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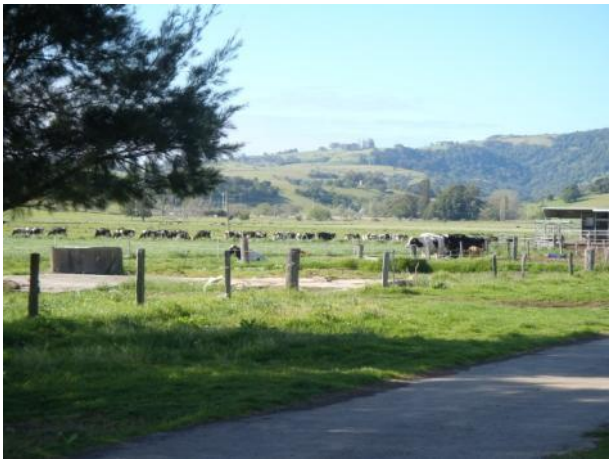
Coastal Zone Management Plan for the Minnamurra River Estuary




June 2015

Coastal Zone Management Plan for the Minnamurra River Estuary

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Cover photos: Top left: Dairy farming, Top Right: Terragong Drain (photo courtesy D. Wiecek), Bottom left: Lower estuary recreational use (photo courtesy A. Wilson), Bottom Right: Lower estuary and entrance (photo courtesy D. Wiecek).

PROJECT 15-001 – CZMP FOR MINNAMURRA RIVER ESTUARY

REV	DESCRIPTION	AUTHOR	REVIEW	APPROVAL	DATE
0	Draft for Council review	R. Campbell, K, Pratt, U. Makings	K. Pratt, M. Howland	M. Howland	12/12/14
1	Final Draft for Public Display	R. Campbell, K, Pratt	M. Howland	M. Howland	23/2/15
2	Minor edits	R. Campbell	K. Pratt	R. Campbell	28/2/15
3	Updated with Committee feedback	R. Campbell	K. Pratt	R. Campbell	313/15
4	Incorporating feedback from public display	R. Campbell	M. Howland	M. Howland	22/6/15

EXECUTIVE SUMMARY

The Minnamurra Estuary Management Plan (1995 EMP) adopted in 1995 and reviewed in 2003 identified on-ground projects and initiatives aimed at protecting and restoring key environmental assets and social amenity. Many of the high priority projects have been implemented, including erosion control works, urban stormwater management, planning and development controls, weed control and water quality monitoring programs. This Coastal Zone Management Plan (CZMP) for the Minnamurra River Estuary recognises the achievements of the previous EMP, identifies new management issues that have arisen since the original plan was adopted and addresses the new (2013) State government requirements for coastal zone management. The CZMP supports the goals and objectives of the *NSW Coastal Policy 1997* and assists in implementing integrated coastal zone management for the Minnamurra River Estuary.

The study area is bounded by the topographical catchment of the Minnamurra River and its tributaries and comprises the tidal waterways, foreshore and adjacent land of the Minnamurra River Estuary including the entrance. The Estuary catchment consists of extensive conservation areas, agricultural land, public reserves, urban developments and industrial land including waste depots, sand mines and quarries.

Preparation of this CZMP included consultation with community and agency stakeholders. The main theme raised by the community stakeholders was the desire to protect the existing natural character and beauty of the area and maintain the highly valued recreational opportunities.

The lower estuary is an important community asset and recreational drawcard and is utilised for a variety of water and shore-based activities. The lower estuary also includes numerous residential waterfront properties. Due to its popularity as a recreational asset, many of the issues raised during the stakeholder consultation relate to the community's expectations regarding these recreational pursuits and conflicts with other land uses in the catchment including urban development, farming, extractive industries and solid waste management. The lower estuary and entrance area are popular during peak holiday periods. Due to the limited foreshore infrastructure and land available to support the recreational activities, the area experiences pressures such as inadequate parking, conflicts between recreational activities as well as impacts on the surrounding environment.

Coastal and estuarine processes (e.g. waves, river meander) also impact on social values through bank erosion in the lower estuary. Although many management actions have been implemented to control bank erosion, many locations of bank slumping and undercutting remain, affecting access to the waterway and impacting water quality. Ecosystem health issues in the lower estuary include weeds, water quality degradation and the associated impacts on estuarine habitats as well as recreational pursuits. Boating speed in the lower estuary and waterway safety is a concern raised by many stakeholders. Expansion of mangroves and the potential impacts on waterway access and social amenity is also a key concern for a section of residents of the lower estuary.

Bank erosion and water quality degradation also occur in the mid and upper Estuary. The lower Terragong Swamp supports intensive farming land with issues associated with lack of or poor quality riparian vegetation, nutrient enrichment and cattle access to the foreshore. Gross pollutants (such as litter, silage bails, wrap and twine) are also present at many locations in the river. The presence of feral animals also impacts biodiversity values and potentially agricultural productivity. While these issues can put pressure on the estuarine environment, the area is highly productive and strategically important for the local agricultural sector. Ongoing cooperation between landholders and natural resource management agencies has led to better riparian land management outcomes and a greater awareness of estuary health issues. Despite this, more resources are required to support landholders to improve natural resource management.

The key management issues in the upper estuary and alluvial plain relate to the artificially straightened, narrow deep channel through the Terragong Swamp and historic riparian and catchment vegetation clearance associated with European settlement. The natural floodplain (Terragong Swamp) was drained for dairy farming in the late 19th century and the main channel of the river shifted to the northern side of the

swamp to where it is located today. The incised channel, steep bed slope, lack of riparian vegetation, stock access, natural migration of the river and increased runoff due to vegetation clearing are the key causes of bank slumping. Grade control structures have been installed within the channel to try to raise the bed level of the channel and reduce channel incision, but there is only anecdotal evidence of their effectiveness. Creating a stock exclusion and riparian buffer zone across the swamp is an aspirational goal for the Estuary to complement and enhance the effectiveness of the grade control structures.

Whilst the available data suggest that the water quality in the upstream freshwater catchment is good, the upper and mid estuary (including Rocklow Creek) may be susceptible to pollution from the predominantly cleared and drained floodplain areas used for grazing and other agriculture, urban development, the presence of large quarry sites in the mid catchment and two waste disposal sites in the tidally influenced reaches of Rocklow Creek. The lower reaches of the estuary are well flushed by tidal exchange and generally exhibit good water quality.

Sea level rise (SLR) has the potential to increase the extent and/or severity of bank erosion, water quality degradation (particularly leachate from waste depots) and tidal intrusion in the upper estuary and Terragong Swamp, potentially affecting agricultural productivity. Rising sea levels also have the potential to impact saltmarsh and mangrove communities as well as seagrass beds.

The management of the Minnamurra River Estuary is undertaken by many different government agencies, private organisations and community groups with many separate legislative requirements. Management activities performed by the various land managers are undertaken for a range of purposes including licence compliance, agricultural productivity and general maintenance. These activities generally function in isolation as funding and resources permit. A more strategic and coordinated approach would assist with knowledge sharing, improved access to funding and increased understanding of management issues to improve on-ground outcomes. It is proposed that a CZMP Implementation Committee is established to ensure a coordinated and holistic approach to the delivery and evaluation of the various management actions. The establishment of an Estuary Health Officer position is also recommended to provide the required resources and to ensure the efficient and effective coordination, implementation and evaluation of the priority management actions that have been identified by the various stakeholders. This new position would also strengthen collaboration between the stakeholders and assist with securing grant and other funding for the various actions.

The CZMP management actions have been grouped into 6 key strategies. The strategies and recommended approach are listed below and shown on the following figures.

1. Administration and Delivery of Management Actions:
    - Establish CZMP Implementation Committee to provide a coordinated and more holistic approach and efficient delivery of management programs; and
    - Seek funding for the appointment of an Estuary Health Officer to ensure the efficient and effective coordination, implementation and evaluation of management actions, to strengthen collaboration and assist with securing grants and other funding. It is suggested that this position could operate within local government and be funded in partnership with state government agencies and local government partners. This position could cover specific local estuaries e.g. Minnamurra and Crooked River and other estuaries within the Illawarra if there is partnership interest.
2. Water Quality Management:
    - Continuation of the NSW Monitoring Evaluation and Reporting (MER) water quality monitoring program (undertaken by OEH approximately every 3 years at selected sites in the Minnamurra River Estuary);

- Additional water quality monitoring, comprising regular sampling and event-based data collection (following wet weather events) to assist in identifying sources and causes of poor water quality in the Estuary and direct future pollution control actions;
- Priority water quality research projects at Jamberoo, Gainsborough stormwater ponds and Rocklow Creek;
- Review of stormwater treatment requirements and development of an asset management plan for urban stormwater;
- Continue monitoring in accordance with licence conditions at Minnamurra Depot and Dunmore Depot including monitoring of total ammonia in ground and surface water and development of remedial actions to treat contaminated groundwater;
- Assessment of potential future sea level rise (SLR) impacts on Minnamurra and Dunmore Depot sites and the impact on estuary health;
- Provision of agricultural extensions services and assistance to landholders aimed at increasing the understanding of the issues and facilitating sustainable agriculture initiatives;
- Removal of gross pollutants from the river including litter, feed bales, silage wrap and chemical drums; and
- Ongoing resources for the silage wrap and baling twine recycling program.

3. Control of Bank Erosion:
    - Rehabilitate existing priority erosion sites along the Minnamurra Headland, Charles Avenue, Riverside Drive and Terragong Drain;
    - Progressive identification and removal of weed species along Terragong Drain and improved riparian zone management including livestock exclusion fencing and revegetation of buffer zone;
    - Maintenance and repair of rock revetment;
    - Hydrographic survey of Terragong Swamp; and
    - Ongoing monitoring of extent and severity of bank erosion to identify priority rehabilitation areas (particularly tributaries and upper catchment areas which have not been investigated for this CZMP).
4. Protection of Estuarine and Foreshore Habitat:
    - Undertake a consultation program with the local community and all key stakeholders to assess management options for mangrove encroachment along foreshores;
    - Liaison with Fisheries NSW to discuss the potential for obtaining a permit under the *Fisheries Management Act* to undertake maintenance works;
    - Assessment of trends in seagrass extent, distribution and health and investigation of causes of seagrass variability;
    - Rehabilitation of priority riparian areas;
    - Ongoing weed management and revegetation of public foreshore areas;
    - Prioritisation of locations needing treatment to improve fish habitat and migration;
    - Geomorphological assessment of mid and upper catchment areas;

- Ongoing monitoring and assessment of estuarine vegetation extent and condition and regular update of estuarine vegetation mapping; and
- Investigation of management options to allow migration of vegetation communities in response to SLR.

5. Recreational facilities:
    - Assessment of foreshore reserves visitation and usage and identification of infrastructure requirements;
    - Review of foreshore reserves plans of management and develop master plan for Minnamurra River foreshore reserves;
    - Resident and tourist education program highlighting the importance of protection of water quality, native fauna and estuarine vegetation; and
    - Installation of kayak launching facilities in the mid estuary.
6. Floodplain management:
    - Develop flood studies and a floodplain management plan for the Minnamurra River including consideration of future SLR impacts; and
    - Investigate strategies for management of saline intrusion further inland with future SLR.

The recommended management actions have been compiled into a ten year implementation schedule as shown in Table 1 with responsibilities and indicative costs estimated over the implementation period. The total cost of the CZMP implementation is estimated to be approximately $2.6 million over ten years. The actions will be delivered through a combination of Council and State Government funding (where available). The delivery of the actions may be influenced by the availability of this funding as well as human resources and landholder support and capacity.

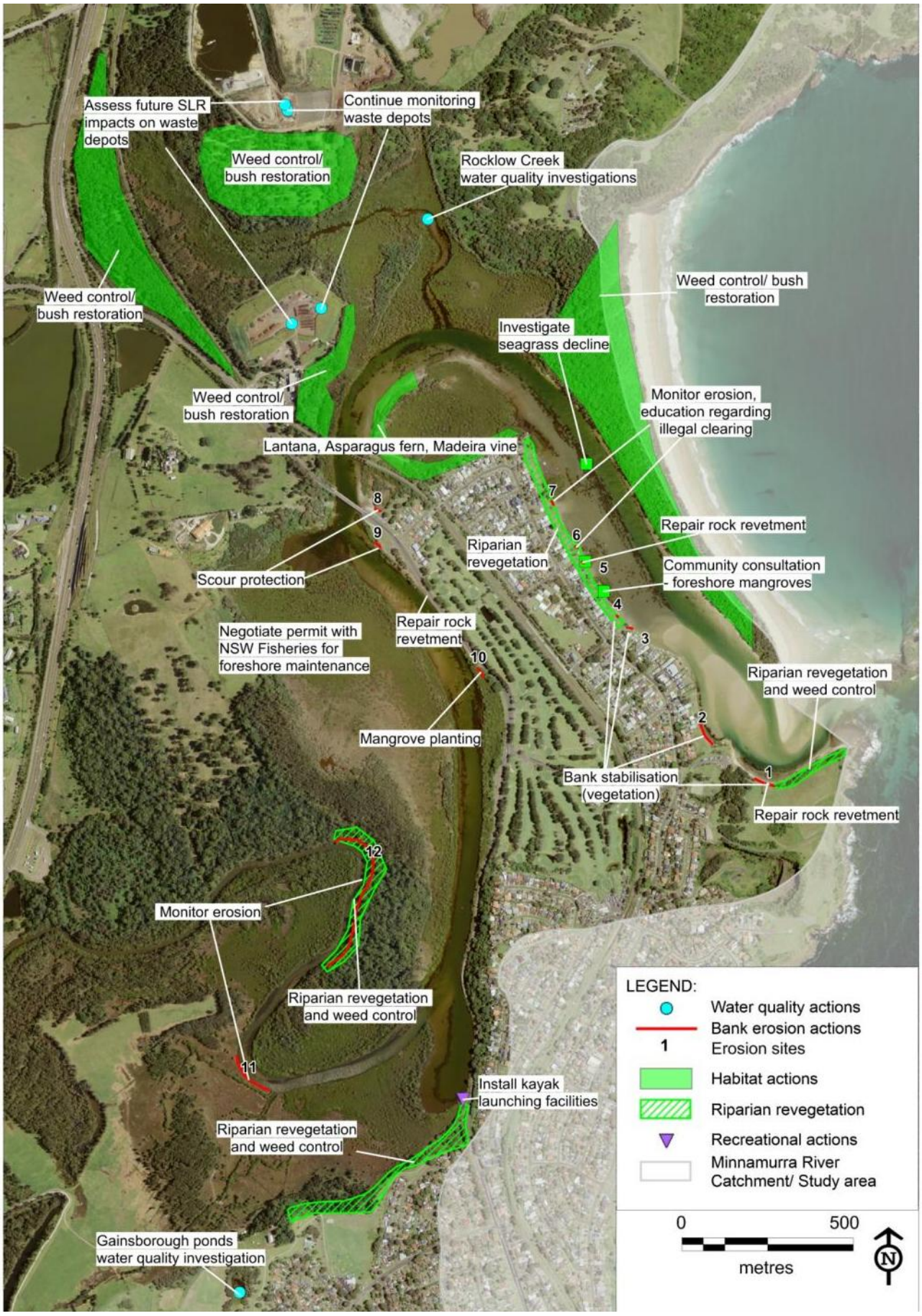


Figure 1: CZMP Management Actions – Lower-Mid Estuary

Note – Site 5 rock revetment has been repaired

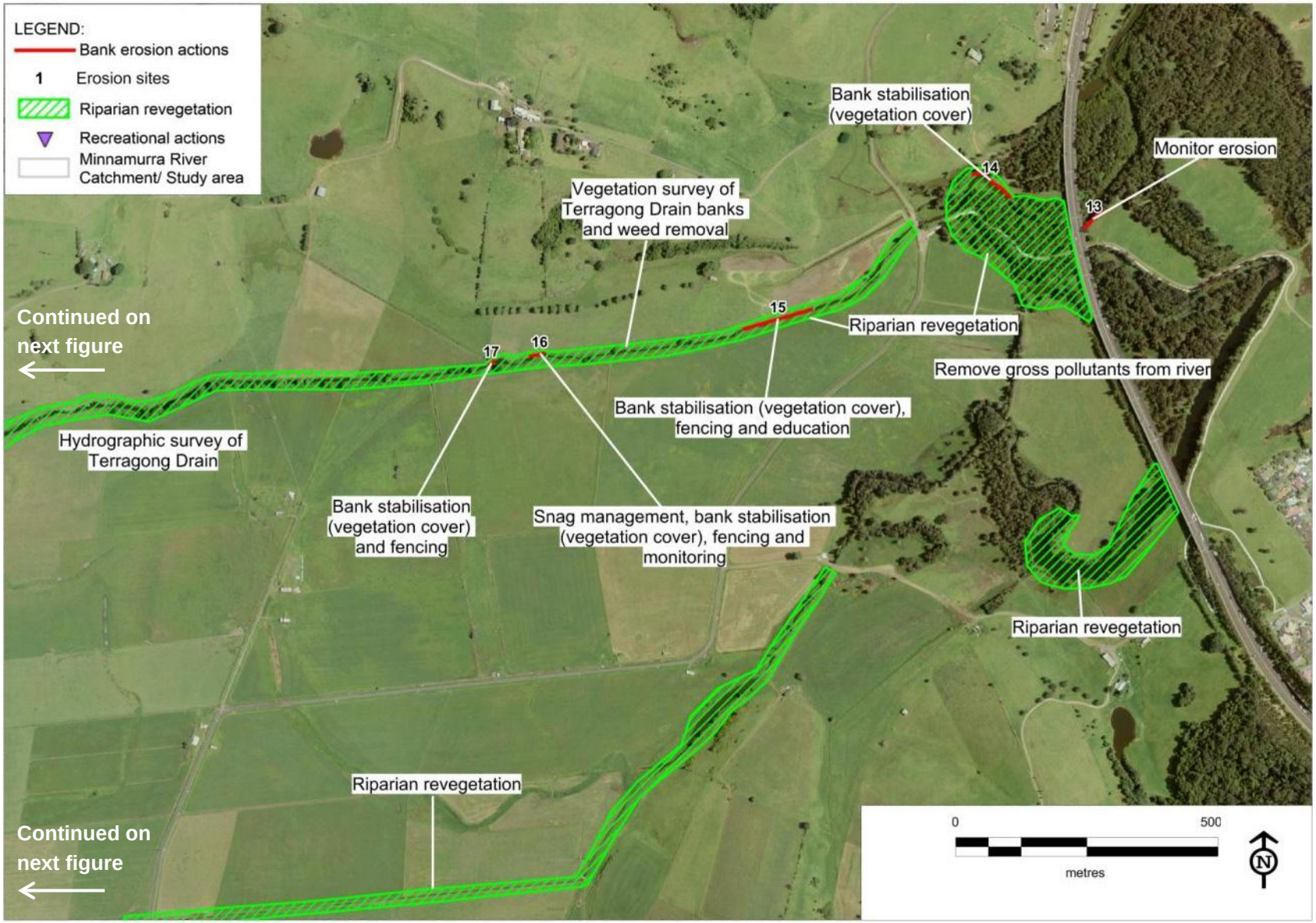


Figure 2: CZMP Management Actions – Upper Estuary and Terragong Swamp

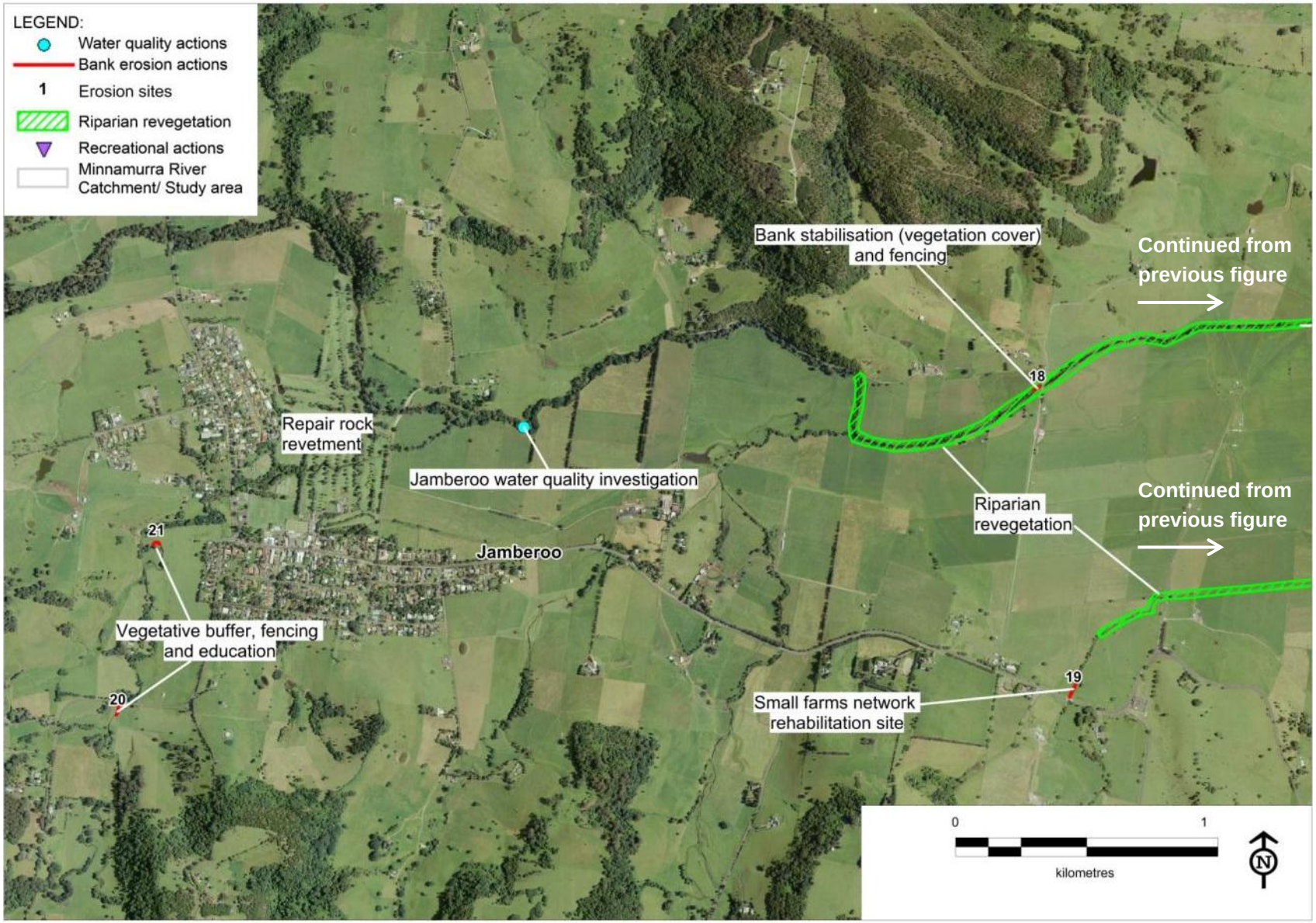


Figure 3: CZMP Management Actions – Jamberoo

Table 1: CZMP Implementation Program

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Strategy 1: Administration and Delivery of Management Actions													
1.1	Establish CZMP Implementation Committee	KMC	-	Note 2									
1.2	Establish estuary health officer position hosted within local government for implementation of Minnamurra River and other CZMP's (local and Illawarra)	KMC	**850,000**	85,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000
Strategy 2: Water Quality Management													
2.1	Continue implementation of current water quality monitoring program as part of MER program.	OEH	-			Note 2			Note 2			Note 2	
2.2	Design and implement an ongoing monitoring program to assist in identification of potential pollution sources	KMC	**125,000**	17,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
2.3	Undertake priority water quality investigations in accordance with the research priorities identified in this CZMP	KMC	**25,000**	5,000		5,000		5,000		5,000		5,000	
2.4	Develop Urban Stormwater Asset Management Plan (Note 3)	KMC	-	Note 2									
2.5	Continue monitoring in accordance with licence conditions at the Dunmore Depot including monitoring of total ammonia in ground and surface water.	SCC	-	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2
2.6	Continue monitoring in accordance with licence conditions at the Minnamurra Depot including development of remedial actions to treat contaminated groundwater.	KMC	-	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2.7	Assessment of future sea level rise impacts on the Minnamurra Depot site.	KMC	**30,000**						30,000				
2.8	Assessment of future sea level rise impacts on Dunmore Depot site.	SCC	**30,000**						30,000				
2.9	Agricultural extensions services and assistance provided to landholders.	South East LLS	**250,000**	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
2.10	Removal of gross pollutants from river including litter, feed bales, silage wrap and chemical drums.	KMC	**20,000**	5,000			5,000			5,000			5,000
2.11	Liaise with Southern Councils Group to provide ongoing resources for the silage wrap and baling twine recycling program including the provision of collection bags and related education programs.	KMC	**-**	Note 2	Note 2								
Strategy 3: Control of Bank Erosion													
3.1	Complete the bank erosion assessment for the entire catchment and monitor extent and severity of bank erosion every 3 years to identify priority areas (all tributaries).	KMC	**25,000**	10,000			5,000			5,000			5,000
3.2	Stabilise banks along Minnamurra Headland (Site 1) with low-growing native species.	KMC	**500**	500									
3.3	Stabilise banks along James Oates Reserve (Site 2) with low-growing native species.	KMC	**1,000**	1,000									
3.4	Stabilise banks above Charles Avenue foreshore rock walls (re-contour and revegetate with suitable species)	KMC	**-**	Included in Action 4.4									

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
3.5	Remove existing rocks and reconstruct rock revetment with appropriate batter slope (Site 1 – Minnamurra Headland).	KMC	**5,000**	5,000									
3.6	Trial mangrove plantings, toe protection and bank revegetation (Site 9)	KMC	**20,000**		10,000	10,000							
3.7	Work with landowners to install livestock exclusion fencing, revegetate buffer zone and install off-stream watering similar to Demonstration Reach Toolbox approach (e.g. Sites 14, 15, 16, 17, 18, 20, 21).	Terragong Drainage Union, private landholders	**-**	Included in Action 2.10									
3.8	Obtain approval to remove fallen tree and relocate to bank with suitable anchoring (Site 16) in conjunction with riparian revegetation and fencing.	Terragong Drainage Union, private landholders	**5,000**	5,000									
3.9	Maintain and repair rock revetment where required (e.g. Minnamurra Headland, Charles Avenue foreshore, Riverside Drive rock wall and Hyams Creek bridge).	KMC	**15,000**	10,000					5,000				
3.10	Vegetation survey of Terragong Drain banks. Progressive removal of weed species.	Terragong Drainage Union, private landholders	**10,000**	5,000					5,000				
3.11	Hydrographic survey of Terragong Swamp for comparison with hydrographic survey completed in 1992 by NSW Public Works to assess change over time.	OEH	**10,000**			5,000					5,000		
Strategy 4: Protection of Estuarine and Foreshore Vegetation													
4.1	Liaise with Fisheries NSW to negotiate a permit for maintenance works.	KMC	**-**	Note 2									

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
4.2	Undertake a consultation program with the local community and key stakeholders including development of options for management of mangrove encroachment along foreshores and education regarding the importance of estuarine vegetation	KMC	-	Note 2	Note 2								
4.3	Assessment of trends in seagrass extent, distribution (including repeat mapping) and health, investigation of causes of seagrass decline.	Fisheries NSW	**15,000**						15,000				
4.4	Revegetate priority riparian areas on public land (Minnamurra Headland, Charles Avenue foreshore and the saltmarsh area adjacent to Cameron Crescent in Gainsborough Estate).	KMC	**110,000**	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000
4.5	Revegetate priority riparian areas on private land (the second meander bend, Terragong Swamp, mid-Jerrara Creek, the foreshores of the Billabong and the *Casuarina glauca* forest area between Princes Highway and Swamp Road.	Terragong Drainage Union, private landholders	**600,000**	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
4.6	Identify priority riparian revegetation areas in the mid-upper catchment and tributaries (Note 3).	KMC	**5,000**				5,000						
4.7	Implement a weed control/bush restoration program for priority sites in public areas	KMC, SCC	**50,000**	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4.8	Identification and prioritisation of stream and riparian locations needing treatment to improve fish habitat and migration	Fisheries NSW	**5,000**	5,000									

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
4.9	Investigation of management options to allow for migration of estuarine vegetation communities in response to seal level rise.	KMC	**10,000**						10,000				
4.10	Geomorphological assessment of mid and upper catchment reaches.	KMC	**10,000**				10,000						
Strategy 5: Recreational Facilities													
5.1	Undertake assessment of Minnamurra foreshore reserves visitation and usage to determine future car parking, facility upgrade and signage requirements to cater for increasing demand	KMC	**25,000**	25,000									
5.2	Review Minnamurra foreshore reserves plans of management (including results of Action 5.1) and develop a master plan for the Minnamurra River foreshore reserves	KMC	**-**			Note 2	Note 2						
5.3	Resident and tourist education program highlighting the importance of protection of water quality, native fauna, fish habitat and estuarine vegetation. Include dog control, safe boating and review of signage.	KMC	**3,000**		3,000								
5.4	Investigation and assessment of a suitable site for kayak launching facilities with consideration of impacts of disturbance on fish habitat, estuarine and riparian vegetation.	KMC	**20,000**									20,000	
Strategy 6: Floodplain Management													
6.1	Develop flood studies and floodplain management plan for the Minnamurra River	KMC	**250,000**						125,000	125,000			

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
6.2	Investigate strategies for management of saline intrusion further inland with future sea level rise.	KMC	**10,000**							10,000			
Monitoring and Review Actions													
7.1	Annual review of CZMP progress	KMC	**-**	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2
7.2	Ten year review of CZMP	KMC, OEH	**70,000**										70,000
7.3	Investigation of the impact on estuary health due to potential land use changes for consideration in the 5 yearly LEP review	KMC, SCC	**20,000**	10,000					10,000				
Total			**2,624,500**	**289,500**	**211,000**	**218,000**	**223,000**	**203,000**	**428,000**	**348,000**	**203,000**	**223,000**	**278,000**

Notes:
1. Refer Table 15 and Appendix 8 for potential grant funding.
2. Shaded years represent the proposed year of implementation for each action. Some actions are considered to be included in existing Council staff responsibilities or covered by current funded programs. Additional funds are not required.
3. Capital expenditure for installation of new devices, ongoing asset maintenance and renewal and riparian restoration has not been included.
4. Design and assessment is required to confirm budget for construction of new facilities.

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

The Minnamurra River Estuary is located on the south coast of New South Wales, approximately 5 km north of Kiama within the Kiama and Shellharbour local government areas (LGA).

1.1 Purpose of this Coastal Zone Management Plan

The *Minnamurra Estuary Management Plan* (1995 EMP, PBP, 1995a) was completed under the direction of Kiama Municipal Council (KMC), Shellharbour City Council (SCC) and the Minnamurra River Estuary Management Committee (now disbanded) following the planning process for estuary management prescribed in the NSW Government's 1992 *Estuary Management Manual*.

The 1995 EMP was reviewed in 2003 (Panayotou, 2003). The 2003 EMP Review provided a detailed evaluation of the management issues, objectives, options and results of management actions from the 1995 EMP as well as identifying new issues. The 1995 EMP had been operational for 8 years with many of the actions recommended in that plan substantially completed or ongoing at the time of the 2003 EMP Review.

In 2013/14, KMC received funding through NSW Government Estuary Management Program to undertake a new review of the 2003 EMP. Since the plan was developed, the body of knowledge on the potential impacts of climate change on physical and ecological processes within estuaries has increased, and new policies have been released by the NSW Government to guide local councils in their preparations for climate change impacts. This new review considers the potential impacts of climate change and refocuses priorities, now that many of the actions identified in the original 1995 EMP (and 2003 EMP Review) have been implemented. The review process provided additional opportunities for the local community to have a say in the ongoing management of Minnamurra River Estuary (refer Section 4).

The primary purpose of a Coastal Zone Management Plan (CZMP) is to describe proposed actions to be implemented by a council, other public authorities and potentially by the private sector to address priority management issues in the coastal zone over a defined implementation period. These issues include managing risks to public safety and built assets, pressures on coastal ecosystems and community uses of the coastal zone.

This CZMP consists of a scheduled sequence of actions that are recommended to address the management issues identified for the Minnamurra River Estuary. Actions to address climate change issues have been identified that require further research and funding prior to implementation.

The main considerations during the development of the Minnamurra River Estuary CZMP were to:

- Involve the community and stakeholders in the preparation of the CZMP including making information relating to the plan publicly available;
- Maintain the condition of high value coastal ecosystems and rehabilitate priority degraded coastal ecosystems;
- Address the current and potential risks to estuary health;
- Protect amenity, maintain and improve public access arrangements to foreshores and support recreational uses;
- Link Council's coastal zone management planning with other planning processes in the coastal zone to facilitate integrated coastal zone management; and
- Base decisions on the best available information and reasonable practice, including adopting an adaptive management approach.

This revised management plan recognises the achievements of the 1995 EMP (and the 2003 EMP Review) and identifies new management issues that have been identified since the original Plan was adopted.

1.2 The Coastal Zone Management Process

Coastal councils are required to prepare CZMPs in accordance with the Minister's guidelines adopted in 2013 under section 55D of the *Coastal Protection Act, 1979.* This CZMP for the Minnamurra River Estuary supports the goals and objectives of the *NSW Coastal Policy 1997* and assists in implementing integrated coastal zone management for the Minnamurra River Estuary. This CZMP was prepared in accordance with Part 4A of the *Coastal Protection Act, 1979* and addresses the new CZMP guidelines (OEH, 2013a).

The CZMP guidelines specify the minimum requirements that are to be met when preparing a CZMP, in addition to the requirements in the Act. The minimum requirements in the guidelines relate to:

- Preparation of the CZMP;
- Coastal risk management;
- Coastal ecosystem health; and
- Community uses of the coastal zone.

The coastal risk management components will be addressed through future targeted coastal hazard assessments and CZMPs and a Minnamurra River flood study. As such, these components of the CZMP guidelines will not be directly addressed through the Minnamurra CZMP but will be addressed in future planning. The coastal ecosystem health and community use components of the guidelines constitute the main components of this CZMP for the Minnamurra River Estuary.

Appendix 1 summarises the minimum requirements and how they have been met by this CZMP.

The main aim of this CZMP is to protect and enhance the key values of the study area by increasing resilience of the coastal zone and addressing key threats through efficient, effective and timely management. This will be achieved through the implementation of integrated, balanced, responsible strategies to restore and maintain the ecological sustainability and local character of the estuary as well as the recreational and commercial activities associated with it. The CZMP provides links to other related management strategies which will assist in achieving the objectives of the CZMP.

The management strategies contained in this CZMP will inform Council's future strategic planning, as well as other government agencies with responsibility for management of Minnamurra River Estuary. The Plan will be adopted by Council after submissions received as part of the public exhibition phase have been considered.

At the time of preparation of this CZMP, the NSW Government was reforming its approach to coastal management in NSW. The legislative amendments associated with stage one of the NSW Government's coastal reforms commenced in January 2013. The main elements of the stage one coastal reforms relate to approval for coastal protection works, section 149 information and the consideration of coastal hazards in the context of local circumstances (the State Government will no longer recommend state-wide sea level rise benchmarks). Stage two of the reforms has a strategic focus and is closely linked to the current planning reforms and local government reviews. Future review of this CZMP will consider the policy context in place at that time.

It is not Council's intention to have this plan certified by the Minister, as it is expected that a Municipality wide CZMP will be developed in the future for identification and management of coastal hazards.

1.3 Development of the CZMP

To achieve the aims outlined above, the CZMP was prepared through a series of project phases. Each phase was an essential step in the development of the CZMP. The key phases were as follows:

- Collection and consolidation of background information from a range of sources including existing documentation, Council staff, external stakeholders and the community;

- Field survey conducted by Council and OEH staff with mapping of associated issues and suggested management approaches;
- Analysis of the information from existing studies on estuary health and community uses to identify management issues;
- Development and prioritisation of potential options to address the management issues;
- Development of a strategic plan to address the priority management issues including an implementation framework with clearly defined and prioritised outcomes, actions, timeframes, funding, responsibilities and monitoring requirements; and
- Consultation with stakeholders to obtain feedback on the proposed strategy.

The development of the CZMP has followed a risk-based and adaptive management approach to the assessment of issues, options and the overall implementation plan. Risks are assessed in terms of the risk to the environment, public safety and assets posed by identified threats, but also in terms of the risk that these threats may pose to the likely success of any management option being considered as part of the CZMP. The hierarchy for risk management options starts at avoidance of risk, changing the likelihood or consequence of the risk through to sharing, or simply informed acceptance of the risks. All management options have been assessed considering social, environmental and economic implications.

Adaptive management is facilitated by the inclusion of monitoring and verification actions in the CZMP but also in the general approach to assessing issues, options and the implementation schedule for actions. Interim actions have been proposed to manage high risks if these can only be mitigated over the longer term or the risks are likely to increase with time. A lack of detailed knowledge on issues does not preclude positive management action where such action is logical and can be modified with appropriate feedback obtained through monitoring.

1.4 Overview of the Study Area

The Minnamurra River Estuary is located near Kiama on the NSW south coast within the Kiama and Shellharbour local government areas (LGAs). The study area comprises the tidal waterways, foreshore and adjacent land of the Minnamurra River Estuary including the entrance and tributaries (refer Figure 4 and Figure 5). The boundary of the study area follows the topographical catchment for the Minnamurra River. Emphasis is placed on the estuary, with consideration given to the wider catchment where it affects the estuarine processes and natural resources.

Urban areas within the estuary catchment include Minnamurra, Kiama Downs and the Gainsborough residential estate in the lower catchment and Jamberoo in the mid-catchment area. Rural activities occur on much of the mid-upper catchment including Terragong Swamp. The Jamberoo Valley contains high value dairy and grazing land with much of the catchment foothills classed as productive agricultural land with naturally fertile soils.

Figure 4: Minnamurra River – lower Estuary and entrance

Source: OEH (2012)

The Kiama area is a popular tourist destination. Water and land-based recreational activities include sight-seeing, walking, nature appreciation, swimming, fishing and boating. The estuary catchment includes golf courses and other tourist facilities in the upper catchment. The Killalea State Park to the north of the river provides a variety of recreational activities including surfing, fishing, camping, walking and picnicking. There are two national parks/nature reserves in the upper Minnamurra River catchment - Budderoo National Park in the west of the catchment and Barren Grounds Nature Reserve in the south west.

Two waste depots are located within the Minnamurra River Catchment - the Minnamurra Recycling Facility (Minnamurra Depot) and the Dunmore Recycling and Waste Disposal Depot (Dunmore Depot). The Minnamurra Depot landfill operations closed in 2006 and the site was rehabilitated in accordance with an approved EPA Landfill Closure Plan. The Dunmore Depot is currently operated as an approved EPA licensed landfill.

There are also two quarries operating within the Minnamurra River Catchment at Dunmore and Albion Park and sand mining operations at Dunmore. The Princes Highway and Illawarra Railway Line pass through the mid and upper estuary areas.

The Minnamurra River Estuary is a mature, wave dominated barrier estuary (as classified by Roy *et al*., 2001). The estuary has a total catchment area of 117 km^2 comprised of several sub-catchments including those of Rocklow, Jerrara, Fountaindale, Hyams, Frys and Turpentine creeks (Figure 5).

The upper headwaters of the Minnamurra River and its tributaries originate in the eastern escarpment of the coastal range before flowing eastwards towards the township of Jamberoo where it enters an alluvial plain characterised by Terragong Swamp. The swamp was drained from the 1860s for agricultural purposes. As a part of this scheme, the main river channel was merged into a man-made formalised channel which runs along the northern margin of the former swamp before joining with the estuary just upstream of the Princes Highway crossing approximately 7.5 km from the entrance. The estuary then meanders in a general north-

east direction through Minnamurra before entering the ocean at Minnamurra Point. The entrance, which is permanently open and untrained, is protected by the rocky headland of Minnamurra Point and Stack Island, a small rocky island approximately 300 m offshore. Minnamurra Beach extends southward from Killalea State Park to the entrance at Minnamurra Point.

The far upper Minnamurra River catchment on the escarpment is dominated by forest within Budderoo National Park and Minnamurra Falls Reserve. The mid reach of the river is dominated by the urban area of Jamberoo, recreational areas, the Terragong Swamp and cleared pasture. Downstream of Terragong Swamp the upper sections of the estuary are surrounded by coastal wetlands including mangrove forests and saltmarsh. The mid to lower estuary includes recreational areas and the urban areas of Minnamurra and Kiama Downs. Rocklow Creek (which joins the Minnamurra River in the lower estuary) comprises mostly cleared upper and mid catchment with extensive mangrove and saltmarsh areas in the lower reaches. Sand mining and quarry developments are located just upstream of the Princes Highway crossing on Rocklow Creek and two waste depots are situated downstream of the highway within the tidal reaches.

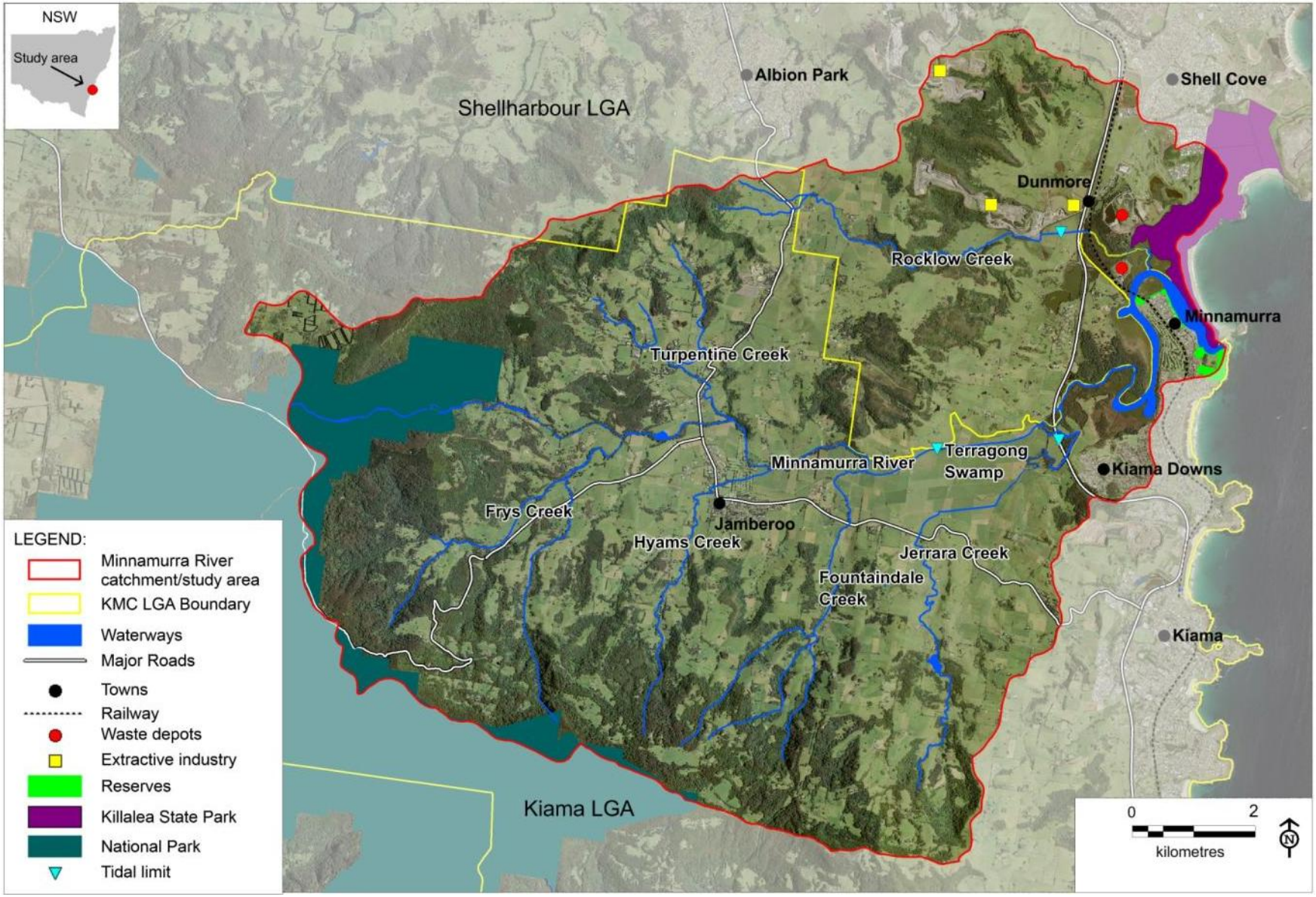


Figure 5: The Minnamurra River CZMP study area (Minnamurra River Catchment) and key features

1.5 Management Context

The Minnamurra River Estuary catchment consists of farming land, extensive wetlands, extractive industries, waste disposal facilities, Crown land, Council reserves, recreational areas and residential developments. The Estuary is managed and regulated by the following agencies and government authorities:

- KMC is responsible for the management of public spaces, assets and facilities around the Minnamurra River Estuary within the Kiama LGA (the majority of the Estuary). The Kiama Local Environmental Plan (LEP) 2011 guides planning decisions within the municipality;
- SCC is responsible for the management of public spaces, assets and facilities around the Minnamurra River Estuary within the Shellharbour LGA (a small proportion of the lower estuary, north of the river). The Shellharbour LEP 2013 guides planning decisions within the municipality;
- The NSW Department of Trade and Investment - Crown Lands (Crown Lands) is responsible for the sustainable management of the Crown Land estate which encompasses the dry land and the submerged land of the State's waterways 5.5 km out to sea and includes the ocean floor, most coastal estuaries, many large riverbeds and some coastal wetlands;
- The Killalea State Park Trust manages the Killalea State Park (Crown Land);
- The NSW Department of Primary Industries – Fishing and Aquaculture (Fisheries NSW) regulates recreational and commercial fishing, investigates fish kills, manages invasive species and native species, populations and communities listed as threatened under the *Fisheries Management Act 1994* (including mangroves, saltmarsh and seagrass which are listed as "threatened" and are protected on Public Water Land and the foreshore up to the Highest Astronomical Tide level.)*;*
- The Terragong Drainage Union (the land owners adjoining Terragong Swamp) is responsible for the maintenance of the drain including cattle management, weed management and integrity of the drain. The Union was formed as a result of the transfer of Crown Grazing Leases to freehold farming land in 1974 and was gazetted under the *Drainage Act, 1939* (repealed by the *Water Management Act, 2000*);
- RailCorp owns and manages the railway corridor and rail assets within the Minnamurra River Estuary catchment;
- Navigation infrastructure, oil spill and vessel based pollution and boating is managed by NSW Roads and Maritime Services (RMS);
- The Princes Highway and associated infrastructure is managed by RMS;
- The Illawarra Local Aboriginal Land Council (LALC) manages Aboriginal heritage interests in the area;
- The Southern Rivers Catchment Management Authority (SRCMA) has played a key role in the management of natural resources such as the Minnamurra River Estuary and surrounding lands. The SRCMA has been working in cooperation with the Councils and NSW Department of Primary Industries to deliver incentives aimed at improving biodiversity values and water quality through better industry practices. In January 2014, South East Local Land Services (LLS) was established integrating the catchment management authority, livestock health and pest authority and some agricultural advisory services of the NSW Department of Primary Industries;
- The Office of Environment and Heritage (OEH) works closely with local councils and communities to reduce threats from flooding and coastal storms and ensure that people in NSW are well informed about these risks and better equipped to adapt to climate change. OEH also works with local councils and communities to maintain or improve the health of estuaries;

- Sydney Water owns and operates the Bombo sewerage system including the urban areas of Jamberoo, Kiama Downs and Minnamurra and provides treated effluent to the Kiama Golf Club for irrigation of the golf course;
- The NSW Environment Protection Authority (EPA) licenses and regulates the operation of industrial premises including the solid waste landfills at Dunmore and Minnamurra and quarries at Dunmore and Albion Park;
- National Parks and Wildlife Service (NPWS) manages the Budderoo National Park, Minnamurra Rainforest Centre and the Barren Grounds Nature Reserve; and
- The NSW Office of Water is responsible for managing access to surface and groundwater in accordance with the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources*.

In addition, many community and business organisations have a role in the management of the catchment:

- The Small Farms Network was created in 2004 in partnership with Southern Councils Group (SCG), SRCMA and NSW DPI. The Small Farms Coordinator position (now funded by the South East LLS) provides support to community groups and landholders to access services and advice on sustainable land management. The Network has been active in the organisation and delivery of training on sustainable land management and the delivery of on-ground projects within the Minnamurra River Catchment;
- Landcare Illawarra is a community based organisation which has been active in weed management and revegetation activities on private land within the catchment;
- Conservation Volunteers Australia is a community based organisation which has been active in weed management and revegetation activities on Council land within the catchment;
- The University of Wollongong has undertaken many research projects within the catchment;
- Boral (operators of Dunmore Quarry) undertakes land rehabilitation and monitoring within the quarry site; and
- KMC established the Estuary Management Committee to assist with the preparation of the 1995 EMP (now disbanded) and has also established a current Estuary Management Plan Review Committee consisting of community representatives.

The two councils, government agencies, statutory bodies and community groups are implementing management programs in parallel with the preparation of this CZMP. Many of these initiatives are related to the management of the Minnamurra River Estuary, foreshore areas and coastline. As there are many organisations responsible for land use management in the study area, effective coordination will be required to address management issues. This CZMP will complement and inform existing and proposed plans of management.

2. EXISTING MANAGEMENT PLANS

2.1 Estuary Management Plan

The study area for the 1995 EMP and 2003 EMP Review extended from the entrance at Minnamurra Point to Factory Lane in Terragong Swamp. The study also considered the ecological systems and catchment-wide land use matters that could affect the management of the estuary. The principal issues considered in the 1995 EMP were (PBP, 1995a):

1. Riverbank erosion and sedimentation – Charles Avenue foreshore, breaching of entrance barrier, sedimentation opposite Minnamurra Bends, bank erosion at the sharp meander, upstream of the sharp meander, the channel through Terragong Swamp and sedimentation associated with cleaning of ditches;
2. Water quality – tip leachate, leaking septic systems and farming practices;
3. Conservation generally;
4. Road transport corridors – Princes Highway bypass;
5. Entrance stability;
6. Land use management; and
7. Recreation.

Issues 1 and 2 were considered to be more important than issues 3 to 7. The 1995 EMP provided a list of prioritised management objectives addressing the above issues and recommended the following actions:

- Tombolo (rock groyne) beach protection along Charles Avenue;
- Water quality data collection program;
- Define extent of wetland conservation areas and prepare an information program;
- Study flooding aspects and options on Terragong Swamp;
- Reshape channel and/or incorporate drop structures in channel through Terragong Swamp;
- Map wildlife conservation habitats;
- Establish inventory of heritage items;
- Upgrade public picnic and rest stop areas;
- Landscape public reserve areas;
- Develop appropriate land use planning controls;
- Entrance stability study;
- Vegetate dunes to enhance entrance stability; and
- Prepare principles for road transport corridors.

Key points from the 2003 EMP review are discussed below (Panayotou, 2003):

- Following community consultation, timber groynes were installed along Charles Avenue instead of the proposed rock groynes to provide a softer management approach;
- Active erosion along the old Princes Highway (near the picnic and parking area) had been stabilised but further erosion was noted upstream of that area;

- Two grade control structures (rock ramps) were built between Browns Lane and Factory Lane to stabilise the banks along the Swamp and reduce bank slumping. Erosion was still occurring between the two structures;
- Research into sedimentation of the estuary found that strong tidal flows and flooding would prevent closure of the entrance mouth;
- Council-funded University projects were undertaken to research water quality related to:
    - Production of a flushing model for the estuary (Monash University field measurements in 1999);
    - The constructed wetland at Gainsborough residential development – the performance of the treatment pond system was found to be successful (Roso, 1998);
    - Another study (Hensen, 1998; cited in the CMS, Reinfelds, 1999) found nutrient levels increasing downstream along Terragong Swamp; and
    - Monitoring of Rocklow Creek showed high levels of nutrients.
- Groundwater monitoring associated with the waste disposal sites continued;
- KMC prepared a stormwater management plan in 1999;
- Mapping of changes to wetlands using historical aerial photographs (Chafer, 1998; cited in the CMS, Reinfelds, 1999);
- Wetland distribution and monitoring program (Wollongong University);
- Both Councils prepared LEPs and planning controls addressing land use practices;
- A community lands plan of management was prepared for Gainsborough, Minnamurra Headland and Minnamurra River Reserves;
- KMC acquired land for environmental protection as a wetland buffer zone (at the second meander bend of the river);
- SCC established an inventory of heritage items;
- The *Remnant Vegetation and River Corridor Action Plan for the Minnamurra Catchment* (Harris, 2002) was prepared;
- A report on the vegetation assemblages of the catchment was prepared (Black, 2001);
- The Princes Highway bypass was constructed in the early 2000s across Terragong Swamp; and
- Some recreation areas were upgraded including Trevethan Reserve and Highway roadside areas.

The only issue from the 1995 EMP which was not addressed in 2003 was flood management on Terragong Swamp.

Many of the actions from the 2003 EMP are ongoing and remain relevant to the future management of the estuary. This CZMP includes some of these ongoing actions (with some modifications).

2.2 Other Management Actions

The various land managers continue to implement management actions within the catchment which complement the work undertaken by Council as part of the 1995 EMP. These include:

- Killalea State Park – ongoing weed management, pest fauna controls, ecological surveys and social enterprise initiatives at Killalea State Park;

- Fisheries NSW – fish surveys and stocking (Bass);
- Terragong Drainage Union – spraying of weeds, cattle management and fencing along the drain;
- Southern Rivers Catchment Management Authority (CMA, now LLS) - riparian weed management, revegetation, erosion controls, farm improvements and landholder liaison;
- Small Farms Network - riparian weed management, revegetation, stock fencing, off-stream stock watering, dairy effluent management and landholder training;
- Private landholders – land management actions in the upper catchment;
- Landcare Illawarra - weed management and revegetation activities;
- Conservation Volunteers Australia - weed management and revegetation activities;
- The University of Wollongong has an ongoing research interest in the Minnamurra River Estuary including the implications of climate change; and
- Boral - land rehabilitation and monitoring as part of its quarry operations.

A 

B 

C 

D 

E 

F 

Figure 6: Completed on-ground actions from the 1995 EMP and 2003 EMP review

A – Timber groynes, Charles Avenue, B – Rock revetment – Riverside Drive, C - Rock ramp – Terragong Drain, D – rock revetment - Charles Avenue foreshore (D. Wiecek, 2014), E – fishing jetty and shared path, F – Swamp Road cycleway (D. Wiecek, 2014).

2.3 Summary of Completed On-Ground Actions

Completed on ground works are shown on the following figures and discussed in Appendix 2.

Figure 7: Locations of on-ground works implemented in the lower estuary

Figure 8: Locations of on-ground works implemented in lower Rocklow Creek catchment

Figure 9: Locations of on-ground works implemented around Minnamurra Bends

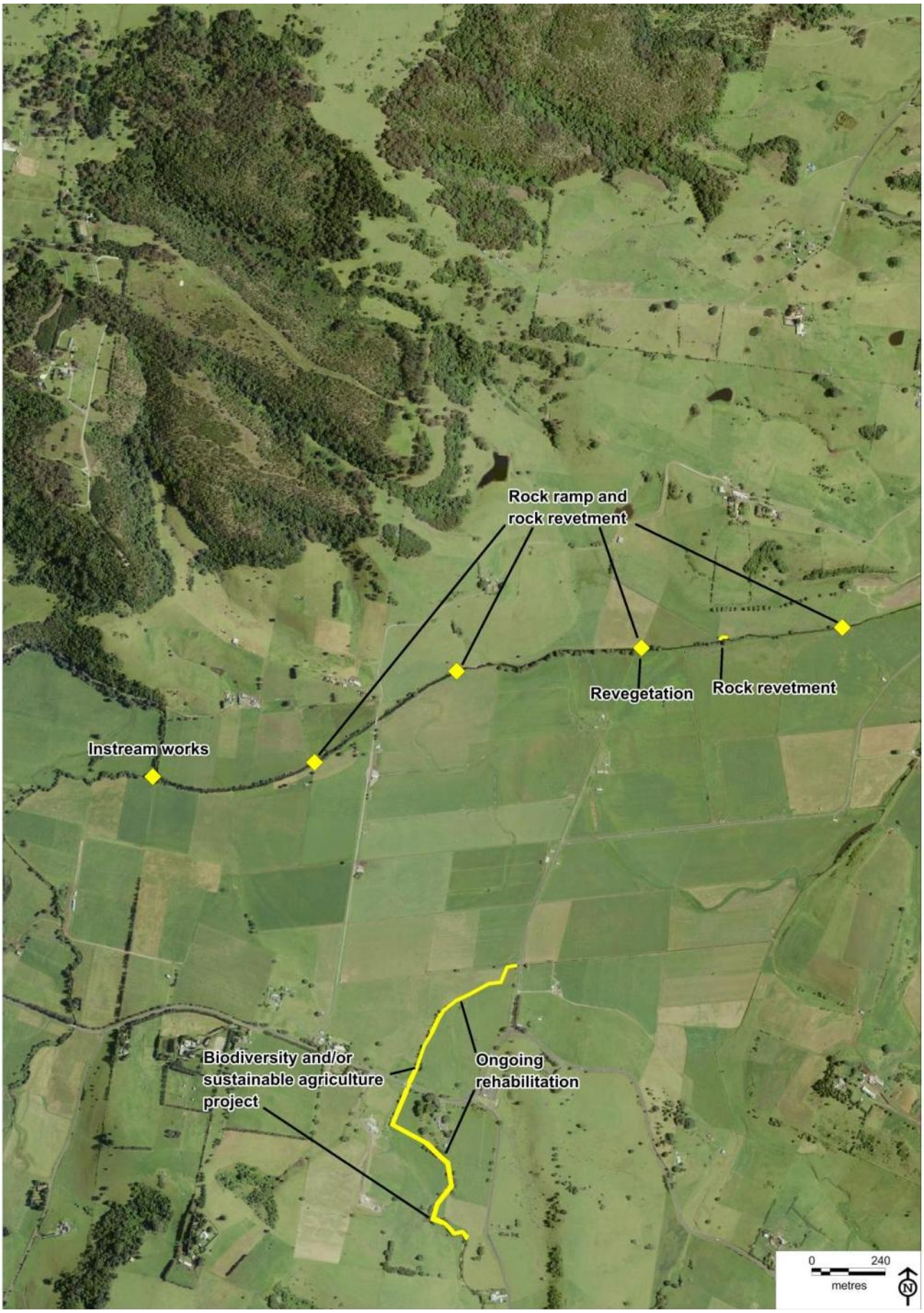


Figure 10: Locations of on-ground works implemented in mid-reaches of the Minnamurra River and Terragong Swamp

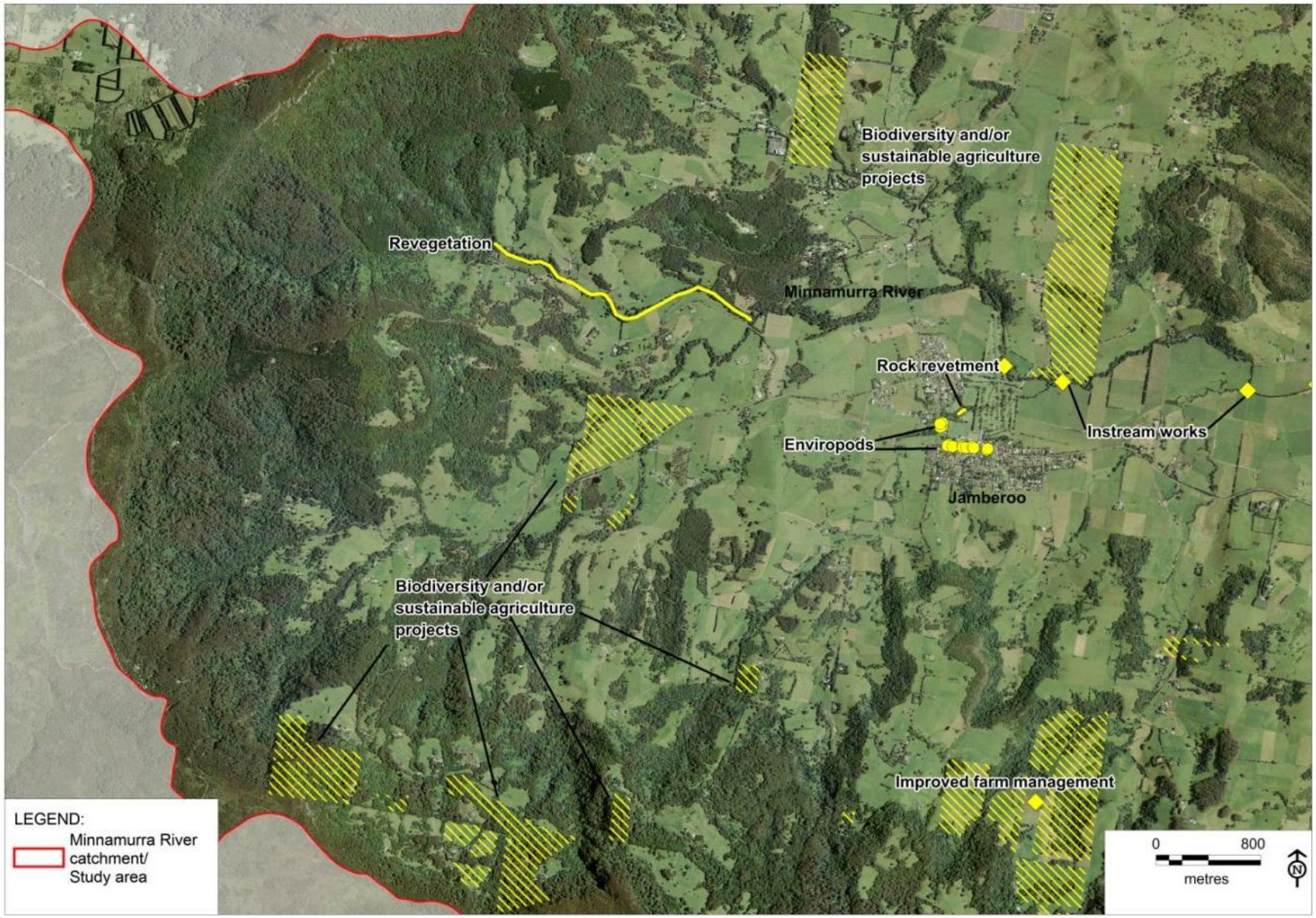


Figure 11: Locations of on-ground works implemented in upper catchment

3. STUDY AREA CHARACTERISTICS

3.1 Land Uses

3.1.1 Current Land Use and Zoning

Current land uses in the catchment are summarised in Table 2. The spatial distribution of land uses is shown in Figure 12.

