Government Gazette

of the State of

New South Wales

Number 102
Friday, 22 September 2017

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By Authority
Government Printer

ISSN 2201-7534

COUNCIL NOTICES

KIAMA MUNICIPAL COUNCIL

COASTAL PROTECTION ACT 1979

Section 55H

Gazettal and Commencement of a Coastal Zone Management Plans

Kiama Municipal Council with the certification of the Minister for Planning, have prepared and adopted the Coastal Management Plans for Crooked River and Minnamurra River in accordance with section 55 of the *Coastal Protection Act 1979*.

The Coastal Zone Management Plans will help guide the future management of the Crooked River and the Minnamurra River. The Plan contains a series of management aims, objectives and associated actions to help protect and enhance the rivers, their foreshores and catchments and promote public access to the waterways.

The Plans will remain in force until such time as they are amended or repealed by Coastal Management Programs that replace them.

The Plans may be viewed on Council's website at

Crooked River

http://www.kiama.nsw.gov.au/ArticleDocuments/621/17%2014045%20%20Final%20Coastal%20Zone%20Management%20Plan%20for%20the%20Crooked%20River%20Estuary%20v1%2009022017.pdf.aspx

Minnamurra River

http://www.kiama.nsw.gov.au/ArticleDocuments/722/Minnamurra-CZMP-low-res.pdf.aspx

A hard copy may be viewed at Council's main office.

COASTAL ZONE MANAGEMENT PLAN FOR THE CROOKED RIVER ESTUARY

Final Version November 2015

Kiama Municipal Council has prepared this document with financial assistance from the NSW Government through the Office of Environment and Heritage Estuary Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

Crooked River Coastal Zone Management Plan

Kiama Municipal: Paul Czulowski, Byron Robinson

NSW Office of Environment and Heritage: Gabrielle Pietrini, Danny Weicek

Crooked River Estuary Management Plan Review Committee Members – Clr Andrew Sloan, Bill Preston, Brian Sharpe, Susan Griffiths, Howard Jones, Michael Gleeson, Dr Michael Hindmarsh, Rod Thomas

Revision	Description	Author	Approval	Date
1	Correction of inconsistencies and minor issues raised by Sydney Water	Byron Robinson	Paul Czulowski	9 February 2017

Executive Summary

The Crooked River Estuary Management Plan (CREMP 2003) was developed and adopted by Kiama Municipal Council in 2003. This followed on from the formation of an estuary management committee in 1993 and various studies and reports culminating in the completion of a data compilation study in 1998 which informed the development of the plan. The Crooked River Coastal Zone Management Plan (CRCZMP) recognises the achievements of the CREMP 2003 and seeks to identify new and ongoing threats to the health of the Crooked River estuary, and propose management responses which aim to maintain and improve estuary health. Since the development of the CREMP 2003, the evidence and awareness of 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 Coastal Zone Management Plan (CZMP) has flagged the potential issues associated with climate change impacts and identified important research priorities for the future.

This review has been conducted in line with the requirements of the NSW Government '*Guidelines for Preparing Coastal Zone Management Plans'*, and the CRCZMP supports the goals of the *NSW Coastal Policy 1997*.

Preparation of the CRCZMP included consultation with the local community, landholders and both public agency and private industry stakeholders. Similar to the original community consultation undertaken for the CREMP 2003, the main values and issues raised by the community centered around the natural beauty and tranquility of the Crooked River estuary, and the safe and clean environment it provides for the community to utilise for passive and active recreation.

The key management issues identified under this CZMP have been grouped under key strategic areas, these are:

1. Management of catchment inputs
2. Estuary processes
3. Management of aquatic and terrestrial biodiversity
4. Balancing community uses, cultural heritage and ecological values
5. Governance and implementation.

