GRCCC
Georges River Combined Councils' Committee

Georges River Estuary Coastal Zone Management Plan

Final Report

May 2012

Georges River Estuary Coastal Zone Management Plan

Prepared For:	GRCCC
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

DOCUMENT CONTROL SHEET

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Title :	Georges River Estuary Coastal Zone Management Plan
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Synopsis :	The Georges River Estuary Coastal Zone Management Plan provides a strategic framework and action plan for the future management of the Georges River Estuary. It aims to redress current issues, and conserve existing values, using a range of implementation mechanisms, including planning instruments, on-ground works, and education programs. The Plan includes an indicative costing, potential funding sources, and identifies key agencies and Councils for responsibility of implementation and future monitoring.

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EXECUTIVE SUMMARY

		Details in…
Goal	The primary goal of the Georges River Estuary Coastal Zone Management Plan is "*to conserve and improve the existing natural environment of the Georges River Estuary, and to improve the water quality of the estuary through targeted pollution reduction*"	Section 4
Purpose	This Coastal Zone Management Plan (CZMP) provides strategic direction and guidance on future strategic and environmental planning within the estuary and its catchment. It also provides an Action Plan for undertaking targeted works and other initiatives aimed at achieving the overall Goal of improving estuary condition.	Section 1
Audience	The primary audience of the Coastal Zone Management Plan is Councils within the Georges River Estuary catchment. Other stakeholders, including relevant government agencies and organisations, community groups and the general public, should also refer to this document in respect to management of the estuary	Section 1.3
Context	This Coastal Zone Management Plan has been developed under the NSW Government's Estuary Management Program in accordance with the specifications of Part 4a of the *Coastal Protection Act 1979*. It complies with the requirements of the NSW Coastal Policy 1997, and the Sydney Metropolitan Catchment Action Plan (Management Target CTECM1). It is also consistent with the NSW Government's Sea Level Rise Policy Statement and the Botany Bay Water Quality Improvement Plan, and follows the new Guidelines for Preparation of Coastal Zone Management Plans (DECCW, 2010b). This Plan covers all estuarine waters of the Georges River, from Towra Point to Liverpool Weir. The Plan covers the river foreshores, the Botany Bay foreshore between Towra Point and Cooks River (ie predominantly Lady Robinsons Beach) and all tidal waters that flow into the study area. Consideration has also been given to the wider Georges River catchment insofar as it impacts on estuarine quality and ecological health. This Plan does not cover any open coast sandy beaches or rocky headlands. This Plan presents a summary of the relevant environmental processes of the estuary, and their interactions with the human use and other social and economic values places on the estuary, its foreshores, and the wider catchment area.	Section 1
Status	This Plan is currently in a draft form. The Plan has undergone extensive review by relevant stakeholders and government agencies, as facilitated through the GRCCC and the Georges River Estuary Management Committee. With final endorsement by Councils, the Plan will be given to the Minister for the Environment for certification. Once certified, Councils will adopt the Plan and will publish it in the Government Gazette.	
Relationship to other plans	The Coastal Zone Management Plan is complementary to planning instruments and environmental management strategies and initiatives being used and implemented by each of the Councils and other stakeholders. This includes new LEPs and DCPs for the Councils, as well as Catchment-based strategies, such as the Botany Bay Water Quality Improvement Plan. Implementation of this Plan, particularly the natural resource management strategies, is a key action in the Sydney Metropolitan Catchment Action Plan (SMCMA, 2009) and will assist in achieving Priority E4 of the State Plan. Once gazetted, this Plan is to be consulted during all future reviews of	Section 1.7

		Details in…
	Environmental Planning Instruments and place-based Plans across the catchment area. It is also to be taken into account in determining development applications under Section 79C of the *Environmental Planning and Assessment Act 1979* that may potentially have an impact on the estuary or its surrounding foreshore environments.	
Management Aims	Nine (9) broad Aims have been developed covering the most pertinent issues: **A. Water Quality: To optimise water quality within the Georges River Estuary and its tributaries** **B. Aquatic and Riparian Habitat: To protect, enhance and restore aquatic habitats and foreshore vegetation** C. Recreation and Amenity: To protect and enhance public access to the foreshore **D. Landuse Planning and Development: To minimise the negative impacts of development in the catchment on waterway health** **E. Bank Erosion and Sedimentation: To actively manage bank erosion and sedimentation** F. Foreshore Protection: To manage existing built foreshore assets while maximising environmental values G. Natural and Cultural Heritage: To identify, acknowledge and protect natural and cultural heritage **H. Climate Change and Sea Level Rise: To plan for and adapt to the potential impacts of climate change on the natural and built environments of the estuary** I. Monitoring and Evaluation: To develop and support coordinated monitoring, reporting and evaluation programs for the Georges River Estuary The risk of not achieving Aims A, B, D, E and H is considered 'intolerable' (shown in bold above). The remaining Aims represent 'tolerable' (but still undesirable) risks if not achieved. Tolerable and intolerable risks were determined using a modified risk assessment approach (see Appendix C for details)	Section 4.1
Management Objectives	A total of twenty seven (27) Management Objectives have been defined, which relate to each of the nine broad aims. The Management Objectives were prioritised based on the importance of each Aim and the degree to which each Objective addresses the Aims. The top 10 ranked Management Objectives *(in priority order)* are: **A1.** Reduce the volume & pollutant load of stormwater runoff through the catchment **A3.** Improve the performance of sewer overflows **A2.** All greenfield and redevelopments should have a minimal negative impact on flow and water quality, meeting targets for water quality proposed in the Botany Bay and Catchment WQIP **A5.** Strive to protect undeveloped areas of the broader catchment that act as a buffer to water quality **A6.** Minimise the negative impacts of new and existing commercial operations in the catchment and estuary on flow and water quality **E1.** Reduce the extent and severity of bank and foreshore erosion while minimising the impacts on estuary health **A4.** Minimise build-up of gross pollutants and illegal dumping of waste into and along the estuary foreshore and waterways	Section 4.2

		Details in...
	E2. Reduce the causes and impacts of sedimentation in the estuary **B3.** Protect and improve the extent and condition of estuarine and riparian vegetation **B2.** Minimise the cause and spread of invasive species in aquatic and terrestrial habitats	
Best Management Options	A wide range of potential management options were formulated, including options canvassed from community and stakeholder representatives. An evaluation process was conducted and the options prioritised into three categories: 1. Best Management Options (BMOs); 2. Next Best Options (NBOs); and 3. Other Options. For the purposes of this Plan, only the BMOs were included in the Action Plan. **This includes some 25 Options that help address all 9 broad Aims**. A summary of the BMOs is presented in Table ES-1 overleaf. Relative prioritisation for implementation of the 25 BMOs has been based on the relative ranking of the Management Objectives that the BMOs primarily address. The BMOs have been identified based on the 'approaches' to actions required, namely: • Strategic Planning & Development Controls • Engineering Works & Asset Management • Environmental Rehabilitation & Monitoring • Environmental Planning • Communications & Education • Recreation & Heritage • Compliance The Action Plan provided as part of this Coastal Management Zone Plan gives implementation details for each of the BMOs, including specific locations of applicability (where relevant), costings, timing, and responsibilities for implementing the BMOs.	Section 5
Implement-ation respon-sibilities	For the majority of BMOs, the responsibility for implementation rests with the relevant departments within the local Councils. The GRCCC is also responsible for some BMOs, through the existing Riverkeeper program and may also have a role in co-ordinating and guiding some of the actions of Councils to ensure consistency of approach. In addition to the GRCCC, the NSW Office of Environment and Heritage (Department of Premier & Cabinet) and all partner Councils shall continue to assist with the management and co-ordination of implementation of the Plan through their on-going participation on the Georges River Estuary Management Committee.	Section 6
Program of actions	Specific actions have been identified for most BMOs to help relevant authorities with implementation. Based on the priority of the BMO, actions are recommended to commence over the next 4 years or so, with highest priority actions to commence immediately (subject to funding availabilities)	Section 6
Costs and funding	There are a small number of BMOs that will require significant new sources of funding. These BMOs involve a substantial number of individual works across the study area, including retrofitting new WSUD devices and various bank erosion management works, especially along the mid to upper estuary reaches. Many of the remaining BMOs only require in-kind involvement from existing staff, while other BMOs will only need relatively small external financial	Section 6

		Details in...
	support, similar to existing contributions to environmental works along the Georges River. Once gazetted, this Plan can be used as a lever for obtaining environmental funds through the Federal and/or State Governments (e.g. Estuary Management Program).	
Indicators for success	The ultimate success of the Georges River Estuary CZMP is to be gauged by how well the overall Aims of the Plan have been met. Given that the Aims are broad and likely to be measurable over long timescales only, a series of Performance Measures have been incorporated into the Action Plan for each BMO to identify progress and short term successes in Plan implementation.	Section 6
Consultation	Consultation with the relevant Councils, other stakeholders, and the community has underpinned the development of this Plan. The community will also have the opportunity to review the Plan during a public exhibition period.	Section 3
Review and amendment provisions	This Plan has an indicative 5-10 year timeframe. Progress with implementation should be formally reviewed annually. Contingency measures should be activated if progress is slow. A complete review and amendment of the Plan should occur after a minimum 5 years, and should redress outstanding issues, new environmental management practices, new scientific data, and changed governance and administrative arrangements.	Section 8

Table ES-1 Summary of Best Management Options (BMOs)