Table 2: Minnamurra River Catchment land use (based on 2014 CERAT mapping provided by OEH)

Type	Description of land use category	Area (ha)	% of total catchment
Cleared	Cleared land, production forestry, dryland agriculture and plantations, intensive animal production, mining, waste treatment and disposal	140	1.2%
Conservation	Forest, nature conservation	539	4.6%
DryForb	Perennial and seasonal horticulture	5	0.0%
Grazing	Grazing land	6,719	57.3%
Irrig5	Irrigated modified pastures and cropping	32	0.3%
IrrTree5	Irrigated perennial horticulture	15	0.1%
River	Estuary/coastal waters	89	0.8%
Sand	Estuary/coastal sand	0	0.0%
Scrub	Nature conservation, native vegetation, grazing with natural vegetation	3,211	27.4%
TreeHort	Plantation forestry, cropping, perennial horticulture	2	0.0%
Urban	Urban land including rural residential areas	843	7.2%
Wetland	Marsh/wetland	124	1.1%
TOTAL		**11,719**	**100%**

Grazing is the dominant land use in the catchment occupying 57% of the land area and the majority of the lower catchment areas. Vegetated areas comprise a total of 33% of the catchment including Scrub, Conservation and Wetland categories. This vegetation is located along the upper catchment, elevated land in the mid-catchment, and wetland areas in the lower catchment east of the Princes Highway. Urban land accounts for just over 7% of the catchment land area with major urban centres in Minnamurra, Shell Cove, Kiama Downs and Jamberoo. Rural residential areas are also evident in the catchment. Cleared land (not including urban areas) comprises 1.2% with the main areas in the northeast corner of the catchment, occupied by quarries and waste disposal operations. Area of intensive agricultural production including irrigated crops make up a relatively small proportion of the catchment (approximately 0.5%) and are scattered throughout the catchment.

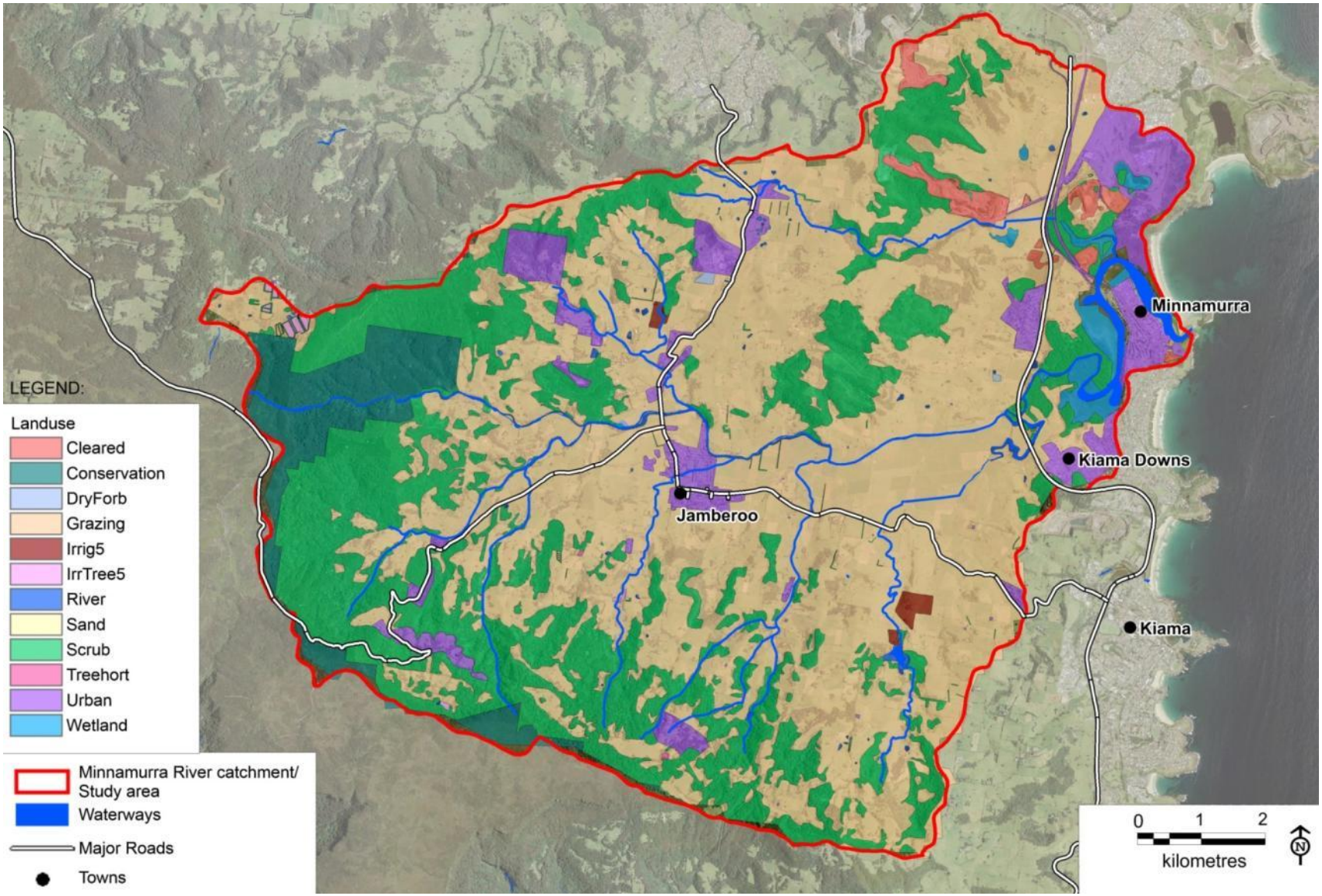


Figure 12: Major land uses of the study area

Source: CERAT land use modelling supplied by OEH

LEPs are the primary tool for managing the development and utilisation of land within an LGA in line with the process set out in the *Environmental Planning and Assessment Act 1979*. A LEP is a legal instrument that imposes standards to control development. LEPs are also used to reserve land for open space, schools, transport or other public purposes as well as to control advertising and protect trees and vegetation and generally comprises a written document and accompanying maps. There is potential for research projects to investigate the impacts on estuary health due to potential land use changes including increased urbanisation, urban consolidation, agricultural intensification and agricultural diversification as well as sea level rise. This research could provide important contextual and technical information for consideration in the LEP review process for both Kiama and Shellharbour Councils.

3.1.2 Urban Development

Urban areas within the estuary catchment include Minnamurra, Kiama Downs and the Gainsborough residential estate in the lower catchment and Jamberoo in the mid-catchment area. The urban residential areas are zoned low density residential under the KMC LEP 2011. The *Kiama Urban Strategy* (KMC, 2011a) identified the need for urban infill to provide for the anticipated population and dwelling growth in the LGA. A small amount of medium-density residential zoning is included in Kiama Downs along Meehan Drive with the majority provided for in Kiama, Gerringong and Gerroa (outside the study area). Small areas to the north of the Princes Highway in Kiama Downs and around Jamberoo have also been identified as potential urban expansion areas in the *Kiama Urban Strategy* (KMC, 2011a). Given the relative scale of urban development in the Minnamurra River catchment, it will be extremely important that any new urban subdivisions have high standards of erosion and sediment controls during the construction phase as well as high level stormwater treatment controls to minimise pollutant and nutrient runoff to the river post-construction.

Some areas of undeveloped land are also identified in the SCC LEP 2013 for low density residential development west and north-east of the Shell Cove golf course (SCC, 2013).

While future land development within the Minnamurra catchment is limited, the surrounding regions (particularly in Shellharbour LGA) are significant urban expansion areas which are expected to increase visitor numbers to the Minnamurra River Estuary in the future.

3.1.3 Agriculture

Rural activities occur on much of the mid-upper catchment including the Jamberoo Valley and Terragong Swamp. The Jamberoo Valley contains high value productive farming land with much of the catchment foothills classed as useful agricultural land with soils of naturally high fertility (Reinfelds, 1999). Historically, agricultural land use, particularly dairying has dominated land use in the Jamberoo Valley. Dairy cattle numbers in the Kiama LGA peaked in 1962/63 at 15,500 head and declined to a little under 9,000 head by 2001 due to low returns, the loss of markets, high rates of farmer exit from dairying and the removal of market support measures (Gill *et. al*., 2008). Farmers have responded to these pressures by increasing herd size, increasing fodder production and beef cattle grazing, increasing intensity of inputs, increasing milk production, or by exiting the industry. There are now only one or two active dairy farms on Terragong Swamp.

3.1.4 Recreation

The Kiama area is a popular tourist destination. Water and land-based recreational activities in the Minnamurra River estuary and catchment include sight-seeing, walking, nature appreciation, swimming, fishing and boating. The estuary catchment includes golf courses at Minnamurra and Shell Cove. The Killalea State Park to the north of the river provides a variety of recreational activities including surfing, fishing, camping, walking and picnicking. The Minnamurra River estuary, particularly around the entrance, has seen an increase in visitation in recent years, with issues raised during consultation relating to conflict

between boating in the estuary and other more passive recreational pursuits. This is likely to be due to population growth in adjoining areas of Shellharbour and increasing awareness in the region of recreational opportunities and scenic amenity.

Recreational areas in the Jamberoo Valley include the Jamberoo Golf Course, Budderoo National Park, Jamberoo Action Park, Minnamurra Falls, Minnamurra Rainforest and the Illawarra Fly Treetop Walk.

3.1.5 Conservation Areas

The study area includes part of Killalea State Park (Figure 13) which is Crown Land managed by the Killalea State Park Trust. The park is managed to provide for a range recreational activities while conserving the natural environment and cultural resources. It encompasses approximately 265 ha and contains a small camping area with a bunkhouse, walking tracks, wetlands, rainforest, access to Minnamurra beach and 'The Farm' and access to the Minnamurra River Estuary. A plan of management for Killalea State Park was prepared in 1998 and is currently being updated.

There are two National Parks/Nature Reserves in the upper Minnamurra River Catchment (Figure 14) - Budderoo National Park in the west of the catchment and Barren Grounds Nature Reserve in the south west.

Budderoo National Park spans an area of 7,120 ha with approximately 480 ha located within the Minnamurra River Catchment. The park was created in 1986 and came under the management of National Parks and Wildlife Service (NPWS) which started an extensive long-term weed eradication and rainforest rehabilitation program. Barren Grounds Nature Reserve was created in 1956 and covers an area of 2,024 ha with approximately 124 ha situated within the Minnamurra River Catchment. These areas are managed by NPWS under the Budderoo National Park, Macquarie Pass National Park, Barren Grounds Nature Reserve and Robertson Nature Reserve plans of Management.

SEPP 14 wetlands cover approximately 260 ha within the lower Minnamurra River Catchment (refer Section 6.4.3).

Figure 13: Killalea State Park

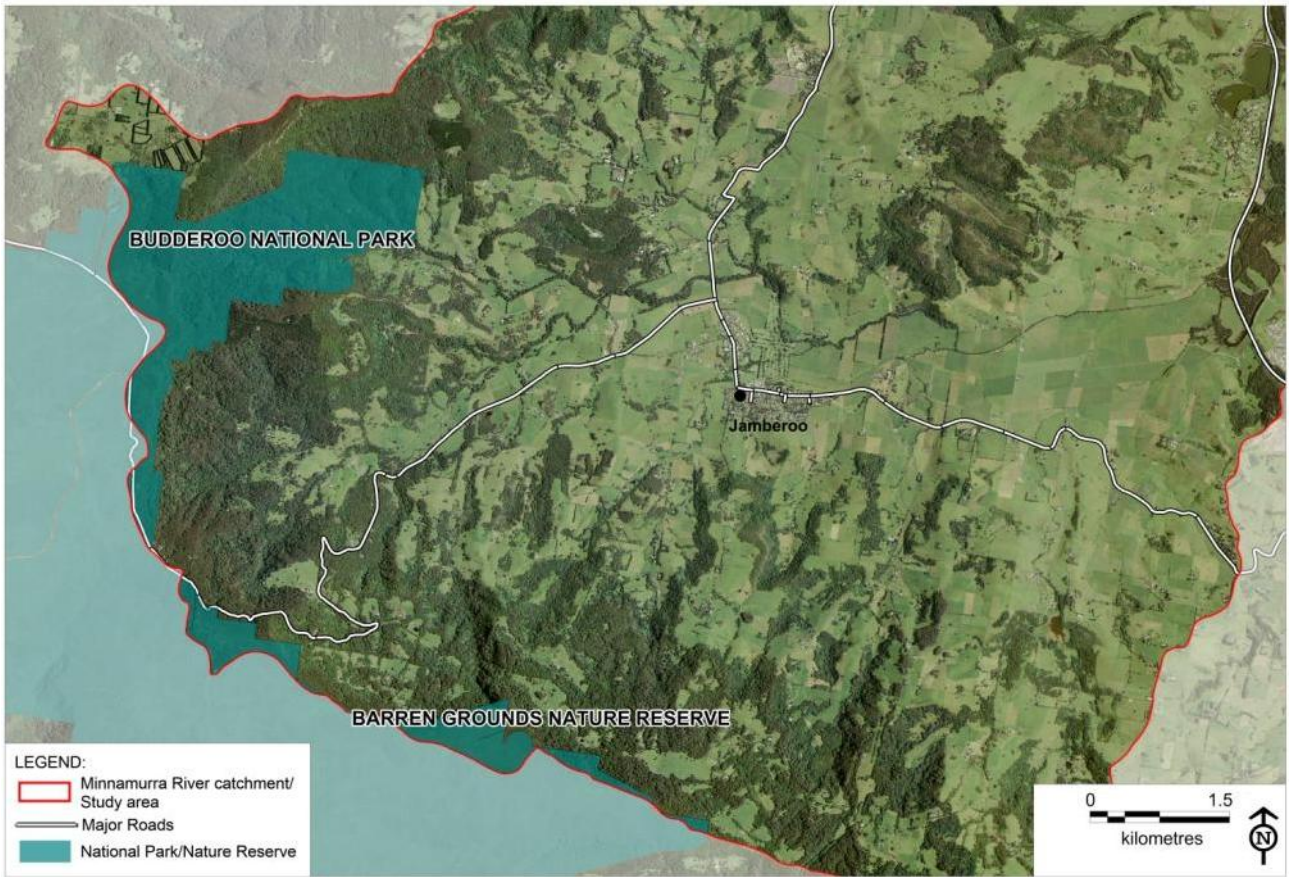


Figure 14: National Parks and Nature Reserves within the Minnamurra River Catchment

3.1.6 Solid Waste Management

Two waste depots are located within the Minnamurra River Catchment (Figure 15), the Minnamurra Recycling Facility (Minnamurra Depot) and the Dunmore Recycling and Waste Disposal Depot (Dunmore Depot).

The Minnamurra Depot is situated on the northern side of the Minnamurra River Estuary between Riverside Drive and Rocklow Creek (Figure 15) and was owned and operated by KMC as a Solid Waste Class 1 Landfill until its closure in 2006. Between 1945 and 1998 the landfill also accepted 'night soil' waste (liquid pump-out sullage from on-site sewage management systems). The Minnamurra Depot covers an area of approximately 20 ha and includes (E2W, 2012):

- A rehabilitated elevated capped land fill mound ranging from 1 to 14 m AHD;
- A weighbridge and administration building;
- KMC truck parking area;
- KMC storage sheds;
- Dog pound; and
- An historic night soil deposit.

Since 2006 the Minnamurra Depot has accepted green waste and small amounts of recyclables under operation by KMC. All other general waste materials from the KMC area are diverted to the Dunmore Depot. Current site operations include (E2W, 2012):

- Activities and maintenance of landfill mound, mulching, material storage and landscaping;

- Recycling transfer station;
- KMC storage;
- KMC machinery wash bay; and
- Above ground fuel storage.

Figure 15: Waste depot locations

The Dunmore Depot is situated approximately 500 m north of Minnamurra Depot (on the opposite side of Rocklow Creek) on Buckleys Road, Dunmore (Figure 15). The Dunmore Depot was established in 1945 and SCC has managed the site since 1983. Before the mid-1980s there was no control on the disposal locations or the types of waste disposed of at the landfill. In the mid-1980s the landfill operations became better controlled (Environmental Earth Sciences, 2013) and is now operated under two Environmental Protection Licences (EPL) administered by the EPA.

Historically, night soil and grease traps were deposited at the site with approximately 600,000 L/week of effluent disposed at the site until 1989 when these operations ceased (Environmental Earth Sciences NSW, 2012). Ash material and spent dolomite from a steel mill was also disposed of at the site and due to the uncontrolled nature of disposal at the landfill prior to the mid-1980s, other industrial wastes are likely to have been dumped at the site (Environmental Earth Sciences NSW, 2012).

Currently, the site accepts approximately 49,600 tonnes per annum of waste (in 2010) from both the Shellharbour City and Kiama Municipal Council LGAs including (Golder Associates, 2010):

- Mixed municipal waste;
- Commercial and industrial waste including asbestos;
- Virgin excavated natural material (VENM);

- Concrete, rock, brick and tile;
- Construction and demolition waste; and
- Green and wood waste.

The typical land fill operation process is (Golder Associates, 2010):

- Vegetation and top soil stripping (top soil being used for landfill cover);
- Surface sand extraction;
- Shallow sand extraction;
- Deep sand extraction;
- VENM back filling;
- Construction of clay liner constituting compacted clay overlain with a geosynthetic clay liner and high density polyethylene liner;
- Leachate collection system;
- Solid waste landfilling;
- Covering of waste;
- Site capping and revegetation; and
- Rehabilitation.

In addition to the landfill at the site, SCC also undertakes sand mining operations in the south western area of the site. A larger scale sand mining operation was also conducted directly adjacent to the east of the site, however, operations here ceased in 2007 and this area is now currently utilised by Dunmore Resources and Recycling (Environmental Earth Sciences, 2012).

3.1.7 Extractive Industries

There are two quarries operating within the Minnamurra catchment at Dunmore and Albion Park and sand mining operations at Dunmore (Figure 16).

The Dunmore Quarry is located approximately 2.5 km north-west of Minnamurra within the Rocklow Creek catchment and within the SCC LGA (Figure 16). Boral operates the quarry within its total land holding of 8.5 km^2 to produce a range of fine and coarse aggregates, which are used mainly in concrete and asphalt production (DIPNR, 2004). The resource at the quarry is latite, a fine grained volcanic rock similar to basalt. The quarry is regulated by an EPL issued by the EPA under which Boral is licenced to extract a maximum of 2 million tonnes of material.

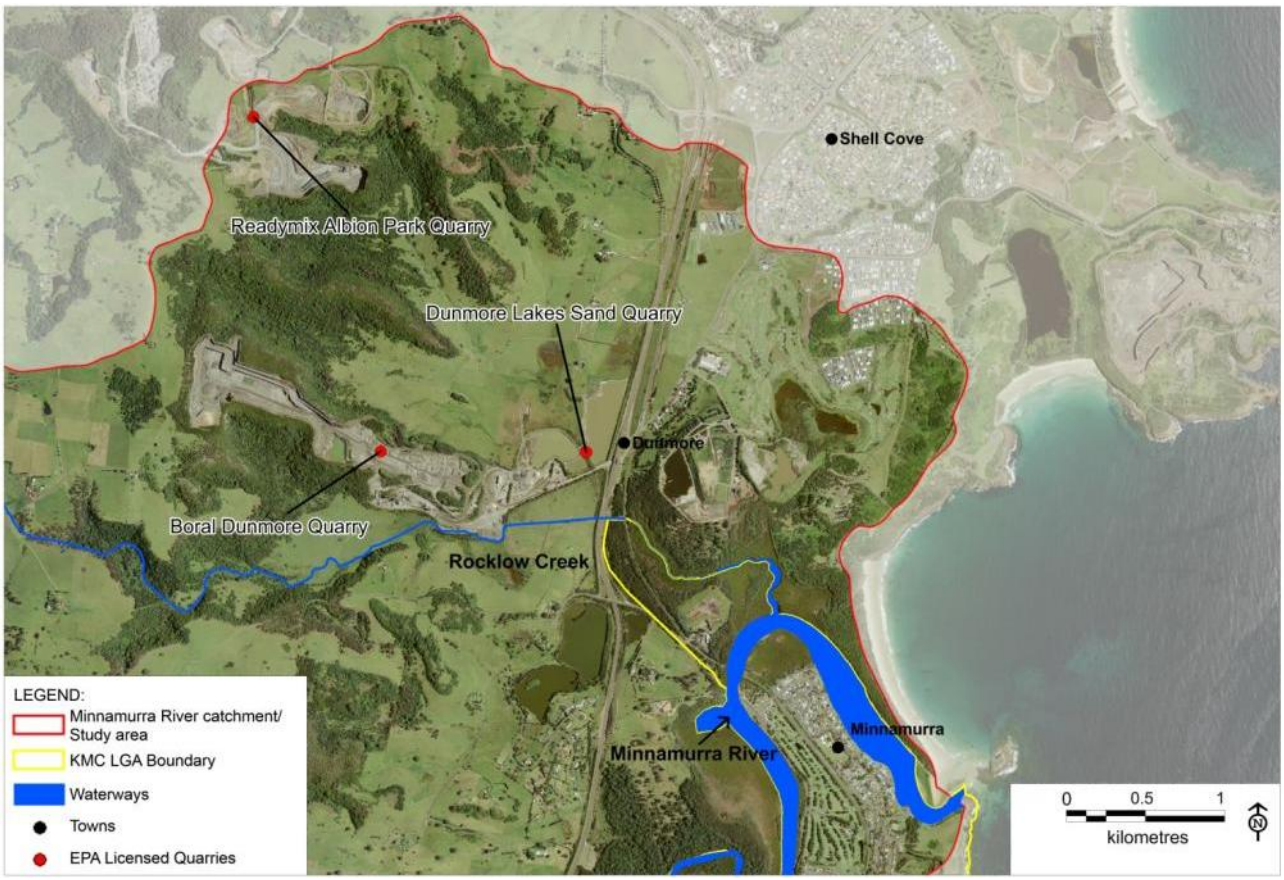


Figure 16: Extractive industry locations

The major on-site activities of the quarrying operation at the Dunmore Quarry include (DIPNR, 2004):

- Extraction at the original Dunmore quarry and the Croom Farm and Rail Infrastructure Corporation areas;
- Processing plant, including staged crushing and screening facilities;
- Quarry product stockpile areas;
- Quarry fines stockpile areas;
- Concrete batching plant;
- Office, car park and weighbridge;
- Workshop/maintenance area;
- Rail siding for the loading of product;
- Laboratory;
- Water control structures including dams, pumps and water tanks;
- Explosive magazine; and
- Site meteorological station.

There are several other latite quarries within the vicinity of Albion Park (Figure 16). The Holcim Albion Park Quarry is partially located within the Minnamurra River Catchment approximately 1 km north of the Dunmore Quarry.

3.2 Summary of Estuary Processes

3.2.1 Physical Characteristics

The key physical characteristics of the Minnamurra River Estuary are outlined in Table 3.

Table 3: Minnamurra River Estuary physical characteristics

Characteristic	Data	Notes
Catchment area	117 km^2	Refer Figure 5.
Estuary area	1.9 km^2	Includes areas mapped as open water, mangrove and saltmarsh areas.
Estuary volume	1,516 ML	Based on areas at 0.6 m AHD (Roper *et al.,* 2011)
Average depth	1.0 m	Estimated by dividing the total volume at 0.6 m AHD by the total surface area of the estuary including mangrove areas but excluding saltmarsh (Roper *et al.*, 2011)
Estuarine Macrophytes		
Seagrass extent:	0.184 km^2	Based on 2009 mapping
Saltmarsh extent:	0.298 km^2	
Mangrove extent:	0.946 km^2	

Sources: Roper *et al*. (2011), 2009 mapping of estuarine macrophytes

3.2.2 Geomorphology

The Minnamurra River Estuary can be divided into three main geomorphological zones - marine dominated zone, estuarine zone and riverine channel/alluvial plain zone (Figure 17). A summary of the characteristics and processes of each zone is provided below.

The marine dominated zone extends from the entrance to the northern point of the first river meander opposite Rocklow Creek and includes the Minnamurra Beach sand barrier. The river entrance is bound from the south by the 20 m high rocky Minnamurra Point and is flanked from the north by a 1.6 km long coastal sand barrier (spit). On the seaward side of the entrance is a large shallow ebb tide delta (sandbank) that extends east towards Stack Island. Just on the inside of the entrance is a relatively large shallow flood tide delta (sandbank) that is often exposed during lower tides. The size and shape of both sandbanks fluctuates according to tidal, flood and wave conditions.

The main channel from the entrance generally follows the eastern bank adjacent to the sand barrier to the first meander. The western side of this barrier is well vegetated and is considered to be stable. The main channel near the entrance is prone to change and has a tendency to split around the flood tide delta before re-joining at the entrance. Part of the main flow splits and flows along the western bank which is exposed to wave and tide processes which can lead to erosion along this bank. Intertidal flats extend upstream of the flood tide delta along the western side.

The estuarine zone extends from Rocklow Creek upstream to Swamp Road bridge and north and south to the bedrock limit encompassing the majority of the intertidal and wetland environments of the estuary. This zone exhibits several geomorphological features including barriers/back-barriers, the main channel with three meander bends, point bars, intertidal flats, mangroves, saltmarsh, creeks and backwaters. Generally, erosion is occurring on the outside of the meander bends (particularly the first meander), with deposition

occurring on the inside forming point bars. In the straights between the meanders, sediment is deposited forming intertidal sand flats. Towards the upstream end of the estuarine zone, the original channel was straightened in the floodplain, leaving cut-off embayments.

The riverine channel/alluvial plain zone extends upstream from Swamp Road bridge encompassing the entire floodplain up to the township of Jamberoo. The main channel of Minnamurra River in this reach is an artificially straightened, narrow deep channel. The floodplain (Terragong Swamp) was drained for dairy farming and the main channel of the river shifted to the northern side of the swamp to where it is located today. Relicts of the previous meandering channel are visible as cut-off embayments on the floodplain, south of the current channel. The river channel in this section was enlarged in the 1950s and 1970s.

The upper catchment areas include the headwaters of the Minnamurra River and tributaries, the Illawarra escarpment and coastal plain.

Figure 17: Minnamurra River Estuary geomorphological features

A - Minnamurra Beach sand spit and flood tide delta, B - Vegetation and intertidal sand flats along the western bank of the straight between the first and second meander (D. Wiecek, 2014), C - Alluvial floodplain and artificially straightened channel (D. Wiecek, 2014), D – floodplain and Illawarra escarpment.

3.2.3 Entrance Stability

The stability of the Minnamurra River entrance was raised as an issue by the community in the 1995 EMP. The community was concerned that the entrance may become shallower and eventually close. The 1995 EMP noted that:

- A 'permanently open' entrance would be expected with such entrance morphology;

- There are no anecdotal or written records of the entrance having closed (refer to Appendix 3 for an analysis of historical aerial photographs);
- During sustained periods of low swell activity, it would be expected that sediment deposition would occur in the lee of Stack Island;
- During storms and floods this material would erode and then re-accumulate during 'normal' conditions; and
- An entrance bed level that broadly fluctuates with seasons and storms constitutes the natural behaviour of the entrance.

Figure 18: Minnamurra River entrance and Stack Island (view from Minnamurra Point)

A study of the morphological change in the Minnamurra River Estuary was undertaken by Bessell (2002). Conclusions are summarised below:

- The processes of shoal development and erosion are a cyclic phenomenon which is dependent on the climatic influences of a particular period;
- During drier periods, sands are transported into the entrance via tidal currents and swash deposition during large wave events and are eroded during wet periods (flood flows);
- The quantity and velocity of the fluvial flow entering the estuary is sufficient to be a dominant influence over sedimentation, hence is able to naturally scour an entrance channel that remains permanently open; and
- The concerns of the growth of the sand spit and tidal shoal, which would lead to the eventual closure of the estuarine mouth, are unwarranted.

3.2.4 Soils

Soils of the Minnamurra River Catchment are summarised in Reinfelds (1999) and are outlined below:

- Soils on the plateau at the very headwaters of Minnamurra River are generally infertile organic sands;
- Escarpment soils are dominated by landslip colluvium, stoney lithosols with areas of basalt derived krasnozems;
- The mid-catchment is dominated by krasnozems, red and brown podosols with the foothills dominated by yellow podzolic soils;

- Land around waterways at the base of the escarpment is dominated by coarse alluvial soils grading to finer alluvial soils further downstream on the floodplain; and
- Podzols and siliceous sands occur on the coastal dune and hind-dune areas.

Generally, fine textured soils high in clay have low soil erodibility levels as do coarse textured soils high in sand associated with the lower Estuary. Medium textured soils high in silt (associated with the floodplain and Terragong Swamp) are generally the most erodible. The former natural course of the River in the lower reaches of the Terragong Swamp flowed atop a column of vertically accreted gravel and sand directly beneath the channel. Diversion of the channel to the adjacent fine grained alluvium is considered to contribute to channel bed incision and associated bank erosion (Reinfelds, 1999). Erosion hazards for the Kiama soil landscapes are rated as moderate-high for concentrated flows and extreme for non-concentrated flows (Hazelton, 1992).

3.2.5 Estuarine Hydrodynamics

Hydrodynamic processes operating in the Minnamurra River can be separated into two aspects, fluvial aspects and tidal aspects.

Fluvial

The Minnamurra River Catchment is approximately 120 km^2 and roughly triangular in shape. Rocklow Creek, the major sub-catchment (approximately 24 km^2) draining the northern portion of the Minnamurra River Catchment enters the estuary approximately 2 km from the Minnamurra River entrance. A large number of smaller streams drain from the south and west into the Minnamurra River, most of them discharging upstream of Swamp Road bridge. The river has an 80^{th} percentile flow of 8.0 ML/day and a 50^{th} percentile flow of 25 ML/day at Browns Lane (NSW Office of Water, 2015).

Figure 19: Rocklow Creek near the confluence with Minnamurra River (D. Wiecek, 2014)

Flooding is a common occurrence on the Minnamurra River floodplain. Floods have been associated with rainfall events located in different parts of the catchment. Flood levels are higher in the upper catchment and at their lowest in the lower estuary and the entrance. The average maximum flood level on Terragong Swamp is approximately 4.0 m AHD with a maximum of 4.9 m AHD recorded in the 1950s at the eastern end of the swamp. During flood events the Minnamurra River floodplain has a major impact on reducing peak flows with flood flows exiting the floodplain being approximately 15% smaller than those entering the swamp (PBP, 1995b).

Tidal

The tide level range (the difference between high and low tide) is at its largest at the entrance and remains stable for approximately the first 6 km of the estuary before decreasing sharply upstream to the tidal limit (approximately 9.6 km from the entrance on Minnamurra River). Peak tidal velocities in the upper and lower estuary occur during the ebb tide with peak velocities in the mid estuary occurring during the flood tide. Overall, tidal velocities are generally higher in the lower estuary (PBP, 1995b).

Tidal circulation processes are dominant in the estuary. During periods of dry weather, ocean water (typical salinity of 35 ppt) penetrates almost 3 km upstream from the entrance and water with salinity as high as 20 ppt penetrates upstream of Swamp Road bridge into the formalised channel of Terragong Swamp. During wet weather, the salt is efficiently flushed back down the river. Saline water returns to the estuary relatively quickly after a flood event with the 20 ppt interface penetrating approximately 3 km from the entrance within two days of an event (PBP, 1995b). Information from the 1992 tidal gauging study (MHL, 1992) is provided in Appendix 4.

3.2.6 Sedimentation

Minnamurra River Estuary sediment types are discussed in the 1995 EMP and are outlined below:

- The proportion of heavy minerals (characteristic of marine sands) in the estuarine bed sediments decreases with distance upstream while the proportion of rock fragments (characteristic of fluvial sands) increases with distance upstream with a significant increase approximately 6 km from the mouth, suggesting this is the dominant area of marine-to-fluvial transition;
- Shell fragments are found throughout the estuary, as far upstream as 10 km from the entrance;
- The sediment from the entrance to the sand bar approximately 4.5 km upstream is generally well sorted sand containing rounded quartz grains and a relatively high proportion of shell and heavy minerals;
- The sediment upstream from approximately 6.5 km upstream from the entrance contained large clay clumps, likely resulting from bank collapse. The sediment profile generally coarsened with depth below bed level, had a high carbonate content, a large proportion of organic and charcoal material, a relatively high silt and clay content and poor sorting;
- The sand bars in the upper estuary appear to be influenced by flood flows; and
- There was no indication that sediments from the upper reaches of the estuary actively deposit in the Minnamurra Bends area.

Estuarine bed sediments from the entrance to the mid-upper estuary (the meander bends) are generally dominated by marine sediments. From the mid-estuary upstream, bed sediments are dominated by fluvial sediments, however, evidence of marine sands were found as far as 10 km upstream from the entrance (PBP, 1995b).

Estuarine sedimentation processes occurring within the Minnamurra River Estuary were also discussed in the 1995 EMP and are summarised below:

- Since the formation of the barrier dunes at the end of the last ice age and subsequent infilling of the inlet, the river has meandered across the valley creating the floodplain and swamps. Fluvial sediments have been spread across the floodplain over the top of the marine sands. Re-working of these fluvial sediments and erosion of the barrier dunes by flood flows and tidal movements have contributed to the current features of the estuary channel;
- Sediment load contributed from the erosion at the ‘Minnamurra Bends’ meanders and the erosion of marine sands west of Wants Hill is considered to be the most significant sediment loads to the estuary;

- Sediment from the 'Minnamurra Bends' area is deposited in the straight between the two bends and downstream adjacent to the golf course and upstream of the Riverside Drive bridge. These shoals vary in size and shape according to flow conditions. Sediments are deposited there during flood events and re-worked by tidal flows in between flood events; and
- The processes can be expected to continue in the future with the degree of sedimentation reflecting hydrodynamic influences operating within the estuary.

Panayotou *et al.* (2007) studied the rates and patterns of sedimentary infill in the Minnamurra River Estuary. Results from the study suggest that sediment accumulation in the Minnamurra River Estuary seems to be minimal with most sediment either being deposited from overbank flow into the upper intertidal and supratidal areas or flushed out to sea, therefore bypassing the estuary. Results from the assessment of recent sedimentation patterns of the estuary indicate that the Minnamurra River Estuary will not close but will continue to evolve into a more confined river channel with expanding intertidal environments and with continual flushing from both tidal and fluvial processes.

3.2.7 Climate

The region experiences a temperate climate with mild maximum and low minimum temperatures. Rainfall is not predominantly seasonal but the majority of rain falls in late summer through to early winter. Rainfall throughout the Minnamurra catchment ranges from an annual average of 1,508 mm at the Jamberoo (Druewalla) weather station in the upper catchment to 1,253 mm at the Kiama Bowling Club weather station (since 1897) on the coast (BOM, 2014). Average daily temperatures on the coast vary from 16°C to 25°C in summer and from 9°C to 18°C in winter (BOM, 2014).

Climate Change

Natural variations in temperature and rainfall in NSW are influenced by the naturally variable climate systems. Although there is natural variability in the climate, there is consensus among the majority of leading climate scientists that the rate and magnitude of climate change is outside the expected range of this natural variability. Climate change is an important consideration for strategic planning, particularly in coastal areas where the combined effects of sea level rise and increased storminess are considered key threats.

Sea level rise is anticipated to result in management issues including increased inundation of low lying lands, infrastructure and development and implications for drainage and flooding in urban areas. The issue of potential increased storminess is less well understood. It is generally anticipated that rainfall events will become more intense, even if average rainfall reduces, in response to climate change. This may result in effects such as more floods as well as greater capacity for erosion and runoff and pollution of waterways within the catchment. Locally, there will be impacts from climate change that are unavoidable such as sea level rise and changes to rainfall patterns and therefore long-term management planning needs to consider the likely changes to the estuary and the factors constraining adaptation to such change.

Average sea levels are projected to continue to rise throughout the 21st century. In 2009 the NSW Government released the *NSW Sea Level Policy Statement* and associated guidelines to assist coastal councils in their planning for sea level rise impacts. These guidelines indicated that a mean sea level rise, relative to 1990 levels, of 0.4 m should be expected by 2050 and 0.9 m by the year 2100 and this was used as the basis for coastal planning. This broad policy was withdrawn in 2013, recognising that a single set of predictions may not satisfactorily reflect local conditions and that councils should adopt locally relevant projections as appropriate. In the absence of detailed localised studies, many NSW councils, including KMC and SCC continue to use the 2050 (+0.4 m) and 2100 (+0.9 m) projections provided in the rescinded *NSW Sea Level Policy Statement*, as the most appropriate basis for coastal planning and risk assessment.

4. COMMUNITY AND STAKEHOLDER CONSULTATION

KMC is committed to open and transparent communication with the public and government agencies in order to ensure that the community's views are appropriately reflected in strategic planning for the LGA. Community and stakeholder consultation is also a key component of the CZMP development process.

Extensive consultation has been undertaken during the preparation of the 1995 EMP and other studies including the 1999 Catchment Management Study, 1999 Stormwater Management Plan and Jamberoo sewerage scheme investigations (undertaken by Sydney Water).

Stakeholder consultation was also undertaken during preparation of this CZMP including (refer Appendix 5):

- KMC established an EMP Review Committee to oversee the preparation of this CZMP. The Committee consists of five community representatives who were identified through a call for expressions of interest, as well as two Kiama Council officers, one Shellharbour Council officer and three Kiama Councillors. In addition, representatives from the following organisations have met with the Committee to discuss the CZMP development, current management actions and issues:
    - KMC - Environment Services Department;
    - SCC;
    - University of Wollongong;
    - Department of Primary Industries - Fisheries NSW;
    - Office of Environment and Heritage;
    - Local Land Services;
    - Killalea State Park;
    - Terragong Drainage Union;
    - Boral Quarrying/Dunmore Sand and Soil;
    - Jamberoo Golf Club; and
    - Jamberoo Residents and Ratepayers Association.
- Representatives from other agencies who were not available to attend the meeting were consulted separately (RMS, Office of Water, Illawarra Landcare and Conservation Volunteers Australia).
- A webpage on Council's website describing the project and consultation activities;
- A meeting with the EMP Review Committee at Kiama Council offices on 22 October 2014 to discuss issues, ideas and management priorities;
- A field trip with representatives of the Stakeholder Reference Group on 23 October 2014 to observe issues and discuss management priorities;
- KMC conducted a community survey to identify community values and issues;
- Ongoing liaison and correspondence with community groups and government agencies; and
- Presentation of the Draft CZMP to the Stakeholder Reference Group.

The main theme raised by the community stakeholders was the desire to protect the existing natural character and beauty of the area and maintain the highly valued recreational opportunities. The key concerns raised through the community survey were:

- Waterway safety and conflicts between passive recreation activities (swimming, snorkelling, fishing etc.) and motor boats/jet skis;
- Weed infestation on the spit, along the Minnamurra Bends and Gainsborough path;
- Lack of public walkways/cycle paths along foreshore or clear walking tracks along spit;
- Boat wash;
- Dog access on beaches;
- Impacts from waste management facilities;
- Farmland/agricultural runoff – chemical use, cattle access, grazing of riparian zone, runoff;
- Erosion of banks due to vegetation clearing;
- Impacts of previous residential developments and urban development pressures;
- Poor condition of boat ramps, poor parking and litter;
- Waste/litter including silage wrap in the river;
- Need for improved waterway access for kayaks;
- Changes in vegetation of the spit;
- Foxes;
- Fallen trees in the river instigating bank erosion;
- Rocks along Charles Avenue;
- Over-fishing and collection of bait;
- Golf course chemical use;
- Impacts of climate change (sea level rise, storm surges, flooding);
- Impacts of upstream developments and land use activities;
- The risk of entrance closure/sedimentation and shallowing at the entrance; and
- Sand mining.

Other concerns raised by members of the Committee are:

- Expansion of mangroves along the Charles Avenue foreshore and impacts on access and views;
- The observed loss of seagrass in the lower estuary;
- The impact of runoff from upstream developments and activities;
- The increase in visitors to the area during weekends and holiday periods and the associated impacts (e.g. rubbish, parking) and conflicting waterway uses and safety concerns;
- Expansion of urban areas (including Shell Cove) and further increase in visitors to the estuary;
- Land use practices and impacts on estuary health;
- The potential increase in flooding due to new developments;
- Slumping of banks along Terragong Drain;

- The lack of riparian vegetation within the mid and upper catchment including the main tributaries; and
- Impacts of poor riparian condition, in stream condition and water quality on native fish life cycles and migration, particularly Australian Bass.

The Final Draft CZMP will be placed on public exhibition for a minimum of 21 days (as per legislative requirement) in 2015. Formal (written) submissions on the Draft CZMP will be sought from the community and stakeholder groups. Submissions will be considered in the development of the Final CZMP.

5. SUMMARY OF ESTUARY VALUES

The key values of the Minnamurra River Estuary relate to preservation of the natural character, maintenance of productive farm land and extractive industries as well as the highly valued passive recreational opportunities. The estuary values have been derived from the information provided by stakeholders and previous studies. Further information is provided in the following sections.

- Social and Recreational Values:
    - Safe access to the river and foreshores for walking, cycling, swimming, paddling and fishing;
    - Clean water for recreational pursuits;
    - The lack of commercial development;
    - Scenic qualities of the river and escarpment;
    - The residential area of Minnamurra is closely associated with the Estuary and coastal environment; and
    - Residents value the lifestyle associated with living near the river and the coast and take a great deal of pride in the foreshore and river bank.
- Cultural Values:
    - The most prominent cultural values and sites around Minnamurra River stem from the Aboriginal history and significance of the estuary and surrounding area to the Aboriginal people. The study area includes landscapes that are known to be archaeologically sensitive for Aboriginal archaeological sites including shell middens, open campsites, artefacts scatters and shell middens with artefact scatters sites; and
    - European heritage sites related to cedar getting, farming and basalt extraction.
- Environmental Values:
    - Conservation areas include State Parks, National Parks and Nature Reserves;
    - The wetland areas support high biodiversity;
    - Many Endangered Ecological Communities (EECs) have been mapped within the study area. These communities have been determined to be facing a very high risk of extinction in NSW in the near future using criteria prescribed in the *Threatened Species Conservation Act 1995*;
    - The upper catchment supports areas that form part of the largest sub-tropical rainforest remnants in south-east NSW, with many species at the southern limit of their range in this location;
    - The Dunmore Hills area contains the largest and most intact remnants of native vegetation between the Illawarra escarpment and coast;
    - The catchment contains at least three plant species endemic to the Illawarra and many endangered and vulnerable species and populations as well as protected native plants;
    - The Minnamurra River Estuary has extensive areas of seagrass beds and mangroves. These are important habitat areas for fish and are highly valued nursery areas. A proportion of the riparian vegetation along the Minnamurra River Estuary has been mapped as SEPP 14 Coastal Wetlands;

- The Estuary supports a wide variety of fish species of commercial, environmental and recreational importance; and
- The Estuary supports a wide variety of shorebirds, waders and seabirds.

- Commercial Values:
  - The Minnamurra River Estuary is an important holiday destination for those people who do not wish to stay in a highly developed environment;
  - Tourism is generated from day trippers and visitors to tourist facilities and conservation areas;
  - The mid and upper catchment includes extensive areas of highly productive farmland; and
  - The quarries provide a significant sand and hard rock resource.

6. ECOSYSTEM HEALTH STATUS AND PRESSURES

An understanding of coastal ecosystem health and the vulnerability of the system to pressures is required to provide a sound basis for designing management actions and understanding the effects of management practices. This section provides an assessment of the health of Minnamurra River Estuary including:

- The health status; and
- The pressures affecting estuary health status and their relative magnitude.

The 1995 EMP (PBP, 1995a; PBP 1995b) and the 1999 CMS (Reinfelds, 1999) provide extensive background information on the study area. The following sections provide a summary of the key estuary features and new data available since 1999.

6.1 2010 Condition Assessment

The *NSW Natural Resources Monitoring, Evaluation and Reporting* (MER) program provides information on natural resource condition and trends within catchments. The MER program collects data on NSW estuaries and reports on the condition of the various system components and pressures impacting on natural resources. Key indicators including water quality parameters, macrophyte and fish indicators are assessed and condition ratings are assigned for each round of sampling. The latest MER condition assessment for the Minnamurra River was reported in the NSW *State of Catchments* (SoC) *2010* report (DECCW, 2011) and technical details provided in Roper *et al.* (2011).

The overall condition rating for the Minnamurra River Estuary was assessed as "Good" from an average of all scores which ranged from poor for seagrass (due to a loss in area) to very good ratings for turbidity and saltmarsh. Macroalgae and fish data were not assessed for the Minnamurra River Estuary during the 2010 MER assessment. Condition data are discussed further Section 6.3 (Water Quality) and Section 6.4.2 (Estuarine Vegetation).

The 2010 SoC report also summarised the main pressures affecting the health of the Minnamurra River Estuary. Some pressure categories were assessed as being very low pressures including a low level of disturbed habitat, good tidal flows and minimal annual fishing catch. Freshwater flows were described as being a low pressure on river health due to small increases in water extraction and catchment runoff. Other factors were considered to be high pressures in the catchment such as cleared land, population density, sediment and nutrient inputs. The overall pressure score was "Moderate" for the estuary. The following table provides the MER pressure rating results for the Minnamurra River Estuary in 2010.

Table 4: 2010 pressure rating for Minnamurra River Estuary

Indicator	Pressure Index Rating	Pressure indicator notes
Cleared land	High	66% of catchment is cleared
Population	High	42 people/km^2
Sediment input	High	531% increase in annual TSS from natural
Nutrient input (TN and TP)	High	568% increase in annual TP and 158% increase in TN from natural
Freshwater flow	Low	1.65% surface flows extracted 37% increase in catchment runoff

Indicator	Pressure Index Rating	Pressure indicator notes
Disturbed habitat	Very Low	0.81% of the estuary perimeter occupied by structures 0% of estuary occupied by aquaculture
Tidal flow	Very Low	Entrance is permanently open
Fishing	Very Low	0.68 t/km^2 annually
Overall Pressure Index	**Moderate**	**Average Score**

Source: Adapted from Roper *et al.* (2011)

6.2 Coastal Eutrophication Risk Assessment Tool (CERAT)

OEH scientists have developed the Coastal Eutrophication Risk Assessment Tool (CERAT) to help identify and prioritise land use planning decisions to protect and preserve the health of estuaries in NSW. The tool can be used to better understand and predict the relationship between land use in catchments and its impact on estuaries and coastal lakes. The catchment models provide estimates of the amounts of nutrients and sediments exported from land considering key factors for runoff quantity and quality such as land use (e.g. urban development, agriculture, cleared areas, natural forest, etc.), climate, rainfall, soil type, groundwater and surface water flows, tidal flushing etc.

Figure 20, Figure 21 and Figure 22 provide the spatial results of the CERAT modelling undertaken for the Minnamurra River Catchment for total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) downloaded from the CERAT web site (OEH, 2014c).

The model shows that the majority of the upper catchment areas which are vegetated have low exports of sediment and nutrients. Areas with irrigated crops and pastures, horticulture, or areas of intensive animal production or waste treatment and disposal had the highest levels of pollutant exports. Of particular note are cleared areas in the northeast corner of the catchment, which are occupied by quarries and waste disposal operations (shown in Figure 20). These areas are predicted to contribute very high levels of sediment and nutrients to catchment waterways. Grazing land is the dominant land use in the catchment and is predicted to export low to moderate levels of nutrient and sediment with a degree of variability at different locations in the catchment due to varying soil types, topography and hydrology. Urban areas can be significant sources of nutrients but Minnamurra, Kiama Downs and Jamberoo are predicted to contribute relatively moderate loads of sediment and nutrients to the estuary. The high levels of sediment and nutrients shown as sourced from the industrial sites (quarries and waste depots) do not consider EPA Licence conditions or monitoring data.

Note that areas in the south-west corner of the catchment have notably higher levels of pollutant export compared to areas with similar land use and topography in other areas of the catchment (e.g. Terragong Swamp). This difference is mainly due to higher rainfall and soil types assigned to these areas in the model which results in higher catchment flows and therefore higher export of pollutants. The block-like appearance is due to the coarseness of the model and in reality the change in pollutant export coefficients across the catchment is likely to be a much less linear in nature. It should be noted that CERAT is a model providing estimates rather than real data.

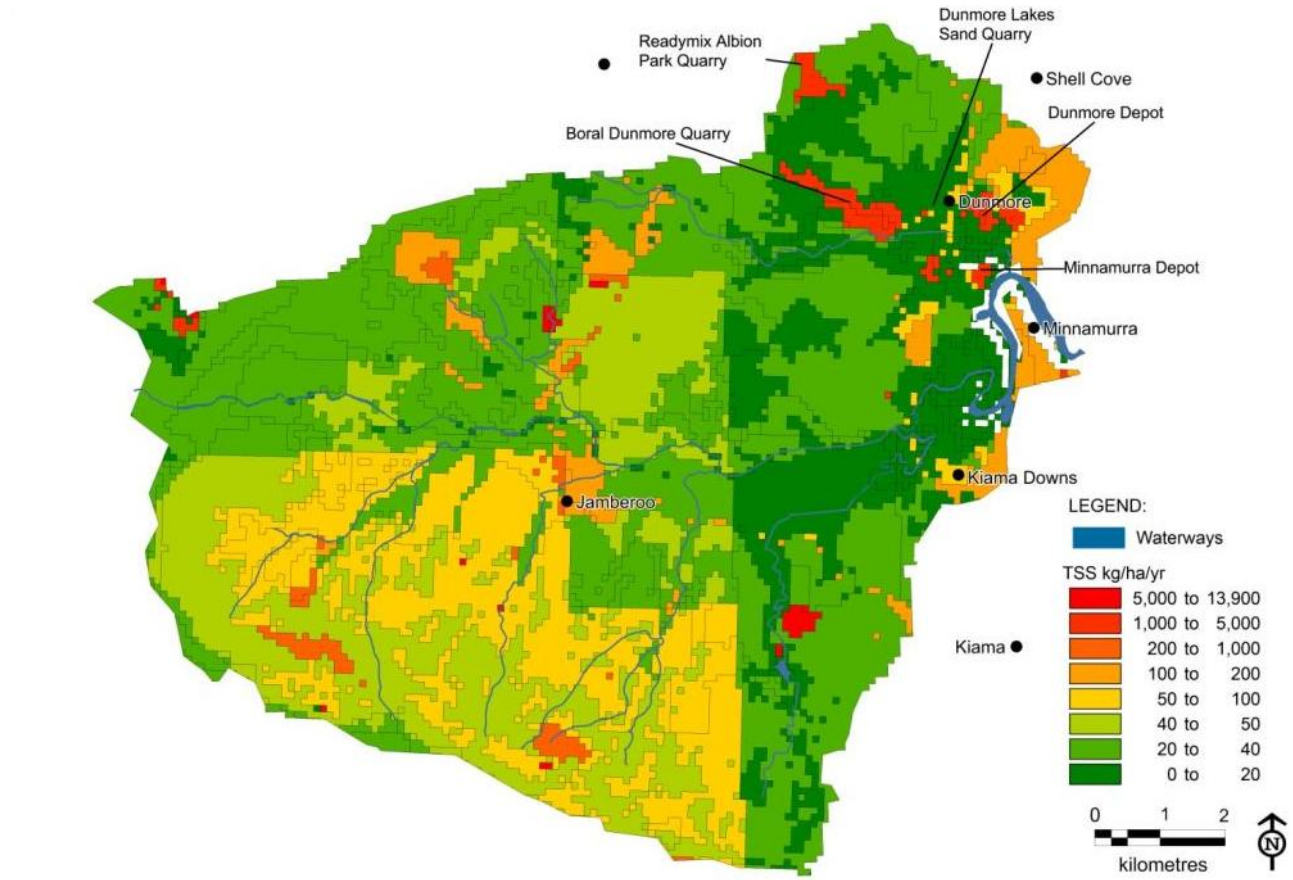


Figure 20: Modelled TSS load

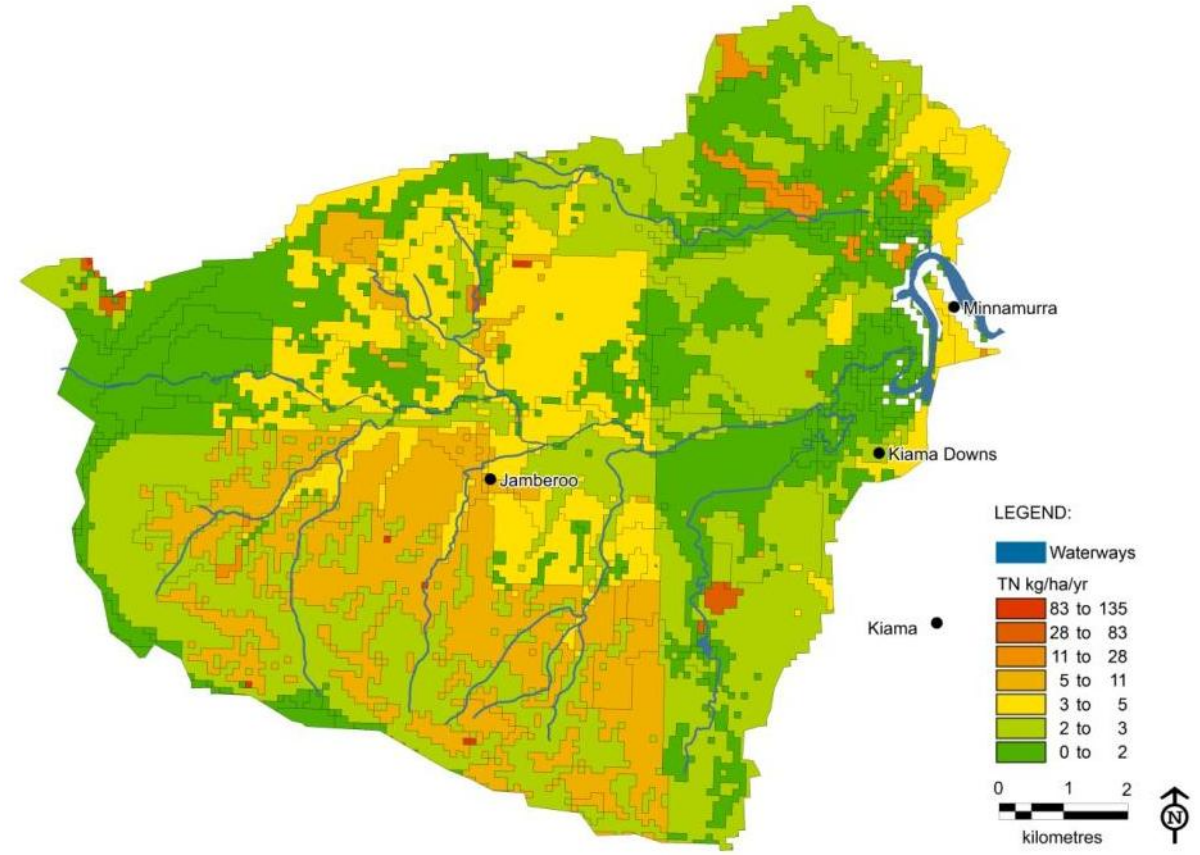


Figure 21: Modelled TN load

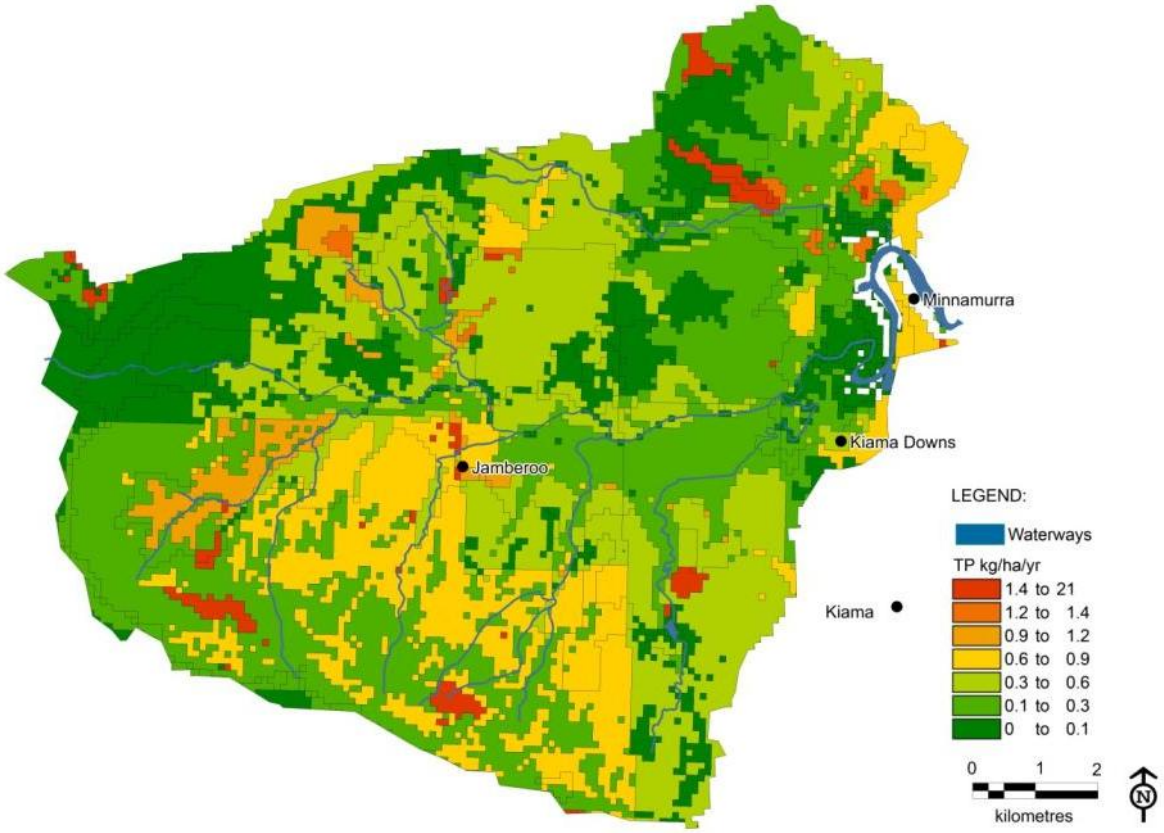


Figure 22: Modelled TP load

6.3 Water Quality

The 1995 EMP ranked water quality as the second most important issue affecting the Minnamurra River Estuary. The primary concerns raised by the Estuary Management Committee at that time were tip leachate, leaking septics and the impact of farming practices (PBP, 1995a). Similar concerns exist today with less emphasis on leaking septics due to Jamberoo being connected to Sydney Water's Bombo sewerage system in the mid-2000s.

A detailed description of the available water quality data is provided in Appendix 6.

Review of previous reporting and assessment of the recent data (MER program 2007-2008, MER program 2011-2012 and KMC data from 2006-2007) indicates that water quality is variable throughout the catchment. While there are very limited recent data available for the lower estuary downstream of Riverside Drive Bridge, visual water quality is generally observed to be very good with good water clarity and no discernible issues at this location. Good water quality in the lower estuary is likely to be largely attributable to efficient tidal flushing as was reported in Reinfelds (1999). Generally, the mid and upper estuary and Rocklow Creek are prone to poor water quality episodes with elevated nutrient concentrations at times. Nutrient concentrations (measured as TN and TP) frequently exceeded ANZECC guidelines for aquatic ecosystem health at most sites sampled in 2006/07, 2007/08 and 2011/12 (refer Figure 23 for sampling sites, Figure 24 for selected results and Appendix 6 for full results). Overall there appears to be an improvement in nutrient concentrations through time when comparing 2006/07 to 2007/08 and 2011/12 levels. This improvement may be a result of management actions such as connection of Jamberoo to the reticulated sewerage system, or improved land management practices reducing nutrient export to waterways, although it is not possible to be conclusive from the available water quality information. While the perceived improvements are encouraging, the recommended guidelines for aquatic ecosystem health are still not being achieved at several sites, and further work is required to reduce pollutant export to the system.

Median chlorophyll a concentrations were within the ANZECC guidelines for all sites and time periods except at site MER Zone 2 (lower/mid estuary) sampled in 2007/08, when the median of all values was equal to the guideline. There were a number of occasions at Zone 1 and Zone 2 in 2007/08 and a small number of occasions in 2011/12 where chlorophyll a was in excess of guidelines (see chlorophyll a chart in Figure 24) indicating there are occasions when phytoplankton growth is an issue in the mid and upper estuary. Chlorophyll a concentrations typically increase with increasing nutrient loads, as phytoplankton take up nutrients and increase biomass. However, in the Minnamurra River Estuary, even though nutrient levels are high, chlorophyll a concentrations are generally within recommended guidelines for ecosystem health. It is possible that there may be other factors limiting phytoplankton growth in the system (e.g. flushing rates, water temperature and light levels). More frequent sampling of all related parameters would be required in order to fully evaluate the cyclic response of chlorophyll a (i.e. algae levels) to nutrient levels..

Levels of bacteria at the upper estuary site near Swamp Road Bridge were also in excess of safe primary contact recreation guidelines during 2006/07, indicating potential pollution from livestock or failing on-site sewerage systems. Because the MER sampling in 2007/08 and 2011/12 did not include bacteria, it is not possible to determine if there was an improvement over time in this parameter.

The site with the best water quality, where all guidelines were achieved for aquatic ecosystem health was in the upper catchment upstream of Jamberoo (sampled during 2006/07 only). This site is likely to be indicative of natural water quality conditions in a largely unmodified catchment. In contrast, the Rocklow Creek site, near the Princes Highway displayed the poorest water quality of all sites sampled with very low dissolved oxygen, high turbidity, elevated nutrients and bacteria. Rocklow Creek has a high degree of pressure due to a very high degree of modification from natural condition including a predominantly cleared upper catchment used for grazing and other agriculture and the presence of large quarry sites in the mid catchment and two waste disposal sites in the tidally affected reaches.

