7.0 Estuarine Vegetation

7.1 Overview

For the purpose of this study, estuarine vegetation is defined as that which is found in the sub- tidal zone, inter-tidal zone, and riparian vegetation which is contiguous with these zones.

The scope of the vegetation assessment for this study includes riparian vegetation which is located up to 40m landward of the Mean High Water Mark (MHWM). However most vegetation within this zone is usually not considered 'estuarine' by definition, due to topography. A high proportion of vegetation within this zone has tolerance to salinity – but that which originates from sea spray, and not through tidal effects. These communities are defined as supra-tidal, and are less affected by threats and issues that impact upon estuarine vegetation, which are the focus of this study's vegetation assessment.

Estuarine vegetation communities in the study area include seagrasses, mangroves, saltmarsh, and Swamp-oak forest. Each one of these vegetation communities can tolerate salinity and, with the exception of Swamp-oak forest communities, have a tolerance to regular or permanent inundation.

The specific outcomes of the estuarine vegetation assessment are to:

- Map, document and illustrate existing and potential threats to estuarine vegetation;
- Identify specific actions, longer term management actions, and overarching strategies that need to be undertaken in order to protect and rehabilitate existing estuarine vegetation remnants, as well as strategies for present and future sustainable management of these communities and their possible expansion; and
- Prioritise management actions and strategies in the context of each LGA and the entire study area.

7.2 Methods

7.2.1 Desktop Study

Desktop analysis (using Arcview v.9.3) was undertaken to assess existing vegetation mapping and develop a series of A3 colour maps for use in field investigations. The following GIS data was analysed:

- GIS ortho-rectified aerial photography (5km tiles for 2005 and 2009);
- Habitat_sydney_harbour_2003 (SM-CMA seagrass shapefile);
- 94z56syd_foreshore_veg22jan2007 (SM-CMA vegetation shapefile);
- Mean high water tide mark (NSW Maritime shapefile); and
- Stormwater pipes (local government GIS files converted to shapefiles);
- Moorings (NSW Maritime shapefile);
- Draft Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area, SM-CMA (2009).

7.2.2 Field Investigations

Field investigations were conducted by boat and from land, which included:

- Visual assessment of habitat conditions for seagrasses;
- Qualitative observations and opportunistic sampling to confirm the presence of mapped seagrasses;
- Identification of existing and potential impacts on seagrasses, from the following:
  - existing moorings,
  - stormwater outlets, and
  - boat ramps and other recreational usage of the foreshore.

Boat-based inspections focussed on the following aspects:

- Verification of mapped vegetation for which most previous studies relied on aerial photographic interpretation; and
- Identifying potential threats and management issues that are only obvious from the seaward edge.

Land-based inspections were undertaken to identify management issues arising from land-based activities, verify condition and extent of existing mapped intertidal and riparian vegetation, and identify opportunities for rehabilitation, and / or enhancement of these communities.

7.3 Relevant Legislation

Legislation, planning and policies that are applicable to the management of estuarine vegetation within the study area include the following:

7.3.1 Environmental Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environmental Protection and Biodiversity and Conservation Act* 1999 (EPBC Act) protects matters of National Environmental Significance. The EPBC Act ensures there is a process for national environmental assessments and approvals for matters of National Environmental Significance.

Matters of National Environmental Significance within the study area that may influence in the manner in which estuarine vegetation is managed, include:

- Turpentine-Ironbark Forest;
- Terrestrial migratory bird species;
- Wetland migratory bird species; and
- Migratory marine bird species; and,
- ‘Over-fly Marine” areas for (as reported in “Other matters protected by the EPBC Act”).

Turpentine-Ironbark Forest is listed as a critically endangered ecological community under the EPBC Act. National listing means that activities likely to have a significant impact upon Turpentine-Ironbark Forest must be referred to the Commonwealth Minister for assessment and approval (unless otherwise exempted under the EPBC Act).

Migratory species are those animals that migrate to Australia and its external territories, or pass through or over Australian waters during their annual migrations. Examples of migratory species are species of birds (e.g. albatrosses and petrels), or mammals (e.g. whales). The study area contains habitat for migratory wetland bird and marine bird species.

Australia is party to international conventions and agreements to protect many migratory species, in particular:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention);
- China-Australia Migratory Bird Agreement (CAMBA); and,
- Japan-Australia Migratory Bird Agreement (JAMBA).

Most migratory species listed under these international conventions and agreements are now protected under the EPBC Act. Significant impact criteria assessment for migratory species (under this Act), is defined as an action that is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

- Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species;
- Result in invasive species, that are harmful to the migratory species, becoming established in an important habitat for the migratory species; or,
- Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of migratory species.

Where proposed actions are likely to impact on these matters of National Environmental Significance, referral under the EPBC Act is required.

7.3.2 Environmental Planning and Assessment Act 1979 (EP&A Act)

The EP&A Act is the primary legislation controlling development activities in the State. It establishes two avenues in which environmental impact processes are employed:

1. Part 4 developments: uses of land and developments which require consent under Local Environment Plans (LEP), Regional Environmental Protection Plans (REP), or State Environmental Protection Plans (SEPP); and
2. Part 5 activities: uses of land or development for which consent is not required.

Applicable to Part 4 developments within the study area are:

- SEPP 19: Urban Bushland;
- Sydney REP (Sydney Harbour Catchment) 2005; and
- Local Environment Plans (LEPs), prepared by each Council within the study area.

7.3.3 Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act* 1995 (TSC Act) is the primary legislation for management of threatened species and endangered ecological communities in NSW. The TSC Act sets out the process for the listing of such species and communities and also provides for the establishment of recovery plans. Three endangered ecological communities listed under Part 3 of Schedule 1 of the TSC Act and one vulnerable species under Schedule 2 of the TSC Act occur within or adjacent to the the study area:

- Sydney Turpentine – Ironbark Forest of the Sydney Basin Bioregion;
- Swamp-oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions;
- Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions; and,
- *Wilsonia backhousei*.

Listing under the TSC Act places statutory obligations upon the landowner or authority responsible for the management of land that contains these communities or species. In particular, management should aim to reduce the threats to these communities and ensure appropriate determination is made where proposed activities may impact on these communities or species.

7.3.4 National Parks and Wildlife Act 1970

A licence under section 132C of the *National Parks and Wildlife Act 1970* will be required if an activity is proposed for scientific, educational or conservation purposes that is likely to result in one or more of the following:

- Harm to any protected fauna, or to an animal that is a threatened species or is part of an endangered population or an endangered ecological community;
- Harm to any protected native plant, or any plant that is a threatened species or is part of an endangered population or an endangered ecological community. A license is required to collect voucher specimens for identification purposes, pick cuttings or whole plants, or collect seed;
- Damage to critical habitat; and
- Damage to a habitat of a threatened species, an endangered population or an endangered ecological community.

7.3.5 Fisheries Management Act 1994

The *Fisheries Management Act* 1994 and *Fisheries Management Amendment Act* 1997 (FM Act) provides for the conservation, protection and management of fisheries, aquatic systems and habitats in NSW. The FM Act applies in relation to all waters that are within the limits of the State, and regulates certain activities that have the potential to impact on aquatic habitats.

Under the FM Act, notification or permits are required from the Department of Investment and Industry NSW (I&I NSW) for activities involving dredging and reclamation, blockage of fish passage, development of certain waterfront land and the construction of structures within aquatic habitats (e.g. bridges, roads, causeways, pipelines), and harm to marine vegetation.

'*harm*' in relation to marine vegetation, means gather, cut, pull up, destroy, poison, dig up, remove, injure, prevent light from reaching or otherwise harm the marine vegetation or any part of it.

7.3.6 Water Management Act 2000

A Controlled Activity Approval (CAA) is required under the *Water Management Act 2000* (formerly the *Rivers and Foreshores Improvement Act 1948*) when undertaking development within 40m of a river, estuary or lake for certain activities.

Local government authorities are exempt from requiring a CAA. However when a local government authority is the proponent (in this instance, Council), consultation with the NSW Office of Water is good practice, and ensures that any proposed development or activity upholds State legislation in combination with the objectives of local environment and development control plans.

Where Councils are the determining authority for a proposed development that is located within 40m of a river, estuary or lake, the development application must be referred to the NSW Office of Water if the activity is not exempt, for the issuing of a CAA and subsequent consent conditions developed that ensure compliance with this Act.

A consent condition that will be relevant to management of estuarine vegetation is a requirement to develop a vegetation management plan which must be approved by the NSW Office of Water (or DII where mangroves will be impacted upon) prior to the development proceeding. This will incur an application fee by the proponent, and possible lodgement of a bond, the latter usually commensurate with the value of works required to fully implement the VMP.

The establishment and maintenance phases, required by the VMP, may vary in duration, but anywhere between 2 to 5 years should be anticipated (dependent on the relative size of the development and works required to implement the VMP).

Note: while the NSW Office of Water (and/or DII) is responsible for compliance under this Act, Councils, through virtue of proximity to development sites, are better placed to assist in regular monitoring to ensure that the VMP is being implemented appropriately – by way of feedback to the NSW Office of Water (and/or DII).

7.3.7 Regional and Local Planning Instruments

7.3.7.1 Sydney Environment Protection Plan (Major Projects) 2005

SEPP (Major Projects) 2005 identifies developments which are to be treated as Part 3A projects. Part 3A projects are developments that, in the opinion of the Planning Minister, are of State or regional environmental planning significance, or for which an Environmental Impact Statement under Part 5 would have been required. In practice, Part 3A projects are usually large government infrastructure projects, such as roads, pipelines, desalination plants and dams, but can also include large private developments which are not carried out by a public authority.

Once a project falls within the category of a Part 3A project, then the assessment and approval process under Part 4 or Part 5 of the EP&A Act cease to apply and is replaced by the Part 3A process.

The EP&A Act itself does not state which kinds of projects are covered by Part 3A. Rather, Part 3A projects are identified in Schedule 1 and Schedule 2 of SEPP (Major Projects) 2005.

Schedule 1 of the SEPP provides a list of the types (or classes) of development which can be considered to be major project. Examples relevant to the study area could include certain marina facilities, or remediation of some contaminated sites.

Schedule 2 of the SEPP lists specific sites (rather than general categories) which can be considered to be Part 3A projects. This list includes things such as high-impact developments (landfill, mining, marinas, subdivisions etc) within the coastal zone, certain industrial developments at Kurnell, and developments on Sydney Harbour Foreshore sites.

7.3.7.2 Sydney Environment Protection Plan (SEPP) No.19

SEPP 19 aims to protect and preserve bushland within urban areas. It sets out matters that a consent authority must consider when assessing development within areas zoned for urban bushland or in adjoining areas. Councils are also required to regard the general and specific aims of the Policy when preparing draft local environmental plans for any land to which the Policy applies. Priority is to be given to retaining bushland, unless the relevant Council is satisfied that significant environmental, economic or social benefits will arise which outweigh the value of the bushland.

7.3.7.3 Sydney Regional Environment Plan (Sydney Harbour Catchment) 2005

The regional environmental plan (REP) relevant to the study area is the Sydney REP (Sydney Harbour Catchment) 2005. The principal aim of the REP is to ensure that the catchment, foreshores, waterways and islands of Sydney Harbour are recognised, protected and maintained as an outstanding natural asset and public asset of national and heritage significance for existing and future generations.

The Sydney Harbour Foreshores and Waterways Area Development Control Plan (DCP) is the primary planning instrument under the REP which needs to be taken into consideration by land owners, developers and consent authorities when preparing or assessing development applications within the area covered by the REP.

Performance-based criteria and guidelines relating to matters such as foreshore access, visual and natural environments, recreation and maritime industrial uses are established by the DCP with the aim of:

- Protecting ecological communities within the area covered by the REP;
- Ensuring that the scenic quality of the area is protected or enhanced;
- Providing siting and design principles for new buildings and waterside structures within the area; and,
- Identifying potential foreshore access locations in the area.

Except as otherwise provided by the REP, Councils must not grant development consent to any development unless satisfied that it is consistent with the aims of the REP and the objectives of the zone in which it is proposed to be carried out.

7.3.8 Draft Sea Level Rise Policy Statement (NSW DECCW, 2009)

Sea level rise is now a scientifically accepted reality. However the scale of predicted increase in mean sea level rise remains less certain. For example:

- IPCC (2007) project an increase in mean sea level of between 0.18m and 0.59m by the end of the 21st century, with the possibility of an additional 0.1m to 0.2m due to ice sheet flow;
- CSIRO has predicted additional localised sea level rise of up to 0.12m on the east coast of Australia due to thermal effects of the East Australian Current (McInnes *et al*., 2007); and
- Rahmstorf (2007) suggests that on the basis of the trend measured by most recent satellite observations, it is likely that future sea level rise will track close to the upper limit of the above projections. Rahmstorf (2007) suggests that a level of up to 1.4m above 1990 sea levels may be possible.

