase) level of risk from coastal hazards.	- Potential positive impact on visual and recreational amenity of the Park.	3	$400,000	Design, EIA, tender, project management, site establishment, installation of a tide gate. See also cost as listed in Mason Park PoM.	$2,500		$417,559	0.53	56
Estuarine Ecology: Undertake ongoing monitoring and management of aquatic and terrestrial weeds (incl. noxious weeds) and introduced species (both flora and fauna). Primary Objective Addressed: 4C											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
20_HUN4		- Reduction in weed infestations. - Improved condition and extent of native vegetation. - Removal of weeds without immediate replacement with native vegetation may result in erosion and sedimentation, and may temporarily reduce habitat availability for some species.	- Improved visual amenity and recreational access. - Potential short term visual impacts.	4	$ -		$50,000	Assumes annual salary for 0.4 FTE hours for Bushcare coordinator and budget for materials as required.	$351,179	0.72	48
Estuarine Ecology: Improve the environmental value of existing seawalls through the addition of habitat, where feasible. Primary Objective Addressed: 4D											
21_PAR3	For purposes of costing, assume replacement seawalls identified as being in poor condition in AECOM (2010).	- Increase in the extent of intertidal habitat.	- Opportunity for public education.	2	$1,333,875	Design, EIA, tender, project management, site establishment.	$2,000		$1,347,922	0.33	62
21_ASH2	For purposes of costing, assume replacement seawalls identified as being in poor condition in AECOM (2010) in addition to monitoring.	- Increase in the extent of intertidal habitat. - Reduce risk of poor condition infrastructure negatively impacting on the environment.	- Improved monitoring and maintenance framework. - Opportunity for public education.	2	$260,000	Design, EIA, tender, project management, site establishment. Develop monitoring framework and systems.	$4,000	Annual maintenance of seawalls, plus regular monitoring.	$288,094	0.37	54
21_LEI4	For purposes of costing, assume replacement seawalls identified as being in poor condition or failing in AECOM (2010).	- Increase in the extent of intertidal habitat.	- Opportunity for public education.	2	$1,230,000	Design, EIA, tender, project management, site establishment. Upgrade seawalls.	$2,000		$1,244,047	0.33	61
21_CAN4	For purposes of costing, assumes replacement the two seawall sections identified.	- Opportunities for habitat creation may arise. - Reduce risk of poor condition infrastructure negatively impacting on the environment.	- Improved monitoring and maintenance framework.	3	$3,265,875	Design, EIA, tender, project management, site establishment. Upgrade seawalls.	$16,000	Assume 0.2 FTE hours.	$3,378,252	0.46	58
21_RYD4	For purposes of costing, assumes replacement the two seawall sections identified, as well as monitoring.	- Opportunities for habitat creation may arise. - Reduce risk of poor condition infrastructure negatively impacting on the environment.	- Improved monitoring and maintenance framework. - Opportunity for public education.	2	$840,000	Design, EIA, tender, project management, site establishment, upgrade seawalls. Develop monitoring framework and systems.	$4,000	Annual maintenance of seawalls, plus regular monitoring.	$868,094	0.34	59
Bank Condition: Formally negotiate with Harbour City Ferries for a change in vessel (from the RiverCat) that would have less wake impacts. Primary Objective Addressed: 5A											
22_COM08	Reference is made to linked action 22_COM09.	- Potential for reduction in bank erosion and sedimentation. - Potential for improved water quality. - Potential for improved extent and condition of riparian vegetation.	- Potential for improved visual and recreational amenity.	5	$ -		$1,600	Assume 0.1 FTE staff member over two years.	$11,238	1.23	10

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
22_COM09	Reference is made to linked action 22_COM08.	- Potential for reduction in bank erosion and sedimentation. - Potential for improved water quality. - Potential for improved extent and condition of riparian vegetation.	- Potential for improved visual and recreational amenity.	5	$ -		$38,000	Assume 0.1 FTE hours for a staff member and $30,000 for rehabilitation costs.	$266,896	0.92	37
Bank Condition: Encourage bank and foreshore erosion control techniques that maximise the use of riparian and estuarine vegetation. Primary Objective Addressed: 5B											
23_COM10		- Potential for reduction in bank erosion and sedimentation. - Potential for improved water quality. - Potential for improved extent and condition of riparian vegetation.	- Potential for improved visual and recreational amenity.	4	$5,000	Collate and update as required existing materials.	$6,000	Printing and distribution of brochures and liaison; assume 0.05 FTE hours.	$47,141	0.86	43
23_CAN5		- Opportunities for habitat creation may arise. - Reduce risk of poor condition infrastructure negatively impacting on the environment. - Reduction in bank erosion and sedimentation. - Improved water quality. - Potential for improved extent and condition of riparian vegetation.	- Reduced risk to public safety posed by failing or poor condition infrastructure. - Improved recreational and visual amenity.	4	$877,500	Design, EIA, tender, project management, site establishment. Upgrade seawalls.	$2,000		$891,547	0.67	60
23_RYD5		- Reduction in bank erosion and sedimentation. - Improved water quality. - Potential for improved extent and condition of riparian vegetation	- Reduced risk to members of the public from any unstable banks. - Improved visual amenity.	4	$55,125	Design, EIA, tender, project management, site establishment. Rehabilitate foreshore.	$1,103		$62,872	0.83	44
Bank Condition: All management authorities involved in the building, design and approval of new seawalls, or major upgrades of existing seawalls, should promote their compliance with the Environmentally Friendly Seawalls guideline (DECC and SMCMA, 2009) within legislative constraints. Primary Objective Addressed: 6B											
24_HUN5	Costing assumes internal communication only.	- Promotes the incorporation of habitat features in seawalls. Could result in increase in intertidal habitat extent.	- Good opportunity for education.	3	$ -		$1,500	Assume one week of staff members time for liaison with internal staff.	$10,535	0.75	28
24_MAR3		- Promotes the incorporation of habitat features in seawalls. Could result in increase in intertidal habitat extent.	- Good opportunity for education. - Improved governance.	5	$ -		$1,500		$10,535	1.24	6
24_LEI5		- Promotes the incorporation of habitat features in seawalls. Could result in increase in intertidal habitat extent.	- Good opportunity for education.	4	$ -		$1,500	Assume one week of staff members time for liaison with internal staff.	$10,535	0.99	15
Human Usage and Recreation: Maintain and improve existing public access (i.e. bike and walking paths) for the Parramatta River estuary to provide transport linkages throughout the LGAs, giving consideration to sensitive environmental locations. Primary Objective Addressed: 7A											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
25_COM11	Existing guideline documents and other supporting materials should be used where possible.	- Potential to reduce impacts of human activities on the environment. - Potential for improved condition and extent of habitat.	- Improved connectivity of public access. - Promotes the use of alternative, more environmentally friendly forms of transport. - Potential for improved public health.	4	$ -		$1,500	Assume one week of staff members time for liaison with internal staff.	$10,535	0.99	7
25_COM12		- Potential to improve management of public access, thereby reducing impact of human activities on the environment.	- Improved connectivity of public access. - Promotes the use of alternative, more environmentally friendly forms of transport. - Potential for improved public health.	4	$ -		$4,000	Assume 0.05 FTE hours.	$28,094	0.90	18
25_PAR4	Assumes four cycleway sections on the northern bank of the Parramatta River estuary within the Parramatta LGA.	- Potential to improve management of public access, thereby reducing impact of human activities on the environment.	- Improved connectivity of public access for a large number of users. - Promotes the use of alternative, more environmentally friendly forms of transport. - Potential for improved public health.	2	$100,000	For investigations and design work.	$39,000		$373,920	0.36	64
25_PAR5	Will likely involve both internal communications and adoption of a collaborative approach with developers through the DA/master planning process.	- Value added benefits may be accrued through the inclusion of landscaping with native species (habitat creation).	- Improved connectivity of public access. - Promotes the use of alternative, more environmentally friendly forms of transport. - Potential for improved public health.	3	$ -		$8,000	Assume 0.1 FTE hours. Note: Cost to be born as part of normal operations under existing budget.	$56,189	0.63	36
25_STR5	Implementation should consider the need to link in with existing transport services and other pathways both within the Strathfield LGA and beyond. Reference is made to the Powells Creek Masterplan.	- Potential to improve management of public access, thereby reducing impact of human activities on the environment.	- Improved connectivity of public access. - Promotes the use of alternative, more environmentally friendly forms of transport. - Potential for improved public health.	2	$3,820,000	For purposes of costing incl. development of a strategy and construction of up to 5km cycleway across 5 sites.	$50,000	Cycleway maintenance, review plan regularly.	$4,171,179	0.30	65
Human Usage and Recreation: Develop and implement an integrated approach to the provision of recreational amenity for the estuary as a whole. Primary Objective Addressed: 7B											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
29_COM13		- Reduce risk of poor condition infrastructure negatively impacting on the environment. - Potential to reduce impacts of human activities on the environment. - Potential for improved condition and extent of habitat.	- Promotes good governance and strategic planning. - Provides for improved recreational access and amenity. - Potential benefits for public health. - Improved equity re: provision of resources.	4	$150,000	Undertake needs analysis and prepare strategy.	$ -		$150,000	0.77	34
29_MAR4	This action should also consider environmentally friendly features or approaches to providing facilities.	- Potential to improve management of public access, thereby reducing impact of human activities on the estuary.	- Provides improved access for the boating public. - Provides improved connectivity between the waterway and the foreshores. - May result in traffic impacts if not properly considered at the design stage.	2	$ -		$4,000	Assume 0.05 FTE hours.	$28,094	0.45	38
Human Usage and Recreation: Work together to develop and implement a program for industry and the community to raise awareness of issues relating to estuary management and estuarine health. Key elements of the program could include: - Good catchment management practices; - The heritage significance of the estuary and its foreshores; - The types of activities that are permitted, or are not permitted, in different parts of the foreshore or waterway; - The use of vegetation for bank and foreshore protection works; - The potential impacts of climate change on the estuary; and - How individuals can reduce their impact on the estuary. Primary Objective Addressed: 2B											
32_COM14	It is recommended that this action target these key groups in the first instance.	- Potential to reduce impacts of human activities on the estuary.	- Improved education and community awareness of the estuary and its management. - Promotes behavioural change.	5	$15,000	Develop strategy, collate existing materials.	$6,000	Printing and distribution of brochures and liaison; assume 0.05 FTE hours.	$57,141	1.05	8
32_COM15		- May result in a reduction in the extent of human impacts on the estuary through behavioural change.	- Improved education and community awareness of the estuary and its management.	5	$75,000	Graphic design, tender and install 8 new signs in first year.	$40,000	Replacement or installation of up to 5 signs per year, plus maintenance.	$355,943	0.90	22
Monitoring, Evaluation & Reporting: Develop and implement a communication strategy for the implementation stage of the Parramatta River Estuary CZMP. Primary Objective Addressed: 8A											
33_COM16	Reference is made to Section 6 of the CZMP on KPIs and reporting.	- May result in a reduction in the extent of human impacts on the estuary through behavioural change.	- Improved community awareness of the estuary and its management. - Provides transparency and accountability on implementation of estuary management program.	6	$5,000	Develop strategy.	$10,000	Assume 2 week of a staff members time per year, plus graphic design as required.	$75,236	1.23	19
Monitoring, Evaluation and Reporting: Develop and implement a holistic and rigorous monitoring program that coordinates the efforts of the various stakeholders responsible for management of the Parramatta River estuary and includes monitoring of climate change impacts. Primary Objective Addressed: 8A											