Monitoring of groundwater and surface water in the vicinity of the Minnamurra Depot suggests that leachate from the site is impacting water quality in the nearby Rocklow Creek, although there are indications that the level of impact is decreasing over time. Monitoring of the Dunmore Depot found evidence of leachate impact in groundwater sampling, but no discernible impact on Rocklow Creek. Sea level rise is expected to increase the rate of leaching of pollutants at both sites through raising of groundwater levels, increased flooding of the sites and lateral infiltration of the mound by tidal waters which will increase flushing of contaminants into the surrounding groundwater and surface water. Ongoing monitoring of the waste depots is required to identify any impacts that the facilities may have on the surrounding waterways so that remediation can be undertaken if necessary.

A study of stormwater quality downstream of the Gainsborough residential estate (Roso, 1998) indicated that untreated urban stormwater runoff was generally of poor quality with nutrients and heavy metals being the key pollutants of concern. The stormwater treatment ponds at Gainsborough were assessed as performing well in 1998, however it is unclear whether the ponds have the same treatment capacity today and whether maintenance actions are required at this site. The study concluded that the events causing the greatest impact on river water quality were short, high intensity storms which flush pollutants from urban areas to waterways downstream but do not have enough runoff volume to increase flow in the river which would act to flush pollutants out of the estuary.

Gross pollutants in the Estuary include litter, cigarette butts and farm waste such as chemical drums, feed bales, silage wrap and baling twine (refer Section 6.12).

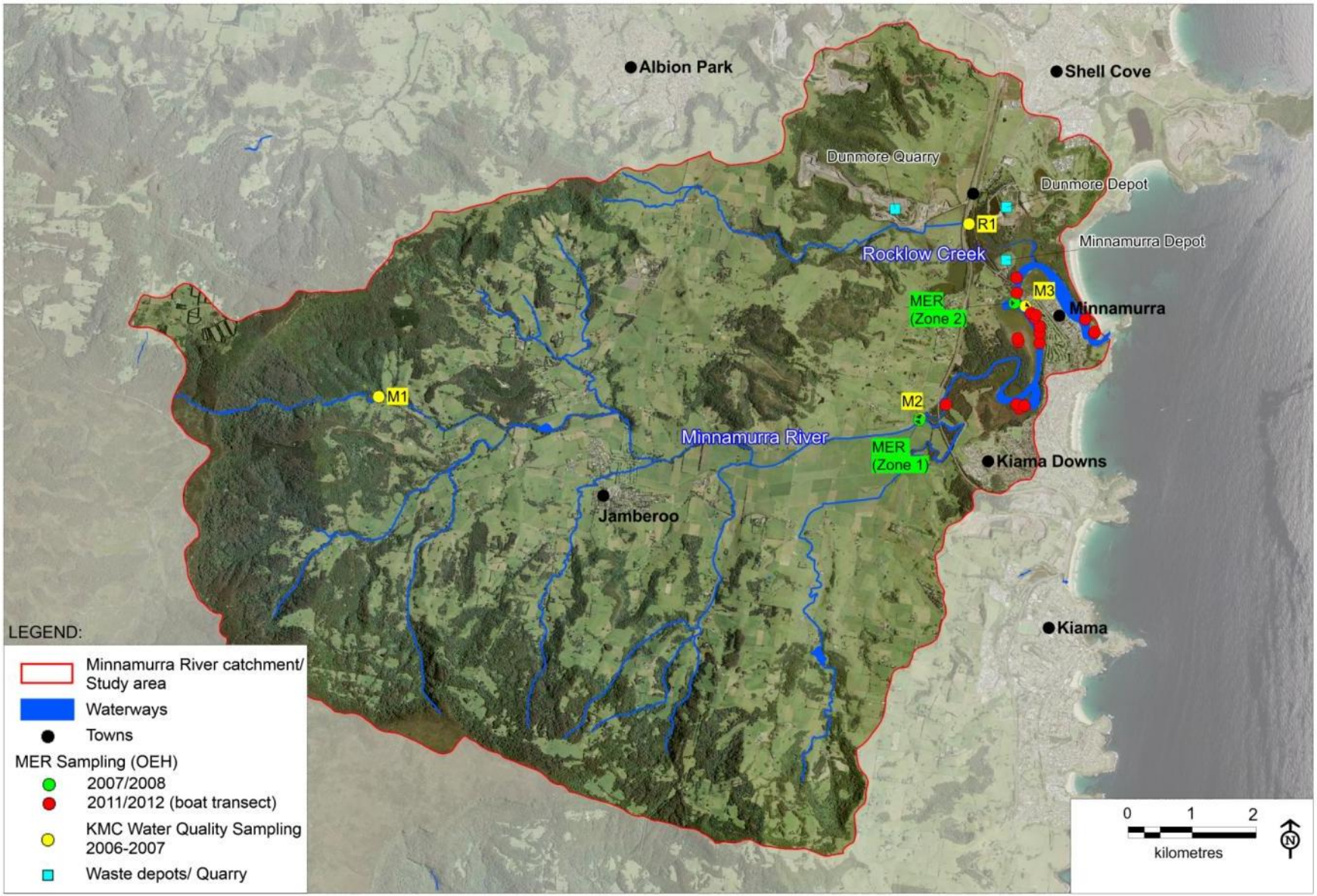


Figure 23: Recent water quality sampling sites within the Minnamurra River Catchment

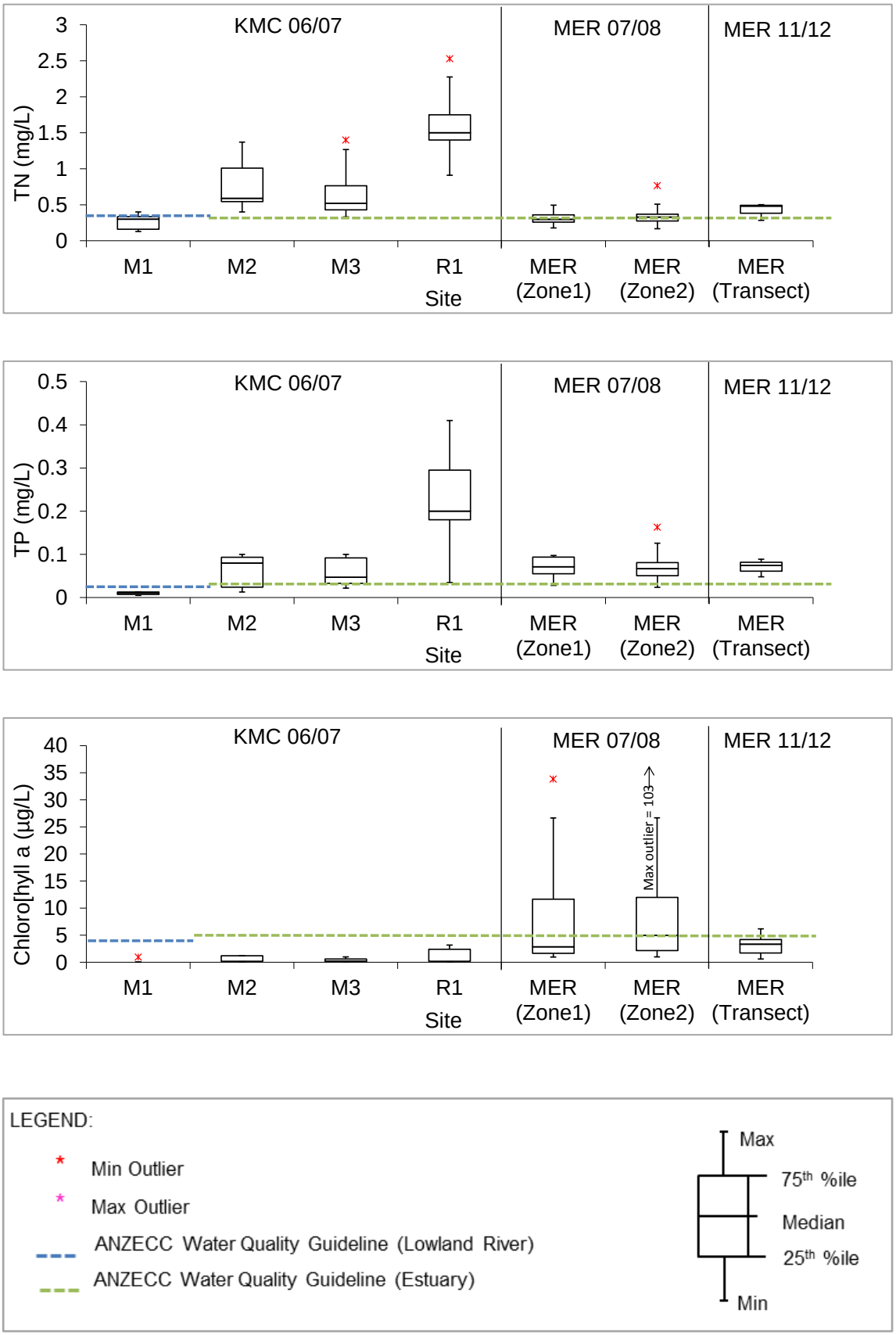


Figure 24: Nutrient and Chlorophyll a results for the Minnamurra River Catchment from 2006/07 (KMC), 2007/08 (OEH) and 2011/12 (OEH)

Refer to Appendix 6 for all water quality results.

6.4 Vegetation

Native vegetation remnants and vegetated riparian zones have significant ecological value and provide many important ecosystem functions, including:

- Bank stability;
- Land use buffering and water quality filtering;
- Fisheries habitat (root masses and fallen logs/trees) and a food source from litter fall;
- Terrestrial habitat for flora and fauna; and
- Community, recreational and intrinsic values and scenic amenity.

Native vegetation mapping for the Kiama LGA was undertaken in 2003/2004. This was later updated and digitised in 2006 (Kevin Mills and Associates, 2006) including mapping of Endangered Ecological Communities (EECs). There are eleven EECs known to occur within the Minnamurra River Catchment as shown on Figure 25.

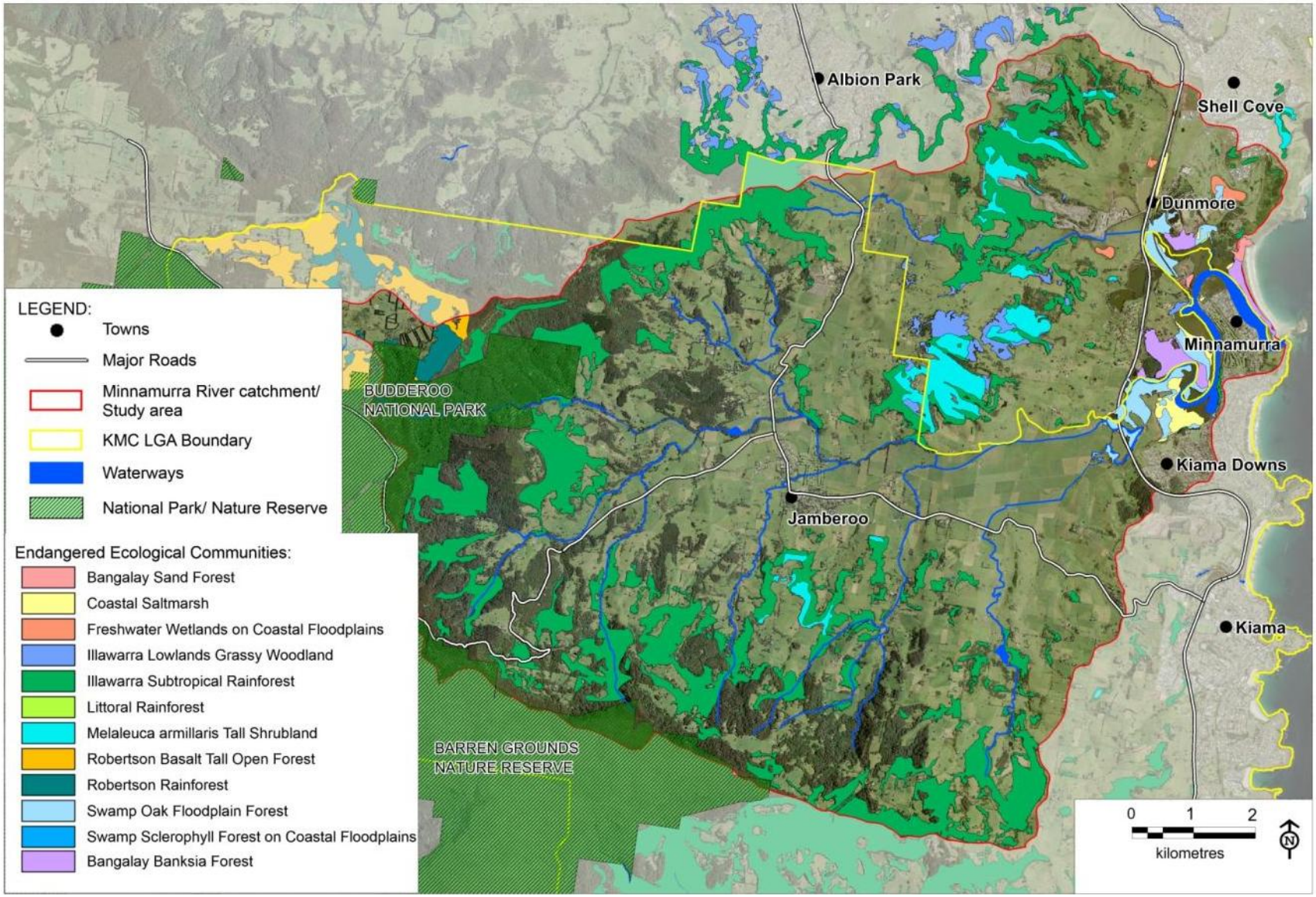


Figure 25: Endangered Ecological Communities in the Minnamurra River Catchment mapped by KMC and SCC

Note: Bangalay Banksia Forest shown in the lower estuary in this figure is incorrectly described as “Robertson Basalt Tall Open Forest - possible in part” by SCC.

In general, the distribution of vegetation throughout the Minnamurra catchment is patchy and fragmented. Native vegetation covers approximately 33% of the catchment area, with the remaining areas cleared for agriculture, urban development, roads, and industrial developments or occupied by waterways or water bodies. The largest areas of continuous vegetation exist in the upper catchment with areas of eucalypt forest and rainforest and areas within the Budderoo National Park and Barren Grounds Nature Reserve. The mid catchment areas are predominantly cleared and are mostly occupied by grazing land. However, patches of native shrubland and heathland exist south of Jamberoo and large tracts of vegetation are present around Dunmore Hills including Illawarra Subtropical Rainforest, *Melaleuca armillaris* Tall Shrubland and Illawarra Lowlands Grassy Woodland EECs. Remnant vegetation on the floodplain and Terragong Swamp is extremely fragmented with the largest tract of vegetation existing as Swamp Oak Floodplain Forest in the mid to upper estuary, in the vicinity of Minnamurra Bends. Harris (2002) reported that this tract of floodplain forest is the largest remaining area of its kind in the Illawarra region with an area of some 27.5 ha. Estuarine wetlands occur along the Minnamurra River immediately downstream of freshwater Swamp Oak Floodplain Forest in the tidally affected reaches. The majority of wetland areas are protected within designated SEPP14 Coastal Wetland areas (refer Section 6.4.3).

Intact vegetation in catchment areas provides many important ecosystem functions, including habitat for native flora and fauna and the maintenance of good water quality. In this regard, the Minnamurra River Catchment has a relatively high pressure due to historical clearing of native vegetation (only 33% of the catchment contains native vegetation cover today – refer Section 3.1.1).

Previous reporting has highlighted many significant features of vegetation in the Minnamurra Catchment including:

- The upper catchment supports areas that form part of the largest sub-tropical rainforest remnants in south-east NSW, with many species at the southern limit of their range in this location (Harris, 2002);
- The Dunmore Hills area is particularly significant, containing the largest and most intact remnants of native vegetation between the Illawarra escarpment and coast (SRCMA, 2012);
- The catchment contains at least three plant species endemic to the Illawarra (KMC, 1999);
- Extensive areas of mangroves and seagrass exist in the Minnamurra Estuary; and
- The estuary supports the largest stand of mangroves between George's and Shoalhaven Rivers and one of the largest stands of *Casuarina glauca* (Swamp Oak) forest in the Illawarra region.

A search of the NSW Atlas of Wildlife was conducted for the Minnamurra River Catchment for this CZMP. Results of the search included a total of 4,107 records of 949 plant species including:

- 5 plant species classified as Endangered and 2 species classified as Vulnerable under the *Environment Protection Biodiversity Conservation (EPBC) Act 1999*;
- 1 Endangered plant population, 7 plant species classified as Endangered and 2 plant species classified as Vulnerable under the *Threatened Species Conservation (TSC) Act, 1995*;
- 77 additional plant species protected under the *National Parks and Wildlife Act* (NPW) Act, *1974*; and
- 194 exotic (weed) species.

Another valuable information source is the Illawarra Bushland Database which provides information collected by flora surveys undertaken across the Wollongong, Shellharbour, Kiama, Wingecarribee and Shoalhaven Local Government Areas. The database is a web platform freely available to the public providing details of plant species including approximate time and locations of surveys, plant species names and author. The database includes a large number of vegetation survey sites across the Minnamurra River catchment from the Minnamurra Spit and lower estuary, to Minnamurra Rainforest in the upper catchment.

6.4.1 Riparian Vegetation

Native riparian vegetation along the Minnamurra River and tributaries is patchy, with good cover in the upper catchment areas, sparse cover in the mid catchment and floodplain areas and generally dense cover along the tidal reaches downstream of Swamp Road Bridge. The key issues related to riparian vegetation are:

- Historical clearing;
- Weed encroachment; and
- Livestock access to banks;

Much of the riparian vegetation along the tidal reaches of the Minnamurra River have some kind of environmental protection including areas mapped as either SEPP 14 Coastal Wetlands, Estuarine Vegetation (Mangroves/Saltmarsh) or EECs (Bangalay Sand Forest, Swamp Oak Floodplain Forest, and Bangalay Banksia Forest). Mangroves and Coastal Saltmarsh EEC are discussed in Section 6.4.2.

Land ownership along the riparian section consists of Council Reserve, Crown Reserve or Killalea State Park with a short section of private land along Charles Avenue foreshore in the lower estuary, privately owned land in the mid-upper estuary (the Minnamurra bends), Crown Reserve (grazing lease) along the Terragong Swamp and lower Jerrara Creek and private land in upstream areas. The opportunity to carry out large-scale revegetation works on publicly owned land is therefore limited to the lower estuary areas.

The *Shoalhaven Illawarra Riparian Cover Mapping Study* (DWE, 2008) mapped riparian vegetation cover for the Minnamurra River Catchment using SPOT-5 Satellite imagery and classified riparian land into six cover classes. The steeper slopes in the south-west have relatively good woody vegetation cover, but poor woody cover exists for most other parts of the catchment where grazing, intensive agriculture, industry and urban areas predominate (DWE, 2008). DWE (2008) recommended that good vegetation in the upper slopes should be protected and rehabilitation efforts should extend east from these areas. Where new urban development occurs, efforts should be made to encourage the rehabilitation of riparian corridors (DWE, 2008).

The *Remnant Vegetation and River Corridor Action Plan for the Minnamurra Catchment 2002* (Harris, 2002) provides further detailed assessment of vegetation remnants, riparian zones and existing management actions undertaken by various groups and organisations within Minnamurra sub-catchments. The plan also identifies a number of recommendations for vegetation management and maps priority areas for future vegetation actions in each of the Minnamurra sub-catchments. Priorities are based on two main principles - that representation of all vegetation communities is essential and that protection of intact remnants is more efficient than attempting to rehabilitate highly degraded areas. Riparian corridors are recognised as a key for providing connection between intact vegetation remnants. It is not clear how much of the plan has been implemented to date, however it provides detailed background information and guiding principles for future vegetation management actions in the catchment and it is a useful basis for planning for on-ground projects at specific locations. It would be useful to have priority vegetation categories available in a GIS mapping format to allow for further analysis with factors such as land zoning, property boundaries, corridor linkages, topography, fauna records etc. and to track ongoing progress of implementation combined with other monitored ecosystem variables such as water quality. This is particularly important in terms of planning riparian corridor restoration works, which requires careful selection of sites to maximise the value of management effort and cost.

The CMS (Reinfelds, 1999) noted that *Casuarina cunninghamiana* is the most common riparian zone tree along freshwater reaches of the lower Minnamurra River and provides stability to channel banks. The key issues related to riparian vegetation identified by the CMS were:

- Coral Trees were identified as a key weed species to be eradicated;
- Livestock access to channel banks; and

- Lack of native vegetation along channel banks is a key cause of bank erosion problems in the Minnamurra River Catchment.

The *Illawarra Biodiversity Strategy* (2011) provides a regional approach which aims to guide a program for biodiversity management for the three Illawarra Councils. It will be used to assist in developing policy, informing strategic planning and to define a program of 'on-ground' actions. The wetland and riparian areas of the lower Minnamurra River are classified as 'highest priority' areas for investment of biodiversity funding covering an area of approximately 145 ha. Terragong Swamp and an area of bushland south of Kiama downs (total area of approximately 13.4 ha) are classified as 'high priority' areas, and an area in the vicinity of Jamberoo (approximately 5.3 ha) has been assigned 'moderate priority' for investment.

Further prioritisation on a local scale is required to select sites for on-ground works that will deliver the greatest benefit. As part of the catchment assessment undertaken for this CZMP, various sites have been identified for riparian revegetation as follows (these sites are mapped in Section 9.1 - Management Actions):

- Bank erosion sites as discussed in Section 6.5;
- Minnamurra Headland (refer also weed management in Section 6.4.4);
- Charles Avenue foreshore;
- The second meander bend (erosion site, refer Section 6.5);
- Terragong Swamp;
- The saltmarsh area adjacent to Cameron Crescent in Gainsborough Estate;
- Mid-Jerrara Creek;
- The foreshores of the Billabong (lower Jerrara Creek, west of Princes Highway which are grazed to the water's edge); and
- The *Casuarina glauca* forest area between Princes Highway and Swamp Road (currently affected by cattle access).

In addition, further assessment of the mid-upper catchment areas (including tributaries) is required to identify other priority riparian re-vegetation areas.

6.4.2 Estuarine Vegetation

Estuarine vegetation refers to seagrass, mangrove and saltmarsh plant communities within the estuary. Seagrass occurs in the intertidal or sub-tidal (marine) zone and is generally covered with water except during very low tides. Mangroves occur in the intertidal zone between low and high tide and saltmarsh communities occur mostly behind mangroves in the upper limits of the intertidal zone and are only inundated briefly on high tides (Figure 26). In an estuary, riparian vegetation is vegetation above the high tide level and generally does not include estuarine vegetation.

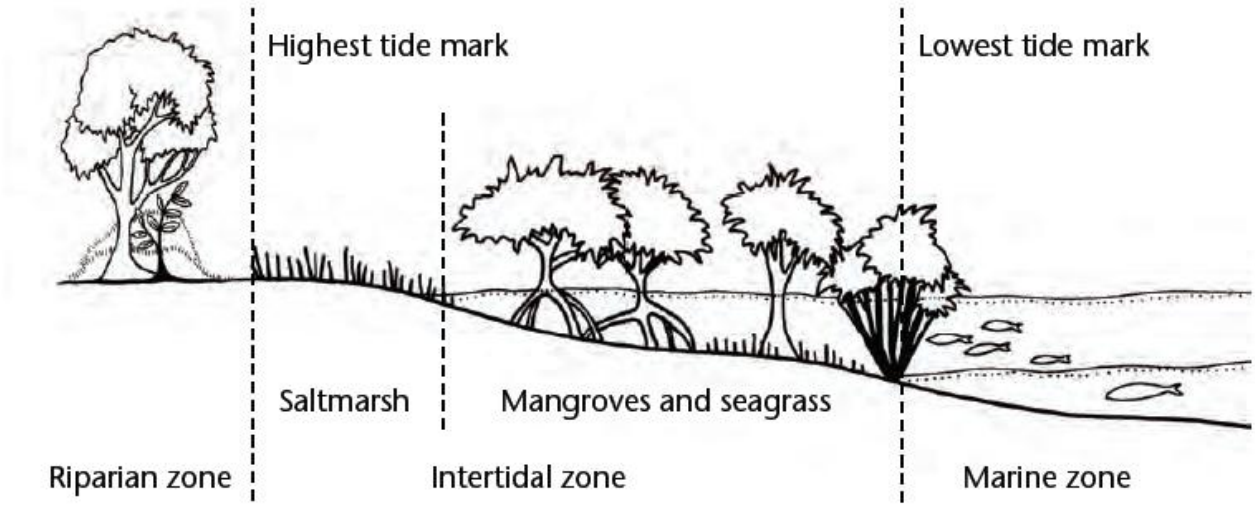


Figure 26: Zonation of estuarine vegetation

Source: OEH (2014)

Saltmarsh, mangrove and seagrass habitats are essential nursery areas for many species of commercially and recreationally important fish and crustaceans and the food they eat, contributing large amounts of organic material to the ecosystem (refer Section 6.6.1). Depending on their type and location, they can reduce the effects of erosion due to waves or currents and help trap sediments. Saltmarsh and mangroves also act as a buffer and a filtration system for sediment and nutrients entering the waterway from the terrestrial environment. Natural events such as floods and storms can impact on seagrass, mangrove and saltmarsh. However, human actions such as river works, infrastructure, actions that exacerbate bank erosion, direct disturbance from boat propellers as well as urban runoff, grazing, vegetation clearing and vehicular access can also influence the distribution and abundance of estuarine macrophytes.

Estuarine vegetation including mangroves, seagrass and saltmarsh are protected under the *Fisheries Management Act 1994* and a permit is required from NSW DPI to undertake works or activities that may harm them. In addition, Coastal Saltmarsh has been listed as an EEC under the *Threatened Species Conservation Act* (refer Figure 25 for mapping).

Estuarine Vegetation distribution

Figure 27 shows the location of mangroves, seagrass and saltmarsh in the Minnamurra River Estuary in 2006 and 2009. Early studies by West *et al.* (1985) determined that mangrove forests at Minnamurra (0.484 km^2 in 1985) represented the largest single area of mangroves between the Georges River in Sydney and the Shoalhaven River near Nowra. Since then the area of mangroves has expanded substantially and remains a regionally important community occupying an area of 0.946 km^2 in 2009. Both Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) occur in the Minnamurra River Estuary, although Grey Mangrove is the dominant species (Oliver *et al.*, 2012). The River Mangrove generally occurs as a narrow band along the water's edge and also as a wider band behind Grey Mangroves (PBP, 1995).

Saltmarsh communities generally exist immediately upslope of mangrove areas in the upper limits of the tidal zone. Isolated patches fringe mangroves in Rocklow Creek and the Minnamurra River below the Riverside Drive bridge. Large saltmarsh areas are evident on the western side of the river upstream of the Riverside Drive bridge and also in the vicinity of the Minnamurra bends (Figure 27).

Eelgrass (*Zosteraceae* family) is the species of seagrass occurring between low tide level to a depth of approximately 1.5m below low tide in the Minnamurra River Estuary (PBP, 1995). In 2009, Fisheries NSW mapped large areas of seagrass beds in the lower estuary from an area just upstream of the Riverside Drive bridge to the mouth. Long narrow bands of seagrass are evident in the mapping from upstream of the bridge to the Minnamurra bends. Smaller patches of seagrass beds existed beyond this to the tidal limit in 2009

(Figure 27). There is concern in the community about the recent loss of seagrass area in the Minnamurra River which is discussed below.

Estuarine Vegetation condition

As part of the NSW MER program (refer Section 6.1), an assessment of estuarine vegetation was undertaken by comparing changes in extent between 1985 and 2006. Fisheries NSW conducted the surveys as part of the Comprehensive Coastal Assessment. The percentage change in total area of seagrass, saltmarsh and mangrove communities between the two surveys was used to assign a condition index rating for the estuary. While there are well documented limitations in comparing the two surveys, the rating provides a broad indication of change that is useful for determining whether further investigation and/or action is required.

Estuarine vegetation condition ratings for the Minnamurra River Estuary in 2010 (reported in Roper *et. al*., 2011) are provided in Table 5.

Table 5: Estuarine vegetation condition rating for Minnamurra River Estuary in 2010

Indicator	Condition Index Rating	Condition indicator notes
Seagrass	Poor	-50% loss from 1985 to 2006
Mangrove	-	Further investigation required
Saltmarsh	Very Good	+66% gain from 1985 to 2006

Source: Adapted from Roper *et al*., 2011

The 2010 MER condition rating for Minnamurra was ‘Poor’ for seagrass, based on a loss of 50% in seagrass area between 1985 and 2006. Mangrove condition was not reported because further investigation at a local scale is required to determine if change in observed increase in extent (+82% increase from 1985 to 2006) is positive or negative for estuary health (Roper *et al*., 2011). Saltmarsh condition was assessed as ‘Very Good’ with a 66% increase in saltmarsh area between the two surveys.

Subsequent to the comparison between surveys undertaken in 1985 and 2006, Fisheries NSW completed additional estuarine vegetation surveys based on the latest aerial photography for Minnamurra River Estuary in 2009 utilising a similar methodology as 2006. This 2009 data set (shown in Figure 27) was subsequently used to compare against the 2006 data, providing an update on estuarine vegetation extents. Table 6 compares the areas of mapped estuarine vegetation communities in 2006 and 2009. Seagrass shows the most dramatic change with an increase in area of 57% between 2006 and 2009. Saltmarsh area decreased by 9% while mangroves increased by 8%.

Table 6: Change in area of estuarine vegetation communities in Minnamurra River

Indicator	2006	2009	2006-2009	
Habitat	**Area (km^2)**	**Area (km^2)**	**Change (km^2)**	**Change (%)**
Mangrove	0.88	0.95	0.0669	8%
Saltmarsh	0.33	0.30	-0.028	-9%
Seagrass	0.12	0.18	0.0672	57%

The main areas of mangrove expansion between 2006 and 2009 can be seen occurring in upper Rocklow Creek, the western bank of the mid estuary and in the upper estuary, particularly on the northern side of the river (Figure 27). The main areas of saltmarsh reduction were in the upper estuary over this time period, while some new areas were mapped in 2009 that did not appear in 2006 mapping (Figure 27).

Saintilan and Williams (1999) discuss a number of potential reasons for changes in the distribution of saltmarsh and mangrove communities in the Minnamurra River Catchment including increases in rainfall, revegetation of areas cleared for agriculture, altered tidal regimes or estuary water levels and increases in nutrient levels and sedimentation. In some areas the gain in mangrove area and simultaneous loss of saltmarsh could be explained by the landward expansion of mangroves into saltmarsh areas (e.g. the mid estuary) as discussed by Chafer (1998) (cited in Saintilan and Williams, 1999). In other areas such as in the upper estuary, saltmarsh does not appear to have been replaced by mangroves, and the reasons for reduced saltmarsh area are unclear.

Seagrass was assessed as increasing markedly from 2006 to 2009, increasing in area by approximately 57%. However, observations since then have shown significant reductions in seagrass extent, particularly in the lower estuary. The review of historical aerial photographs given in Appendix 3 suggests that the extent of seagrass adjacent to Charles Avenue diminished between summer 2009 and summer 2011 and further diminished between summer 2011 and summer 2013. Community members have also noted a decline in seagrass extent in recent years. There are suggestions that the decline was a result of flooding which occurred in March 2011 and again in February/March 2012.

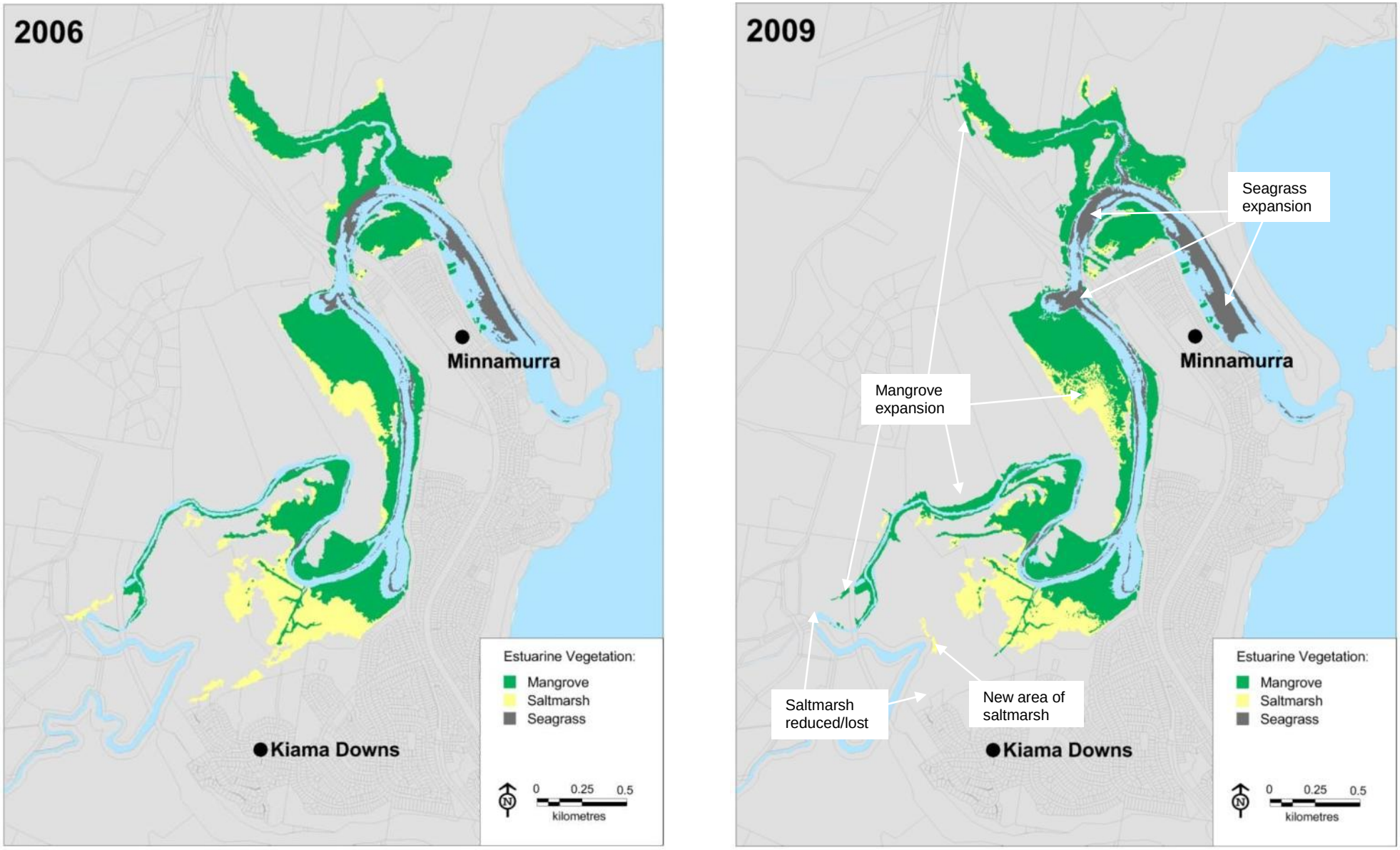


Figure 27: Estuarine macrophytes 2006 (left) and 2009 (right) (mapping provided by KMC)

There are a number of threats to estuarine vegetation that require careful management to ensure ongoing protection for these important habitats. Key issues relating to estuarine vegetation are:

- Water quality, in particular high nutrient concentrations and high turbidity. High nutrient levels can lead to excessive epiphytic algae growth on seagrass which restricts light penetration to the plant and therefore the ability of the plant to photosynthesise. High turbidity caused by suspended particles in the water column affects seagrass in the same way by restricting photosynthesis. To date, there have not been any detailed assessments of factors affecting seagrass health in the Minnamurra River, such as the impact of epiphytic algae growth. Analysis of the available water quality information for the estuary (refer Section 6.3 and Appendix 6) detected an overall improvement in terms of nutrient and turbidity concentrations through time when comparing 2006/07 to 2007/08 and 2011/12 levels. Because seagrass condition and distribution is expected to increase with better water quality conditions, the observed decline in seagrass area observed is at odds with this result. This suggests that either the water quality information has not captured all events that may be affecting seagrass, or there are other factors that are affecting seagrass health.
- Boat damage to seagrass, including propeller damage, anchoring, vehicle and foot traffic causing direct damage to plants;
- Stock access to saltmarsh;
- The landward expansion of mangroves and seaward expansion of swamp oak forest into saltmarsh areas, reducing saltmarsh extent. Oliver *et al*. (2012) demonstrated that there has been a consistent pattern of mangrove encroachment into saltmarsh evident in mapping from aerial photographs over the period 1938–2011;
- Estuarine and wetland vegetation communities in the Minnamurra River Estuary are highly vulnerable to sea level rise and the presence of barriers to the natural migration of communities may result in significant decline in area of these habitats (refer Section 6.15.3);
- Construction of illegal river access through mangroves and saltmarsh (e.g. right bank, first meander bend); and
- Weeds impacting saltmarsh and Swamp Oak Forest.

The natural colonisation of mangroves along the Charles Avenue foreshore is a significant concern to the residents in this area. Residents believe there has been an increase in the extent of mangroves along the Charles Avenue foreshore over the past 15 – 20 years although this has not been observed in historical aerial photography. Residents are concerned that the foreshore will eventually become overgrown thus affecting property values, access and the scenic and recreational benefits of the foreshore. Recent observations of mangrove germination to the south, between James Holt Reserve and North Street Reserve are causing most of the concerns.

6.4.3 SEPP 14 Wetlands

Four wetlands in the Illawarra region are recognised as nationally important in the Directory of Important Wetlands in Australia (Environment Australia, 2001). Minnamurra River Estuary, including Dunmore Swamp is included in this list.

The location of wetland areas designated under *State Environmental Planning Policy No. 14 - Coastal Wetlands* (SEPP 14) within the Minnamurra River Catchment is shown on Figure 28. The Policy was introduced in 1985 to protect coastal wetlands and stipulates planning and development controls under the *Environmental Planning and Assessment Act, 1979* to ensure that developments in or adjacent to wetlands have little impact on wetland values. Figure 28 highlights the significant areas of wetlands in the Minnamurra River Estuary.

The SEPP 14 wetland areas upstream of Riverside Drive on the western bank are privately owned apart from the land purchased by KMC for environmental protection south of the second meander. The Minnamurra and Dunmore waste depots border the SEPP 14 areas around Rocklow Creek.

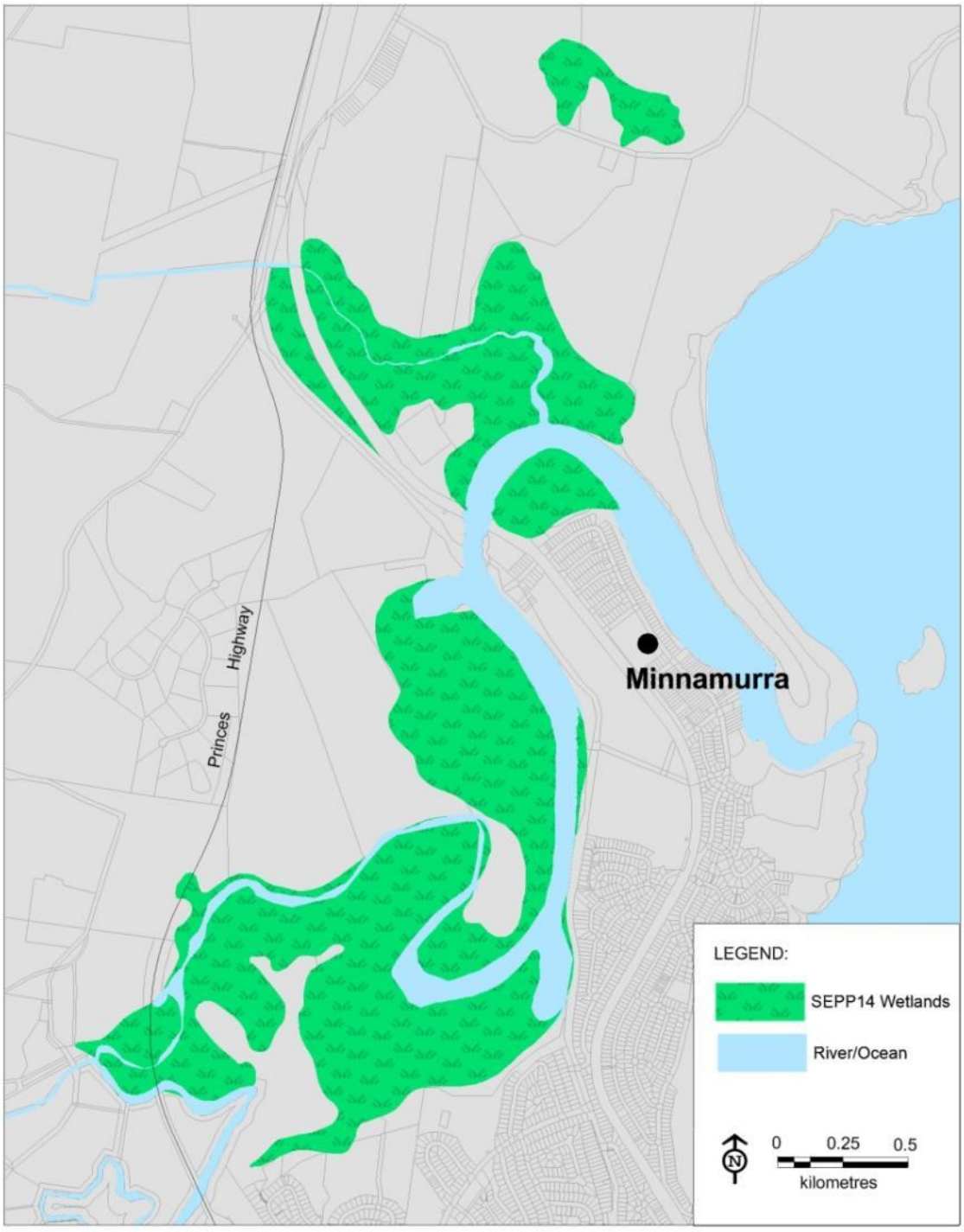


Figure 28: SEPP 14 Wetlands

6.4.4 Weeds

Weeds have been identified as an ongoing issue in the Minnamurra catchment impacting biodiversity, habitat values and visual amenity. In recent consultation undertaken as part of this CZMP, the community identified weed infestation on the spit, along the Minnamurra Bends and Gainsborough cycleway as issues requiring management action. In a study on vegetation remnants in the catchment, Harris (2002) noted that terrestrial

weeds are most likely to occur where the existing canopy has been modified, altering the resilience of remnants to withstand invasion.

Table 7 provides an overview of some of the major weed species of concern in the Minnamurra River Catchment. The locations of serious weed encroachment observed during the catchment assessment for this CZMP (site observations) are shown in Figure 29. Many other species have been recorded in the study area and are listed in the BioNet Atlas of NSW Wildlife and the Illawarra Bushlands Database.

Table 7: Weed species of concern in the Minnamurra River Catchment reported by various sources

Weed species	Description of occurrence	Source
Coral tree (*Erythrina X sykesii*)	Occurring along waterways, this species was identified as a key weed species to be eradicated in the 1999 CMS. While it does not set seed it can sucker from any part of the plant (e.g. fallen branches, pruning, etc.)	Reinfelds (1999), site observations
Broad- leaved privet (*Ligustrum lucidum*)	Declared noxious in the Shoalhaven LGA, the species is widespread with some large infestations in the Burra Creek area, above Curramore Road and along Factory Lane adjacent to the River.	Black (2001)
Lantana (*Lantana species including ornamentals*)	Class 4 noxious weed. Widespread throughout the catchment with the largest infestations (identified by aerial photography) in the Minnamurra Rainforest, Budderoo National Park and in the lower rivulet area. Observed by Council and OEH in the lower estuary and adjacent to the waste depots.	Black (2001), site observations
Bitou bush (*Chrysanthemoides monilifera ssp rotundata*)	Class 4 noxious weed found in coastal dune environments including Killalea Reserve.	Black (2001), site observations
Madeira vine (*Anredera cordifolia*)	Present but not often seen and was therefore highlighted for management action to prevent it becoming a major problem. Observed by Council and OEH at James Holt Reserve.	Black (2001), site observations
Camphor laurel (*Cinnamomum camphora*)	Distribution is increasing and there is currently little action being undertaken to control them	Harris (2002)
African lovegrass (*Eragrostis curvula*)	Class 4 noxious weed that occurs as scattered roadside plants at Gerroa and Minnamurra.	IDNWA (2012)
African boxthorn (*Lycium ferocissimum*)	Class 4 noxious weed found along the Minnamurra River	IDNWA (2012)
Aligator weed (*Alternanthera philoxeroides*)	Class 2 noxious weed found at Dunmore. This noxious aquatic weed has the potential to smother waterways and in some instances become terrestrial, posing a threat to native habitat and agricultural enterprises.	SRCMA (2013)
Wild tobacco bush (*Solanum mauritianum*)	Present along riparian areas	Site observations
Asparagus fern (*Asparagus sethiopicus*)	Class 4 noxious weed, occurring throughout wetland and forested areas, particularly apparent in the lower Minnamurra Estuary in areas such as Killalea State Park and riparian areas in reserves along the river.	Site observations

Figure 29: Locations of weed outbreaks observed during catchment assessment in 2014 (key species)

6.5 Erosion

During the preparation of the 1995 EMP, erosion and sedimentation was considered by the community, at the time, to be one of the most important issues affecting the Minnamurra River Estuary. The general causes of bank erosion are:

- Natural migration of the river;
- Scouring during floods;
- Wave action from wind and boats;
- Runoff flowing down the banks; and
- Mobilisation of sediment by human and animal traffic.

The presence of vegetation significantly inhibits erosion and the presence of dispersive soils facilitates erosion.

6.5.1 Past Erosion Issues

The 1995 EMP noted that erosion affected parts of the estuary right throughout the study area from the entrance upstream to Factory Lane upstream of Terragong Swamp. The erosion assessment conducted for the 1995 EMP (PBP, 1995b) found that:

- In the lower estuary the main area identified was bank erosion along the public foreshore reserve on Charles Avenue at Minnamurra. Long period ocean waves were identified as the prime source of energy for the erosion, however, boat wake, foot traffic, loss of vegetation and local erosion at stormwater outlets were considered to exacerbate the erosion problem;
- Erosion of the 'sharp meander' in the Minnamurra Bends (mid-estuary) area was identified as an issue. River flow scour on the outside of the bend was identified as the main contributing factor of the erosion. However, the rate of recession was found to be slow and hence the capacity of for a breach of the barrier system in the foreseeable future was considered to be insignificant;
- The steep banks upstream of the Minnamurra Bends were perceived to be eroding, however this was attributed to natural meander development. Due to the reduced curvature of the channel in this area compared to the meanders downstream it was considered that erosion rates in this area would be lower; and
- Erosion of the banks through Terragong Swamp was attributed to the river trying to change from its artificially confined, straight steep and narrow form to a natural wider, flatter and meandering channel.

The erosion issues identified in the 2003 EMP Review (Panayotou, 2003) are briefly outlined below:

- Bank erosion along the Charles avenue foreshore was still considered to be a major issue;
- Bank erosion (identified since the 1995 EMP) was occurring south of the old Princes Highway Bridge (Riverside Drive); and
- Bank erosion and channel scouring along the stretch of river through Terragong Swamp from Swamp Road bridge to Factory Lane was still considered to be an issue.

6.5.2 Previous Erosion Management Actions

Lower Estuary

Various actions from the 1995 EMP and 2003 EMP Review have been undertaken to control erosion throughout the estuary. The 1995 EMP presented and explored several options for the management of the bank erosion along Charles Avenue including rock revetment, proprietary wall, stabilised beach berm (intertidal retaining wall) and embayed shoreline (groynes).

Following the 1995 EMP a small pilot area along Charles Avenue was chosen for a trial management strategy of timber groynes to control the bank erosion (refer Figure 6 in Section 4). The groynes have since deteriorated with rotting timber rails and detached sediment fencing. Some of the groynes are licensed mooring points for private boats.

In 2003, there was considered to be a slight accretion of sand and new mangrove seedlings were present (Panayotou, 2003). As a continuation of previous bank erosion works undertaken adjacent to Charles Avenue, KMC in partnership with OEH and SRCMA undertook further bank stabilisation works involving stabilising the toe of the bank using large rocks, reshaping the bank and planting with low growing native plants along most of the length of the Charles Avenue foreshore (Figure 30) (KMC, 2009). Concrete matting has also been used in some locations to stabilise the bank (Figure 30). The Charles Avenue residents are actively planting gardens along the wall to assist with erosion control. Some of the rocks from these revetments have become displaced.

The stands of mature mangroves are also assisting with erosion control although large areas remain cleared (Figure 30). The *Minnamurra Reserves Plan of Management* (KMC, 2001) highlights the need for direct planting of mangrove seedlings to complement the timber groynes and rock revetment. Mangroves have started to naturally germinate in many of the open flats areas along the Charles Avenue foreshore adjacent to the rock revetments.

Several landowners along Charles Avenue that directly adjoin the riverbank have constructed rock, concrete and besser brick retaining walls on their property boundary on the bank in an attempt to stop bank erosion. Parts of the old masonry walls are in poor condition (Figure 30). These *ad hoc* measures can be effective at curbing erosion on the stretch of bank to which they are applied however, have the potential to exacerbate erosion further along the bank.

A 

B 

C 

D 

E 

Figure 30: Charles Avenue erosion and existing controls

A – Concrete matting, B – plantings (photo: A. Wilson), C – Private retaining walls, D – Rock revetment, E – remnant mangroves

Mid Estuary

The riverbank in the vicinity of the picnic and parking area along Riverside Drive has been stabilised with rock revetment and a fishing jetty has been installed. The rock revetment in this area is steep with displacement of some large boulders (Figure 31). A lower rock revetment has also been constructed downstream of the timber access stairs.

A  B 

Figure 31: Riverside Drive erosion controls

A – Rock revetment, B – Downstream of timber stairs

Terragong Swamp

The 1995 EMP proposed several options for the control of bank erosion through the Terragong Swamp. The options included;

- Drop structure and energy dissipater – regarded as a cost effective option but would require levees to control localised flooding and would pose a fish passage barrier;
- Lined channel - would minimise effect on farmland although would reduce amenity of the area and provide very little habitat or ecological value; and
- Reshaped channel - would require battering back banks and revegetating. Combined with drop structures would control the propensity towards meandering and local scour. This option was considered likely to consume productive farmland.

Two grade control structures (rock ramps) were built between Browns Lane and Factory Lane in the late 1990s to lend stability to banks along the Terragong Swamp and reduce the size and number of bank slumps (Panayotou, 2003). Reinfelds (1999) notes that the Browns Lane structure appeared to be more effective than the Factory Lane structure which was likely due to the lower channel gradient at the Browns Lane structure. The toe of the Factory Lane structure was since extended and rock was placed in the downstream pool to reduce scour.

The SRCMA, in partnership with local landholders and the Terragong Drainage Union (TDU) installed three additional rock ramp structures with integrated fish ways in 2011. The ramps were designed to act in concert with previously installed upstream grade control structures to slow floodwaters, stop bed erosion and also aid in retaining channel sediments post floods. SRCMA (2012) reports that the works have been tested by numerous high flows and have proven able to withstand floods.

At each rock ramp, rock revetment was also installed to stabilise the banks and vegetation has since covered most of the banks. Stock exclusion fencing has also been installed at the second ramp (upstream from Swamp Road) with Casuarina planted along the fence line along the southern bank. Weeds (e.g. tobacco weed) have since colonised the buffer strip (approximately 2 metres wide) and follow-up work is required.

A  B 

Figure 32: Terragong Drain rock ramps

A – Downstream ramp near Swamp Road, B – Second ramp between Swamp Road and Browns Lane

6.5.3 Current Erosion Sites

Preliminary identification and assessment of the current erosion sites has been undertaken for this CZMP based on the catchment assessment undertaken by KMC and OEH (refer Appendix 7). The assessment does not cover the entire catchment but focusses on the estuary, Terragong Swamp and areas of known erosion. Erosion is also occurring in many of the tributaries of the upper catchment due to a combination of poor condition of riparian vegetation, livestock access and grazing, steepness of banks, flooding and natural river meander. Further investigation will be required to identify upper catchment areas which require remediation.

The current erosion sites, their assessed risk and example photos are shown on Figure 33, Figure 34 and Figure 35. Further detail is provided in Appendix 7.

Figure 33: Locations of bank erosion sites in the lower to mid-estuary

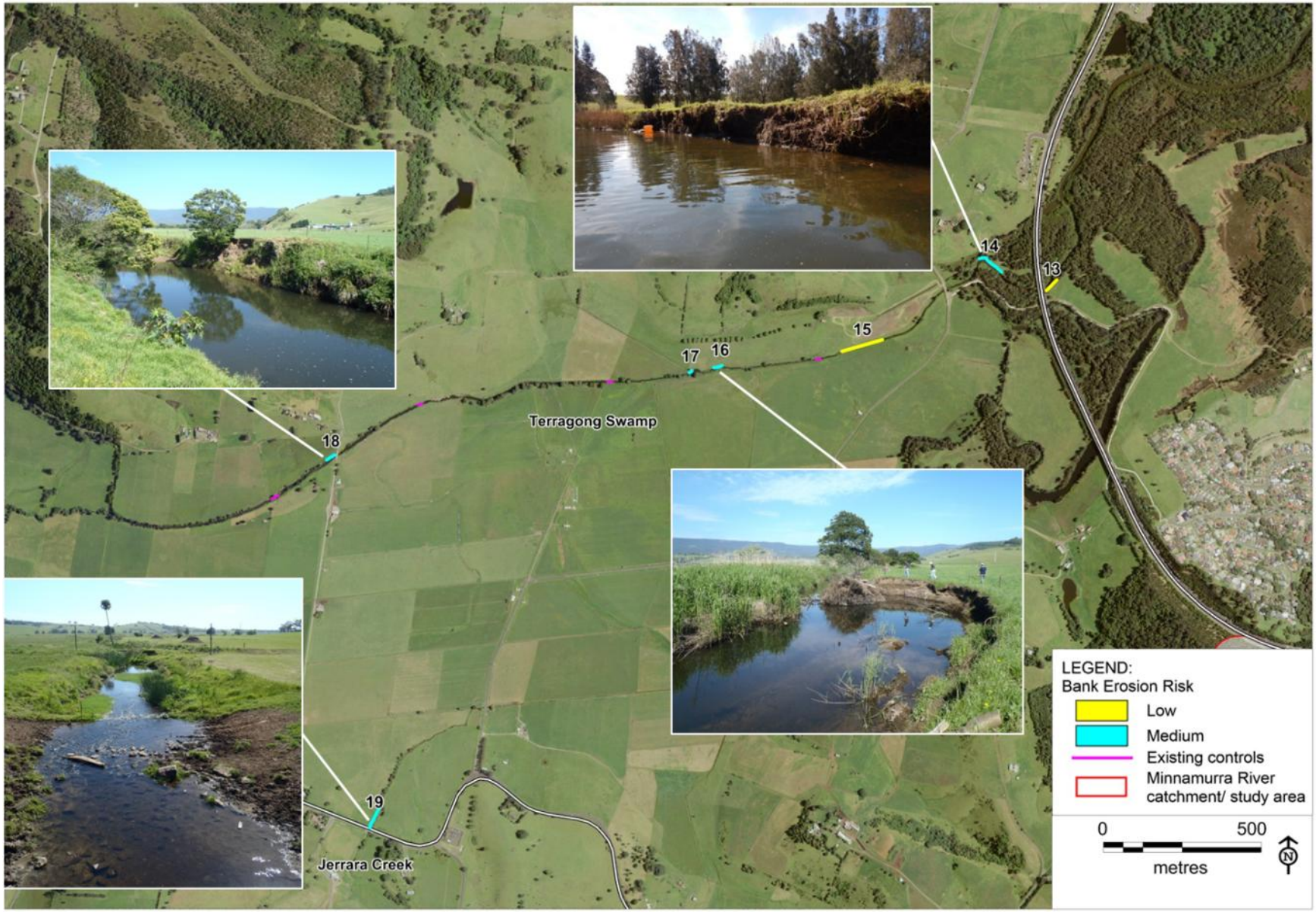


Figure 34: Locations of bank erosion sites in the upper estuary and lower Terragong swamp

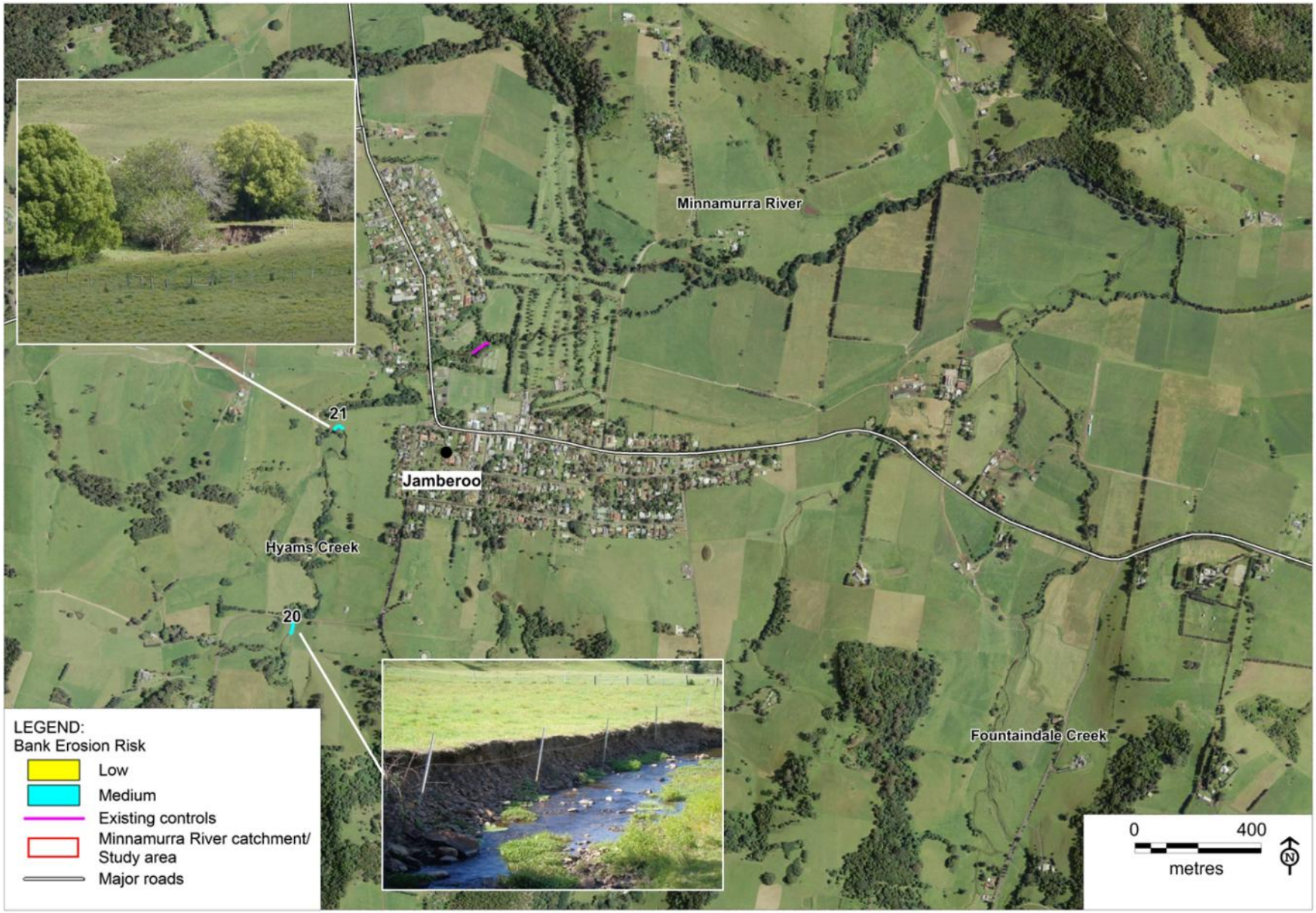


Figure 35: Locations of bank erosion sites in Hyams Creek

6.6 Fauna

6.6.1 Fish

In the estuarine reaches of the system, estuarine vegetation such as saltmarsh, mangroves and seagrass provide important habitat for estuarine fish. These habitats provide essential nursery and foraging areas for many commercial and recreationally important species such as bream, whiting, flathead, luderick and mullet. Recent decline in seagrass areas within the lower estuary is considered a concern with regards to the reduction of potential fish habitat. Intertidal sand and mudflats are rich in prey species such as yabbies (nippers), worms and various molluscs providing important foraging areas for many fish species. Rocky structures and deep water within the estuary provide important habitat for predatory species such as mulloway.

Freshwater reaches of rivers and streams provide a diverse range of habitats that support a range of aquatic ecosystems. These ecosystems evolve around and are sustained by the in-stream and riparian habitat features of the waterway as well as water quality. Large woody debris (snags) are an important and essential in-stream habitat as they provide shelter and structure to fish and other aquatic organisms to hide from predators, ambush prey, seek refuge from strong flows and for spawning sites. Snags are important habitat for many fish species particularly Australian bass. Riparian vegetation provides important ecological and riverine functions including:

- Habitat and refuge structure for fish and other aquatic fauna;
- Habitat for terrestrial fauna;
- Regulating micro-habitats (e.g. shading regulates water temperatures particularly during warm seasons);
- Stabilising banks; and
- Regulating water quality (e.g. filtering run-off).

Riparian vegetation not only provides shelter and food for many fish species but also aquatic organisms such as shrimp and crayfish. In particular, many smaller fish species such as gudgeons, take refuge in the shadows and bankside structure. Similarly, larger fish (particularly Australian bass) also utilise shade and bankside structure to ambush prey. Riparian vegetation also provides habitat structure for turtles (often use low branches to bask or catch prey) and platypus (which are known to utilise undercut banks, root systems, and thick riparian vegetation to disguise their den entrances). The lack of in-stream snags and riparian vegetation and general lack of suitable habitat in stretches of the Minnamurra River and its tributaries, in particular Jerrara Creek and throughout Terragong Swamp is a concern with regards to fish habitat.

West & Jones (2001) conducted a shallow water fish survey of the Minnamurra River Estuary. Sampling included seine netting across several sites throughout the estuary during the summer and winter of 1998. A total of 25 species were recorded including groper, leatherjackets, rabbitfish, pufferfish, Glassy perchlet, luderick, Flat-tail mullet, Sand mullet and various gobies.