Various Australian State Governments have adopted, or intend to adopt, specific benchmarks, as follows:

- The NSW Government's draft Sea Level Rise Policy Statement (DECC, 2009) has adopted sea level rise of 0.4m by 2050 and 0.9m by 2100; whereas
- The Urban Taskforce (2009) reports that:
  - South Australia has a 0.3m benchmark by 2050,
  - the Gold Coast City Council in Queensland requires developers to make an allowance for a sea level rise of 0.27m over the next 50 years, and
  - Victoria has adopted a benchmark of an 0.8m sea level rise to the year 2100

The potential impacts of sea level rise are further emphasised by many commentators such as Haines (2008) who importantly identifies that sea level rise will continue beyond the end of this century and the extent of existing forecasts. In light of the identified trends and uncertainties, coastal land-use planning needs to recognise the scope for change and the implications this has for current resource allocation decisions in the short, medium and longer term.

A primary objective of this study is to inform and guide the development of an Estuary Management Plan, which will provide a number of rehabilitation and related management actions that should be implemented within a period of (typically) five years. This will present the Parramatta River Estuary Committee with a series of difficult decisions. Prioritising management actions will require finding a balance between immediate rehabilitation responsibilities, the short term desire to improve access and amenity, and the longer term recognition that some areas will be inundated and may not warrant dedication of scarce resources.

A comprehensive analysis of future impacts from sea level rise in relation to estuarine vegetation is beyond the scope of this study. However consideration has been made in relation to the potential for landward migration of estuarine vegetation located within the intertidal zone (e.g. mangroves, saltmarsh and riparian vegetation, but excludes seagrasses). For the purpose of this study, landward migration is categorised as either ‘limited’ or ‘potential’, where:

- ‘limited’ indicates areas in which landward migration would be prevented due to seawalls, roads, development, infrastructure, or elevation; and
- ‘potential’ indicates areas which comprise natural shorelines, open space, or vegetated land upslope of each vegetation community or patch.

The impacts of sudden water level rise (i.e. compared to gradual and incremental rise over a number of decades, and other impacts anticipated from climate change (e.g. storm surge, altered rainfall, temperature and evapotranspiration) has not been considered. These aspects are presently considered too unpredictable and beyond the scope of works for this study.

7.4 Seagrasses

7.4.1 Description

Seagrasses are highly specialised flowering plants that live in marine and estuarine habitats. They are rooted in the soft sediments of near-shore environments with leaves appearing above the sediment, similar to that of terrestrial grasses. Being true plants, they require light to photosynthesise, and are therefore limited by the clarity of water.

Seagrass plants and seagrasses meadows are highly productive and support a rich variety of other plants and animals. They are particularly valuable as nursery, feeding and shelter areas for many aquatic animals, including commercially and recreationally important fish, mollusc and crustacean species. In addition to providing these functions, seagrasses are particularly valuable as their roots act to stabilise soft sediments, and the leaves can buffer wave action. Without seagrasses, estuaries and coastal habitats may destabilise, and patterns of erosion and deposition of sediments around many of our estuary and coastal areas would alter.

Seagrass meadows, just like most other natural habitats, are not constant, but change over time. These changes may be caused by natural processes or by human activity. Natural events include storm and flood-induced erosion, while human-induced losses can be caused by:

- Poor water quality (increased turbidity levels, suspended solids, nutrient levels, introduction of pest species);
- Dredging and reclamation;
- Water based recreational activities and commercial practices (damage from trawling, boat propellers, boat launching, fishing and bait collection); and,
- Development of the foreshore environment (e.g. sea walls, bridges, marinas).

7.4.2 Seagrass Mapping

A map that described seagrass cover in Sydney Harbour and its tributaries was first produced in the 1970s (West *et al*. 1985). This has subsequently been updated, with each update employing different methods to estimate seagrass extent (West *et al*. 1985; West *et al*. 2004). In 2004, it was estimated that seagrass cover in the Sydney Harbour study area had declined from 129 ha to 52 ha with the largest seagrass loss in Middle Harbour. Conversely, new seagrass meadows had established in Iron Cove Bay, Five Dock Bay and Hen and Chicken Bay (West *et al*. 2004).

Seagrass cover has been recently reassessed to confirm whether changes in seagrass cover over time have been real or whether they are attributable to different methods used to estimate cover in earlier studies (West and Williams 2008). Table 7-1 provides a summary of the results from each seagrass cover study, noting that the areas presented include all seagrasses mapped for Sydney Harbour and its tributaries (i.e. Parramatta River, Lane Cove River, Middle Harbour and the lower estuary area). Whilst the numerical change in area over time can vary depending on methods used, it is undeniable that there has been a reduction in cover in the study area over the last few decades. Reduced cover was also recorded in Botany Bay, where 60% of original seagrass cover had disappeared by the mid 1980s (Larkum & West 1990).

Table 7-1. Area of seagrass in Sydney Harbour over recent decades reported in West and Williams (2008).

Aerial Photo	Photo interpretation	Field survey	Area (ha)
1978	West *et al.* 1985	Jan. 1981	128.6
1978	West and Williams 2008	Not possible	59.2
1986	West and Williams 2008	Not possible	87.4
2000	West *et al.* 2004	Sydney Harbour: May 2002, Parramatta River: March-June 2003	51.9*
2003	West and Williams 2008	Not undertaken	49.5

* initially reported by West *et al.* 2004 as 51.7ha but modified in a corrigendum.

7.4.3 Seagrass Distribution

Four geomorphic zones have been delineated for the Parramatta River estuary:

- Marine Tidal Delta;
- Central Mud Basin;
- Fluvial Delta and
- Riverine Channel (Mesley 2003).

The study area comprises only three of these zones (Central Mud Basin, Fluvial Delta and Riverine Channel), with the fourth zone (Marine Tidal Delta) dominating much of the Sydney Harbour entrance which is a significant distance downstream of the current study area's boundary.

In terms of geomorphic zones (Figure 7-1), the following trends have been previously reported:

- The highest seagrass cover has been found in Central Mud Basin environments;
- Small patches of seagrasses were found in the Fluvial Deltas at Middle Harbour and Lane Cove River, but none were found in the analogous section of the Parramatta River (i.e. within the present study area);
- No seagrass cover has been found in the Riverine Channel zones; and
- Except for southern strapweed (*Posidonia australis*), seagrass cover was greater on the southern shorelines of the estuary than on the northern shorelines. (West *et al*. 2004; West and Williams 2008):

Observations made during field investigations for this study support these trends, with seagrass cover only found downstream of Concord Road, Ryde Bridge. This section of the study area is closely aligned to the Central Mud Basin geomorphic categorisation of the estuary, with the exception of the river upstream of Majors Bay to the Ryde Bridge which lies within the Fluvial Delta zone.

Within the Fluvial Delta zone, three locations were identified in which seagrass cover has not been mapped from previous field surveys. These three locations all lie within the river and bays adjacent to the City of Canada Bay LGA. Specifically, seagrass patches were found to the north east of Brays Bay within the river channel, and within the northern most zones of Yaralla Bay and Majors Bay in close proximity to the river channel (Figure 7-2).Table 7-2 provides a summary of seagrass areas which are known, or predicted to occur within the study area (West and Williams, 2008) and a comparison to more recent observations made during field inspections for this study (September – November, 2009).

Table 7-2. Seagrass communities within the study area by LGA

LGA	West & Williams 2008 (ha)	2009				
		Confirmed (ha)	Unverified (ha)	Sub-total# (ha)	Not Evident (ha)	Change 2008-09# (ha)
Ashfield	0.16	0.00	0.16	0.16	0.00	0.00
City of Canada Bay	8.95	8.58	0.30	8.88	0.07	0.07
Department of Defence	0.17	0.00	0.17	0.17	0.00	0.00
Hunters Hill	0.04	0.00	0.00	0.00	0.04	-0.04
Leichhardt	0.88	0.62	0.03	0.65	0.23	-0.23
Ryde	0.06	0.06	<0.01	0.06	0.00	<0.01
Totals	**10.25**	**9.21**	**0.71**	**9.92**	**0.341**	**0.15**

includes area of unverified seagrass

The results shown in Table 7-2 indicate that 92.6% of confirmed seagrass habitat (i.e. 9.2 ha) is located within waterways adjacent to the City of Canada Bay LGA, with 6.8% and the remaining <1% located adjacent to Leichhardt LGA and Ryde LGA (respectively).

Changes in seagrass cover since mapping from 2003 aerial photography (West and Williams 2008) has been estimated as follows:

- 90% of mapped seagrass cover confirmed, which:
  - includes 3,537.2 m2 (0.34 ha) of newly detected seagrass patches (City of Canada Bay LGA),
  - includes an increase of 406.6 m2 (0.04 ha) in existing seagrass patches found in Looking Glass Bay (Ryde LGA), but,
  - excludes areas in which seagrass may have decreased in cover;
- 3.3% of seagrass cover not evident; and
- 6.7% of seagrass cover not able to be verified.

Verification of some areas of seagrass cover was not possible from boat-based field inspections due to the shallowness of mapped patches. Further land-based inspection undertaken was also constrained due to poor water clarity and / or high levels of sedimentation and excessive organic gross pollutants (mainly leaf litter).

While it is recognised that seagrasses can be itinerant, or variable in cover and distribution, based on current trends it is anticipated that a proportion of the unverified seagrass habitat areas would be (a) not evident, or (b) present, but either decreased in extent, and / or in poor condition.

Areas in which poor habitat was observed included: downstream from Hawthorne Canal and Dobroyd Canal in Iron Cove Bay; opposite stormwater outlets on the eastern foreshore of Iron Cove Bay; and opposite stormwater outlets on the southern foreshore of Five Dock Bay. The substratum in these areas was either blanketed with fine silty sediments and algal growth, or excessive amounts of leaf litter, which suggests that seagrass growth would be sub-optimal if possible (Figure 7-3).

7.4.4 Seagrass Composition

Seagrass composition previously reported in Sydney Harbour (West and Williams, 2008) includes monospecific and mixed stands of the genera *Zostera, Posidonia* and *Halophila*. Generally, *Halophila spp*. are found in more exposed localities and areas where sediments are unstable, while *Zostera spp*. commonly occur in intertidal zones. In sheltered areas, where there is little movement of water and the sediments are stable, all local species may be found.

Detailed analysis of seagrass composition conducted by West *et al.,* (2004) found *Zostera* to be the most dominant seagrass in the Parramatta River estuary (Table 7-3).

Table 7-3. Seagrass composition reported by West *et al*., 2004

Composition	Area (ha)	Percent of total cover (%)
Zostera	18.1	62.1
Zostera mixed	8.3	28.3
Halophila	2.7	9.1
Halophila mixed	0.1	0.5
Total	**29.2**	**100%**

During field investigations for this study, the dominant seagrasses observed were *Halophila spp*. with *Zostera spp.* less abundant. *Posidonia australis* was not evident during field investigations although the bulk of this species was previously mapped as occurring in the Marine Delta environment, and is not expected to occur within the current study area.

Table 7-3 provides a summary of seagrass composition verified during field investigations and Figure 7-4 illustrates the locations of verified seagrass habitat within the study area.

Table 7-4. Seagrass composition evident during 2009 field investigations

Composition	2009 (ha)	Percent of total cover (%)
Zostera	1.7	18.7
Zostera mixed	0.3	3.5
Halophila	2.6	28.4
Halophila mixed	4.6	49.4
Total	**9.2**	**100%**

A noticeable difference is evident when comparing the percent cover of seagrass composition found during this study and West et al., in 2004. The area assessed by West *et al*., in 2004 (Table 7-5) extended further downstream than the present study area.

Irrespective, it would appear that there has been a significant increase in cover of mixed meadows of *Halophila* from 0.151 ha (within the larger study area) to that of 4.561 ha (within the present and smaller study area). This provides a strong indication that *Zostera* has decreased in extent within the estuary.

Research has indicated that seagrass distribution has been relatively static over the past decades – post losses reported by West *et al*. 2004; and West and Williams 2008. However, the dominance of *Halophila* may signal that environmental conditions that influence seagrass composition have altered over the past six years.

Given that *Zostera* is reported to provide greater habitat complexity than *Halophila* (Roberts *et al.,* 2009) a decrease in its distribution and cover could be of concern. *Halophila ovalis* has been observed to replace seagrass meadows previously dominated by *Zostera capricornii* following thermal stress from discharge of heated process waters in NSW, north of Sydney. While not researched, the colonisation of *H.ovalis* in habitat formerly dominated by Z*.capricornii* suggests that this species is more capable of colonisation of seagrass habitat following disturbance. This is consistent with findings in South Australia, where the sequence of colonisation seems to be that *Halophila* moves into disturbed areas first (Clarke and Kirkman 1989).

den Hartog (1970) also describes *H.ovalis* as a pioneer species in denuded areas, and suggests this species to be the least important in biological function except in being well adapted to unstabilised bottoms, and able to cause significant accretion.

Presently there is insufficient data to assess whether a decline in *Zostera* has or is occurring within the current study area, and whether *Halophila* has a competitive advantage over the *Zostera* genus in response to anthropogenic disturbance. These are knowledge gaps in which the collection of quantitative data regarding species composition is required.