Action ID	Notes on Implementation and Decommissioning (as required)	Key Environmental Impacts	Key Social Impacts	Benefit Index	Preliminary Indicative Capital Cost	Capital Cost Comments	Preliminary Indicative Annually Recurrent Cost	Annually Recurrent Cost Comments	Net Present Value	Cost:Benefit Ratio	Overall Ranking
34_COM17	Reference is made to the recommendations on monitoring and evaluation in Section 6 of the CZMP. Linked actions include 32_COM16 and 34_COM20.	- Improved understanding of estuary processes. - Potential to improve condition and health of estuary, and respond to emerging environmental issues.	- Promotes good governance via potential for an adaptive management response as required. - Improved community awareness of the estuary and its management.	6	$50,000	Detailed design of monitoring program, establish frameworks.	$200,000	Based on cost of implementation of the Georges River monitoring program, relies on substantial volunteer support.	$1,454,716	0.97	35
34_COM18	Reference is made to Section 6 of the CZMP.	- Improved understanding of estuary processes. - Potential to improve condition and health of estuary, and respond to emerging environmental issues. - May result in a reduction in the extent of human impacts on the estuary through behavioural change.	- Promotes good governance via potential for an adaptive management response as required. - Improved community awareness of the estuary and its management. - Provides transparency and accountability on implementation of estuary management program.	6	$ -		$50,000	Annual reporting, including both an annual report and quarterly report cards.	$351,179	1.08	21
34_COM19	Reference is made to Sections 6 and 7 of the CZMP.	- Improved understanding of estuary processes. - Potential to improve condition and health of estuary, and respond to emerging environmental issues.	- Provides transparency and accountability on implementation of estuary management program. - Allows the Committee to respond to emerging issues as required. - Promotes adaptive management by reviewing success of implementation and modifying management approach as required.	5	$ -		$35,000		$245,825	0.93	30
34_COM20	This is an important activity for improving our understanding of how tidal and flood flows impact on estuarine hydrodynamics, and also in terms of monitoring for the potential impacts of climate change. With respect to the latter, a long term data set would be required, and therefore it is recommended that the gauges be installed as a priority activity.	- Potential to gain an improved understanding of estuary processes generally, but particularly in relation to tidal processes & flood flows. - Opportunity to monitor for the potential effects of SLR, noting that a long time series of data would be required.	- Potential to provide additional information to inform management initiatives. - Potential for use in awareness raising within the community on estuary processes.	5	$60,000	Design, EIA, tender, project management, site establishment. Install 3 gauges.	$4,500		$91,606	1.01	20
Coastal Hazards: Assess the potential impacts of SLR on the estuary foreshores. Primary Objective Addressed: 10A											
39_COM21	Reference is made to Section 2.5 and Appendix C of the CZMP, which contains the Coastal Hazard Assessment (CHA) report.	- The CHA provides an improved understanding of how SLR projections might impact on estuarine processes. - The CHA provides information that can inform long term strategic planning for conservation of intertidal estuarine habitats.	- The CHA provides information that could inform long term strategic planning for public access and recreational amenity. - The CHA provides information that can help reduce the level of risk from coastal hazards.	3	$25,000	Review and refinements to the CHA incorporating new data obtained.	$ -		$25,000	0.68	24

*An asterix in Tables F1 and F2 indicates where an option was not identified as a high ranking option, but has been brought forward into the Implementation Plan anyway for various reasons. These options include:

- Option 12 – the Committee agreed this action should be included in the Plan to support initiatives already under way,
- Option 9 – SOPA and Sydney Water agreed this action should be included in the Plan to manage impacts within Bicentennial Park, and
- Option 36 – Action 8_CAN2 could also be classified under this option (currently classified under Option 8).

Appendix G

Process Sub-Plans

Sub-Plan - Land Use and Development (Upper Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- LGA Boundaries
- Parramatta River Estuary

Land Use:

- Parkland
- Residential
- Industrial
- Commercial

Action 1_COM1

Encourage the development or review of Plans of Management for all fresh water and saltwater wetlands in the PRCG area, focusing initially on high and medium priority wetlands identified in the SMCMA Wetlands Prioritisation process.

N
W E
S

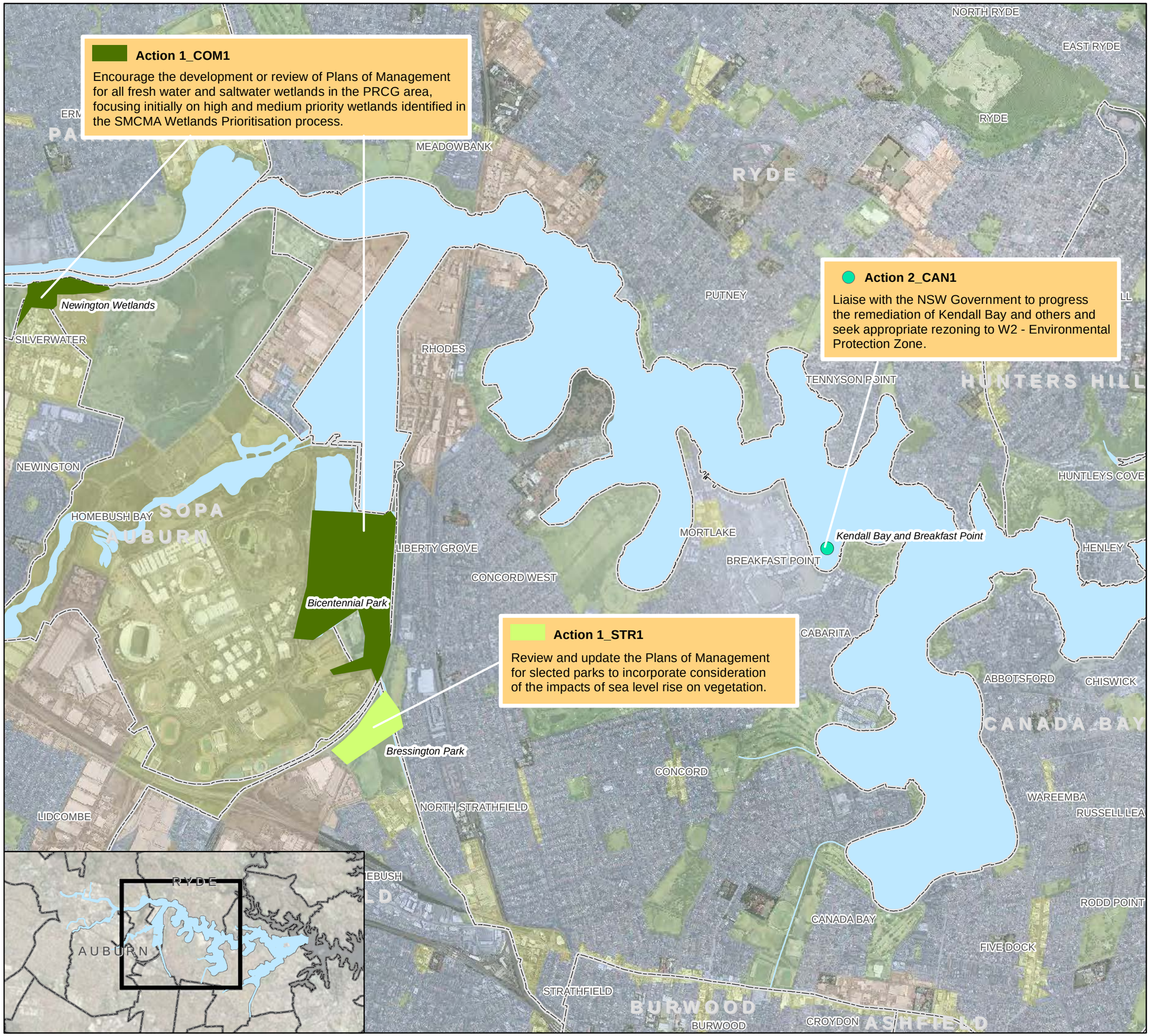
FIGURE G.1a

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG001a_LUandDevelopment_Upper.mxd 01
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.



Sub-Plan - Land Use and Development (Middle Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- LGA Boundaries
- Parramatta River Estuary

Land Use:

- Parkland
- Residential
- Industrial
- Commercial

N
W E
S

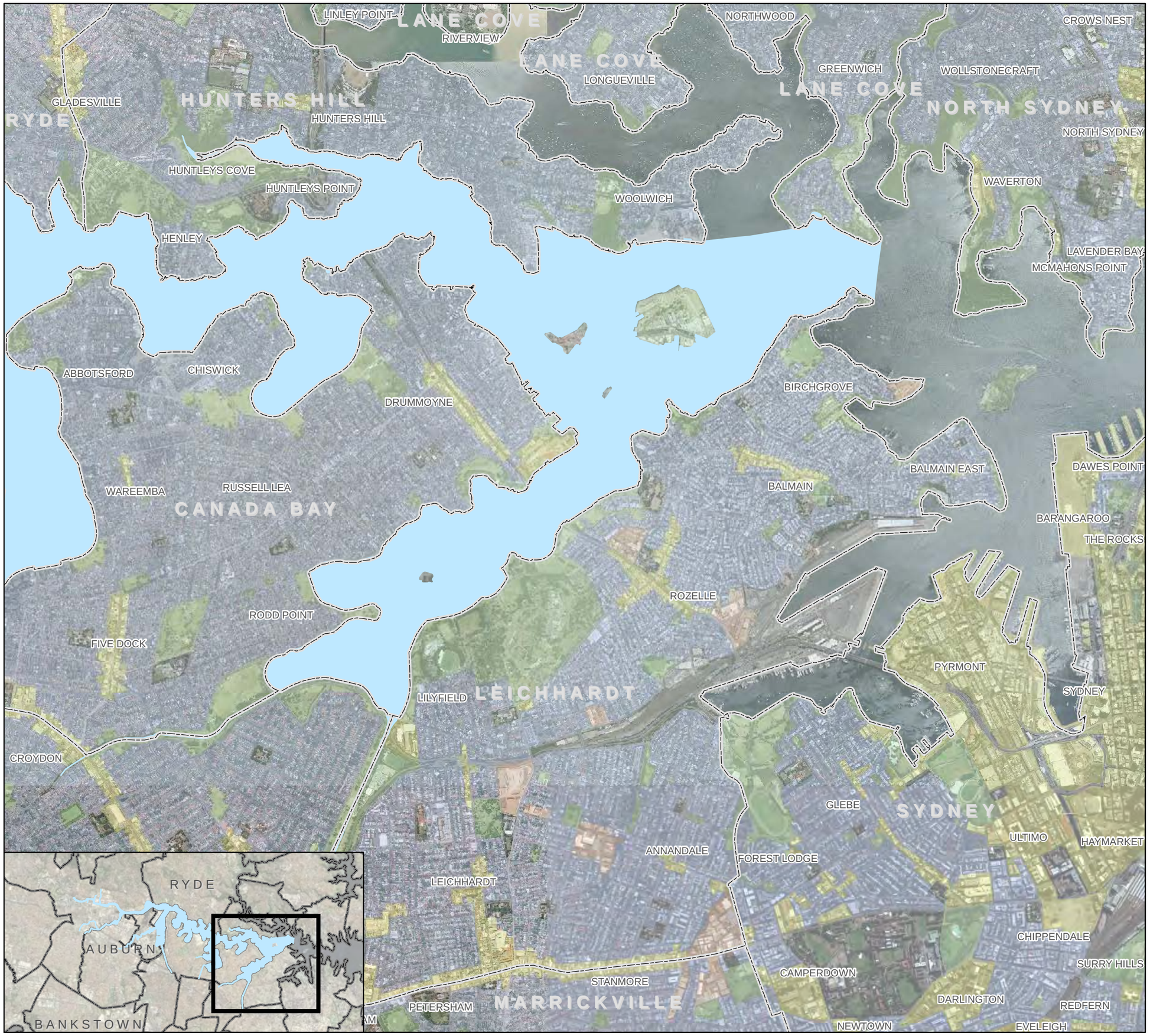
FIGURE G.1b

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG001b_LUandDevelopment_Mid.mxd 01
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.



Sub-Plan - Land Use and Development (Lower Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- LGA Boundaries
- Parramatta River Estuary

Land Use:

- Parkland
- Residential
- Industrial
- Commercial

No Actions under this Sub-Plan for this area.