Theme / Aim	Action / Strategy	Priority	Option Approach	Costs
Water Quality	**MA2**: Update or prepare new WSUD controls within DCPs	HIGH	Strategic Planning & Development Controls	Staff time only
	MA3: Retrofit new WSUD devices in existing urban areas	HIGH	Engineering Works & Asset Management	**Very significant capital costs**
	MA4: Maintenance of WSUD devices, GPTs, SQIDs etc	HIGH	Engineering Works & Asset Management	**Large annual costs**
	MA6: Sediment/erosion control during & after construction	HIGH	Compliance	Staff time only
	MA8: Riverkeeper teams for clean-up & illegal dumping	HIGH	Environmental Rehabilitation & Monitoring	Continue existing funding + add. funding for large or special projects
	MA10: Develop & adopt WSUD action plans	HIGH	Environmental Planning	Staff time only
	MA15: SWC liaison regarding sewer problems	HIGH	Environmental Planning	Staff time only
Aquatic and Riparian Habitat	**MB4**: Rehabilitation of estuarine wetlands & riparian vegetation	HIGH	Environmental Rehabilitation & Monitoring	Staff time + Landcare grants
	MB7: Support and continue bushcare/landcare groups	HIGH	Environmental Rehabilitation & Monitoring	Staff time + Landcare grants
	MB8: Riverkeeper teams for bush regeneration & weed control	HIGH - MEDIUM	Environmental Rehabilitation & Monitoring	Continue existing funding + add. funding for large or special projects
	MB9: Private landholder education re: habitat & vegetation	HIGH - MEDIUM	Communications & Education	Staff time + printing costs
Recreation and Amenity	**MC3**: Interpretive education materials on recreation	LOW	Communications & Education	Staff time + printing costs
	MC5: Contribute to boating strategy revision	LOW	Environmental Planning	Staff time only
Landuse Planning and Development	**MD3**: Use Best Management Practices for Council works	MEDIUM	Strategic Planning & Development Controls	Staff time only
	MD4: Consistency with CZMP in future EPI reviews	MEDIUM	Strategic Planning & Development Controls	Staff time only
	MD5: New & revised PoMs to be compatible with CZMP	MEDIUM	Strategic Planning & Development Controls	Staff time only
Bank Erosion and Sedimentation	**ME2**: Boat wake erosion impacts and strategies	HIGH	Environmental Planning	Staff time + Maritime input
	ME3: Targeted control of ad-hoc foreshore access	MEDIUM	Engineering Works & Asset Management	Relatively small costs
	ME4: Prioritise & remediate erosion, using vegetation, where possible	HIGH	Engineering Works & Asset Management	**Very significant capital costs**
Foreshore Protection	**MF1**: Councils to comply with eco-friendly seawall guidelines	MEDIUM	Strategic Planning & Development Controls	Staff time only
	MF5: Educate landholders re: eco-friendly seawalls	MEDIUM - LOW	Communications & Education	Staff time + printing costs
Natural and Cultural Heritage	**MG4**: Work with Aboriginal Groups and others to determine options for threatened heritage sites	LOW	Recreation & Heritage	Staff time only
Climate Change and Sea Level Rise	**MH3**: Mapping of Sea Level Rise and areas for vegetation retreat	MEDIUM	Environmental Planning	Relative small cost
Monitoring and Evaluation	**MI2**: Support GRCCC River Health Monitoring Program	MEDIUM	Environmental Rehabilitation & Monitoring	Continue existing funding + seek supplementary $
	MI3: Support, implement & monitor CZMP effectiveness	LOW	Environmental Rehabilitation & Monitoring	Staff time only

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1 INTRODUCTION AND STRATEGIC CONTEXT

1.1 Why Develop a Coastal Zone Management Plan?

The coastal zone of NSW represents a priceless natural resource, and is immensely valuable from an ecological, social and economic perspective. In addition to the open coast beaches and headlands, the NSW coastal zone contains over 130 estuaries that vary in size from small coastal creeks and lagoons to large lakes and rivers. Estuaries contain diverse ecosystems that form the foundation of the coastal food chain. They provide important habitats for a variety of marine and terrestrial plants and animals.

Georges River (photo: OEH)

The Georges River is a highly valued estuary within the Sydney Metropolitan Area. It retains significant ecological value and also acts as a resource for a variety of recreational pursuits. The juxtaposition of natural and urban environments surrounding the Georges River Estuary demands that special management considerations are made to ensure the long term balance and sustainability of this precious resource.

The Georges River Estuary Coastal Zone Management Plan (Estuary Management Plan) (herein referred to as the Georges River CZMP) has been prepared by environmental consultants BMT WBM, with assistance from isNRM, on behalf of the Georges River Combined Councils' Committee (representing constituent Councils: Bankstown, Fairfield, Hurstville, Liverpool, Rockdale, Kogarah and Sutherland[1]) and the NSW Office of Environment and Heritage (OEH), formerly known as the Department of Environment, Climate Change and Water (DECCW).

The Plan builds on the comprehensive Georges River Estuary Data Compilation and Processes Study (SMEC, 2010), in accordance with the State Government's Estuary Management Process (refer Section 1.6), to satisfy the objectives of the NSW Estuary Management Policy 1992, the NSW Coastal Policy 1997 and the *Coastal Protection Act 1979* (and amendments in 2010). It also helps to satisfy the Sydney Metropolitan Catchment Management Authority's (SMCMA) catchment target *CTECM1: Improvement in the condition of estuaries and coastal lakes*, and contributes to the implementation of target E4 of the NSW State Plan.

Since the original commencement of the Estuary Management Process for the Georges River, the NSW Government has introduced various reforms to coastal management, including the Sea Level Rise Policy Statement (2010) and new Guidelines for Preparation of Coastal Zone Management Plans (2010) (note that for the purposes of revised legislation, including the gazettal process, this

[1] Wollondilly Shire and Campbelltown City Councils are included in the GRCCC, but as they have no frontage onto the estuarine reaches of the river, they were not individually included as part of this Estuary Management Plan.

document is officially called a "Coastal Zone Management Plan" for the Georges River Estuary. These types of plans were formerly known as Estuary Management Plans).

In accordance with Part 4A of the *Coastal Protection Act 1979*, this Coastal Zone Management Plan is to be gazetted by the Councils following certification by the Minister for Environment. Once gazetted, this document must be considered and taken into account when undertaking works or development, or when making new plans that cover areas affected by this plan. A breach of the Plan will result in an offence and associated penalties, as outlined in Part 4A, Division 2 of the CP Act.

Importantly, in following the 'Guidelines for Preparation of Coastal Zone Management Plans', Councils are considered to have acted in good faith and thus are exempt from liability relating to land affected by coastal hazards (including future hazards such as sea level rise and associated coastal inundation) as prescribed in Section 733 of the *Local Government Act 1993*.

The Georges River Estuary Coastal Zone Management Plan satisfies the intent and objectives of these new reforms and initiatives taken by the NSW Government, as well as the fundamental principles originally espoused in the Coastal Policy and the previous Estuary Management Policy.

Actions in this plan may require approval under the *Environmental Planning and Assessment Act 1979* and other legislation and should be considered as intended actions subject to these approvals. In the event of any inconsistency between a statutory instrument or development consent issued under the EP&A Act and this plan, the statutory instrument or development consent applies to the extent of the inconsistency.

Any actions, including project funding, noted in this plan for completion by or contribution from the NSW Government, its Departments or Agencies should be considered as requests for funding or action. The NSW Government will consider these requests when determining its state-wide priorities relating to coastal zone management. If any such actions are not completed in accordance with the plan, this is not to be considered a breach of Section 55L of the *Coastal Protection Act 1979*.

1.2 Purpose of the Plan

The primary purpose of the Georges River Estuary Coastal Zone Management Plan is to provide strategic direction and guidance on future actions within the estuary and its catchment, which will help to achieve long term balanced environmental sustainability. The fundamental goal of the Coastal Zone Management Plan is to achieve balanced and sustainable demands on the estuary from ecological needs and recreational (human) pursuits.

The Plan shall be used to inform other strategic documents that aim to manage and rationalise human activities and development within the catchment, such as Regional Strategies, Local Environmental Plans (LEPs) and Development Control Plans (DCPs).

The Plan aims to fulfil Councils' requirement for applying the principles of Ecologically Sustainable Development (ESD) to the Georges River Estuary and its catchment. The Plan also provides an opportunity for future climate change to be considered in the strategic management and planning of the estuary and surrounding sensitive coastal lands.

1.3 Who is this Plan for?

The primary audience for this Coastal Zone Management Plan is Councils within the Georges River Estuary catchment. Other stakeholders, including the government departments and the general public, are also likely to take a keen interest in the future management of the estuary, and therefore have been considered during preparation of this Plan.

1.4 One Plan for the Whole Estuary

While the estuary and its catchment are partitioned into different Local Government Areas (LGAs) for administrative convenience, the natural processes occurring within the estuary are largely cross-jurisdictional. A coordinated approach has therefore been adopted to investigate and address management needs across the whole of the estuary.

Issues, and associated management responses, are likely to be similar across many LGAs, meaning that there are significant advantages to managing the estuary in a coordinated and integrated manner. Pooled funds and resources are also likely to be more efficiently used, without the need for duplication.