A fish survey was also conducted by Cardno (2013) in Jerrara Dam, Jerrara Creek and Minnamurra River (within the vicinity of the Jerrara Creek confluence) during October 2012. Species recorded in Jerrara Creek and Jerrara Dam included Long-finned eel, Short-finned eel, Flathead gudgeon, Striped gudgeon, Cox's gudgeon, Australian bass and Australian smelt. Species recorded at the Minnamurra River sites included Short-finned eel, luderick, Sea mullet and Australian bass. The brackish billabongs which formed the original course of the River are considered to be important breeding grounds for Australian bass (Harris, 2002).

NSW Fisheries has also undertaken several fish surveys as a part of the Monitoring, Evaluating and Reporting Program including targeted Australian grayling surveys. Surveys were undertaken at Minnamurra Falls, Jamberoo and Swamp Road and recorded a total of 15 species of fish, prawns and eels (Table 8).

None of the fish species recorded are of conservation significance (i.e. threatened species) however many species, in particular Australian bass, are considered to be recreationally important species.

Table 8: NSW Fisheries Minnamurra River catch records summary

Site	Species Recorded
Minnamurra Falls	Cox's gudgeon, Long-finned eel
Jamberoo	Australian bass, Australian smelt, Bullrout, Common jollytail, Cox's gudgeon, Dwarf flat-headed gudgeon, Empire gudgeon, Long-finned eel, Short-finned eel, Striped gudgeon, unidentified gudgeon
Swamp Road	Australian bass, Australian smelt, Dwarf flat-headed gudgeon, Eastern gambusia, Empire gudgeon, Long-finned eel, School prawn, Sea mullet, Short-finned eel, Striped gudgeon, Yellowfin bream.

Source: NSW Fisheries (2014)

Many of the species of fish that occupy the freshwater reaches are for at least a part of their lifecycle considered to be migratory or undertake broad scale (non-migratory) movements. Species such as Australian bass, various species of mullet and eels are well known for their catadromous (fresh to salt water) migrations to spawn and others, such as Australian smelt, for their potadromous (within freshwater) migrations. For example, Australian bass migrate from freshwater reaches downstream to brackish water in the cooler months where they spawn. During spring they migrate back upstream to the freshwater reaches again. In order for these species to successfully undertake their important and necessary migrations they require unrestricted passage.

In-stream physical structures such as dams, weirs, barrages, culverts and causeways are generally the greatest barriers to fish passage. Jerrara Dam on Jerrara Creek is currently a barrier to upstream and downstream (during low flows) migration. During high flows fish can exit the dam downstream over the spillway, however, they cannot migrate back upstream over the spillway. KMC is currently in the process of decommissioning Jerrara Dam. As a part of the decommissioning process, a part of the dam wall will be removed and a fishway installed which will provide connectivity between habitats either side of the dam allowing migration of fish through the area.

Other instream structures, such as the rock ramp erosion structures installed in the Minnamurra River through the swamp do not pose a significant barrier to fish passage. These structures have integrated fishways allowing fish to pass freely though the structures.

6.6.2 Birds

The Minnamurra River Estuary is home to a wide range of bird species utilising the area for both food and shelter. Land-based birds inhabit vegetation along the foreshore and riparian areas along the river and throughout the catchment. Shorebirds forage along the sandbanks, mangroves and seagrass areas at low tide. Other waders such as herons and ibis (OEH, 2014a) forage along the shoreline and saltmarsh of the estuary and across flats of the swamp. Seabirds including cormorants, terns, gulls, kestrels and pelicans (OEH, 2014a) feed on fish and other aquatic animals in the lower estuary and adjacent beaches. Large predatory birds, such as the threatened Eastern osprey, hunt throughout the estuary. White bellied sea eagles nest within the catchment and are often seen hunting near the river mouth and spit. Pied oyster catchers are also often sighted (B. Robinson).

Native birds that are dependent on closed forest include the Topnot pigeon, Brown cuckoo-dove, Emerald pigeon, Large-billed scubwren, Green catbird, Olive whistler, Powerful owl, Masked owl and Sooty owl (Harris, 2002).

6.6.3 Other Native Fauna

Harris (2002) reports that some native fauna including Parma wallaby and Eastern quoll are no longer found in the catchment and others (Platypus and Long-nosed potoroo and many bird species) are rarely sighted. Surviving species are:

- Greater gliders prefer mature undisturbed blue gum forests on the upper slopes of the catchment;
- Long-nosed potoroos prefer tall open forest and rainforest with thick undergrowth such as in Barren Grounds Nature Reserve;
- Tiger quolls inhabit woodlands, shrublands, tall open forest and mangroves;
- Grey-headed flying foxes feed on blossoms of native plants and fruits of rainforest plants and play a vital role in the pollination of eucalypt species and dispersal of rainforest fruits; and
- Reptiles including the Diamond python and Tiger snake live in riverine corridors and closed forest.

Killalea State Park Trust is currently undertaking an ecological survey as part of the review of its Plan of Management. This will provide additional information about species present in the Park.

6.6.4 Domestic Dogs

Off-leash dog walking areas are provided at Minnamurra Headland (just south of the estuary catchment) as well as other headlands and beaches within Kiama LGA. Council is currently trialling an on-leash swimming area at Trevethan Reserve, Minnamurra - a designated area in the Minnamurra River between the rail and road bridges. Dogs are not currently permitted off-leash within the Minnamurra River Estuary catchment or permitted to swim in the river (apart from the trial swimming area).

Issues raised by the community and managers of Killalea State Park relating to dogs are:

- The signs advising dog access areas are confusing and difficult to read (relating to understanding of the mean high water mark, Figure 36);

Figure 36: Dog regulatory signage

- Dogs are often seen swimming either on leash or off-leash in prohibited areas, particularly near the entrance;

- The trial swimming area is located near the popular fishing jetty;
- Impacts of dog faeces and urine on water quality (at the trial swimming area as well as prohibited areas);
- Dogs are taken across the river to Killalea State Park, particularly in peak tourist times; and
- Impacts on native fauna including disturbance of nesting and foraging activities and relocation due to laying of scents.

Council and Killalea rangers patrol and fine illegal dog activity when resources permit.

6.6.5 Feral Animals

Feral animals such as foxes, deer, rabbits and pigs within the vicinity of the Minnamurra River Estuary have been raised as a concern by members of the community and managers of Killalea State Park:

Since their introduction in the mid-1800s, foxes have become widespread throughout Australia occupying over three quarters of the mainland except for the tropical north. Foxes have been attributed as the primary cause for the population decline and loss of many small native marsupials and rodents through the country. They are also damaging to agriculture as they often take juvenile livestock. Foxes carry a variety of parasites including *Echinococcus granulosus*, the Hydatid tapeworm and a number of other parasites which are able to be transmitted to humans, domestic animals and livestock. Of particular concern is the role foxes could play in an outbreak of rabies if this virus is introduced to Australia.

Predation by the red fox has been listed under the TSC Act 1995 as a key threatening process. A threat abatement plan (TAP) for predation by the European Red Fox *Vulpes vulpes* has been prepared and is being implemented by NPWS. There are no TAP priority fox control sites within the Minnamurra River Catchment. Foxes are currently managed in NSW through programs including fox threat abatement plans to protect the environment, and property pest management plans to manage the impact to livestock enterprises. However, it has always been optional for landholders to participate in fox pest control programs and, as a result, can reduce the effectiveness of control programs because foxes disperse into vacant territory, and are more likely to re-colonise previously controlled areas. To improve the management of foxes as a pest, NSW Primary Industries has developed a pest control order for the European Red fox which will apply throughout NSW. The proposed pest control order is currently on exhibition.

There are anecdotal reports that pigs inhabit the Killalea and Dunmore area around Rocklow Creek and the waste depot. Pigs are generally found in close proximity to damp areas but are found in a variety of habitats including, forests, swamps and floodplains, marsh areas, woodlands and grasslands. Pigs are opportunistic omnivores with a varying diet from grass, foliage, roots, grains, fruits and berries to small animals and carrion. Consequently, feral pigs cause detrimental impacts on both agriculture and the environment. Predation, habitat degradation, competition and disease transmission by feral pigs is listed under both the TSC Act 1995 and the EPBC Act 1999 as a key threatening process. A threat abatement plan for the predation, habitat degradation, competition and disease transmission by feral pigs was prepared under the EPBC Act 1999 by the Department of Environment and Heritage (2005).

Rabbits are numerous in modified areas as well as nearby intact vegetation. Deer are present throughout the Illawarra and are a threat to the Swamp Wallaby and establishment of bush regeneration areas. Deer have been sighted around Killalea State Park, presumably from Dunmore rural areas.

6.7 Acid Sulfate Soils

Acid Sulfate Soils (ASS) are acidic and sulfur rich soils found within the floodplain of coastal areas generally below 5 m AHD. Potential Acid Sulfate Soils (PASS) is the common name given to soil and sediment containing iron sulfide (usually pyrite). They can become Actual Acid Sulfate Soils (AASS) and produce sulfuric acid if they become exposed to air through excavation or lowering of the water table.

The water quality impacts of Acid Sulfate Soil (ASS) runoff on the estuarine environments include low pH, high concentrations of dissolved iron, aluminium and other metals. Exposure to ASS runoff can impair gill function and increase susceptibility to disease in fish, particularly Epizootic Ulcerative Syndrome (EUS), otherwise known as Red Spot Disease. Major negative implications of ASS impacts include fish kills and major aquatic habitat changes, reduced plant growth (acid scalds), and corrosion of concrete, iron and steel structures.

Under the 2011 KMC LEP, parts of the study areas are classified as ASS. These include (refer Figure 37):

- The lower and mid estuary and its foreshores are classified from Class 1 through to Class 5 ASS;
- The mid to upper estuary are predominantly Classes 2, 3 and 5;
- From Swamp Road upstream to around the midpoint between Swamp Road and Factory Lane the soils are generally classified as Class 2, 3 or 5 ASS and;
- From the midpoint between Swamp Road and Factory Lane soils are predominantly Class 4 and 5 ASS.

There have not been any issues raised in relation to ASS in the Minnamurra River Estuary.

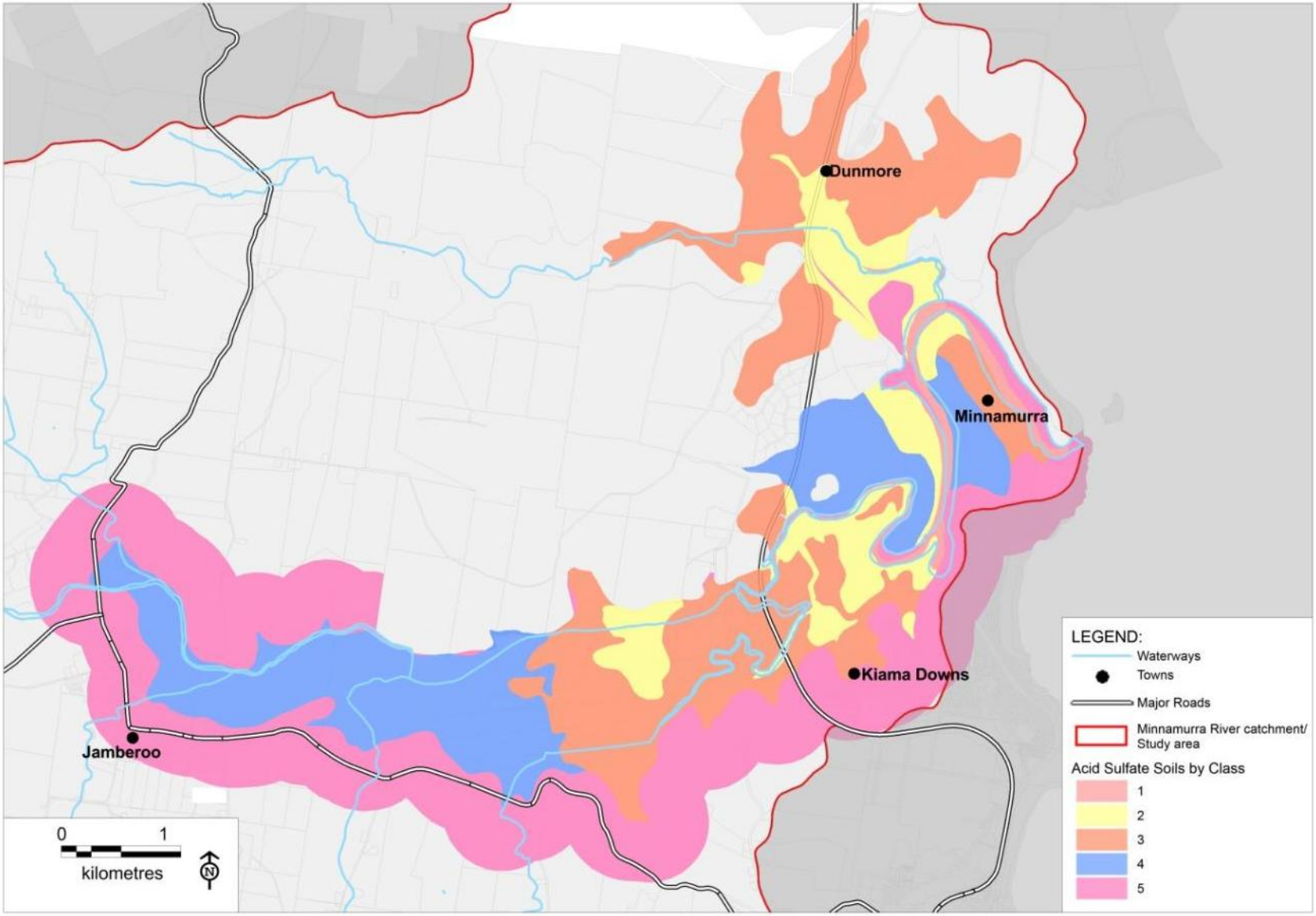


Figure 37: ASS Risk Maps

Table 9 provides the development consent requirements for works on land classed as ASS.

Table 9: Development consent required for the carrying out of works on land shown in ASS map

Class of Land	Works
1	Any works.
2	Works below the natural ground surface. Works by which the watertable is likely to be lowered.
3	Works more than 1 metre below the natural ground surface. Works by which the watertable is likely to be lowered more than 1 metre below the natural ground surface.
4	Works more than 2 metres below the natural ground surface. Works by which the watertable is likely to be lowered more than 2 metres below the natural ground surface.
5	Works within 500 metres of adjacent Class 1, 2, 3 or 4 land that is below 5 metres Australian Height Datum and by which the watertable is likely to be lowered below 1 metre Australian Height Datum on adjacent Class 1, 2, 3 or 4 land.

6.8 Urban Stormwater and Drainage

Urban drainage can affect estuarine processes through:

- Changes to the hydrologic characteristics (catchment hardening) of lands generating increased runoff and making them drain more quickly, partly due to the increased imperviousness, i.e. road, roofs, etc.;
- The use of hydraulically efficient stormwater pipe systems which remove stormwater to the waterways more quickly; and
- Changing the quality of stormwater runoff due to urban pollutant sources.

Stormwater from urban areas can often discharge significant loads of pollutants to receiving water bodies. These pollutants include litter, nutrients, sediment, oxygen-depleting substances and hydrocarbons, which are transported from the site by urban runoff or stormwater.

There are three main urban stormwater catchments within the study area in primarily residential areas – Minnamurra and Kiama Downs (Gainsborough) shown on Figure 38 and Jamberoo shown on Figure 39.

An undergraduate engineering thesis (Roso, 1998) assessed the quality of water draining into the lower estuary from Gainsborough estate. Within the Gainsborough estate, 45% of the development (approximately 370 homes to the east) drains directly to the Minnamurra River through the SEPP 14 wetlands near the second meander. The remaining properties drain to Pond 1 (to the south) or Pond 2 (closer to the river). Pond 1 flows to Pond 2 therefore runoff from approximately one quarter of the houses receives treatment in both ponds and one quarter from one pond (Figure 39). Pond 1 was not originally designed to be a pond, but the channel is flat and water pools to a shallow depth, promoting growth of bullrushes (Roso, 1998). A summary of the water quality results from Roso (1998) is provided in Appendix 6.

KMC has installed stormwater pollution control devices in the Minnamurra and Jamberoo catchments although these are not regularly maintained by Council. The stormwater outlet at the end of Rangoon Reserve no longer has a litter capture net. Litter has also been observed near stormwater outlets (refer Section 6.12). From the available water quality data it is not possible to separate stormwater influences from diffuse catchment runoff and other potential point sources of pollution in the catchment.

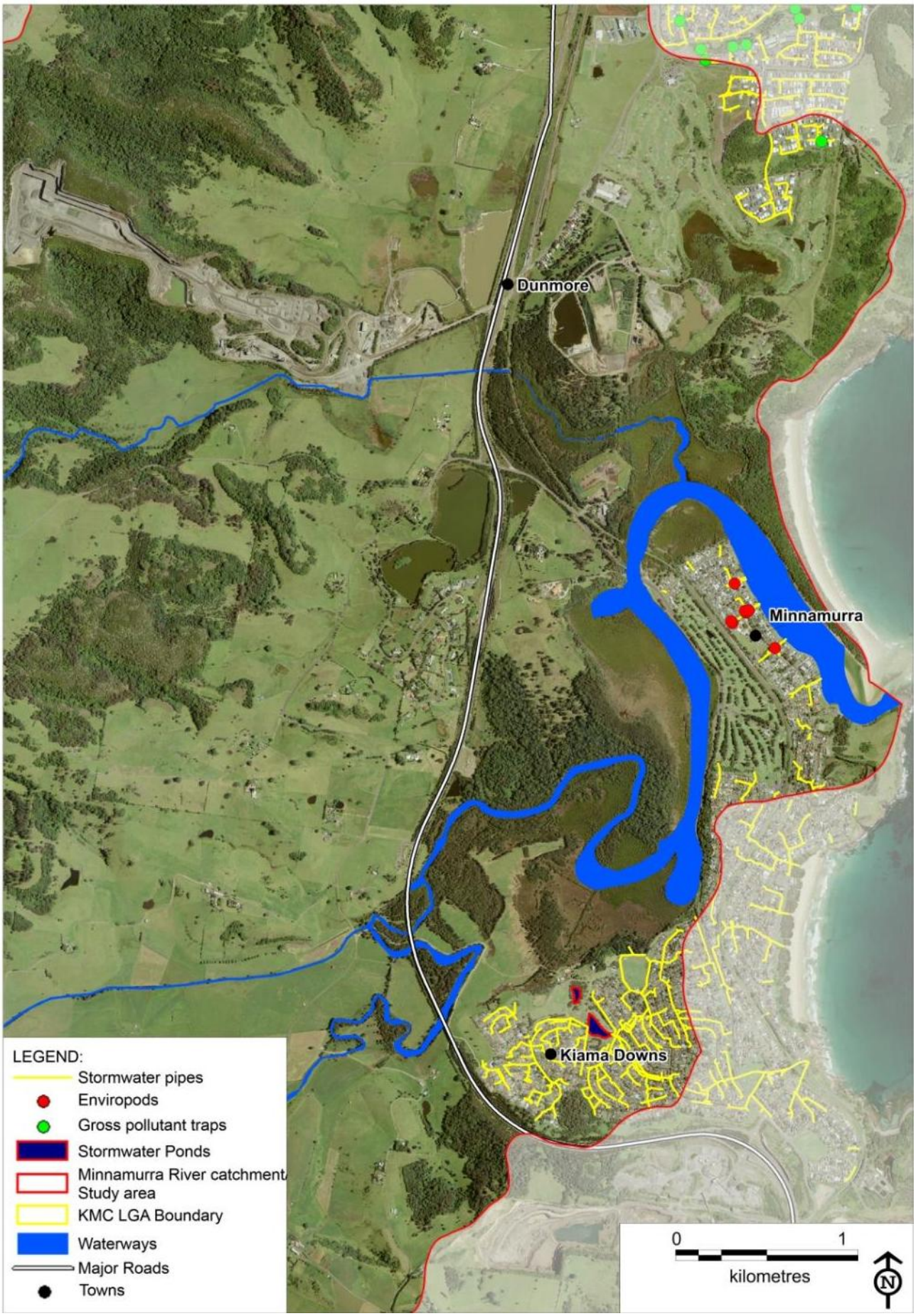


Figure 38: Minnamurra and Kiama Downs urban stormwater systems

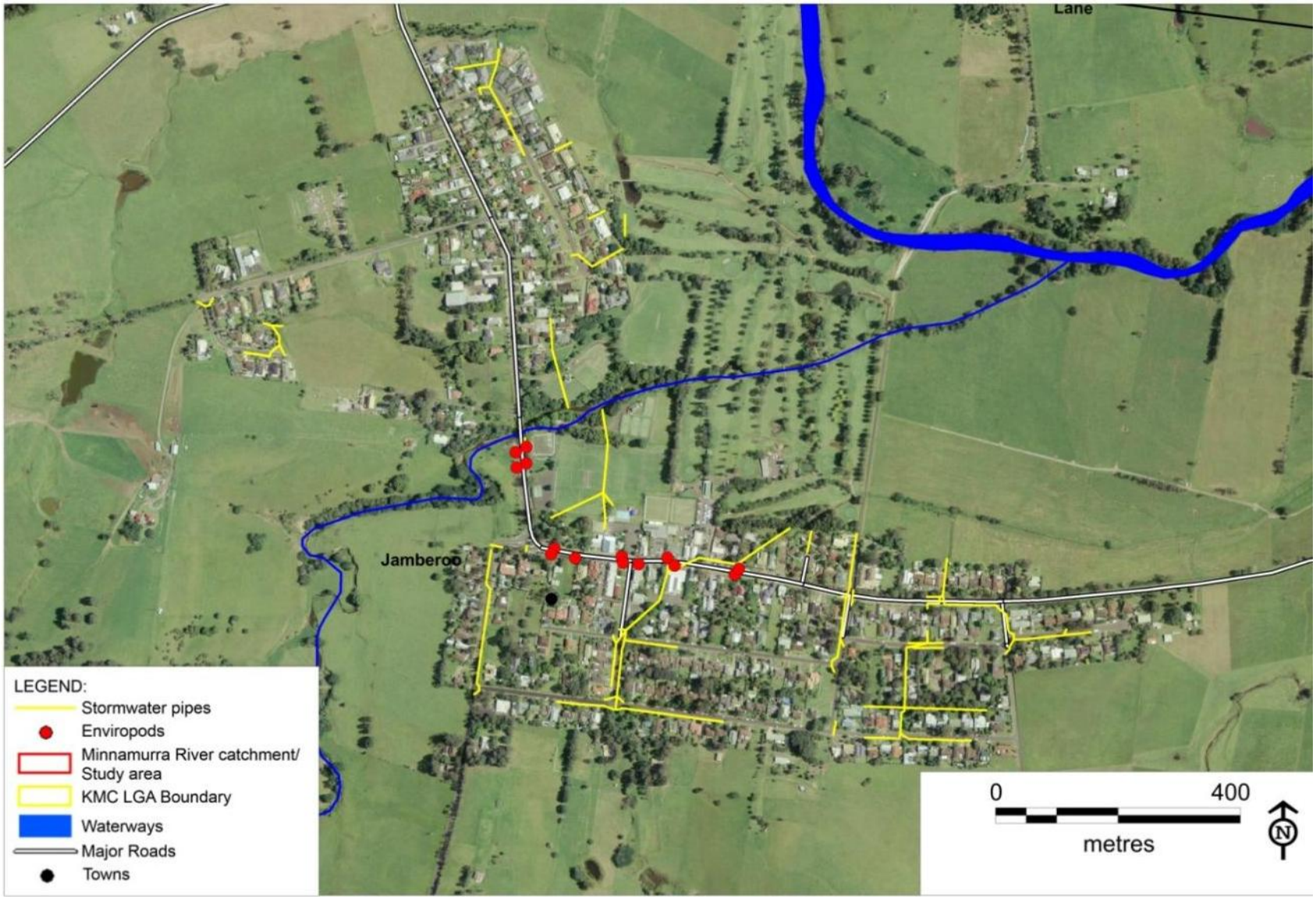


Figure 39: Jamberoo urban stormwater systems

Stormwater asset mapping provided by KMC and SCC. Note that mapping of infrastructure may not be complete.

The KMC Stormwater Management Plan was prepared in 1999 and reviewed in 2003. Many of the actions in the 2003 review are linked to the 2003 EMP Review actions. The status of actions from the 2003 Stormwater Management Plan are summarised below:

- Survey, locate and digitise stormwater drains and modelling of drainage system and integrate into KMC GIS and engineering databases - Being completed as part of the development of Council's asset management plan. Areas of Jamberoo and Kiama Downs need to be ground-truthed;
- Best-practice management standards and WSUD - Controls within the Council DCP and requirements of Council's Water Sensitive Urban Design Policy (2005) are incorporated into development assessments;
- Regular inspection of all construction sites – Sites are inspected following complaints and as resources permit;
- Provision of additional vocational training to Council is undertaken when funding and opportunity permits;
- Install litter baskets/ nets/ grates/ racks at various locations in Minnamurra/Kiama Downs catchment – 6 Enviropods (pollutant traps) have been installed along Charles Avenue (KMC, 2009);
- Habitat enhancement in concrete grid revetment along Minnamurra River at Rangoon Road – Rangoon Reserve is grassed with a concrete retaining wall and stormwater drains flowing to the river;
- Construct detention pond for runoff from Havelock Place, Gainsborough – not undertaken;
- Maintain GPTs and constructed wetlands on North Kiama Bypass – the drainage system for the bypass includes rock sediment traps and combined sedimentation and accidental spill basins;
- Install litter baskets/ nets/ grates/ racks at various locations in Jamberoo catchment - 19 Rapid Stormwater Filtration (RSF) units were installed (KMC, 2009);
- Jamberoo sewerage scheme (Sydney Water) – complete (refer Section 6.9);
- Litter management policies, garbage services and stormwater pit maintenance – mechanical street sweeping, maintenance of litter baskets and GPTs and distribution of doggie bags is ongoing;
- Monitoring of capture rates of pits and GPTs – not undertaken;
- Stormwater education program – program targeting builders and developers and residents in lower Minnamurra catchment as well as local newsletter and ongoing activities of the community based environment group and school-based education programs (KMC, 2009);
- Sewerage overflows – refer Section 6.9;
- Environmental audits of industrial and commercial premises – Commercial and industrial issues are investigated and remediation ordered when pollution events occur or complaints are registered with Council;
- Spill management procedures on RMS and Council roads;
- Water quality monitoring – refer Section 6.3; and
- OSSM inspection program – refer Section 6.10.

KMC is in the process of developing an asset management plan, including a planned maintenance program for the stormwater systems. Maintenance activities such as regular cleaning of pollution control devices and pits is essential for effective operation of the stormwater system. In addition, an assessment of the maintenance and functioning of the Gainsborough stormwater treatment ponds is required. Council is

currently preparing an Asset Management Plan which should address many of these issues. KMC plans to carry out maintenance works on the Gainsborough Ponds in 2015/16.

6.9 Sewerage Systems

A centralised sewage treatment plant situated at Bombo (located outside the Minnamurra River Catchment) services all urban areas in the central and eastern Minnamurra River Catchment (Jamberoo, Kiama Downs and Minnamurra) as shown in Figure 40 and Figure 41. The Bombo STP provides secondary treatment, denitrification and disinfection. After disinfection the majority of the secondary treated water is returned to the environment through direct ocean discharge off the rock shelf on Bombo Headland (1,705 ML in 2012/13). A proportion of the treated effluent from the Bombo STP is re-used for irrigation purposes at the Kiama Golf Club with 81 ML re-used at the club during 2012/13 (Sydney Water, 2013). The small urban area in the north eastern corner of the catchment (southern area of Shell Cove) within the SCC LGA is serviced by a centralised STP located at Shellharbour.

The wastewater operational activities of Sydney Water are regulated by EPA Licences. The Sewage Treatment System Impact Monitoring Program (STSIMP) was developed in consultation with OEH and implemented from July 2008. The STSIMP has been designed to quantify and evaluate the effects of Sydney Water operations on the environment, as required by licences. The indicators selected are based on current knowledge of the relationship between pollutants and ecological or human health impacts. The program is consistent with national water quality guidelines (ANZECC, 2000) and NSW State of the Environment reporting, as well as the objectives of previous monitoring programs undertaken by Sydney Water, NSW OEH and other agencies. The licences have referenced the STSIMP to specify environmental monitoring and reporting requirements for Sydney Water's wastewater operations. Each licence also directly specifies other types of monitoring requirements such as wastewater discharge quantity and quality, as well as performance standards. Sydney Water is required to prepare annual reports on monitoring from all of these programs to assess its environmental performance in relation to the licences issued by the EPA. Beach suitability grades for Boyds Beach, Bombo Beach and Surf Beach, Kiama were good or very good during 2012/13 (Sydney Water, 2013).

Figure 40: Minnamurra and Kiama Downs sewerage system

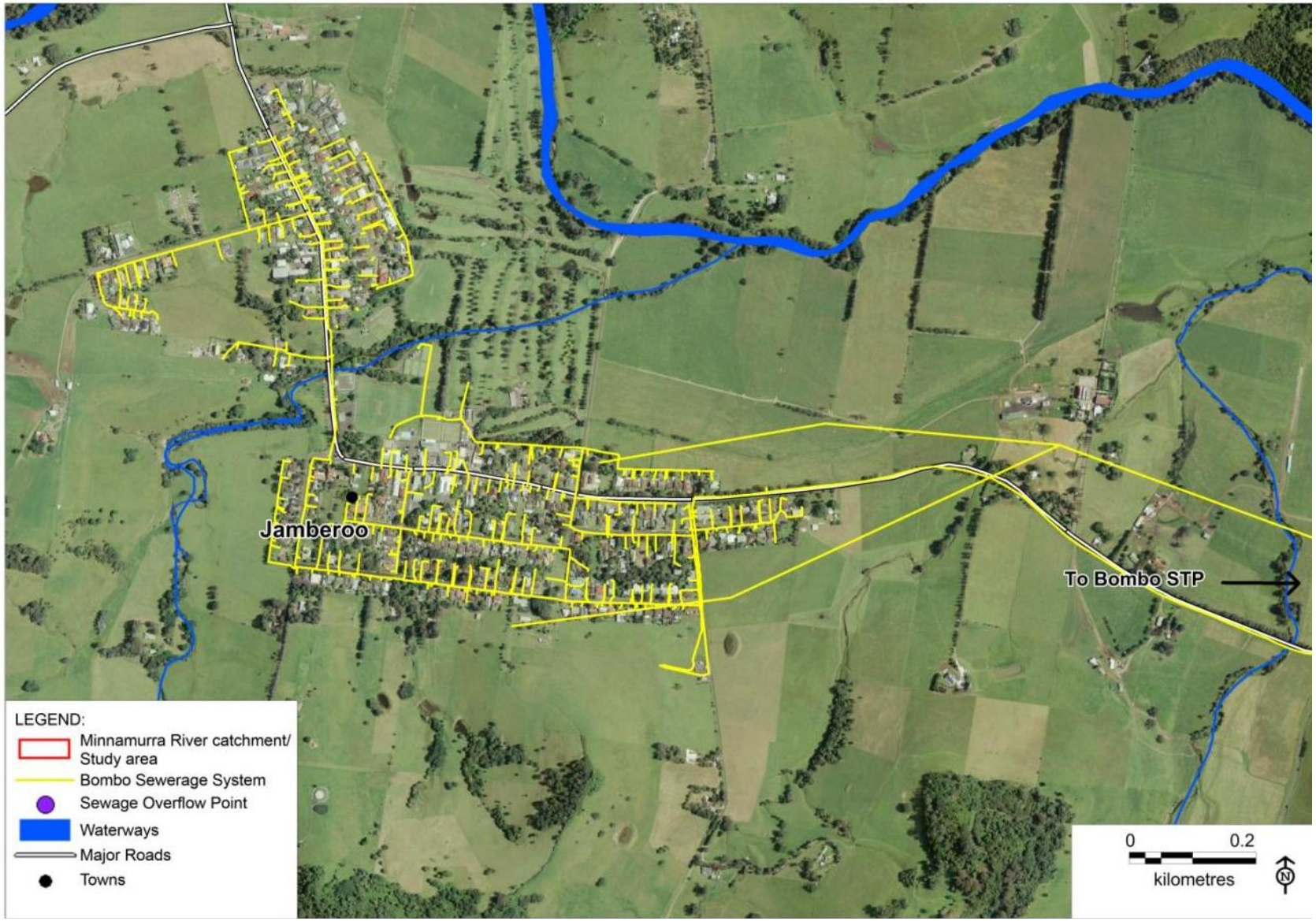


Figure 41: Jamberoo sewerage system

Dry weather overflows may also occur due to blockages in the sewerage system caused by tree roots and wastewater pipe breakages, while wet weather overflows are normally due to infiltration of stormwater and illegal connections exceeding the system's capacity. Overflows result in untreated or partially treated effluent being discharged into waterways with extent of the effect depending on the volume and frequency of the overflows.

Sydney Water prepared sewerage system overflows EISs and specified management actions for priority overflow sites in each sewerage system. The EIS for the Kiama sewerage system (Sydney Water, 1998) found no overflows of major concern. Wet weather discharges are small and infrequent, the STP has the capacity to treat most (if not all) discharges and chokes and exfiltration are not major problems. The main overflows of concern were found to be sewerage pumping station failures and impacts on sensitive receiving environments. The performance of some aspects of the system failed to meet Sydney Water objectives and therefore some actions were required in the system including increased wet weather containment, reduction in partially treated STP discharges, reduction in overflows caused by chokes and additional storage and back-up power facilities at pumping stations (Sydney Water, 1998).

Hydraulic models are used to predict the overflow performance of the sewerage systems (Table 10).

Table 10: Modelled sewerage overflows – Kiama sewerage system

Overflow Site [1]	Overflow type	Number of overflow events per 10 years	10 year overflow duration (hours)	10 year overflow volume (ML)
1	Untreated diluted sewage	3	29	2.1162
5	Untreated diluted sewage	7	72	8.5027
7	Untreated diluted sewage	6	54	5.9220
12	Untreated diluted sewage	11	104	7.1222

1. See Figure 40 for site locations. There are no overflows in Jamberoo.

6.10 On-site Sewerage Management Systems

Properties located in non-urban areas of the catchment are serviced by decentralised on-site sewage management systems (OSSM) such as septic tanks. These include small, unlicensed treatment plants servicing tourist facilities which are regulated by KMC. Figure 42 indicates that there are approximately 385 OSSMs located throughout the catchment within the KMC LGA (data are not available for the SCC LGA). Under the KMC *On-site Sewage Management Strategy* (KMC, 2004) systems within the KMC LGA are risk ranked as either a low or high risk system (high risk systems being located in an environmentally sensitive area). There are approximately 60 recorded high risk systems located throughout the catchment within the KMC LGA. High risk systems are subject to annual audits and low risk systems are subject to an audit every four years. If an audit reveals that a system is non-compliant or defective then council will contact the owner to discuss measures to rectify the problem or issue an order for rectification if necessary.

Leaking OSSMs were identified as a water quality issue by the community in the 1995 EMP. Analysis of groundwater data concluded that they could be contributing to high groundwater nutrient levels in Terragong Swamp (PBP, 1995b). In the mid-2000s, approximately 320 dwellings in the (previously) unsewered rural village of Jamberoo were connected to the Kiama sewerage system.

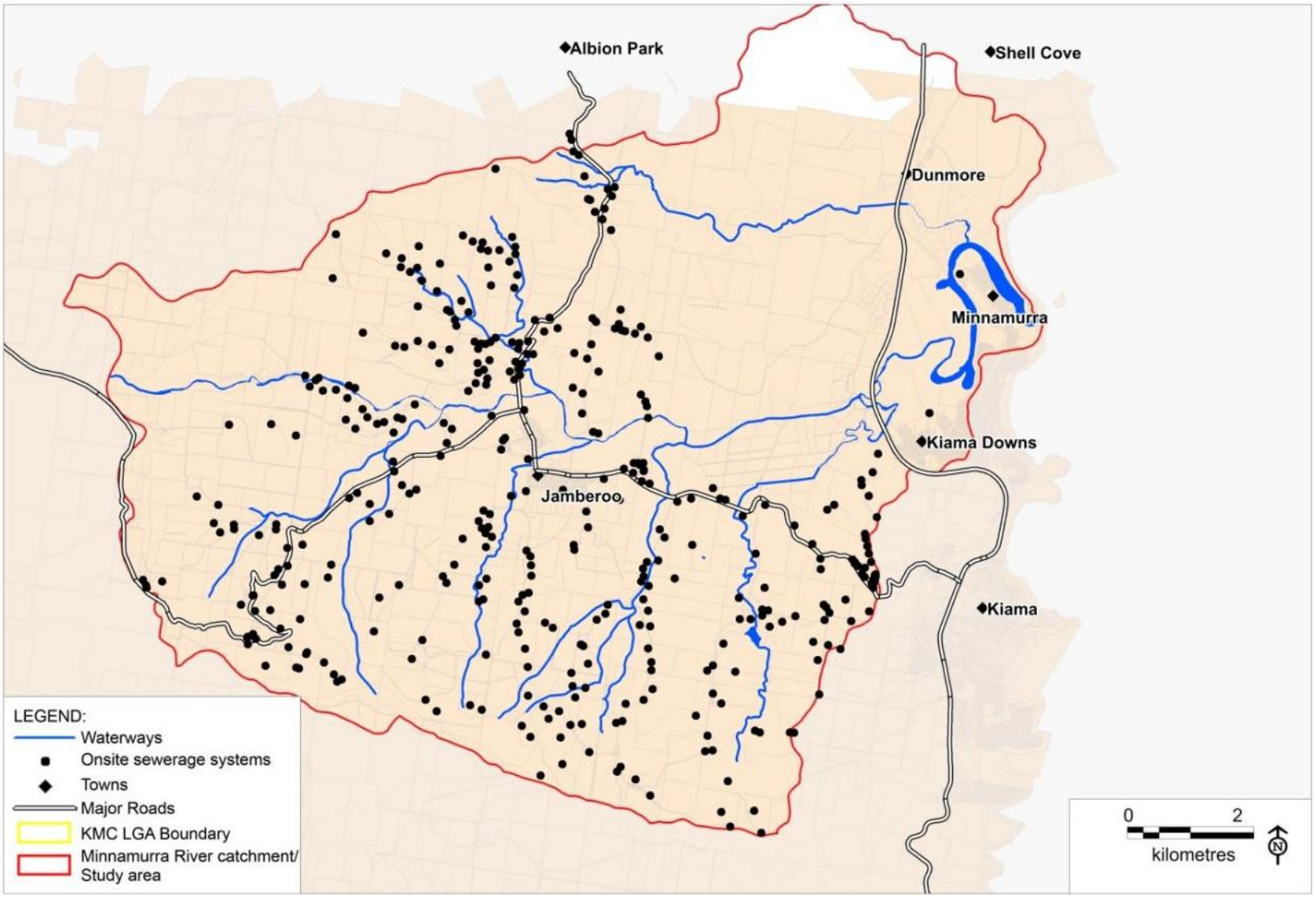


Figure 42: On-site sewerage systems in Kiama LGA

Note: SCC OSSM mapping was unavailable

6.11 Water Extraction

The Minnamurra River is part of the Plan area for the *Greater Metropolitan Region Unregulated River Water Sources Water Sharing Plan* (Office of Water, 2011a). Under the Water Sharing Plan, the total surface water entitlement in the Minnamurra River Management Zone is 978 ML/year (41 licences) with 55% used for irrigation purposes (NSW Office of Water, 2011 and 2014). Water access licences are in place for:

- Domestic and stock (a category of access licence for landholders who cannot access water under basic landholder rights (i.e. their property does not directly front a river, lake or estuary, or have an underlying aquifer) – 11 licences totalling 42.5 mL/a; and
- Unregulated river – a category of access licence that covers purposes such as irrigation, industry, mining, recreation and general farming; in most water sources, irrigation accounts for the majority of this type of licence – 30 licences totalling 935.9 ML/a (NSW Office of Water, 2014).

Under the *Water Management Act, 2000*, extraction of water for basic landholder rights (BLR) does not require a licence, although in the case of accessing groundwater under BLR the bore must still be approved by the Office of Water. BLR includes water for domestic and stock purposes extracted from a water source fronting a landholder's property or from any aquifer underlying the land, and for native title rights.

The Report Card for the Minnamurra River provides the background information considered in the preparation of the WSP. The report card identifies the following considerations for the freshwater section to the mangrove limit (NSW Office of Water, 2011):

- High hydrologic stress due to peak extraction demand exceeding available flows in December;
- High relative in-stream value due to the presence of threatened species and endangered populations;
- High risk to in-stream value due to extractions from the water source; and
- Medium relative economic significance of irrigation – medium economic dependence of local community on water extracted for irrigation, no industrial or town water supply extraction and 4% of population employed in irrigated agriculture.

For the estuary section, the report card identifies:

- Medium sensitivity to inflows (low flows) from the upstream catchment;
- High estuary value – due to the presence of threatened species, threatened ecological community and high diversity;
- Medium catchment hydrologic stress as peak extraction is generally less than available flows in December; and
- Estuary values are at high risk from extractions from the freshwater sections.

Water access rules (including low flow access conditions and cease to pump rules during declining flows) are defined in the Water Sharing Plan to protect low flows from irrigation and address the risks listed above. There is currently an embargo on new extraction entitlements from the river and water trading is minimal. The WSP will be reviewed in 2021.

6.12 Litter

The presence of litter in the waterways, foreshores and trapped in vegetation is a concern of many community members. There are also concerns about rubbish from Dunmore Depot blowing into Rocklow Creek within Killalea State Park.

Feed bales and silage wrap and baling twine can be seen in some areas of the estuary (Figure 43A). Feed bales may be washed into the river in flood conditions, creating a relatively localised issue but efforts should be made to remove these due to high biological oxygen demand of the decomposing feed and the remaining twine and silage wrap. Silage wrap is present in many locations along the river in both estuarine and freshwater reaches, caught in riparian vegetation and on in-stream structures.

There is also litter (and cigarette butts) present at many of the public foreshore areas including the new fishing jetty (Figure 43B). Litter (from stormwater drains along Riverside Drive) is also present in mangrove areas adjacent to the golf course (Figure 43C).

A 

B 

C 

Figure 43: Litter

A – silage wrap (D. Wiecek, 2014), B – fishing jetty, C – litter in mangroves near stormwater outlet, Riverside Drive (D. Wiecek, 2014)

6.13 Contaminated Land

At the time of the 2003 EMP Review, there were two service stations in the study area and the review recommended distribution of EPA Policy guidelines on pollution from service station forecourts. There are currently no service stations within the catchment.

There are no records of Notices under the *Contaminated Land Management Act 1997* within the study area (the EPA has not issued regulatory notices to any sites in the study area). The Dunmore Equestrian Centre (planned for the site of the Kosseris development) is listed as a contaminated site notified to the EPA, although the EPA considers the contamination of the site is not significant enough to warrant regulatory intervention under the *Contaminated Land Management Act 1997.*

6.14 Flooding

The Illawarra catchments including the Minnamurra River are prone to very high magnitude floods per unit catchment area. An exceptional flood occurred in the Minnamurra River catchment at the turn of the century with large floods also in 1959, 1972 and 1975 (Reinfelds, 1999). Community members have also reported floods occurred in more recent times (early autumn in 2011 and 2012, Figure 44). The high frequency of large floods is due to the small catchment area, the frequency of localised intense storms and large number of small catchments along the escarpment.

Inundation of low-lying land is caused by a range of factors which can act either individually or in combination and can have differing effects in terms of the frequency and extent of inundation, event duration, predictability and type of impact. The key causes of inundation of the Minnamurra River floodplain are:

- Minnamurra River catchment flooding;
- Tidal/storm surge inundation; and
- Poor site drainage.

Figure 44: High river levels at Charles Avenue foreshore during floods (11/3/2011)

Photo courtesy A. Wilson

6.15 Impacts of Climate Change on Ecosystem Health

Sea level rise is anticipated to result in management issues including increased inundation of low lying lands, infrastructure and development and implications for drainage and flooding in urban areas (refer Section 3.2.7). With an increasing mean sea level, the elevations of the peaks of the highest astronomical tides will also rise, meaning that susceptible areas will be inundated to greater depths and more frequently in future. Changes in salinity and water quality in estuaries may result and saline interfaces will migrate further upstream over time. Erosion inside the Minnamurra River Estuary may also be affected by sea level rise. The foreshores of the lower estuary will be affected by recession and, potentially, a higher energy foreshore wave climate caused by deepening of water adjacent to the foreshore. A higher energy wave climate will tend to flatten sandy foreshores around the lower estuary. Coastal hazards will be addressed separately in Council's Municipality-wide CZMP.

6.15.1 Impacts on Water Quality

Minnamurra Depot

The Minnamurra Depot is situated on the northern side of the Minnamurra River Estuary, between Riverside Drive and Rocklow Creek (Figure 15). The site is approximately 20 ha of which approximately 6 ha is

occupied by a landfill mound (refer Section 3.1.6). The site is generally very low lying at approximately 1 m AHD and is surrounded on the northern and western sides by saltmarsh and mangroves.

The height of the landfill mound ranges from 1 m to 14 m (AHD) with 3:1 batter slopes. The top of mound is capped with a 0.5 m clay layer, overlain with 0.1 m thick compacted road base layer. The sides of the mound are capped with a 0.5 m thick clay layer overlain by a 0.3 m evapotranspiration layer (soil/compost mix) which reduces the infiltration of rainfall into the landfill mound. However, it is estimated that approximately 30% of rainfall infiltrates the mound. There is no sealing layer underneath the mound however it is underlain by an approximately 0.5 m thick organic silt layer then by fine to medium grained sands (E2W, 2012).

Groundwater at the site is contained in a semi-confined sandy aquifer with the groundwater level around 1 m below natural ground level (approximately 0.5 m AHD). Groundwater salinity ranges from freshwater to saline, with the freshwater-saltwater interface interpreted to exist at the boundary of the *Casuarina* and mangroves at the site. Hydraulic gradient is likely to be variable, however, the general direction of groundwater flow is considered to be from south-west to north-east across the site towards the confluence of Rocklow Creek and Minnamurra River (E2W, 2012).

Groundwater at the site is vulnerable to contamination from the landfill mound due to the following factors:

- There is no underlying sealing layer;
- Some infiltration (approximately 30%) occurs through the mound;
- The underlying soils are made up of predominantly permeable sands; and
- The groundwater table is shallow.

There is currently some contamination of groundwater at the site, in particular ammonia and nitrate as discussed in Appendix 6. Groundwater sampling indicates current contaminant plume migration towards Rocklow Creek and Minnamurra River (E2W, 2013). Further, surface water quality monitoring in Rocklow Creek indicates leachate from the site is impacting water quality within Rocklow Creek (refer Appendix 6).

An assessment of sea level rise impacts indicates that the projected 2100 highest astronomical tides (HAT) will encroach into low lying areas of the site such that tidal waters during a HAT will be moving overland to the site and flood the base of the mound (Figure 45 and Figure 46). Such events are likely to exacerbate contamination of groundwater and surface water via a number of processes:

- Groundwater levels are likely to rise as the river level increases with sea level rise. The groundwater level is currently relatively shallow, approximately 0.5 m below the base of the land fill mound. Any increase in the groundwater level will reduce the vadose zone and subsequently the distance contaminants have to travel to enter the groundwater, thereby reducing the potential for attenuation of contaminants in the soil. Additionally, a rising water table and associated capillary fringe will effectively flush out contaminants held within the base of the landfill mound or the soil below it, into the groundwater table; and
- Currently, potential contamination of the receiving water body (Rocklow Creek) is via groundwater pathways where transport of contaminants is generally reduced by natural attenuation processes before entering surface water bodies (E2W, 2012). Inundation of the site during HAT events is likely to result in some lateral infiltration of the mound by tidal waters. Water may infiltrate through and under the capping during such events and drain out both laterally (as surface water) and vertically (into the groundwater table) leaching contaminants from the landfill mound. This has the potential to significantly accelerate the export of contaminants from the site as they are being leached by and directly exported to the receiving water body.

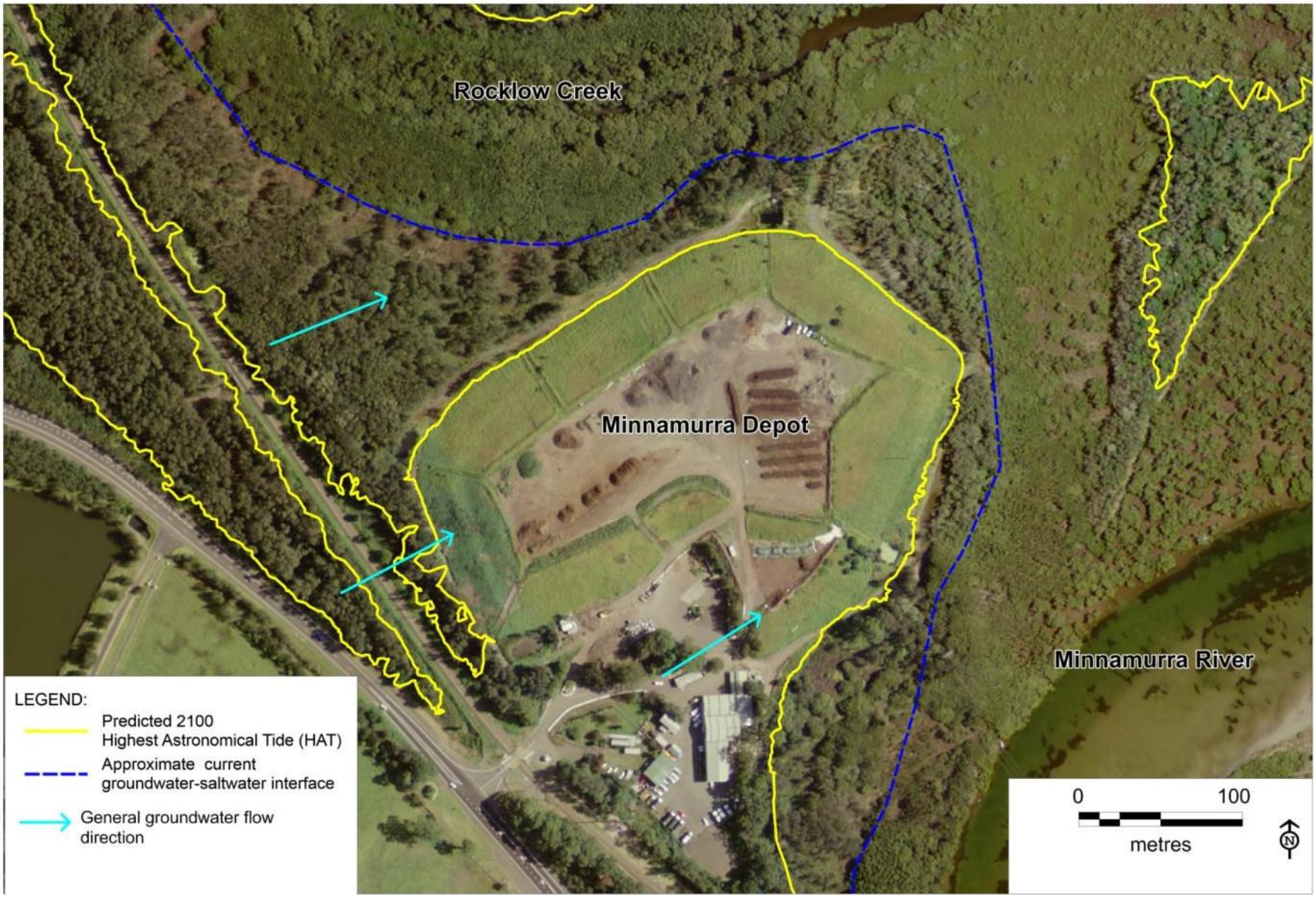


Figure 45: Predicted 2100 highest astronomical tide at Minnamurra Depot

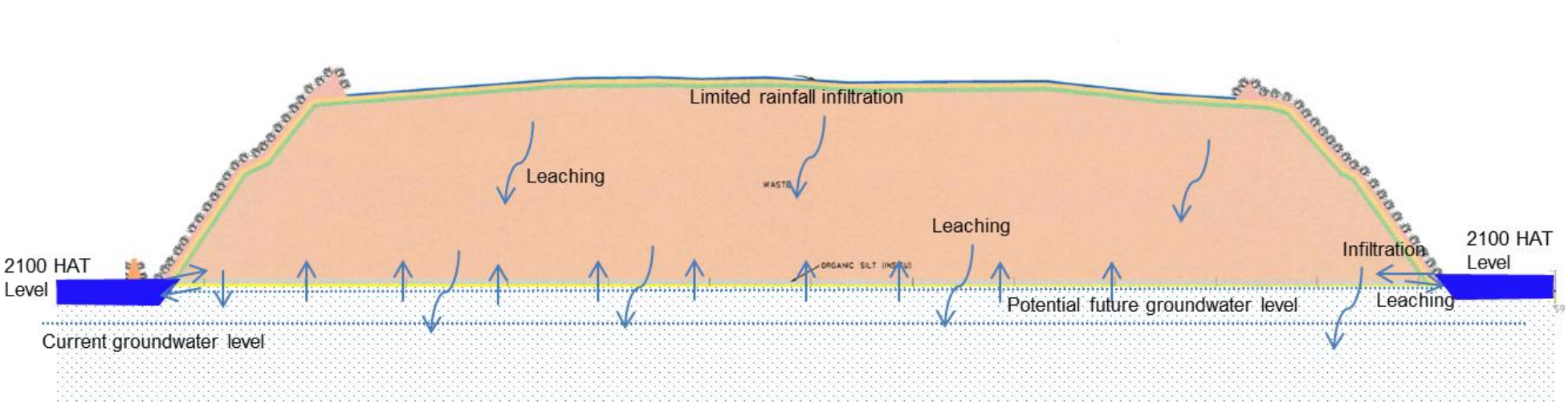


Figure 46: Potential effects of sea level rise on Minnamurra Depot landfill mound

Source: Modified from E2W (2008)

The low lying areas of the mound are the most susceptible to both groundwater level rise and inundation, particularly along the eastern and northern flanks which have an average footprint level of 0.96 m and 1.0 - 1.15 m AHD respectively (E2W, 2012). Contaminants leached from the mound are likely to include current contaminants of concern (ammonia and nitrate) and due to the historic uses of the landfill, potentially other pollutants. Contaminated leachate from the site could potentially result in negative water quality impacts on downstream groundwater and receiving surface water bodies such as Rocklow Creek and the lower Minnamurra River Estuary.

Projected future HATs are generated using future sea level rise heights and therefore there is some level of uncertainty around these. Additionally, there is only a limited understanding of the current and future groundwater, surface water and contamination processes occurring at the site, however, the risk of future negative water quality impacts warrants further investigation into the mechanisms, processes and impacts of sea level rise on the Minnamurra Depot and what can be done to minimise these.

Dunmore Depot

The Dunmore Depot is situated approximately 500 m north of the Minnamurra Depot (on the opposite side of Rocklow Creek) approximately 4 km south of Shellharbour (Figure 15). The depot was established in 1945 and is still currently operating as a landfill site along with sand dredging operations (refer Section 3.1.6). The site currently consists of historic land fill areas, active landfill areas, historic sand dredging area and an active sand dredging area in the western area of the site.

Groundwater at the site flows in a general southerly direction at a rate of approximately 0.4 m/year towards Rocklow Creek. There is some contamination of groundwater at the site and high levels of ammonium and nitrate detected in on-site surface water ponds however, to date there has been no reported evidence of leachate detected in surface water downstream of the site in Rocklow Creek (refer Appendix 6).

Sea level rise modelling indicates that 2100 HATs will encroach onto the site resulting in the potential for increased contamination of groundwater and contamination of downstream surface waters. As for the Minnamurra Depot, groundwater levels are likely to rise as the river level increases with sea level rise.

Higher groundwater levels decrease the distance leachate has to travel before entering the groundwater table thereby reducing the opportunity for contaminants to be attenuated in the soil before entering the groundwater. There is also potential for rising groundwater to essentially flush out contaminants currently stored in strata above the groundwater table. Research indicates that tidal influence on groundwater in the area is generally limited to between 5 and 50 metres from the tidal creek (Rocklow Creek) (Environmental Earth Sciences, 2013). As sea level rises, this tidally influenced zone is likely to migrate further from the creek towards the Dunmore Depot increasing tidal pumping (or flow) of groundwater from the site and consequently increasing contaminant export from the site.

Figure 47 indicates the predicted future HATs are likely to flow to a section along virtually the base of the levee bank on the western perimeter of the site. This is likely to result in the inundation of a sediment pond located on the western side of the levee bank which may result in some stormwater management implications. Further, flooding of the sediment ponds by tidal waters may result in the flushing and release of potential contaminants directly to the receiving water body (Rocklow Creek). Depending on the structure of the levee bank, immediate topography and hydraulic permeability of the bank, HAT inundation of the base of the levee bank may have the potential to result in the infiltration of tidal waters through the bank potentially compromising its integrity.

As outlined above, projected future HATs are generated using future sea level rise heights and therefore there is some level of uncertainty around these. Additionally, there is only a limited understanding of the current and future groundwater, surface water and contamination processes occurring at the site, however, the greater risk of future negative water quality impacts warrants further investigation into the mechanisms, processes and impacts of sea level rise on the Dunmore Depot and what can be done to minimise these.

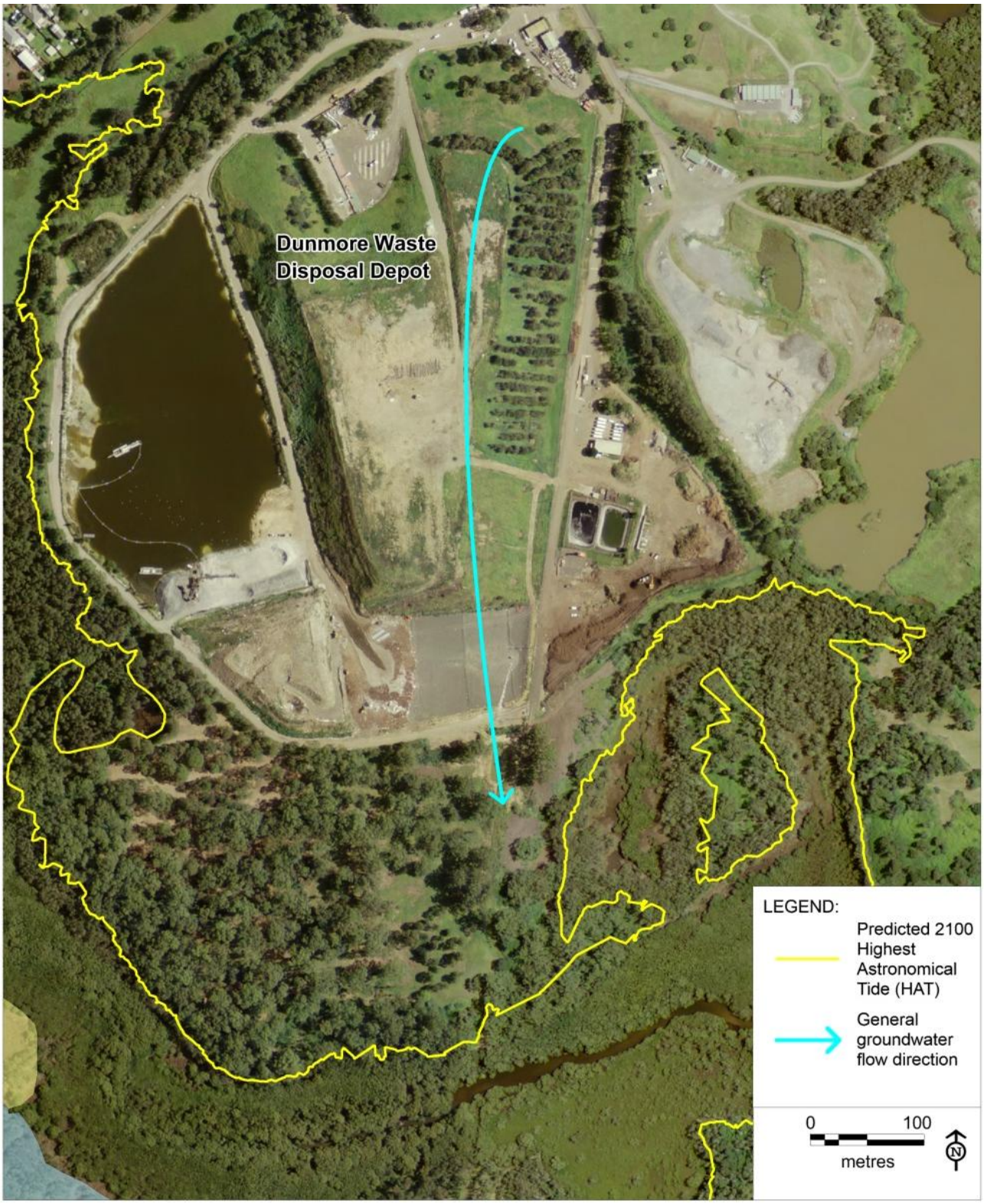


Figure 47: Predicted 2100 highest astronomical tide at Dunmore Depot

6.15.2 Floodplain Management Impacts

Inundation of low lying lands is likely to increase with continued climate change with increased storminess contributing to demands on stormwater infrastructure and sea level rise continuing to exacerbate issues associated with tidal intrusion and inundation.

Projected sea level rise is likely to result in saline intrusion further inland, as tides push further upstream. Rogers and Woodroffe (undated) report that sea level rise may eventually result in tidal penetration further upstream in the Minnamurra River, and the plains that have been drained and have sustained dairy and grazing may be subject to overtopping, tidal creek incision or saline intrusion. They also report that the low-lying alluvial plains may increasingly accommodate catchment runoff as a result of future climate change impacts. Further analysis of potential sea level rise impacts as part of future flood modelling work is required to evaluate impacts on the floodplain and current uses. If increased likelihood of saline intrusion and flooding of the floodplain is confirmed by modelling, management action will be required to mitigate impacts.