N
W E
S

FIGURE G.1c

1:25,000 Scale at A3

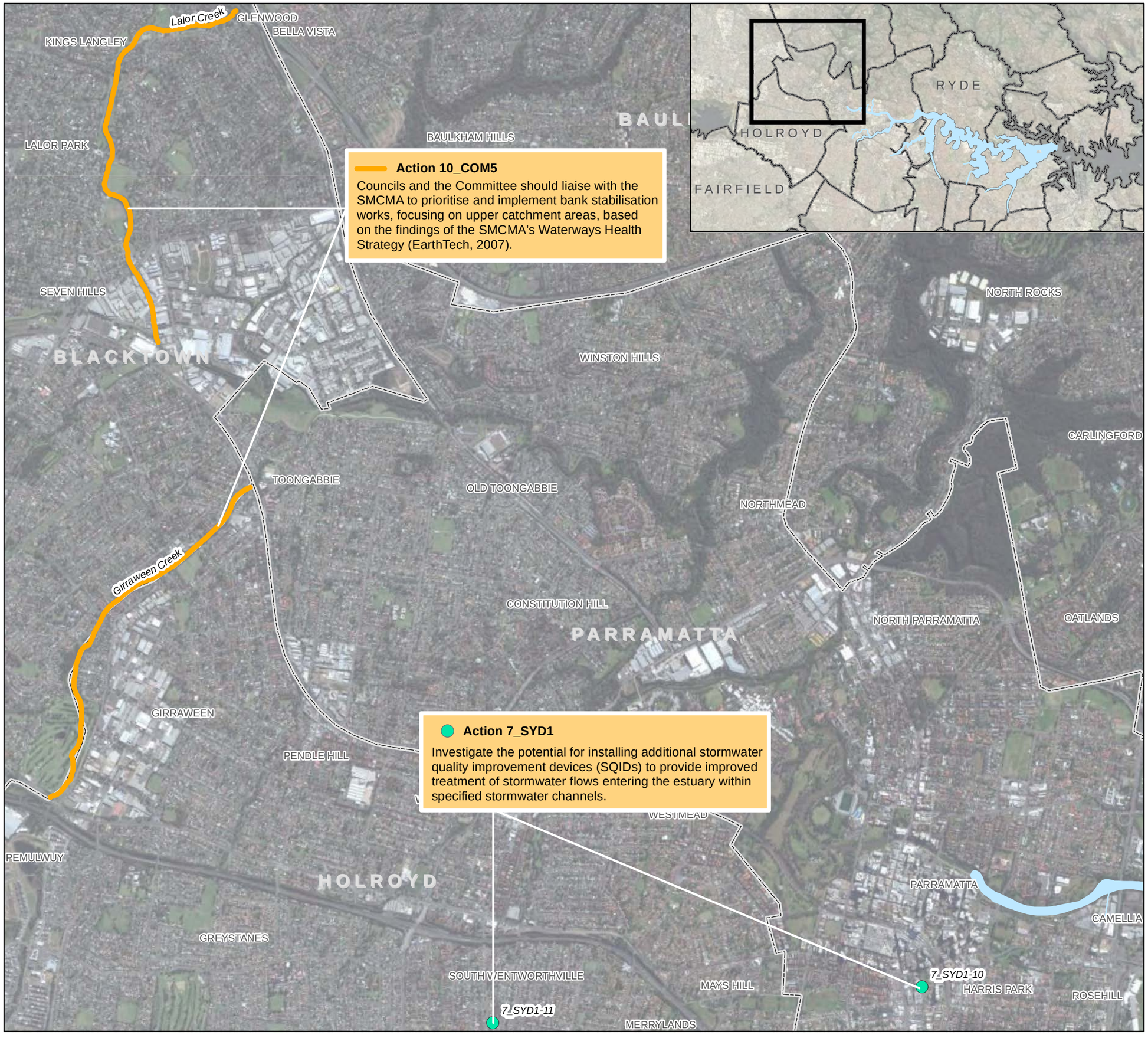
Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG001c_LUandDevelopment_Lower.mxd 01
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority, Bing and associated third party suppliers.

Sub-Plan - Water and Sediments (Far Upper Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN



Legend

- LGA Boundaries
- Parramatta River Estuary

N
W E
S

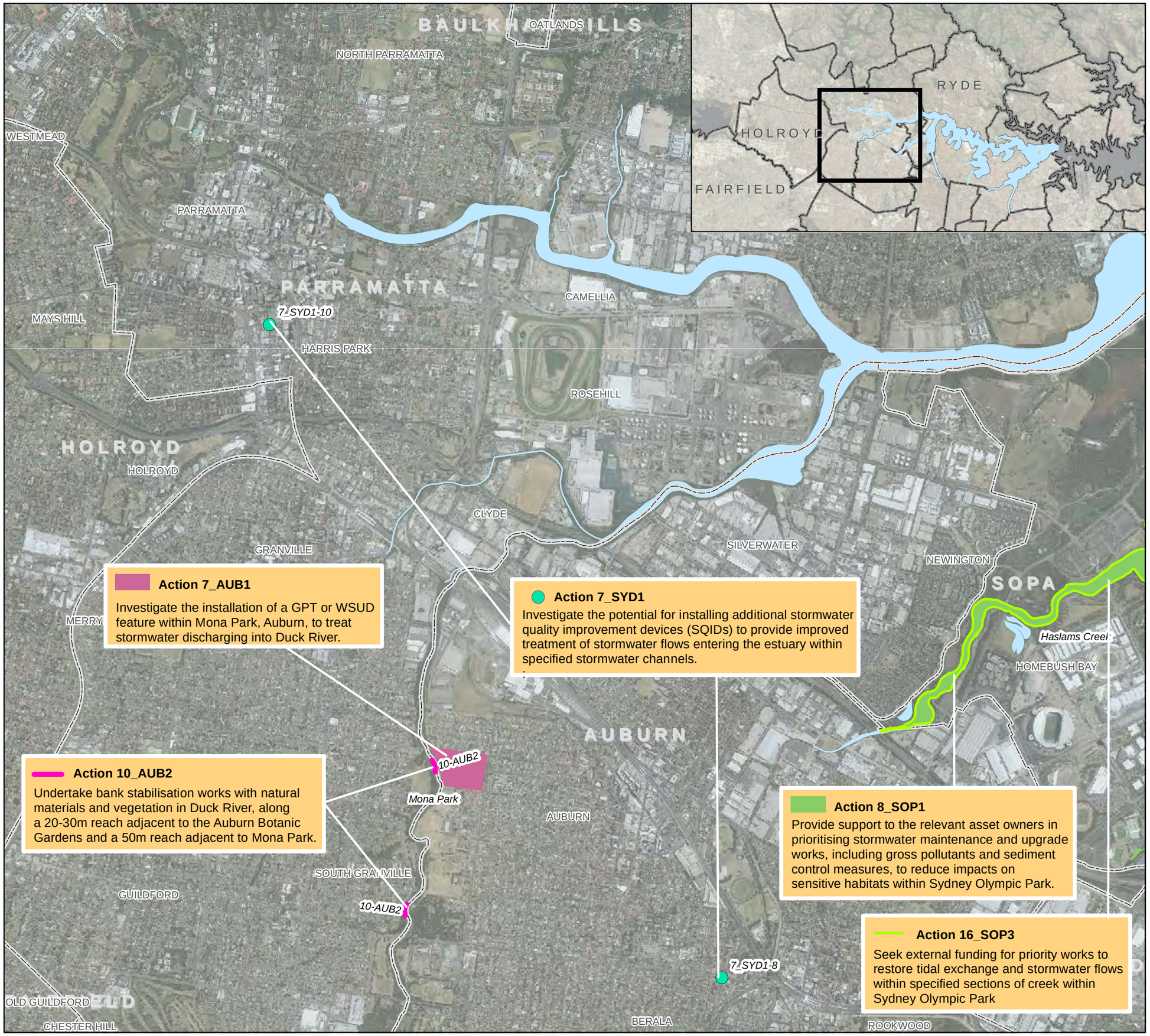
FIGURE G.2a

1:28,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG002a_WaterAndSediments_FarUpper.mxd 01
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Bing and associated third party suppliers.



Sub-Plan - Water and Sediments (Upper Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- LGA Boundaries
- Parramatta River Estuary

N
W E
S

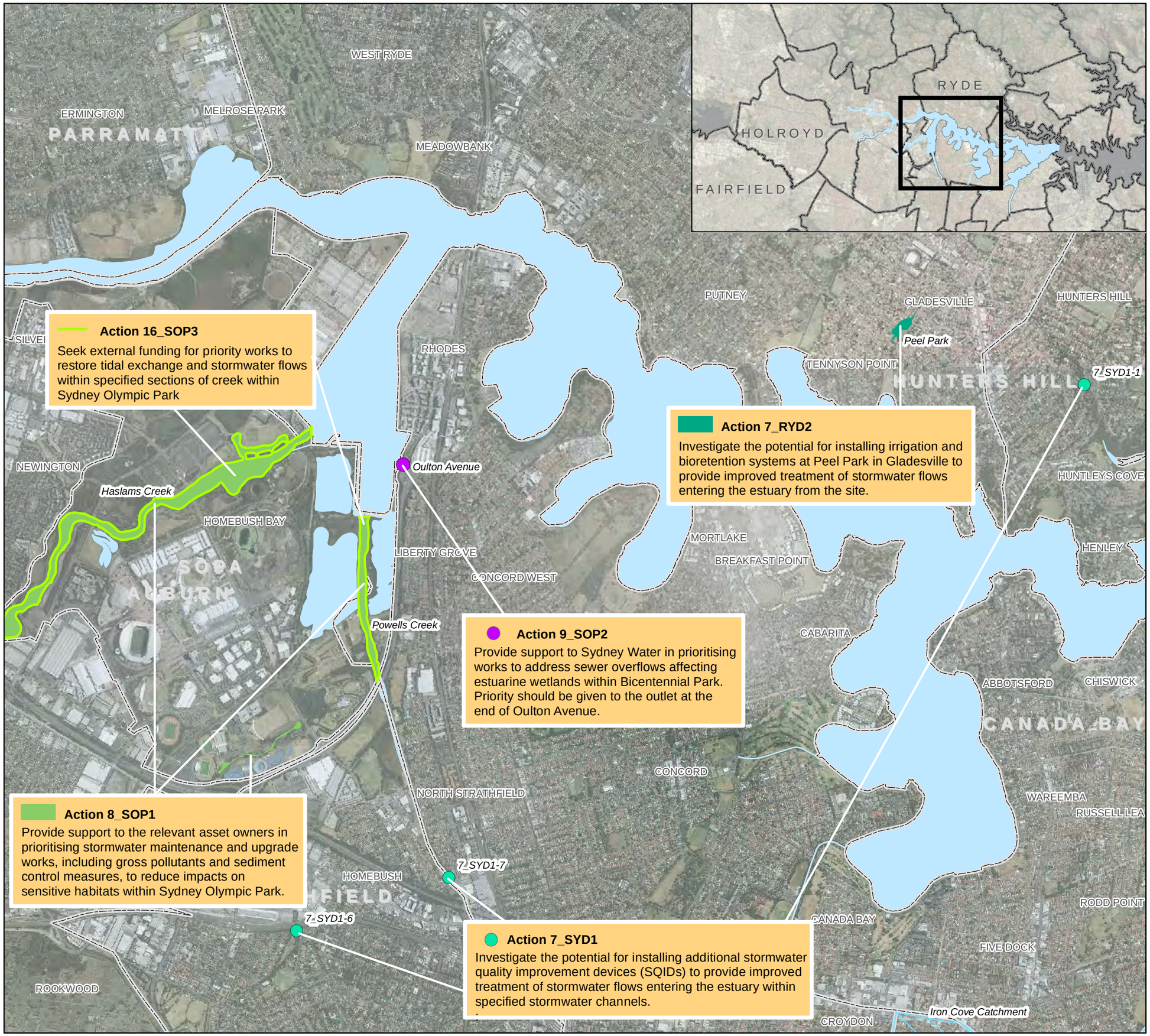
FIGURE G.2b

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG002b_WaterAndSediments_Upper.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.



Sub-Plan - Water and Sediments (Middle Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.2c

1:25,000 Scale at A3

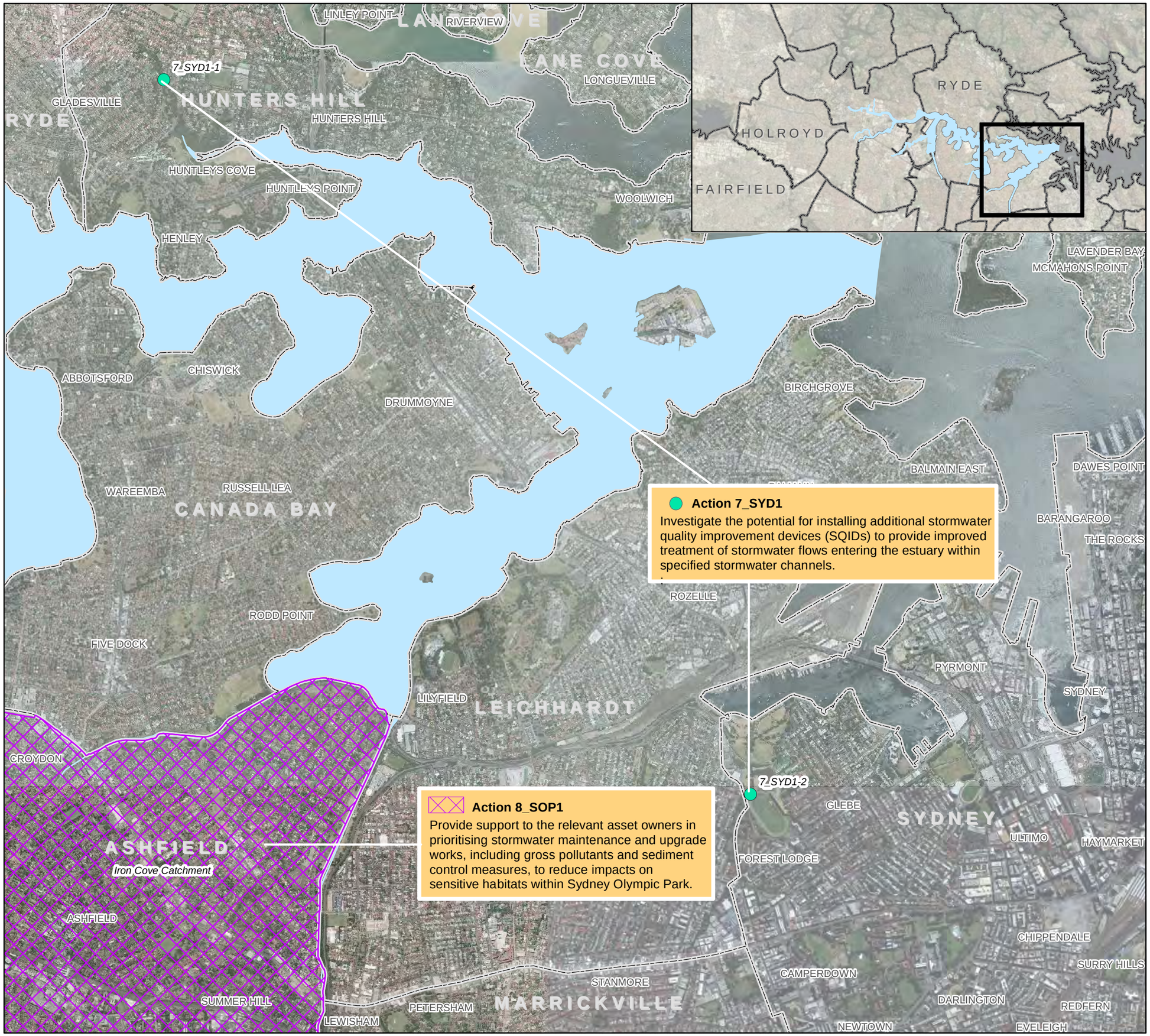
Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG002c_WaterAndSediments_Mid.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Sub-Plan - Water and Sediments (Lower Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN