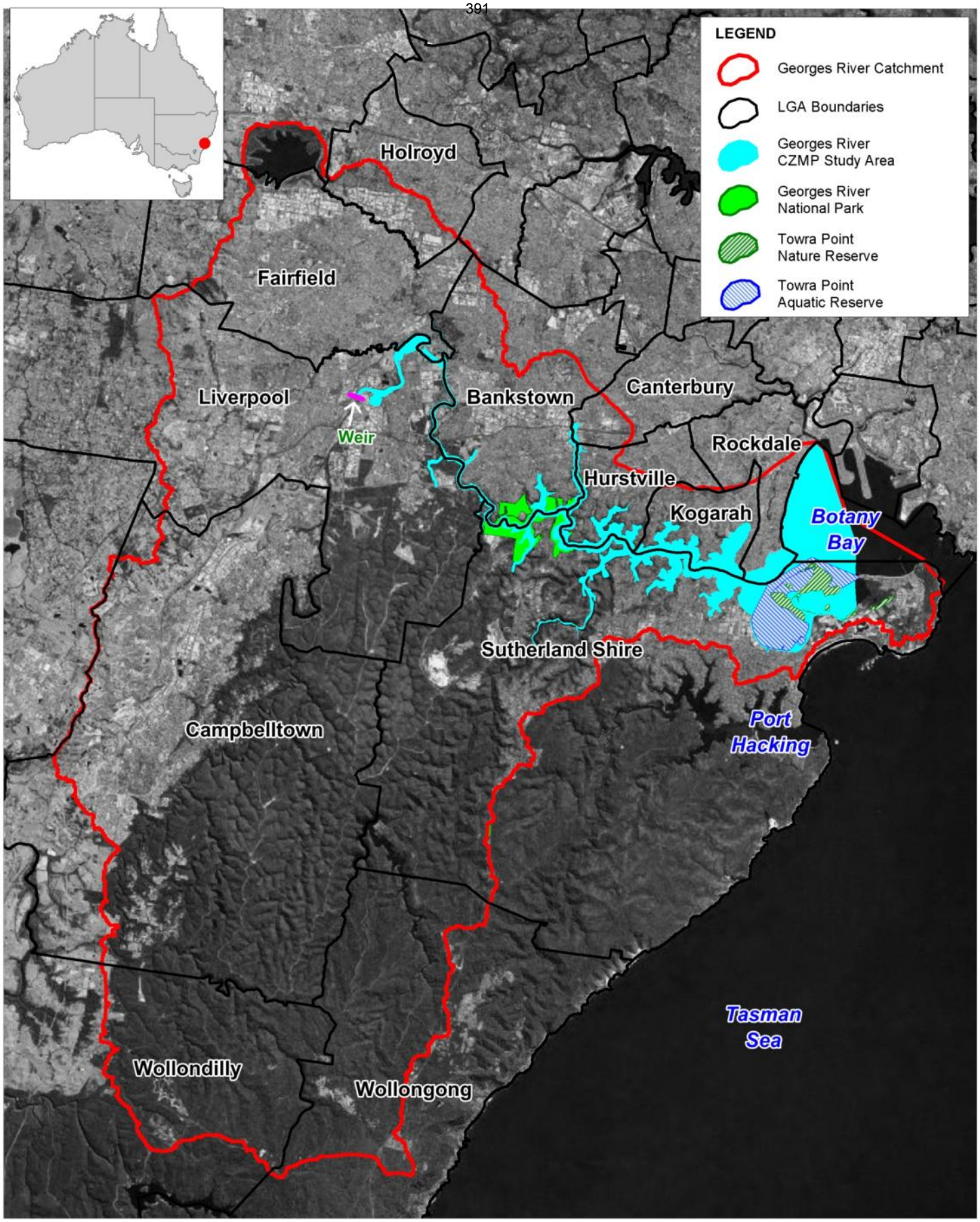
Importantly, a whole of estuary assessment is able to identify and prioritise issues and management responses at the catchment-scale, while co-ordinated and combined applications to funding bodies can also be made to support implementation. Adopting a whole-of-estuary approach allows priority actions to be implemented that will have the best overall outcome for the estuary.

1.5 What Area Does the Plan Cover?

This Plan covers the entire Georges River Estuary waterway, located in the southwest of Sydney (Figure 1-1). The upstream limit of the Georges River Estuary is at Liverpool Weir, a distance of 46km from the mouth at Botany Bay. This Plan extends downstream and into Botany Bay as far as Towra Point. The Plan also covers the south and western foreshore of Botany Bay between Towra Point and the Cooks River entrance (predominantly covering Lady Robinsons Beach) and all associated tidal waterways that drain into the study area (including Scarborough Ponds).

The estuary is divided into two regions: Upper Reaches, between Liverpool Weir and Salt Pan Creek; and Lower Reaches, from Salt Pan Creek to Botany Bay. Major tidal tributaries to the estuary include Cabramatta Creek, Prospect Creek, Salt Pan Creek, and Woronora River. As activities beyond the banks of the estuary can have a significant impact on its health, the entire catchment of the Georges River has therefore also been *considered* as part of the Plan, insofar as it impacts on the condition of the estuary. The Georges River Estuary catchment area covers a significant portion of the Greater Sydney Metropolitan Region, with a population of more than a million people. The land surrounding the estuary is highly urbanised and supports many land uses including: residential, Army firing range, market gardens, agriculture, mining, industrial manufacturing, landfills and nuclear research facilities.

The lower reach of the Georges River Estuary has been heavily modified and residential development extends to the foreshore in most locations. The estuary is also a popular recreational area for many people in the surrounding communities for fishing, waterskiing, swimming and watersports.



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Study Area

GRCCC
Georges River Combined Councils' Committee

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1.6 NSW Estuary Management Process

For the past 20 years, the Estuary Management Process in NSW has been guided by the Estuary Management Policy (1992) and Estuary Management Manual (1992). Recently, the NSW Government released new *Guidelines for Preparing Coastal Zone Management Plans* (the CZMP Guidelines), which replace the Estuary Management Manual and combines the former coastal and estuary management processes. Under the new CZMP Guidelines, estuary management is required to focus on addressing risks to the health of estuaries through practical management actions. Focus is guided towards estuary health, because this aspect is not explicitly investigated or managed through any other council or state planning process.

Fundamentally, the steps required to prepare a Coastal Zone Management Plan, in accordance with the CZMP guidelines, are:

1. Identify and discuss the planning framework relevant to management of the estuary;
2. Prioritise management objectives based on a combination of issues that need attention, and conservation of natural and social values;
3. Assess and select potential management options to achieve the objectives;
4. Detail a schedule of activities for the implementation of the best management options; and
5. Indicate responsibilities and sources of funding for implementing the best options.

The development of the Plan has been co-ordinated by the GRCCC, and overseen by the Georges River Estuary Management Committee, which has representatives from all relevant Councils as well as key state agencies and other stakeholders.

Once the Plan has been endorsed by the community, GRCCC, member councils and partner agencies, the recommended management options can start to be implemented, in accordance with the framework presented in the Plan.

A key platform of the new CZMP Guidelines is the adoption of a risk-based approach to the management of estuary health. Risk-based management of estuaries has several key advantages, including:

- all risks are assessed and compared equally, ensuring that management efforts are directed towards those areas or issues that post the greatest risk to estuary health and sustainability;
- better streamlining of the Plan with existing Council's operational plans, as the risk approach inherently requires that existing management efforts are included in the assessment of risk, rather than a duplication of actions;
- the risk approach identifies the highest priority risks, which are not currently being managed (sufficiently) through any other process, targeting management resources towards the highest priority issues;
- management options can be designed to reduce the likelihood of the risk (e.g. planning setbacks) and the consequence of the risk (e.g. emergency management works); and
- where there is a high level of community concern regarding an issue that presents a low risk, monitoring and trigger levels can be set without absorbing funding resources unnecessarily.

Under Section 733 of the *Local Government Act 1993*, councils are taken to have acted in 'good faith' and receive an exemption from liability where their actions were done substantially in accordance with the "coastal management principles" given in the CZMP Guidelines (DECCW, 2010b). Further, intended changes to Section 117 of the *Environmental Planning and Assessment Act 1979* will require the CZMP Guidelines be taken into consideration when councils prepare their local environment plans (LEPs).

The "coastal management principles" (DECCW, 2010b) and how these principles have been addressed or achieved within this Georges River Estuary Management Study and Plan are given in Table 1-1.

Table 1-1 Coastal Management Principles (DECCW, 2010b) addressed by the Georges River Estuary Plan

	Coastal Management Principles	Addressed by Georges River Estuary Management Study and Plan	Report Section
Principle 1	Consider the objectives of the Coastal Protection Act 1979 and the goals, objectives and principles of the NSW Coastal Policy 1997 and the NSW Sea Level Rise Policy Statement (2009)	The Georges River Estuary management objectives are aligned with the NSW Coastal Policy and NSW Sea Level Rise Policy Statement 2009.	1.6
Principle 2	Optimise links between plans relating to the management of the coastal zone	Relevant existing plans and initiatives being adopted by state agencies and the various Councils have been identified through the consultation workshops and have been integrated into the implementation of Best Management Options	3, 6
Principle 3	Involve the community in decision-making and make coastal information publicly available	Comprehensive consultation with community and targeted stakeholders has been undertaken in developing this plan, including workshops, on-line surveys, and interviews with stakeholders and community members	3
Principle 4	Base decisions on the best available information and reasonable practise; acknowledge the interrelationship between catchment, estuarine and coastal processes; adopt a continuous improvement management approach	This Plan has been preceded by an exhaustive assessment of Estuary Processes (SMEC, 2010). Management options have recognised the complex interactions between catchment and estuarine environments. The on-going monitoring and evaluation requirements will ensure that management of the estuary will be adaptive, cognisant of existing and emerging issues and treatment options.	2.2, 8
Principle 5	The priority for public expenditure is public benefit; public expenditure should cost effectively achieve the best practical long-term outcomes	Assessment of potential management options has recognised the public benefit as priority	Appendix D

	Coastal Management Principles	Addressed by Georges River Estuary Management Study and Plan	Report Section
Principle 6	Adopt a risk management approach to managing risks to public safety and assets; adopt a risk management hierarchy involving avoiding risk where feasible and mitigation where risks cannot be reasonably avoided; adopt interim actions to manage high risks while long-term options are implemented	This plan has been prepared giving consideration to ISO 31000:2009 International Standard Risk Management Principles and Guidelines. Risks associated with 'not achieving Management Aims' have been assessed, while assessment of options have considered the potential for reducing risks.	1.6, 5, Appendix D
Principle 7	Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty in risk predictions	The adaptability of management options to future circumstances was a consideration in selection of preferred options.	5, Appendix D
Principle 8	Maintain the condition of high value coastal ecosystems; rehabilitate priority degraded coastal ecosystems	Specific objectives and options for prioritising rehabilitation for at risk coastal and estuarine ecosystems have been developed.	4.2.2, 5
Principle 9	Maintain and improve safe public access to beaches and headlands consistent with the goals of the NSW Coastal Policy	Appropriate public access to estuary foreshores has been considered in developing objectives and options for this Plan.	4.2.3, 4.2.5, 5
Principle 10	Support recreational activities consistent with the goals of the NSW Coastal Policy	This plan supports the on-going use of the Georges River Estuary waterway and public foreshore areas for recreational pursuits, which is reflected in its objectives and management options	4.2.3, 5

1.7 Key Legislation and other Instruments Guiding Estuary Management

The Georges River Estuary and its catchment are subject to a myriad of environmental planning and management instruments and legislation, spanning some seven LGAs (each with its own planning framework, policies and plans). In addition to these instruments and statutory documents, there is also a vast array of management plans and strategies that are relevant to the Georges River, ranging from overarching Commonwealth initiatives down to site specific Plans of Management. Strategies and plans that relate just to natural resource management (NRM) within the Georges River catchment were identified previously by Evans and Peck (2008), and are summarised in Figure 1-2.

In addition to legislated Acts of Parliament, there are two main types of statutory environment planning instruments (EPIs): Local Environmental Plans (LEPs) and State Environmental Planning Policies (SEPPs). There are also other instruments that guide management of natural resources, including the Georges River.