7.4.5 Management Issues

Factors threatening existing seagrasses (extent and individual species) within the study area were identified as:

- Poor water quality:
  - excessive quantities of gross pollutants (sediment and organic materials blanketing seagrass, reducing light penetration, and /or inhibiting new growth in adjacent habitat),
  - elevated nutrients which promote algal and epiphytic growth on seagrass leaves (which in turn reduces light penetration), and
  - turbidity (which in turn reduces light penetration).
- Damage from water based recreational activities:
  - boat propellers, anchors (direct damage and uprooting plants),
  - watercraft launching (in particular dragging of non-motorised boats, surf skis etc directly damaging seagrass leaves and uprooting plants),
  - shading from jetties (which in turn reduces light availability); and
- Uncertainty of impacts from climate change (i.e. potential loss of habitat from sea level rise, increased storm activities).

7.4.5.1 Water Quality

The issue of greatest concern currently impacting on seagrass habitat is the quality of stormwater originating from various sub-catchments. Current stormwater pollution control infrastructure, the maintenance of such infrastructure, and other stormwater management practices (e.g. street sweeping) appear to be insufficient. This is particularly evident in the southern end of Iron Cove Bay, in which the following was observed:

- Excessive volumes of leaf litter blanketing the sea bed and stranded by tides along the foreshore;
- Large quantities of floating gross pollutants stranded by tides along the foreshore (e.g. PET bottles and other litter);
- Rock outcrops southwest of Rodd Point covered in fine silt and algae;

- Poor water visibility; and
- The absence or decrease in extent of a number of previously mapped seagrass patches.

Additional areas in which existing seagrass growth is impacted upon by poor water quality include:

- Five Dock Bay (City of Canada Bay LGA);
- Looking Glass Bay (Ryde LGA);
- Hen and Chicken Bay (City of Canada Bay LGA); and
- Iron Cove Bay (Leichhardt LGA) opposite smaller inflow areas along the eastern shoreline.

Areas in which poor water quality is likely to be preventing regeneration of previously mapped seagrasses (i.e. those previously mapped in 1943, 1978, and 1986) include, but are not limited to:

- Majors Bay (City of Canada Bay LGA);
- Yaralla Bay (City of Canada Bay LGA);
- Brays Bay (City of Canada Bay LGA);
- Tarban Creek (Hunters Hill LGA); and
- Morrison Bay (Ryde LGA).

A critical review of existing stormwater management practices and maintenance regimes (e.g. GPT cleaning frequency, the necessity for additional GPT installations) should be facilitated as a matter of urgency. This should 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. It is understood that most Councils in this catchment (Burwood, Marrickville, Ashfield, City of Canada Bay and Leichhardt) on average conduct weekly cleaning in busy commercial areas, and 2-3 weekly cleaning of residential areas.

It is recommended that each Council assess where additional gross pollutant trapping and/or street sweeping is required, by investigating the following aspects:

- Those residential areas with a high density of street trees;
- The propensity of street trees to drop leaves (including seasonality and potential for seasonal variation in maintenance programs); and
- An assessment of leaf litter (collected in stormwater booms and excess leaf litter entering Iron Cove Bay).

Further recommendations for stormwater management are provided in Section 3.0 (*Estuarine Stormwater Outlets and GPTs*) and LGA and site specific management recommendations are provided in Section 9.0 of this study.

7.4.5.2 Water Based Recreational Activities

Moorings, boat launching facilities (formal or otherwise), ad hoc launching of watercraft, and the location of jetties that appear to be impacting on existing seagrass growth include:

- Parramatta River east of Drummoyne Bay (launching of small unmoored watercraft – City of Canada Bay LGA);
- Moorings downstream of Hawthorne Canal in Iron Cove Bay (Leichhardt and Ashfield LGAs);
- Rodd Point (launching of water skis – City of Canada Bay LGA);
- North-eastern shoreline of Iron Cove Bay (boat ramp – Leichhardt LGA); and
- Private jetties and boat ramps along both the northern and southern shoreline of the river (Hunters Hill, Ryde, City of Canada Bay LGAs).

7.4.5.3 Sea Level Rise

As will be the situation for other intertidal vegetation (e.g. saltmarsh and mangroves), many of the existing seagrass habitats may be constrained by a lack of ‘space’ within which migration into shallower areas over time is possible.

Seagrasses are capable of growing in depths from very shallow water to 5-30m deep. However the availability of light will influence the depth range in which growth is possible (among other variables

such as grazing, phenology, e.g. leaf length, and physical and chemical parameters). Hence the importance of improving water quality and in turn water clarity, which will be critical in offsetting any potential longer term change to the depth of existing seagrass habitat areas. Seagrass locations in which landward migration will be constrained include the following:

- New growth found in Brays Bay and Majors Bay;
- All locations within Hen and Chicken Bay, Five Dock Bay and Iron Cove Bay in which seawalls replace natural shoreline; and
- Most areas of natural shoreline which comprise rock outcrops.

7.4.6 Management Recommendations

Management recommendations include, but are not limited to the following:

- Provision of formalised launching areas (i.e. dinghys, surf skis, kayaks), or the introduction of exclusion zones for launching of non-motorised watercraft in foreshore areas where existing launching activities are impacting on seagrass habitat;
- Introduction of seagrass-friendly moorings;
- Design of new, and replacement of existing, decking of jetties with mesh decking to allow sunlight penetration to underlying seagrass beds;
- Educational signage to promote avoidance of:
  - walking through seagrass areas at low tide
  - digging for bait in seagrass beds
  - anchoring in seagrass beds
  - dragging dinghy's, surf skis through seagrass beds, and
  - travelling across seagrass beds in boats at low tide in order to minimise the potential for propeller damage.

Locations in which seagrass would benefit from seagrass friendly moorings were ranked by size and proximity to moorings (Table 7-5).

Table 7-5. Ranking of seagrass locations

Scoring	1	2	3	4
Extent of seagrass patch (ha)	<0.01	0.01-0.10	0.10-0.5	>0.5
Proximity to moorings (m)	>40	20-40	10-20	<10

Scores for each seagrass patch were multiplied to provide a priority score which is biased towards large seagrass patches in close proximity to moorings. Table 7-6 identifies the top 36 patches of seagrass (out of 69 seagrass patches near moorings) which should be considered for seagrass friendly moorings on this basis. These locations are illustrated in Figure 7-5 and further discussed within individual LGA management summaries (Section 9.0).

Table 7-6. Areas where seagrass friendly moorings should be considered

Habitat	Area (ha)	Location	LGA	Score
Halophila and Zostera	0.51	Iron Cove Bay	Canada Bay	16
Zostera	0.50	Five Dock Bay	Canada Bay	12
Not evident	0.18	Iron Cove Bay	Leichhardt	12
Zostera	0.46	Five Dock Bay	Canada Bay	9
Halophila	0.11	Majors Bay	Canada Bay	9
Not evident	0.02	Tarban Creek	Hunters Hill	8
Halophila	0.69	Hen and Chicken Bay	Canada Bay	8
Halophila and Zostera	1.82	Hen and Chicken Bay	Canada Bay	8
Zostera	0.01	Drummoyne Bay	Canada Bay	8
Halophila and Zostera	0.08	Iron Cove Bay	Canada Bay	8
Zostera	0.08	Iron Cove Bay	Leichhardt	8
Halophila and Zostera	0.11	Hen and Chicken Bay	Canada Bay	6
Halophila	0.01	Hen and Chicken Bay	Canada Bay	6
Halophila	0.02	Hen and Chicken Bay	Canada Bay	6
Halophila	0.22	Five Dock Bay	Canada Bay	6
Zostera	0.27	Five Dock Bay	Canada Bay	6
Halophila and Zostera	0.02	Iron Cove Bay	Canada Bay	6
Halophila and Zostera	0.09	Iron Cove Bay	Canada Bay	6
Halophila	0.03	Looking Glass Bay	Ryde	4
Halophila and Zostera	0.02	Looking Glass Bay	Ryde	4
Halophila and Zostera	0.04	Hen and Chicken Bay	Canada Bay	4
Halophila and Zostera	0.03	Hen and Chicken Bay	Canada Bay	4
Halophila and Zostera	0.02	Hen and Chicken Bay	Canada Bay	4
Zostera	0.01	Hen and Chicken Bay	Canada Bay	4
Zostera	0.01	Hen and Chicken Bay	Canada Bay	4
Zostera	0.05	Hen and Chicken Bay	Canada Bay	4
Zostera	0.03	Hen and Chicken Bay	Canada Bay	4
Zostera	0.06	Hen and Chicken Bay	Canada Bay	4
Zostera	0.01	Drummoyne Bay	Canada Bay	4
Zostera	0.01	Drummoyne Bay	Canada Bay	4
Not evident	0.01	River South	Canada Bay	4
Halophila and Zostera	0.01	Iron Cove Bay	Canada Bay	4
Not evident	0.03	Iron Cove Bay	Leichhardt	4
Halophila and Zostera	0.17	Hen and Chicken Bay	Canada Bay	3
Halophila	0.24	Hen and Chicken Bay	Canada Bay	3
Halophila and Zostera	0.10	Iron Cove Bay	Canada Bay	3

Previous recommendations made by West *et al.* (2004) and West and Williams (2008) generally included the following:

- That the cover present in the 1980s be used as a management target;
- That areas of seagrass in good or excellent condition be maintained, and those of poor or average condition be managed in such a way that their ecological function and integrity improves;

- Assess modifications to the shoreline and/or bed of the estuary in the context of potential, rather than actual, growth of seagrass; and
- That vegetation maps be produced at regular (e.g. two year) intervals to assist with foreshore conservation and oil spill contingency planning.

These recommendations are supported although the cover present in the 1980s as a management target may need to be re-considered within the context of climate change, in particular forecasted sea level rise.

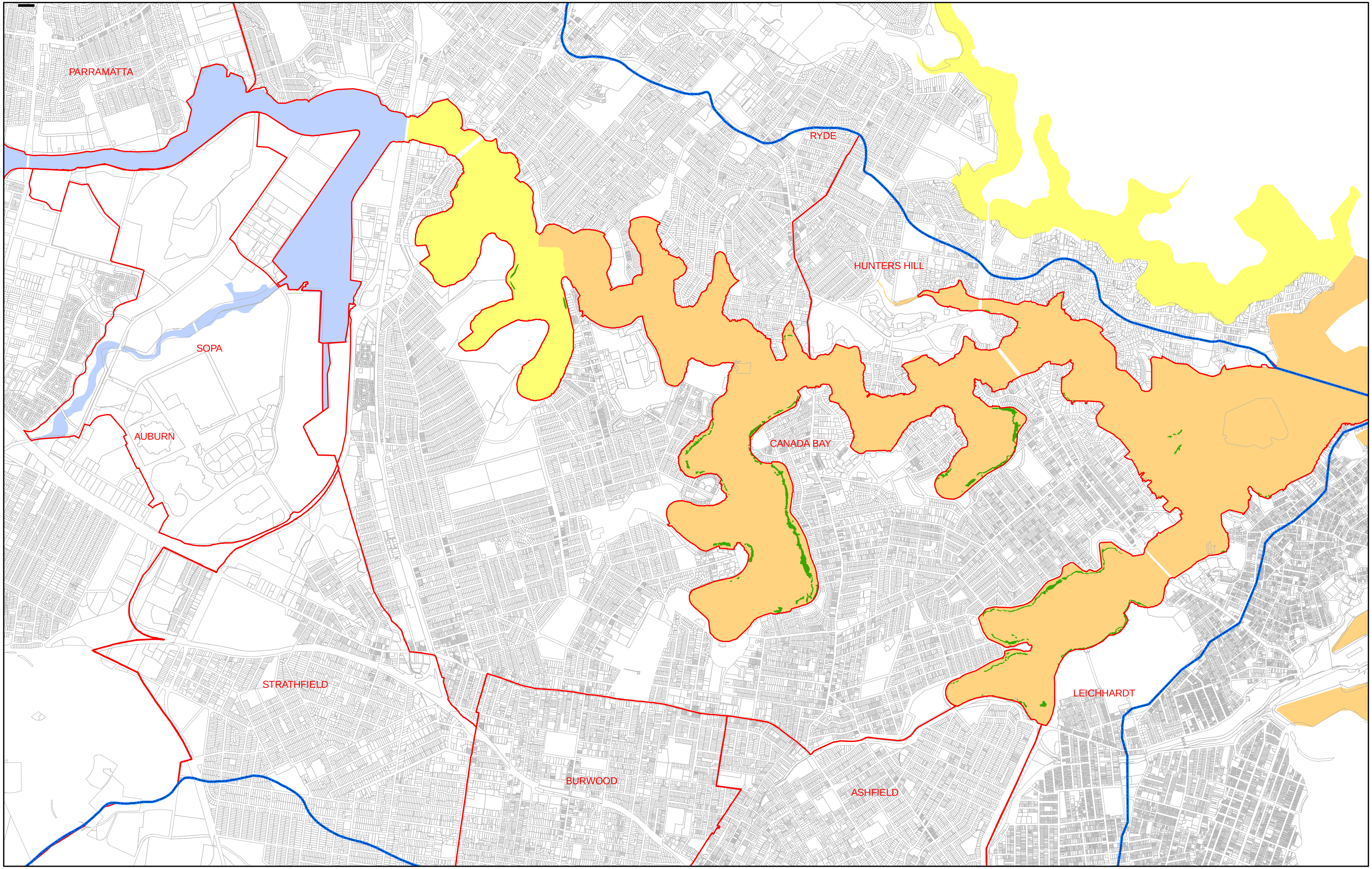
During the timeframe of this study, the SM-CMA commissioned a historical study of estuarine vegetation which included the current study area. Draft GIS data layers provided included aerial photographic interpretation of seagrass distribution analysed from photography taken in 1943, 1978, 1986, 2003, and 2005. However, receipt of this data was after preliminary desktop analysis, preparation of field maps, and field investigations conducted for this study.