6.15.3 Impacts on Estuarine Vegetation

Sea level rise is expected to increase the average water depth and extend tidal propagation in the Minnamurra River Estuary with associated changes in salinity regime. It is anticipated that sea level rise will result in the landward recession of fringing estuarine wetland systems. The location of estuarine habitats such as mangrove stands and saltmarsh are controlled principally by tidal range and salinity influence and will gradually respond to changes in average water levels and salinity. There is a risk that natural upslope migration of these wetlands will be curtailed by anthropogenic constraints such as roads, rock walls, retaining walls and urban development on the landward side (DECC, 2009). This impact has been named “Coastal Squeeze” by the Department of Climate Change (now OEH, DECC, 2009) (refer Figure 48 below). Under these conditions the landward side of these important habitats will be fixed but the lower margin will gradually be pared away, leading to a loss of habitat area.

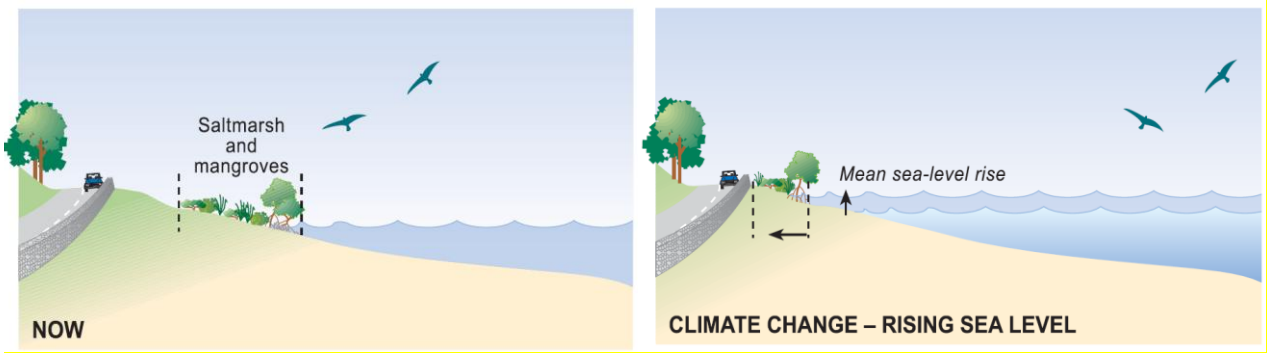


Figure 48: ‘Coastal squeeze’ under sea level rise: impact of development
Source: DECC, 2009

The *Kiama Municipal Council Climate Change Risk Assessment* (SKM, 2009) identified habitat loss as an ‘extreme risk’ for the 2050 and 2070 scenarios due to sea level rise and flood events impacting on saltmarsh and mangrove migration. Oliver *et al*. (2012) recently completed a study which modelled the response of mangrove and saltmarsh community response to projected sea level rise through the 21st century at a selected site in the mid-Minnamurra estuary (shown on Figure 49). The analysis involved the examination of surface elevation and sedimentation within mangrove and saltmarsh at Minnamurra estuary to project the broad pattern of change using several simulation models and the upper and lower bounds of projected sea-level rise scenarios. The study reported that sedimentation has been continuing beneath intertidal wetlands and the historical trend has been the gradual expansion of mangroves landward into saltmarsh (refer to photogrammetric vegetation mapping in Figure 49). Modelling of sea level rise scenarios indicates continuation of this trend with mangroves moving into saltmarsh and swamp oak areas (Figure 49). While the three different models used show very different results, some common patterns emerge:

- The area of saltmarsh and swamp oak (*Casuarina*) at this site is significantly reduced in all four models;
- Mangroves initially maintain or expand in area but towards the end of the simulation begin to decline; and
- For rapid SLR scenarios water dominates the study site by 2100.

The Oliver *et al.* (2012) study concluded that the coastal wetlands at Minnamurra are highly vulnerable to sea level rise with models predicting a significant loss of saltmarsh (and swamp oak communities) in the next 40 years, and the most rapid sea-level rise scenario indicating loss of mangrove communities by the end of the century without management intervention. The study suggests that suitable buffer zones are required to enable landward migration of intertidal wetlands into terrestrial habitats. The degree of success with which they can migrate landwards depends on the condition of upslope land. Physical barriers including steep topography and structures such as roads and buildings, may limit the capacity of saltmarsh to migrate. In these situations, *in situ* adaptation measures may be required such as sediment nourishment to prevent the loss of saltmarsh communities (Oliver *et al.*, 2012).

To examine the likely migration of estuarine vegetation in the Minnamurra River Estuary with sea level rise, and the impact of barriers to migration on an estuary-wide scale, a broad assessment was undertaken as part of this CZMP based on the upper tidal limit of estuarine vegetation. The potential areas were then compared to the existing barriers to migration such as roads, tracks and built assets. This allowed for an estimate of the impact of sea level rise on future estuarine habitats in the study area.

The assessment contained a number of assumptions as follows:

- Constraints to migration were assumed to be hard barriers (e.g. buildings, roads etc.);
- There was no assessment of the rate of sedimentation which may affect SLR;
- There was no consideration of management actions such as mowing of public park areas or active removal of vegetation. It has been assumed that estuarine vegetation would be allowed to colonise unconstrained areas including public reserves and private property;
- The estimation of the upper limit for estuarine vegetation was made by considering approximate known tidal ranges for estuarine vegetation communities and adjusting these ranges to fit what is currently present in Minnamurra River Estuary. Vegetation communities may have greater or lesser tolerance ranges than those assumed in this assessment; and
- This assessment created an estimated maximum combined area for mangrove and saltmarsh expansion with predicted future sea level rise across the whole estuary. It did not differentiate between mangroves and saltmarsh and defers to more detailed local studies (e.g. Oliver *et al*., 2012) for discussion of predicted future interactions between the two vegetation types).

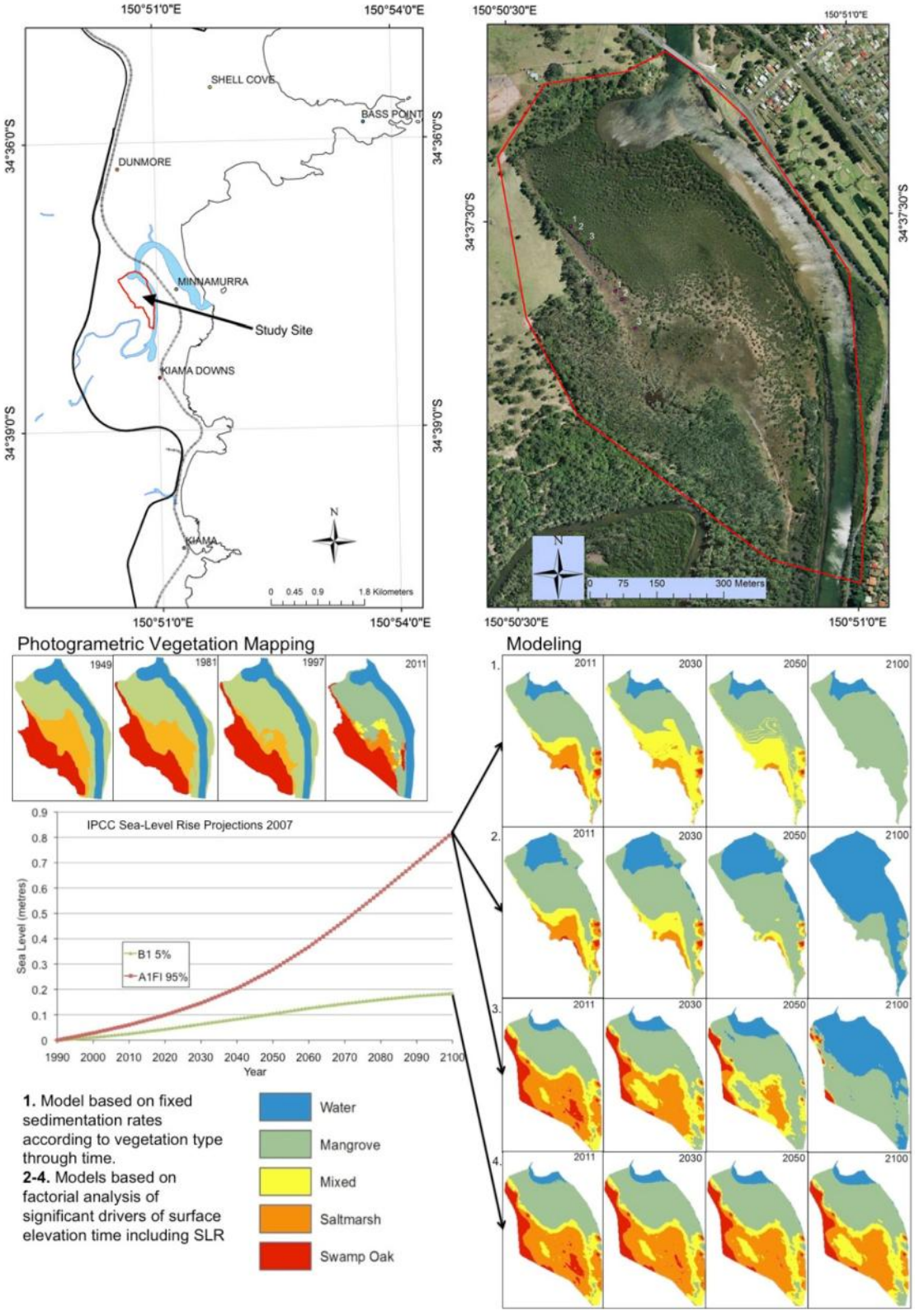


Figure 49: Top - Location of study site in the Minnamurra River Estuary (Source: Oliver et al., 2012) Bottom - Summary of changes to wetland vegetation at a monitored site in the Minnamurra River

Notes for bottom figure: the upper left shows historical changes in vegetation distribution derived from aerial photographs (mangrove encroachment into saltmarsh areas evident over time), and the right hand panels show projected future distribution based on 4 different models and sea-level scenarios (based on Oliver et al., 2012; sourced from Rogers and Woodroffe, undated).

Figure 50 and Figure 51 show the estimated potential upper limit for estuarine vegetation migration considering existing barriers and the sea level rise projection for 2100 (refer Section 3.2.7 for discussion of

adopted sea level rise projections). The assessment was undertaken by evaluation of the elevation ranges currently occupied by estuarine vegetation (using DPI 2009 estuarine habitat mapping) and comparison with the digital elevation model of the area. The influence of sea level rise was then determined by shifting the upper elevation limit of estuarine vegetation by the anticipated sea level rise to 2100.

Based on this assessment, the following changes in estuarine vegetation distribution are expected:

- The area suitable for seagrass beds is unlikely to change significantly in the lower estuary due to sea level rise to 2100, due to the shallow nature of the estuary at this location and areas suitable for migration of seagrass. In the mid and upper estuary, where seagrass currently exists as thin bands along the shoreline, it is possible that seagrass will be lost from these areas as water depth increases beyond the limit acceptable for seagrass growth and no upslope transition is possible;
- The potential migration of saltmarsh and mangrove communities appears to be restricted in some areas by physical barriers such as roads, retaining walls, property boundaries and steep topography. These areas are shown on Figure 50 and Figure 51 and include:
    - The lower estuary foreshore along Charles Avenue. While existing mangroves are patchy in this location, the presence of the retaining wall along the foreshore means that as sea levels rise, the few remaining mangroves may eventually be lost completely. Along the north facing section of Charles Avenue, a patch of existing saltmarsh is mapped adjacent to the retaining wall. It is likely that this saltmarsh area will be taken over by mangroves as sea levels rise and the community is ‘squeezed’ between mangroves and the retaining wall;
    - A similar situation exists in Trevethan Reserve where physical barriers include Riverside Drive, the train line and adjacent (elevated) urban areas;
    - Upstream of the Riverside Drive crossing migration of estuarine vegetation may be curtailed by the presence of rock revetment bordering the estuary;
    - The site of the Minnamurra Depot, which is elevated and capped also presents a barrier to migration; and
    - The Princes Highway presents a barrier in the vicinity of mid-Rocklow Creek and the Minnamurra Bends area.
- At other locations, mangrove and saltmarsh communities appear to have potential for migration due to sea level rise as tidal limits push up into areas currently occupied by either freshwater wetland vegetation (e.g. Swamp Oak Forest EEC) or terrestrial vegetation with very few existing physical barriers to migration including (refer Figure 50 and Figure 51 for mapped locations):
    1. Along Rocklow Creek up to the Princes Highway (Site 1). In this location the 2100 upper tidal limit is expected to reach the highway barrier and it is possible that Swamp Oak Forest EEC in this location could be completed replaced by estuarine vegetation. Depending on the future management of land upstream of the Princes Highway crossing, estuarine vegetation may migrate along Rocklow Creek to colonise limited areas just beyond the highway bridge;
    2. Upstream of the Riverside Drive crossing, on the west side of the river opposite the golf course (Site 2). This is the area subject to extensive monitoring and modelling work (Oliver *et al*., 2012) where mangroves are predicted to overtake saltmarsh and Swamp Oak areas in the short term and then eventually mangroves will also be reduced as sea levels rise further; and
    3. In the vicinity of Minnamurra Bends and lower Terragong Swamp there are large areas of existing freshwater wetlands (Site 3), and grazing land directly upslope of existing estuarine vegetation, which may be subject to tidal inundation by 2100. While freshwater wetlands

may eventually give way to estuarine wetlands, agricultural use of upslope land will form a barrier to migration.

It is apparent that the expansion of estuarine vegetation communities with sea level rise in these areas may come at the expense of freshwater wetland communities, predominantly areas mapped as Swamp Oak Forest EEC and SEPP14 Wetlands. These freshwater wetlands areas are likely to be reduced in size and potentially be lost from this location due to saltwater inundation. Just as there are barriers to the migration of estuarine vegetation, there are also barriers to the migration of freshwater wetland areas including natural topographic barriers and anthropogenic barriers such as the Princes Highway and areas of existing agricultural land use. Barrier to vegetation migration should be a key consideration for future management of the floodplain.

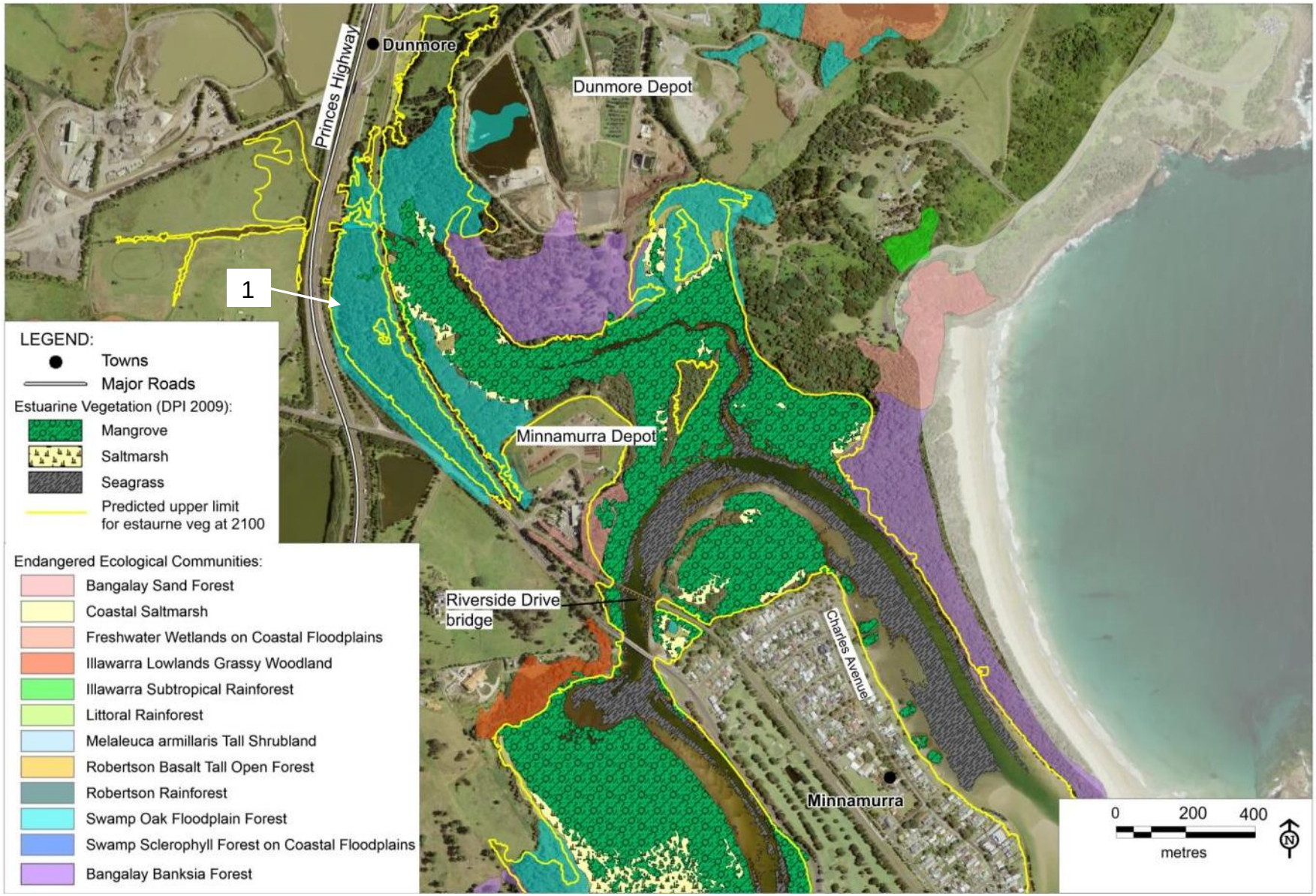


Figure 50: Potential areas for migration of estuarine vegetation types with sea level rise – lower estuary

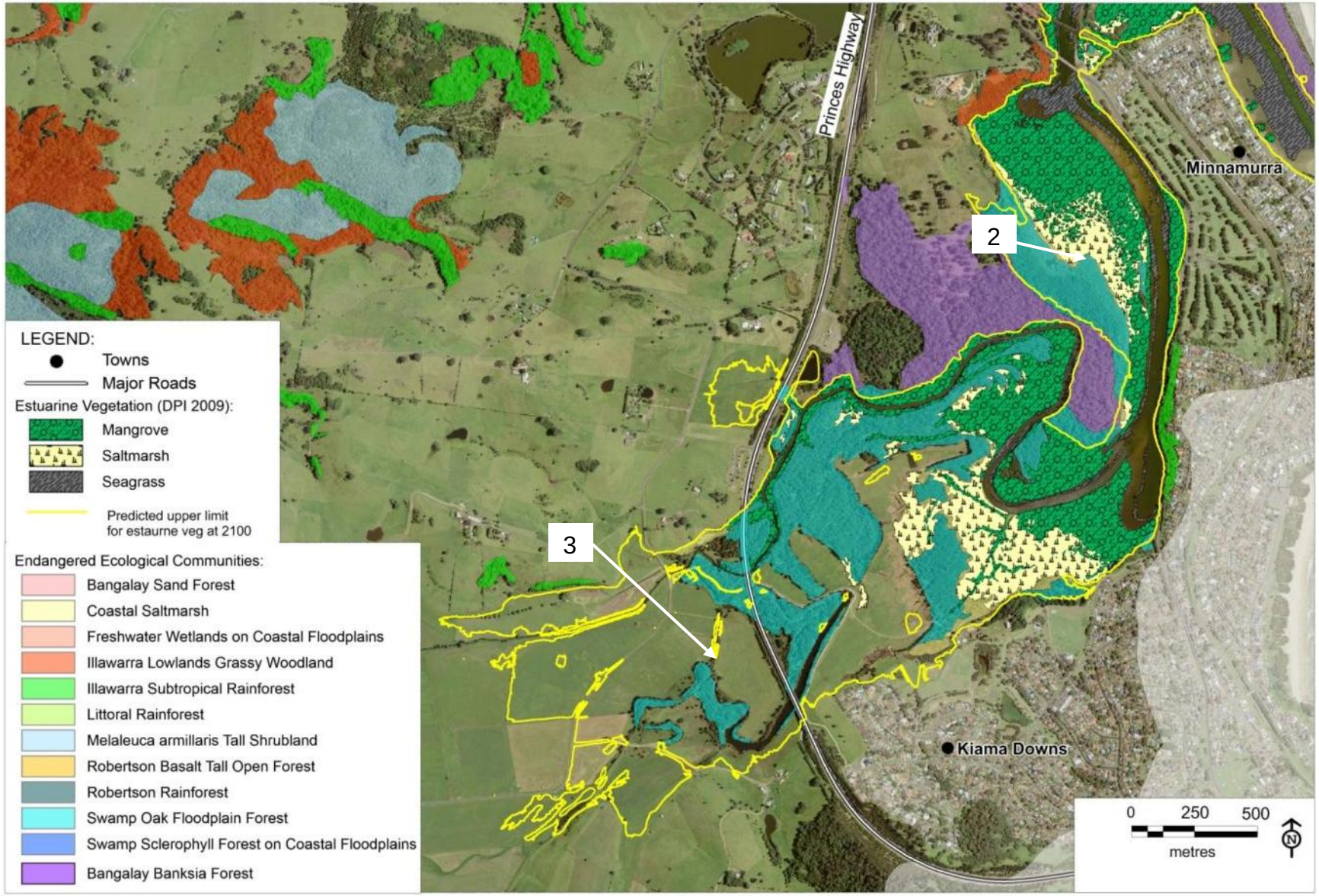


Figure 51: Potential areas for migration of estuarine vegetation types with sea level rise – mid and upper estuary

7. COMMUNITY USES

KMC recognises the importance of community uses of the coastal zone. This section provides an assessment of community uses in Minnamurra River Estuary:

- The current access arrangements to beaches, headlands and waterways in the study area, their adequacy and any associated environmental impacts;
- Any potential impacts on these access arrangements; and
- The cultural and heritage significance of the study area.

The scenic amenity of Minnamurra River Estuary is valued highly by the local community and visitors to the area. Specific characteristics identified in recent consultation activities include the need to preserve the natural beauty, the quiet and peaceful surroundings and maintain the environmental integrity of the area. It is apparent from resident observations and Council staff reports that the James Oates Reserve and other reserves further north along the river foreshore are becoming more popular with tourists and the local community. Whilst very seasonal, the peak visitation at the reserves means that in the near future, additional car parking and amenities may be required to cater for the increased usage.

7.1 Recreational Activities

The maintenance and enhancement of the amenity of Minnamurra River Estuary is important to maintain community enjoyment and tourism in the Kiama LGA. The Estuary is an important recreational destination for tourists and local residents and is used for passive recreational activities such as sightseeing, bird-watching, fishing, swimming and paddling. Power boats also access the river, particular during peak tourist season. Personal water craft are banned within 300 m of all beaches in the Municipality and within the Estuary. However they are permitted to launch at the James Oates Reserve boat ramp and proceed directly offshore.

Recreational activities are concentrated in the lower estuary, downstream of the road bridge with activities including surfing, swimming, fishing, surf lifesaving club training (boats and nippers), school excursions, commercial kayak and canoe classes/training and boating. Three golf courses are located in the catchment – at Minnamurra, Shell Cove and Jamberoo. Other tourist and recreation facilities are located in the upper catchment around Jamberoo. At peak times (weekends and holidays), there is a significant increase in the number of visitors to the Estuary, bringing associated impacts such as parking, litter, dogs, conflicts between boats and swimmers and increased potential for accidents. With urban development in Shell Cove and surrounding areas, recreational usage in the Estuary is increasing.

A  B 

Figure 52: Social Values: A - Waterfront properties along Charles Avenue (D. Wiecek, 2014), B – Paddle boarding

The 1995 EMP recommended enhancement of the existing boating and foreshore amenities (public picnic and rest stop areas and landscaping public reserves) and boating navigation in the main estuary. Recreational facilities have since been upgraded at Trevethan Reserve and at roadside areas south of the bridge.

7.2 Fishing

Recreational fishing is popular within the Minnamurra River and its estuary. Recreationally important fish species that inhabit the lower estuary and often targeted by local and visiting anglers include flathead, luderick, bream and whiting. Baitfish species including garfish and mullet also utilise the lower estuary. The Minnamurra River Estuary hosts a wide range of other aquatic fauna including, prawns, shrimp, crabs, polychaete worms, gastropods and oysters of which many are collected by anglers for bait (PBP, 1995b).

Australian bass, another recreationally important species, utilise the brackish water area of the upper estuary for spawning. In particular, the cut off embayments (billabongs) that formed the original course of the river adjacent to the upper estuary were considered to be important Australian bass breeding habitat. Conversely, the artificially straightened channel of the upper estuary provides little fish habitat (Reinfelds, 1999) but provides an important link to the freshwater habitat upstream. There were schools of Australian bass observed in the channel during the field visit to the grade control structures involving members of the EMP review committee. Jerrara Dam, situated in the upper Jerrara Creek, was stocked by NSW DPI with 1600 Australian bass in October 2011 and a further 5,000 in September 2012 (Cardno, 2013).

Community stakeholders raised concerns regarding overfishing and excessive bait collection (particularly nippers) within the lower estuary. Despite this, there are no data to suggest overfishing is having a negative impact on fish stocks in the estuary. Fisheries NSW is responsible for the control and regulation of recreational fishing in NSW. The current recreational fishing rules applicable to the Minnamurra River Estuary are published in *Illawarra Recreational Fishing Guide. Primefact 870* (NSW DPI, 2012). The Minnamurra River is closed to any method of fishing involving the use of a net (except dip nets, scoop nets and landing nets) or spearfishing (NSW DPI, 2012).

7.3 Boating

The Estuary channel is generally shallow and extensively in filled with marine and river sediments. The entrance shoal area is seen as a barrier to boat navigation at low stages of the tide. The channel exits close to a natural rocky breakwater and the bar crossing is dangerous.

Many stakeholders raised concerns relating to boating including:

- Boats not observing speed limits; and
- Safety of swimmers crossing the entrance to and from Killalea;

Boats can cause damage to seagrass beds through mooring damage, groundings, anchoring and propeller damage. Maritime boating maps indicate that anchoring is permitted in all areas of the Estuary.

RMS representatives patrol, monitor and assess the navigation channel when resources permit. RMS manages the placement of navigation aids (buoys, markers, etc.) and waterway mapping to assist the boating public (refer Figure 53). A four knot speed restriction zone is in place in the Minnamurra River. The Boating Handbook (RMS, 2012) also defines other regulations such as distance from swimmers (10 knot speed limit when swimmers are within 60 m). RMS also conducts land-based boating education campaigns at boat ramps, schools and boating retailers.

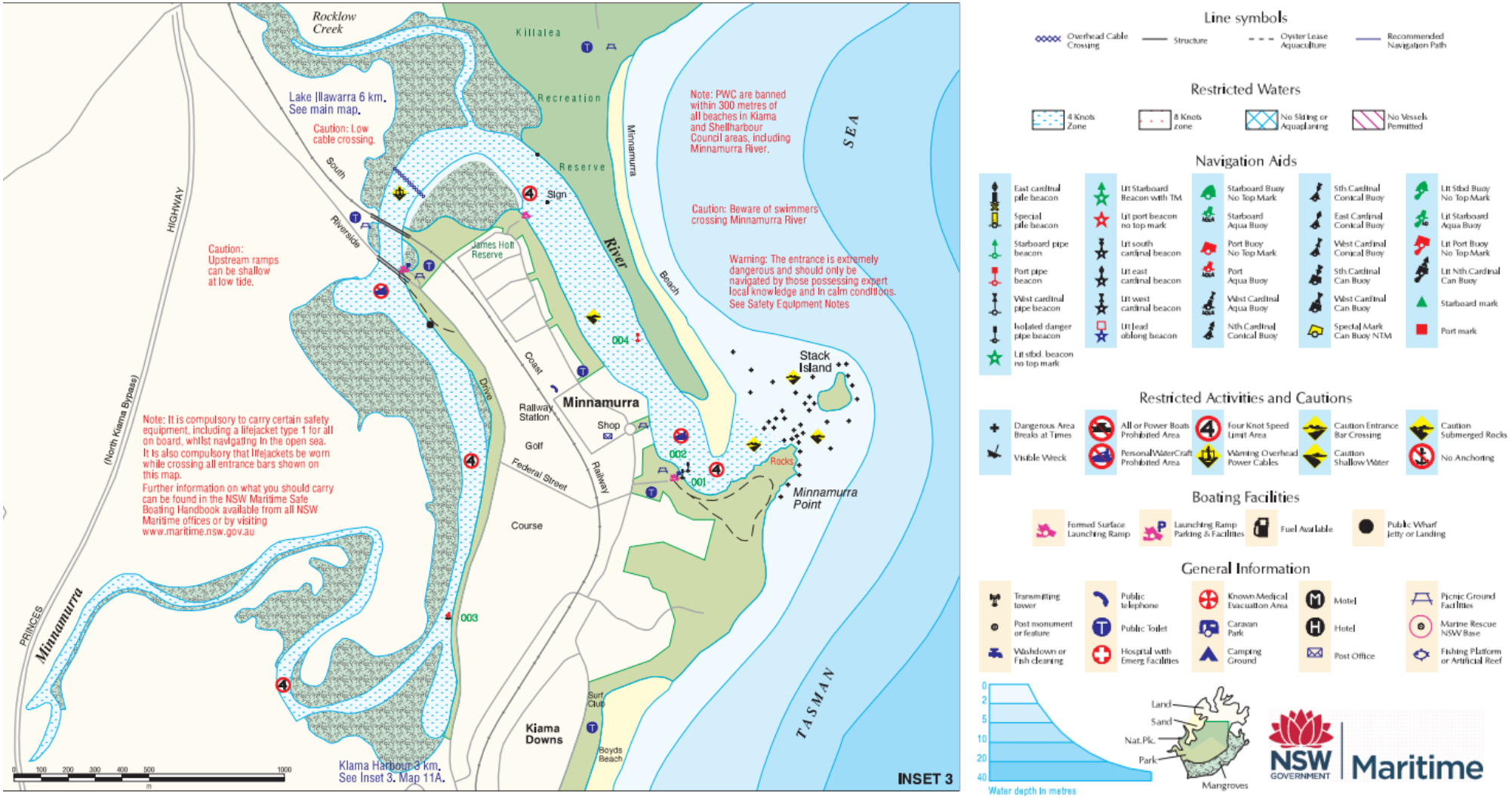


Figure 53: Minnamurra River Boating Map

Source: NSW Maritime Boating Maps (2014)

7.4 Access

Whilst providing and maintaining access to public lands in coastal environments is important, access and use must be balanced by protection of the environment and the maintenance of public safety.

Council recognises that:

- Access to and sympathetic use of publicly owned lands is desirable where it does not conflict with environmental management objectives;
- Uncontrolled public access has the potential to irreparably damage fragile estuarine environments; and
- Human safety is a prime consideration when planning access to estuaries.

7.4.1 Riverfront Land Tenure

Figure 54 illustrates the riverfront land tenure of the lower Minnamurra River Estuary:

- The southern side of the entrance on Minnamurra Point is the Council managed Minnamurra Headland Reserve which provides community access to the headland or recreation and scenic values. The northern side of the entrance is Killalea State Park (see Section 3.1.5) which covers a total area of approximately 265 ha, from the mouth of the estuary upstream to the first bend;
- Adjoining Minnamurra Headland reserve is James Oates Reserve which provides community access facilities including a boat ramp and a car parking area. There is also an information signboard about the Minnamurra River Catchment and Kiama Coast Walk;
- Upstream from James Oates Reserve, direct community access to the estuary is restricted by approximately 400 m of residential properties directly fronting the shoreline (apart from Rangoon Reserve);
- Community land at James Holt Reserve extends along Charles Avenue from North Street along the riverfront (3.64 ha of river frontage). This area acts as a buffer between the residential land and the river and provides public access to the estuary for various forms of recreation including boat access;
- Crown reserve encompasses the areas of mangrove and saltmarsh on the inside (southern side) of the first river bend;
- Rocklow Creek downstream of the railway bridge is bordered by approximately 26 ha of Crown reserve;
- Trevethan Reserve provides community access to the estuary on the southern bank between the Riverside Drive bridge and the railway bridge. The reserve provides a boat ramp, fishing jetty, parking and public toilets. There is also a saltmarsh educational signage at the reserve;
- Crown reserve adjoins Trevethan Reserve and runs along the river bank on the western side of riverside drive upstream to the end of the golf course; and
- In general, private property encompasses all the riverfront land on the northern side of the river from the Riverside Drive bridge upstream to Swamp Road.

Figure 55 illustrates the riverfront land tenure of the upper estuary and through the Terragong Swamp. The Jerrara Creek ‘billabong’ is surrounded by Crown Reserve. Riverfront land through the swamp upstream to the junction of Fountaindale Creek is also Crown Reserve. The remaining river frontage (including the upper catchment) is private property.

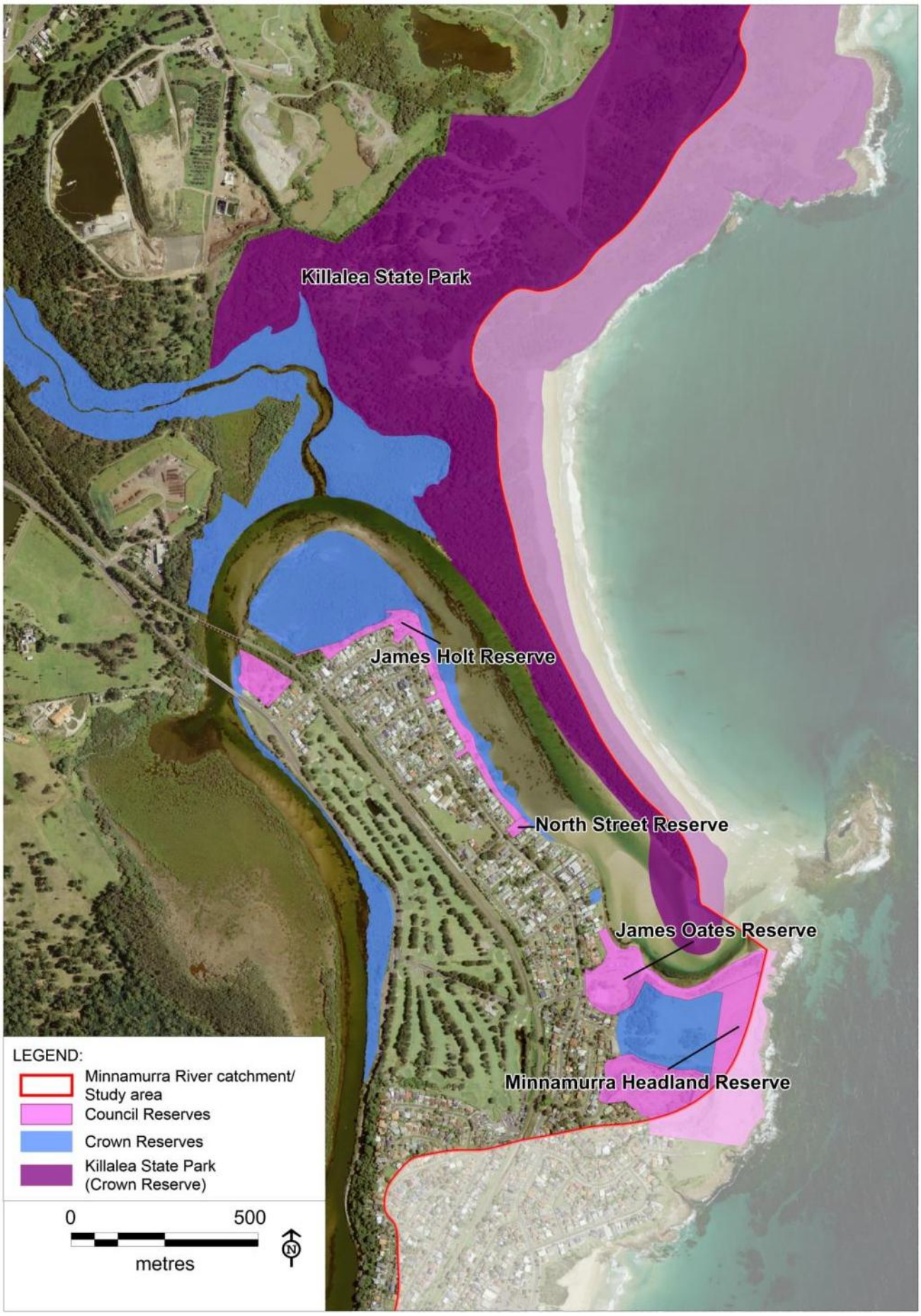


Figure 54: Lower Minnamurra River Estuary land tenure

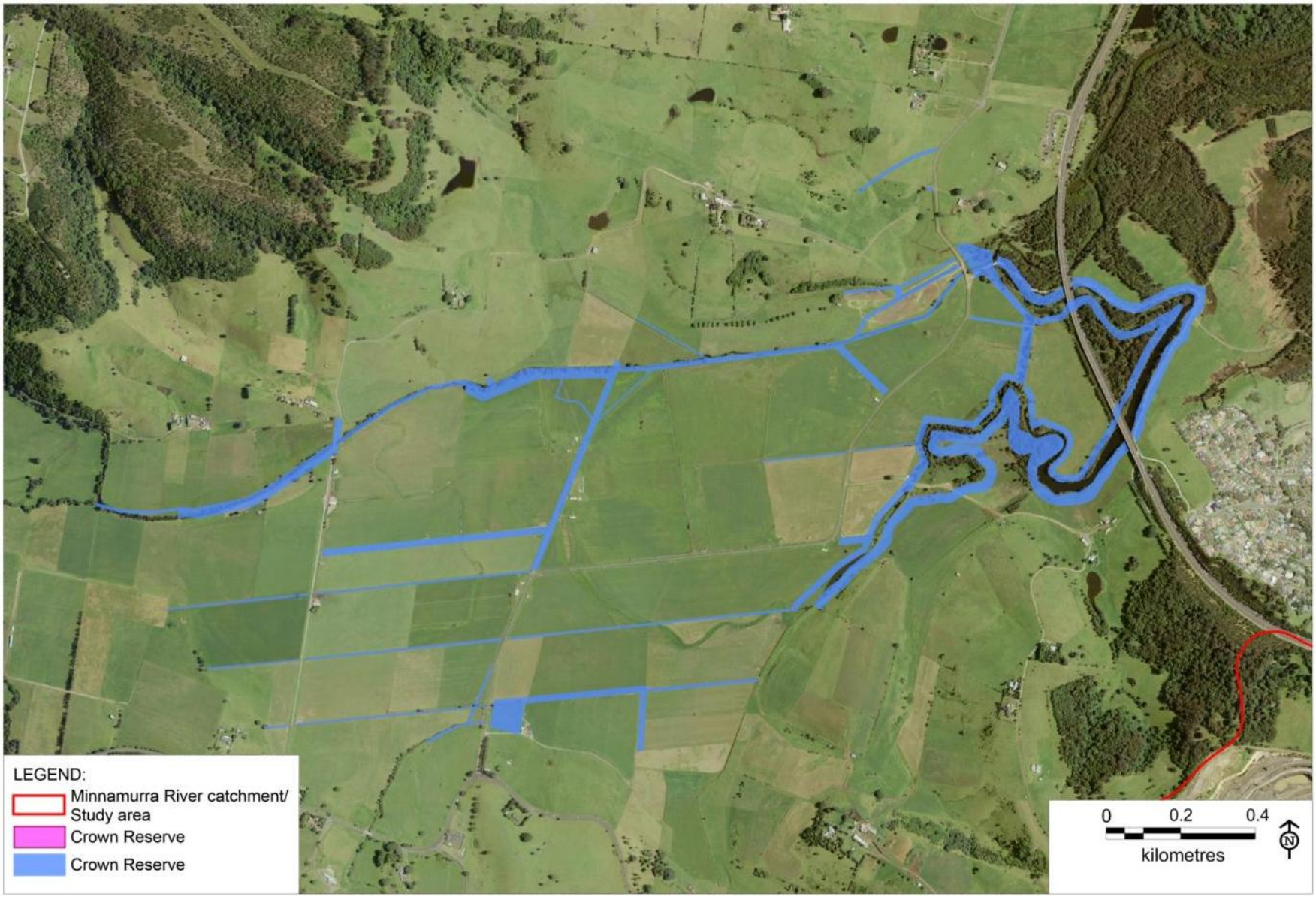


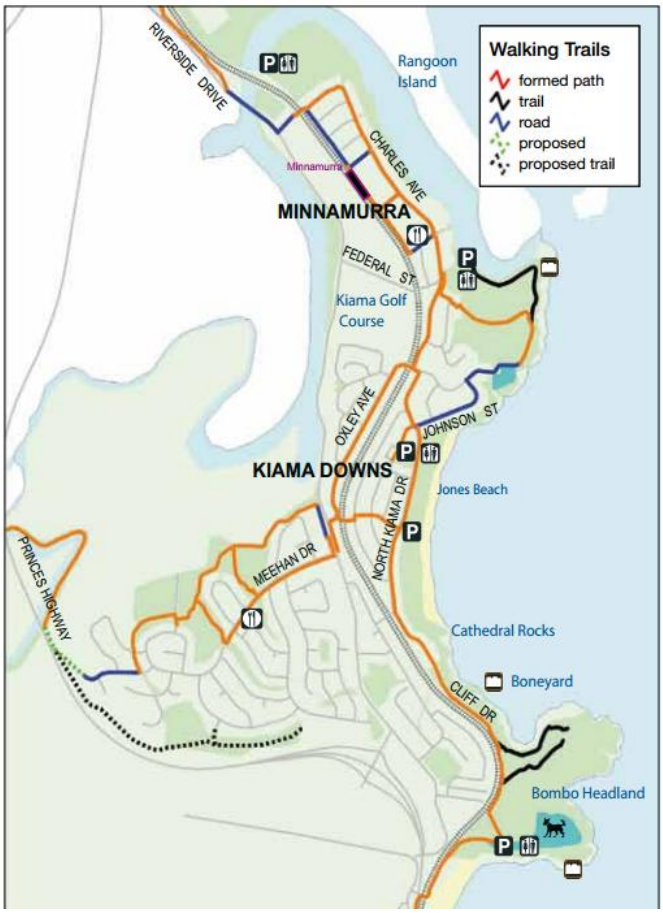
Figure 55: Terragong Swamp riverfront land tenure

7.4.2 Pedestrian and Cycling Access

Walking trails and cycling routes have been established around the lower estuary providing access to the waterway, foreshores and headlands (Figure 56). Council plans to extend the Swamp Road cycleway between Kiama Downs and Jamberoo with part funding from RMS for a 300 m extension to be completed in 2014/15.

Council is also funding the construction of a whale watching platform and picnic settings at Minnamurra Headland, to be constructed by the Minnamurra Lions Club in 2015/16.

A



B

Figure 56: A: Walkways and B: Cycle Paths

Source: KMC (2011b), KMC (undated)

7.4.3 Foreshore and Boating Access

Boat launching access is available from three ramps located on the lower estuary (Figure 53):

- Off James Oates Reserve at the river entrance (single lane concrete, incline 1V:8H, toilets and parking for 12 vehicles). There is insufficient parking for boat trailers and cars during peak periods (weekends and holidays);
- North-east of the railway station off Charles Avenue in James Holt Reserve (single lane concrete, incline 1V:7H, parking for 10 vehicles, no facilities). Due to its location on the inside bank of the bend in the river, the ramp at James Holt Reserve extends onto a substantial mud flat which is exposed at low tide at which times the ramp is not useable (KMC, 2001); and

- Into river at south-east end of Highway road bridge off Trevethan Street (single lane concrete, incline 1V:20H, ample parking, no facilities). The ramp, picnic facilities and car parking areas at Trevethan Reserve were upgraded in 2000. Due to the low gradient, access during high tides is limited due to boats grounding on the lower sections of the ramp. A public jetty has been installed at Trevethan reserve for fishing access.

A 

B 

C 

Figure 57: Boat ramps

A – Entrance, James Oates Reserve, B – James Holt Reserve, C - Trevethan Reserve

There are 40 small craft moorings on the Minnamurra River (Transport for NSW, TfNSW, 2014). Many boats are moored at the timber groynes and along Charles Avenue foreshore. Mooring is not permitted within 8 m of mangroves or pneumatophores.

Pedestrian and small craft access to the foreshore and river is also available at many locations along the lower estuary.

Access issues identified in the *Regional Boating Plan* (Transport for NSW, 2014) are summarised below. The issues related to boating speed and parking have also been raised during stakeholder consultation.

Table 11: Issues identified in Regional Boating Plan

Issue Category	Description	Opportunities and Potential Solutions	Related regional action
Safety	Boating speed - waterway users not acting in accordance with guidelines and safe practices.	TfNSW and RMS to review and upgrade education, communication and compliance campaigns.	Review strategies to improve boating behaviour and safe boating practices across the region.
Access	No fish cleaning tables available.	Council to liaise with DPI to provide fish cleaning tables at Minnamurra boat ramp (off Charles Avenue).	Work with councils and other agencies to enhance and optimise existing facilities at strategic locations, especially at harbours and locations with ocean access.
	Limited car and trailer parking especially during peak times.	Review opportunities to increase car and trailer parking capacity at Kiama boat ramp (off Blowhole Point Road).	
	Car and trailer parks occupied by single cars.	Refer issue to council to review trailer parking signage at Kiama boat ramp (off Blowhole Point Road) and enforce restrictions.	
	No toilet or boat wash-down facilities available.	Review opportunities to provide toilet and boat wash-down facilities at Kiama boat ramp (off Blowhole Point Road).	

Source: Transport for NSW (2014)

While the *Regional Boating Plan* focuses on centralised facilities at Kiama boat ramp, there is a need to provide additional parking facilities at Minnamurra (James Oates Reserve) as well as opportunities for facility improvements including amenities and fish cleaning tables.

7.5 Cultural and Heritage Environment

Cultural heritage is recognised as an important coastal zone management issue due to the long association of Aboriginal communities with the coastal zone over many tens of thousands of years. More recently, European settlement has also made extensive use of the coastal zone, resulting in a multi-layered pattern of cultural usage of coastal sites and resources.

Aboriginal groups occupying the Minnamurra region were the Dharawal, the Wodi Wodi (Wadi Wadi), Guarandada and Wandandian. Aboriginal occupation of the area is evidenced by past remains, the most common of which are characteristic mounds of shells called middens. Middens reveal important anthropological associations with the natural environment, including diet, living conditions and development. Other evidence of Aboriginal occupation includes surface camp sites, stone arrangements, axe grinding grooves, tools, weapons and burial sites. These are generally not as common as middens (PBP, 1995b). The 1995 EMP reported on the recorded Aboriginal heritage sites within the Minnamurra River Estuary but considered that these should be verified.

There have been a number of localised archaeological impact assessment surveys associated with recent road expansions, tourism development, mining development and site notification. The majority of these studies resulted in the identification and assessment of previously unknown Aboriginal archaeological sites. This work focused on estuarine/wetlands, rivers and hill top dunes, landscapes that are known to be archaeologically sensitive for Aboriginal archaeological sites such as shell middens, open campsites artefacts scatters and shell middens with artefact scatters sites (Biosis Research, 2011).

The first recording of Kiama was by George Bass in 1797. During the early years of the nineteenth century, the area was rapidly exploited for timber (mainly cedar getting), followed by settlement. The Kiama coast was officially surveyed in 1819 when Surveyor-General John Oxley and Deputy Surveyor-General, James Meehan explored the area. The site of Kiama township was reserved by the government in 1826 and proclaimed in 1836. Kiama was proclaimed a Municipality in 1859 and included much of the present day area from the Minnamurra River west to Kangaroo Valley and south to Crooked River. Settlement in the area proceeded throughout the nineteenth century, with land grants being provided for wheat, dairying and pig-farming. In the 1870s, blue metal extraction (basalt) was to become an important supplementary industry to dairy farming (PBP, 1995b).

The Kiama LEP 2011 identifies many heritage items in the study area, particularly around Jamberoo. The Shelharbour LEP 2013 also identifies many heritage items around Croom and Dunmore.

7.6 Impacts of Climate Change on Community Uses

Sea level rise has the potential to reduce community waterway access through increased frequency of inundation of shoreline access routes or infrastructure. However, the effects of sea level rise will generally take several decades to advance to the stage where a loss of amenity is significant enough to be regarded as an impact. Sloped structures such as boat ramps and access stairs are less likely to be affected by increasing sea levels, as access to the water's edge will remain possible in the long-term (2100), although use of associated features may be affected. In other cases, where specific elevation thresholds may be exceeded due to sea level rise, there will become a time when this effect becomes significantly worse within a short period. Examples of this type of impact may include low-lying car parks, jetties or constrained walking tracks at the water's edge.

An evaluation of the potential effects of sea level rise was undertaken through comparison of projected changes in mean sea level (discussed in Section 3.2.7), tidal plane information and topographic elevations inferred from LiDAR surveys from 1992. No ground survey information of key infrastructure was available however comparison of the LiDAR data combined with site inspection provided sufficient understanding in order to determine the likely timeframe and implications of sea level rise impacts on community access infrastructure. The key community access infrastructure or features affected by sea level rise are discussed below. There are also access points from private residences that may be impacted by sea level rise.

Table 12: Community access infrastructure and features affected by sea level rise

Asset	Construction	Expected significant reduction in amenity	Nature of impact	Assumed asset lifespan and/or refurbishment timeframe
Minnamurra Headland Reserve	Grassed	2100+	Inundation and increased erosion of foreshore reserve	N/A
James Oates Reserve boat ramp	Concrete slab boat ramp	2100+	Inundation of boat ramp	2040 (25 years)
James Oates Reserve foreshore	Grassed	2100+	Inundation and continued erosion of foreshore reserve	N/A
Rangoon Reserve foreshore	Concrete retaining wall and steps	2100+	Inundation of lower concrete steps	2030 (15 years)

Asset	Construction	Expected significant reduction in amenity	Nature of impact	Assumed asset lifespan and/or refurbishment timeframe
North Street Reserve foreshore	Grassed and vegetated along sections of rock revetment	2100+	Inundation and erosion of foreshore reserve (apart from areas of rock revetment)	N/A
Various ramps and stairs along Charles Avenue foreshore	Concrete ramps/steps and handrails	2100+	Inundation of lower concrete steps	2030 (15 years)
James Holt Reserve boat ramp	Concrete slab boat ramp	2100+	Inundation of boat ramp although higher water levels will improve access at low tide	2030 (15 years)
Trevethan Reserve boat ramp	Concrete slab boat ramp	2100+	Inundation of boat ramp and associated car parking areas (alongside ramp)	2040 (25 years)
Trevethan Reserve fishing jetty/ boardwalk	Timber piers and deck	2050+	Inundation and waves over decking	2030 (15 years)
Riverside Drive stairs	Timber stairs on concrete slab	2015 (currently occurring)	Increased inundation of lower landing and part of stairway during high tides.	2025 (10 years)
Riverside Drive jetty	Timber piers and deck	2050+	Inundation and waves over decking	2025 (10 years)
Estuary beaches constrained by landward banks, retaining walls and rock revetment	Natural	2015 (currently occurring)	Access along the length of foreshore is constrained by high water against the private retaining walls and rock revetment.	N/A
Killalea State Park estuary foreshore	Natural	2015 (currently occurring)	Access along the length of foreshore may be affected depending on future die-back of Bangalay banksia forest along the spit.	N/A

The tidal range between mean low and high water levels is approximately 0.8 m and the predicted future mean low water level (0.431 m at 2100) is similar to the current mean high water level (0.529 m). Therefore areas that are currently only accessible at low tide will no longer be accessible with long-term sea level rise. In addition, lower landings of steps are expected to be inundated at low tides in future. Although access to the water is not compromised, any further access from the base of the stairs in either direction is limited by

the steep banks and lack of high tide beach. Sea level rise will exacerbate this issue and reduce the tides stages at which suitable access beyond the steps can be achieved.

Other estuary beach locations also have reduced high tide access. This is largely due to erosion of the banks on the landward edge, which create steep banks leading to the water's edge (e.g. the Headland and James Oates Reserves). At the moment only high tide access is curtailed, however continuation of erosion and further squeezing of the high tide beach with sea level rise will mean that these issues are likely to be exacerbated in the future.

The James Oates Reserve, James Holt Reserve and Trevethan Reserve boat ramps are unlikely to become unserviceable within the sea level rise scenarios considered (up to 0.7 m rise by 2100), however they have associated assets that may become less useable over time (including information signs and fishing jetty). Long-term repositioning or increased elevation of these assets would be appropriate. Similarly, the Riverside Drive steps and jetty are unlikely to be compromised by sea level rise prior to 2100, however they may become less useable at high tides and will probably require some degree of modification during future refurbishments to accommodate rising sea levels. Despite minor adjustments to related facilities, which would be undertaken as a matter of course during refurbishment/replacement activities, there are no indications major assets will become unserviceable due to rising sea levels in the long-term (2100). Council's future coastal hazard planning will provide further information in this regard.

8. ESTUARY MANAGEMENT OPTIONS

The Minnamurra River Estuary management issues and options have been grouped into six key strategies:

1. Administration and delivery of management actions;
2. Water quality management;
3. Control of bank erosion;
4. Protection of estuarine and foreshore habitat;
5. Recreational facilities; and
6. Floodplain Management.

The existing approach and recommended additional actions to implement the management strategies are discussed in the following sections. For each management strategy, the recommended management approach has been identified by considering:

- The key values of the Minnamurra River Estuary (refer Section 5) and the objectives of this CZMP;
- The information available on the current extent and severity of the management issue and the expected impact on estuary health (Section 6) and community uses (Section 7);
- The need for additional data collection, strategic planning and/or studies to confirm the required future direction;
- The success of various approaches in resolving similar management issues in the Minnamurra Estuary and other locations;
- The expected cost of implementation; and
- Feedback from stakeholders and expected level of support and acceptance of the proposed approach.

For erosion control, a range of on-ground options are available to reduce the risk of erosion and the impact on estuary health. These options have been considered for each erosion site and the selected approach has been based on the assessed erosion risk and the success of the options in reducing erosion risk in the Minnamurra Estuary and other locations.

In addition to the CZMP strategies, existing complimentary programs will contribute to the management of many of the identified issues. These include:

- Fisheries NSW recreational fishing regulations;
- RMS boating regulations;
- Feral animal control programs (KMC, SCC and Killalea State Park Trust);
- Weed control programs (Illawarra Noxious Weeds, Killalea State Park Trust);
- Regulation and inspection of on-site sewerage management systems (KMC and SCC); and
- Sewage Treatment System Impact Monitoring and related programs including monitoring of treated effluent reuse on Kiama Golf Course (Sydney Water).

8.1 Strategy 1 – Coordination of Management Actions

8.1.1 Existing Management Approach

The management of the Minnamurra River Estuary is undertaken by many different government agencies, private organisations and community groups with many separate legislative requirements. Management activities performed by the various land managers are undertaken for a range of purposes including licence compliance, agricultural productivity and general maintenance. These activities generally function in isolation and as funding and resources permits. Many of the actions identified in the 1995 EMP and 2003 EMP Review have been implemented by Council, land owners and government agencies with funding, resources and technical support from the OEH, SRCMA (now South East LLS), Small Farms Network and volunteer groups. The various land managers continue to implement management actions within the catchment which complement the work undertaken by Council as part of the EMP. The University of Wollongong has been active in research projects related to the Estuary.

8.1.2 Recommended Future Management Approach

A more strategic and coordinated approach would assist with knowledge sharing, improved access to funding and increased understanding of management issues to improve on-ground outcomes.

CZMP Implementation

Successful implementation of this CZMP will require collaboration between a range of stakeholders including the councils, state government, statutory bodies, industry, landholders and the community. Management of the Estuary can be improved through better coordination, a more holistic approach and efficient delivery of management programs.

It is recommended that KMC establish an Implementation Committee (which may consist of existing EMP Review Committee members as well as additional members to ensure coverage across the full range of issues and geographic areas) which has the following aims:

- Oversight and implementation of the CZMP actions;
- Coordination of studies and sharing of knowledge;
- Identification of funding sources for priority projects;
- Establishment of demonstration projects and sites;
- Sharing of knowledge with the wider community; and
- Future reviews of the CZMP.

The establishment of an Estuary Health Officer position is also recommended to provide the required resources and to ensure the efficient and effective coordination, implementation and evaluation of the annual priority management actions that have been identified by the various stakeholders. The position will also strengthen collaboration between the stakeholders and assist with securing grant and other funding for the various actions. The position should be hosted within KMC with joint funding for this position between Council and other State agencies.

Asset Management

Effective Council policy, adequate resources and strategic planning is required to support the implementation of the CZMP, particularly in relation to asset management planning. This is discussed further in relation to weed management (Strategy 4 - Protection of Estuarine and Foreshore Habitat), urban stormwater (Strategy 2 – Water Quality Management) and waterway assets (Strategy 5 – Recreational Facilities).

Research Priorities

There have been a number of research projects and investigations undertaken within the Minnamurra River catchment in recent times. Projects have been undertaken by a range of individuals and organisations including those contracted by KMC, community groups, government agencies and students at the University of Wollongong. The information gathered by these studies has provided insights into the health of many ecosystem components and pressures impacting on the Estuary. It is recognised that there are opportunities for further research in the catchment that can assist in the ongoing delivery and refinement of this CZMP. Coordination of research efforts would maximise the relevance of such studies and assist in filling priority gaps in knowledge. The priority projects recommended in this CZMP should be coordinated by the Estuary Health Officer in consultation with the CZMP Implementation Committee (particularly the University of Wollongong and potentially other research facilities). The aim is to progressively implement existing priority projects and direct future catchment research projects, undertake monitoring of key ecosystem components, develop consistent methodologies and evaluation methods and provide ongoing review of research findings.

Current priority research projects include:

- Short-term water quality investigations (potentially university projects) to investigate specific issues or sites and to evaluate potential sources of poor water quality. These could include follow up projects, which repeat previous methodologies and provide information on changes over time and to assist in evaluating pollutant sources and the need for management action. For example (refer Strategy 2 – Water Quality Management):
    - A repeat of the Gainsborough stormwater ponds water quality assessment (Roso, 1998) would be useful to assess the current treatment capacity of the ponds and to direct works such as maintenance (e.g. de-silting) to improve performance (refer Section 8.2.2: Urban Stormwater);
    - Assessment of water quality in the Minnamurra River in the vicinity of Jamberoo, after the connection of the township to the Sydney Water Kiama sewerage system and compare to data collected pre-connection; and
    - Other opportunities exist in Rocklow Creek, where it would be useful to determine and differentiate the impact of a number of potential pollutant sources (e.g. agriculture, quarries, waste depots etc.).
- Investigation of the impacts on native fish habitat, riparian condition and potential barriers to migration, particularly in relation to Australian bass populations and the need/desire for management actions such as habitat restoration, fish passage requirements and/or stocking programs (Strategy 4 - Protection of Estuarine and Foreshore Habitat);
- Geomorphological assessment of catchment reaches from the upper catchment through to the estuary such as ‘RiverStyles’ or similar classification system to document key catchment features (Strategy 4 - Protection of Estuarine and Foreshore Habitat) and assist in identifying riparian revegetation priorities in the mid-upper catchment and tributaries;
- Assessment of the impacts of increasing visitor numbers to the Estuary as surrounding urban areas expand and potential for increases in litter, parking issues, boat ramp usage, conflicting recreational uses, foreshore access, domestic dogs etc. (refer Strategy 5 – Recreational Facilities);
- Erosion risk assessment discussed in Strategy 3 – Control of Bank Erosion;
- Investigation of management options to allow for migration of estuarine vegetation communities in response to sea level rise (Strategy 4 - Protection of Estuarine and Foreshore Habitat);
- Research land use change scenarios and their predicted impact on estuary health. This could include consideration of agricultural intensification and agricultural diversification, urban expansion and urban consolidation as well as sea level rise, potentially using CERAT (refer Section 6.2) or

other predictive modelling tool. This information can practically inform future regional planning decisions and feed into both Shellharbour and Kiama Council's LEP review processes (refer Section 3.1.1);

- Investigation of options to address saline intrusion with future sea level rise (Strategy 6 – Floodplain Management); and
- Causes of seagrass decline in the lower estuary as discussed in Strategy 4 - Protection of Estuarine and Foreshore Habitat.

The above priority investigations have been scheduled for implementation under relevant strategies in the CZMP Management Plan (Section 9).

8.2 Strategy 2 – Water Quality Management

8.2.1 Existing Approach

Monitoring Programs

In recent years water quality information for the Minnamurra River Estuary has been limited. The most recent comprehensive water quality monitoring was undertaken by KMC in 2006/07. Since then the NSW MER program has undertaken two assessments in the Estuary in 2007/08 and 2011/12 with the next round of sampling planned for the summer of 2014/15. Groundwater and surface water sampling is undertaken at the two waste depots along Rocklow Creek in accordance with EPA licence requirements. Several short-term investigative university projects have been undertaken at various locations in the catchment over the years including assessment of stormwater treatment at Gainsborough residential estate treatment ponds, assessment of major tributaries including Jerrara Creek, Coylers and Rocklow Creeks and Terragong Swamp groundwater (refer Appendix 6).

Urban Stormwater

Council has installed stormwater quality improvement devices (Enviropods, refer Figure 38) at some outlets in Minnamurra and Jamberoo although maintenance of these devices is undertaken only once they become a problem when full. Drain stencilling of the drains containing Enviropods will occur in early 2015. This will include an assessment of the condition of the devices, as well as determining a cleaning schedule for the areas with higher pollutant loads. The stencilling will also provide Council staff and the public with an easy identification for drains containing Enviropods.

Council is currently developing an Urban Stormwater Asset Management Plan which will include:

- Collection of data including asset condition;
- Identification of stormwater management issues and rectification actions;
- Identification of the need for stormwater treatment and pollution controls including gross pollutant traps;
- Development of a renewal strategy;
- Development of guidelines for maintenance and asset rectification; and
- Training of Council staff.

On-Site Sewerage Management

Under the KMC *Onsite Sewage Management Strategy* systems within the KMC LGA are risk ranked as either a low or high risk system (high risk systems being located in an environmentally sensitive area). There are approximately 60 recorded high risk systems located throughout the catchment within the KMC LGA.

High risk systems are subject to annual audits and low risk systems are subject to an audit every four years. If an audit reveals that a system is non-compliant then council will contact the owner to discuss measures to rectify the problem and issue an order for rectification for any non-compliance.