Within these 5 strategic areas there are a number of key management issues which are addressed by actions which aim to deal with the pressures on estuary health and maintain community access and areas of significance. These issues include:

- management of faecal and nutrient inputs into the Crooked River and its tributaries
- management of acid sulfate soils and mitigation of runoff events which occur periodically
- management of identified bank erosion and sources of sediment
- management of riparian areas in the estuary and its tributaries
- management of terrestrial and aquatic biodiversity
- research into the potential climate change impacts on estuary health and agricultural productivity
- ensuring strategic implementation of on ground works throughout the catchment
- ensuring the community can access information relating to the Crooked River estuary.

The management actions have been listed in Chapter 9 of this management plan.

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1. INTRODUCTION

The Crooked River estuary and wider catchment is located within the Kiama Municipal Council and Shoalhaven City Council Local Government Areas at the northern end of Seven Mile Beach, 130 kilometres south of Sydney. The review of the Crooked River Estuary Management Plan 2003 was started in 2013, with financial assistance from the NSW Government estuary management program and technical support provided by the NSW Office of Environment and Heritage staff.

1.1 2003 CROOKED RIVER ESTUARY MANAGEMENT PLAN

Preparation of the first Crooked River Estuary Management Plan 2003 (CREMP 2003) was preceded by the formation of the Kiama Municipal Council Estuary Management Committee in 1993. The committee was formed to engage key stakeholders and community representatives for information and advice on estuary management issues within the Kiama LGA. This process lead to a number of studies on estuary health and baseline condition, culminating in the preparation of the Estuary Data and Compilation Study (1998) which was a key step to informing the preparation of the CREMP, finalised in 2003.

The CREMP 2003 has been the primary document guiding natural resource management investment and actions in the catchment for the past decade. With the introduction of the new Coastal Zone Management Guidelines, new legislation and new information pertaining to the potential impacts of climate change and sea level rise, the Plan is in need of review to consider these new and emerging issues. In the decade since its development, there have been a number of major projects and changes within the catchment of the Crooked River, including:

- the closure and rehabilitation of the former landfill and night soil depot at Seven Mile Beach, Gerroa
- the extension of the sand mine adjacent to Blue Angle Creek
- the construction of the Gerringong to Berry Bypass (under construction at the time of plan review)
- the expansion of the Gerringong urban area within the Union Creek catchment
- connection of the townships of Gerringong and Gerroa to sewer.

These changes have happened in parallel with the achievements of the CREMP 2003 and the review of the Plan gives Council, the community and government agency stakeholders the opportunity to identify issues from the previous plan which are still current, report on actions that have been achieved and recognise issues which may no longer be relevant.

1.2 PURPOSE OF THE REVIEW

The primary purpose of the review of the CREMP 2003 is to articulate proposed actions to be implemented by Kiama Municipal Council (KMC), other public authorities, land holders and private sector stakeholders to address priority management issues for the Crooked River estuary. The new CZMP seeks to protect and enhance this much valued community asset and maintain ecosystem function to ensure the Crooked River remains a healthy and viable natural ecosystem into the future. Specific management actions will seek to address and balance the following issues:

- pressures on estuary health
- community use of the estuary
- impacts of future predicted climate change and sea level rise

KMC has received funding through the NSW Estuary Management Program, to undertake the review of the CREMP 2003 and produce the updated Crooked River Coastal Zone Management Plan (CRCZMP).

1.3 Coastal Zone Management Process

The primary purpose of a Coastal Zone Management Plan (CZMP) is to integrate strategies and facilitate actions across government organisations and the community to balance both the community needs and ecological needs to restore, maintain and enhance coastal environments and estuary health.

The Crooked River Coastal Zone Management Plan (CRCZMP) has been prepared in accordance with part 4A of the *Coastal Protection Act 1979*, and the minimum requirements of the *'Guidelines for Preparing Coastal Zone Management Plans'*, (DECCW, 2010[2]). The review of the CREMP 2003 in this context relates to Section 55C clause 1(e) which stipulates, '*where the plan relates to an estuary, the management of estuary health and any risks to the estuary arising from coastal hazards'*.