As such a comprehensive assessment of variations between each of these years was not possible within the time frame remaining for this study. However there appears to be considerable variation between mapped seagrass from 2005 aerial photography in comparison to that found during field investigations.

While substantial work has been undertaken to quantify the distribution of seagrass within the study area, the results from field investigations for this study, and the variation in results from aerial photographic interpretation, serve to demonstrate the need to conduct field surveys for the purpose of collecting quantitative data for ongoing analysis and management guidance.

To this end, it is recommended that consultation with the Aquatic Ecosystem Unit of the New South Wales Department of Investment and Industry (I&I NSW)[10] be undertaken to develop an appropriate mapping method and quantitative sampling design for seagrasses within the study area.

[10] I&I NSW have developed a low-altitude high resolution technique (LAHR) which provides a means of capturing digital images of the spatial arrangement of patches of seagrasses across an estuarine landscape. Importantly, this technique can discriminate between the three main genera of seagrasses found in New South Wales estuaries (i.e. *Posidonia, Zostera* and *Halophila*) (Roberts *et al.* 2009, Creese *et al*. 2009).



Coord. System: GDA94 MGA Zone 56
DPI_vegetation survey aquatic 2003
AECOM_ground truth 2009

River Catchment | LGA Boundaries | Seagrasses | Riverine Channel | Fluvial Delta | Central Mud Basin

PARRAMATTA RIVER ESTUARY PROCESSES STUDY
GEOMORPHIC ZONES OF STUDY AREA

0 0.25 0.5 1 km

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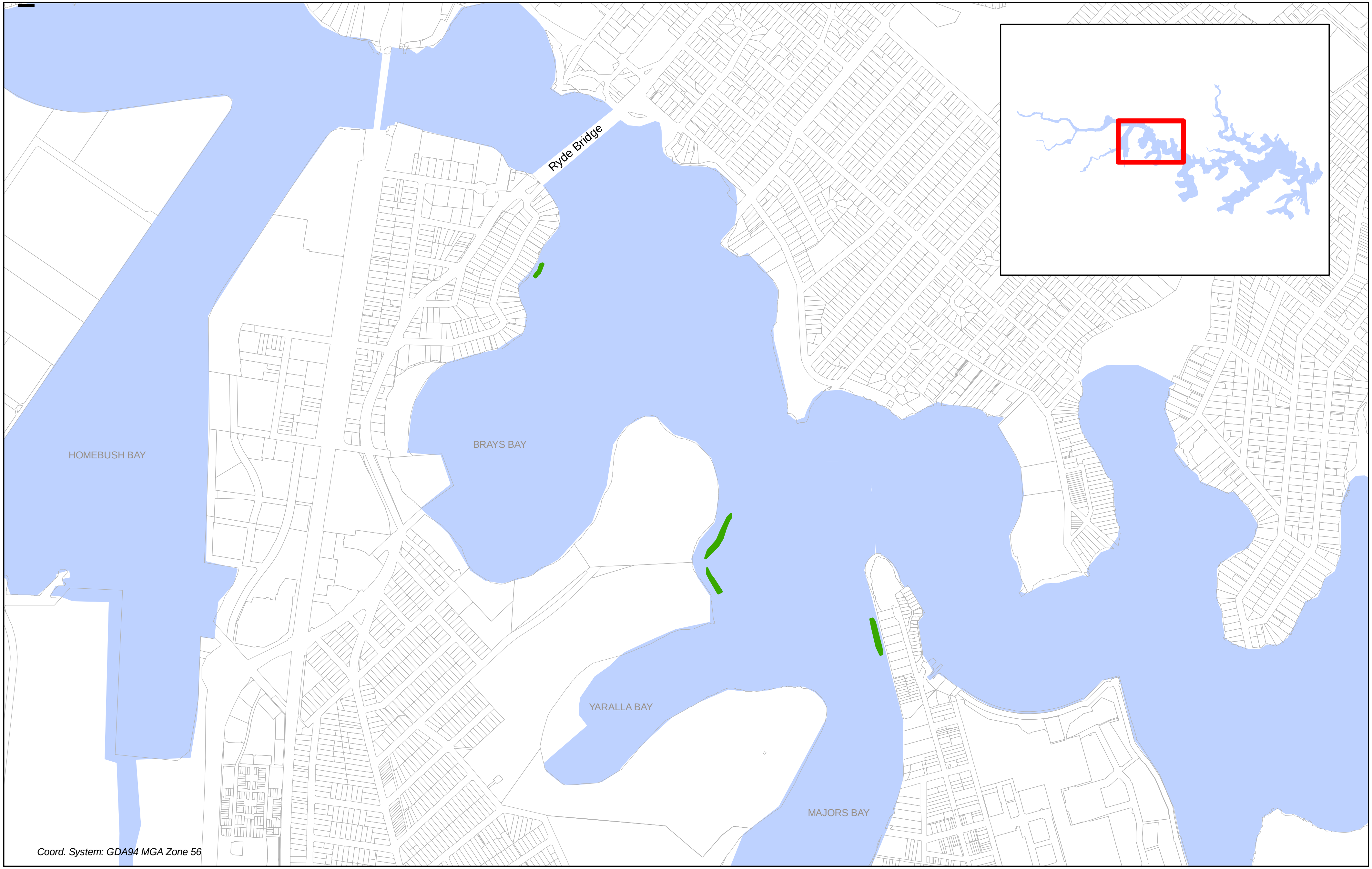
Fig. **7.1**



Seagrasses

0 0.1 0.2 0.4 km

PARRAMATTA RIVER ESTUARY PROCESSES STUDY

NEW LOCATIONS OF SEAGRASS

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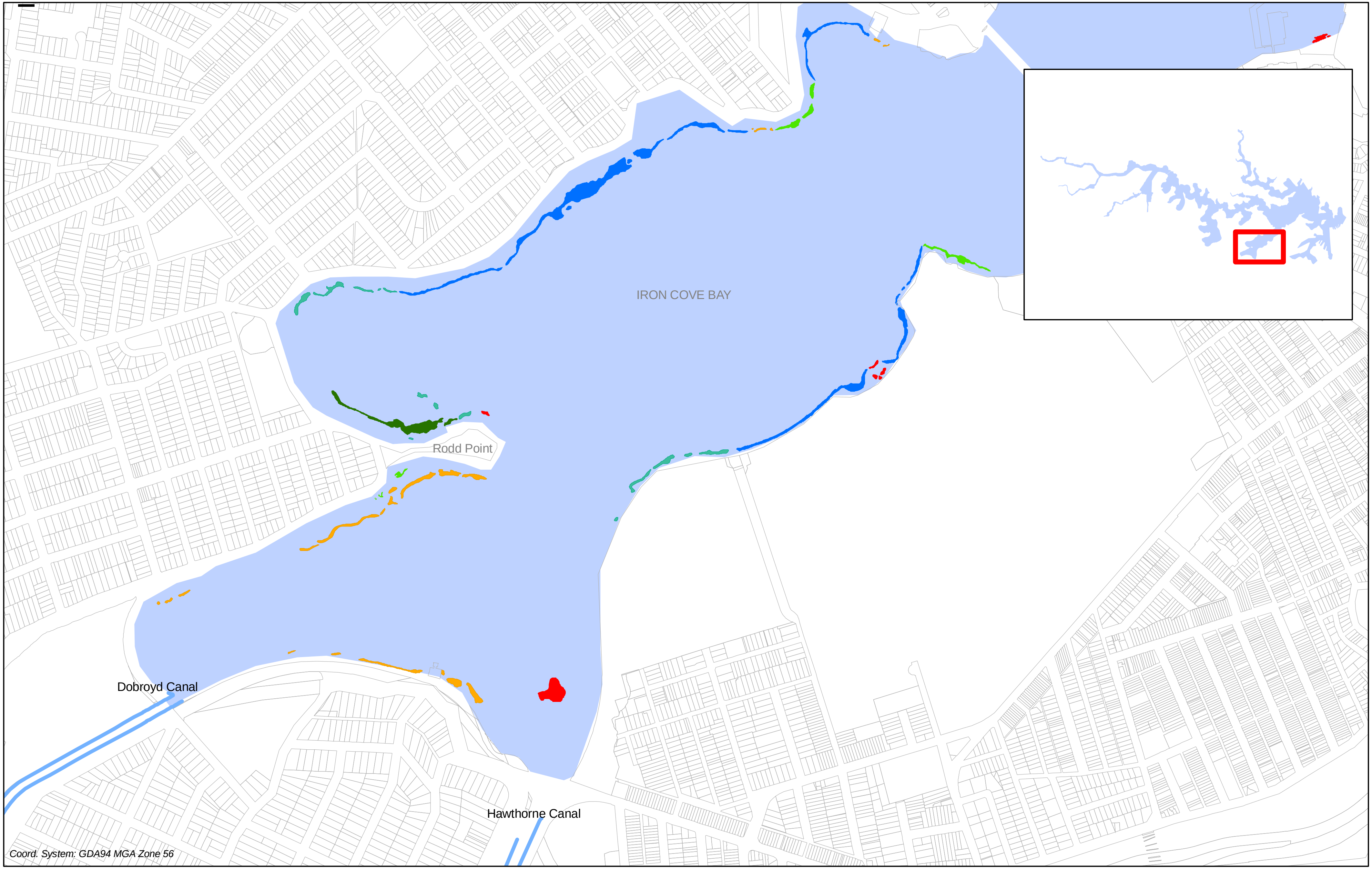
Fig. **7.2**



Seagrass mapping:
DPI_vegetation survey aquatic 2003
AECOM_ground truth 2009

Halophila
Halophila and Zostera
Zostera
Zostera and Halophila
Unable to verify
Not evident

PARRAMATTA RIVER ESTUARY PROCESSES STUDY
WATER QUALITY IMPACTED SEAGRASS IN IRON COVE BAY

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0 0.125 0.25 0.5 km

Fig. **7.3**

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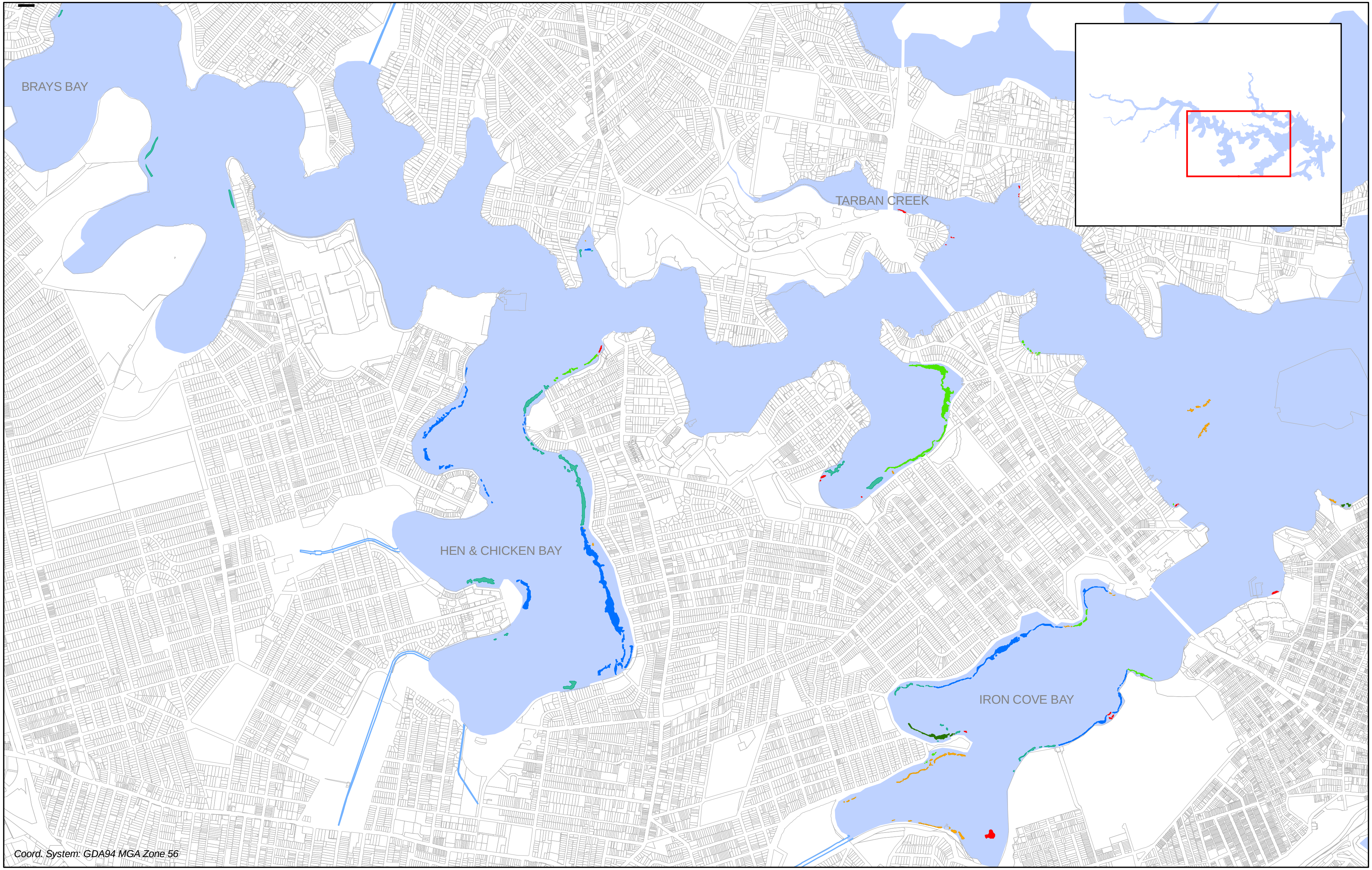