Legend

- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.2d

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG002d_WaterAndSediments_Lower.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Sub-Plan - Bank Condition (Upper Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- Stormwater Outlets
- Existing Seawalls
- Existing Natural Shore
- LGA Boundaries
- Parramatta River Estuary

No Actions under this Sub-Plan for this area.

N
W E
S

FIGURE G.3a

1:25,000 Scale at A3

Metres
0 200 400 600 800

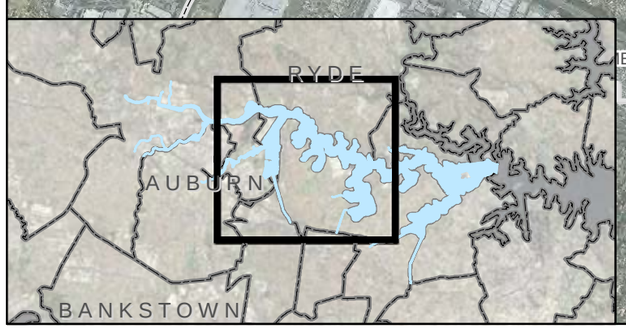
Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG003a_BankCondition_Upper.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Action 23_RYD5

Rehabilitate sections of eroding foreshore identified as being of a high priority and in poor condition in the Estuary Processes Study (AECOM, 2010), subject to available funding.

NORTH RYDE
EAST RYDE
WEST RYDE
ERMINGTON
MELROSE PARK
PARRAMATTA
MEADOWBANK
RYDE
PUTNEY
HUNTERS HILL
GLADESVILLE
SILVERWATER
RHODES
TENNYSON POINT
HUNTERS HILL
NEWINGTON
SOPA
AUBURN
HUNTLEYS COVE
MORTLAKE
HENLEY
HOMEBUSH BAY
LIBERTY GROVE
CONCORD WEST
BREAKFAST POINT
CABARITA
ABBOTSFORD
CHISWICK
CANADA BAY
CONCORD
NORTH STRATHFIELD
WAREEMBA
RUSSELL LEA
LIDCOMBE
RODD POINT
CANADA BAY
FIVE DOCK
STRATHFIELD
BURWOOD
CROYDON
ASHFIELD



Sub-Plan - Bank Condition (Middle Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- Stormwater Outlets
- Existing Seawalls
- Existing Natural Shore
- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.3b

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG003b_BankCondition_Mid.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Sub-Plan - Bank Condition (Lower Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Action 24_HUN5

Disseminate the Environmentally Friendly Seawalls Guideline (DECC, 2009) to Council staff, particularly those involved in the assessment of Development Applications, to encourage the promotion of the guidelines. Ensure that planned repairs to specified seawalls comply with the guidelines wherever possible.

Action 23_CAN5

Repair and/or upgrade sections of seawall, natural shoreline and adjacent affected infrastructure around Iron Cove, including the sections identified in the Estuary Processes Study (AECOM, 2010). Design in accordance with the DECC (2009) Guidelines for Environmentally Friendly Seawalls where possible.

Legend

- LGA Boundaries
- Parramatta River Estuary

N
W E
S

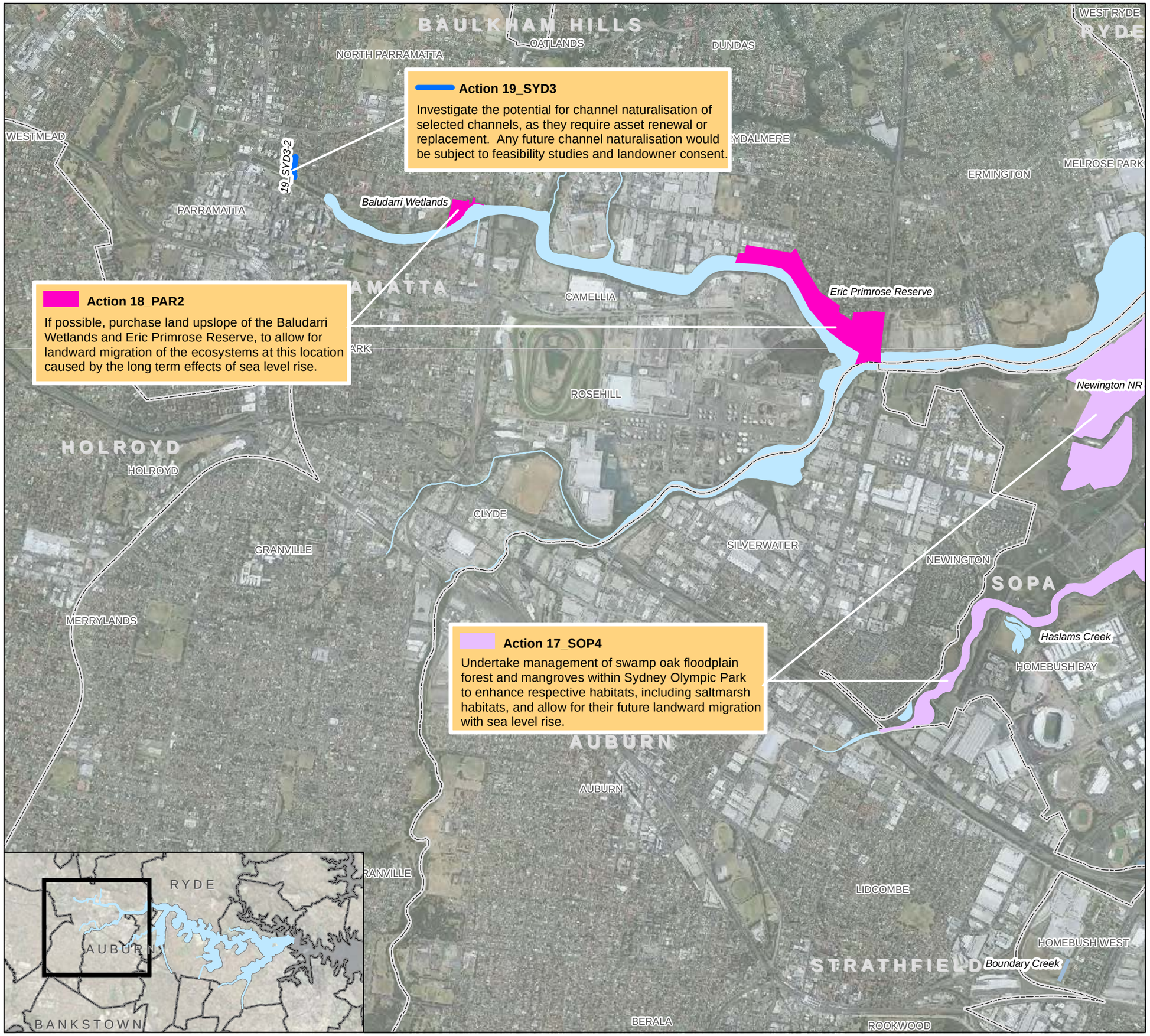
FIGURE G.3c

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG003c_BankCondition_Lower.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.



Sub-Plan - Estuarine Ecology (Upper Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.4a

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG004a_EstuarineEcology_Upper.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Action 17_SOP4

Undertake management of swamp oak floodplain forest and mangroves within Sydney Olympic Park to enhance respective habitats, including saltmarsh habitats, and allow for their future landward migration with sea level rise.

Action 21_RYD4

Upgrade/repair specified seawall sections identified as being in poor condition and of a high priority in the Estuary Processes Study (AECOM, 2010). Incorporate additional vegetated habitat in designs, subject to funding.

Action 20_HUN4

Continue bush regeneration in all reserves of the Parramatta River estuary catchment located within Hunters Hill LGA, including undertaking the recommendations made by AECOM (2010), including management of Phoenix palms, Coral trees, Green Cestrum, mangroves, Alligator Weed and Camphor Laurels.

Action 17_HUN3

Undertake management of estuarine vegetation within Gladesville Reserve and Riverglade Reserve to enhance saltmarsh habitats in these areas and allow for future landward migration with sea level rise.

Action 17_HUN2

Provide for the ongoing monitoring, conservation and management of estuarine vegetation and adequately address stormwater/sewage issues in Tarban Creek (in Riverglade Reserve).

Action 17_STR3

Provide for the ongoing monitoring, conservation & management of saltmarsh, swamp oak floodplain forest and mangrove communities in Mason Park to enhance estuarine habitat and allow for future landward migration with sea level rise.

Action 13_STR2

Manage public access and/or off-leash dog walking near the Mason Park wetlands. Managing public access may involve formalising a walking trail, prohibiting access or installing signage to indicate appropriate activities.

Action 17_CAN3

Undertake enhancement of estuarine vegetation as a stabilisation method in areas of erosion, and to protect existing seawalls from further erosion, in locations specified by (AECOM, 2010).

Action 19_SYD3

Investigate the potential for channel naturalisation of selected channels, as they require asset renewal or replacement. Any future channel naturalisation would be subject to feasibility studies and landowner consent.

Action 19_SYD4

In consultation with Strathfield Council and the City of Canada Bay, consider the addition of tide gates along Powells Creek to increase the flushing of the Mason Park wetlands, subject to feasibility studies.

Action 21_CAN4

Develop and commence a staged implementation program to include environmentally friendly seawalls as key options for seawall and foreshore management, where reasonable and feasible. As a priority, repair/ upgrade specified existing seawall sections.

MEADOW BANK
RYD-S23
RYD-S11
Newington NR
SILVERWATER
RHODES
PUTNEY
TENNYSON POINT
RYD-S06
HUNTERS HILL
Tarban Creek Reserve
Riverglade Reserve
Gladesville Reserve
HENLEY
NEWINGTON
Haslams Creek
HOMEBUSH BAY
LIBERTY GROVE
MORT LAKE
BREAKFAST POINT
RYD-S03
CONCORD WEST
Powells Creek
CABARITA
CAN_S28
ABBOTSFORD
CHISWICK
CANADA BAY
Hen and Chicken Bay
19_SYD3-1
Mason Park
NORTH ST
WAREEMBA
RUSSELL LEA
19_SYD3-4
RODD POINT
BURWOOD
SOPA
AUBURN
RYDE
BANKSTOWN

Sub-Plan - Estuarine Ecology (Middle Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- Seagrass
- Mangroves
- Saltmarsh
- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.4b

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG004b_EstuarineEcology_Mid.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Action 17_HUN3
Undertake management of estuarine vegetation within Gladesville Reserve and Riverglade Reserve to enhance saltmarsh habitats in these areas and allow for future landward migration with sea level rise.

Action 20_HUN4
Continue bush regeneration in all reserves of the Parramatta River estuary catchment located within Hunters Hill LGA, including undertaking the recommendations made by AECOM (2010), including management of Phoenix palms, Coral trees, Green Cestrum, mangroves, Alligator Weed and Camphor Laurels.