The existing environmental planning and strategic management frameworks relevant to the Georges River are summarised below, with further information provided in Appendix A.

1.7.1 State Environmental Planning Policies

There are a number of State Environmental Planning Policies (SEPPs) that may be relevant to the Georges River Estuary. These include:

- Greater Metropolitan Regional Environmental Plan No 2—Georges River Catchment (this is now regarded as a SEPP);
- SEPP 19 – Bushland in Urban Areas
- SEPP 44 – Koala Habitat Protection
- SEPP 50 – Canal Estate Development
- SEPP 62 – Sustainable aquaculture
- SEPP 71 – Coastal Protection
- SEPP (Major Development) 2005
- SEPP (Infrastructure) 2007
- SEPP (Mining, petroleum production and extractive industries) 2007
- SEPP (Western Sydney parklands) 2009

Of particular note, Division 25 of SEPP (Infrastructure) 2007 refers to waterway and foreshore environmental management activities, including riparian corridor management, bank stabilisation, weed management, revegetation activities, and the creation of foreshore accessways. In this regard, the relevant local Council is deemed to be the public authority, and as such, does not require development consent to undertake waterway and foreshore environmental management activities.

Additionally, Greater Metropolitan Regional Environmental Plan (REP) No. 2 (Georges River Catchment) is also deemed a SEPP (as REPs are phased out of the planning hierarchy). The Georges River Catchment REP aims to protect the water quality of the Georges River and its tributaries as well as the environmental quality of the whole catchment. The REP establishes the framework within which local, State and Federal agencies will consult so that there is a consistent approach to planning and development within the Georges River catchment.

Key SEPPs relevant to the Georges River Estuary are discussed further in Appendix A.

1.7.2 Local Environmental Plans and Development Control Plans

Local Environmental Plans (LEPs) are planning instruments produced by local councils to direct the type of development in local government areas. LEPs aim to conserve the natural environment, whilst creating attractive living areas and ensuring development complies with ecologically sustainable principles. Through planning and development controls, they allow councils to regulate the ways in which land is used by defining permissibility for different types of development across an entire LGA, as a requirement of the Environmental Planning and Assessment Act 1979. LEPs are statutory documents, meaning it is illegal to develop land contrary to that permitted by the LEP.

Development Control Plans (DCPs) are non-statutory instruments that support the LEPs, by providing specific, more comprehensive guidelines for types of development, or specific areas within a local government area. DCPs contain a specific range of conditions (including visual amenity, drainage,

access, pollution control, vegetation etc.) aimed at optimising land use in an environmentally sustainable manner.

On 31 March 2006, the Standard Instrument (LEPs) Order 2006 was gazetted. Its purpose is to reduce the number of planning documents and improve the consistency in documents across local councils by introducing a standard template LEP. The Standard Instrument provides for 34 standard zones for LEPs, for use by Councils when preparing their new LEPs according to the Standard Instrument. Councils are required to update existing LEPs to accord with the Standard Instrument Order by 2011. Within the Georges River Estuary catchment, only Liverpool has a gazetted LEP that complies with the Standard Instrument, while all other Councils have draft LEPs in preparation. A list of the LEPs and DCPs relevant to the Georges River Estuary are presented in Table 1-2.

Table 1-2 Local Government Planning Instruments

Local Environmental Plan	Development Control Plan
Sutherland Shire LEP 2006	Sutherland Shire DCP 2006
Kogarah LEP 1998	Various DCPs (to be consolidated)
Hurstville LEP 1994 (and draft 2011)	Hurstville DCP1 / DCP2
Rockdale LEP 2011	Rockdale DCP 2011
Bankstown LEP 2001	Bankstown DCP 2005
Fairfield LEP 1994 (and draft 2010)	Fairfield DCP 2006
Liverpool LEP 2008	Liverpool DCP 2008

1.7.3 State and Commonwealth Legislation and Policies

There are a number of NSW and Commonwealth Parliamentary Acts that are relevant to the management of the Georges River Estuary and catchment. Key Acts and policies are listed below, while further details are given in Appendix A:

- *Environmental Planning and Assessment Act 1979;*
- *Coastal Protection Act 1979;*
- *Local Government Act, 1993;*
- *Crown Lands Act 1989;*
- *National Parks and Wildlife Act, 1974;*
- *Fisheries Management Act, 1994;*
- *Threatened Species Conservation Act, 1995;*
- *Heritage Act 1977;*
- *Protection of the Environment Operations Act, 1997;*

- *Noxious Weeds Act 1993;*
- *Water Management Act 2000;*
- *Native Title Act 1977;*
- NSW Coastal Policy 1997;
- NSW Sea Level Rise Policy Statement 2010;
- Planning for Bushfire Protection 2006;
- NSW State Plan; and
- *Commonwealth Environmental Protection and Biodiversity Conservation Act 1999.*

1.7.4 Sydney Metropolitan Catchment Action Plan 2009

The Sydney Metropolitan Catchment Action Plan (CAP) 2009 has been prepared by the Sydney Metropolitan Catchment Management Authority (SMCMA). The aim of the CAP is to set out a 10 year strategic framework for balanced natural resource management across the rural, coastal and urban catchments of the CMA area. The CAP defines targets and direct investment of public and private resources to achieve sustainable natural resource management in line with community expectations. While the CAP is not a regulatory plan, it serves to complement other natural resource management plans, including the Georges River Estuary Coastal Zone Management Plan. The SMCMA is in the process of reviewing/updating the CAP, and it will be important that the new CAP supports the aims and objectives of this CZMP.

The CAP has a key role in addressing the priorities of the NSW State Plan. The NSW State Plan Priority E4 identifies targets which will guide the implementation of the CAP to ensure better outcomes for native vegetation, biodiversity, land, rivers and coastal waterways, such as the Georges River Estuary.

Within the CAP, Catchment Target CTECM1 states that “By 2016, there is an improvement in the condition of estuaries and coastal lakes”. This catchment target relates directly to the aims and objectives of this Georges River Estuary Coastal Zone Management Plan, while the CZMP would also contribute to Catchment Target CTW1 “By 2016 there is a net improvement in the health of modified waterways and riparian corridors and conservation of natural waterways”. The CAP identifies a number of Management Targets that will contribute to improvements in the condition of estuaries (refer Table 1-3). The key Management Target is MTECM1.5. The preparation of Estuary Management Plans (or Coastal Zone Management Plans) for the major estuarine waterways and integration of these to identify regional scale management priorities will provide the framework for a coordinated and strategic approach to dealing with marine pests, in-stream and foreshore structures and vegetation rehabilitation. The CAP states that the most important benefit of a coordinated approach to estuary management is the rationalisation of conflicting policy and operational objectives across State and Local Government institutions, so that clear and consistent objectives and valuing of estuary health emerge. This is particularly pertinent for the Georges River Estuary Coastal Zone Management Plan, which transects seven different Local Government Areas. The CAP also highlights potential benefits in reducing the potential for duplication of effort or contradictory effort.

The preparation and implementation of this Georges River Estuary Coastal Zone Management Plan is evidently a critical step towards achieving the desired outcomes of the CAP. Indeed, the Coastal Zone Management Plan will help to achieve Catchment and Management Targets across the entire spectrum of Biodiversity, Water, Land and Community issues that are central to the CAP.

Table 1-3 Key CAP Management Targets relevant to Estuary Management

	Management Target
MTECM1.1	By 2016 the threats posed by marine pests have been reduced
MTECM1.4	By 2016, new in-stream and foreshore structures are designed and constructed in an ecologically sensitive manner
MTECM1.5	By 2016 the condition of estuaries and coastal lake systems will be maintained or improved through development and implementation of natural resource management plans (including estuary management plans).
MTECM1.10	By 2016, the extent, condition and connectivity of estuarine vegetation is maintained and/or improved by facilitating the protection and rehabilitation of estuarine vegetation at high priority sites.
MTW5.2	By 2012 local councils have incorporated and implemented provisions in the revised LEPs, DCPs and related codes and policies that promote WSUD and other practices that reduce the impact of stormwater on the environmental values of waterways
MTECM2.3	By 2016 active management will protect or improve key estuarine and marine habitat areas in partnership with relevant authorities and user groups
MTW1.1	By 2016 selected high priority reaches of waterways and riparian corridors are protected and rehabilitated.
MTW3.1	By 2010 a Water Quality Implementation Plan for Botany Bay and its catchment has been developed and commenced.

1.7.5 Other Natural Resource Management Initiatives

In addition to the CAP, there are a large number of other natural resource management initiatives that are applicable to the Georges River Estuary, ranging from peak Commonwealth strategies, down to place-based Plans of Management. An overview of existing natural resource management strategies is provided in Figure 1-2, as derived from Evans and Peck (2008).

In developing the Georges River Estuary Coastal Zone Management Plan, due consideration has been given to these existing strategies, and their potential for implementation across the LGAs relevant to the Plan.