Seagrass mapping:

I & I NSW: vegetation_survey_aquatic_2003
AECOM: seagrass_groundtruth_2009

Halophila	Zostera
Halophila and Zostera	Zostera and Halophila
Unable to verify	Not evident

PARRAMATTA RIVER ESTUARY PROCESSES STUDY

SEAGRASS COMPOSITION IN THE STUDY AREA

0 0.2 0.4 0.8 km

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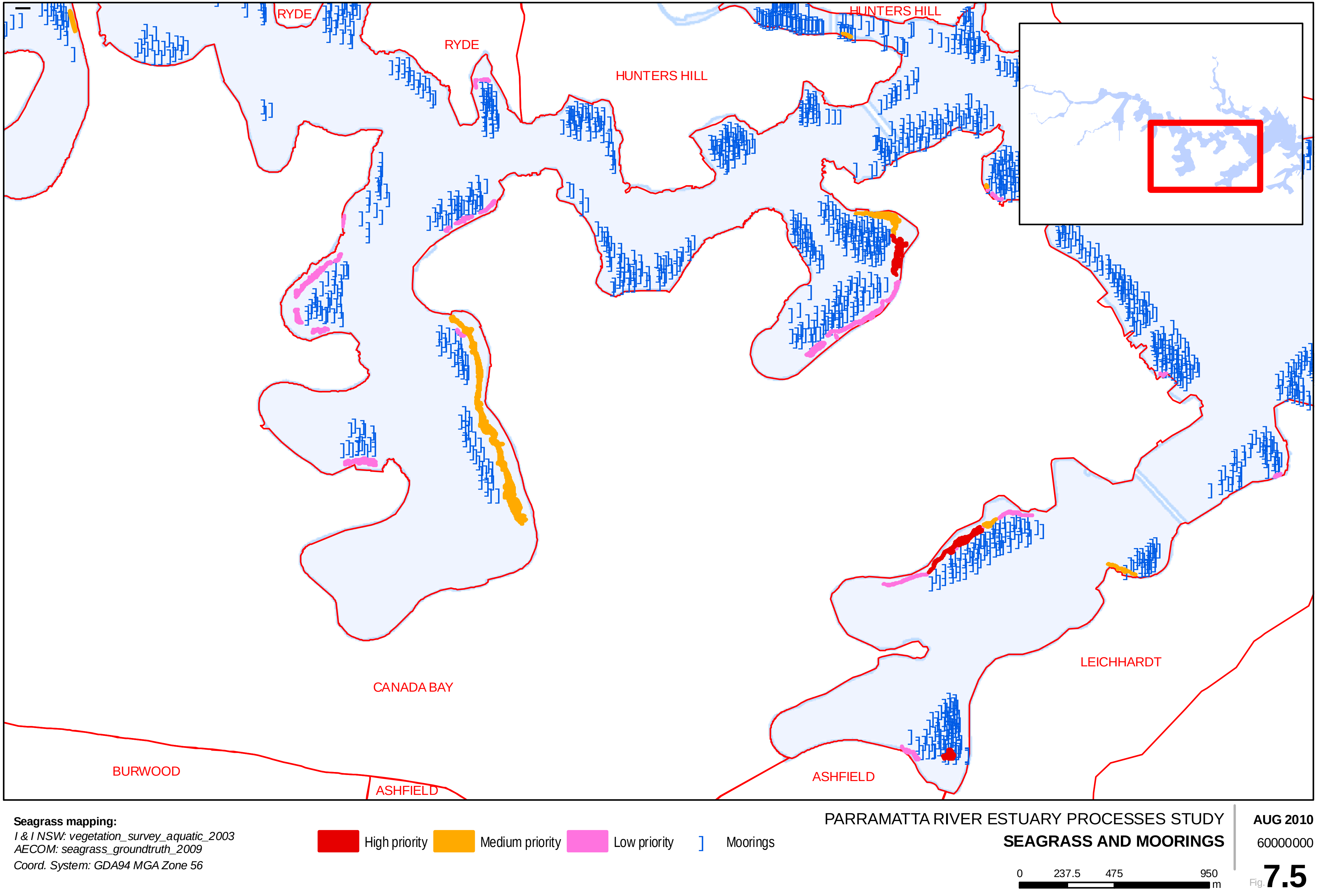
Fig. **7.4**



PARRAMATTA RIVER ESTUARY PROCESSES STUDY

SEAGRASS AND MOORINGS

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Fig. 7.5

7.5 Mangroves

7.5.1 Description

Mangroves occur in the seaward edge of the intertidal zone and are inundated by tides on a daily basis. In order to survive in this environment, mangroves have developed specialised root-like structures (pneumatophores), which protrude from the substrate, usually higher than the mean high tide, and act like 'breathing tubes' facilitating oxygen transport within the plant.

Mangroves are important habitats, providing large amounts of organic matter, which is eaten by many small aquatic animals. In turn, these detritivores provide food for larger carnivorous fish and other animals. Additionally mangrove pneumatophores provide algal and bivalve habitat.

Mangrove pneumatophores protect shorelines from erosion (in combination with the mangrove tree or shrub itself). Mangrove root systems are efficient at dissipating wave energy (Massel *et al.* 1999). Likewise, they slow down tidal water enough that its sediment is deposited as the tide comes in and are not re-suspended when the tide leaves, except for fine particles (Mazda *et al* 1997). As a result, mangroves build their own environment (Mazda *et al.* 2005).

7.5.2 Mangrove Distribution in the Study Area

Mangrove communities in the study area are dominated by Grey mangrove (*Avicennia marina*), and less commonly River mangrove (*Aegiceras corniculatum*). Mangroves are the most widespread component of estuarine vegetation within the study area, although mangroves are believed to be more widely distributed and abundant in comparison to pre-European settlement along the Parramatta River (McLoughlin 2000).

Cumulatively the area in which mangroves occur within the study area is estimated at around 149 ha. The largest areas of mangrove stands occur within Homebush Bay and its tributaries (located within Sydney Olympic Park) and thereafter along the river and its tributaries within the Parramatta LGA (Table 7-7).

Table 7-7. Extent of Mangrove Cover by LGA

LGA	Total (ha)	% of Study Area
Auburn	13.2	8.9
Canada Bay	19.8	13.3
Hunters Hill	1.2	0.8
Parramatta	40.0	26.9
Ryde	10.2	6.9
Strathfield	0.4	0.3
Sydney Olympic Park	63.8	42.9
TOTAL	148.6	100%

7.5.3 Management Issues

Factors threatening mangroves within the study area were identified as:

- Local clearing and development activities;
- Poor water quality;
- Erosion from vessel wash;
- Physical damage from watercraft, trampling and vandalism; and
- Uncertainty of impacts from climate change (i.e. potential loss of habitat from sea level rise, increased storm activities).

7.5.3.1 Sea level rise

Table 7-8 provides a summary of areas in which landward migration of mangroves is limited or may be possible (refer Section 7.3.8 and Figure 7-6).

Table 7-8. Potential for landward migration of mangroves by LGA

LGA	Total area (ha)	Limited		Potential	
		Area (ha)	% of total	Area (ha)	% of total
Auburn	13.16	11.3	86%	1.8	14%
City of Canada Bay	19.79	8.2	41%	11.5	59%
Hunters Hill	1.19	0.3	25%	0.9	75%
Parramatta	39.97	36.3	91%	3.6	9%
Ryde	10.24	8. 7	85%	1.6	15%
Strathfield	0.37	0.1	27%	0.3	73%
Sydney Olympic Park	63.84	50.4	79%	13. 5	21%
TOTAL	**148.56**	**115.3**	**78%**	**33.2**	**22%**

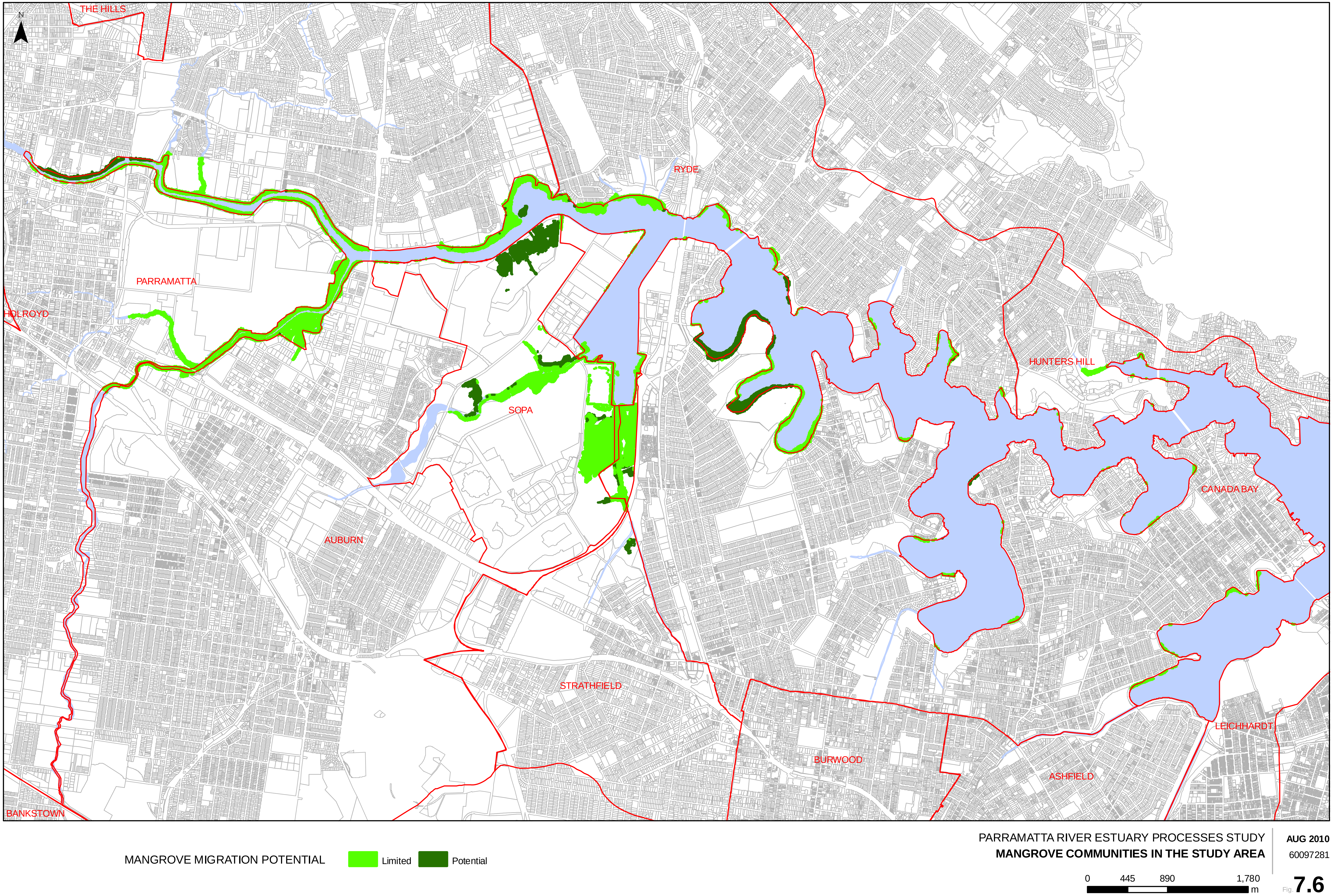
Based on the presence of obvious impediments to landward migration, an estimated 78% of existing mangrove communities will potentially be impacted upon by sea level rise. Of further concern, is that areas broadly categorised as having potential for landward migration include:

- Vegetated areas in which existing endangered ecological communities (e.g. saltmarsh and Swamp-oak forest) occur, and which would be replaced by mangrove migration; and
- Areas in which landward migration will potentially require management intervention to facilitate migration (e.g. removal of pathways, or other modifications).

7.5.3.2 Erosion

Erosion within the study area is particularly severe upstream of Silverwater Bridge due to the narrow channel width and shallow depth at this location combined with the size of vessel operating resulting in a distinctive wave climate. Most undermining of mangroves occurs upstream of the bridge in the Ryde and Parramatta LGAs, and a small portion of the Auburn LGA at the confluence of Duck River and Parramatta River. Additional impacts are found lower in the estuary typically in close proximity to wharves and other areas of high watercraft activity (e.g. north of Kissing Point wharf in the Ryde LGA).