Waste Collection

KMC operates urban and rural garbage and recycling services and kerbside collection. KMC has also established a drumMuster (the national program for the collection and recycling of empty, cleaned, non-returnable metal and plastic agricultural chemical containers) collection point at the Minnamurra Recycling Facility. The Southern Councils Group (SCG) has partnered with the South Coast and Highlands Dairy Industry Group (DIG) and KMC to establish a silage wrap and baling twine recycling project in the Illawarra utilising the Plasback product stewardship scheme for plastics. SCG with the financial support of the NSW OEH has assisted KMC to purchase a baler to compact silage and twine bagged and deposited by local farmers at Council's Minnamurra Recycling Facility. SCG also purchased bags for distribution by the DIG to local farmers to encourage a proactive approach to the recycling of used silage wrap and twine by members of the dairy industry.

8.2.2 Recommended Future Management Approach

Water Quality Monitoring

Ongoing water quality monitoring at selected sites throughout the catchment will assist in identifying sources and causes of poor water quality and direct future pollution control actions. Monitoring can also be used to track improvements in water quality in response to management actions and provide data about the success of management. Both dry weather and event-based data collection (following wet weather events) will be important to characterise the system.

The NSW MER program undertaken by OEH will continue to assist in assessing the health of the Estuary over longer time frames (monitoring cycle of approximately every three years). More comprehensive and targeted water quality monitoring is required at selected sites within the Minnamurra River Catchment in order to provide detailed information regarding specific pollution sources and to track changes in water quality as a result of management actions.

Ongoing water quality monitoring over various climatic conditions is required to adequately characterise water quality in the Estuary and identify pollutant sources. The key objective is to identify and address key causes of water quality decline and to improve water quality throughout the Estuary. The effective design of a monitoring program is crucial to achieving useful outcomes. Programs need to have objectives based on key questions for the monitoring, specific indicators and adequate sampling design in order to provide useful information with limited resources. Figure 58 provides an overview of the basic design framework for sampling programs.

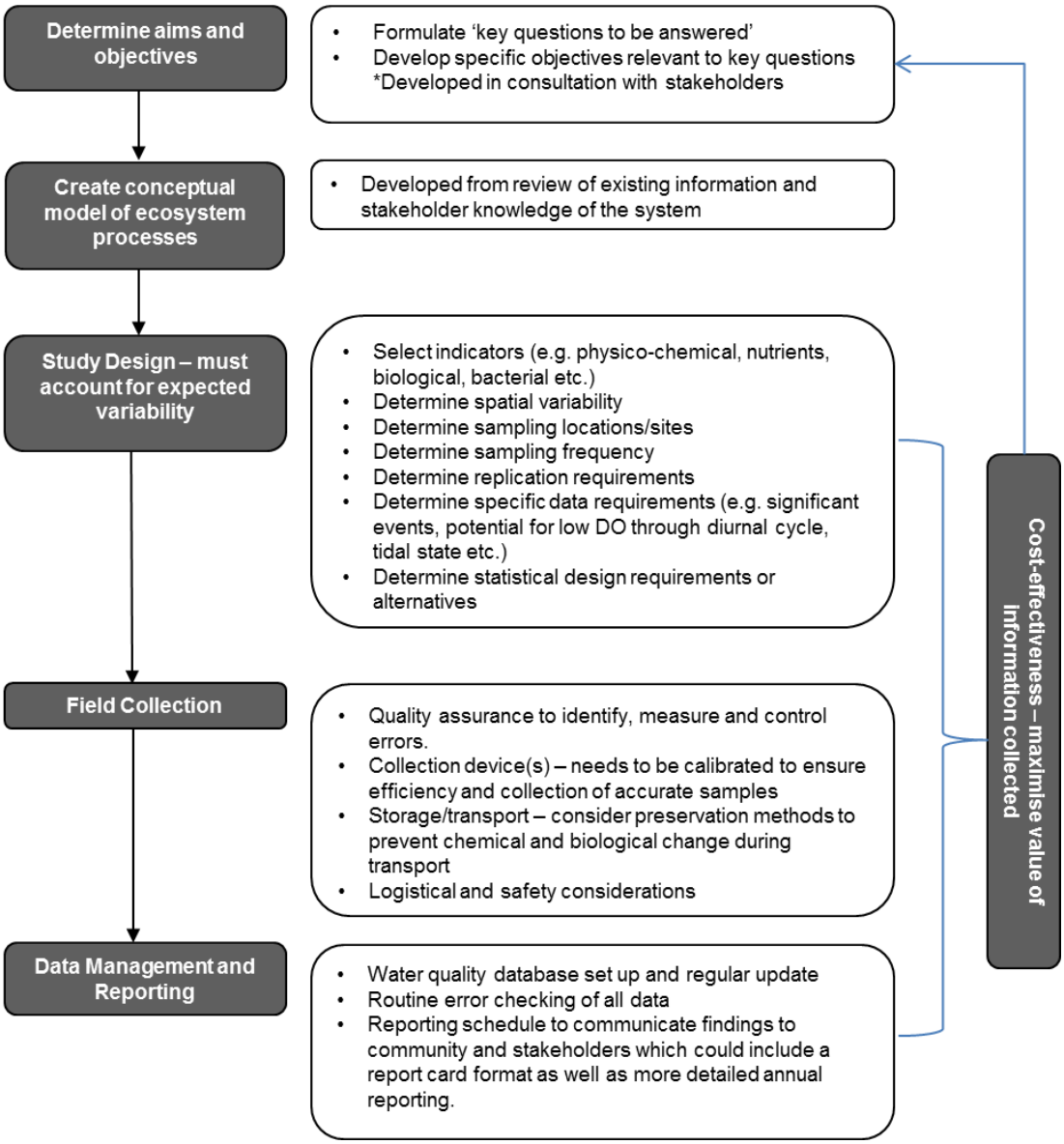


Figure 58: Framework for sampling program design

Source: Adapted from ANZECC (2000) and Maher *et al*., (1993)

To assist in identifying sources of pollution in the Minnamurra River Catchment, monitoring methodologies would need to be designed and implemented including routine sampling and event-based monitoring at selected sites. Considerations for design of a water quality monitoring program are:

- The reason for sampling needs to be clearly stated and objectives specified based on key questions for monitoring. The development of a conceptual model will assist the clarification of objectives and choice of sample sites and indicators to be sampled;
- Potential sources of variability (e.g. tides, rainfall) must be considered to allow for collection of representative samples;
- Site selection, timing of sample collection and frequency of sampling will be crucial in obtaining accurate results and eliminating factors of variation. Site selection should incorporate assessment of:
    - Sites used in previous monitoring to allow for comparison through time. This includes a site in the upper catchment upstream of Jamberoo (site M1 sampled by KMC in 2006/07), sites in the mid and upper estuary (sites M2 and M3 sampled by KMC in 2006/07 and MER in

2007/08) and a site in Rocklow Creek downstream of the Princes Highway (site R1 sampled by KMC in 2006/07) (Refer to Figure 64 in Appendix 6 for mapped site locations);

- An additional site in the lower estuary (downstream of Rocklow Creek) with a particular emphasis on assessing recreational water quality;
- Agricultural drains (potential sources of nutrients, low dissolved oxygen, sediment, faecal contamination, etc.);
- Stormwater outlets (potential sources of sediment, nutrients and other pollutants, etc.); and
- Other specific sites of concern to the community/stakeholders as appropriate.

- As a minimum, sampling should aim to capture at least three moderate to high rainfall events annually. After the initial year of sampling, review of results will determine further monitoring requirements;
- Water quality parameters to be assessed will be selected according to the type of pollution source under investigation. As a minimum the following parameters are suggested: pH, temperature, dissolved oxygen, salinity/conductivity, turbidity (water clarity indicator), chlorophyll a (indicator of algal growth), TN, TP and *Enterococci* (bacterial contamination indicator).The measurement of nutrient concentrations, including the different forms (e.g. nitrate, ammonia) will provide further information to assist in the identification of likely sources of pollution and should be considered where funding permits;
- Depending on the types of pollution being investigated, *in situ* measurements using a water quality sonde (for physico-chemical parameters) in addition to grab samples (for lab analysis of *Enterococci*, chlorophyll a, nutrients, etc.) will require manual sampling in the field. An alternative (or complimentary method) is deployment of water quality data loggers at key sites in relation to potential sources. Data loggers would remain in place for a period of time continuously recording water quality for a range of physico-chemical parameters (e.g. turbidity, dissolved oxygen, pH, temperature, salinity, conductivity). This is particularly valuable in understanding diurnal dissolved oxygen concentrations, a key indicator of ecosystem health and to explore the potential impacts on fish communities. However, the significant additional cost of data loggers may prevent their implementation if equipment is not currently owned or available for Council use; and
- Specific methodologies would need to be developed and incorporated into a sampling program that is suitable for implementation considering logistical and safety constraints associated with weather-dependant sampling. The availability of grant funding and Council resources may determine the timing of the sampling program.

It is important that the collected water quality data are utilised appropriately, and the value of the information is fully realised. Significant expenditure is required to collect water quality information and to ensure monitoring is cost-effective so the use of information needs to be maximised wherever possible. A water quality database is a valuable tool to organise data as results are received and to complete error checking and tracking of water quality trends through time. As a minimum, annual reporting of water quality results should be conducted as part of ongoing monitoring in the catchment. Results can be incorporated into Council's SOE reporting. A simplified 'report card' format, with emphasis on visual display of results may be appropriate for communicating results to a broad audience.

In addition to the ongoing water quality monitoring program there is also potential for further short-term university projects in the catchment to investigate specific issues or sites and to evaluate potential sources of poor water quality (discussed in Section 8.1.2 Research Priorities).

Urban Stormwater

Urban stormwater can be a source of contamination following wet weather. Installation of additional stormwater quality improvement devices (SQIDs) at additional major outlets would reduce pollution but would require ongoing maintenance to be successful. Monitoring is required to determine the high priority areas for SQIDs. This would involve a review of effectiveness of stormwater treatment devices and best available technologies considering:

- Water quality data;
- Information on the material collected in the pits and traps;
- Condition and performance of existing devices;
- Best-available technology;
- Flooding and sea-level rise impacts;
- Occupational health and safety considerations e.g. for maintenance and rectification;
- Amenity and public safety considerations;
- Life cycle costs; and
- Other Council asset management considerations.

Future urban consolidation has the potential to increase impacts from urban runoff and overload existing stormwater treatment ponds and other infrastructure. The requirements for servicing of future growth will be addressed in Council's Urban Stormwater Asset Management Plan.

A similar investigation to the 1998 study by Roso could be undertaken to assess the impact of stormwater on the Minnamurra River and current stormwater pond performance and recommend appropriate maintenance actions where necessary. In addition to the sampling undertaken upstream and within the ponds, sampling in the Minnamurra River at representative sites both upstream and downstream of the stormwater discharge point, would assist in evaluating the impact of stormwater on the river. There may be additional sites for monitoring in areas that have been developed since the 1998 study. It will be important to sample a range of wet and dry conditions, including high flow events, with consideration of tidal conditions to allow for adequate assessment of conditions and treatment performance.

Waste Depots

Monitoring at the Minnamurra Depot has indicated that leachate is likely to be impacting on water quality in Rocklow Creek and recommendations from the 2013 annual report are that groundwater remediation (e.g. extraction and further treatment) be undertaken if ammonia concentrations exceed 100 mg/L in groundwater samples on two consecutive monitoring rounds in 2013 or 2014 (E2W, 2013). This CZMP supports both the ongoing monitoring of waste disposal sites and the further development of remedial actions to treat contaminated groundwater in order to reduce impacts on water quality in Rocklow Creek and the downstream Minnamurra River Estuary.

The review of waste depot annual reporting conducted as part of this CZMP identified inconsistencies in the monitoring of ammonia concentrations at both Minnamurra and Dunmore waste depots, and it is recommended that future monitoring ensures that total ammonia (the sum of NH_3 and NH_4^+) is measured in both ground and surface water sampling. This will allow for leachate impacts to be fully assessed and an accurate comparison with aquatic ecosystem health guidelines to be undertaken for Rocklow Creek.

Impacts of projected future sea level rise may also have implications for management of the waste depot sites (refer Section 6.15). To gain a full understanding of the processes involved and likely impacts and to identify suitable management measures, a further more detailed investigation and risk analysis into the

potential future sea level rise impacts on both the Minnamurra and Dunmore waste depot sites is recommended. The investigation should detail:

- Future sea level rise projections and modelling;
- Hydrogeology including tidal influence;
- Surface hydrology including future overland tidal water flow paths; and
- Current and future contaminants and contaminant behaviour.

Additionally, potential management options should be considered including:

- Groundwater interception trenches;
- Groundwater barriers and pump-out systems; and
- Tidal water barrier walls/levees.

Agricultural and Rural Land Management

Management of agricultural lands in the catchment has a major influence on water quality and riparian vegetation condition within the Estuary. Liaison with individual landholders is a key strategy for facilitating positive change and it is necessary to ensure that farmers have industry support and can access management information, industry incentives and marketing initiatives that maximise positive outcomes for the Estuary as well as the agriculture industry. To address the identified management issues, education and support is required in relation to:

- Management of dairy effluent;
- Stock exclusion fencing;
- Nutrient budgeting and soil management;
- Protection of the riparian zone, weed management and vegetative stabilisation including re-establishment of previously cleared riparian corridors (refer Section 6.4.1);
- The use of shelter belts for habitat corridor linkages;
- Formalised stream crossings; and
- Off-stream stock watering.

There are a range of programs and initiatives from various government agencies (e.g. South East LLS), industry groups (e.g. DIG), Volunteer Groups (Illawarra Landcare and Conservation Volunteers Australia) and SCG (Small Farms Network) to promote sustainable agricultural land management. These existing initiatives should be supported with linkages provided between agricultural land management and flow on effects to downstream environments and values. This would require increased coordination as proposed in Strategy 1 – Coordination of Management Actions as well as support of research initiatives which are consistent with the CZMP objectives. Where suitable, it may be possible to seek funding as part of this CZMP for agricultural initiatives that can be shown to have a positive impact on estuary health. The monitoring programs should report on identified sources of agricultural impacts and particularly any improvements in water quality following works. This will provide feedback on management practices and provide support for ongoing implementation.

Increasing the understanding of the issues and the need for sustainable agriculture initiatives will be a factor in the success and ongoing support of existing programs. This will also be important to ensure increasing uptake of initiatives by landholders into the future and to promote farm management planning to address specific environmental issues while providing for long-term economic planning to facilitate changes to more

estuary-friendly land use practices. Sustainable farming projects have been undertaken in the catchment that would provide useful demonstration sites e.g. Clover Hill Dairies and other Fountaindale Creek sites.

Continued implementation of the KMC *Onsite Sewage Management Strategy* is a requirement under the *Local Government Act 1993* and is supported by this CZMP to appropriately identify, assess and manage OSSMs in rural areas of the catchment. OSSMs which are faulty can be significant contributors of nutrients and faecal contamination in the estuary.

Gross Pollutants

There are many examples of gross pollutants in the river which would require a specialised removal program (e.g. feed bales, silage wrap and chemical drums). This should be undertaken on a regular basis, potentially as part of Clean Up Australia Day. It is understood that the silage wrap and baling twine recycling program was successful while the collection bags were distributed free of charge. The SCG should also consider reinstating this service and providing ongoing education to improve the success of the recycling program subject to available funding.

Other Related Measures

Additional options including erosion control (Strategy 3 – Control of Bank Erosion) and rehabilitation of riparian zones (Strategy 4 - Protection of Estuarine and Foreshore Habitat) will contribute to improved water quality outcomes.

8.3 Strategy 3 – Control of Bank Erosion

8.3.1 Existing Approach

Various areas of river bank have been targeted by the relevant land managers with varying approaches to bank stabilisation including:

- Rock revetment along Charles Avenue foreshore, Minnamurra Headland and Riverside Drive (KMC);
- Weed control and revegetation projects at various locations by CMA, Landcare, Conservation Volunteers Australia and the Small Farms Network;
- Livestock fencing (farmers and Terragong Drainage Union); and
- In-stream rock ramps (Terragong Drainage Union and CMA).

These projects are undertaken when funding is available. The Small Farms Network is currently working with a landowner along Jerrara Creek (Site 18, refer Section 6.5.3) to rehabilitate the river bank with removal of Willow trees and other weeds, fencing and revegetation of the buffer zone with funding provided by Commonwealth environmental grants and tree stock provided by Landcare Illawarra. While other similar programs have been undertaken at other sites within the catchment, this project provides a potential demonstration site showcasing the collaborative efforts of the landowner, volunteer groups and support organisations.

8.3.2 Recommended Future Management Approach

Rehabilitation should focus on the highest risk erosion sites as identified In Section 6.5.3. High priority areas for rehabilitation of the river bank are those currently affected by severe or moderate erosion in high value areas (biodiversity areas, priority community access, etc.) or where a risk to estuary health is present. The potential impact on built assets has also been considered.

Management approaches will depend on the location and underlying cause of river bank erosion. Potential options to address bank erosion including those assessed in the 1995 EMP are discussed in Table 13.

Table 13: Potential options to address bank erosion

Option		Description	Pros	Cons	Comments
All areas					
3A	Monitor	No additional action to control erosion. Continued monitoring and assessment of erosion risk is required to identify priority areas for rehabilitation.	• Minimal cost	• Continued erosion, reduction in water quality and impacts on estuarine vegetation. • Loss of community land, facilities and private land including agricultural land.	In some areas, erosion is natural and doing nothing may be appropriate. In other areas, doing nothing is not consistent with the values of the Estuary.
3B	Bank stabilisation – hard options	Rock armouring, sand bags, logs (brushing).	• Good ongoing protection from erosion if appropriately designed, particularly rock armouring. • Can be applied where limited space exists. • Simple and relatively inexpensive to maintain if designed and constructed appropriately. • No impact on views.	• High cost. • Rock walls will alter the natural appearance of the area. • Sand bags can be unsightly, they degrade and can be easily vandalised. • Wave reflection may cause erosion to opposite bank and beach berm in front of wall.	Rock armouring is an appropriate option in areas of severe erosion or to protect from bank recession and loss of land. Brushing may also be successful if vegetation establishes to provide long-term stability. While existing rock revetment along Charles Avenue foreshore has been largely successful, erosion is occurring at the upstream and/or downstream extents of these controls indicating they may not be keyed-in appropriately. In areas of sharp river meander, hard options may instigate or accelerate morphological changes elsewhere in the Estuary.

Option		Description	Pros	Cons	Comments
3C	Bank stabilisation – proprietary wall	Concrete mattress or sheet pile.	• No impact on views	• Often higher reflectivity leading to increased toe scour and higher incidence of reflected erosion. • Hardening of soft foreshore edge. • Diminishes access to water. • Less flexible than rock with damaged structures usually more costly to repair. • Destroys riparian habitat and limits growth of riparian vegetation. • Limits or displaces habitat for burrowing animals.	Not expected to have any advantages over rock revetment.
3D	Bank stabilisation – mangroves	Planting of mangroves to trap sediment and riparian vegetation to stabilise banks.	• Low cost. • Does not interfere with access. • No wave reflection. • Environmentally beneficial e.g. habitat creation, sediment capture, nutrient processing.	• Requires buffer area inland of bank and intertidal beach area. • Weed management and maintenance of riparian areas is required. • Vegetation canopies may impact on views. • May affect waterway access.	Mangrove planting has been successful in other estuaries (e.g. Shoalhaven) if combined with wave barrier. A mangrove plantings trial in accordance with *Mangrove Planting on the Shoalhaven River, NSW – A Guide for Restoration of Tidal River Erosion* (Shoalhaven Riverwatch Inc.) may be appropriate in some areas.
3E	Bank stabilisation – vegetative cover	Progressive weed removal and replanting of appropriate native species.	• Natural means of water quality improvement and bank stabilisation. • Habitat creation.	• Requires landowner assistance. • Weed management and ongoing maintenance of riparian areas is required. • May also require other minor structural repairs, re-contouring or additional stabilisation approaches such as rock revetment.	Expected to be a suitable form of erosion control for some sections of the estuary if appropriate species are used.
3F	Control of runoff	Scour protection along drainage lines.	• Effective low cost option	-	Likely to be appropriate for scoured urban stormwater outlets.

Option		Description	Pros	Cons	Comments
Lower and mid estuary					
3G	Rock fillets	Intertidal retaining wall.	• Does not limit beach access. • Improved beach amenity. • No impact on views. • Allows re-establishment of riparian vegetation. • Permits establishment of benthic fauna populations.	• May interfere with near-shore inundation regime affecting existing mangroves. • Intertidal wall will impact on water access from the shoreline. • Suitable rock footings would be required to maintain stability of the wall and withstand wave impacts. • Alters the appearance of the foreshore. • Significant approval and timing requirements. • High cost.	As rock revetment has been constructed along much of the Charles Avenue foreshore, this option would duplicate the existing protection and is therefore not required. Other erosion locations are not suitable for this approach.
3H	Groynes	Either permanent groynes constructed of rock or temporary sand bag groynes.	• Groynes would assist in deflecting the channel and trapping sand to reduce erosion.	• Potential impacts on navigability and estuarine vegetation. • Erosion may be relocated to down drift of the groynes. • Temporary groynes may be damaged by floods. • A substantial ocean event may still result in erosion. • Significant approval and timing requirements. • High cost.	Timber groynes along Charles avenue foreshore are deteriorating and have not been effective in trapping sand. As rock revetment has been constructed along much of the Charles Avenue foreshore, this option would duplicate the existing protection and is therefore not required at that location. At other locations, groynes are expected to impact on the navigation channel.

Option		Description	Pros	Cons	Comments
3J	Education regarding illegal vegetation clearing	Provide information to landowners about effects of vegetation removal (particularly mangroves).	• Low cost	• Difficult to enforce.	Should be continued as part of NSW Fisheries regulatory functions. May be combined with estuarine vegetation protection options (refer Section 8.4).
Upper Estuary, Terragong Swamp and tributaries					
3K	Fencing/ livestock exclusion	Barrier to livestock grazing and access to waterway.	• Successful protection from livestock trampling and grazing.	• Requires landowner assistance. • Loss of productive farming land.	Can be successful if adequate vegetated buffer distance is provided.
3L	Education – agricultural impacts	Ongoing liaison and education regarding impacts of farming practices (refer Section 8.2.2).	• Likely to be successful if funding/incentives available.	• Requires landowner involvement.	Education should be used to support any management approach.
3M	Line channel	Channel lined with proprietary mattress.	• Controls meandering of the river. • Maximises use of agricultural land.	• High cost. • Would need to extend to full length of channel. • Visual and environmental impacts.	Funding is not expected to be available from landholders or external grants. This option is not recommended for these reasons.
3N	Channel reshaping	Channel widened, banks battered and vegetated.	• More natural appearance.	• Reshaped channel would consume agricultural land. • Would need to be associated with revegetation to be successful. • May not full inhibit river meander. • High cost.	Funding is not expected to be available from landholders or external grants. This option is not recommended for these reasons.
3P	Snag management	Removal of fallen trees/flood debris.	• Removal of obstruction will reduce stream flows against banks.	• Snags are important habitat for aquatic ecology. • Erosion will still continue if banks are not fully vegetated.	Bank erosion may stabilise itself following removal of the snag, but then likely to become an issue somewhere else and additional stabilisation such as rock revetment, reinstatement of riparian zone and stock exclusion is also required.

Recommended Erosion Controls

The recommended approach to rehabilitate the river bank to improve water quality and riparian condition and protect assets is listed in Table 14. Areas of highest risk should be rehabilitated in the short-term (years 1-3). Where minor erosion exists, ongoing monitoring of the extent and severity is recommended with rehabilitation undertaken if funding or resources become available. In addition, continued monitoring and assessment of erosion risk is recommended every 3 years.

Table 14: Recommended approach to rehabilitate bank erosion

ID *	Location	Approach	Responsibility	Timing
Lower and mid-estuary				
1	Right bank, Minnamurra Headland	Remove existing rocks and reconstruct rock revetment (Option 3B) with appropriate batter slope. Option 3E – Bank stabilisation – vegetative cover (low-growing native species).	KMC	Medium term
2	Right bank, James Oates Reserve	Option 3E – Bank stabilisation – vegetative cover (low-growing native species).	KMC	Medium term
3	Charles Avenue foreshore, first (downstream) timber groyne. Above rock revetment	Option 3E – Bank stabilisation – vegetative cover.	KMC	Medium term
4	Charles Avenue foreshore, second timber groyne. Above rock revetment	Option 3E – Bank stabilisation – vegetative cover. Repair/replace concrete matting.	KMC	Medium term
5	Charles Avenue foreshore, opposite Links Street. Rock revetment collapse.	Remove existing rocks and reconstruct rock revetment (Option 3B) with appropriate batter slope (this has been completed). Option 3J - Education regarding illegal vegetation clearing (refer Strategy 4 - Protection of Estuarine and Foreshore Habitat).	KMC	Short term
6	Charles Avenue foreshore	Option 3A - Monitor extent and severity of erosion. Option 3J - Education regarding illegal vegetation clearing.	KMC	Ongoing
7	Charles Avenue foreshore, opposite River Street	Option 3A - Monitor extent and severity of erosion. Option 3J - Education regarding illegal vegetation clearing.	KMC	Ongoing
8	Trevethan Reserve, near boat ramp	Option 3F – scour protection as funding becomes available.	KMC	Medium term
9	Right bank, Riverside Drive	Option 3F – scour protection as funding becomes available.	KMC	Medium term

ID *	Location	Approach	Responsibility	Timing
10	Right bank, Riverside Drive, end of rock revetment	Option 3D – Mangrove planting with additional rock revetment to taper into and along the banks.	KMC	Short-medium term
11	Right bank, first meander	Option 3A - Monitor extent and severity of erosion.	Private landowner	Ongoing
12	Left bank, second meander of Minnamurra Bends	Option 3A - Monitor extent and severity of erosion.	Private landowner	Ongoing
13	Right bank, adjacent to and downstream of Princes Highway bridge	Option 3A - Monitor extent and severity of erosion.	Private landowner	Ongoing
14	Left bank, midway between highway bridge and Swamp Road bridge.	Option 3E – Bank stabilisation – vegetative cover (erosion at this site was noted in the 1995 EMP and does not appear to have increased in severity).	Private landowner	Short-term
15	Left bank, on straight upstream from Swamp Road bridge.	Option 3E – Bank stabilisation – vegetative cover (vegetation is expected to recover when livestock access is restricted). Option 3K - Fencing/ livestock exclusion. Option 3L - Education – agricultural impacts.	Private landowner	Short-term
16	Left bank, mid swamp	Option 3P – Snag management. Fallen tree may be relocated to bank if suitable anchoring can be included. Option 3E – Bank stabilisation – vegetative cover. Option 3K - Fencing/ livestock exclusion. Option 3A - Monitor extent and severity of erosion.	Private landowner	Short-term
17	Left bank, mid swamp, mouth of farm drain	Option 3E – Bank stabilisation – vegetative cover. Option 3K - Fencing/ livestock exclusion.	Private landowner	Ongoing
18	Left bank, upstream of Browns Lane bridge	Option 3E – Bank stabilisation – vegetative cover. Option 3K - Fencing/ livestock exclusion.	Private landowner	Ongoing
19	Left and right bank, Jerrara Creek downstream of Jamberoo Road bridge.	Small Farms Network rehabilitation project (weed removal, revegetation of riparian buffer, stock exclusion fencing). Potential future demonstration site.	Private landowner	Ongoing

ID *	Location	Approach	Responsibility	Timing
20	Right bank, Hyams Creek upstream form Wyalla Road bridge	Option 3E - Creation of vegetated buffer on banks. Option 3K - Fencing/ livestock exclusion. Option 3L - Education – agricultural impacts.	Private landowner	Short-term
21	Right bank, Hyams Creek	Option 3E - Creation of vegetated buffer on banks. Option 3K - Fencing/ livestock exclusion. Option 3L - Education – agricultural impacts.	Private landowner	Short-term

* Site ID refers to Figure 33, Figure 34 and Figure 35. Left and right bank is described when looking downstream.

Maintenance of Existing Erosion Controls

Some existing rock revetment areas require maintenance to restore the integrity of the rock wall and ensure public safety and ongoing bank stabilisation. These include:

- Minnamurra Headland;
- Charles Avenue Minnamurra foreshore;
- Riverside Drive Kiama Downs rock wall; and
- Hyams Creek pedestrian bridge, Jamberoo.

Council will need to assess all rock walls to ensure the necessary repair works are included in the annual maintenance schedule and budget allocation and / or grant funding is identified where available. Maintenance work along banks and within waterways will require approval from Fisheries NSW and Crown Lands. Where possible, the batter slope in these areas should be decreased to improve bank stability.

Reduction in erosion risk along Terragong Swamp

Option 3L (education - agricultural impacts) should be a key component of agricultural extension services as discussed in Section 8.2.2 - Agricultural and Rural Land Management.

Due to a lack of stabilising vegetation along the channel of Terragong Swamp, fallen trees have created a flow blockage and diverted flow onto the opposite bank, exacerbating bank erosion in places along the Swamp. In parallel with the snag management option (Option 3P), a survey of the river bank along Terragong Swamp should be undertaken to identify high risk trees such as Coral trees (*Erythrina X sykesii*) growing close to banks. Progressive removal of weed species as well as replanting the buffer zone with appropriate bank stabilisation species (Option 3E) and fencing/livestock exclusion (Option 3K) is required. The Swamp is a priority area for riparian vegetation rehabilitation as discussed in Section 6.4.1.

Ongoing erosion risk assessment

As part of this CZMP, a survey of the Minnamurra River Estuary section was undertaken by Council and OEH to identify current areas of bank erosion. A survey of the remaining upper tributaries areas is recommended to build on the information provided in this CZMP. This would focus on erosion risk and vegetation management investigations as follows:

- Assessment of bank condition, stability and erosion risk including vegetation condition, weeds, slope and soil type;
- Coastal hazards contributing to erosion risk such as tidal inundation, the interaction of tidal waters with catchment flows and increased storminess;
- GIS mapping of features of natural importance and built assets;
- Identification of high impact land use, where vegetated buffers will provide benefits in soil retention/interception and improvement of overland runoff, thus improving water quality;
- The location of sites to promote activities and act as demonstration sites to communicate best practice approaches; and
- Identification and prioritisation of bank erosion areas that would benefit from riparian planting and other management measures.

Hydrographic survey of the Estuary up to Browns Lane was undertaken in 1992 and other survey data is available from 1994. A new hydrographic survey of the Swamp could be undertaken to assess the rate of channel erosion through change in channel dimensions and bed slope and assess the effectiveness of the installed grade control structures. The cross-sections at Swamp Road (3) and Browns Lane (1) should be replicated, with additional survey points upstream and downstream of the grade control structures. The survey should be repeated approximately every 5 years or in response to a major flood event. The information provided should be reviewed as part of the erosion risk assessments (discussed above) and the next review of the CZMP.

8.4 Strategy 4 - Protection of Estuarine and Foreshore Habitat

8.4.1 Existing Approach

Biodiversity Management

DPI undertakes mapping of estuarine vegetation in NSW. The NSW MER program utilises this information to assess mangrove, seagrass and saltmarsh condition as a percentage of change in area since last reporting.

A number of vegetation management initiatives have been undertaken in the Minnamurra River catchment to date including:

- The *Illawarra Biodiversity Strategy and Local Action Plan 2010* was developed and adopted;
- The *Remnant Vegetation and River Corridor Action Plan* for the Minnamurra River Catchment 2002 (Harris, 2002) provides detailed assessment of vegetation remnants, riparian zones and existing management actions undertaken by various groups and organisations within Minnamurra Sub-Catchments. The plan also identifies a number of recommendations for vegetation management and maps priority areas for future vegetation actions in each of the Minnamurra River sub-catchments.
- Development and implementation of the *Roadside Vegetation Management Plan* to protect good quality remnant vegetation and to identify areas for revegetation and corridor enhancement;
- Mapping of wildlife corridors within the Kiama LGA;
- Mapping of native vegetation including EECs across the catchment;

- Much of the riparian vegetation along the tidal reaches of the Minnamurra River, have some kind of environmental protection including areas mapped as either SEPP 14 Coastal Wetlands, Estuarine Vegetation (Mangroves/Saltmarsh) or EECs (Bangalay Sand Forest, Swamp Oak Floodplain Forest, and Robertson Basalt Tall Open Forest).
- Rehabilitation projects such as Jerrara Dam bush restoration;
- Tree planting at annual Kiama High School National Tree Days;
- KMC advises and assists work of various Landcare Groups throughout the Municipality;
- Educational signage at Minnamurra Wetlands (Trevethan Reserve);
- Weed management, planting and protection of mangroves and riparian species at various sites including Trevethan Reserve, the south east shore at Riverside Drive and the southern headland at James Oates Reserve;
- Three year funding secured by KMC from NSW Government in 2011 for implementation of the *Weeds Action Program* and *NSW Invasive Species Plan* within the Kiama LGA;
- KMC assisted with the implementation of SCG Commonwealth grant funded *Eastern Australia Boneseed Eradication and Containment* project;
- Local weed control programs for private landholders and government agencies continued on high priority areas;
- Weed inspection and treatment for Council lands;
- Minnamurra River inspected along its length to ensure no new aquatic weed outbreaks; and
- South Coast Communities Sea Spurge Control Project aims to establish a northern control line against the encroachment of Sea Spurge (*Euphorbia paralias*).

Other actions have been undertaken through partnerships with Boral and OEH, Landcare Illawarra and Wildlife Information Rescue and Education Service (WIRES) around Dunmore associated with the Boral Quarry. These groups have been working together over a number of years to implement projects to improve the condition of native vegetation and habitat for fauna species. In addition to work with flying foxes, fencing has been installed to restrict stock access to high conservation value areas, weeds have been controlled and nesting boxes have been installed for micro chiropteran bats (SRCMA, 2013).

In addition the CMA funded Alligator weed (*Alternanthera philoxeroide*) and *Salvinia* eradication program contracted SCC and the Illawarra District Noxious Weeds Authority (IDNWA) to manage outbreaks at Dunmore using chemical treatment. These weeds are of particular concern given their potential to occupy fresh and brackish wetland and riparian areas throughout the Minnamurra River catchment. All sites managed for aquatic weeds under this program will be monitored for regrowth for the next 10 years. Any new growth will be appropriately managed. Downstream monitoring points have also been established (SRCMA, 2013). It will be important for future information and education programs to keep the issue of noxious weeds in the public arena and enable the community to be able to assist in identifying and stopping their spread.

There have also been a number of studies looking at vegetation in the Minnamurra River catchment including vegetation survey and mapping studies, riparian corridor investigations and management planning and investigations of projected sea level rise impacts on estuarine vegetation. The Killalea State Park Trust is currently preparing an updated plan of management including an ecological study across Killalea State Park. This work will provide valuable information on biodiversity values and issues in this section of the Estuary.

Threatened Species Management

The *Threatened Species Conservation Act, 1995* provides for the conservation of threatened species, populations and ecological communities of animals and plants (although the Act does not generally apply to fish). The Act sets out a number of specific objects relating to the conservation of biological diversity and the promotion of ecologically sustainable development. Identified species, populations, ecological communities and key threatening processes are listed in the Schedules to the Act. Provision is made for the preparation of recovery plans for listed threatened species, populations and ecological communities and threat abatement plans to manage key threatening processes. The Act also provides for the declaration and mapping of habitats that are critical to the survival of those identified threatened species, populations and ecological communities that are classified as endangered (critical habitats).

Aquatic habitat and fishery protection

Fisheries NSW administers the *Fisheries Management Act 1994* and associated Regulations. The department has jurisdiction over all fish and marine vegetation in state waters and these powers also extend to Commonwealth waters for some species and fishing methods. To meet the primary objectives, Part 7 of the *Fisheries Management Act* deals with the protection of aquatic habitats and Part 7A deals with threatened species conservation. Under Part 4 of the *Environmental Planning and Assessment Act, 1979*, NSW DPI (Fisheries NSW) is a 'determining authority' for local development including:

- Section 201 (*Fisheries Management Act*) - permit to carry out works of dredging or reclamation (i.e. any excavation within, or filling or draining of, water land or the removal of woody debris, snags, rocks or freshwater native aquatic vegetation or the removal of any other material from water land that disturbs, moves or harms these in-stream habitats);
- Section 205 - permit to harm (cut, remove, injure, destroy, shade etc.) marine vegetation (saltmarshes, mangroves, seagrass and seaweeds); and
- Section 219 – permit to obstruct the free passage of fish.

8.4.2 Recommended Future Management Approach

Estuarine Vegetation

In order to address some resident concerns about mangrove encroachment in the lower estuary affecting access and scenic amenity, it is recommended that a consultative process is established between Fisheries NSW, Crown Lands, KMC, the residents and the wider community. This should include an assessment of the issues, information regarding the value of estuarine vegetation, discussion of suitable options for mangrove management while satisfying Fisheries NSW legislative obligations for protection of estuarine vegetation and aquatic habitat, consideration of current reserve plans of management and wider community attitudes and benefit.

In relation to Council maintenance of foreshore assets, significant time and cost efficiencies can result from a maintenance permit as separate approvals would not be required for works covered by the permit. Maintenance permits (under the *Fisheries Management Act, 1994*) are used, for instance, in Northern NSW for minor maintenance works by local councils that may involve harming marine vegetation such as clearing stormwater outlets, foreshore asset maintenance and maintaining access to estuary foreshores. However, key considerations will include Council's priorities and funding available for ongoing maintenance.

The review of historical aerial photographs given in Appendix 3 suggests that the extent of seagrass adjacent to Charles Avenue diminished between summer 2009 and summer 2011 and further diminished between summer 2011 and summer 2013. Community members have also noted a decline in seagrass extent in recent years. There are a number of potential causes of seagrass decline including natural factors (e.g. seasonal changes) and human-induced factors (e.g. poor water quality such as elevated turbidity or

high nutrient levels). However, from the currently available information it is difficult to determine the reasons for the observed seagrass decline in the Minnamurra River (refer Section 6.4.2). In order to better direct management effort it is recommended that an investigation of factors affecting seagrass decline is undertaken. A key aim of the study would be to differentiate between natural fluctuation in seagrass area (as a result of seasonal changes, scour or burial and response to climatic conditions) and changes due to human induced impacts such as water quality decline or physical disturbance. Because seagrass habitats are temporally and spatially dynamic it will be necessary to collate a range of information to help understand extent and health of this community. A review of historical distribution in relation to potential factors of change may assist in understanding fluctuations. There have been a number of previous studies looking at estuarine vegetation changes in the Estuary and other similar systems and these will be a valuable starting point for research. Repeat mapping of seagrass distribution should be undertaken to document current status. Ground-truthing of seagrass locations is necessary to confirm seagrass presence.

Estuarine and wetland vegetation communities in the Minnamurra River Estuary are highly vulnerable to sea level rise. To minimise the potential for future significant losses in vegetation communities it will be necessary to allow for the landward migration of vegetation communities in response to sea level rise. Buffer zones are likely to be required in a number of areas to facilitate upslope migration. Migration may be restricted in some locations due to the presence of steep topography or physical barriers such as roads and structures and property boundaries. Consideration of the location and extent of buffer zones should be undertaken as well as other management options such as buy-back of low-lying floodplain areas likely to be affected by saltwater intrusion, allowing for natural processes and colonisation in response to sea level rise (refer also Strategy 6 – Floodplain Management).

Riparian Vegetation

The restoration and/or rehabilitation of vegetated riparian corridors would result in a significant reduction in bank erosion and sediment displacement while enhancing ecosystem values and improving water quality for the Estuary as a whole. The existing bush regeneration, rehabilitation and weed management activities carried out by Council and other stakeholders are supported by this CZMP. The poor condition of the majority of the riparian zone along the mid and upper estuary and along many of the tributaries means that complete restoration is an immense task. It is therefore recommended that resources are allocated to priority sites for rehabilitation to direct on-ground rehabilitation works for maximum benefit. The *Remnant Vegetation and River Corridor Action Plan* for the Minnamurra River catchment (2002) identifies a number of recommendations for vegetation management and maps priority areas for future vegetation actions in each of the Minnamurra sub-catchments. The Plan provides detailed background information and guiding principles for future vegetation management actions in the catchment and is a useful basis for planning for on-ground projects at specific locations. More recently the *Illawarra Biodiversity Strategy* (2011) provides a regional prioritisation of areas for biodiversity investment. The lower Minnamurra River, comprising an area of over 145 ha is classified as one of the highest priority sites. As part of this CZMP, a catchment assessment was undertaken which identified a number of sites for riparian revegetation and these are considered to be the current priority areas.

The remainder of the catchment (mid-upper catchment and tributaries) should also be assessed to determine riparian condition. It would be useful to have priority vegetation categories available in a GIS mapping format to allow for further analysis with other digitised factors such as land zoning, property boundaries, corridor linkages, topography, fauna records, etc. and to track ongoing progress of implementation combined with other monitored ecosystem variables such as water quality. This is particularly important in terms of planning riparian corridor restoration works, which requires careful selection of sites to maximise the value of management effort and cost. Prioritisation should consider a number of factors including:

- Results of previous prioritisation work (e.g. Illawarra Biodiversity Strategy (2014), Harris (2002) and studies undertaken as part of this CZMP (e.g. geomorphological assessment and erosion risk assessment);
- Identification of high impact land use, where vegetated buffers will provide benefits in soil retention/interception and improvement of overland runoff, thus improving water quality;
- The location of key habitats and wildlife corridors and enhancement of these areas through greater connectivity created by riparian restoration;
- Targeted programs to address riparian weeds;
- The location of sites in terms of public visibility to promote activities and act as demonstration sites and to enhance aesthetic qualities of the Estuary; and
- Land ownership and landowner willingness – from preliminary assessment it is evident that the opportunity to carry out large-scale revegetation works on publicly owned land is limited to the lower estuary areas.

Follow up monitoring and annual review could be conducted by the proposed Estuary Health Officer to determine the effectiveness of works, accuracy of cost estimation and to recommend ongoing work.

Encouraging farmers to protect and enhance the riparian zone through actions such as fencing of stock is a key part of riparian vegetation and erosion management (refer Section 8.2.2 - Agricultural and Rural Land Management). A recent model for the detailed planning and implementation of river, wetland and catchment restoration is the Demonstration Reach Toolbox developed and applied since 2005 in the creation of stream demonstration reaches in the Murray-Darling Basin as part of the Basin Authority's former Native Fish Strategy. The principles of the Toolbox and its comprehensive detailed guides constitute a practical and tested model for the planning and implementation of a long-term project to address and remediate the Minnamurra River catchment.

Weed Control

While many stakeholder groups are undertaking weed management actions within the Minnamurra River catchment, there is currently no coordinated or ongoing approach to weed management. The Illawarra Noxious Weeds Authority manages noxious weed control on Council land and monitors noxious weed control on private land to ensure compliance with legislative responsibilities. There are many weeds which are not listed as noxious which have a large impact on riparian and other land within the catchment. Effective weed control requires large amounts of resources and funds to be allocated for many years for a significant impact to be made. Weed encroachment is an ongoing issue affecting many values and it is recommended that funding be allocated to an ongoing targeted weed control program either for the catchment or as part of an LGA – wide Council program. Weed control programs should be undertaken for public reserves and assets such as the Swamp Road Cycleway, Minnamurra Headland, Trevethan Reserve and public land in Jamberoo as well as sites identified in the catchment assessment for this CZMP. It is recommended that KMC continue to apply for funding to assist with weed control in priority areas, and allocate internal staff resources where available to target these priority sites.

Fish Habitat and Migration

The decommissioning of Jerrara Dam and installation of a fishway will provide connectivity between habitats upstream and downstream of the dam allowing migration of fish through the area. This presents an opportunity to investigate the potential for fish habitat and migration improvements within the Minnamurra River catchment. It is recommended that a prioritisation study is undertaken as part of, or subsequent to the Dam decommissioning to identify stream and riparian locations that require improvement in fish habitat as well as identifying other in-stream barriers.

8.5 Strategy 5 – Recreational Facilities

8.5.1 Existing Approach

KMC has been progressively upgrading recreational facilities (e.g. shared path and fishing jetty at Trevethan Reserve) in the Estuary as funding permits. Future facilities will include a whale watching platform and picnic settings at Minnamurra Headland.

RMS representatives patrol, monitor and assess the navigable channel in the Minnamurra River when resources permit. RMS manages the placement of navigation aids (buoys, markers, etc.) and waterway mapping to assist the boating public. A four knot speed restriction zone is in place in the Minnamurra River. The Boating Handbook also defines other regulations such as distance from swimmers (10 knot speed limit when swimmers are within 60 m). RMS also conducts land-based boating education campaigns at boat ramps, schools and boating retailers.

Regulatory and information signs are in place at boat ramps and along the foreshore including dog management, navigation warnings, boating and fishing regulations.

8.5.2 Recommended Future Management Approach

Boat ramps and associated infrastructure

There is insufficient parking for boat trailers and cars at James Oates Reserve during peak periods (weekends and holidays). Additional car parking facilities could be provided between the entrance road and tennis courts (Figure 59). An upgrade to this area could include additional facilities such as rubbish bins, fish cleaning tables, wash down areas, toilets/showers and information/regulatory signage.

Figure 59: Potential area for additional car parking at James Oates Reserve

Monitoring of the adequacy of current rubbish collection facilities in reserves along the Minnamurra River will continue to be important given the large numbers of tourists visiting the area in peak season.

Boating speed and conflict with passive recreational uses is a key concern for the lower estuary. Regional actions such as current RMS boating programs and Transport for NSW initiatives are considered to be the appropriate mechanism to address this. Additional signage at key boat ramps (such as James Oates Reserve) would also assist with boating education. Given the RMS resource constraints, reserve signage could include a hotline phone number to report boating issues. RMS has introduced integrated signs that contain information specific to each site and can be modified to suit local circumstances (Figure 60).

Figure 60: RMS integrated boating signage

Dog Control

Dog access to the foreshores and waterway is also a key concern for the Estuary. Improved (easier to understand) and more frequent signage is required in association with Council education programs. The on-leash swimming area trial at Trevethan Reserve runs until end February 2015. At the completion of this trial, Council should determine the need for dog swimming areas in the Estuary (dogs are permitted off-leash at Bombo, Jones and Werri beaches) and conclude the trial with a resident and tourist education program (potentially in association with Killalea State Park) highlighting the importance of protection of water quality, native fauna and estuarine vegetation.

Passive Craft

Feedback from the community identified the desire for a non-motorised craft launching area, away from existing motor boat launching facilities. This would help to reduce conflict between the different craft users. The basic facility requirements include a clear track and gently sloping access point with adequate parking areas. One community suggestion was to use Duguid Way, Kiama Downs to access the Estuary at the second meander bend of the river. This area is part of the land acquired by Council for environmental protection as a wetland buffer zone (zoned E2 Environmental Conservation) and hence any development of an access path would need to be consistent with planning provisions for the area. Under the KMC LEP 2011, recreation areas are permitted with consent. Waterway access in this area is constrained by mudflats and formalised launch facilities may be required. Proprietary kayak docks and launching facilities are available but additional investigation, design and approvals is required to determine the appropriate facilities and location for the launching area.

Foreshore Access

Currently pedestrian access along the Estuary is available through Minnamurra and Kiama Downs connecting to the Swamp Road Cycleway but pedestrians cannot access the foreshore through the Minnamurra Bends. Members of the community have requested consideration of a boardwalk or similar foreshore access through the Minnamurra Bends and Council has undertaken preliminary investigations and established a budget cost estimate of between $1.1 million and $1.4 million for the boardwalk. This has been identified and adopted by Council in its *Strategic Footpath Asset Plan 2012-2022* subject to available funding and further investigation.

Waterway Asset Management

As part of Council's asset management planning, it is recommended that a strategic and progressive review of the Council's plans of management for Minnamurra River foreshore reserves is undertaken, with a view to creation of an overall master plan for the public reserves along Minnamurra River. The review should address the needs and desires of both the permanent residents of Minnamurra and the many visitors and holidaymakers to the region. It should also include identification of the works required to maintain, upgrade and replace existing facilities as required for an efficient network of assets as well as looking at what additional facilities may be required to cater for the public use of this and other municipal waterways and reserves.

Due to the seasonal nature of the use of many of the facilities, the required level of service can be difficult to quantify. It is recommended that peak demand during 'shoulder season' be satisfied to ensure the greatest benefit for the overall community without spending large amounts upgrading facilities that will reach capacity on only a few occasions during the year. Considerations will include:

- The need for safety improvements at the location;
- The community desire for the facility;
- The capacity of the existing facility;
- The usage of each facility;
- Upgrade and maintenance requirements to achieve the desired levels of service; and
- The ability to gain additional funding for the works.

8.6 Strategy 6 – Floodplain Management

8.6.1 Existing Approach

Council plans to undertake a floodplain management study for the Minnamurra River under the NSW Floodplain Management Program administered by OEH. The Program provides financial support to councils and eligible public land managers to:

- Make informed decisions on managing flood risk by preparing floodplain risk management plans (and associated background studies) under the floodplain risk management process;
- Implement floodplain risk management plans to reduce flood risk to both existing and future development, and reduce losses through a range of property, flood and response modification measures as outlined in the manual; and
- Provide essential information to the State Emergency Service to enable the effective preparation and implementation of local flood plans to deal with flood emergency response.

8.6.2 Recommended Future Management Approach

Further work is required to fully understand the inundation risk for the floodplain and there is a need to determine factors such as the frequency, duration and depth of flooding. The floodplain management plan needs to provide an assessment of flooding risk and associated data to enable a strategic assessment of management options including emergency management, structural solutions and planning measures.

It is recommended that information is provided to improve understanding of likely inundation frequency, duration and depth of inundation from coastal processes as well as catchment flooding. This study should include an assessment of the risk of ocean water intrusion via the stormwater system and consider the

implications of catchment flooding, extreme ocean level events and the influence of wave setup at the entrance to the Minnamurra River Estuary.

As discussed in Section 6.15, projected sea level rise is likely to result in saline intrusion further inland, as tides push further upstream. The Terragong Swamp provides a number of agricultural opportunities for local farmers and is considered to be some of the most productive land in the municipality supporting cropping, beef and dairy production. Maintaining this area as productive land will not necessarily be in conflict with improving estuary health outcomes, however there is the likelihood that some productive land will become unviable due to saline intrusion. The following options for management are recommended for consideration:

- Do nothing – agricultural land is gradually modified as saltwater intrudes upstream and may not be suitable for certain uses (pasture grasses may die-off, water not suitable for irrigation or stock watering, etc.);
- Artificial intervention with the aim of preventing saline intrusion further upstream i.e. installation of flood gates – this comes with a range of management implications (water quality, flooding, ASS issues, fish passage issues, etc.) as well as the need for ongoing integrated management and monitoring to ensure proper flood mitigation function and to minimise water quality and other environmental impacts. There are many examples where this has been implemented in similar catchments, with significant ongoing issues (e.g. Richmond River, Clarence River, etc.); and
- Buy back or form landholder agreements for agricultural land in low-lying areas likely to be affected by saltwater intrusion. Management of this land may be passive (e.g. allowing for natural processes and colonisation in response to sea level rise) or active by implementing rehabilitation of riparian zones and/or wetlands, filling drains and restore more natural floodplain elevations to return to natural floodplain swamp - or a combination of management. This approach may include potential rezoning, buffer zones, extension of SEPP 14 wetlands areas etc. This option could solve a number of identified issues including:
    - Removal of barriers to vegetation community migration (e.g. SEPP14 wetland/Swamp Oak Forest EEC, mangrove/saltmarsh) in response to sea level rise (refer Section 6.15.3);
    - Improve water quality outcomes by reducing pollutant sources (stock, dairying, other agricultural sources);
    - Reduce flooding impacts by return to a more natural hydrology (e.g. backswamps/wetlands areas that retain floodwaters and allow for nutrient uptake, sediment deposition etc.) and slow release of flood water to the Estuary; and
    - Habitat creation and extending existing wetland areas which have been identified as regionally significant.

    However there will be a number of challenges to overcome if this approach is taken including cost implications and the willingness of landholders to participate in such a scheme.

9. THE MANAGEMENT PLAN

9.1 Management Actions

The recommended actions are described in Table 15. Actions consist of a combination of studies, investigations and on-ground works. Some actions require additional design or assessment prior to implementation of on-ground works.

The recommended management actions have been described in terms of:

- Action description – an outline of the scope of works required; and
- Priority – based on the assessed risk to estuary health or community uses, cost, environmental impact and community preferences, each action has been assigned a priority (high, medium or low) or is an ongoing project;
- Responsibility – responsibilities for implementation of the management strategies have been assigned to the relevant land manager. In addition, support from various other local government and non-government organisations and groups including industry bodies, Aboriginal groups, private landholders and community groups will be essential in the implementation of the plan to assist in implementation of the action, either through their regulatory role or land management function or as a potential funding, human resource or information source;
- Cost Estimate – a broad estimate of costs for implementation over the 10 year life of the plan is provided. Cost estimates provided in the action descriptions are preliminary only and based on the best available information;
- Potential Funding – the CZMP strategies are expected to be funded through Council and State government contributions, monetary grants and in-kind contributions. However, the availability of Council resources, particularly funding for new assets, will depend on existing budget commitments and work programs.

  Identification of grants and successful application is an important component of this CZMP. A summary of potentially relevant and available grant schemes is given in Appendix 8. It is important to note that many grants and funding sources are only available up to a limited budget and as such, the available grants are changing from year to year. It will be necessary to keep abreast of current funding availability throughout the implementation of the CZMP. In most cases it is expected that in-kind contributions will be provided by Council.

  Where actions are implemented through a concurrent program, additional expenditure and funding have not been included. Where a study/review is required to determine the appropriate level of expenditure, the cost of the review has been estimated in the action planning. Implementation costs should be confirmed by the results of the review; and
- Timing – based on the priorities developed in this CZMP, timeframes for management actions have been developed for a ten year period. This CZMP and the progress of the management actions should be reviewed to ensure the actions remain relevant and the implementation of the plan is being achieved.

Table 15: 2015 CZMP Management Actions

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
Strategy 1: Administration and Delivery of Management Actions							
1.1	Establish CZMP Implementation Committee	High	KMC	OEH, SCC, Fisheries NSW, South East LLS	Staff costs only	N/A	Short term
1.2	Establish estuary health officer position hosted within local government for implementation of Minnamurra River and other CZMP's (local and Illawarra)	High	KMC	OEH, South East LLS	$85,000 p.a.	KMC, NSW Estuary Management Program, State and Federal funding through LLS	Short term
Strategy 2: Water Quality Management							
2.1	Continue implementation of current water quality monitoring program as part of MER program and review of results. Program to be undertaken in 2014/15 summer and repeated every 3 years.	High	OEH	KMC	Included in existing program	NSW Estuary Management Program	Ongoing
2.2	Design and implement a monitoring program to assist in identification of potential pollution sources. Considerations for design of the program are discussed in Section 8.2.2.	Medium	KMC	OEH	$5,000 for design and $12,000 p.a (Note 4)	KMC, NSW Estuary Management Program	Ongoing
2.3	Undertake priority water quality investigations in accordance with the research priorities identified in Section 8.1.2 including Jamberoo, Gainsborough stormwater ponds and Rocklow Creek.	Medium	KMC	OEH	$5,000 every second year (allowance for priority studies)	KMC, NSW Estuary Management Program, University of Wollongong	Ongoing
2.4	Develop Urban Stormwater Asset Management Plan including a review of existing stormwater treatment systems and the need for scour protection to reduce erosion (Note 3).	High	KMC	-	Included in existing Council program	N/A	Short term

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
2.5	Continue monitoring in accordance with licence conditions at Dunmore Depot including monitoring of total ammonia in ground and surface water.	High	SCC	EPA	Included in existing Council program	N/A	Ongoing
2.6	Continue monitoring in accordance with licence conditions at Minnamurra Depot including development of remedial actions to treat contaminated groundwater.	High	KMC	EPA	Included in existing Council program	N/A	Ongoing
2.7	Assessment of future sea level rise impacts on Minnamurra Depot site and the effects on estuary health.	Medium	KMC	OEH, EPA	$30,000	KMC	Medium term
2.8	Assessment of future sea level rise impacts on Dunmore Depot site and the effects on estuary health.	Medium	SCC	OEH, EPA	$30,000	SCC	Medium term
2.9	Agricultural extension services and assistance provided to landholders (management of dairy effluent, stock exclusion fencing, nutrient budgeting and soil management, protection of the riparian zone, weed management and vegetative stabilisation including re-establishment of previously cleared riparian corridors, the use of shelter belts for habitat corridor linkages, formalised stream crossings and off-stream stock watering).	High	South East LLS	KMC, Illawarra Landcare, Crown Lands	$25,000 p.a.	State and Federal funding programs through LLS, private landholders, DPI Habitat Action Program	Ongoing
2.10	Removal of gross pollutants from river including litter, feed bales, silage wrap and chemical drums.	Medium	KMC	-	$5,000 every 3 years	Community groups (Clean Up Australia Day), OEH Environmental Restoration and Rehabilitation Grants	Ongoing
2.11	Liaise with Southern Councils Group to provide ongoing resources for the silage wrap and baling twine recycling program including the provision of collection bags and related education programs.	High	KMC	Southern Councils Group	Included in existing program	Southern Councils Group	Ongoing

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
Strategy 3: Control of Bank Erosion							
3.1	Complete the bank erosion assessment for the entire catchment and monitor extent and severity of bank erosion every 3 years to identify priority areas (all tributaries).	Ongoing	KMC	OEH, SCC	$10,000 initially and $5,000 every 3 years	KMC	Ongoing
3.2	Stabilise banks along Minnamurra Headland (Site 1) with low-growing native species.	Medium	KMC	OEH, Conservation Volunteers Australia	$500	KMC, Conservation Volunteers Australia	Medium term
3.3	Stabilise banks along James Oates Reserve (Site 2) with low-growing native species.	Medium	KMC	OEH, Conservation Volunteers Australia	$1,000	KMC, Conservation Volunteers Australia	Medium term
3.4	Stabilise banks above Charles Avenue foreshore rock walls (re-contour and revegetate with suitable species)	Medium	KMC	OEH, Conservation Volunteers Australia	Included in Action 4.4	KMC, Conservation Volunteers Australia	Medium term
3.5	Remove existing rocks and reconstruct rock revetment with appropriate batter slope (Site 1 – Minnamurra Headland). Obtain approvals for maintenance along foreshore areas (refer Action 4.1).	High	KMC	OEH, Conservation Volunteers Australia	$5,000	KMC	Short term
3.6	Trial mangrove plantings, toe protection and bank revegetation (Site 10)	Medium	KMC	OEH, Conservation Volunteers Australia	$20,000	KMC, NSW Estuary Management Program	Short term

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
3.7	Work with landowners to install livestock exclusion fencing, revegetate buffer zone and install off-stream watering similar to Demonstration Reach Toolbox approach (e.g. Sites 15, 16, 17, 18, 20, 21).	Medium	Terragong Drainage Union, private landholders	South East LLS	Included in Action 2.10	State and Federal funding programs through LLS, private landholders, Landcare, DPI Habitat Action Program	Short term
3.8	Obtain approval to remove fallen tree and relocate to bank with anchoring (Site 16) in association with riparian re-vegetation and stock exclusion. Where possible, maintain aquatic habitat.	High	Terragong Drainage Union, private landholders	South East LLS, Crown Lands	$5,000	State and Federal funding programs through LLS, private landholders	Short term
3.9	Maintain and repair rock revetment where required for public safety or erosion control (e.g. Minnamurra Headland, Charles Avenue foreshore, Riverside Drive rock wall and Hyams Creek bridge). Obtain approvals for maintenance along foreshore areas (refer Action 4.1).	High	KMC	-	$10,000 initially and $5,000 every five years	KMC	Ongoing
3.10	Vegetation survey of Terragong Drain banks. Progressive removal of weed species.	High	Terragong Drainage Union, private landholders	South East LLS, Crown Lands	$5,000 initially and $5,000 every five years	State and Federal funding programs through LLS, private landholders	Ongoing
3.11	Hydrographic survey of Terragong Swamp for comparison with hydrographic survey completed in 1992 by NSW Public Works to assess change over time. This may be undertaken in parallel with any hydrographic survey undertaken for the KMC flood study.	Medium	OEH	KMC, Crown Lands, Terragong Drainage Union	$5,000 every 5 years (or in response to a major flood)	NSW Estuary Management Program	Ongoing

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
Strategy 4: Protection of Estuarine and Foreshore Habitat							
4.1	Liaise with Fisheries NSW to negotiate a permit for foreshore maintenance works.	High	KMC	Fisheries NSW	Staff costs only	N/A	Short term
4.2	Undertake a consultation program with the local community and key stakeholders including development of options for management of mangrove encroachment along foreshores and education regarding the importance of estuarine vegetation.	High	KMC	Fisheries NSW, CZMP Implementation Committee	Staff costs only	N/A	Short term
4.3	Assessment of trends in seagrass extent, distribution (including repeat mapping) and health, investigation of causes of seagrass decline.	High	Fisheries NSW	OEH, KMC	$15,000	DPI Habitat Action Program, University of Wollongong	Medium term
4.4	Revegetate priority riparian areas on public land (Minnamurra Headland, Charles Avenue foreshore and the saltmarsh area adjacent to Cameron Crescent in Gainsborough Estate) – refer Section 6.4.1.	High	KMC	OEH. Fisheries NSW, South East LLS, Conservation Volunteers Australia	$11,000 p.a. (Note 5)	NSW Estuary Management Program, State and Federal funding programs through LLS	Ongoing
4.5	Revegetate priority riparian areas on private land (the second meander bend, Terragong Swamp, mid-Jerrara Creek, the foreshores of the Billabong and the *Casuarina glauca* forest area between Princes Highway and Swamp Road) – refer Section 6.4.1.	High	Private landholders	OEH. Fisheries NSW, South East LLS, Illawarra Landcare	$60,000 p.a. (Note 6)	NSW Estuary Management Program, State and Federal funding programs through LLS	Ongoing
4.6	Identify priority riparian revegetation areas in the mid-upper catchment and tributaries (Note 3).	Medium	KMC	OEH, South East LLS	$5,000	DPI Habitat Action Program, State and Federal funding programs through LLS	Medium term

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
4.7	Implement a weed control/bush restoration program for priority sites in public areas.	High	KMC, SCC	OEH, South East LLS, Conservation Volunteers Australia	$5,000 p.a.	KMC, State and Federal funding programs through LLS, Conservation Volunteers Australia	Ongoing
4.8	Identification and prioritisation of stream and riparian locations needing treatment to improve fish habitat and migration	High	Fisheries NSW	KMC, University of Wollongong	$5,000	DPI Habitat Action Program, University of Wollongong	Short term
4.9	Investigation of management options to allow for migration of estuarine vegetation communities in response to sea level rise (e.g. buy-back of low-lying floodplain areas likely to be affected, establish buffer zones etc.)	Medium	KMC	Fisheries NSW, University of Wollongong	$10,000	DPI Habitat Action Program, University of Wollongong	Medium term
4.10	Geomorphological assessment of mid and upper catchment reaches to document key catchment features and provide background information for erosion risk assessment and identification of weed control and riparian revegetation requirements.	Medium	KMC	OEH	$10,000	OEH Environmental Education Grants, NSW Estuary Management Program	Medium term
Strategy 5: Recreational Facilities							
5.1	Undertake assessment of Minnamurra foreshore reserves visitation and usage to determine future car parking, facility upgrade and signage requirements to cater for increasing demand.	High	KMC	Crown Lands	$25,000	KMC, Transport for NSW, RMS, NSW Trade and Investment – Crown Lands Public Reserves Management Fund, DPI – Recreational Fishing Trust	Short term

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
5.2	Review Minnamurra foreshore reserves plans of management (including results of Action 5.1) and develop a master plan for the Minnamurra River foreshore reserves.	Medium	KMC	Crown Lands	Included in existing Council program	KMC, Transport for NSW, RMS, NSW Trade and Investment – Crown Lands Public Reserves Management Fund, DPI – Recreational Fishing Trust	Short-medium term
5.3	Resident and tourist education program highlighting the importance of protection of water quality, native fauna, fish habitat and estuarine vegetation. Include dog control, safe boating and review of signage needs.	High	KMC	SCC, Killalea State Trust, OEH	$3,000	OEH Environmental Education Grants, NSW Estuary Management Program	Short term
5.4	Investigation and assessment of a suitable site for kayak launching facilities with consideration of impacts of disturbance on fish habitat, estuarine and riparian vegetation.	Low	KMC	Fisheries NSW, RMS	$20,000	DPI – Recreational Fishing Trust, RMS	Long-term
Strategy 6: Floodplain Management							
6.1	Develop flood studies and floodplain management plan for the Minnamurra River with consideration of information provided in this CZMP.	High	KMC	OEH	Included in existing Council program	KMC, OEH Floodplain Management Program	Short term
6.2	Investigate strategies for management of saline intrusion further inland with future sea level rise.	Medium	KMC	OEH	$10,000	KMC, OEH Floodplain Management Program	Medium term
Monitoring and Review Actions							
7.1	Review of CZMP progress: Review and document the implementation progress and effectiveness of the proposed actions as part of Council's annual State of the Environment Reporting	High	KMC	CZMP Implementation Committee	Included in existing Council reporting	-	Annual

Action		Priority	Responsible Body	Support Agencies	Cost (Note 1)	Potential Funding (Note 2)	Timing
7.2	Ten year review of CZMP: The CZMP and the specified management actions will be reviewed to ensure they are being achieved and are resulting in the desired outcomes. A ten year review (or earlier if warranted by legislative or management changes or improved scientific understanding) of the CZMP will consider: • Results of the annual reviews (Action 6.1); • Any barriers identified to the effective implementation of actions or overall success of actions; • Any new or updated scientific knowledge; • Data provided by the data collection and monitoring actions (Actions 1.6, 2.6, 3.7, 4.1, 4.2); and • Prevailing community attitudes, government policy, strategic planning and estuary management issues.	High	KMC, OEH	CZMP Implementation Committee	$70,000	OEH Coastal or Estuary Management Program, KMC	Year 10
7.3	Investigation of the impact on estuary health due to potential land use changes for consideration in the 5 yearly LEP review	Medium	KMC, SCC	CZMP Implementation Committee	$10,000 every 5 years	OEH Coastal or Estuary Management Program, KMC, SCC	Ongoing

Notes:

1. Some actions are considered to be included in existing Council staff responsibilities or covered by current funded programs. Additional funds are not required.