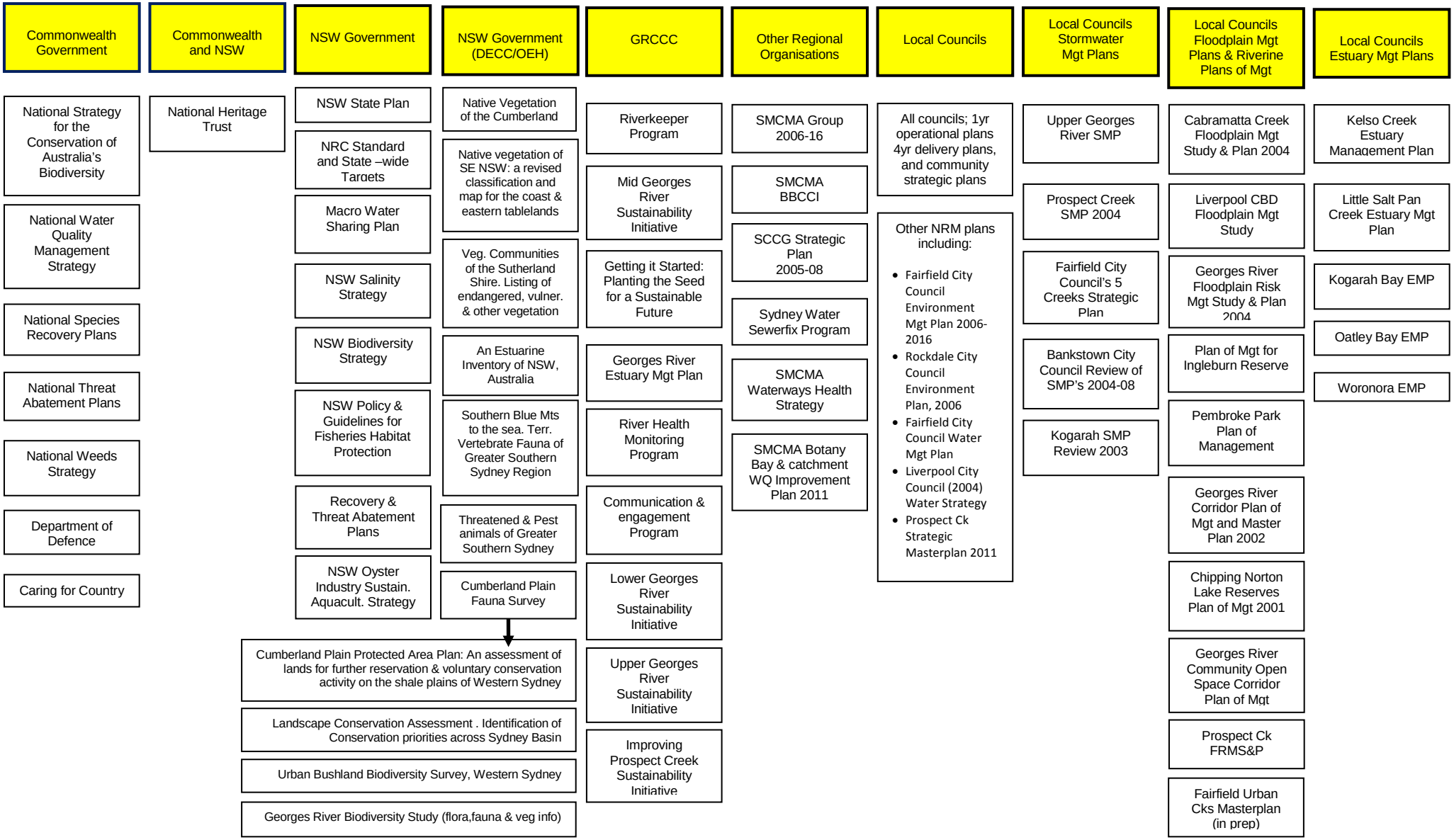


Figure 1-2 Georges River NRM Strategies (adapted from Evans & Peck, 2008)

2 PROCESSES, VALUES AND ISSUES OF THE GEORGES RIVER

2.1 Preamble

Liverpool Weir (photo: OEH)

The Georges River Estuary has experienced significant change over the past 200 years. The upstream limit of the estuary, Liverpool Weir, was constructed by convict labour 175 years ago to supply water to the growing township of Liverpool. As a result, the estuary now has a clearly delimited upstream end, and the weir is listed with the National Trust.

During the early years of settlement in the district, the estuary would have received a significant supply of sediment as the catchment was progressively cleared and then farmed. The more contemporary transition from rural to urban landuse throughout the 20th Century would have also placed additional stress on the estuary through high sediment loading, contaminated leachate (including sewage) and general urban pollutant runoff. Intensification of the catchment landuse continues today, and would still be potentially increasing pollutant loads to the estuary.

Uncontrolled sand extraction throughout the mid 20th century in the upper reaches of the estuary has dramatically changed the river morphology. Implications of this have been dire for the estuary, with reduced tidal flushing, accelerated bank erosion, and water pollution. Water quality within the Georges River Estuary was also significantly compromised by direct discharges from the Glenfield Sewage Treatment Plant, which continued up until 1986. Meanwhile, sediments in the estuary remain affected from a long history of commercial activities and on-going urban runoff.

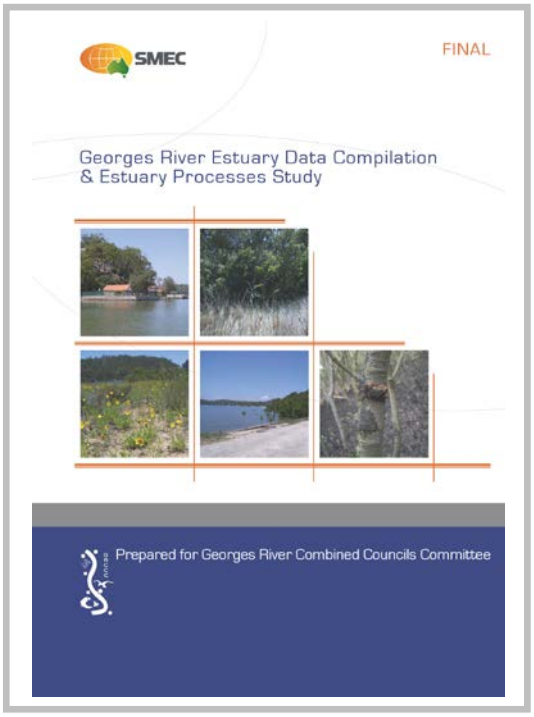
Despite these notable historical impacts and stressors, the Georges River Estuary has managed to maintain significant environmental value. Large sections of the catchment to the south remain forested, while a diversity of habitats and species can still be found across the estuary, including many Endangered Ecological Communities (EECs). In many respects, the Georges River has become typical of most urban estuaries, wherein environmental values need to find be balanced against the demands from a community that resides and recreates within and around the waterway. Indeed, as the urban pressures increase, the value of any residual natural environment also increases. Highlighting this point, Towra Point, at the entrance to the Georges River in Botany Bay, is the only notable area of saltmarsh left in Sydney, contains some 50% of all of Sydney's mangroves, and is an internationally recognised and significant Ramsar site (DECCW, 2010c). Towra Point also contains an Aquatic Reserve and a Nature Reserve.

The community values the Georges River estuary primarily for its environmental services, and also its recreational potential. Primary contact activities are desirable across the estuary, while the community considers that ecological conditions should be maintained at a high conservation level (but recognising that some areas are also moderately to highly disturbed) (SMCMA, 2011).

Councils and other landuse managers are taking steps towards controlling runoff and improving the overall environmental health of the estuary. There are some 30 bushcare groups within the

catchment, while major investment has been made to try and rehabilitate degraded foreshores and estuarine areas (including clean-up of previous oyster farms). Also, the Sydney Metro CMA's recent Botany Bay Catchment Water Quality Improvement Plan [BBWQIP] (2011) aims to reduce pollutant loads through catchment-based measures. This Coastal Zone Management Plan should complement these existing initiatives by recommending a range of measures that focus on a holistic perspective for environmental sustainability of the estuary.

2.2 Estuary Processes (SMEC, 2010)



A comprehensive Estuary Data Compilation and Processes Study for the Georges River was carried out by SMEC (2010), and forms the necessary prerequisite stage to this Coastal Zone Management Plan. It documents the key physical, chemical and biological processes occurring within the Georges River Estuary (and catchment) that have an impact on the existing condition of the waterway and its future management needs and limitations.

Presented below is a summary of this Data Compilation and Processes Study.

2.2.1 Geology and Estuary Type

The Georges River Estuary is classified as a drowned river valley. The estuary is characterised by a deep channel and steep rocky foreshores along the lower reaches, which opens up into extensive alluvial floodplains towards the upper end of the estuary. The lower reaches have been carved into Hawkesbury sandstone (shown in yellow in Figure 2-1), while the upper reaches more reflect Wianamatta shale geology of gentle undulating slopes draining to a low alluvial plains (shown in Red in Figure 2-1).

The Georges River flows into Botany Bay, which is roughly circular (8km in diameter) and has a typical depth of 4.5m. The entrance channel to Botany Bay has been dredged to a depth of 21m to accommodate vessel movements into and out of Port Botany.

The Georges River was first surveyed by Cook in 1770, although since then there have been major morphological changes, notably in the upper reaches of the estuary where extensive dredging and reclamation has occurred over the past 60-70 years. Typical depths along the Georges River estuary are about 4 m.

The total length of the Georges River (extending up to Appin, at an elevation of some 350m above sea level) is around 100km, although the estuarine component is limited by Liverpool Weir, located approximately 46km from the river mouth. Geological surveys of paleo river channels indicate that during previous glacial periods (when sea level was 100m+ lower than at present), the Georges River (as well as the Cooks River) flowed through the existing Kurnell sand dunes and across Bate Bay towards the edge of the continental shelf (Albani and Rickwood, 2010) (refer Figure 2-2).