The CRCZMP will inform and complement Council's and other organisations' strategic documents that aim to manage and reduce the impacts of human activities and development within the catchment. Priority management actions will be incorporated in Council's Delivery and Operational Plans for implementation as funding and resources become available or are allocated. The review of the plan also allows Council the opportunity to identify and plan for future climate change impacts, both in terms of researching the effects on human activities and infrastructure and importantly identifying estuary health implications.

The fundamental principles for the preparation of CZMP's to address estuary health are to:

- consider the objectives of the Coastal Protection Act 1979 and the goals, objectives and principles of the NSW Coastal Policy 1997 and the impacts of sea level rise
- optimise links between plans relating to the management of the coastal zone
- involve the community in decision making and make coastal information publicly available
- base decisions on the best available information and reasonable practice; acknowledge the interrelationship between catchment, estuarine and coastal processes; and adopt a continuous improvement management approach
- prioritise public expenditure for public benefit; public expenditure should cost-effectively achieve the best practical long-term outcomes
- maintain the condition of high value coastal ecosystems; rehabilitate priority degraded coastal ecosystems.

The CRCZMP supports the goals and objectives of the NSW Coastal Policy 1997 and assists in implementing integrated coastal zone management for the Crooked River estuary and its catchment.

The NSW Coastal Policy is the NSW Government's main objective document guiding the response to the challenges of achieving future sustainable growth on the NSW coastline, balancing environmental, economic, cultural and recreational needs. The policy is based on two fundamental principles of ecologically sustainable development and integrated coastal zone management.

The *NSW Coastal Policy 1997* applies to urban and non-urban non-metropolitan areas along the NSW coast covering land:

- three nautical miles seaward of the mainland and offshore islands
- one kilometre landward of the open coast high water mark; and
- one kilometre around all bays and estuaries.

The *NSW Coastal Policy 1997* has nine goals and a number of objectives under each goal which are:

1. to protect, rehabilitate and improve the natural environment
2. to recognise and accommodate natural processes and climate change

3. to protect and enhance the aesthetic qualities
4. to protect and conserve cultural heritage
5. to promote ecologically sustainable development
6. to provide for ecologically sustainable human settlement
7. to provide for appropriate public access and use
8. to provide information to enable effective management
9. to provide for integrated planning and management.

At the time of preparation of this CZMP, the NSW Government was reforming its approach to coastal management in NSW. Future review of the CRCZMP will consider the policy context in place at that time.

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

1.4 The Study Area

Figure 1, depicts the Crooked River catchment area over which this plan applies. The study area comprises the tidal waterways and foreshore adjacent to the Crooked River estuary including the entrance and tributaries. Greater emphasis is placed on the estuarine reach, however consideration is given to other areas of the catchment where issues or processes are potentially affecting estuary health, as the condition of the estuary is heavily influenced by catchment wide factors.

The catchment area of Crooked River is $32km^2$ and is predominantly rural, with natural vegetation extensively cleared for dairy and beef cattle grazing. Other land uses and operations within the catchment include two large holiday parks, a rehabilitated landfill site, a waste water recycling plant, a large vineyard, extractive industry (sand mining), and urban areas of Gerringong and Gerroa. According to the report '*Assessing the condition of estuaries and coastal lake ecosystems in NSW*' (2011), prepared by the NSW Office of Environment and Heritage (OEH), Crooked River has an estuarine area of $0.28km^2$ including areas classified as saltmarsh.

The main tributaries of the Crooked River are Blue Angle Creek, which extends to the south of the main Crooked River channel just west of the road bridge, and Union Creek which travels through parts of Gerringong's urban and industrial zones and large tracts of rural land.