2. Refer Appendix 8 for potential grant funding.

3. Capital expenditure for installation of new devices, ongoing asset maintenance and renewal and riparian restoration has not been included.

4. Water quality program cost assumes ongoing bi-monthly sampling (6 times per year) and 3 event samples at 7 sites per year. Lab analysis costs are based on Chlorophyll a, TN, TP at all sites and bacteriological analysis (*Enterococci*) at lower estuary site only. Physico-chemical parameters assumed to be sampled with hand-held probe at hire rate of $100/day. Staff sampling costs estimated as $100/hr allowing 2 hrs for each sampling event. Regular updates of water quality database (1/2 hr each sample) and annual reporting (16 hrs) also allowed for in cost. External costs can be reduced where Council staff resources are available. Additional sites and/or water quality parameters as determined through design of program will increase costs.

5. Riparian revegetation on public land assumes revegetation and follow-up weed control for 3 years at $30,000 per ha.

6. Riparian revegetation on private land assumes stock exclusion, revegetation for 20m buffer zone and follow-up weed control for 3 years at $50,000 per ha.

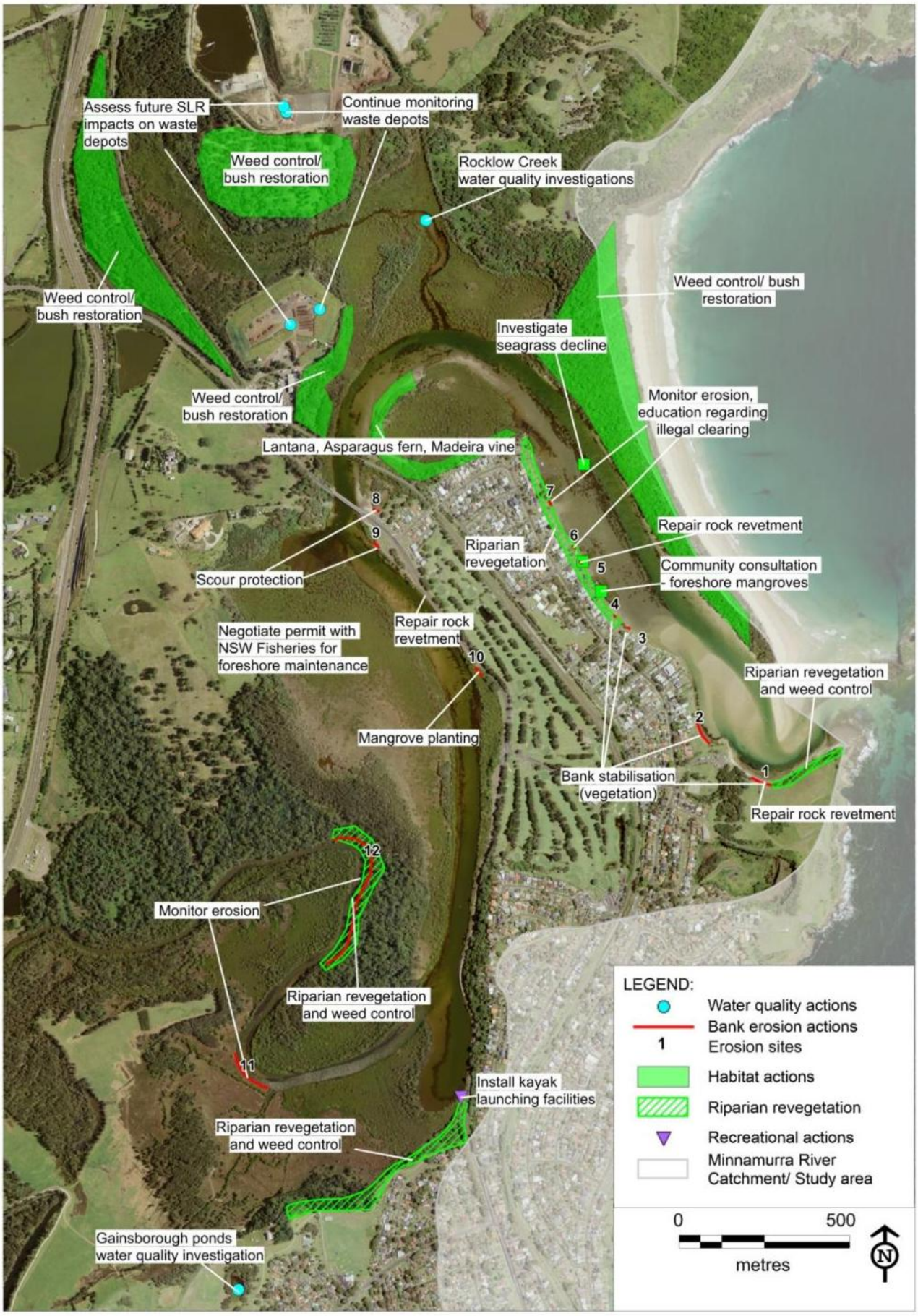


Figure 61: CZMP Management Actions – Lower-Mid Estuary

Note – Site 5 rock revetment has been repaired

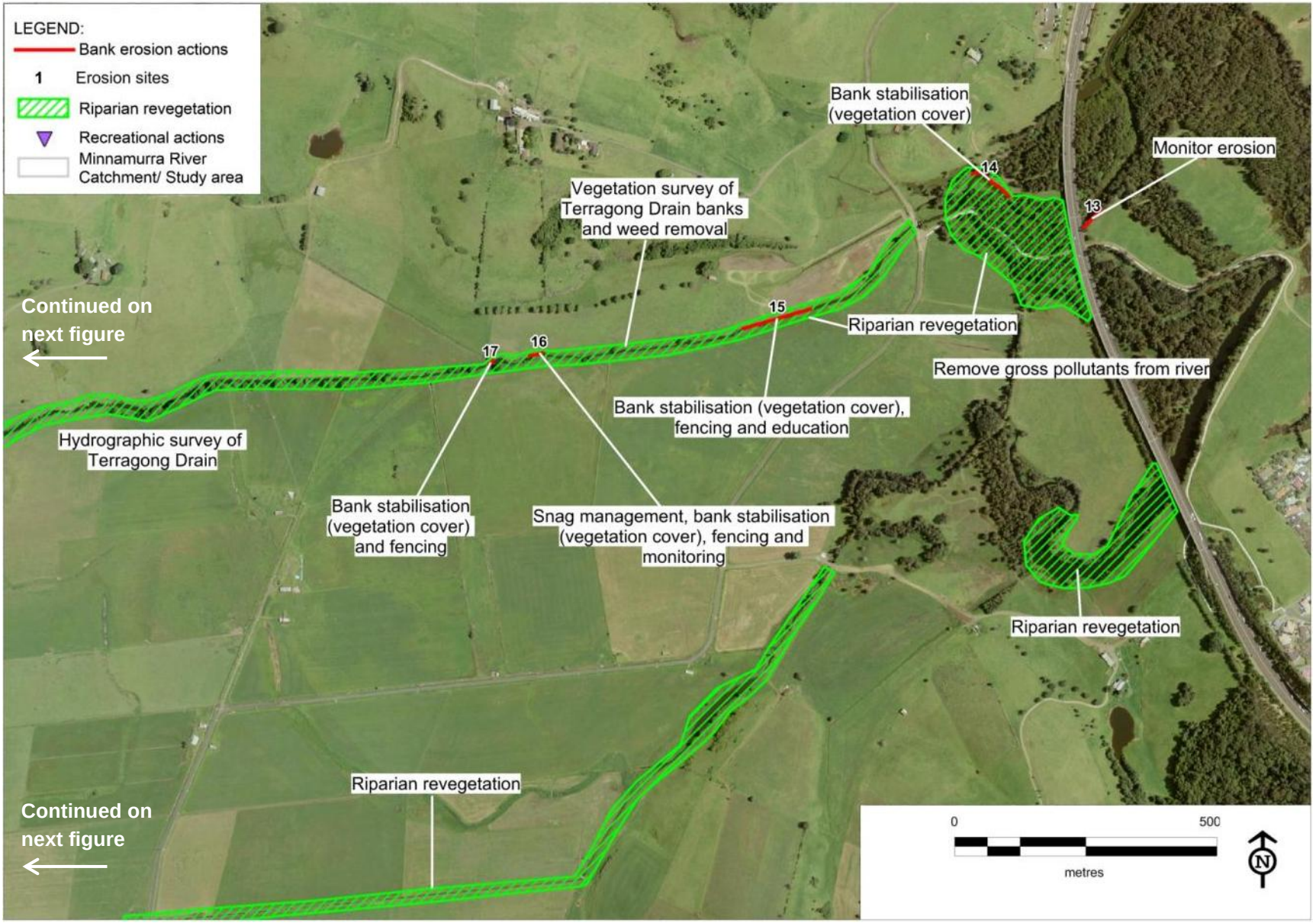


Figure 62: CZMP Management Actions – Upper Estuary and Terragong Swamp

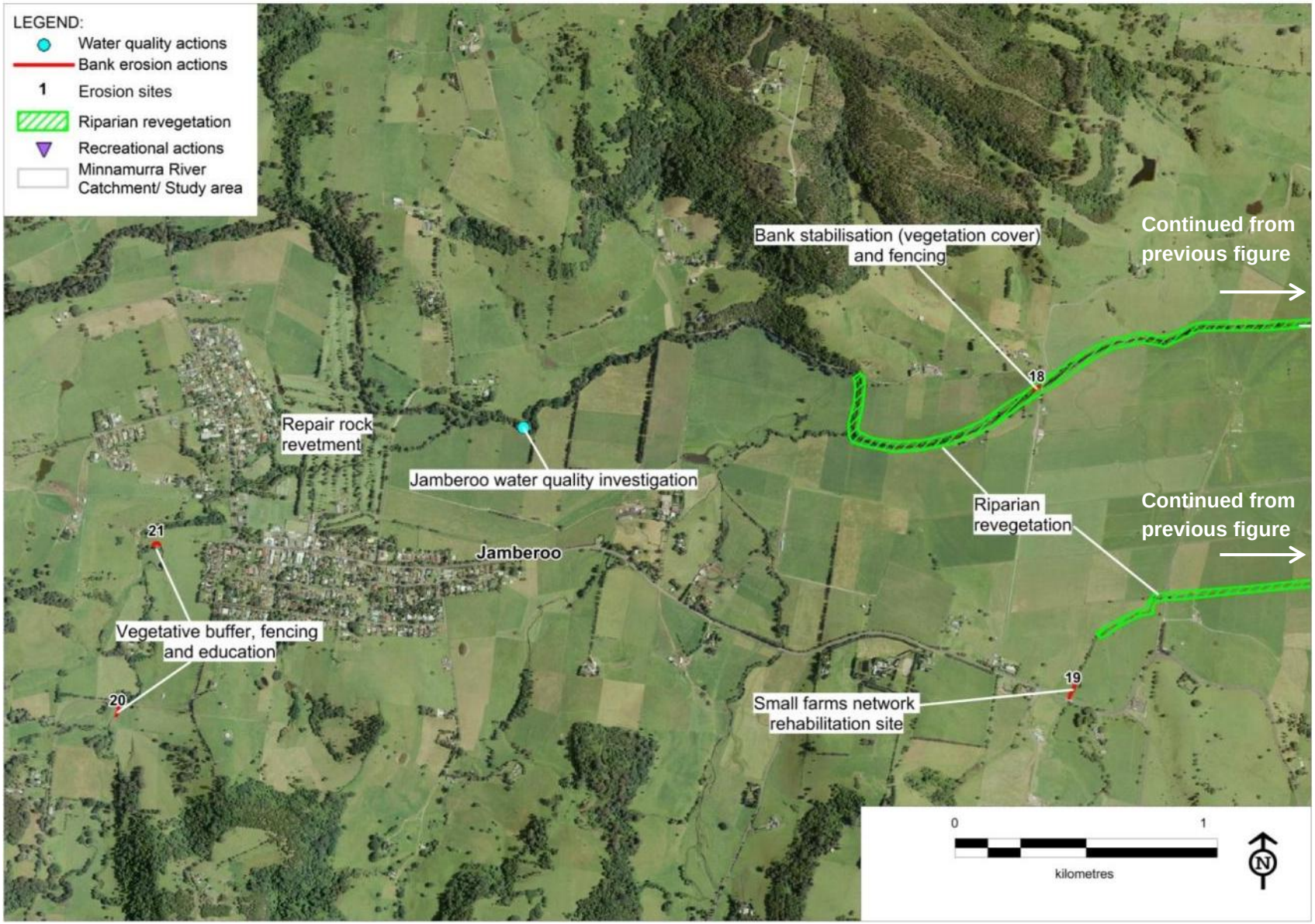


Figure 63: CZMP Management Actions – Jamberoo

9.2 Implementation Program

The implementation process will be based upon collaboration and a shared partnership approach and requires commitment from Council, other government and other non-government agencies, the agricultural sector and private landowners located within the catchment area. The involvement of and partnership with the South East LLS and research institutions is essential in order to protect primary industries, the local economy and the environment of the Minnamurra River catchment for the benefit of present and future generations.

The establishment of the CZMP Implementation Committee will result in a coordinated and holistic approach in the delivery of and evaluation of the various management actions. The establishment of an Estuary Health Officer position is considered paramount to provide the required resources and to ensure the efficient and effective coordination, implementation and evaluation of the annual priority management actions that have been identified by the various stakeholders. The position will also strengthen collaboration between the stakeholders and assist with securing grant and other funding for the various actions. Joint funding for this position between Council and other State agencies is recommended.

The recommended management actions have been compiled into a ten year implementation schedule as shown in Table 16 with responsibilities and indicative costs estimated over the ten year implementation period. The total cost of the CZMP implementation is estimated to be approximately $2.6 million over ten years. The actions will be delivered through a combination of Council and State government funding (where available) and the delivery of the actions may be influenced by the availability of this funding as well as human resources.

Table 16: CZMP Implementation Program

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Strategy 1: Administration and Delivery of Management Actions													
1.1	Establish CZMP Implementation Committee	KMC	-	Note 2									
1.2	Establish estuary health officer position hosted within local government for implementation of Minnamurra River and other CZMP's (local and Illawarra)	KMC	**850,000**	85,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000
Strategy 2: Water Quality Management													
2.1	Continue implementation of current water quality monitoring program as part of MER program.	OEH	-			Note 2			Note 2			Note 2	
2.2	Design and implement an ongoing monitoring program to assist in identification of potential pollution sources	KMC	**125,000**	17,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
2.3	Undertake priority water quality investigations in accordance with the research priorities identified in this CZMP	KMC	**25,000**	5,000		5,000		5,000		5,000		5,000	
2.4	Develop Urban Stormwater Asset Management Plan (Note 3)	KMC	-	Note 2									
2.5	Continue monitoring in accordance with licence conditions at the Dunmore Depot including monitoring of total ammonia in ground and surface water.	SCC	-	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2
2.6	Continue monitoring in accordance with licence conditions at Minnamurra Depot including development of remedial actions to treat contaminated groundwater.	KMC	-	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2.7	Assessment of future sea level rise impacts on the Minnamurra Depot Site.	KMC	**30,000**						30,000				
2.8	Assessment of future sea level rise impacts on the Dunmore Depot Site.	SCC	**30,000**						30,000				
2.9	Agricultural extensions services and assistance provided to landholders.	South East LLS	**250,000**	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
2.10	Removal of gross pollutants from river including litter, feed bales, silage wrap and chemical drums.	KMC	**20,000**	5,000			5,000			5,000			5,000
2.11	Liaise with Southern Councils Group to provide ongoing resources for the silage wrap and baling twine recycling program including the provision of collection bags and related education programs.	KMC	**-**	Note 2	Note 2								
Strategy 3: Control of Bank Erosion													
3.1	Complete the bank erosion assessment for the entire catchment and monitor extent and severity of bank erosion every 3 years to identify priority areas (all tributaries).	KMC	**25,000**	10,000			5,000			5,000			5,000
3.2	Stabilise banks along Minnamurra Headland (Site 1) with low-growing native species.	KMC	**500**	500									
3.3	Stabilise banks along James Oates Reserve (Site 2) with low-growing native species.	KMC	**1,000**	1,000									
3.4	Stabilise banks above Charles Avenue foreshore rock walls (re-contour and revegetate with suitable species)	KMC	**-**	Included in Action 4.4									

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
3.5	Remove existing rocks and reconstruct rock revetment with appropriate batter slope (Site 1 – Minnamurra Headland).	KMC	**5,000**	5,000									
3.6	Trial mangrove plantings, toe protection and bank revegetation (Site 9)	KMC	**20,000**		10,000	10,000							
3.7	Work with landowners to install livestock exclusion fencing, revegetate buffer zone and install off-stream watering similar to Demonstration Reach Toolbox approach (e.g. Sites 14, 15, 16, 17, 18, 20, 21).	Terragong Drainage Union, private landholders	**-**	Included in Action 2.10									
3.8	Obtain approval to remove fallen tree and relocate to bank with suitable anchoring (Site 16) in conjunction with riparian revegetation and fencing.	Terragong Drainage Union, private landholders	**5,000**	5,000									
3.9	Maintain and repair rock revetment where required (e.g. Minnamurra Headland, Charles Avenue foreshore, Riverside Drive rock wall and Hyams Creek bridge).	KMC	**15,000**	10,000					5,000				
3.10	Vegetation survey of Terragong Drain banks. Progressive removal of weed species.	Terragong Drainage Union, private landholders	**10,000**	5,000					5,000				
3.11	Hydrographic survey of Terragong Swamp for comparison with hydrographic survey completed in 1992 by NSW Public Works to assess change over time.	OEH	**10,000**			5,000					5,000		
Strategy 4: Protection of Estuarine and Foreshore Vegetation													
4.1	Liaise with Fisheries NSW to negotiate a permit for maintenance works.	KMC	**-**	Note 2									

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
4.2	Undertake a consultation program with the local community and key stakeholders including development of options for management of mangrove encroachment along foreshores and education regarding the importance of estuarine vegetation	KMC	-	Note 2	Note 2								
4.3	Assessment of trends in seagrass extent, distribution (including repeat mapping) and health, investigation of causes of seagrass decline.	Fisheries NSW	**15,000**						15,000				
4.4	Revegetate priority riparian areas on public land (Minnamurra Headland, Charles Avenue foreshore and the saltmarsh area adjacent to Cameron Crescent in Gainsborough Estate).	KMC	**110,000**	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000
4.5	Revegetate priority riparian areas on private land (the second meander bend, Terragong Swamp, mid-Jerrara Creek, the foreshores of the Billabong and the *Casuarina glauca* forest area between Princes Highway and Swamp Road.	Terragong Drainage Union, private landholders	**600,000**	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
4.6	Identify priority riparian revegetation areas in the mid-upper catchment and tributaries (Note 3).	KMC	**5,000**				5,000						
4.7	Implement a weed control/bush restoration program for priority sites in public areas	KMC, SCC	**50,000**	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4.8	Identification and prioritisation of stream and riparian locations needing treatment to improve fish habitat and migration	Fisheries NSW	**5,000**	5,000									

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
4.9	Investigation of management options to allow for migration of estuarine vegetation communities in response to seal level rise.	KMC	**10,000**						10,000				
4.10	Geomorphological assessment of mid and upper catchment reaches.	KMC	**10,000**				10,000						
Strategy 5: Recreational Facilities													
5.1	Undertake assessment of Minnamurra foreshore reserves visitation and usage to determine future car parking, facility upgrade and signage requirements to cater for increasing demand	KMC	**25,000**	25,000									
5.2	Review Minnamurra foreshore reserves plans of management (including results of Action 5.1) and develop a master plan for the Minnamurra River foreshore reserves	KMC	**-**			Note 2	Note 2						
5.3	Resident and tourist education program highlighting the importance of protection of water quality, native fauna, fish habitat and estuarine vegetation. Include dog control, safe boating and review of signage needs.	KMC	**3,000**		3,000								
5.4	Investigation and assessment of a suitable site for kayak launching facilities with consideration of impacts of disturbance on fish habitat, estuarine and riparian vegetation.	KMC	**20,000**									20,000	
Strategy 6: Floodplain Management													
6.1	Develop flood studies and floodplain management plan for the Minnamurra River	KMC	**250,000**						125,000	125,000			

Action / Year (Note 1)		Responsible Body	Ten year total ($'000)	1	2	3	4	5	6	7	8	9	10
				2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
6.2	Investigate strategies for management of saline intrusion further inland with future sea level rise.	KMC	**10,000**							10,000			
Monitoring and Review Actions													
7.1	Annual review of CZMP progress	KMC	**-**	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2
7.2	Ten year review of CZMP	KMC, OEH	**70,000**										70,000
7.3	Investigation of the impact on estuary health due to potential land use changes for consideration in the 5 yearly LEP review	KMC, SCC	**20,000**	10,000					10,000				
Total			**2,624,500**	**289,500**	**211,000**	**218,000**	**223,000**	**203,000**	**428,000**	**348,000**	**203,000**	**223,000**	**278,000**

Notes:
1. Refer Table 15 and Appendix 8 for potential grant funding.
2. Shaded years represent the proposed year of implementation for each action. Some actions are considered to be included in existing Council staff responsibilities or covered by current funded programs. Additional funds are not required.
3. Capital expenditure for installation of new devices, ongoing asset maintenance and renewal and riparian restoration has not been included.
4. Design and assessment is required to confirm budget for construction of new facilities.

9.3 Measures of Success of the CZMP

Success of the CZMP will be indicated by the implementation of substantial measures to address the root cause of issues facing the Estuary, as well as conclusive documentation of the effectiveness of such measures. Success of the CZMP will be gauged by:

- Stakeholder acceptance;
- Adoption of the CZMP by Council;
- Incorporation of the plan recommendations into business planning for the responsible agencies;
- Securing sufficient funds to implement the actions;
- Implementation of actions in an efficient and timely manner;
- Uptake of actions by stakeholders and others;
- Positive stakeholder feedback on improvements; and
- Measured improvements in ecosystem health such as improved water quality.

Ongoing community involvement will be required to ensure successful implementation of the CZMP. This will include:

- Ongoing consultation with interested and committed community groups;
- A high degree of engagement and collaboration with landholders;
- On-ground participation in management actions, particularly local community groups such as Landcare, Conservation Volunteers Australia, Terrgaong Drainage Union and Small Farms Network;
- Consultation and collaboration with local Aboriginal representatives and groups; and
- Education programs.

Achievement of the management plan objectives is reliant on community understanding and effective involvement in the management process.

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GLOSSARY AND ABBREVIATIONS

Acid sulfate soils (ASS)	Acid sulfate soils are the common name given to soils containing iron sulfides. In Australia, the acid sulfate soils of most concern are those which formed within the past 10,000 years, after the last major sea level rise. When the iron sulfides are exposed to air and produce sulfuric acid, they are known as actual acid sulfate soils. The soil itself can neutralise some of the sulfuric acid. The remaining acid moves through the soil, acidifying soil water, groundwater and, eventually, surface waters.
AHD	Australian Height Datum is a geodetic datum for altitude measurement in Australia. According to Geoscience Australia, "In 1971 the mean sea level for 1966-1968 was assigned the value of 0.000m on the Australian Height Datum at thirty tide gauges around the coast of the Australian continent".
Amenity	A desirable or useful feature or facility of a building or place
Anthropogenic	Any phenomenon caused by human activities.
Bacteriological	Related to bacteria (microorganisms involved with infectious diseases and nitrogen fixation)
Capillary fringe	The layer directly above the groundwater table in which water seeps up into soil pores from the groundwater table
Chlorophyll a	The green pigment in plants used to capture and use energy from sunlight to form organic matter (see photosynthesis). Concentrations of chlorophyll a in the water column are used as an indicator for phytoplankton and benthic algae biomass. It provides a useful proxy indicator of the amount of nutrients incorporated into phytoplankton biomass, because phytoplankton have predictable nutrient-to-chlorophyll ratios.
CZMP	Coastal Zone Management Plan
DECCW	Former (NSW) Department of Environment, Climate Change and Water (now OEH)
Diffuse Source Pollution	Non-point source pollution such as sediment or nutrients from catchment runoff or groundwater inputs.
DIG	Dairy Industry Group
DPI	(NSW) Department of Primary Industries
EEC	Endangered Ecological Community
Ecology	The interactions between organisms and their environment
Ecosystem	Refers to all the biological and physical parts of a biological unit (e.g. an estuary, forest, or planet) and their interconnections.
EMP	Estuary Management Plan
EPA	Environment Protection Authority
EPS	Estuary Processes Study
Estuarine	Part of the river channel with a mix of fresh water and salt (tidal) water
Foreshore	That part of the shore that lies between the mean high tide mark and the mean low tide mark
Groundwater	Water underneath the earths surface stored in soil pore space and rock fractures.
Hydrodynamics	The motion of a fluid and interactions with its boundaries
Hydrology	The study of water and its properties, including precipitation onto land and returning to oceans
KMC	Kiama Municipal Council
LALC	Local Aboriginal Land Council
LEP	Local Environmental Plan
LLS	Local Land Services
MER	NSW Natural Resources Monitoring, Evaluation and Reporting Strategy

NH_3	Ammonia
NH_4+	Ammonium (iodised ammonia)
NPWS	National Parks and Wildlife Service
SRCMA	Southern Rivers Catchment Management Authority
OEH	Office of Environment and Heritage
OSSM	On-site Sewerage Management (e.g. septic tanks)
Physico-chemical	Physical properties dependent on and influencing chemical structure, properties and reactions
Point Source Pollution	A single point of pollutant discharge. For example, effluent from a sewage treatment plant.
ppt	parts per thousand (salinity measure)
Reticulated Sewage System	Sewage piped to a centralised sewage treatment plant for treatment and disposal.
Riparian	Of, on or relating to the banks of a watercourse
RMS	NSW Roads and Maritime Services
Salinity	The level of salt dissolved in the water
SCC	Shellharbour City Council
SCG	Southern Councils Group
Sedimentation	The deposition or accumulation of sediment
SEPP	State Environmental Planning Policy
SQIDs	Stormwater Quality Improvement Devices
SRCMA	Southern Rivers Catchment Management Authority
STP	Sewage Treatment Plant. Raw sewage is collected from homes and businesses and transported via a network of pipes and pump stations to the sewage treatment plant, a centralised system for treatment and disposal.
Terrestrial	Living or growing on land (not aquatic)
Turbidity	A measure of the amount of light-attenuating particles in a water body.
Vadose Zone	The area of soil between the earth's surface and the top of the groundwater table.

Appendix 1: Minimum Requirements of the CZMP Guidelines (OEH, 2013a)

Coastal councils are required to prepare draft plans in accordance with the CZMP guidelines adopted by the Minister for the Environment under section 55D of the Coastal Protection Act 1979 (OEH, 2013a). The Guidelines specify the minimum requirements that are to be met when preparing a draft CZMP, in addition to the requirements in the Act. The minimum requirements in the guidelines relate to:

- Preparation of the CZMP;
- Coastal risk management;
- Coastal ecosystem health; and
- Community uses of the coastal zone.

The following tables summarise the minimum requirements and how they have been met in this CZMP and other related planning processes.

Table 17: Minimum Requirements: CZMP planning process content and outcomes

Minimum Requirement	Reference
CZMPs are to contain a description of:	
• how the relevant Coastal Management Principles have been considered in preparing the plan	Table 18 below.
• the community and stakeholder consultation process, the key issues raised and how they have been considered	Section 4 and Appendix 4.
• how the proposed management options were identified, the process followed to evaluate management options, and the outcomes of the process	Section 8
CZMPs are to contain proposed management actions over the CZMP's implementation period in a prioritised implementation schedule which contains:	
• proposed funding arrangements for all actions, including any private sector funding	Section 9.1 and Appendix 6.
• actions to be implemented through other statutory plans and processes	Sections 1.4
• actions to be carried out by a public authority or relating to land or other assets it owns or manages, where the authority has agreed to these actions (section 55C(2) (b) of the Coastal Protection Act 1979).	Section 9
• proposed actions to monitor and report to the community on the plan's implementation, and a review timetable.	Section 9 – Monitoring and Review Actions
CZMPs are to be prepared using a process that includes:	
• evaluating potential management options by considering social, economic and environmental factors, to identify realistic and affordable actions	Section 8
• consulting with the local community and other relevant stakeholders. The minimum consultation requirement is to publicly exhibit a draft plan for not less than 21 days, with notice of the exhibition arrangements included in a local newspaper (section 55E of the Coastal Protection Act 1979)	Section 4 and Appendix 4
• considering all submissions made during the consultation period. The draft plan may be amended as a result of these submissions (section 55F of the Coastal Protection Act 1979).	Section 4
CZMPs are to achieve a reasonable balance between any potentially conflicting uses of the coastal zone.	Section 9.

Coastal Management Principles have been developed to inform strategic considerations in coastal management, including the preparation of CZMPs. The Principles have been considered in the evaluation of the coastal management actions documented in this CZMP as discussed below.

Table 18: Coastal Management Principles addressed by the CZMP for the Minnamurra River Estuary

Principle		Reference
1	Consider the objects of the Coastal Protection Act 1979 and the goals, objectives and principles of the NSW Coastal Policy 1997	Section 1.2
2	Optimise links between plans relating to the management of the coastal zone	Sections 1.4
3	Involve the community in decision-making and make coastal information publicly available	Section 4 and Appendix 4
4	Base decisions on the best available information and reasonable practice; acknowledge the interrelationship between catchment, estuarine and coastal processes; adopt a continuous improvement management approach	This CZMP
5	The priority for public expenditure is public benefit; public expenditure should cost-effectively achieve the best practical long-term outcomes	Sections 9
6	Adopt a risk management approach to managing risks to public safety and assets; adopt a risk management hierarchy involving avoiding risks where feasible and mitigation where risks cannot be reasonably avoided; adopt interim actions to manage high risks while long-term options are implemented	Sections 1.3, 8 and 9
7	Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty in risk predictions	Sections 1.3, 8 and 9
8	Maintain the condition of high value coastal ecosystems; rehabilitate priority degraded coastal ecosystems	Section 8
9	Maintain and improve safe public access to beaches and headlands consistent with the goals of the NSW Coastal Policy	Section 8.5
10	Support recreational activities consistent with the goals of the NSW Coastal Policy	Section 8.5

Table 19: Minimum Requirements for Coastal Risks (OEH, 2013a)

Minimum Requirement	Reference
A CZMP which addresses coastal risks should include:	
A description of: • coastal processes within the plan's area, to a level of detail sufficient to inform decision-making • the nature and extent of risks to public safety and built assets from coastal hazards • projected climate change impacts on risks from coastal hazards (section 55C(f) of the Coastal Protection Act 1979). based on council's adopted sea level rise projections or range of projections. Councils should consider adopting projections that are widely accepted by competent scientific opinion • suitable locations where landowners could construct coastal protection works (provided they pay for the maintenance of the works and manage any offsite impacts), subject to the requirements of the Environmental Planning and Assessment Act 1979, and • property risk and response categories for all properties located in coastal hazard areas	Coastal Risk Management components will be addressed in Council's shire-wide CZMP and Minnamurra River flood study
Proposed actions in the implementation schedule to manage current and projected future risks from coastal hazards, including risks in an estuary from coastal hazards. Actions are to focus on managing the highest risks (section 55C(d) and (e) of the *Coastal Protection Act 1979*)	
Where the plan proposes the construction of coastal protection works (other than emergency coastal protection works) that are to be funded by the council or a private landowner or both, the proposed arrangements for the adequate maintenance of the works and for managing associated impacts of such works (section 55C(g) of the *Coastal Protection Act 1979*)	
An emergency action subplan, which is to describe: • intended emergency actions to be carried out during periods of beach erosion such as coastal protection works for property or asset protection, other than matters dealt with in any plan made under the State Emergency and Rescue Management Act 1989 relating to emergency response (sections 55C(b) and (g) of the Coastal Protection Act 1979) • any site-specific requirements for landowner emergency coastal protection works, and • the consultation carried out with the owners of land affected by a subplan.	

Table 20: Minimum Requirements for Coastal Ecosystems (OEH, 2013a)

Minimum Requirement	Reference
A CZMP which addresses coastal ecosystem management is to include:	
A description of: • the health status of estuaries within the plan's area • the pressures affecting estuary health status and their relative magnitude • projected climate change impacts on estuary health (section 55C(f) of the *Coastal Protection Act 1979*), based on council's adopted sea level rise projections or range of projections.	Section 6

Minimum Requirement	Reference
Proposed actions in the implementation schedule to respond to estuary health pressures (section 55C(e) of the *Coastal Protection Act 1979*)	Sections 8.1, 8.2, 8.3 and 8.4
An entrance management policy for intermittently closed and open lakes and lagoons (ICOLLs)	No ICOLLS in Minnamurra River Estuary
An estuarine monitoring program, consistent with the NSW Natural Resources Monitoring, Evaluation and Reporting (MER) Strategy.	Section 8.2

Table 21: Minimum Requirements for Community Uses (OEH, 2013a)

Minimum Requirement	Reference
CZMPs are to contain:	
Proposed actions in the implementation schedule that protect and preserve beach environments and beach amenity, and ensure continuing and undiminished public access to beaches, headlands and waterways, particularly where public access is threatened or affected by accretion (section 55C(c) of the *Coastal Protection Act 1979*)	Sections 8.1, 8.2, 8.3, 8.4 and 8.5
A description of: • the current access arrangements to beaches, headlands and waterways in the plan's area, their adequacy and any associated environmental impacts, • any potential impacts (e.g. erosion, accretion or inundation) on these access arrangements, and • the cultural and heritage significance of the plan's area.	Section 7
Proposed actions in the implementation schedule to manage any environmental or safety impacts from current access arrangements, and to protect or promote the culture and heritage environment	Section 8

Appendix 2: Status of 1995 Estuary Management Plan and 2003 EMP Review management actions

A summary of the status of actions from the existing Plan is given in this Appendix. Actions that have been undertaken are also displayed on Figure 6, page 12.

Table 22: Review of Actions from 2003 EMP Review

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
Riverbank erosion and sedimentation					
1	Continue with stabilisation plan for Charles Avenue shoreline.	KMC	High	Timber groynes and rock revetment have been installed along the foreshore (Figure 6A, Figure 68 – Site 3, 4, 6).	Some areas of bank erosion exist at the ends of the revetments. Some rocks have been displaced. The effectiveness of the timber groynes appears to be minimal in trapping sand and settling mangrove seedlings. The timber groynes are now used for boat moorings.
2	Stabilise active erosion at Princes Highway.	RMS	High	Erosion along Riverside Drive (old Princes Highway) was stabilised with rock revetment (Figure 6B).	Some rocks have been displaced, placing structure at risk of failure.
3	Put in place a strategy for the preparation of a River Channel and Riparian Management Plan (see also Land Use Management).	KMC and assistance from OEH.	High	Some in-stream works have been completed. Riparian management plan not completed.	Strategy for management of riparian lands is still required.
Water Quality					
4	Modify stormwater outlets along Charles Avenue.	KMC	High	Some litter baskets and Enviropods have been installed.	Maintenance and repair of stormwater assets is required.
5	Study of estuary water quality, including Jerrara and Fountaindale Creeks.	KMC	High	MER program conducted in 2006/07 and 2011/12 within estuary and upper Minnamurra River only. No monitoring of tributaries. REF for Jerrara Dam completed in May 2013 for decommissioning of dam included some water quality data.	Monitoring of tributaries would assist in identification of management issues.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
6	Continue ongoing monitoring program of water and groundwater quality at waste depots.	KMC & SCC	High	EPA licence monitoring is ongoing.	Monitoring should be undertaken according to tidal state. Future sampling should assess total ammonia. Councils to liaise with EPA.
7	Follow up on future RTA monitoring and management of stormwater outlets along the new bypass.	RMS	High	The North Kiama Bypass includes sedimentation and spill controls although these are not monitored or maintained by RMS.	The need for additional controls will be assessed in the CZMP.
8	Investigate and reduce the magnitude/ frequency/ causes/ impacts of sewerage pumping station overflows to Minnamurra River Estuary.	Sydney Water	High	Sydney Water has completed the Sewerage Overflows EIS and identified improvements to the sewerage system to reduce the occurrence and impact of overflows. Hydraulic modelling is used to assess the overflow performance of the sewerage system.	Sydney Water will continue to monitor and report on the performance of sewerage system as part of its licence requirements.
9	Coordination of Rocklow Creek water monitoring for Dunmore Sand and Soil, Kiama Municipal Council and Shellharbour City Council Waste Depots, Princes Highway.	KMC, SCC & RMS	High	Ongoing monitoring is undertaken by the Councils as part of licence requirements for the waste depots and by Boral as part of licence requirements for quarry and sand extraction operations. No coordination of monitoring programs.	Although the current monitoring programs are undertaken for specific purposes (licence requirements), coordination and compilation of results may be useful in identifying and assessing management issues.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
10	Locate, survey and digitise all existing public and private stormwater drains within the Minnamurra Catchment. Integrate data into GIS and engineering databases 70% completed as of 1999. Detailed modelling with appropriate software of existing drainage systems across entire LGA.	KMC & SCC	Medium	Being completed as part of Council's asset management plan. Areas of Jamberoo and Kiama Downs need to be ground-truthed.	Asset management plans are required.
11	Clump planting of aquatic macrophytes (Common Reed – *Phragmites australis*) in Minnamurra Golf Course watercourse. Limit use of herbicides along watercourses.	KMC & Kiama Golf Course	Medium	There are aquatic macrophytes present in the Minnamurra Golf Course water course.	Holistic approach to stormwater treatment is required across the catchment based on priorities for water quality improvement, management action and ongoing maintenance requirements.
12	Distribute EPA Policy guidelines on pollution from service station forecourts – there are service stations in the Study Area	KMC	Low	Jamberoo service station now closed. No service stations present in Minnamurra Catchment area.	Action is no longer relevant.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
13	Undertake daily water quality monitoring over December to February summer season and weeks over Easter utilising existing Beachwatch sampling protocols	Surf Life Saving & KMC	Low	No Beachwatch sampling in Minnamurra River. Sydney Water has assessed the beach suitability grades for Boyds Beach, Bombo Beach and Surf Beach as good or very good.	While the lower estuary is well flushed and water quality is generally good in this location, past water quality monitoring (2006/07) in the upper estuary has shown elevated bacterial levels. Considering the growing popularity of the lower estuary at Minnamurra for recreational use, it may be prudent to conduct some bacterial analysis at the site to assess swimming risk. The need for ongoing Beachwatch sampling can be determined based on initial results.
14	Investigate and reduce the magnitude/ frequency/causes/impacts of sewerage pumping station overflows to Minnamurra River Estuary.	KMC, SCC and Sydney Water	Low	Refer Action 8.	
15	Maintain and if possible improve the water quality off Minnamurra beach by investigating the magnitude, frequency and causes of sewerage system overflows and other incidents, from Sydney Water corporation records.	Sydney Water	Low	Refer Action 8.	
Conservation					
16	Provision of off-stream stock watering troughs, dams and shade.	Property owners	Medium	Some projects have been implemented with assistance from the Southern Rivers CMA and Small Farms Network.	Ongoing liaison with property owners is required to identify potential project sites.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
17	Establish better fish habitats in the lower Minnamurra River between Factory Lane grade control structure and Swamp Road.	KMC, Fisheries, Floodplain Management Plan.	Medium	In stream works (new rock ramps) have been constructed. Fallen trees (snags) are removed to limit bank erosion. Habitat enhancement works have not been undertaken.	There are still many opportunities for habitat enhancement within Terragong Drain.
18	Investigate the revision of the 'environmental protection' and 'high conservation area' zoning classifications for Kiama and Shellharbour LGAs using vegetation mapping.	KMC & SCC	Medium	Vegetation mapping included in the LEPs as E2 and E3 zoning.	Action is complete.
Conservation - Wildlife					
19	Minnamurra River Corridor Action Plan.	Minnamurra Environment Group & KMC	High	The Action Plan completed in 2002 provides recommendations for vegetation management and maps priority areas for future vegetation actions in each of the Minnamurra Sub-Catchments.	Implementation of riparian improvement projects is still required.
20	Initiate a platypus and freshwater fish survey focussing on Australian bass and Australian grayling in Minnamurra River and billabongs of the old course.	NSW Fisheries	Low	Fisheries NSW commenced freshwater / estuary fish sampling in 2011. Platypus survey not undertaken.	Ongoing as part of MER program.
21	Investigate whether the billabongs forming the original channel and the upper Minnamurra estuary warrant classification as 'critical habitat' for Australian bass in the Illawarra region under the *Fisheries Management Act* (1994).	NSW Fisheries	Low	Not undertaken. Australian bass have been stocked in Minnamurra River waterways including Jerrara Dam and the ponds at Dunmore quarry.	Australian bass is a common recreational species and is not listed as endangered or threatened.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
22	Enhance riparian and aquatic habitat values on stormwater affected watercourses and to reduce the impact of nutrient delivery from urban areas to environmentally sensitive watercourses.	KMC & SCC	Low	Not undertaken.	The majority of riparian land is on private property. Refer Action 10.
23	Define, identify and map wildlife habitat area.	KMC & SCC	Low	Various studies have been undertaken.	Ongoing
24	Establish education programs.	KMC & SCC	Low	Education programs relating to urban stormwater were undertaken in 2008/09.	Ongoing education and awareness programs are required.
25	Investigate potential for protection/conservation agreements and enlargement of conservation area.	KMC, SCC and OEH	Low	Not undertaken.	Ongoing protection of existing conservation areas is required.
Conservation – Wetlands and Riparian Zones					
26	Establish education programs.	KMC, SCC, DLWC, Fisheries, RTA & Waterways Authority	Medium	Refer Action 24.	
27	Assess status of wetlands with possibility of extending protected wetland areas and provide fringe buffer zones.	KMC & SCC	Medium	Riparian land mapping updated and included in the LEPs. Council has purchased land for a wetland conservation area within the mid-estuary (Figure 6).	Needs to be reconsidered in light of sea level rise and impacts on wetland vegetation in this CZMP (Refer Section 6.15.3). This CZMP will investigate potential locations/need for buffers.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
28	Research extent and cause(s) of loss of seagrass beds as identified by Chafer, 1998a (*A Spatial-temporal Analysis of Estuarine Vegetation Change in the Minnamurra River 1938 – 1997*).	NSW Fisheries	Medium	Mapping of seagrass extent was undertaken in 2009 (Section 6.4.2). West report used for State of the Catchments reporting 2010.	Aerial photography shows significant loss of seagrass in the lower part of the estuary since 2009. Assessment of trends in seagrass fluctuation could be pursued as research project. Research into the causes of decline may consider water quality impacts (e.g. turbidity, nutrients), flooding impacts and physical disturbance such as scour or burial and human impacts from trampling, boat propellers, etc.
29	Increase areas of SEPP 14 wetlands.	RTA, KMC & OEH	Medium	SEPP 14 wetlands mapped in the LEPs and in this CZMP (Section 6.4.3).	Needs to be reconsidered in light of sea level rise and impacts on wetland vegetation in this CZMP (Refer Section 6.15.3). Need for investigation of potential locations/need for buffers.
Conservation – Heritage					
30	Identify status and scope for preservation.	KMC & SCC	Medium	Kiama Heritage Review undertaken, and results included in Schedule 5 of the Kiama LEP 2011.	Action is complete.
Road Transport Corridors					
31	Monitor and minimise impact/s of construction and use of the Bypass including management of stormwater and impacts on wetlands.	RMS	High	Stormwater controls were in place during the bypass construction. Ongoing monitoring is not undertaken.	Refer Action 7.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
32	Monitor the RTA removal of fill from the billabong.	RMS	High	Assumed complete as part of the bypass construction. Some of the fill now forms the base for the property access road and Swamp Road cycleway and cannot be removed.	Action is no longer relevant.
Land Use Management					
33	RTA implement stormwater controls along Bypass.	RMS	High	Refer Action 7.	
34	Ensure future development maintains or improves existing environmental conditions.	KMC & SCC	High	Ongoing. Controls within the Council DCP and requirements of Council's Water Sensitive Urban Design Policy are incorporated into development assessment.	Ongoing.
35	Support development of Terragong Drainage Union Management Plan which complies with requirements of the *Water Management Act.*	Terragong Drainage Union	High	A brief for the development of the review of the management plan was prepared by DLWC, but not enacted, due to staffing and departmental changes.	Strategy for management of riparian lands is still required.
36	S177(2) State Significant Hard Rock and Sand Resource boundary review.	SCC, DUAP	High	Completed by Department of Planning and SCC.	Action is complete.
37	Clarify issues identified in the Stressed Rivers Assessment Report in relation to the estuary.	KMC & SCC	High	The *Greater Metropolitan Region Unregulated River Water Sources Water Sharing Plan* was gazetted.	Action is no longer relevant.
38	Monitor effectiveness of existing stormwater ponds at Gainsborough.	KMC	Medium	No monitoring undertaken since 1998. Stormwater ponds are undergoing maintenance in 2015/16 (Section 6.8).	Research into the effectiveness and impact of the ponds is required.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
39	Implement more stormwater controls.	RMS & KMC	Medium	Not undertaken.	There are potential locations for more GPTs although asset management planning is required.
40	Prepare a Floodplain Management Plan for Terragong Swamp.	KMC, SCC & OEH	Medium	Floodplain management planning will be undertaken when funds are available. LiDAR of LGA is completed.	Floodplain management planning is still required.
41	Review the capacity of wet weather effluent storage tanks (or containment systems) that accompany future aerated wastewater treatment systems in accordance with current standards	KMC & SCC	Low	Council OSSM System inspections program is ongoing. Orders issued for maintenance, operation and repair if problems are detected.	Ongoing.
42	Undertake environmental audit of industrial and commercial premises.	KMC & SCC	Low	Council EHOs investigate pollutions incidents when they occur or if concerns are reported by general public.	Action is no longer relevant.
43	Investigate the need for on-site management of dairy waste on individual properties and provide support where appropriate.	KMC, SCC & OEH	Low	Dairy industry program was undertaken previously by DPI. Program is not currently operating.	Effective management of dairy effluent waste is required.
Entrance Stability					
44	Undertake a study to investigate entrance stability status.	KMC & DLWC	High	Studies were undertaken in 2002 and 2007.	Action is complete.
45	Control Bitou bush at Killalea Reserve.	LLS and Illawarra Noxious Weed Authority	High	Killalea State Park implements ongoing weed management programs. Bitou bush is considered to be at a manageable level at Killalea Reserve.	Ongoing.

Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
Recreation					
46	Implement proposal for fishing jetty and connection under Princes Highway bridge.	KMC	High	Fishing jetty / shared pathway connection under bridge is complete (Figure 6E).	Action is complete.
47	Assess feasibility of Walking Tracks and Cycleway Committee proposal for cycle path to Swamp Road.	KMC	Medium	First stages between Gainsborough and Swamp Road completed (Figure 6F). Next stage along Swamp Road is under construction. Final route to join with Jamberoo has been determined.	Action is complete.
48	Continue ongoing upgrade of recreation facilities.	KMC	Low	Facilities are upgraded as required when funds are available.	Ongoing. Some responses from community survey identified boat ramps as needing improvement.
49	Investigate boardwalk that connects under the bridge and through mangroves, downstream of Princes Highway.	KMC	Low	Board walk under bridge complete. A boardwalk through Minnamurra Bends has been identified and adopted by Council in its *Strategic Footpath Asset Plan 2012-2022* subject to available funding and further investigation.	Further investigation is required.
50	Monitor main estuary channel for boating navigation.	RMS	Low	No monitoring undertaken. Shallowing towards entrance of river has been observed in last few years. Concerns have been raised by community over sediment deposits downstream of Minnamurra Bends.	Ongoing patrol and assessment is undertaken by RMS.

Appendix 3: Review of Historical Aerial Photography

This Appendix provides a comparison of the available aerial photography showing the Minnamurra River entrance between 1948 and the present.

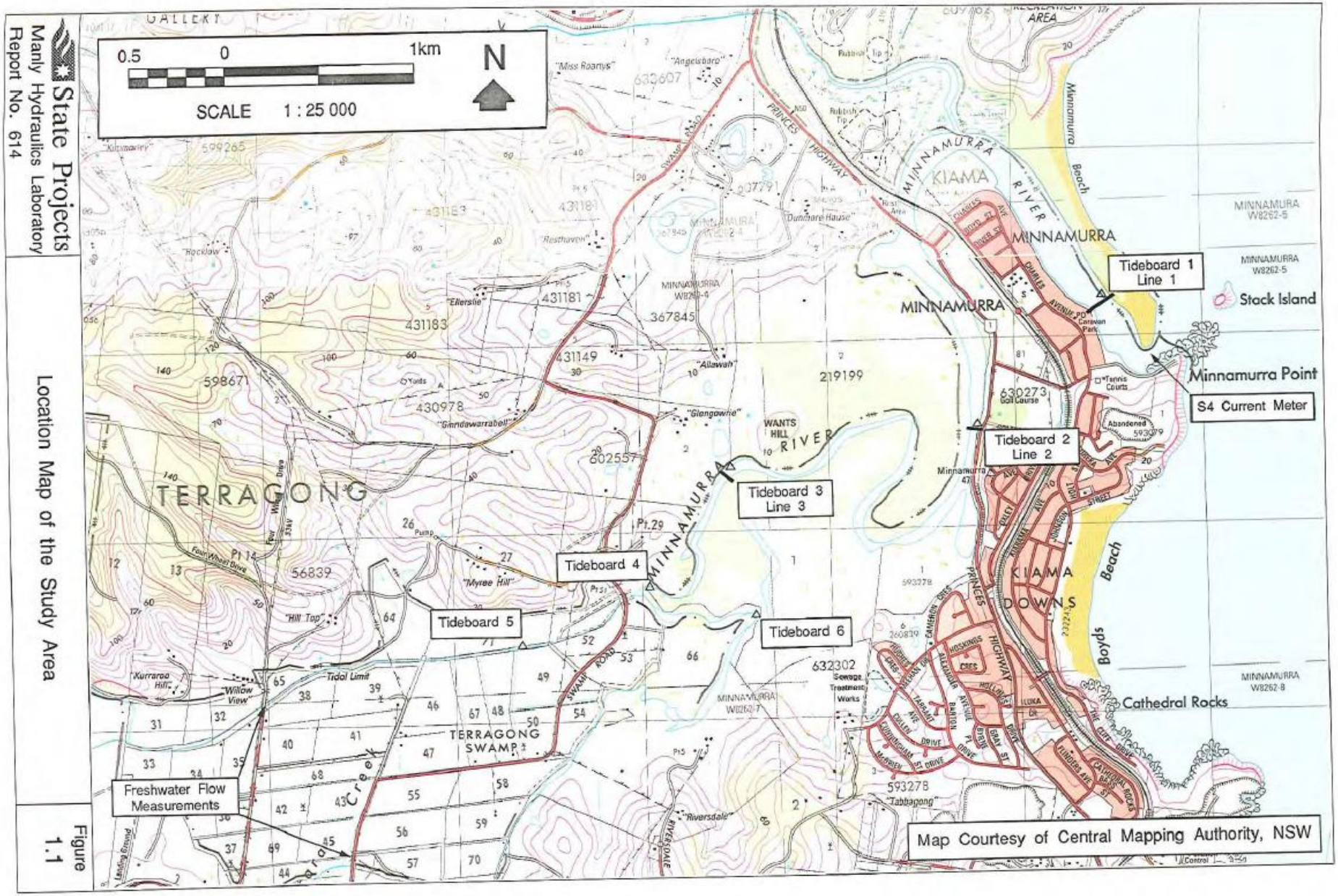
Table 23: Comparison of aerial photography of the Minnamurra River entrance

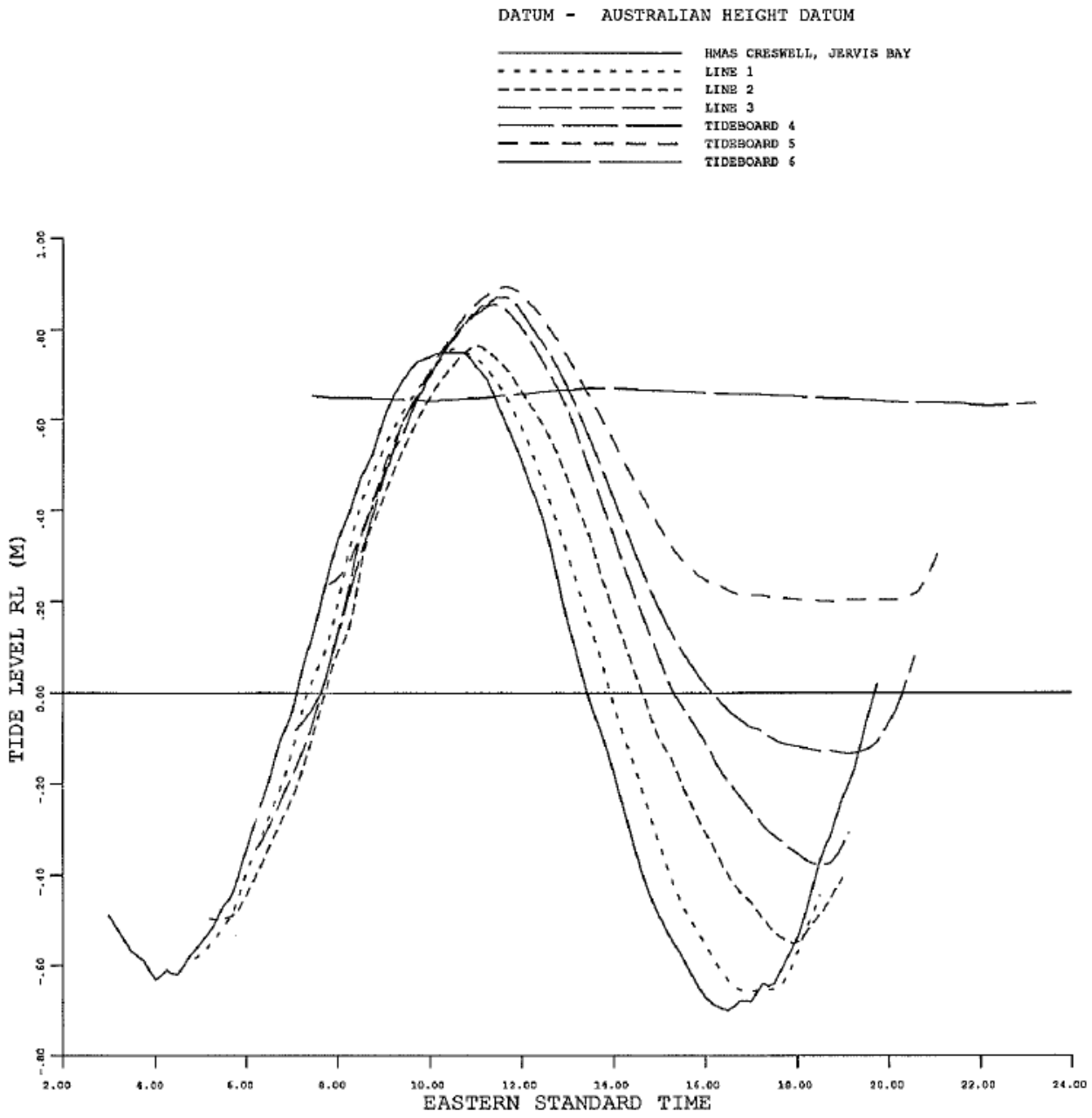
	1948 (Lands Department): • Start of the Minnamurra development concentrated near the entrance. • Sparse vegetation on entrance spit. • Possible seagrass meadows present. • Sparse mangroves along future Charles Avenue foreshore.
	1966 (Crown Lands): • Minnamurra development expanded to current extent. • Mangroves cleared to patchy areas along Charles Avenue foreshore. • Vegetation on entrance spit is well established. • Sandbank near James Oates Reserve appears to have migrated further upstream. • Scattered seagrass adjacent to Charles Avenue.
	1981 (BHPAIR): • Golf course is present. • Seagrass meadows present adjacent to Charles Avenue and along northern bank inside the spit. • Limited change in mangroves along Charles Avenue foreshore. • Vegetation on southern end entrance spit has reduced in area on the ocean side.

	1988 (BHP Engineering): • Channel through lower estuary and entrance appears to be deeper and more defined. • Well defined main channel opposite Charles Avenue with prolific seagrass meadows on each side. • Seagrass meadows also prolific opposite the entrance to Rocklow Creek and along the straight adjacent to the golf course. • Seagrass is evident as far upstream as the bends. • Kiama landfill is visible. • Limited change in mangroves along Charles Avenue foreshore
	1997 (BHP): • Entrance spit vegetation appears to have migrated south which may be due to revegetation work undertaken between 1991 and 1993. • Entrance channel upstream to opposite James Oates Reserve appears shallower, narrower and less defined than in 1988. • Sandbank near James Oates Reserve appears to have migrated further upstream. • Seagrass distribution throughout the estuary appears to have reduced since 1988. • Limited change in mangroves along Charles Avenue foreshore
	2003 (Google Earth): • Seagrass meadows adjacent to Charles Avenue have expanded since 1997. • Seagrass opposite the entrance to Rocklow Creek and in the straight adjacent to the golf course have returned. • Limited change in mangroves along Charles Avenue foreshore

	February 2009 (KMC): • Shallow entrance with rocks in the middle of the mouth mostly covered by sand. • Sandbank adjacent to and upstream of James Oates Reserve has extended further upstream since 2003. • Seagrass meadows throughout the estuary appear to have expanded since 2003 to areas similar to 1988. • Seagrass is apparent in Rocklow Creek. • Limited change in mangroves along Charles Avenue foreshore.
	January 2011 (Google Earth): • Entrance appears to have deepened with rocks in the middle of the mouth now clearly visible and a wider, deeper more defined entrance channel. • Seagrass adjacent to Charles Avenue appears to have diminished since 2009. • Limited change in mangroves along Charles Avenue foreshore.
	December 2013 (Google Earth): • Entrance looks as though it has become shallower. • Seagrass throughout the entire estuary appears to have become more sparse since 2011. • Limited change in mangroves along Charles Avenue foreshore.

Appendix 4: Tide Gauge Data (MHL, 1992)


0.5
0
1km
N
SCALE 1 : 25 000
Tideboard 1
Line 1
Tideboard 2
Line 2
Tideboard 3
Line 3
Tideboard 4
Tideboard 5
Tideboard 6
S4 Current Meter
Stack Island
Minnamurra Point
Freshwater Flow
Measurements
Map Courtesy of Central Mapping Authority, NSW
MINNAMURRA
KIAMA
TERRAGONG
TERRAGONG
SWAMP
MINNAMURRA
RIVER
WANTS
HILL
RIVER
KIAMA
DOWNS
Beach
Boyds
Beach
Cathedral Rocks
Tidal Limit
Creek
Creek
Report No. 614
Manly Hydraulics Laboratory
State Projects
Location Map of the Study Area
Figure
1.1


DATUM - AUSTRALIAN HEIGHT DATUM
HMAS CRESWELL, JERVIS BAY
LINE 1
LINE 2
LINE 3
TIDEBOARD 4
TIDEBOARD 5
TIDEBOARD 6
TIDE LEVEL RL (M)
1.00
.80
.60
.40
.20
0.00
-.20
-.40
-.60
-.80
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
EASTERN STANDARD TIME

Appendix 5: Stakeholder Consultation Activities

Appendix 6: Water Quality Data

This Appendix provides a summary of the available water quality data for the Minnamurra River Estuary.