Action 17_HUN2
Provide for the ongoing monitoring, conservation and management of estuarine vegetation and adequately address stormwater/sewage issues in Tarban Creek (in Riverglade Reserve).

Action 21_CAN4
Develop and commence a staged implementation program to include environmentally friendly seawalls as key options for seawall and foreshore management, where reasonable and feasible. As a priority, repair/ upgrade specified existing seawall sections.

Action 17_LEI2
Liaise with the State Government to identify potential rehabilitation and habitat management opportunities for incorporation into the re-development of Callan Park including provision for potential impacts of climate change.

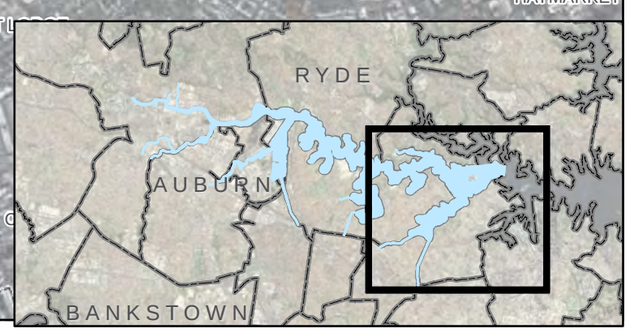
Action 21_ASH2
Utilise seawall data and photographs as a benchmark for ongoing monitoring. In particular, continue to monitor ASH_S03 for any decrease in structural stability. Include intertidal habitat in eventual seawall repair/replacement.

Action 17_CAN3
Undertake enhancement of estuarine vegetation as a stabilisation method in areas of erosion, and to protect existing seawalls from further erosion, in locations specified by (AECOM, 2010).

Action 19_SYD3
Investigate the potential for channel naturalisation of selected channels, as they require asset renewal or replacement. Any future channel naturalisation would be subject to feasibility studies and landowner consent.

Action 21_RYD4
Upgrade/repair specified seawall sections identified as being in poor condition and of a high priority in the Estuary Processes Study (AECOM, 2010). Incorporate additional vegetated habitat in designs, subject to funding.

Tarban Creek Reserve
Riverglade Reserve
Betts Park
Gladesville Reserve
Kellys Bush
Five Dock Bay
CAN_S28
CAN_S23
RYD-S02
Hen and Chicken Bay
Sisters Bay
Half Moon Bay
Iron Cove Bay
Callan Park
Haberfield Foreshore
19_SYD3-3
19_SYD3-5
RYDE
GLADESVILLE
HUNTERS HILL
LONGUEVILLE
NORTH SYDNEY
HUNTLEYS COVE
HUNTLEYS POINT
HENLEY
WOOLWICH
AVENDER BAY
ONS POINT
ABBOTSFORD
CHISWICK
DRUMMOYNE
BIRCHGROVE
WAREEMBA
RUSSELL LEA
CANADA BAY
BALMAIN EAST
BALMAIN
DAWES POINT
BARANGAROO
THE ROCKS
RODD POINT
ROZELLE
FIVE DOCK
PYRMONT
LILYFIELD
LEICHHARDT
SYDNEY
CROYDON
GLEBE
ULTIMO
HAYMARKET
STANMORE
PETERSHAM
MARRICKVILLE



Sub-Plan - Estuarine Ecology (Lower Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend
- Seagrass
- Mangroves
- Saltmarsh
- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.4c

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG004c_EstuarineEcology_Lower.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority, Bing and associated third party suppliers.

Sub-Plan - Human Usage (Upper Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Action 25_PAR4

Improve public access along the estuary foreshores by completing the Parramatta Valley Cycleway Shared Path within the LGA by constructing the following missing links:
A) 1 Park Road
B) Pike to South Street Section
C) Baludarri Wetlands
D) Gasworks Bridge
E) Lennox Bridge Portal Project.

Legend

- Foreshore Boating Facilities
- Moorings
- Other Recreation Facilities
- LGA Boundaries
- Parramatta River Estuary

N
W E
S

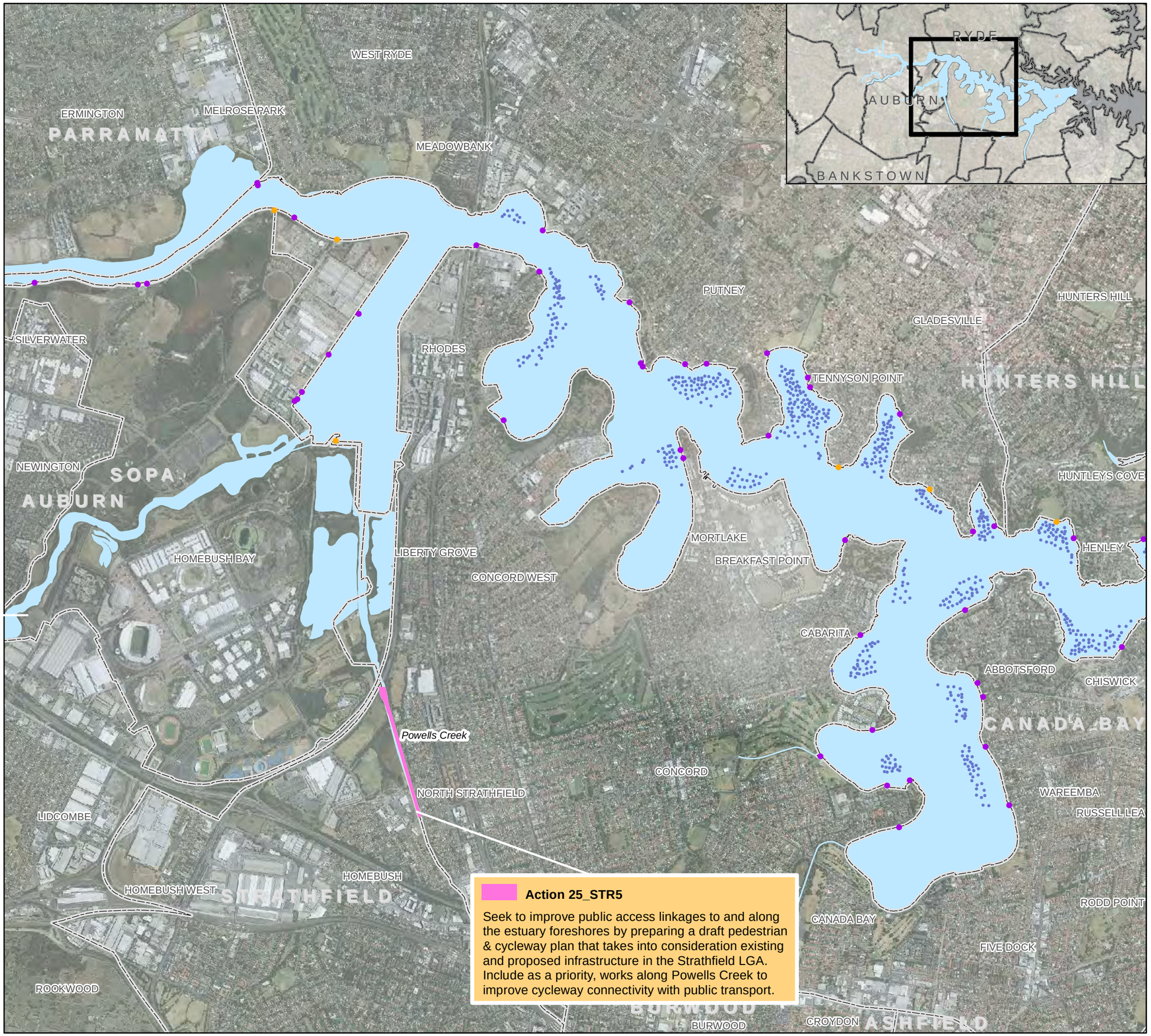
FIGURE G.5a

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG005a_HumanUsage_Upper.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.



Action 25_STR5

Seek to improve public access linkages to and along the estuary foreshores by preparing a draft pedestrian & cycleway plan that takes into consideration existing and proposed infrastructure in the Strathfield LGA. Include as a priority, works along Powells Creek to improve cycleway connectivity with public transport.

Sub-Plan - Human Usage (Middle Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- Foreshore Boating Facilities
- Moorings
- Other Recreation Facilities
- LGA Boundaries
- Parramatta River Estuary

N
W E
S

FIGURE G.5b

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG005b_HumanUsage_Mid.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority and associated third party suppliers.

Sub-Plan - Human Usage (Lower Estuary)

PARRAMATTA RIVER ESTUARY
COASTAL ZONE MANAGEMENT PLAN

Legend

- Foreshore Boating Facilities
- Moorings
- Other Recreation Facilities
- LGA Boundaries
- Parramatta River Estuary

No Actions under this Sub-Plan for this area.

N
W E
S

FIGURE G.5c

1:25,000 Scale at A3

Metres
0 200 400 600 800

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2012-08-16
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2929
Map: GG005c_HumanUsage_Lower.mxd 02
Data source: NSW Land and Property Information (LPI)
Aerial Imagery supplied by Sydney Metropolitan Catchment Management Authority, Bing and associated third party suppliers.

Appendix H

Overview of Existing Monitoring Activities

This Appendix provides a brief overview of existing monitoring programs and activities conducted by a range of organisations within the Parramatta River, including details of indicative sampling locations and parameters monitored.

H.1 Existing Monitoring Activities in the Parramatta River Estuary

There are a number of existing monitoring programs conducted within the Parramatta River estuary. Monitoring of a range of different environmental parameters is currently carried out by most of the Committee members, as well as independent consultancy companies and universities. Some of these activities are conducted under larger programs such as Streamwatch and Harbourwatch, and most target water quality monitoring. There have also been a number of targeted investigations that have been conducted over the years, primarily in relation to research projects (e.g. Sydney University sedimentary contamination sampling) or proposed developments (e.g. for the Sydney Olympic site or dredging works for the RiverCat).

Sediment and water quality monitoring undertaken within the Parramatta River estuary has recently been compiled and reviewed by the Water Research Laboratory (WRL) in the 2011 *Sydney Harbour Catchment Water Quality Improvement Plan: Data Compilation and Review*. WRL (2011) found that Sydney Water has the most comprehensive water quality monitoring program and existing data set for the estuary, although it is understood that only three of their seven sites are currently being monitored.

Other variables currently monitored for the Parramatta River estuary include:

- *Water Quality Monitoring* – Recreational water quality: pathogenic bacteria such as faecal coliforms, e.g. under Harbourwatch by OEH; and water quality more generally: various variables are monitored by councils, primarily in catchment tributaries, but some estuarine sites have been sampled in the past (e.g. by OEH);
- *Gross Pollutants* – volumes of material removed, by councils and RMS (Maritime);
- *Sediment Quality* – various variables, most of the work has been undertaken by the University of Sydney School of Geosciences;
- *Estuarine Macrophytes* - mangroves, saltmarsh and seagrass, by DPI, OEH and HNCMA;
- *Estuarine Fauna* – Fish: primarily limited studies for environmental impact assessment (EIA) purposes, and PCC has been sampling populations to test the effectiveness of new fish ladders; and avifauna: primarily limited studies for EIA purposes, although ongoing monitoring is undertaken by bird watchers and the data collated by organisations such as the Cumberland Bird Observers Club; and
- *Invasive Species* – DPI takes primary responsibility for the monitoring of terrestrial and aquatic weeds, and the Sydney Weeds Committee has also undertaken some mapping work in collaboration with the HNCMA.

The majority of estuarine health monitoring conducted to date has been relatively ad hoc, and has not been coordinated by a central authority. Whilst a range of monitoring activities and other investigations have been undertaken, there is significant variation in the spatiotemporal scale and type of the monitoring activities undertaken. In addition methods employed have been varied, for example, specific details on sampling techniques, QA/QC protocols, frequencies of sampling, analyses applied and methods of reporting are not standard, and in many cases is not known. Often the monitoring activity in question targets a specific risk (e.g. human health in the case of Harbourwatch), and the data generated is not necessarily useful as a wider indicator of estuarine health. These can present a challenge in terms of collating data for analysis and interpretation on estuarine processes/health, particularly in the context of the range of natural variation typically observed in estuarine systems.

There is a demonstrated need to develop an improved understanding of estuarine health in the Parramatta River. This will require improved coordination and consolidation of ongoing monitoring activities, data collation, analysis and reporting. The variables and units of measurement adopted should ideally be consistent across all activities. In addition, it is recommended that a consistent approach to QA/QC is also adopted. This process will also need to be linked with the reporting requirements under the MER Strategy. As previously indicated, for many variables there is no baseline currently established. However, for other variables it may be possible to collate and analyse some of the existing data in order to develop a baseline for benchmarking.