Approximately nine kms of shoreline was found in which mangroves are subject to erosion (Table 7-9). Erosion and undermining of mangroves are described in detail and management options provided within Section 5.0 (*Foreshore Erosion*) of this study.



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PARRAMATTA RIVER ESTUARY PROCESSES STUDY

MANGROVE COMMUNITIES IN THE STUDY AREA

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Fig. **7.6**

Table 7-9. Mangrove areas subject to erosion

LGA	Site no	Locality	Length (m)
Auburn	01	Duck River Eastern Bank	572.8
Canada Bay	22	West of Concord Hospital Watergate, Brays Bay	377.8
Parramatta	01	West of West Ryde Wharf	23.2
	02	George Kendall Reserve, Ermington	1,059.2
	03	Eric Primrose Reserve, Ermington	339.4
	05	Thackeray St Footbridge to Rydalmere Rail Bridge	1,003.0
	06	Rydalmere Rail Bridge to James Rouse Drive	260.9
	08	James Ruse Dr to west of Macarthur St	1,222.8
	09	West of Macarthur St Bridge, South Bank	109.2
	10	West of Macarthur St Bridge, South Bank	70.3
	11	East of James Ruse Drive Bridge, South Bank	166.5
	12	East of James Ruse Drive Bridge, South Bank	282.7
	14	East of James Ruse Drive Bridge, South Bank	280.2
	15	Southeast of Rydalmere Rail Bridge, South Bank	176.9
	16	West of Thackeray St Footbridge, South Bank	667.4
	17	Thackeray St Bridge to Duck River Confluence	1,129.1
	18	Duck River to Parramatta River Confluence	651.9
Ryde	08	Adj. Ryde & Concord Sailing Club, Putney	158.7
	09	Bennelong Park, Putney	102.0
	11	Settlers Park, Putney	333.2
	12	Korpie Reserve, Melrose Park	96.4
	15	East of West Ryde Wharf	111.0
		TOTAL	**9,194.6**

7.5.3.3 Water quality

The typically fine anoxic sediments that deposit under mangroves act as sinks for a variety of heavy metals. Subsequently, trace metal contamination in seawater and aquatic biota may eventuate in areas in which mangroves are cleared for development (or otherwise removed), and the underlying sediments are disturbed.

Altered water quality and pollutants can directly affect mangroves in a range of ways:

- Changes in pH, redox potential (dissolved oxygen) and salinity can render heavy metals and other toxicants more available to keystone mangrove animals (i.e. crabs and worms) which are essential to the health of mangrove communities (Volkman 1994);
- Heavy metals can lead to inhibition of photosynthesis and respiration in mangroves, causing die back (Melville and Burchett 2002);
- Floating oil deposited on mangrove roots on receding tides, can suffocate mangroves and / or have toxic effects on keystone mangrove animals (Volkman 1994 and Duke 1996); and
- Excessive input of sediment and other gross pollutants can smother pneumatophores and potentially suffocate mangroves.

Key areas in which stormwater impacts were observed to be directly impacting on mangrove communities include the following:

- Kissing Point Bay and Bennelong Park, Putney (Figure 7-7, Ryde LGA);
- Meadowbank Memorial Park, Meadowbank (Ryde LGA);
- Melrose Park Reserve, Melrose Park (Ryde LGA);

- Lower Duck River (Parramatta and Auburn LGAs); Kendall Bay, Breakfast Point (City of Canada Bay LGA);
- Five Dock Bay, Drummoyne (City of Canada Bay LGA); and
- Iron Cove Bay (City of Canada Bay LGA).

The quality of stormwater runoff in the study area is discussed in Section 3.0 (*Stormwater Management and GPTs*) of this study.

Figure 7-7. Stormwater inflow in Bennelong Park, Putney (Ryde LGA)

7.5.3.4 Other management issues

Direct impacts on mangrove communities observed in the study area include:

- Ad hoc storage of non-motorised watercraft (e.g. dinghies) within mangrove areas (Figure 7-8). This appears more common within residential areas which lack recreational zoning. Formalised dinghy storage areas would assist in mitigating impacts to estuarine vegetation.
- The use of informal access trails and other trampling effects. Trampling can decrease the density of pneumatophores, which in turn affects the health of mangroves. Educational signage, fencing, track closure or relocation of existing trails should be considered.
- Deliberate lopping of tree limbs or poisoning of mangrove where such growth impinges on residential views. Noticeable impacts to mangrove trees occur in both Five Dock Bay and Iron Cove Bay (Figure 7-9 and Figure 7-10).

  Ongoing policing of mangrove damage and penalising offenders, while difficult, is necessary in order to discourage further vandalism.

  Alternatively, the resilience of mangroves to pruning could be experimentally investigated in collaboration with DII (as a potential management solution in areas where repeat tree vandalism offences occur).

  Further LGA and site specific management recommendations are provided in Section 9.0 of this study.

Figure 7-8. Dinghy storage underneath mangroves (and / or tied up to trees), Canada Bay.

Figure 7-9. Tree vandalism in Five Dock Bay, Drummoyne

Figure 7-10. Mangrove death in Iron Cove Bay (Henley Marine Drive, Five Dock)

7.6 Coastal Saltmarsh

7.6.1 Description

Saltmarsh occupies tidally influenced shores that are protected from wave action, including shores of drowned river valleys, barrier estuaries, and saline lakes. The intertidal zone in which saltmarsh is found typically occurs from the mean high water level (MHWL) and the highest astronomical tide (HAT). The location of saltmarsh within the intertidal zone and relative to mangrove and seagrass communities is illustrated in Figure 7-11.

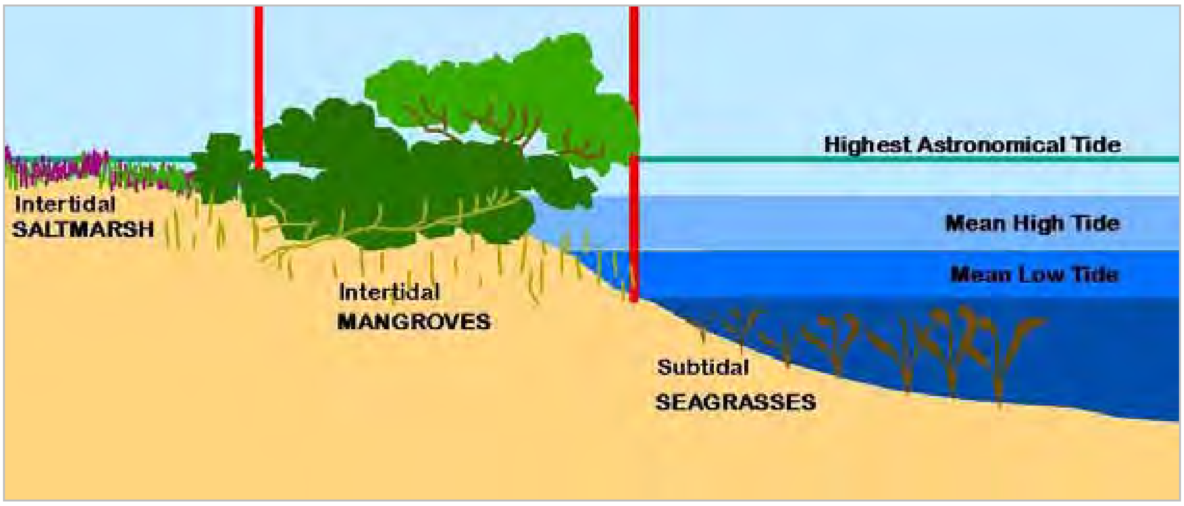

Figure 7-11. Common habitat zones in an estuary (adapted from Kailola *et al.* 1993)

Saltmarshes are characterised by plant species adapted to surviving in saline, often hypersaline environments, and are dominated by halophytic (salt tolerant) low growing succulents, grasses and rushes. Saltmarsh species found in the study area include *Sarcocornia quinqueflora* (Samphire), *Sporobolus virginicus* (Salt couch), *Suaeda australis* (Seablite), *Samolus repens* (Creeping brookweed) and *Juncus kraussii* (Sea rush). More rarely found is the vulnerable saltmarsh species *Wilsonia backhousei*.

Birds, insects, mammals, crabs, molluscs and fish use saltmarsh at different phases of the tide. Fish and crabs feed in saltmarsh during king and spring tides and shorebirds often feed at low tide. Bats have also been known to forage for insects in saltmarshes.

Crabs are perhaps the most conspicuous fauna in saltmarsh mostly due to their burrows. Crabs are consumed by large predatory fish but also produce copious larvae. Research has shown the importance of saltmarsh to estuarine fish (Mazumder *et al*., 2005) and the direct trophic link between saltmarsh zooplankton (mostly crab larvae) and fish.

Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions is listed as an Endangered Ecological Community (EEC) in Part 3 of Schedule 1 of the *Threatened Species Conservation Act 1995* (TSC Act). The listing of saltmarsh as an EEC under the TSC Act places statutory obligations upon the owner, or manager responsible for, land that contains such communities.

7.6.2 Saltmarsh Distribution in the Study Area

Cumulatively the area in which saltmarsh occurs within the study area is estimated at around 23 ha. The largest areas of saltmarsh occur within Homebush Bay (located within the Sydney Olympic Parklands)[11] and thereafter within Mason Park Wetlands (Strathfield LGA), and along the river and its tributaries within Auburn LGA and Parramatta LGA respectively (Table 7.10 and Figure 7-12).

Table 7-10. Extent of Saltmarsh Cover by LGA

LGA	Total (ha)	% of Total Area
Auburn	1.31	5.7
City of Canada Bay	0.72	3.1
Hunters Hill	<0.02	0.1
Parramatta	0.89	3.8
Ryde	0.26	1.1
Strathfield	1.32	5.7
Sydney Olympic Park	18.60	80.4
TOTAL	**23.11**	**100%**

Note: areas in hectares (ha) reported as extent of saltmarsh does not represent all potential saltmarsh habitat (i.e. large areas of non-vegetated mudflats or other bare areas have for the most part not been included, except where relatively small and discontinuous).

7.6.2.1 Wilsonia backhousei

Wilsonia backhousei is a mat-forming prostrate herb, with dark green, narrow, fleshy (succulent) leaves and small solitary and white flowers. *W.backhousei* forms dense carpet-like groundcover, to 10 to 15 cm high.

The Scientific Committee made its final determination to list *W.backhousei* under the TSC Act due to the likelihood for the species to become endangered unless the circumstances and factors threatening its survival or evolutionary development cease to operate. This determination was made in advance of Coastal Saltmarsh being listed as an endangered ecological community. The factors threatening the survival of *W.backhousei* identified by the Scientific Committee are:

A significant decline in the abundance of this species due to loss of habitat;

- Slow recovery from damage (caused by trampling and vehicle use);
- Threats to saltmarsh communities such as: changes to salinity regimes resulting from modified drainage or discharge of stormwater; and invasion of weeds such as *Juncus acutus*.

W.backhousei occurs in the following locations within the study area:

- Brays Bay saltmarsh City of Canada Bay;
- Mason Park saltmarsh, Strathfield Council;
- Sydney Olympic Park (Newington Nature Reserve, foreshore of Parramatta River, the Waterbird Refuge and saltmarsh in Bicentennial Park), and Haslams Creek;

---

[11] The Sydney Olympic Park Authority (SOPA) has conducted a range of wetland and saltmarsh specific mapping and management projects over the past decade. Spatial data used to generate the figures are based on mapping assessed from 2003 aerial photography conducted by SM-CMA in collaboration with DII and NSW Maritime Authority. Spatial data generated from SOPA mapping projects is likely to be more accurate and therefore it is acknowledged that there is likely to be variance in the figures reported.

- The foreshore of Duck River in Silverwater (Auburn LGA);
- The foreshore of Parramatta River (Parramatta LGA); and
- The foreshore in Melrose Park (Ryde LGA).

As this species is very rarely found in most saltmarsh communities, its management should be considered within the context of its listing as an individual species, and not assumed within the context of protecting saltmarsh communities as a whole. Further, *W. backhousei* is typically found within higher elevations (often on the margins fringing saltmarsh communities), and therefore will be more vulnerable to landward migration constraints.

7.6.3 Management Issues

Threats commonly cited that impact on saltmarsh communities and that are prevalent within the study area typically fall into the following categories:

- Altered hydrology and water quality;
- Interspecific competition;
- Weed infestations;
- Mowing;
- Rubbish/refuse dumping, litter;
- Access (trampling); and
- Sea level rise.