Available Information

A list of the water quality information available for the Minnamurra River Catchment is provided in Table 24 including details of the data collected, timeframes, sites and reporting of results. The locations of sampling sites for KMC 06/07 and OEH 07/08 and OEH 11/12 data are shown on Figure 64. The data are analysed in the following sections.

Table 24: Summary of available water quality data and reporting

Data Source	Dates and frequency	Methods	Sites	Reporting of key findings
Kiama Municipal Council 2006/2007	1 year of sampling July 2006 - June 2007 (monthly samples)	Water quality probe for in-situ measurements and grab samples collected for laboratory analysis	Minnamurra River: M1 (Freshwater); M2 (Upper Estuary); M3 (Mid Estuary). Rocklow Creek: R1.	Analysis of data provided below
OEH – MER Sampling Program 2007/2008 and 2011/2012	10 months of sampling from Sep 2007 – June 2008 (monthly samples).	Water quality probe for in-situ measurements and grab samples collected for laboratory analysis.	Minnamurra River: 2 sites: Zone 1 (mid estuary at Swamp Road Bridge); and Zone 2 (lower estuary upstream of Rocklow Creek confluence).	Analysis of data provided below Summary of turbidity and chlorophyll a reported in State of Catchments Reporting.
	6 months of sampling from Nov 2011 – April 2012 (monthly samples).	Boat-mounted water quality probe for in-situ transect measurements and grab samples collected for laboratory analysis.	Several sites – sampled behind boat between the estuary mouth and approximate upper extent of mangroves.	
Minnamurra Depot Groundwater and Surface water monitoring (KMC)	Quarterly groundwater, surface water and leachate monitoring.	Sampling on-site and off-site groundwater wells and surface water.	Several groundwater wells. Surface water sampled at 3 sites along Rocklow Creek.	Annual reports completed for Council as per EPA licence conditions (discussed below).
Dunmore Recycling and Waste Depot Environmental Monitoring (Shellharbour City Council)	Quarterly groundwater, surface water and leachate monitoring since 1992.	Sampling on-site and off-site groundwater wells and surface water.	Several groundwater wells Surface water sampled at on-site ponds and 3 sites along Rocklow Creek.	Annual reports completed for Council as per EPA licence conditions (discussed below).
Dunmore Quarry water quality monitoring of discharge from the site.	Daily monitoring required when water is discharged from the site.	Sampling surface water for conductivity, Oil and Grease, pH, TSS and turbidity.	Four monitoring points located at on-site discharge points adjacent to upper Rocklow Creek (upstream of Princes Highway).	Reported by Boral in EPL mandatory reporting.
Jerrara Dam Decommissioning Aquatic Ecology Assessment (Cardno, 2012)	Sampling over 2 days in October 2012.	Water quality probe for in-situ measurement of physical parameters.	8 sites in Jerrara Creek, Jerrara Dam and the Minnamurra River near confluence of Jerrara Creek.	Discussed in Jerrara Dam REF and summarised below.

Data Source	Dates and frequency	Methods	Sites	Reporting of key findings
Streamwatch	Various as funding permits. The program was discontinued after 2010/2011 due to lack of funding.	Volunteer program including community groups and schools using water quality probe and grab samples. Results are quality assured by program coordinators.	Several sites on Rocklow Creek, Minnamurra River and Jamberoo Valley.	Reported in KMC SoE reporting and discussed below.
University projects	1998-1999, various frequency.	Various including surface and groundwater sampling.	Several points along Minnamurra River, constructed wetland and treatment pond system at Kings Drain.	Discussed in 1999 CMS and summarised below.
Jamberoo Water Quality Study (AWS EnSight, 1998)	1998	Designed to investigate the impact of on-site sewage management systems on water quality in the Minnamurra River. 12 dry weather and 6 wet weather events were captured.	8 sites in Jamberoo Creek, Hyams Creek, Fountaindale Creek and Minnamurra River.	Discussed in 1999 CMS and summarised below.
Water Quality Monitoring in an Urban Sub-catchment of the Minnamurra River (Roso, 1998)	1997-1998	Investigated potential sources of pollution to the Minnamurra River, centred on the treatment performance of stormwater treatment ponds. Nutrients were the main parameters of interest.	3 sites upstream, between and downstream of Gainsborough stormwater treatment ponds.	Reported by Roso (1998) and discussed below.
Minnamurra River Pilot Study (PWD, 1995)	Sampled over 2 days in September 1993	Sampling surface water for temp, pH, DO, turbidity, nutrients, chlorophyll a. faecal coliforms and suspended solids.	Grab samples at 15 sites and 4 continuous data loggers measuring pH, DO and temp over 2 days at Albion Park road bride and Swamp Road Bridge.	Discussed in 1999 CMS and summarised below.
Sydney Clean Waterways Programme (AWS EnSight, 1995)	1995	Dry and wet weather sampling across 26 catchments in Sydney and the Illawarra to investigate water quality from different landuse catchments.	Minnamurra River site was located at Browns Lane (in the mid-catchment downstream of Jamberoo).	Discussed in 1999 CMS and summarised below.
Sydney Water Sampling	1992	Two sample occasions – following prolonged dry and wet weather.	6 sites spread between the mouth and Swamp Road (approx. tidal limit).	Discussed in 1999 CMS and summarised below.
Kiama Municipal Council	1991, 1992, 1993	Water quality probe for in-situ measurements and grab samples collected for laboratory analysis. Sites included surface water and groundwater.	Minnamurra River, Rocklow Creek and Jerrara Creek.	Discussed in 1995 EMP and summarised below.

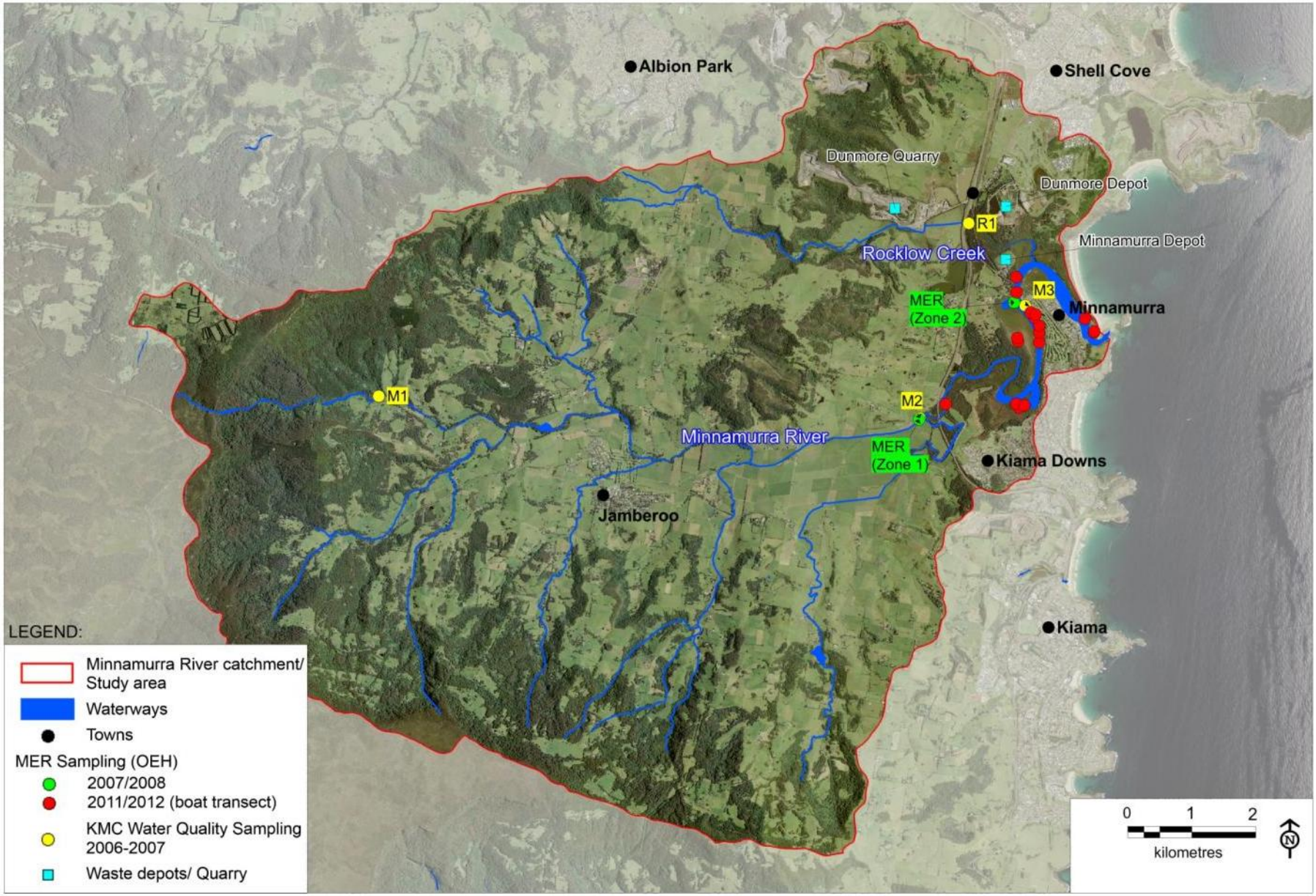


Figure 64: Recent water quality sampling sites within the Minnamurra River Catchment

Kiama Municipal Council Monitoring 2006/2007

Council conducted monthly sampling at four sites in the Minnamurra River Estuary for one year (July 2006 - June 2007). Samples were collected from a total of four sites, comprising three in the Minnamurra River (freshwater site upstream of Jamberoo (M1) and upper (M2) and mid estuary (M3) sites) and one site in Rocklow Creek (R1). In-situ measurements were collected with a water quality probe and grab samples were collected for laboratory analysis. An assessment of the range of key ecosystem parameters is provided below.

MER Monitoring 2007/2008 reported in 2010 State of Catchments Report

The MER program is considered to provide a good assessment of overall ecosystem health in the Minnamurra River Estuary and allows for broad tracking of ecosystem health through time (repeated approximately every three years). It is consistent with other ecosystem health monitoring being undertaken in NSW which allows for comparison with other waterways. Repeated monitoring through time will allow for tracking of water quality trends for key parameters and long-term changes in condition on an estuary-wide scale. Because of the broad nature of the MER program, it is not intended to provide detailed water quality information at specific locations or to evaluate the impact of potential pollution sources or changes in water quality due to management practices in the short-term. To sufficiently evaluate sources of water quality decline and to track changes due to management actions, it is necessary to design and implement a water quality monitoring program for this purpose.

The 2010 SoC Report assigned water quality ratings for the Minnamurra River Estuary based on sampling undertaken in 2007/2008. Key parameters used in the assessment were chlorophyll a and turbidity. Chlorophyll a results were reported as 'Good' with a 75-<90% compliance with the trigger value and turbidity was reported as 'Very Good' with a >90% compliance with the trigger value. Other parameters were sampled during the 2007/2008 MER sampling program. Analysis of the complete dataset was carried out as part of this review as discussed below.

Table 25: Water quality condition rating of Minnamurra River Estuary (based on samples collected from 2007/2008)

Indicator	Condition Index Rating	Condition indicator notes
Chlorophyll a	Good	75-<90% compliance with trigger value
Macroalgae	-	Not sampled
Turbidity	Very Good	>90% compliance with trigger value

Source: Adapted from Roper *et al*. (2011)

MER Monitoring 2011/2012

MER water quality monitoring was also completed in the Minnamurra River Estuary in 2011 and 2012. Sampling took place over a period of six months from November 2011 to April 2012 and methodologies comprised logging of water quality using a boat-mounted water quality probe and grab samples collected for laboratory analysis. Samples were taken between the ocean mouth of the estuary and the approximate upper extent of mangroves.

At the time of writing this report, the updated SoC Report was not yet available. However, water quality data collected by the program was provided by OEH for analysis as part of this CZMP (refer below).

The MER monitoring will be repeated in the summer of 2014/15 by OEH with results reported in MER report cards for the estuary. This analysis will be referencing the MER trigger values as listed in Table 26.

Waste Depot Groundwater and Surface Water Monitoring

During the preparation of the 1995 EMP there was a community perception that both Dunmore Depot and Minnamurra Depot were contributing to poor water quality in Rocklow Creek and to downstream environments in the Minnamurra River Estuary. The 1995 EMP reported stakeholder observations of 'pockets of putrid water visible from the train' at the Dunmore Depot but that no analyses of this water were available to assess pollutant levels or impacts on Rocklow Creek. There were also anecdotal reports of infections experienced by recreational users of the waterway and some stakeholders attributed this to the operation of Dunmore Depot. However no investigation was undertaken and therefore the nature and causes of these infections were not confirmed. Community concern about water quality impacts from waste management facilities was raised again as part of stakeholder consultation conducted for this CZMP (refer Section 4).

Assessment of the available surface water and groundwater data from Dunmore Depot was undertaken as part of the 1995 EMP. This assessment concluded that the depot had mostly acceptable contaminant levels in accordance with criteria for contaminated sites and concluded that there was insufficient evidence to link groundwater quality in the vicinity of the Dunmore Depot to high nutrient levels in Rocklow Creek (PBP, 1995b). Data for Minnamurra Depot were not available at that time (PBP, 1995b). The 1999 CMS (Reinfelds, 1999) identified both depots as potential point sources of pollution to Rocklow Creek and the Minnamurra River Estuary. The 2003 EMP Review once again noted the depots as potential sources of negative water quality impacts, however, the review did not include any further investigation of the impact of the waste depots on Rocklow Creek but recommended continued monitoring of both waste depot sites.

Water samples from Rocklow Creek and the Minnamurra River were collected by DECCW (now OEH) in 1991 and 2005 (Denis Pascall, August 2005 cited in E2W, 2012), as part of a water quality and landfill impact assessment for the area (Forbes Rigby, 1996 cited in E2W, 2012). The following conclusions were made as a result of this sampling work:

- Concentrations of most indicators (except dissolved oxygen) are considerably higher in Rocklow Creek than in Minnamurra River; and
- The concentration of ammonia (one of the primary leachate indicators) measured at several locations along Rocklow Creek indicate that Dunmore Depot and Minnamurra Depot may be contributing leachate into the estuarine environment.

Minnamurra Depot Monitoring

The groundwater at the Minnamurra Depot is vulnerable to pollution due to the permeable sands and shallow depth to groundwater. The Minnamurra River and Rocklow Creek and associated estuarine wetlands are located immediately downstream of the site.

KMC undertakes quarterly groundwater and surface water monitoring in and around the Minnamurra Depot in accordance with EPA licence requirements. The waste facility was closed in 2006, and capping was completed in 2008. It now acts as a waste collection and transfer facility only, with all waste transferred off-site for reuse and/or disposal at the Dunmore Depot (refer Section 6.8 for further details and history of the depot). The aim of the monitoring is to identify any impacts that the facility may have on the surrounding waterways so that remediation can be undertaken if necessary.

Elevated levels of nutrients, in particular ammonia have been detected in groundwater at the site since 1999. Ammonia levels exceeded ANZECC guidelines at all groundwater monitoring wells sampled in 2012/2013. E2W (2013) report that ammonia trends are generally variable over time although most groundwater locations are showing a downward trend over time. Nitrate concentrations in groundwater ranged from not detected to 6.68 mg/L (in excess of the 0.7 mg/L ANZECC guideline). E2W (2013) reported that nitrate concentrations were lower than previous years. Groundwater sampling indicates contaminant migration towards Rocklow Creek and the Minnamurra River (E2W, 2013).

Results of surface water sampling between 1999 and 2013 show increased levels of ammonia and nitrate at downstream sites, compared to upstream of the waste depot. This suggests that leachate from the site is impacting water quality in the nearby Rocklow Creek, a tributary of the Minnamurra River. In 2012/13, nitrate levels at three out of the four downstream sites exceeded the ANZECC guideline for aquatic ecosystems. Ammonia was reported to be within the adopted ANZECC guideline (2.84 mg/L, corrected to pH 7.3) at all surface water sites. E2W (2013) report that the actual difference between upstream and downstream concentrations has reduced since 1999, indicating a reducing impact of leachate on the downstream environment.

E2W conclude that additional time (3+ years) is required to confirm consistent and widespread improvement in water quality trends due to landfill rehabilitation. With regard to groundwater ammonia, E2W (2013) recommends that groundwater remedial works (e.g. extraction and further treatment) be undertaken if ammonia concentrations exceed 100 mg/L in groundwater samples on two consecutive monitoring rounds in 2013 or 2014.

It is noted that surface water samples were not sampled according to tidal state in 2012/13. Because Rocklow Creek is tidal, it is vital that samples are taken with consideration of tides to ensure that nomination of upstream/downstream sites is valid. The fact that sampling did not consider tidal state raises questions about the validity of upstream/downstream sampling results. E2W (2013) note this in their report recommendations for future monitoring.

In addition, E2W reports on NH_3-N (un-ionised ammonia). The ANZECC guideline trigger value used in the assessment is based on total ammonia (the sum of NH_3 and NH_4^+ ionised ammonia) (refer to Table 8.3.7 and Section 8.3.7.2 of ANZECC 2000). It is important that future sampling for both groundwater and surface water in Rocklow Creek assess total ammonia, so that an accurate comparison with aquatic ecosystem health guidelines can be undertaken.

Dunmore Depot Monitoring

SCC conducts quarterly monitoring of groundwater and surface water in the vicinity of the Dunmore Depot in accordance the EPA licence requirements. The Dunmore Depot is located approximately 500 m north of the Minnamurra Depot on the opposite side of Rocklow Creek.

Results of the 2012/13 sampling indicate that several of the groundwater bores exhibited strong signs of leachate influence which can be attributed to the historical and current landfill leachate and effluent leachate (Environmental Earth Sciences, 2013). Several of the on-site surface water ponds also showed evidence of possible leachate impact with both ammonium (NH_4-N) and nitrate concentrations exceeding the guideline values. Inferred groundwater contours show the general direction of groundwater to be to the south-south-east towards Rocklow Creek. Groundwater results indicate that the movement of leachate is likely to be slow (approximately 0.4 m/year). Despite the contamination in the groundwater wells and the flow of groundwater in the direction of Rocklow Creek, Environmental Earth Sciences (2013) reported that there was no evidence of leachate detected in surface water downstream of the site in Rocklow Creek.

Environmental Earth Sciences report NH_4-N only in the 2012/12 annual report. The ANZECC guideline trigger value used in the assessment is based on total ammonia (the sum of NH_3 and NH_4^+) (refer to Table 8.3.7 and Section 8.3.7.2 of ANZECC 2000). Discussion with the consultant as part of this review has confirmed that the reported results are in fact for total ammonia, but the laboratory listed them as NH_4-N as it was found to be the dominant form. Future reporting will ensure total ammonia is reported to avoid confusion. It is important that future monitoring measures and reports on the total ammonia concentration in groundwater and surface water so that an accurate assessment of the impact of leachate on downstream sensitive environments can be made.

Dunmore Quarry and Dunmore Lakes Sand Project Monitoring

The Dunmore Quarry surface water monitoring program involves the regular monitoring of dam waters and the associated licensed discharge and overflow points to Rocklow Creek. Monthly samples are monitored for pH, total suspended solids, conductivity, turbidity, oil and grease. On a 6-monthly basis additional parameters are tested including total dissolved solids, total nitrogen, total phosphorus, arsenic, cadmium, chromium, nickel, lead and zinc. During discharge events daily grab samples and field analysis occurs at the dam, overflow points and in Rocklow Creek upstream of the dam and downstream near the Boral boundary to ensure compliance with discharge criteria.

Baseline water quality data are available for Rocklow Creek. Boral has collected grab samples from a site approximately 500 m upstream of the existing water supply dam since March 1999. The baseline water quality monitoring program will continue at monthly intervals.

The Dunmore Lakes Sand Project undertakes ground and surface water monitoring as part of conditions of approval for the development. If there are any exceedance(s) of surface water and groundwater impact assessment criteria this triggers the protocol for the investigation, notification and mitigation of any identified exceedance(s) (R.W Corkery & Co, 2006). A full analysis of this water quality information has not been undertaken as part of this review. There have been no notifications of exceedances of water quality objectives recorded on the POEO Act public register to date.

Jerrara Dam Decommissioning Aquatic Ecology Assessment

Water quality sampling was conducted as part of aquatic ecology assessments to assist in determining the health status of habitats sampled. Physico-chemical parameters were measured with an *in-situ* water quality probe including pH, temperature, dissolved oxygen, salinity and turbidity. Samples were taken for the day of fish sampling only and therefore represent a snapshot of conditions in Jerrara Creek at that time. Mean DO (% saturation) exceeded the upper guideline level at Site 1 (Jerrara Dam – Main Impoundment) (118.6 %) and Site 4 (Mount Brandon Road Crossing) (120.6%) indicating hypersaturation, and possibly excessive algae or aquatic plant growth. All other parameters measured were within ANZECC guidelines.

Streamwatch Monitoring

Streamwatch is a volunteer program initially set up by Sydney Water to involve community and school groups in the monitoring of local waterways. Historically, a number of sites throughout the Minnamurra River Catchment have been sampled at various times including several sites in Rocklow Creek, Minnamurra River and the Jamberoo Valley. Results are quality assured by program coordinators and the latest results are published on the Streamwatch website. The program was discontinued in 2010/2011 due to lack of funding, with the latest water quality data from the Minnamurra area reported in 2010. Recently the Australian Museum has taken over the Streamwatch program, although it is not known if sampling will be undertaken again in the Minnamurra River Catchment. The most recent data summarised in the State of Environment Report 2008/2009 indicated that the two sites monitored within the Minnamurra River were within ANZECC guideline levels for turbidity and primary and secondary contact (recreational use) for 50% - 100% of the time but generally fell outside guideline levels for pH (Kiama Council 2009). The SoE report discusses the need for continued water quality monitoring in Minnamurra River either through Streamwatch or an alternative program.

Estuary Management Plan

The 1995 EMP (PBP, 1995b) reported water quality data collected by KMC, Sydney Water Corporation and Public Works between 1991 and 1993. A summary of the key findings are as follows:

- The system was considered to be well-oxygenated throughout and the lower estuary was well flushed, although there were instances of poor water quality detected;

- Nutrient levels in the Minnamurra River did not exceed ANZECC guidelines, but exceedances were recorded in Rocklow Creek and Jerrara Creek and in Terragong Swamp groundwater;
- The Rocklow Creek site located adjacent to the Princes Highway had the highest nutrient concentrations;
- Generally high levels of ammonia were detected throughout the system;
- Chlorophyll a was generally at low levels in the Minnamurra River and within ANZECC guidelines. However, chlorophyll a was at high concentrations and exceeded ANZECC guidelines in Jerrara, Colyers and Rocklow Creeks; and
- The 1995 EMP noted that water quality observations were based on a limited dataset.

Catchment Management Study

The CMS (Reinfelds, 1999) reported on results of several water quality studies in the Minnamurra River Catchment including:

- Sydney Water Sampling (1992);
- Minnamurra River Pilot Study (PWD, 1995);
- Sydney Clean Waterways Programme (AWS EnSight,1995);
- Jamberoo Water Quality Study (interim results AWS EnSight,1998);
- University of Wollongong Water Quality Studies (1998); and
- Groundwater studies focussing on the Kiama and Shellharbour Council waste depots, sand extraction and backfilling operations.

The CMS noted that the existing information provided a snapshot of conditions for dry and wet weather at different locations and times with no systematic long term water quality monitoring undertaken.

The following conclusions were made regarding water quality at that time:

- High levels of faecal coliforms were consistently recorded in the Minnamurra River and its tributaries both upstream and downstream of Jamberoo (prior to connection of Jamberoo to the Sydney Water sewerage system). Modelled levels exceeded ANZECC guidelines for primary contact recreation for an average of 92 days per year in the central and upper reaches of the estuary. PWD (1995) reported Jerrara Creek as having faecal coliform levels in excess of ANZECC (1992) secondary contact limits and attributed this to run-off from surrounding pastoral land use and potential livestock access;
- Wet weather runoff from Jamberoo is a concentrated source of nutrient and possibly faecal coliform pollution to Minnamurra River and this was attributed mainly to failing on-site sewerage systems. Note that since the mid-2000's Jamberoo has been connected to the Sydney Water sewerage system and it is expected that water quality is now greatly improved with the removal of on-site systems.
- Both faecal coliforms and nutrients tend to accumulate in the upper section of the Minnamurra estuary;
- Efficient tidal flushing in the lower estuary is the main reason for maintenance of healthy water quality in the lower estuary.
- High nutrient concentrations were detected downstream of both Gainsborough (sewered) and Jamberoo (then unsewered) urban areas;

- Some parts of the freshwater reaches of the Minnamurra River, Jerrara Creek, Rocklow Creek and Colyers Creek support high levels of algal growth as evidenced by field observations and high chlorophyll a concentrations. However, some studies found low chlorophyll a concentrations which indicates variation occurs both spatially and through time;
- Ground water studies indicate that ammonia nitrogen plumes in groundwater around tip sites on Rocklow Creek are expected to impact the waterway; and
- Data loggers deployed over a 30 hour period by PWD (1995) showed diurnal variations in pH and dissolved oxygen outside of what would be considered suitable for aquatic ecosystem health at two sites: Station 11 (Albion Park site upstream of Jamberoo); and Station 2 (Minnamurra River, downstream of Rocklow Creek). It was suggested that further diurnal sampling of dissolved oxygen, pH and temperature particularly during periods of low flow was required to assess the likely impact on aquatic ecosystems, particularly fish populations.

Water Quality Monitoring in an Urban Sub-catchment of the Minnamurra River (Roso, 1998)

The study demonstrated that urban stormwater runoff from the Gainsborough urban area was generally of poor quality when untreated. The study noted that at that time only 55% of the Gainsborough area has stormwater treatment prior to discharge to downstream ecosystems. First flush events (when only enough rain falls to transport runoff to waterways and not beyond) contributed the most pollutants, while larger storm events did not contribute the same level of pollutants, due to the increased dilution capacity of greater flows. Roso (1998) concluded that the events causing the greatest impact on river water quality were short, high intensity storms which flush pollutants from urban areas but do not have enough runoff volume to increase flow in the river. Nutrients were the key pollutants of concern.

The overall performance of the ponds was found to be positive, particularly during the warmer months when inflow concentrations are highest and outflows lowest. The study found that first flush events in summer (during low flows) are expected to be contained by the stormwater ponds allowing for the removal of suspended solids and other pollutants through sedimentation and biological uptake.

The Gainsborough housing estate was built in the 1980s and therefore it is assumed that at the time of the Roso (1998) study the ponds were approximately 10-15 years old. Today the ponds would be approximately 25-30 years old and without maintenance, their treatment capacity may be reduced due to sedimentation, reduced volumes, etc. Investigation of treatment performance is required to confirm this.

Analysis of Recent Water Quality Data

The water quality data provided by KMC for analysis as part of this CZMP included:

- MER program 2007-2008;
- MER program 2011-2012; and
- KMC data 2006-2007.

Table 26 provides a summary of median water quality results compared to ANZECC guidelines for aquatic ecosystem health. Figure 65 illustrates the range of results in relation to the water quality guidelines.

Table 26: Median water quality results for KMC and OEH monitoring data collected in 06/07, 07/08 and 11/12

Bold (red) number represents exceedances of the ANZECC water quality guidelines

	DO (% sat)	pH	Turbidity (NTU)	Salinity (ppt)	TN (mg/L)	TP (mg/L)	Chlorophyll a (µg/L)	Enterococci (cfu/100mL)
M1 - freshwater (KMC 06/07)	95.2	8.28	0.20	0.05	0.30	0.01	<0.1*	36
M2 - upper estuary (KMC 06/07)	81.3	7.95	4.30	0.27	**0.59**	**0.08**	1.2	**282**
M3 - mid estuary (KMC 06/07)	**77.2**	7.13	2.25	23.80	**0.52**	**0.05**	0.2	31
R1 – Rocklow Creek (KMC 06/07)	**43.6**	7.26	**12.10**	4.72	**1.50**	**0.20**	2.4	**214**
MER (Zone 1) - upper estuary (OEH 07/08)	84.9	**8.67**	2.10	0.48	**0.30**	**0.07**	3	NR**
MER (Zone 2) – mid estuary (OEH 07/08)	80.0	**8.78**	1.66	0.95	**0.33**	**0.07**	**5**	NR**
MER (OEH 11/12 combined transect data)	92.2	NR**	2.73	15.43	**0.48**	**0.07**	3	NR**
Water Quality Guidelines:								
ANZECC Guideline (Lowland River – M1 only)	85-110% saturation	6.5-8.5	<50	-	<0.35	<0.025	5	-
ANZECC Guideline (Estuarine)	80-110% saturation	7-8.5	<10	-	<0.30	<0.03	4	-
Primary Contact Recreation – descriptions based on NHMRC (2008) sourced from OEH Beachwatch webpage (OEH, 2014d)	Enterococci category (cfu/100mL): • <41 - bacterial levels are safe for bathing according to NHMRC guidelines • 41-200 - bacterial levels indicate an increased risk of illness to bathers, particularly those with lower immune function such as the elderly and young children • 201-500 - bacterial levels indicate a substantially increased risk of illness to bathers • >500 - bacterial levels indicate a significant risk of illness to bathers							
*MER Trigger Values****								
River - lower (salinity ≥ 25 ppt)	-	-	2.8	-	-	-	2.3	-
River - mid (salinity 10 to < 25 ppt)	-	-	3.5	-	-	-	2.9	-
River - upper (salinity < 10 ppt)	-	-	6.6	-	-	-	3.4	-

*The median for M1 was < Limit of recording of 0.1 µg/L

**NR - Data not recorded

***The MER monitoring will be repeated in the summer of 2014/15 by OEH with results reported in MER report cards for the estuary. This analysis will be referencing the MER trigger values.

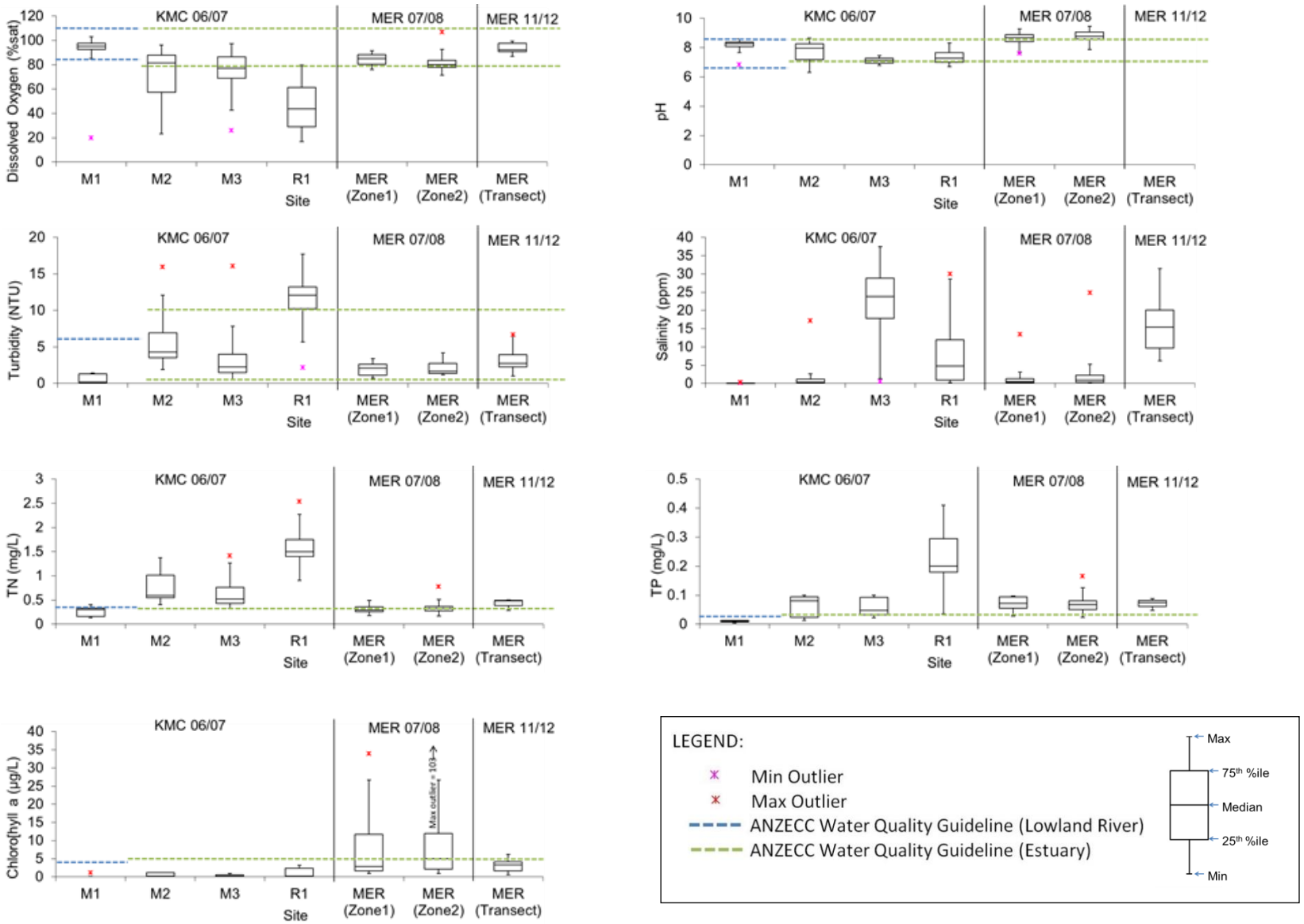


Figure 65: Water quality results for the Minnamurra River Catchment from 2006/07 (KMC), 2007/08 (OEH) and 2011/12 (OEH)

ANZECC water quality guidelines are assessed by comparing the median values of a dataset to the guideline values for aquatic ecosystem health.

Nutrients (measured as TN and TP) were the parameters most frequently exceeding the ANZECC guidelines, indicating a level of eutrophication in the waterways. Site M1 in the upper freshwater catchment was in the best condition with water quality within suitable ranges for healthy aquatic ecosystems for all key parameters. The Rocklow Creek site adjacent to the Princes Highway displayed the poorest water quality indicative of a highly disturbed site with low aquatic habitat value. Sites within the tidal limit of the Minnamurra River displayed varying levels of water quality with nutrient concentrations frequently exceeding the guidelines for aquatic ecosystem health, but an improvement in these parameters is evident in the more recent sampling.

Total Nitrogen (TN) and Total Phosphorus (TP) concentrations were in excess of the ANZECC guideline threshold levels for all sites and throughout all sampling programs except for site M1 in the upper Minnamurra River. The highest nutrient concentrations were recorded during 2006/07 sampling, with Rocklow Creek site displaying the highest levels with median TN concentrations five times the guideline value and TP concentrations over 6 times the guideline value for aquatic ecosystems. Upper and mid-estuary sites M2 and M3 were approximately double the ANZECC guideline levels for TN and TP in 2006/07. Sites in the same vicinity of M1 and M2, sampled in 2007/08 by the MER program as Zone 1 and Zone 2 showed TN levels only slightly in excess of ANZECC guidelines and TP levels similar to the 2006/07 results. In 2011/12 the combined MER transect data for the estuary showed TN levels slightly increased from 2007/08 and TP levels similar to 2007/08. Overall there appears to be an improvement in nitrogen concentrations through time in the Minnamurra River Estuary when comparing 2006/07 to 2007/08, however, 2011/12 levels show a rise in TN concentrations. TP concentrations have varied through time but remained steady and over double the ANZECC guideline levels since 2007/08.

While some improvements in nutrient concentrations in water samples are evident through time, the recommended guidelines for aquatic ecosystem health are not being achieved on average at most sites. Previous reporting and community consultation has nominated several potential nutrient sources in the catchment including agricultural practices (dairy effluent, cattle access to waterways, fertiliser use etc.), possible fertiliser use at the Minnamurra Golf Course, failing on-site sewerage management systems, stormwater from urban areas, landfill leachate and quarries. Management actions in the catchment should aim to identify and prioritise pollutant sources and implement controls to reduce nutrient export to waterways wherever possible.

Median chlorophyll a concentrations were within guideline levels for all sites and times except for site MER Zone 2 in 2007/08, where the median concentration was equal to the ANZECC guidelines (5µg/L). There were a number of occasions at Zone 1 and Zone 2 in 2007/08 where chlorophyll a was well in excess of guidelines (see maximum outliers for chlorophyll a in Figure 65) indicating there are occasions when algal growth is an issue in the mid and upper estuary.

The 2007/08 sampling of the upper and mid estuary sites (Zone 1 and Zone 2) showed slightly elevated pH levels compared to ANZECC guidelines for estuaries. It is possible that periodic algal blooms (indicated by instances of elevated chlorophyll a) could be responsible for the observed increases in pH. pH levels in 2006/07 were within threshold values at all sites. No data on pH were available for 2011/12.

Dissolved oxygen (DO) levels were within accepted ranges for aquatic ecosystem health at all sites except for Rocklow Creek (43.6% saturation) and site M3 in the mid estuary (77.2% saturation). More recent sampling in the Minnamurra River Estuary in 2007/08 and 2011/12 indicates increased overall DO at levels suitable for healthy aquatic ecosystems. It is noted that the more recent MER sampling was generally conducted in the afternoon when DO levels are at their peak, while the 2006/07 data were collected in the morning, when night time respiration by aquatic plants has reduced oxygen in the water column. Future sampling should standardise sampling times and aim to measure DO in the morning to assess any critical DO levels.

Turbidity was high and in excess of guideline levels at the Rocklow Creek site (12.1 NTU) in 2006/07. All other sites were within guideline levels during all years sampled, although there were a few isolated

occasions in 2006/07 where turbidity was in excess of guideline values (see max outliers for turbidity in Figure 65) indicating there are occasions when water clarity is an issue in the mid and upper estuary, a likely response following rainfall events.

Primary contact recreational guidelines were at levels indicating a 'substantially increased risk of illness to bathers (i.e. Enterococci between 201-500 cfu/100mL) at sites M2 in the upper estuary and R1 in Rocklow Creek in 2006/2007. Enterococci levels between 201-500 cfu/100mL implies non-sewage sources of faecal indicators (e.g. livestock) which need to be verified (NHMRC, 2008). These sites are located downstream of extensive areas of grazing land and are likely to be less well-flushed than the lower estuary, which may explain the high levels reported. On-site sewage management systems in rural areas are another possible source of bacterial contamination to waterways. This corresponds to earlier water quality data suggesting that faecal coliforms and nutrients tend to accumulate in the upper reaches of the Minnamurra estuary, but that tidal flushing generally maintains quality throughout the lower estuary (NSW Public Works, 2013). Sites M1 (freshwater) and M3 (mid estuary) had bacterial levels safe for bathing according to NHMRC guidelines. Enterococci were not sampled as part of the MER program in 2007/08 or 2011/12.

Site Observations

Water quality observations were also made during field work for the preparation of this CZMP as follows:

- There appears to be higher turbidity in the upper estuary in the vicinity of the Princes Highway overpass than other parts of the estuary although no monitoring data are available for this site. This may be a result of the sediment characteristics in this area (high carbonate content, a large proportion of organic and charcoal material, a relatively high silt and clay content and poor sorting as discussed in Section 3.2.6);
- Construction runoff with high sediment load was observed being discharged into Hyams Creek;
- Some of the farm drains appear to contain water that is stagnant, turbid and eutrophic (e.g. along Browns Lane and Factory Lane, Figure 66A); and
- The stormwater detention ponds at Gainsborough appear to contain excessive algae although current water quality data are not available to determine if this is impacting water quality in the Minnamurra River (Figure 66B).

A

B

Figure 66: Water quality observations

A – Farm drain (D. Wiecek, 2014), B – Gainsborough stormwater ponds

Appendix 7: Assessment of Current Erosion Sites

This appendix provides a preliminary identification and assessment of the current erosion sites based on the catchment assessment undertaken by KMC and OEH.

Assessment of Current Erosion Sites

Preliminary identification and assessment of the current erosion sites has been undertaken for this CZMP based on the catchment assessment undertaken by KMC and OEH. The assessment does not cover the entire catchment but focusses on the estuary, Terragong Swamp and areas of known erosion. Erosion is also occurring in many of the tributaries of the upper catchment due to a combination of poor condition of riparian vegetation, livestock access and grazing, steepness of banks, flooding and natural river meander. Further investigation will be required to identify upper catchment areas which require remediation.

The following sections present the extent and severity of erosion (based on height of erosion face and presence of vegetation), natural and built assets affected, likely impact on estuary health (e.g. water quality and seagrass impacts), existing erosion controls, key causes of erosion and photos and locations of the erosion sites.

Erosion risk has been assessed as shown in the following matrix.

Table 27: Erosion risk matrix

CONSEQUENCE	Minor	Moderate	Severe
Within close proximity (<20m) to significant assets or potential impact on estuary health	Low	Medium	High
Not within close proximity (>20m) to significant assets or potential impact on estuary health	Low	Low	Medium

LIKELIHOOD (observed erosion)

Lower and Mid-Estuary

Erosion controls (rock revetment and vegetation) have been installed along Minnamurra Headland, the Charles Avenue foreshore and Riverside Drive. While this has been largely successful and localised, erosion is occurring at the upstream and/or downstream extents of these controls (Sites 1-7 and 10). The erosion at Sites 8 and 9 appears to be scour caused by stormwater runoff. Sites 11 and 12 are located on the outside bends of the river and are due to natural river meander. Site 11 was identified as an erosion site in the 1995 EMP.

Figure 67: Locations of bank erosion sites in the lower to mid-estuary

Site 1 – Minnamurra Headland (C. Mason, 2015)

Site 2 – James Oates Reserve

Site 3 – Charles Avenue foreshore

Site 4 – Charles Avenue foreshore

Site 5 – Charles Avenue foreshore (this site has been repaired)

Site 6 – Charles Avenue foreshore

Site 7 - Charles Avenue foreshore

Site 8 – Trevethan Reserve (D. Wiecek, 2014)

Site 9 – Riverside Drive stormwater scour

Site 10 – Riverside Drive (D. Wiecek, 2014)

Site 11 – First meander (D. Wiecek, 2014)

Site 12 – Second meander (D. Wiecek, 2014)

Figure 68: Current erosion sites – lower and mid-estuary

Table 28: Current erosion sites and assessed risk in the lower and mid-estuary

ID	Location	Approximate length of erosion (severity)	Land use/ LEP Zoning [1]	Ownership	Existing erosion controls	Vegetation type/condition [2]	Built assets within 20m of bank	Causes of erosion	Assessed Risk
1	Right bank, Minnamurra Headland	50 m (minor)	Recreation, RE1	Council Reserve	Rock revetment upstream	Grassed reserve, trees/shrubs at either end, seagrass adjacent	None	Waves, boat wake, uncontrolled access	Low
2	Right bank, James Oates Reserve	70 m (minor)	Recreation, RE1, Residential, R2	Council Reserve	Rock revetment upstream	Grassed reserve, seagrass adjacent.	None	Waves, boat wake, uncontrolled access	Low
3	Charles Avenue foreshore, first (downstream) timber groyne. Above rock revetment.	10 m (minor)	Conservation, E2	Crown Land	Rock revetment at base of bank	Grassed reserve, seagrass adjacent.	Residential houses and property	Waterway access, flood scour	Low
4	Charles Avenue foreshore, second timber groyne. Above rock revetment.	5 m (minor)	Recreation, RE1	Council reserve	Rock revetment at base of bank	Grassed, ornamental plants (daisies), seagrass adjacent.	Residential houses and property	Flood scour	Low
5	Charles Avenue foreshore, opposite Links Street. Rock revetment collapse.	5 m (moderate)	Recreation, RE1	Council reserve	Rock revetment upstream and downstream	Grassed reserve, seagrass adjacent.	Residential houses and property	Rock revetment collapse, flood scour.	Medium

ID	Location	Approximate length of erosion (severity)	Land use/ LEP Zoning [1]	Ownership	Existing erosion controls	Vegetation type/condition [2]	Built assets within 20m of bank	Causes of erosion	Assessed Risk
6	Charles Avenue foreshore	8 m (minor)	Recreation, RE1	Council reserve	Rock revetment upstream and downstream	Low native vegetation (e.g. acacia, pigface) and grass, seagrass adjacent.	Residential houses and property	Waves, boat wake, end of rock revetment (continued scour with little sediment drift)	Low
7	Charles Avenue foreshore, opposite River Street	15 m (minor)	Recreation, RE1	Council reserve	Rock revetment upstream	Grass, pigface, seagrass adjacent.	Residential houses and property	Poorly vegetated, waves, flood scour	Low
8	Trevethan Reserve, near boat ramp	2m (minor)	Recreation, RE1, Conservation, E2	Council reserve	None	Grass, mangroves, seagrass adjacent.	Boat ramp, car park	Scour from overland flow	Low
9	Right bank, Riverside Drive	5 m (minor)	Conservation, E2	Road Reserve	None	Grass, mangroves, seagrass adjacent.	Shared path, parking, Riverside Drive	Stormwater scour	Low
10	Right bank, Riverside Drive, end of rock revetment	30 m (moderate)	Conservation, E2	Road Reserve	Rock revetment downstream	Grass, mature mangroves, seagrass adjacent.	Riverside Drive	River meander, channel scour	Medium
11	Right bank, first meander	145 m (minor)	Conservation, E2	Private	None	SEPP 14 Wetlands, Coastal Saltmarsh EEC, seagrass adjacent.	None	River meander, channel scour	Low

ID	Location	Approximate length of erosion (severity)	Land use/ LEP Zoning [1]	Ownership	Existing erosion controls	Vegetation type/condition [2]	Built assets within 20m of bank	Causes of erosion	Assessed Risk
12	Left bank, second meander of Minnamurra Bends	490 m (minor)	Conservation, E3, E2	Private	None	SEPP 14, Bangalay Banksia Forest EEC, seagrass adjacent.	None	River meander, channel scour	Low

1. KMC LEP 2011 zoning: RE1 - public recreation, R2 - Low density residential, E2 - Environmental Conservation, E3 - Environmental management
2. EECs mapped on Figure 25, page 46, SEPP 14 wetlands mapped on Figure 28, page 55, Seagrass mapped on Figure 27, page 53.

Upper Estuary and Lower Terragong Swamp

Figure 69: Locations of bank erosion sites in the upper estuary and lower Terragong swamp

Sites 13 and 14 are located on the outside bends of the river and are due to natural river meander and the lack of stabilising vegetation.

The formalised channel through Terragong Swamp (sites 15-18) is a narrow V-shaped incised channel with steep grade and steep banks which are prone to erosion. The rock ramps have reduced the grade of the channel, however, the channel attempts to naturally migrate as a morpohological reaction to draining of the swamp (which straigthened, shortened and steepened the channel and increased runoff due to catchment clearing). Bank erosion is exacerbated by stock access and fallen trees which cause flow obstructions. Much of the channel shows signs of slumping or erosion.

Site 13 – Princes Highway bridge (D. Wiecek, 2014)

Site 14 – Downstream Swamp Road (D. Wiecek, 2014)

Site 15 – Lower Swamp, upstream Swamp Road (D. Wiecek, 2014)

Site 16 – Lower Swamp

Site 17 – Lower Swamp

Site 18 – Browns Lane

Site 19 –

Figure 70: Current erosion sites – upper estuary and lower Terragong Swamp

Table 29: Current erosion sites and assessed risk in the upper estuary and lower Terragong Swamp

ID	Location	Approximate length of erosion (severity)	Land use/ LEP Zoning [1]	Ownership	Existing erosion controls	Vegetation type/ condition [2]	Built assets within 20m of bank	Causes of erosion	Assessed Risk
13	Right bank, adjacent to and downstream of Princes Highway bridge	40 m (minor)	Grazing, E2	Private	Rock revetment downstream at bridge pylons	Pasture grass, juvenile casuarinas, mature casuarinas at either end, snags, Swamp Oak Floodplain Forest EEC, SEPP 14 wetlands.	Fencing, Princes Highway	Flood scour, channel meander	Low
14	Left bank, midway between highway bridge and Swamp Road bridge.	88 m (moderate)	Grazing, E2	Private	None	Pasture grass, severely undercut. Mature casuarinas approx. 10 m back from eroding face, Swamp Oak Floodplain Forest EEC, Coastal Saltmarsh EEC, SEPP 14 wetlands.	None	Channel meander, flood scour, poorly vegetated	Medium
15	Left bank, on straight upstream from Swamp Road bridge.	135 m (minor)	Grazing	Crown Land	Rock ramp upstream	Pasture grass slumping into channel.	None	Poorly vegetated, cattle access, flood scour, channel meander	Low
16	Left bank, mid swamp	27 m (severe)	Grazing/ Pasture, RU1	Private	Rock ramps upstream and downstream	Pasture grass slumping into channel.	Fencing	Channel meander, high, steep bank, scour behind tree, flood scour, lack of riparian vegetation	Medium

ID	Location	Approximate length of erosion (severity)	Land use/ LEP Zoning [1]	Ownership	Existing erosion controls	Vegetation type/ condition [2]	Built assets within 20m of bank	Causes of erosion	Assessed Risk
17	Left bank, mid swamp, mouth of farm drain	30 m (moderate)	Grazing/ Pasture, RU1	Private, Crown	Rock revetment along downstream bank. Rock ramps upstream and downstream	Pasture grass and various weeds. Large amounts of flood debris lining bank	Fencing	Flood scour, channel meander, lack of riparian vegetation	Medium
18	Left bank, upstream of Browns Lane bridge	10 m (moderate)	Grazing/ Pasture, RU1, E3	Road Reserve, Private	Rock ramp downstream	Pasture grass slumping into channel. Trees at either end of erosion	Fencing	Flood scour, high, steep bank, poorly vegetated	Medium
19	Left and right bank, Jerrara Creek downstream of Jamberoo Road bridge.	10m (moderate) each bank	Grazing, RU1	Road Reserve, Private	None	Pasture grass	Fencing	Cattle access, poorly vegetated	Medium

1. KMC LEP 2011 zoning: E2 - Environmental Conservation, E3 - Environmental management, RU1 – Primary Production
2. EECs mapped on Figure 25, page 46, SEPP 14 wetlands mapped on Figure 28, page 55, Seagrass mapped on Figure 27, page 53.

Hyams Creek

Figure 71: Locations of bank erosion sites in Hyams Creek

Erosion at sites 20 and 21 on Hyams Creek is caused by the poor condition of bank vegetation, flood scour and natural river meander.

Site 20 – Hyams Creek

Site 21 – Hyams Creek

Figure 72: Current erosion sites – Hyams Creek

Table 30: Current erosion sites and assessed risk in Hyams Creek

ID	Location	Approximate length of erosion (severity)	Land use/ LEP Zoning [1]	Ownership	Existing erosion controls	Vegetation type/ condition	Built assets within 20m of bank	Causes of erosion	Assessed Risk
20	Right bank, Hyams Creek upstream from Wyalla Road bridge	40 m (severe)	Grazing, RU2	Private	None	Pasture grass,	Fencing	Channel meander, poorly vegetated, flood scour	Medium
21	Right bank, Hyams Creek	30 m (severe)	Grazing, RU2, E3	Crown Land, Private	None	Pasture grass slumping into channel	Fencing	Channel meander, flood scour, poorly vegetated	Medium

1. KMC LEP 2011 zoning: E3 - Environmental management, RU2 - Rural Landscape

Appendix 8: Potential Grant Funding

This Appendix provides a summary of potential grant funding available to implement this CZMP. This list is provided as a guide only to indicate the range and type of funding programs that are available at the time of preparation of this CZMP. The status of grant programs and availability of funding is continually reviewed in accordance with policy development and priorities.

Agency	Program Name	Description	Criteria/Objectives
State Government			
OEH	NSW Estuary Management Program and Coastal Management Program	The NSW Government's Coastal Management Program's primary objective is to provide support to local councils to manage the risks from coastal hazards such as coastal erosion. A secondary objective of the program is to restore degraded coastal habitats. The NSW Government's Estuary Management Program provides support to councils to improve the health of NSW estuaries and understand the potential risks from climate change. The support provided to councils under these programs includes financial assistance to: • prepare (or update) coastal zone management plans and associated technical studies (including estuary health and coastal hazard assessments) • undertake actions to manage the risks associated with coastal hazards and to protect or improve coastal environments and estuary health. Grant offers are subject to availability of funds for each financial year and statewide priorities. Funding of up to 50% of a project's costs will normally be offered for successful grant applications.	There are two grant categories: • Coastal management grants; and • Estuary Management Grants Under the Coastal Management Program, the NSW Government provides coastal management grants to support local government in managing the risks from coastal hazards, such as coastal erosion, and restoring degraded coastal habitats. Under the Estuary Management Program, the NSW Government provides estuary management grants to support local government work to improve the health of NSW estuaries. Projects which can be subsidised under the program include: • preparation (or updating) of coastal zone management plans and associated technical studies (including coastal hazard assessments) • action to manage the risks from coastal hazards • action to implement environmental repairs, including habitat restoration and conservation projects • pre-construction activities for projects that are eligible and are likely to proceed to construction • development of management tools (such as education projects).

Agency	Program Name	Description	Criteria/Objectives

OEH	NSW Floodplain Management Program	The Floodplain Management Program supports the implementation of the NSW Government's Flood Prone Land Policy as outlined in the NSW Government's Floodplain development manual. The primary objective of the policy is to reduce the impacts of flooding and flood liability on communities and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.	Continuing staged projects and new projects that may be funded include:
			• Preparation of a flood study (including data collection);
			• Prepare or review floodplain risk management study and plan
			• Investigation, design and (where required) completion of a feasibility study for works identified in a floodplain risk management plan (this stage must be undertaken for any works projects that are likely to exceed a total project cost of $500,000)
			• Implementation of actions identified in a floodplain risk management plan, including but not limited to:
			  ○ structural works, such as levees, detention basins, flood gates and improved flow conveyance
			  ○ flood warning systems
			  ○ evacuation management
			  ○ voluntary purchase or house raising.
			Assistance under the program is normally offered by the State Government providing $2 for every $1 provided by the council.

OEH	Environmental Restoration and Rehabilitation Grants	The aim of the Restoration and Rehabilitation (R&R) program is to facilitate projects to prevent or reduce pollution, the waste stream or environmental degradation of any kind, run by community organisations and State and Local government organisations. These projects also aim to improve the capacity of communities and organisations to protect, restore and enhance the environment.	The objectives of the Environmental Restoration and Rehabilitation program are: • to restore degraded environmental resources, including rare and endangered ecosystems • to protect important ecosystems and habitats of rare and endangered flora and fauna • to prevent or minimise future environmental damage • to enhance the quality of specific environmental resources • to improve the capacity of eligible organisations to protect, restore and enhance the environment • to undertake resource recovery and waste avoidance projects and to prevent and/or reduce pollution. The Trust will call for applications to the Restoration and Rehabilitation program in August 2014

Agency	Program Name	Description	Criteria/Objectives
OEH	Environmental Education Grants	The aim of the Environmental Education program is to support educational projects or programs that develop or widen the community's knowledge of, skills in, and commitment to protecting the environment and promoting sustainable behaviour.	The Objectives of the Environmental Education Program are: • facilitate changes in behaviour of individuals and groups which affect specific environmental problems • develop and promote education projects that improve the environment.
OEH	Protecting Our Places	The aim of the Protecting our Places program is to protect land that is culturally significant to Aboriginal people and to support education projects about the environment and its importance in Aboriginal life.	The objectives of the Protecting our Places program are: • to restore or rehabilitate Aboriginal land or land that is culturally significant to Aboriginal people • to educate Aboriginal and other communities about the local environment and the value Aboriginal communities place on their natural environment.
DPI (Fisheries NSW)	Habitat Action Program	Supports the improvement of recreationally important fish populations, engages recreational anglers in fish habitat actions through the Fishers for Fish Habitat project, provides devolved habitat action grants to enhance fisheries in NSW. The Habitat Action Program is funded by the revenue raised by the NSW recreational fishing fee. Habitat Action Grants - Angling clubs, individuals, community groups, local councils and organisations interested in rehabilitating fish habitats in freshwater and saltwater areas throughout NSW can apply for grants.	Habitat rehabilitation projects which may be funded include: • removal or modification of barriers to fish passage • rehabilitation of riparian lands (river banks, wetlands, mangrove forests, saltmarsh) • re-snagging waterways with timber structure • removal of exotic vegetation from waterways • bank stabilisation works • reinstatement of natural flow regimes Habitat Action Grants are available in August each year and require the completion of a habitat-specific Funding Application form. Funding applications must relate to the enhancement of recreational fishing through the improvement of fish habitat. Successful projects are usually funded for one year, however funding may be sought for multi-stage projects that take place over a number of years (e.g. two or three year projects).

Agency	Program Name	Description	Criteria/Objectives
DPI (Fisheries NSW)	Recreational Fishing Trust	All money raised by the NSW Recreational Fishing Fee is placed into the Recreational Fishing Trusts and spent on improving recreational fishing in NSW. The Trusts have provided funding to a wide range projects including: • recreational fishing enhancement • recreational fishing education • fishing access and facilities • aquatic habitat rehabilitation and protection • research on fish and recreational fishing • enforcement of fishing rules - fisheries officers.	Fishing clubs and organisations, universities, councils, community groups, individuals can apply for grants
Roads and Maritime Services	Partnerships	A 'Partnership' would apply to any funding or value in kind (VIK) made available to individuals or organisations to support specific programs or events deemed mutually beneficial.	Programs or events that help deliver, align with, or raise awareness of key objectives outlined in the Results and Services Plan are eligible and cover: • ports to support a growing economy • safe and sustainable waterways; and • improved infrastructure and access to waterways. Any application for a Partnership with RMS would be considered against the backdrop of financial responsibility of public money and resources. This reinforces the need for all partnerships to demonstrate a clear and direct benefit to the boating, maritime and/or maritime property community aligned with appropriate objectives.
NSW Trade and Investment – Crown Lands	Public Reserves Management Fund	Funding is available to develop, maintain and improve land and facilities, including for recovery from natural disasters and the protection of heritage and the environment.	The Public Reserves Management Fund Program (PRMFP) provides financial support for the development, maintenance and improvement of public reserves. Round 2 of the 2014-15 PRMFP is currently expected to commence in August 2014. Applications will be accepted at that time from the managers of caravan parks, state parks, showgrounds and local parks and reserves.

Agency	Program Name	Description	Criteria/Objectives
Federal Government			
Australian Government	Indigenous Heritage Program	The Indigenous Heritage Program (IHP) is an Australian Government initiative that supports the identification, conservation, and promotion (where appropriate) of Indigenous heritage.	Individual project funding for organisations will in general be available up to a maximum of $100,000 (GST exclusive). Individual applicants will generally be eligible for funding up to $5000. Applications for more than these amounts may be considered where the applicant demonstrates special circumstances or a genuine requirement for additional funds. The IHP may also help identify places likely to have outstanding Indigenous heritage value to Australia suitable for inclusion on the National Heritage List.
Other			
Local Land Services	Managing Coastal Wetlands	South East LLS has Australian Government biodiversity funding available to support landholders in priority areas to undertake works on coastal wetlands including salt marsh, mangroves, riparian areas, coastal floodplains, swamps, lakes and estuarine areas.	Funding can be used to manage and protect coastal wetlands including: • fencing to control stock and unauthorised recreational access; • off-stream stock watering points; • removal and control of weeds including blackberry, sharp rush, arrowhead, invasive vine species such as madeira vine, and Japanese honey suckle; • feral animal control including fox, rabbit, deer, goat and pig; • removal of barriers to flow such as removal or modification of floodgates and/or crossings; and • revegetation to maintain and connect vegetation buffers, address erosion or improve habitat. Properties must encompass or be adjacent to wetland areas within priority areas (including Minnamurra River)

Agency	Program Name	Description	Criteria/Objectives
Local Land Services	Landholder and Community Resilience	This program delivers services to farmers, landholders, Landcare and Aboriginal community groups and other partners across the South East region that seek advice on natural resource and biosecurity management. It focuses on building the knowledge and skills of landowners and the community on: • pest plant and animal management • biosecurity and animal welfare • use and care of natural resources • preparedness for natural disaster and biosecurity emergencies.	Landcare and landholder services - These services increase the engagement, capacity and involvement of landholders, groups and networks to participate in pest plant and animal, biosecurity and natural resource management. Aboriginal community services - These services increase the engagement, capacity and involvement of Aboriginal landholders and community groups to participate in pest plant and animal, biosecurity and natural resource management. Regional Landcare facilitation - These services increase the engagement, capacity and involvement of Landcare groups and networks to participate in pest plant and animal, biosecurity and natural resource management.
Local Land Services	Profitable and Sustainable Farming	This program delivers services to farmers and agricultural groups in priority primary production industries (grazing, diary, mixed farming, cropping, viticulture and aquaculture) to assist the South East region's $460 million food and fibre economy. It focuses on providing advice and projects that support enterprises and industries to be more profitable and sustainable including: • agricultural services • pest plant and animal management • biosecurity and animal welfare • use and care of natural resources • preparedness for natural disaster and biosecurity emergencies	Grazing industry services - These services support graziers across the South East region to adopt practices that improve the profitability and sustainability of their enterprise. Dairy industry services - These services support dairy farmers across the South East region to adopt practices that improve the profitability and sustainability of their enterprise.
Transport for NSW	NSW Boating Now - Boating Infrastructure Partnership Program	Funds are allocated according to the Regional Boating Plans.	

Agency	Program Name	Description	Criteria/Objectives
Landcare	20 million trees Programme	The Australian Government will work with the community to plant 20 million trees by 2020, to re-establish green corridors and urban forests.	Round 1 closed 30 October 2014. Applications for grant funding between $20,000 and $100,000 will be accepted from eligible groups, individuals and organisations that intend to plant native trees and associated understorey in a range of urban, peri-urban and regional environments across Australia. Tree plantings may occur on public or private land.