Water Quality Monitoring

The *Sydney Harbour Catchment Water Quality Improvement Plan: Data Compilation and Review* (WRL, 2011) found that water quality data has been collected by various organisations across a number of sites within the estuary catchment. Table H.1 provides a summary of which organisations are currently collecting samples and the parameters of interest.

The categories of water analytes discussed in Table H.1 generally include the following parameters:

- Physico-chemical:
  - pH,
  - Electrical Conductivity (EC) / Salinity,
  - Dissolved Oxygen (DO),
  - Biological Oxygen Demand (BOD),
  - Oxidation/reduction potential (Redox),
  - Temperature,
  - Hardness,
  - Cations / anions;
- Clarity:
  - Secchi disc,
  - Total Suspended Solids (TSS),
  - Total Dissolved Solids (TDS),
  - Turbidity,
  - Colour;
- Nutrients:
  - Nitrogen, which can be measured as Total Nitrogen (TN), or biologically available forms (Total Kjeldahl Nitrogen (TKN), Nitrates and Nitrites (NOx) and Ammonia (NH_4)),
  - Phosphorous, which can be measured as Total Phosphorous (TP), biologically available form Filterable Reactive Phosphorous;
- Biological:
  - Concentrations of Chlorophyll-a or other photosynthetic pigments, either in the water column or from the surficial sediments,
  - Algal counts, including cyanobacteria (blue green algae);
- Bacterial pathogens:
  - Faecal coliforms (FC) and Enterococci; and

- Heavy metals.

Table H.1: Overview of Existing Water Quality Monitoring the Parramatta River (After: WRL, 2011)

Organisation	Details	Water Quality Parameters					
		Physico-chemical	Clarity	Nutrients	Biological	Bacterial	Metals
Auburn City Council	4 sites generally along Duck River (fortnightly since September 2004 – ongoing)	Some	Some	Some	Some	FC	No
Bankstown City Council	70 (various sites inactive) (monthly from July 1997 – ongoing)	Yes	Some	Some	Some	FC	No
The Hills Shire Council	-	Yes	No	Yes	No	Yes	No
Hunters Hill Council	-	No	No	No	No	Yes	No
Parramatta City Council	6 sites (monthly from 1990 – October 2007)	Yes	Yes	Yes	No	No	No
City of Ryde	1 site on Archer Creek within the Parramatta River estuary catchment (in Autumn and Spring from 2004 – ongoing)	Some	Some	Some	No	No	No
OEH	Parramatta River (transect along the River from Ryde Bridge to Camelia from December 2010 – February 2011)	Some	Some	No	Some	No	No
	Homebush Bay	No	No	No	No	No	Yes*
Streamwatch	29 currently active sites in the Sydney Harbour catchment	Some	Some	Some	Some	Yes	No
Harbourwatch	3 currently active sites in the Parramatta River estuary: Cabarita Beach, Chiswick Baths and Dawn Fraser Pool	No	No	No	No	Yes	No
Laxton Consulting	10 sites in the Parramatta River estuary catchment (monthly from 1990 to 2008)	Yes	Yes	Yes	Yes	Yes	No

Organisation	Details	Water Quality Parameters					
		Physico-chemical	Clarity	Nutrients	Biological	Bacterial	Metals
Sydney University	6 month stormwater monitoring on Queen Street and Parramatta Road	No	No	No	No	No	Yes
	866 stormwater samples (9 locations)	No	No	No	No	No	Yes
	8 locations monitored monthly for water quality, analysed for metals	No	No	No	No	No	Yes
	30 samples in Homebush Bay	No	No	No	No	No	Yes
Sydney Water	3 ongoing and 4 past monthly monitoring sites in the Parramatta River estuary (see Table H.2)	Yes	Yes	Yes	Yes	Yes	No
SOPA	29 sites (monthly from 2007 – 2009)	Yes	Some	Some	No	FC	No
Robinson GRC Consulting	Upper Parramatta River (1990 – 1997)	No	Yes	No	No	No	No
Waterwatch	62 sites in the upper Parramatta River estuary catchment	Some	Some	Some	No	No	No

* Also dioxins

Sydney Water has the most comprehensive and contemporary water quality record for the Parramatta River estuary, with three sites located in the study area (Table H.2).

Table H.2: Sydney Water Monitoring Sites in the Parramatta River Estuary (After: WRL, 2011)

Site No.	Site Description	Monitoring Period
PJ00	Homebush Bay	Aug 1995 to Jun 2008
PJ01	Silverwater Bridge	Aug 1995 to Jun 2008
PJ08	Iron Cove	Aug 1996 to Jun 2008
PJ34	Duck River	Aug 1995 to Jun 2008
PJPR	Parramatta Weir	Aug 1995 to present
PJCB2	Cabarita Beach	Jul 2008 to present
PJDFP	Dawn Fraser Pool	Jul 2008 to present

Gross Pollutants

As part of regular operation and maintenance, Sydney Water and several of the local councils record the amount of material removed from their gross pollutants traps (GPTs). However, as noted by AECOM (2010), not all councils record this information, and for those that do the data are recorded and managed differently in accordance with each organisation's particular processes and requirements. AECOM (2010) recommended the consolidation of stormwater management activities and more uniform data collection and reporting format by all stakeholders be facilitated by the Committee, using the present format provided in the City of Canada Bay's State of the Environment reports as a baseline template from which an overarching format could be further developed. This would be a useful activity for benchmarking success of implementation of WSUD features and community education programs on catchment management.

Sediment Quality

Available information on monitoring of estuarine sediments is collated in WRL (2011), a summary of which is provided in Table H.3.

The School of Geosciences at Sydney University has undertaken the most extensive sediment data collection in Sydney Harbour and its catchment, including the Parramatta River estuary catchment. The majority of sampling undertaken in the Parramatta River estuary has been for heavy metals. Table H.3 provides an overview of existing sediment quality monitoring, including number of sediment samples, analytes and data sources for sediment sampling undertaken; however this dataset is not comprehensive.

Table H.3: Overview of Existing Sediment Quality Monitoring (After: WRL, 2011)

Organisation	Sampling Details	Parameters Analysed
Sydney University	140 surficial samples in Port Jackson and 107 samples in catchment streams	Organochlorines
	124 sediment samples in Sydney Harbour	PAHs 2-methylnapthalene
	Offshore sediment samples taken	Metals
	4 offshore sediment cores from the continental margin	Metals
	404 sediment harbour samples (various analysis)	Various
	4 estuarine sediment samples collected on one day in Iron Cove	Metals
	48 sediment samples from Bicentennial Park and 6 sediment samples from Rozelle Bay reclamation	Metals
	69 Sydney Harbour sediment samples	Various
	39 sediment samples in Homebush Bay	Metals
	491 catchment sediment samples taken in different land use areas	Metals
OEH	5 sites in Parramatta River outside Homebush Bay	Metals

Sediments are useful as indicators of historical water quality issues due to the chronological record established by the progressive deposition of sediments. Whilst sedimentary contamination can impact on contemporary water quality,

sediment quality is not recommended as a high priority for monitoring in the Parramatta River estuarine health monitoring program.

Estuarine Macrophytes

The NSW DPI currently has primary responsibility for mapping of aquatic macrophytes (mangroves, saltmarsh and seagrass) in estuaries in NSW, often in collaboration with OEH and CMAs. This mapping is based on a combination of aerial photography interpretation and ground-truthing as part of state-wide projects, such as the recent Seabed Mapping project. The primary objective of the estuarine component of DPI's Seabed Mapping project was to complete a state-wide GIS inventory of mangroves, saltmarsh and seagrass habitats, a task that was started during the Comprehensive Coastal Assessment (Creese *et al*., 2009). Additional data collated by other state agencies, local government authorities or non-government organisations are also registered in the comprehensive database.

The following years of estuarine vegetation GIS data sets for the Parramatta River estuary are held by SMCMA and DPI: 1943, 1978, 1986, 2003 and 2005. An assessment of some of this information is available in West *et al.* (2004) and West and Williams (2008). In 2010 AECOM verified the most recent mapping undertaken by DPI. These data sets can be used as a contemporary benchmark for the extent of estuarine macrophytes.

Estuarine Fauna

Most of the fauna surveys undertaken for the study area were performed for a specific purpose (e.g. for an EIA) and are therefore spatially and temporally limited.

As identified in the *Data Compilation Study* (Cardno, 2008) there are a number of previous studies of avifauna of the Parramatta River estuary, with a number of locations having been surveyed within the last decade, including Leichhardt, Sydney Olympic Park, Homebush, Homebush Bay and the Clyde Refinery Site. Homebush Bay appears to be the most extensively surveyed site for birds, in the Bicentennial Park Wetlands. It is understood that data sourced from bird watchers can also be obtained from organisations such as the Cumberland Bird Observers Club.

Cardno (2008) provide a review of the available literature on fish, and identified that there is generally a lack of information about fish assemblages within the Parramatta River estuary. Homebush Bay appears to have been relatively well surveyed for fish populations over the last 20 years and some of the studies also included Brays and Yaralla Bays. Parramatta City Council recently conducted an investigation into fish assemblage response to new fishways on the Parramatta River. This is a two year project involving electrofishing surveys before and after installation of fishways installed on four weirs on the upper Parramatta River in 2009 and 2010, so again the area surveyed is spatially limited. However, it is understood that no regular/periodic monitoring of fish assemblages is currently being undertaken.

Various sampling programs have also been undertaken for macroinvertebrates, which are commonly sampled as an indicator of waterway health using the SIGNAL method. Parramatta City Council carried out a macroinvertebrate sampling program over two years in 2003 and 2004 at 21 different sites across the Parramatta LGA. Macroinvertebrate sampling is also currently conducted annually in Tarban Creek in the Hunters Hill LGA.

Invasive Species

DPI plays a lead role in the management of invasive species through implementation of the *NSW Invasive Species Plan 2008-2015* (DPI, 2008), which provides for the implementation of the *NSW Weeds Action Program*.

The main principal of weed management is prevention and the primary target is new weeds that pose a significant risk, followed by those weeds that are still able to be suppressed and controlled. The Sydney Weeds Committees manage the Sydney Region and have Regional Weed Management Plans in place for particular invasive species. Weed mapping is undertaken by the Sydney Weeds Committees in collaboration with the HNCMA to determine priorities for control and to monitor results, although not all weeds are mapped. The priority is to record and map new weed incursions to determine how eradication or control is progressing and to monitor for recurrence, which will help prevent further spread. A Priority Weed Mapping project was undertaken in 2007/08 by the SMCMA (now HNCMA) and the Sydney Weeds Committees. Five priority aquatic weeds and two grass weeds in the Sydney Metropolitan region were mapped, including *Alternanthera philoxerioides* (Alligator Weed), which is one of the most serious aquatic weeds present in Australia, classified as a Weed of National Significance and listed as noxious under the *Noxious Weeds Act 1993*. DPI also monitor the aquatic weed, *Caulerpa taxifolia*.

A state-wide MER strategy for invasive species is currently being developed, based around the four approaches to weed management (prevention, eradication, containment and asset protection) using the following three indicators (I&I, 2010):

- New incursions,
- Emerging species, and
- Asset protection through reducing impacts at priority sites.

Given that weed management is being undertaken under these existing programs, it is considered that ongoing assessment under the estuarine health monitoring program is not required. Any data required for assessment against the KPIs in Section 6.1 could be obtained by the Committee as required.

H.2 Other Estuarine Health Monitoring Programs

There are a range of different approaches for monitoring of estuarine health for other estuaries in NSW and elsewhere. This section provides a brief overview of various different programs and how they are implemented.

Georges River Health Monitoring Program

The Georges River Combined Councils Committee aims to assess the health of the Georges River on a regional scale, thereby highlighting priority areas for future conservation works. A total of 42 sites located throughout the entire catchment are monitored, primarily on catchment tributaries. The first two years of the program are funded by a $210,000 Federal Government Caring for Our Country Grant, with significant in-kind support from a network of 200 volunteers from schools, Streamwatch and Bushcare Groups.

It is understood the program is based on the Australian Government Waterwatch framework (DEC, 2004; http://www.waterwatch.org.au/monitoring.html), which includes guidelines on conducting a water quality monitoring program. This program has also recently been modified to be compatible with the NSW MER Strategy. It incorporates the following water quality variables as a so-called 'snap shot' of estuarine health:

- Water quality – pH, Electrical Conductivity (EC), turbidity, temperature, Total Nitrogen (TN) and Total Phosphorous (TP).
- Macroinvertebrates – the number and diversity of macroinvertebrates is used to calculate SIGNAL (Stream Invertebrate Grade Number – Average Level) and Shannon-Wiener Index (diversity) scores, which is an indicator of water quality for aquatic ecosystem health (see Chessman, 2003);

- Riparian and estuarine vegetation – RARC (Rapid Appraisal of Riparian Condition) scoring system; and
- Introduced Species – Plague Minnow, Gambusia (present or absent).