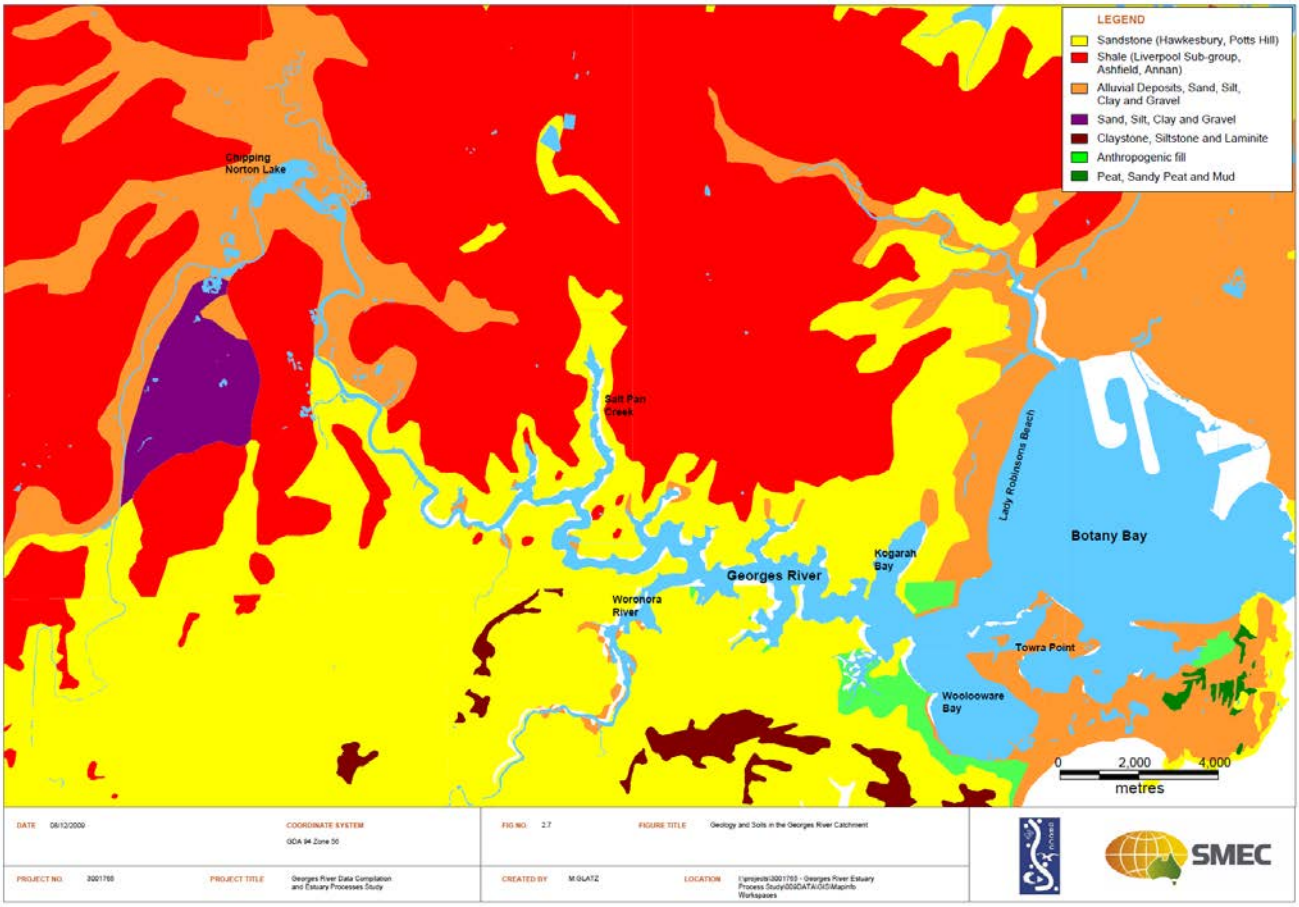


Figure 2-1 Underlying geology surrounding the Georges River Estuary (Source: SMEC, 2010)

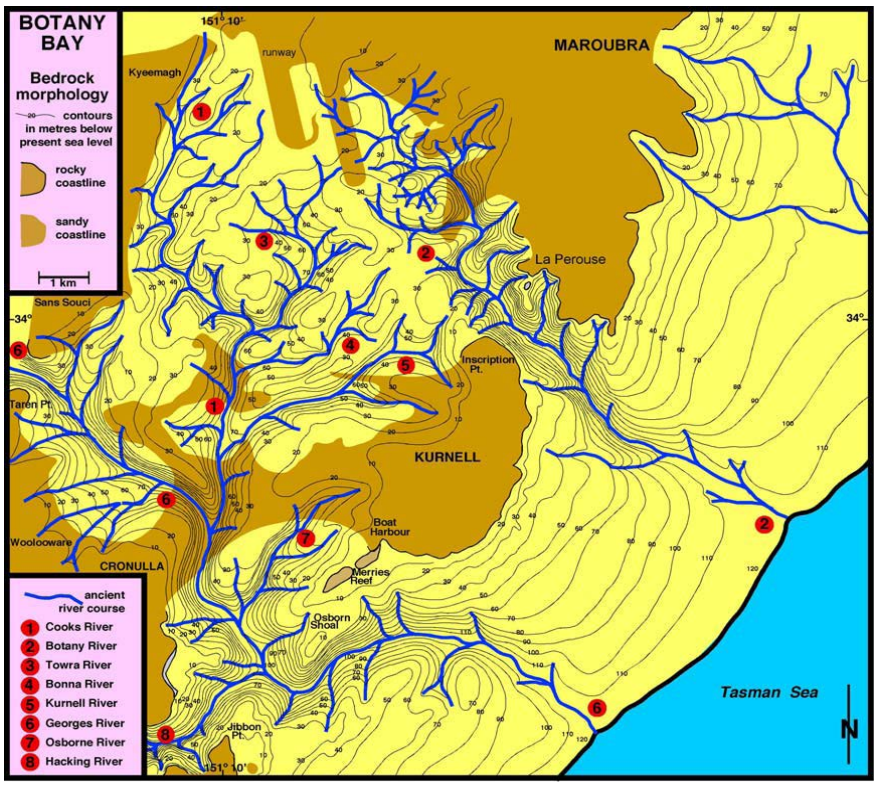


Figure 2-2 Paleo river channels based on bedrock profile (Source: Albani & Rickwood, 2010) (Note, land area shown in brown, seabed shown in yellow)

2.2.2 Sediment Processes

2.2.2.1 Catchment Soils

The soils across the northern portion of the study area, which are derived from the underlying Wianamatta Shale geology (refer Figure 2-1), have a high potential for erosion. The fine-grained and highly dispersive nature of these soils also has a tendency to make receiving waters turbid, especially after rainfall. Compounding this issue is the fact that the northern half of the study area has been extensively developed, thus providing ample opportunity over the past 200 years to liberate sediment from the catchment, which would then have been deposited within the estuary, or advected into Botany Bay and onto the continental shelf during times of flood.

The soils overlying the sandstone regions of the catchment (refer Figure 2-1) tend to be more porous and less dispersive, although they would still be subject to water and wind erosion, especially when overlying vegetation has been disturbed.

2.2.2.2 Sedimentation

The Georges River Estuary (excluding Botany Bay) can be split into three broad regions of bed sediments. These are:

- the main channel reach above Como Bridge which is mainly sandy;
- the main channel reach below Como Bridge which is predominantly composed of clay and silt; and
- the large off-channel bay areas in the lower estuary where the major sediments are flocculent silts and clays.

Overall longitudinal downstream fining of sand bed sediments (i.e. the sediments become finer with distance downstream) illustrates a fluvial dominance in the estuary, especially along the upper reaches. The sediments of the estuary roughly accord to the estuarine zonation developed by Roy *et al.* (2001), with the lower reaches below Como Bridge and the large off-channel bays forming a central mud basin, transitioning to an alluvial delta upstream of Como Bridge, and then a riverine channel from about Picnic Point upstream (refer Figure 2-3). The marine flood tide delta is essentially limited to Botany Bay and areas around Towra Point, although flood tide processes have clearly changed in geological times as the previous link to the ocean became occluded through dune transgression across the Kurnell peninsula, leading to the present day connection through the mouth of Botany Bay.

The rate and location of sedimentation within the Georges River is expected to have been modified due to anthropogenic factors. Development of the catchment would have increased the amount of sediment delivered to the estuary, thus accelerating sedimentation rates. This is typical of most estuaries that have experienced catchment development. Once the development stabilises, runoff rates and hence sedimentation rates, tend to subside. Of specific relevance to the Georges River is the significant amount of dredging that has occurred throughout the upper reaches as part of historical sand extraction enterprises. The uncontrolled extraction has created several very large basins within the river and floodplain morphology, which would act as sediment basins, attracting accelerated rates of fine sedimentation. Similarly, but at a smaller scale, the construction of Liverpool Weir would also have promoted localised sedimentation in the upstream weir pool.

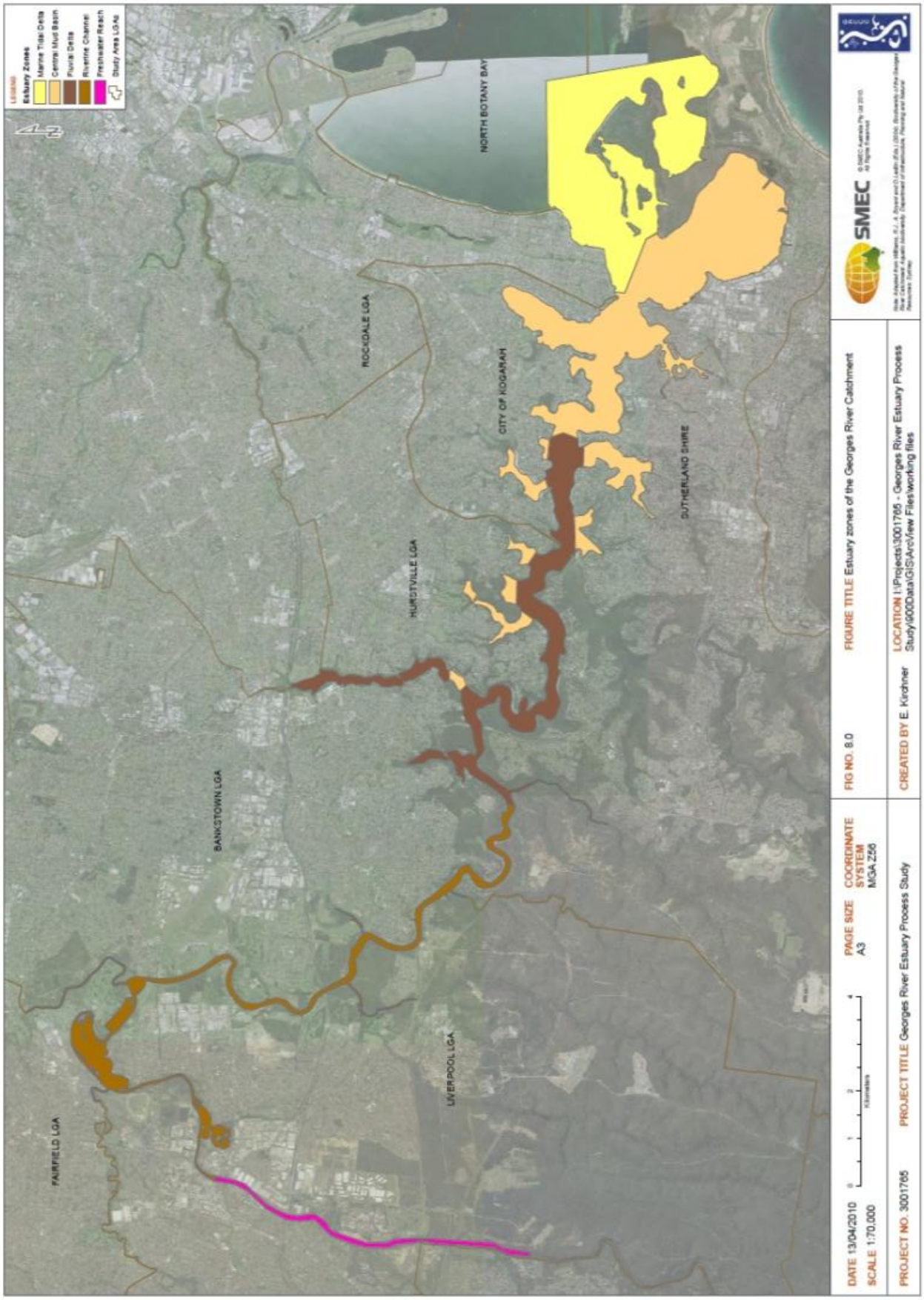


Figure 2-3 Zonation of the Georges River based on sedimentary processes (Source: SMEC, 2010) (refer to SMEC, 2010 for original high resolution mapping)

Associated with the historical deep dredging in the upper reaches, some riverbanks have collapsed and retreated due to over-steep subsurface slopes. The continuing erosion and bank retreat would be contributing to sedimentation throughout the estuary.