7.6.3.1 Altered Hydrology and Water Quality

Alteration to natural flow regimes of waterways, and their floodplains and wetlands, is recognised as a major factor contributing to the loss of biological diversity and ecological function in aquatic ecosystems. Impacts caused from altered hydrology relevant to saltmarsh vegetation include:

- The alteration of tidal flows, which can decrease the tidal extent and frequency of tidal inundation, which in turn decreases soil salinity and promotes the expansion of *Casuarina glauca* (Swamp-oak), freshwater or brackish wetland species, and terrestrial weeds;
- Detention of flows (rainfall and tidal) within artificially ponded areas that should freely drain (i.e. caused by artificial embankments and / or cumulative sediment deposition). This provides habitat for mosquito breeding, exotic and pest plants and animals, and in some cases drowns areas of saltmarsh; and
- Stormwater runoff quality, velocity, and subsequent concentrated flows (which may cause scour) compared to overland 'sheet' flow; and altered salinity regimes (which promote the spread of non-estuarine vegetation.

7.6.3.2 Interspecific Competition

In undisturbed estuaries, there is often a natural succession of vegetation zones from Eucalypt forest through to Swamp-oak forest, and then saltmarsh to mangroves in the intertidal zone. Changes to natural hydrological regimes and other land disturbances, including tidal flushing, increased freshwater inputs, and sedimentation, can promote the spread of mangroves, and conversely, the spread of *Casuarina glauca* (Swamp-oak) and freshwater or brackish macrophytes, into areas occupied by saltmarsh[12].

Encroachment of *Casuarina glauca*, the dominant Swamp-oak floodplain forest canopy species (also an EEC under the TSC Act) into the saltmarsh communities has been attributed to alteration of tidal flows which in turn have lead to decreased soil salinity. Because *Casuarina glauca* is capable of asexual and prolific reproduction through suckering, any one tree occurring within a saltmarsh community is capable of significant displacement of saltmarsh species and reduction of the community as a whole.

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[12] Natural succession of vegetation zones is common but not always the case, estuarine vegetation occurs both in isolation of other communities and occurs within zones of succession.

Encroachment of *Casuarina glauca* into saltmarsh communities within the study area has been exacerbated by extensive use of this species in landscaping and rehabilitation projects located on land upslope of the intertidal zone.

In recent decades there has been widespread invasion of saltmarsh in southeast Australia by mangroves (Mitchell and Adam 1989, Saintilan and Williams 1999, 2000). Expansion of mangroves is a commonly found threat to saltmarsh communities within the study area, which is likely to worsen over time due to forecasted sea level rise.

Freshwater/brackish species include the native emergent macrophytes *Phragmites australis* (Common Reed) and *Typha* spp. (Cumbungi). These species have been observed to expand into saltmarshes within New South Wales due to altered hydrology (i.e. increased freshwater inputs from stormwater runoff), although are less of an issue within the study area in comparison to *Casuarina glauca* and mangrove encroachment.

7.6.3.3 Terrestrial and Aquatic Weeds

The widespread modification and reclamation of the study area's foreshore, and altered hydrology, have provided habitat competition between both saltmarsh and terrestrial vegetation. The extent of weed infestations is logically worse in those areas that are higher in elevation and less frequently inundated by saline water. The exception to this is where weed species are tolerant, or semi-tolerant to salinity.

Salt tolerant weeds known to infest saltmarsh habitat include *Alternanthera philoxerioides* (Alligator Weed) and *Juncus acutus* (Spiny Rush). This species is a highly invasive weed native to Europe and south-west Asia that commonly invades saltmarsh communities in the Sydney Basin bioregion displacing the native species *J. kraussii. J. acutus* is presently a significant problem within Homebush Bay and occurs less densely in other locations within the study area (refer Section 9.0).

Alternanthera philoxerioides is one of the most serious aquatic weeds present in Australia, which is classified as a Weed of National Signifance (WONs) and listed as noxious under the *Noxious Weeds Act* 1993. *A. philoxerioides* was first recorded in Duck Creek in Auburn (in 1969) and continued to spread throughout the Parramatta River catchment.

Other infestations are known to occur within Homebush Bay (SOPA); Haslams Creek (Auburn LGA and SOPA); Bennelong Park, Putney (Ryde LGA), and Betts Park (Hunters Hill LGA).

Other less serious weed species that are commonly present within saltmarshes include *Aster subulatus* (Wild Aster); *Stenatophrum secundatum* (Buffalo Grass); and *Hydrocotyle bonariensis* (Kurnell Curse).

Resource efforts to control weeds should be directed towards saltmarsh areas in which the elevation is suited to more frequent tidal inundation, or where it is considered that control of encroachment by non-native or non-saltmarsh species is more likely to be achievable and comprise a relatively sustainable maintenance task over the longer term. For example, smaller amounts of weed infestations in highly valued saltmarsh areas.

7.6.3.4 Mowing

Where private land or public open space abuts saltmarsh, mowing practices, either inadvertently or deliberately, have gradually encroached into native vegetated areas. Lawn clippings are also commonly dumped into bushland, saltmarsh and mangrove areas. To counter this practise, educational programs, fencing, or other form of physical edging between mowing sites and native vegetation should be undertaken.

Council maintenance of open space should ensure that lawn clippings are captured or otherwise prevented from entering saltmarsh communities.

Issues related to mowing and dumping of lawn clippings were evident along the foreshore of the River in both the Parramatta and Ryde LGAs, and within Brays Bay and Yaralla Bay (City of Canada Bay LGA).

7.6.3.5 Rubbish Dumping

As part of the legacy of land reclamation throughout the Parramatta River, many saltmarsh areas are bordered by fill and rubble. In some cases these materials extend into the saltmarsh zone, limiting the area available for plant growth and habitat for animals. Where this is the case, it may be possible to remove such materials and restore some of the natural character of the foreshore environment (Kelleway *et al* 2007).

Alternatively, overlaying clean fill materials with suitable topsoils may provide suitably elevated habitat for future migration of estuarine vegetation.

The most commonly dumped items were garden waste and old building materials. The former is of particular concern with the potential to introduce weeds (particularly lawn species Kikuyu and Buffalo Grass) into the saltmarsh and surrounding areas.

Dumped materials were observed throughout the subject area, particularly in areas which are out of public view. The worst affected saltmarsh sites include:

- Where industry immediately abuts mangrove and saltmarsh areas along Duck River (Auburn LGA);
- Where residential properties abut both mangrove and saltmarsh areas along the river, Melrose Park (Ryde LGA); and
- Half Moon Bay - Iron Cove Bay (vegetative materials) and Yaralla Bay (building waste) both within the City of Canada Bay LGA.

7.6.3.6 Access Management

Saltmarsh is highly sensitive to physical impacts of trampling and vehicular damage, which can alter the micro-topography, drainage and micro-habitat structure of a saltmarsh. The constituent plant species of saltmarshes are low growing herbs and forbs, which are highly sensitive to physical impacts and depending on the severity of the impacts, can take several years to recover.

By virtue of the high level of development to the foreshore environment of the study area, few opportunities are available for vehicle access to saltmarsh areas, with pedestrian trampling the primary cause of access impacts. Continued trampling of saltmarsh vegetation can cause the isolation and reduction in size of saltmarsh communities, and typical edge effects that decrease a community's resilience to weed infestation.

Informal walking tracks through saltmarshes in the study area are quite common, particularly across smaller and more degraded patches that may not be recognised as vegetation of conservation value to the untrained eye.

Fencing; track closure, relocation, or replacement (i.e. with raised boardwalks); and education signage should be considered to mitigate existing access impacts on sensitive saltmarsh areas.

In addition to pedestrian access impacts, the unformalised storage of non-motorised watercraft (e.g. dinghies) has been identified as a management issue. Areas in which formalisation of watercraft storage would minimise ongoing impacts to saltmarsh and other intertidal communities are detailed within LGA and site specific management summaries (Section 9.0).

7.6.3.7 Sea Level Rise

Saltmarsh communities that will be most vulnerable to sea level rise are those that are limited to migrate upstream or upslope by topography, prevailing land use, and structures. In contrast, much of the widely distributed saltmarsh communities located on reclaimed land, and those presently suffering from inadequate tidal exchange, may well benefit from a modest increase in mean sea level. Table 7-11 provides a summary of estimated saltmarsh areas with either limited or potential opportunity for landward migration (refer Section 7.3.8).

Table 7-11. Potential for landward migration of saltmarsh by LGA

LGA	Total area (ha)	Limited		Potential	
		Area (ha)	% of total	Area (ha)	% of total
Auburn	1.31	1.23	94%	0.08	6%
City of Canada Bay	0.71	0.25	35%	0.46	65%
Hunters Hill	<0.02	<0.01	50%	<0.01	50%
Parramatta	0.89	0.50	56%	0.39	44%
Ryde	0.26	0.20	77%	0.06	23%
Strathfield	1.32	0.55	42%	0.77	58%
Sydney Olympic Park	18.60	5.42	29%	13.18	71%
TOTAL	**23.11**	**8.16**	**35%**	**14.95**	**65%**

An estimated 65% of existing saltmarsh, in the study area, has some potential for landward migration, of which a large proportion is located within Newington Nature Reserve (Sydney Olympic Park). Tidal exchange influencing saltmarsh at this location is regulated by a weir which was purposely built to improve tidal flushing following a history of isolation from tidal flows entering these wetlands from the Parramatta River.

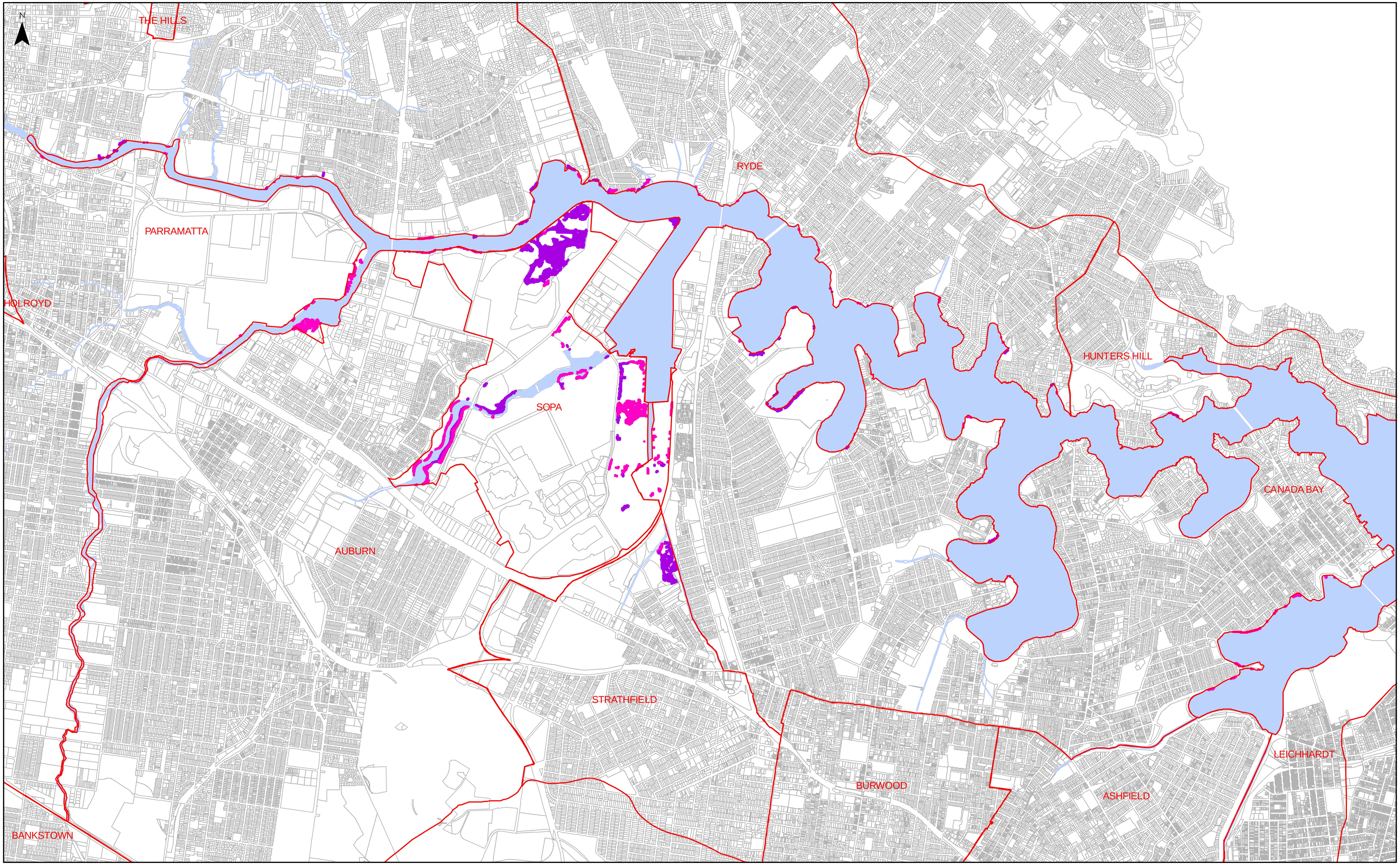
Subsequently all mapped saltmarsh locations within this area have been categorised as having 'potential' for landward migration, on the basis that regulation of inundation into this area (via the weir) should provide some level of mitigation against predicted sea level rise. However not all saltmarsh located within Newington Nature Reserve benefits from improved tidal flushing from the river. Therefore the estimated area of saltmarsh with 'potential' for landward migration, should only be considered as the best possible case scenario over the ensuing period of time in which sea level rise has been forecasted.