It is understood that the sites are monitored quarterly over a period of four weeks. The monitoring results are analysed and published quarterly using a report card format (http://www.georgesriver.org.au/River-Health-Monitoring-Program.html) within which the estuary health is clearly summarised and easily tracked.

The benefits of this approach are that, in focussing on catchment tributaries it is possible to consider potential sources of pollutants in the event that a water quality issue is observed. It also permits the identification of priority areas (e.g. that are high in biodiversity) for conservation. Another benefit of the approach adopted in the Georges River estuary is the high level of involvement by community volunteers, which is a great way of raising awareness about catchment and estuarine health issues. It also results in the community taking ownership of the program, and provides an excellent opportunity for promotion of estuarine health monitoring and management initiatives.

The risks associated with this approach include potential for volunteer fatigue and an associated decline in monitoring. Ensuring adequate QA/QC procedures are followed is also an issue where volunteers are used, and a high level of commitment to providing ongoing training and monitoring of QA/QC protocols is required. In addition, despite the significant contribution of volunteers, the program remains relatively expensive and may not provide a great deal of information on in-estuary processes due to its focus on catchment tributaries.

Southern Rivers CMA Monitoring Program

The Ecosystem Health Monitoring Program for Estuaries and Coastal Lakes in the Southern Rivers Catchment CMA is currently being developed to monitor 76 estuaries in the Southern Rivers region. The Program is currently only in concept phase and has not been implemented yet. The program is a partnership between the CMA, six local councils and other supporting organisations. It will adopt a range of different key variables:

- Extent of estuarine macrophytes (seagrass, saltmarsh, mangroves) (sampling program not yet set);
- Seagrass depth limits;
- Turbidity (NTU) and water clarity (Secchi disc) to be sampled every 12 months and event based over three sites in lagoons and five sites in riverine estuaries;
- Chlorophyll a to be sampled fortnightly over summer and monthly at other times, across three sites in lagoons and five sites in riverine estuaries;
- Wetland health; and
- Water quality (temperature, salinity and pH) to be sampled concurrently with chlorophyll a.

Botany Bay Water Quality Improvement Program

The Botany Bay Water Quality Improvement Program (BBWQIP) is being delivered and managed by the HNCMA and is currently being funded by the Australian Government. The BBWQIP commenced in July 2009 and is ongoing, with the current focus being on implementing the recommendations set out in the *Botany Bay and Catchment Water Quality Improvement Plan*, developed as part of the Program (SMCMA, 2012a).

The Program is seeking to achieve long-term protection of the surface waters of Botany Bay, its estuaries and its catchment. The major activities achieved by the Program from 2009 to date have been (SMCMA, 2012a):

- The development of the *Botany Bay and Catchment Water Quality Improvement Plan*;
- The deployment of a real-time water quality monitoring network for Botany Bay and its estuaries;
- The development of a Water Quality Decision Support System that can be used at the catchment and sub-catchment scales; and
- Partnering with land managers to install water quality improvement devices to treat at least 50 ha of urbanised land.

The five water quality monitoring stations for the Botany Bay Catchment became operational in July 2010, located in the upper and mid Georges River estuary, the upper and lower Cooks River estuary and within Botany Bay. The following parameters are being measured in real-time at each site (SMCMA, 2012a):

- Temperature;
- Salinity;
- Turbidity;
- Chlorophyll-a;
- Dissolved Oxygen; and
- Light (PAR).

Lane Cove River Saltmarsh Monitoring Program

For the Lane Cove River estuary a slightly different approach to monitoring estuarine health was adopted that focuses on saltmarshes as an indicator of estuarine health, thereby effectively monitoring the actual health of a key estuarine ecosystem, rather than making inferences about estuarine health based on other broader indicators (e.g. water quality). This approach can be particularly useful when considering more complex issues, such as the potential impacts of climate change on estuarine ecosystems. The purpose of the monitoring program is both to track trends in saltmarsh health, and to monitor the outcomes of rehabilitation works. The program includes monitoring of the following core variables:

- Hydrology:
  - Changes in water levels with respect to a reference point as measured by either surface water level gauges located both up and downstream of the subject site, or groundwater levels (peizometers) at rehabilitation sites;
  - Changes to areas of inundation (which may be an indicator of SLR) using a photographic record and/or permanent markers;
  - Marsh-surface elevation at contour intervals of 15cm or less, mapped as contours or via a hypsometric curve;
- Soils and Sediments:
  - Pore water salinity in ppt from soil water collected at 15-25cm depth;
- Vegetation:
  - Composition (species per m^2);

  - Abundance (mean height of three tallest specimens of each species of concern per m^2);
  - Density (no. of shoots per quadrant for species of concern);
- Nekton (two faunal groups per sample):
  - Changes in diversity and abundance over time, and changes in biomass over time, for molluscs and crabs;
- Birds:
  - Density (no. of birds per ha, by species);
  - Guild richness (no. of birds per guild, e.g. waterfowl, shorebirds, wading birds, aerial foragers, passerines);
- Invertebrates:
  - Mosquitoes (larvae and pupae per m^2); and
  - Changes in the diversity and abundance of insects and spiders.

There are a number of additional variables that can also be monitored under these categories, such as water quality, sediment accretion rates and sediment elevations. Further information on the saltmarsh monitoring program can be found in Applied Ecology (2010).

The difficulty in applying such a monitoring program within the Parramatta River estuary is that the distribution of saltmarsh is limited and confined largely to the southern bank of the mid-estuary. There are therefore large parts of the catchment that don't drain to saltmarsh areas. However, it would be useful to include a saltmarsh monitoring component within the estuarine health monitoring program, which may then be compared against the data collected from the Lane Cove River.

H.3 General Comments

There are two general approaches to estuarine health monitoring that may be adopted:

- Adoption of a comprehensive monitoring program that covers a range of variables; or
- Monitoring of a much smaller set of key indicators from which it is possible to make inferences about the health of the system as whole.

Both approaches have their advantages and can be resource intensive in their own ways. A combination of the two approaches might be suitable for the Parramatta River estuary. In this case, it is recommended that the Committee consider obtaining support or establish partnerships for monitoring of key indicators (e.g. saltmarsh communities) from SOPA or other research organisations such as the Sydney Institute of Marine Science, or Centre for the Ecological Impacts of Coastal Cities at Sydney University. Research to establish a baseline, track trends or assess rates of variation in specific communities or estuarine processes should be regularly reviewed for relevance to the Parramatta River estuarine monitoring program.

It would also be advantageous if the estuarine health monitoring program adopted for the Parramatta River estuary was consistent with that applied in the Georges River estuary. Both estuaries have similar catchment characteristics, with high levels of urban development including a history of industrial activity. It would be useful to compare estuarine health

indicator values and trends in the data between estuaries. This has potential to act as a benchmarking exercise, not only for these two estuaries, but also for urban estuaries more generally.

Ideally, there should also be some contingency in the monitoring budget for following up on any issues observed during the regular program of monitoring. However, in reality the design of the estuarine health monitoring program will also need to consider the available resources for implementation.

Appendix I

Additional Estuarine Health Monitoring Guidance

This Appendix provides some additional guidance on the implementation of the proposed estuarine health monitoring program for the Parramatta River estuary. It also identifies a range of additional parameters that could potentially be incorporated into the monitoring program in the future in the event that additional funding becomes available (Table I.1).

Sampling Design

In order to develop a comprehensive data set that can be analysed in a statistically rigorous fashion it is necessary to carefully consider the design of the sampling program.

Sources of Variation

Variables are characteristics that can differ from location to location, or from day to day. Consideration must be given to potential sources of variation beyond the sources of specific variables that are the subject of the monitoring program. There are a number of other factors that will influence the reported faecal coliform concentrations, including the sample collection process and the laboratory analysis process. These potential sources of variation must be identified and minimised where possible, so that clear conclusions can be drawn from the monitoring data.

The major sources of variation relate to spatio-temporal effects, i.e. changes over time or space. As outlined above, there are also sources of variation related to the sampling or laboratory methods used. The main sources of variation relevant to the water quality monitoring program include:

- Spatial, or site specific, variation - relating to the particular characteristics of each site e.g. hydrology;
- Temporal variation – e.g. on a day to day basis such as diurnal variations in photosynthetic activity (and consequent effects on DO concentrations);
- Weather – e.g. wet weather or dry weather;
- Tides – as they affect flow direction and mixing;
- Natural variation – there will inherently be a degree of natural variation in the natural environment; and
- Error – sampling or analytical error, such as contamination.

It is impossible to remove or minimise all sources of variation through the sampling design process. However, they should be minimised as much as possible. It is necessary to make an attempt to control or separate out these sources of variation in order to isolate variation attributable solely to the variable of interest.

Sampling for Impact Assessment – Making Comparisons with Baseline Data

The estuarine health monitoring program is effectively an impact assessment of the hypothesis that the management activities outlined in the implementation strategy will have a positive impact on estuarine health, and that therefore the general condition of the estuary will improve from its current condition. Sampling methodologies and statistical design for impact assessment have been refined by a number of researchers beginning with the introduction of the "before-after / control-impact" (or BACI) design (Green, 1979) and further developed by others (including Underwood, 1991, 1992, 1994).

The basic premise of a BACI design is that in order to detect impacts in a statistically rigorous fashion, the sampling design must include the incorporation of at least one "control" (un-impacted) and one "impact" site and that these sites must be sampled both before and after the impact (i.e. the rehabilitation works). This design accounts for both spatial and temporal variation. For example, in the consideration of ecological effects, if there is an environmental disturbance

or change that affects a species, it would appear as the statistically significant difference between the mean abundances of the sampled species in the control and potentially impacted locations before disturbance, and the difference in mean abundances at these locations after disturbance. That is, if there was an impact, the difference between the two locations will be more pronounced after the impact. However, as discussed in a literature review by Underwood (1994), this analysis will be confounded by the lack of replication for control and impact sites. Ideally, control and impact sites should be spatially and / or temporally replicated, preferably in an orthogonal fashion (Underwood, 1991). An orthogonal design has equal numbers of replicates at all levels or treatments (e.g. the same number of samples for the "Before" treatment as for the "After" treatment). This is known as a "Beyond-BACI" sampling design. Times of sampling are random and therefore this type of design nests sources of variation in the data (Underwood, 1991).

Unfortunately a Beyond-BACI style sampling design is not strictly possible for the Parramatta River estuarine health monitoring program due to the lack of what may strictly be termed "control" sites (i.e. unaffected sites). However, the basic sampling design should still consider the requirements of statistical tests by developing an orthogonal design. It is recommended that observed trends in estuarine health for the Parramatta River estuary be compared to those in the Georges River, which will provide some indication of whether changes in variables are the result of natural background variation or due to actual improvements against baseline conditions.

Field Sampling

Sampling Protocols

There are a number of current documents that detail appropriate sampling protocols for different parameters. Where specific sample techniques exist to monitor a particular parameter, the relevant document has been noted in the table, to ensure the sampling and handling methodology is consistent across all sites. The key documents that detail sampling protocols are:

- The MER Sampling Protocols (OEH, 2013; Scanes *et al*., 2009), which provides protocols for sampling for key estuarine MER indicators;
- Australian Standards including:
  - AS/NZS 5667.12:1999 Water Quality - Sampling - Guidance on Sampling of Bottom Sediments,
  - AS/NZS 5667.1:1998 Water Quality - Sampling - Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples, and
  - AS/NZS 5667.6:1998 Water Quality - Sampling - Guidance on Sampling of Rivers and Streams;
- *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC, 2000), which provides protocols for sampling of surface waters, sediments and aquatic organisms;
- *Guidelines for Managing Risks in Recreational Waters* (NHMRC, 2008), which provides protocols for sampling bacteria; and
- *National Protocol for Monitoring of Cyanobacteria and their Toxins in Surface Waters* (NRMMC, 2007), which provides protocols for sampling cyanobacteria.

For purposes of field QA/QC, it can be useful to take field duplicates and field blanks. Field blanks and field duplicates are collected and analysed in order to quantify any variations resulting from the field sampling process itself. For example, water samples may be contaminated during the sampling process. It is also one way of identifying any sources

of error or variation relating to laboratory analytical processes. These blanks and duplicates should be allocated in a random fashion at the outset of the sampling campaign.

Sampling Locations

A number of work health and safety issues need to be considered when selecting sampling sites. Some issues to consider include safe vehicular/pedestrian access to the site, unobstructed and stable ground conditions at the site (particularly along natural creek banks), the sampling requirements (e.g. timing with a rainfall event or particular tidal conditions), travel times between sites, and whether any special sampling equipment will be required (e.g. a boat, or esky).