In Botany Bay, ocean swell waves have an influence on the longshore sediment transport processes occurring along the shoreline, and in particular, Lady Robinsons Beach. Net southerly transport of sand along the southern half of Lady Robinsons Beach has led to accretion at Dolls Point, while there is a net northerly sediment transport along the northern half of the beach. There is also strong westward sediment transport along Towra Point, which is driven by the obliquity of this shoreline to the incoming swell waves.

2.2.2.3 Sediment Quality

The Georges River Estuary received runoff from an intensively urbanised and industrialised catchment. The estuary has also been used for a range of boating and maritime activities, and as such has been a major repository for urban and industrial waste, including metalliferous loadings (e.g. copper, zinc, nickel, lead). Waste dumps and sewerage overflows have also contributed to high pollutant loading into the estuary. Many pollutants, including metals, attach to sediments, which can accumulate within poorly flushed sedimentation zones across the estuary, including the upstream ends of bays and within deeper dredge holes.

Birch *et al.* (1996) report that the majority of estuarine areas in the Georges River have pollutant concentrations (heavy metal, PAH) in the sediments in excess of background levels, although it is considered that this work may have been influenced by localised external factors. Albani and Rickwood (2010) have thus further explored geochemistry of the Georges River Estuary noting the particular shortcomings of previous analytical approaches. Albani and Rickwood (2010) conclude that “the bottom sediments in Georges River are remarkably free of elevated concentrations of most elemental contaminants, but some of the bays and tributaries have sediment that should be considered to be mildly contaminated. For example, Prospect Creek and Salt Pan Creek samples had Zn at an elevated level that should be monitored”.

2.2.2.4 Dredging

Dredging has occurred in Botany Bay and along the Georges River since 1948 (SPCC, 1979). The major dredging occurring in the Georges River Catchment was at Moorebank and Chipping Norton Lakes. Chipping Norton Lakes were originally the result of illegal dredging and unregulated extraction activities between the 1950s and 1977. The average removal depth was 9.5m and 7.5m for the north and south ponds, respectively. Construction sand was also dredged around Riverland Golf Course upstream of Salt Pan Creek prior to the 1980s.

Dredging within Botany Bay has had an impact on the foreshore of the study area, more particularly along Towra Point and Lady Robinsons Beach. Dredging in Botany Bay was carried out to provide deepwater navigation to Port Botany, the Australian Oil Refinery jetty and offshore of Kyeemagh. These changes in bed depth changed the wave refraction processes within the bay, increasing wave energy along the more southern shoreline (e.g. Towra Point, Lady Robinson Beach) (SPCC, 1978).

Major dredging campaigns have also been carried out in Botany Bay to provide fill material for large foreshore reclamation projects, including the Sydney Airport, and Port Botany developments.

2.2.2.5 Bank erosion

The lower reaches of the Georges River are incised within a deep sandstone gorge (ie drowned river valley), and thus are not susceptible to significant bank erosion. The upper reaches on the other hand have developed across alluvial plains of friable and erodible sediment. Changes to the hydrologic flow regime of the estuary (through increased runoff due to urbanisation of the catchment) are likely to have led to a morphological response by the river channel. Indeed, as the process of channel change is slow, it is possible that the upper reaches of the Georges River will continue to adjust for many decades (or even centuries) to come. A general channel widening has been observed between Liverpool Weir and East Hills, with some areas in the upper reaches of the river, already experiencing an increase in cross-sectional area by up to 60%.

Georges River bank erosion (photo: OEH)

Compounding the morphological change in the upper reaches is the broadscale dredging that has occurred, which fundamentally changes the hydrodynamic processes that are responsible for channel adjustment. Furthermore, dredging too close to the sides of the river have led to over-steep subsurface slopes, causing mass failure of riverbanks and accelerated bank recession.

Other factors that are likely to have increased bank erosion along the Georges River include:

- Major floods, which scour the outside of bends – made worse if these banks are eroding due to other processes as well;
- Boat wash and wind waves (compounded if fetch lengths have been increased, e.g. across Chipping Norton Lakes);
- An increase in tidal prism within the upper reaches (i.e. creation of Chipping Norton Lakes), thus increasing tidal velocities along downstream sections; and
- Uncontrolled foreshore access and disturbance of riparian vegetation.

Informal bank protection measures have been employed at various locations along the estuary in an effort to halt bank recession. Dumped concrete blocks, bricks and other building refuse has been used in some locations, which significantly compromises the visual and environmental values of the foreshore, and may not necessarily even reduce erosion (in fact, poorly constructed walls can exacerbate erosion, especially at the edges of the structure). Recent surveys of the entire Georges River foreshores are detailed in the Estuary Processes Study report (SMEC, 2010), and indicate that Chipping Norton Lakes and Floyd Bay have mostly been stabilised through

Seawall at Howard Park (photo: SMEC, 2010)

seawall construction, as well as many foreshores around the lower estuary reaches, while the river channel upstream of Chipping Norton continues to erode significantly. High priority erosion areas have been identified for each LGA along the Georges River, and are detailed in SMEC (2010).

2.2.3 Hydrodynamic Processes

2.2.3.1 Tides

The tides in the Georges River area are typical of the NSW east coast, being semidiurnal with a diurnal inequality. Tidal range (vertical difference between high and low tide) is essentially constant along the River with differences in levels of less than 0.1m between the Liverpool Weir (mean spring tide[2] range of 1.31m) and Botany Bay (mean spring tide range of 1.25m). The tidal lag from Botany Bay up to Liverpool Weir is about 2.5 hours (SPCC, 1978).

The tidal prism is the volume of water held between high tide and low tide. It represents the volume of water exchanged with the estuary each time. Between 1960 and 1980, the tidal prism of the Georges River upstream of Milperra increased from 700,000 m^3 to 1.6 million m^3 due to the construction of Chipping Norton Lakes.

With a large tidal prism, the most downstream sections of the estuary are relatively well flushed. The peak tidal flow rate into the estuary is approximately 4,000 m^3/s. In comparison, the dry weather freshwater inflows to the estuary are about 5 m^3/s, while the peak 1 in 10yr flood flows are about 850 m^3/s. Despite the strong tidal dominance, there are still some 'dead water areas' at the heads of most side embayments.

Tidal currents in both Botany Bay and Georges River are generally less than 1m/s. Dredging in Botany Bay and in the upper reaches of the Georges River have reduced these currents locally, and would likely promote sedimentation, as discussed previously.

2.2.3.2 Waves

Wind waves are generated where winds blow over long stretches (called fetches) of water. Larger wind waves are expected within the Chipping Norton lakes as well as Botany Bay. These waves have a characteristic period ranging from 1 to 5 seconds and contain relatively little energy, although it is directed principally over a narrow portion of the bank profile at the waters edge.

Wake generated by boats has similar wave characteristics to minor wind waves. On larger bodies of water, the boat wake energy is mostly dissipated before reaching shore, however, on narrower waterways, and in locations where boats are closer to the banks (e.g. around boat ramps), wake-induced erosion can be problematic.

Ocean swell waves penetrate the entrance of Botany Bay and are refracted by the bay bathymetry (which has been modified through dredging and reclamation) onto surrounding foreshores. The usual wave period for ocean swell waves is between 8 and 15 seconds, meaning it contains much higher

[2] Spring tides are the larger tides that occur during the course of a month corresponding with full moon and new moon, when the gravitational pull of the moon is greater. The lesser tides, between the spring tides, are called 'neap' tides.

energy than wind or boat waves. Wave heights within Botany Bay are generally less than 0.5m with only 10% of the waves exceeding 1m, and rare occurrences of up to 2m in some locations.

Swell-wave induced longshore sediment transport around the foreshores of Botany Bay has been managed through the construction of shore-normal groynes. Historical changes to the bathymetry of Botany Bay have changed the internal refraction pattern, and thus the longshore processes. Some shorelines have attempted to respond to this by natural realignment (e.g. at Towra Beach).

2.2.3.3 Flooding

The major floodplain areas of the Georges River Estuary are located between Liverpool and East Hills, along Cabramatta Creek and along Prospect Creek. These areas are subject to the most significant flood risk as they are urbanised and located in low-elevated landscapes. The Cabramatta and Prospect Creeks floodplains are of particular concern because they are fully urbanised, with flood flows approximately 190% and 60% higher than natural conditions for these creeks, respectively. The times to reach peak flow conditions would also have reduced significantly as a consequence of urbanisation within the catchments, thus reducing flood response times and increasing risks to the community. Around 30% of the flood prone area contains residential and industrial/commercial developments, while the remaining 70% are mostly open spaces.

1986 flood in Georges River (photo: GRCCC)

Two significant flood events have occurred within the past 30 years - 1986 and 1988. These events have been determined to be about a 1 in 20 year Annual Recurrence Interval (ARI) flood (SMEC, 2010). More than 1000 residential properties along the Georges River, Cabramatta Creek and Prospect Creek were flooded by these events.

The 1956 flood was larger than the 1986 and 1988 events, but was still relatively small compared to the flood of record, in 1873, which attained peak water levels at Liverpool Weir of 10.5m AHD, which is some 3m higher than the 86/88 levels, and 1m higher than the estimated 1 in 100yr ARI flood. In total, there are approximately 8,500 properties potentially affected by flooding up to the Probable Maximum Flood (PMF) along the Georges River Estuary, with over 2,600 of these considered at high risk.