Saltmarsh located within Mason Park Wetlands (Strathfield LGA) contributes an additional 0.77 ha or 5% of saltmarsh with potential for landward migration within the study area. Tidal exchange within Mason Park Wetlands is also regulated by a weir (purposely built to improve tidal flushing). All saltmarsh contained within these wetlands has also been categorised as having potential for landward migration due to this management capacity.

While 65% of saltmarsh areas, within the study area, are identified as having some longer term viability in relation to the impacts from forecasted sea level rise, the potential loss of 35% is significant when considered within the context of both the historical and more contemporary loss of saltmarsh.

The relatively undefined impacts and timing of climate change effects provides an impetus to ensure that the study area's estuarine vegetation is conserved and maintained in a healthy condition. Perhaps more importantly, the longer term survival of these communities warrants deliberate reinstatement or expansion of their existing extents wherever environmental conditions and existing landuses are suitable.

Opportunities to reinstate or expand saltmarsh, and/or reserve upslope land for future natural migration of saltmarsh are provided in Section 9.0 of this study.



SALTMARSH MIGRATION POTENTIAL Limited Potential

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7.7 Estuarine Riparian Vegetation

7.7.1 Description

Based on existing mapping layers[13], approximately 71 ha of estuarine riparian vegetation is present within the study area (Table 7-12).

Table 7-12. Riparian Communities within the Study Area by LGA

LGA	Vegetation Community	Area (ha)	% Study Area
Auburn	Swamp-oak Floodplain Forest	0.4	
	Sub-total	**0.4**	<1%
City of Canada Bay	Coastal Sandstone Gully Forest	<0.1	
	Coastal Sandstone Ridgetop Woodland	0.5	
	Sydney Turpentine-Ironbark Forest	4.5	
	Swamp-oak Floodplain Forest	4.1	
	Sub-total	**9.2**	13%
Hunters Hill	Coastal Sandstone Gully Forest	10.0	
	Coastal Sandstone Ridgetop Woodland	1.4	
	Swamp-Oak Floodplain Forest	0.7	
	Sub-total	**12.1**	17%
Leichhardt	Swamp-Oak Floodplain Forest	0.1	
	Sub-total	**0.1**	<1%
Parramatta	Coastal Sandstone Gully Forest	1.5	
	Swamp-Oak Floodplain Forest	5.5	
	Sub-total	**7.0**	10%
Ryde	Coastal Sandstone Gully Forest	4.6	
	Coastal Sandstone Ridgetop Woodland	0.9	
	Sydney Turpentine-Ironbark Forest	1. 6	
	Swamp-Oak Floodplain Forest	<0.1	
	Sub-total	**7.1**	10%
Strathfield	Swamp-Oak Floodplain Forest	0.7	
	Sub-total	**0.7**	1%
Sydney Olympic Park	Sydney Turpentine-Ironbark Forest	15.8	
	Swamp-Oak Floodplain Forest	18.2	
	Sub-total	**34.0**	48%
Dept. of Defence	Coastal Sandstone Ridgetop Woodland	<0.1	
	Sub-total	**<0.1**	<1%
	TOTAL RIPARIAN	**70.6**	100%

[13] 94z56syd_foreshore_veg22jan2007 (SM-CMA vegetation shapefile) refer Section 7.2.1.

7.7.2 Swamp-oak Floodplain Forest

Swamp Oak floodplain forest was listed as an ‘endangered ecological community’ under the TSC Act in 2004 due to the likelihood of it becoming extinct in nature (in NSW) unless the circumstances and factors threatening its survival cease to operate.

Swamp-oak floodplain forest varies from dense to sparse canopied forests that are dominated (north of Bermagui, NSW) by the canopy species *Casuarina glauca* (Swamp-oak). Other tree species include *Acmena smithii* (Lily pily), *Glochidion ferdinandi* (Cheese tree) and *Melaleuca* species (Paperbarks). The understorey usually contains a sparse cover of shrubs but a continuous ground cover of forbs, sedges, grasses, and leaf litter is typically present. Characteristic to Swamp-oak Floodplain Forest are frequent occurrences of vines (*Parsonsia straminea, Geitonoplesium cymposum, Stephania japonica* var. *discolor*).

The composition of the understorey varies with groundwater salinity. Where soils are more saline, the understorey contains salt tolerant sedges, grasses and forbs (e.g. *Baumea juncea, Juncus kraussii, Phragmites australis, Sporobolus virginicus, Selliera radicans,* and other saltmarsh species). Under less saline conditions the understorey may contain ferns (e.g. *Hypolepis muelleri*), and grass and sedge species less able to tolerate salt (e.g. *Carex appressa*, *Gahnia clarkei, Lomandra longifolia*).

Swamp Oak floodplain forest generally occurs below 20m AHD growing in grey-black clay-loams and sandy loams, where the groundwater is saline or sub-saline, on waterlogged or periodically inundated flats, drainage lines, lake margins and estuarine fringes associated with coastal floodplains.

Most of this habitat within the study area has historically been cleared or reclaimed for industrial, residential or open space requirements. Subsequently remnant communities within the study area are highly fragmented and restricted to narrow bands of growth located immediately upland of, and fringing, the intertidal zone (except where topography and/or geology is unsuitable).

In most of the study area’s Swamp Oak floodplain forest communities, the understorey is either dominated by weed infestations (both shrub and ground cover species), or grasses maintained by mowing. Those communities with a native groundlayer component contain either saltmarsh species or planted groundcover, with characteristic vine species and native non-saline groundlayer species noticeably absent.

Casuarina glauca the dominant canopy species of this community has been widely used in landscaping, bush regeneration and restoration projects. Isolated mature *C.glauca* trees are also widespread throughout much of the open space areas along the foreshores of the study area.

Within the study area, there is approximately 30 ha of Swamp Oak floodplain forest rest, with the largest areas occurring in Homebush Bay (within the Sydney Olympic Park) and thereafter within Parramatta and the City of Canada Bay LGAs (Table 7-13).

Table 7-13. Extent of Swamp-oak Floodplain Forest Cover by LGA

LGA	Total area (ha)	Limited		Potential	
		Area (ha)	% of LGA	Area (ha)	% of LGA
Auburn	0.4	0.23	57%	0.17	43%
City of Canada Bay	4.1	1.08	26%	3.06	74%
Hunters Hill	0.7	0.07	10%	0.63	90%
Leichhardt	0.1	-	-	0.13	100%
Parramatta	5.5	5.20	95%	0.27	5%
Ryde	<0.1	0.06	100%	-	-
Strathfield	0.7	-	-	0.69	100%
Sydney Olympic Park	18.2	8.91	49%	9.30	51%
Total Study Area	**29.8**	**15.5**	**52%**	**14.3**	**48%**

Similar to saltmarsh communities within the study area, over 60% of Swamp-oak forest communities are constrained by impediments to migration upslope of their current location. However, Swamp-oak forest communities are commonly found at much higher elevations than intertidal communities, such as mangroves and saltmarsh, and opportunities for re-establishment are likely to be less difficult (except where constraints are due to development) – albeit at the potential loss of other riparian vegetation or sacrifice of public open space.

7.7.3 Turpentine-Ironbark Forest

Turpentine-ironbark forest is listed as a critically endangered ecological community under the EPBC Act. It is also recognised as two separate endangered ecological communities in NSW under the TSC Act (i.e. Sydney Turpentine-ironbark forest and the Blue Mountains shale cap forest)[14].

Sydney Turpentine-ironbark forest (STIF) has several vegetation layers in its undisturbed state, with the canopy dominated by *Syncarpia glomulifera* (Turpentine) and a range of eucalypt species. Many patches of STIF are now degraded and embedded within highly urbanised environments.

Approximately 22 ha of STIF occur in Homebush Bay (SOPA), in Meadowbank Park (Ryde LGA) and in Brays Bay, Yaralla Bay and Majors Bay (City of Canada Bay LGA) (Table 7-14 and Figure 7-13).

Table 7-14. Extent of Turpentine-ironbark forest by LGA

LGA	Total (ha)	% of Total
City of Canada Bay	4.5	21%
Ryde	1.6	7%
Sydney Olympic Park	15.8	72%
TOTAL	**21.9**	**100%**

7.7.4 Management Issues

The main issues affecting riparian vegetation within the study area are infestations of introduced tree and shrub species, vines, and encroachment of grass species from adjacent open space areas.

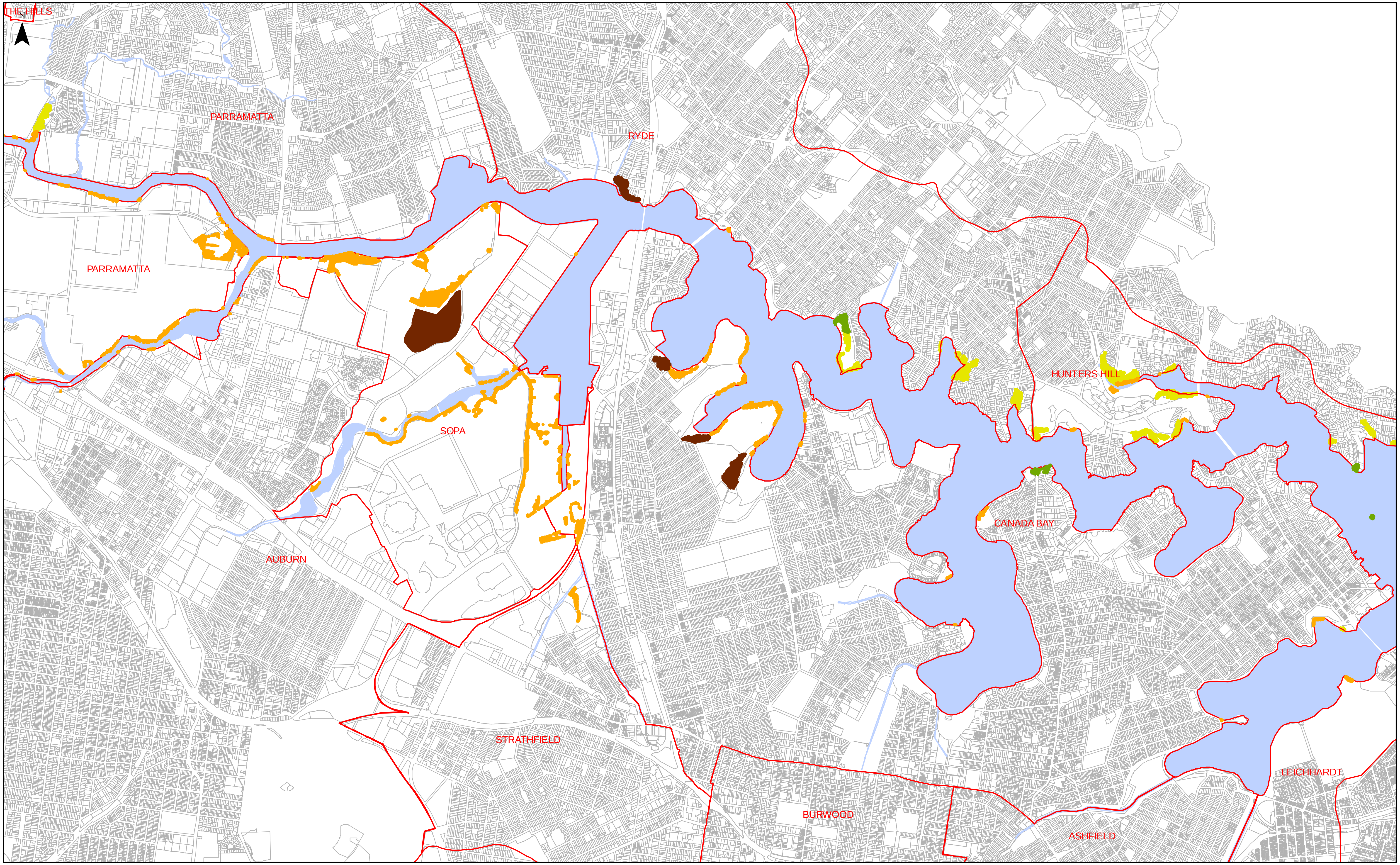
Introduced tree species that monopolise native canopy areas include Coral trees and Camphor laurels, with the small tree / large shrub stratum commonly infested by Phoenix palms and infestations of Green cestrum, Lantana, and the native *Pittosporum undulatum*.

Vine species such as Balloon vine, Madeira vine, and Morning glory are capable of growing from adjacent (non-tidally influenced zones) into native trees and shrubs, eventually smothering large areas and causing dieback.

Sea level rise will also significantly limit the present extent of estuarine riparian vegetation where intertidal vegetation is able to migrate and tidal influences alter soil salinity and inundation frequencies.

As inferred in Section 7.3.8 the prioritisation of management actions (such as weed control programs) may be, by default, driven by the longer term recognition that some areas will be inundated and may not warrant dedication of typically scarce funding and resources.

[14] Turpentine-Ironbark Forest is more commonly known as Sydney Turpentine-Ironbark Forest (STIF) in the study area.



Sydney Turpentine Ironbark Forest
Swamp Oak Floodplain Forest
Coastal Sandstone Ridgetop Forest
Coastal Sandstone Gully Forest

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