Some of the variables suggested for monitoring require the use of chemical preservatives during storage. The relevant Material Safety Data Sheets (MSDS) should be made available to sampling staff and care should be taken in handling any preservatives.

A First Aid kit is an important component of any field kit. Where possible, a person trained in First Aid should be included in the sampling team.

Field Data Sheet

The field data sheet is used to record information relevant to the data analysis, such as weather conditions, the date and time a sample is taken. Space should be provided to make notes or observations. For example, it is prudent to keep track of the photographs that have been taken so that they can be accurately identified later on. Field observations and photographs can be a valuable source of information during the data analysis where unusual or unexpected results are observed. A list of staff who undertook the sampling should also be recorded for QC purposes and so that the individual undertaking the data analysis knows to whom to direct any questions.

For the purposes of the water quality monitoring program, the field data sheet should include:

- Date of sampling;
- Name of samplers;
- Weather conditions;
- Space under each site for:
  - Time sample collected,
  - Observations,
  - Photo number,
  - Water level.

Field data should be entered into a database after the sampling run. In addition to the electronic version, the original data sheets should be kept on file.

Laboratory Techniques and Controls

An internationally accredited and appropriately certified laboratory (e.g. NATA, HOKLAS, SAC-SINGLAS, CAEL, etc.) should be used. The laboratory should have in place QA/QC procedures to maintain the quality system, monitor results and perform internal audits.

To ensure QA/QC of water quality samples sent to a laboratory for analysis, the following activities should be undertaken:

- Ensure chain of custody documentation is provided as this is essential to ensure that errors can be traced,
- Ensure the laboratory receives the samples within the required holding times for each parameter and that samples are stored correctly i.e. on ice if samples require chilling,
- Laboratories generally provide quality control reports and include laboratory control samples and surrogates. Additional samples should also be collected and sent to the laboratory for blanks, laboratory duplicates and matrix spike testing, and
- Review laboratory reports as soon as they are received to check for anomalies in the data, which could be an error on the part of the laboratory. Most samples are retained by the laboratory for an additional short period of time in the event additional sample or checking of anomalous results in required.

Analysis of Data

Concurrent with the process of confirming the parameters for inclusion in the estuarine health monitoring program, the Committee should also consider what statistical or other analyses may be required. This is a key consideration as the selection of sites and parameters will be driven in the first instance by the need for accuracy and resolution, as well as quality control issues.

The statistical techniques used to analyse and interpret the data should be informed by the guidelines or other criteria against which the data is being compared. However, more general, useful statistical analyses include:

- Mean (+/- standard deviation),
- Median,
- 90th percentile, and
- 10th percentile.

For the seasonal Estuary Health Report Cards for the Parramatta River estuary it is recommended the data should be simplified and aggregated in a similar manner to the Georges River Health Monitoring Report Cards, using a simple scoring system to indicate ecosystem health on a scale of A to F. However, a more comprehensive internal annual report should also be prepared to enable the Committee to obtain a more advanced appreciation of trends in estuarine health and factors driving them. Over the first few years of the monitoring program, it will be necessary to gain an understanding of rates of variation in environmental variables for the Parramatta River estuary to permit development of a 'baseline' condition, and possibly also to develop estuary-specific criteria for ecological health (where appropriate).

Work Health and Safety

All sampling should be undertaken in accordance with relevant legislation such as the *Work Health and Safety Act 2011*, *Work Health and Safety Regulation 2011*, and relevant work health and safety policies of the organisations undertaking the monitoring.

Work health and safety considerations for sampling include working near water when collecting water quality samples and when surveying aquatic species (using personnel floatation devices), and ensuring safe site access at each sampling location. In particular, protective gloves should also be worn when undertaking water and sediment quality sampling in case contaminated water or sediments are encountered.

Additional Monitoring Parameters

Table I.1 identifies a range of additional parameters and their associated details that could potentially be incorporated into the monitoring program in the future in the event that additional funding becomes available.

Table I.1: Additional Sampling Parameters for Consideration in the Monitoring Program

ID	Category	Variable^	Units/Attributes	Relevant Sampling Protocol(s)	Relevant Guideline or Trigger Values	Suggested Sampling Sites	Suggested Sampling Frequency (DWS = Dry Weather Sampling, WWS = Wet Weather Sampling)#	Notes
MWQ.2	Water Quality - Physical	Water clarity	Secchi depth (m)	OEH (2013)	N/A	Estuary - min. 3 x locations.	Monthly DWS from September to March	Measured in situ using a secchi disc. Indicator for light penetration.
MWQ.3	Water Quality - Physical	Total Suspended Solids (TSS)	mg/L		N/A	Estuary - min. 3 x locations.	Monthly DWS Event - 3 x WWS per year (to incl. the mouth of major tributaries).	Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.4	Water Quality - Physical	Total Dissolved Solids (TDS)	mg/L		N/A	Estuary - min. 3 x locations.	Monthly DWS Event - 3 x WWS per year (to incl. the mouth of major tributaries).	Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.8	Water Quality - Physical	Biochemical Oxygen Demand (BOD)	mg/L		N/A	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS	Water sample collection for laboratory analysis - refrigerate and store in the dark and max. holding time is 24hrs.
MWQ.10	Water Quality - Physical	Reduction-Oxidation Potential	mV		N/A	Estuary - min. 3 x locations.	Monthly DWS Event - 3 x WWS per year (to incl. the mouth of major tributaries).	Measured in situ with a water quality probe. Suggest taking vertical profiles at each mainstream site.
MWQ.11	Water Quality - Physical	Captured Gross Pollutants	kg type	Weigh captured material during its removal and undertake periodic waste classification surveys / audits to determine types of pollutants captured.	N/A	N/A	N/A	Pollutants should be recorded as per the City of Canada Bay Council's operation and maintenance protocols. AECOM (2010) recommended the City of Canada Bay Council's framework be used to ensure a uniform data collection and reporting format.
MWQ.27	Water Quality - Physical	Heavy Metals	mg/L		various	Estuary - min. 3 x locations.	Quarterly DWS	As per laboratory requirements.
MWQ.28	Water Quality - Physical	Total Petroleum Hydrocarbons	µg/L		various	Estuary - min. 3 x locations.	Quarterly DWS	As per laboratory requirements.
MWQ.29	Water Quality - Physical	Organochlorine and Organophosphate Pesticides	mg/L		various	Estuary - min. 3 x locations.	Quarterly DWS	As per laboratory requirements.
MWQ.30	Water Quality - Physical	Oil and Grease	mg/L		N/A	Estuary - min. 3 x locations.	Quarterly DWS	As per laboratory requirements.
MWQ.19	Water Quality - Nutrients	Total Nitrogen (TN)	µg/L		300 µg/L	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.20	Water Quality - Nutrients	Nitrates and Nitrites (NOx)	µg/L		15 µg/L	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Biologically available form of Nitrogen. Can be useful as a complement to TN data to identify potential sources. Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.21	Water Quality - Nutrients	Ammonia (NH4+)	µg/L		15 µg/L	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Biologically available form of Nitrogen. Can be useful as a complement to TN data to identify potential sources. Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.

ID	Category	Variable^	Units/Attributes	Relevant Sampling Protocol(s)	Relevant Guideline or Trigger Values	Suggested Sampling Sites	Suggested Sampling Frequency (DWS = Dry Weather Sampling, WWS = Wet Weather Sampling)#	Notes
MWQ.22	Water Quality - Nutrients	Ammonium (NH3)	µg/L		N/A	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Can be useful as a complement to TN data to identify potential sources. Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.23	Water Quality - Nutrients	Total Kjeldahl Nitrogen (TKN)	µg/L		N/A	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Biologically available form of Nitrogen. Can be useful as a complement to TN data to identify potential sources. Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.24	Water Quality - Nutrients	Total Phosphorous (TP)	µg/L		30 µg/L	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.25	Water Quality - Nutrients	Filterable Reactive Phosphorous (FRP)	µg/L		5 µg/L	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Biologically available form of Phosphorous. Can be useful as a complement to TP data to identify potential sources. Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.26	Water Quality - Nutrients	Orthophosphate	µg/L		N/A	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year.	Can be useful as a complement to TP data to identify potential sources. Water sample collection for laboratory analysis - refrigerate and max. holding time is 24hrs.
MWQ.12	Water Quality - Biological	Macroinvertebrates	Biotic Index (SIGNAL Score)	Chessman (2003)	Chessman (2003)	Tributaries - major.	Quarterly	Indicator for water quality and ecosystem health.
MWQ.13	Water Quality - Biological	Faecal coliforms (FC)	cfu/100mL	ANZECC (2000) NHMRC (2008)	150 cfu/100mL*	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year (to incl. mouth of major tributaries for source tracking purposes).	Water sample collection for laboratory analysis in sterile sample bottles - refrigerate, store in the dark, analyse preferably within 8 hrs. *Primary contact recreation; median value based on min. of 5 samples collected at regular intervals not exceeding one month, with no single sample exceeding 600 cfu/100mL).
MWQ.14	Water Quality - Biological	Enterococci	cfu/100mL	ANZECC (2000) NHMRC (2008)	35 cfu/100mL*	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year (to incl. mouth of major tributaries for source tracking purposes).	Enterococci have a higher tolerance for saline water than FC. Water sample collection for laboratory analysis in sterile sample bottles - refrigerate, store in the dark, analyse preferably within 8 hrs. *Primary contact recreation; median value based on min. of 5 samples collected at regular intervals not exceeding one month, with no single sample exceeding 60-100 cfu/100mL).
MWQ.15	Water Quality - Biological	*Escherischia coli*	cfu/100mL	ANZECC (2000) NHMRC (2008)	N/A	Estuary - min. 3 x locations. Tributaries - major.	Monthly DWS Event - 3 x WWS per year (to incl. mouth of major tributaries for source tracking purposes).	Water sample collection for laboratory analysis in sterile sample bottles - refrigerate, store in the dark, analyse preferably within 8 hrs.

ID	Category	Variable^	Units/Attributes	Relevant Sampling Protocol(s)	Relevant Guideline or Trigger Values	Suggested Sampling Sites	Suggested Sampling Frequency (DWS = Dry Weather Sampling, WWS = Wet Weather Sampling)#	Notes
MWQ.17	Water Quality - Biological	Phytoplankton	cells/mL	Collect a composite sample for each site comprising five 50cm depth-integrated column (hosepipe) subsamples collected along a 20–30m transect and mixed into a single container (e.g. bucket). Where wading or boat access is not available, collect surface-grab samples (e.g. dipped-bucket samples) instead from around shoreline.	various	Estuary - min. 3 x locations.	Monthly DWS from September to March Weekly during algal blooms	Composite water sample for laboratory analysis in sample bottle dosed with iodine preservative.
MWQ.18	Water Quality - Biological	Cyanobacteria	cells/mL	Open water composite sampling is preferred to avoid buoyant blooms near the shoreline and to account for spatial variability. Sample in the middle of the day.	various	Estuary - min. 3 x locations.	Monthly DWS from September to March Weekly during algal blooms	Composite water sample for laboratory analysis in sample bottle dosed with iodine preservative.
MEE.2	Estuarine Ecology	Seagrass Depth Limits	mAHD	Water depth (for a known tidal level) at the margin of the seagrass bed at 1m intervals, location of each point to be taken using differential-GPS. See OEH (2013).	N/A	Suggest 2 x representative seagrass beds in Hen & Chicken Bay and Iron Cove Bay.	Coincident with estuarine macrophyte mapping.	Indicator for long term water quality (light penetration).
MEE.3	Estuarine Ecology	Estuarine Fish Populations	Taxonomic richness Abundance Biomass	As per MER requirements in OEH (2013). Nested sampling design using gear types that target species from different habitats and adequately covers spatial variation.	N/A		As per MER requirements (annually if possible, at least every 5 to 10 years).	Also monitor in the event of significant fish kills in the Parramatta River or locally in one of its tributaries.
MEE.5	Estuarine Ecology	Terrestrial Weeds	Extent (ha) New infestations		N/A	Entire study area	As per MER requirements (annually if possible, at least every 5 to 10 years).	Undertaken by Sydney Weeds Committee.
MEE.6	Estuarine Ecology	Avifauna	Density (no. birds per ha) Guild richness (no. birds per guild)		N/A	Entire study area	Annually.	Existing data from bird watching clubs may be suitable for this purpose.

^ Parameters marked as green indicate higher priority parameters for inclusion, should additional funding become available.

Wet weather sampling (WWS): >30mm rainfall in the preceding 24 hrs. Dry weather sampling (DWS): No rainfall in preceding 48 hrs.

Note: Key reference documents for sampling and analytical methodologies are OEH (2013) and ANZECC (2000). Where other guidelines on sampling protocols are relevant, they have been referenced.