Development over the past 20 years or so (particularly in the Prospect and Cabramatta Creek catchments) is expected to have potentially modified flood risks along the Georges River. Development within the floodplain has intensified, involving the filling of large tracts of flood-prone land, and has increased exposure to risks. Meanwhile, the construction of Chipping Norton Lakes, sand extraction at Moorebank and the selective removal of homes from floodways (notably in the Milperra – Moorebank and Prospect Creek floodplain areas) are expected to have reduced overall flood risk.

Floodplain management options that have been considered and implemented to some degree within the Georges River Estuary include:

- Voluntary purchase of affected homes;
- Voluntary house raising;
- Flood protection works, such as levees;
- Basins, such as detention basins; and
- Flood warning systems.

2.2.4 Water Quality

2.2.4.1 Flushing and Mixing Characteristics

The Georges River and its tributaries are generally considered to be vertically well-mixed, with relatively small differences in water quality between the surface and bottom of the water column profile. The typical salinity gradient along the estuary is shown in Figure 2-4, highlighting near-marine conditions (i.e. 35ppt) up to Como Bridge, and then a steady decline resulting in more brackish conditions at Liverpool Weir, which has typical salinities of about 5 – 10ppt.

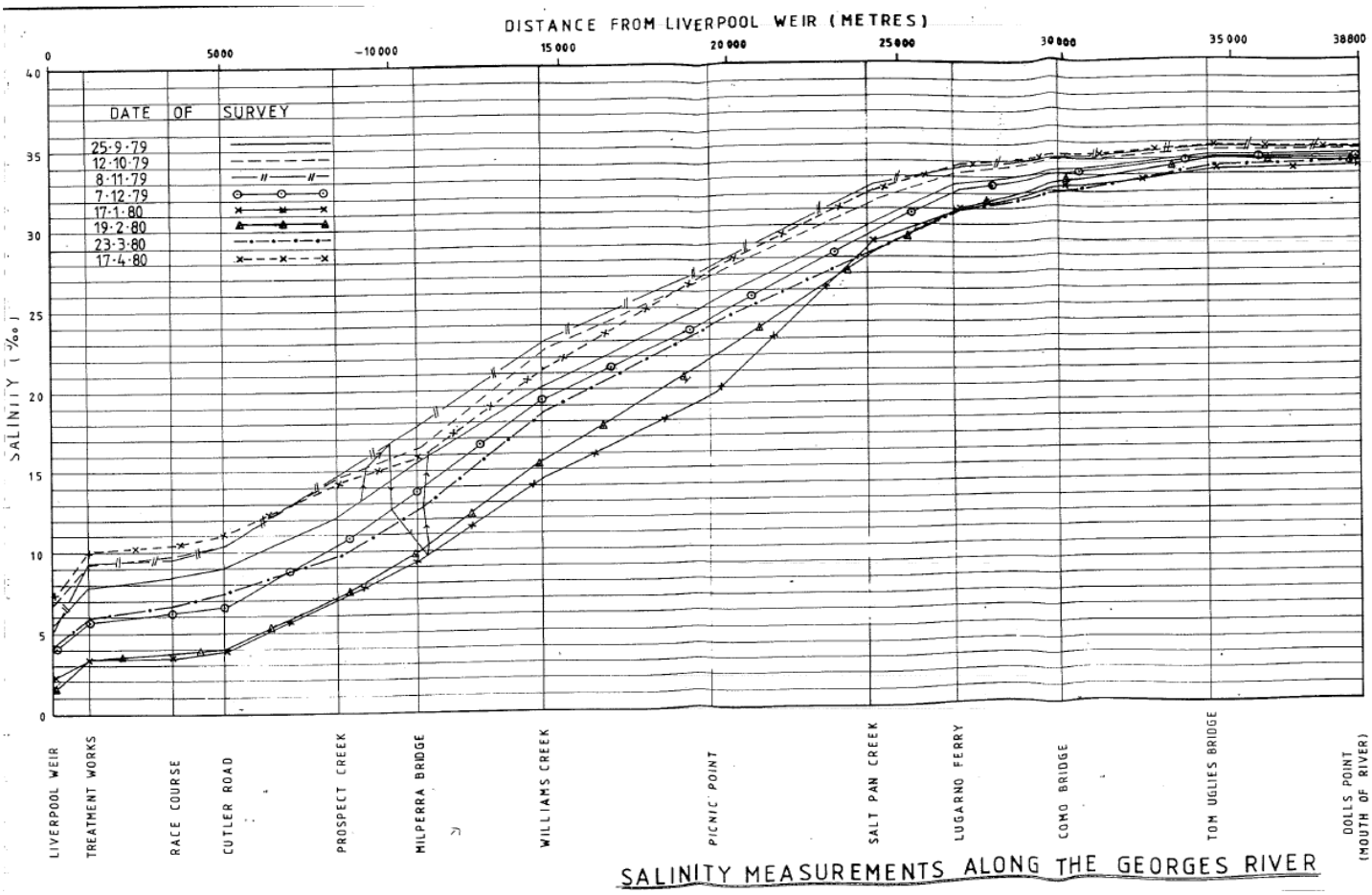


Figure 2-4 Typical salinity profile along the Georges River Estuary (PWD, 1990)

The salinity profile is a function of the typical freshwater inflows, and the relative tidal exchange occurring along the estuary. The near marine conditions downstream of Como Bridge indicate that this section of the estuary receives relatively good tidal exchange. Therefore, pollutants entering the estuary within this reach are comparatively well diluted and dispersed with incoming ocean waters. The degree of tidal exchange then reduces significantly with distance upstream. Even though the freshwater inflows are relatively small, the upper reaches of the estuary remain strongly influenced by the catchment inflows, as indicated by the suppressed salinity concentrations. Therefore, pollutant inputs to this section of the estuary are more critical as there is not as much tidal flushing and dispersion as in downstream reaches.

Under high flow conditions, much of the saltwater can be advected out of the river, particularly the upper reaches, with stratification (freshwater overlying more saline water) lasting for up to two weeks. The recovery of the salt wedge into the estuary would depend on the size of the freshwater event. SPCC (1979) found that return to 'equilibrium' conditions was slow after a freshwater event, indicating relatively poor longitudinal mixing and dispersion characteristics. Deep holes within the river (e.g. Chipping Norton Lakes) would likely retain brackish/saline conditions near the bed except for under the largest of freshwater events. It is expected that high flows would also correspond with poor water quality conditions in the river, and particularly along the upper reaches where catchment runoff would dominate the receiving water environment.

2.2.4.2 Factors affecting water quality

In addition to the natural flushing and dispersion characteristics of the estuary as described above, the water quality of the Georges River has been affected notably by a range of anthropogenic factors. For example, urbanisation of the catchment has contributed greatly to pollutant loadings and poor water quality in the estuary. Also, extensive dredging activities along the river and the eventual construction of the Chipping Norton Lakes have altered the hydrodynamics of the river (and thus flushing and mixing characteristics), and has increased turbidity through localised bank instability.

Land reclamation activities, using waste as fill material, caused the destruction of many wetlands, and have been at least partially responsible for the collapse of the oyster, prawn and fish industry in the Georges River. Sewage from the Glenfield, Holsworthy and Liverpool STPs, which is high in nutrients, pathogens and other pollutants, was directly discharged into the river up to 1986, causing widespread issues of eutrophication and poor water quality in the upper sections of the Georges River. While there has been some recovery from these past activities, many of the toxic chemicals, heavy metals and pollutants still remain in the Georges River bound to riverbed sediments.

A number of point and diffuse sources of pollution continue to contribute to the degradation of water quality in the Georges River. In addition to general catchment runoff from the highly urbanised catchment, which includes a mix of gross pollutants, heavy metals and nutrients, point source sewerage can overflows occur during heavy rainfall. Sydney Water's sewerfix program aims to reduce the frequency of sewer overflows, but with aging infrastructure, the demand for remediation is high. Furthermore, some recreational activities like dirt biking and four wheel driving along the river's foreshores would increase sediment runoff and contribute to water turbidity.

Managing pollutant inputs to the estuary is now a major task for Councils and the SMCMA, with funding and projects aimed specifically at stormwater pollution, including WSUD initiatives. It has been estimated that 95% of the total contaminant load to the Georges River / Botany Bay estuary is

now derived from stormwater runoff, so the recent focus on stormwater management is considered appropriate.

2.2.4.3 Current water quality conditions

Appraisal of the current 'snap shot' river health conditions in the Georges River using a 'report card' format, as established by the GRCCC, is shown in Figure 2-5. Despite the long history of pollution and elevated catchment runoff loads, it is considered that the water quality of the Georges River Estuary has improved in recent years. But there is still a significant range in water quality conditions across the estuary, from very good conditions within areas close to the National Park (e.g. Mill Creek, Woronora River), to highly degraded conditions within the heavily urbanised tributaries (e.g. Cabramatta, Prospect and Salt Pan Creeks).

2.2.5 Ecology

Estuarine vegetation found within and surrounding the Georges River Estuary has been mapped in Figure 2-7 to Figure 2-9. These include:

- Seagrass;
- Mangroves;
- Saltmarsh;
- Estuarine Reedland; and
- Swamp Oak Forest.

There is approximately 375ha of seagrass within the study area, the vast majority of which is located within and around the Towra Point Aquatic Reserve and Towra Point Nature Reserve in Botany Bay. Towra Point contains eelgrass (Zostera) and strapweed (Posidonia) species, while only eelgrass and paddleweed (Halophila) are found within the river channel. Seagrass is considered to be in reasonable condition, with typical levels of epiphytic growth, however, some beds contain prominent swathes that have been cut by boat propellers and mooring chains.

Approximately 470ha of mangroves have been mapped within the study area, with the majority of these again located at Towra Point. Towra Point contains some 50% of the mangroves found within the Sydney metropolitan region. Both the Grey Mangrove and the River Mangrove are present within the estuary.

The area of saltmarsh in and around the estuary covers approximately 145ha, virtually all of which is found at Towra Point, and represents the only remaining substantial saltmarsh area in Sydney. The distribution of saltmarsh has reduced significantly over the past 60 years due to ingress of both swamp oaks and mangroves.

Foreshore mangroves & bushland (photo: OEH)