The townships of Gerringong and Gerroa are popular tourist destinations, and the two holiday parks located on the shores of the Crooked River provide excellent access to the estuary and recreational activities. Popular recreational activities include kayaking / canoeing, swimming and recreational fishing undertaken by residents, day visitors and campers.

The estuary is intermittently closed to the ocean by a sand berm which forms where the river entrance meets the northern end of Seven Mile Beach. The estuary has a large area of mud flats, exposed at low tides in the mid and upper estuary and small patches of mangroves and saltmarsh fringing the main channel and flats west of the road bridge.

Terrestrial vegetation is made up of large areas of Bangalay sand forest Endangered Ecological Community (EEC), Blackbutt Banksia forest and small patches of Littoral Rainforest (EEC) in the Seven Mile Beach Reserve and areas adjoining the Blue Angle Creek. There are stands of *Casuarina glauca* floodplain forests (EEC) in the mid and upper parts of the main channel and fringing some of the tributaries where they enter the estuary. Seagrass is found throughout the system although is limited in the upper part of the estuary, with greatest distribution in the mid part of the estuary west of the road bridge. There are small areas of saltmarsh and mangroves in the middle part of the estuary and there are no listed SEPP 14 wetlands within the Crooked River. The area is recognised as providing habitat for a number of threatened species of flora and fauna and the nationally recognised Coomondery Swamp is located in the adjacent catchment.

The study area contains the former Gerroa Waste Depot and Landfill site, which was closed in 2003 and is being rehabilitated and monitored in accordance with an approved EPA Landfill Closure Plan.

There is also a sand mining operation in the Blue Angle Creek catchment, which is operated by Cleary Brothers under an EPA licence, approved for operation until 2023. The property also contains a significant network of drains which have facilitated the drainage of Foy's Swamp and allowed agricultural production. Agricultural drains are also present on other properties in the catchment and throughout the region.

The Gerroa Wastewater Recycling Plant (Gerroa WRP) is located adjacent to the confluence of Blue Angle Creek and the Crooked River main channel. The Gerroa WRP was commissioned in 2002 and is an advanced tertiary treatment plant which services the townships of Gerringong and Gerroa. Treated waste water is utilised for irrigation of an agricultural property directly adjoining the upper Crooked River estuary.

As can be seen from the aerial photograph in Figure 1, the catchment is predominantly cleared of vegetation apart from the significant vegetation around the Seven Mile Beach National Park and Gerroa WRP, and patches of vegetation linking to the escarpment in the upper reaches of tributaries feeding the Crooked River.

The Crooked River catchment area was highly prized for its cedar trees during the early 1820's, which was quickly followed by the establishment of the agricultural industry once the land had been cleared. The Crooked River catchment continues to provide productive and strategically important agricultural land for the dairy, beef and wine making enterprises present there today. There is also evidence of the significance of the site to the local aboriginal people of the Wodi Wodi aboriginal tribe with shell midden and artefact scatters located on properties around the estuary, including the Gerringong Gerroa WRP site.

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Figure 1: Crooked River catchment and natural drainage

1.5 Management Context

The Crooked River catchment consists of large areas of rural dairying, grazing and lifestyle properties, Council reserves, Crown reserve, National Park and small urban and commercial areas. Whilst the Crooked River CZMP is developed and reported on by Kiama Municipal Council, a number of agencies and state government authorities have a regulatory and/or management role in the catchment including:

- Kiama Municipal Council and Shoalhaven City Council are responsible for the management of public spaces, assets and facilities around the Crooked River catchment within their respective local government areas. Councils also prepare Local Environment Plans, which guide planning decisions within their local government areas through zoning and Development Control Plans (DCPs). Both Council's are also responsible for enforcing environmental legislation including the *Protection of the Environment Operations Act 1997*, and ensuring compliance with relevant environmental legislation when it comes to development.

- The NSW Department of Trade and Investment – Crown Lands (Crown Lands), is responsible for managing public land through the Crown Reserve system. This encompasses the dry land and the submerged land of the State's waterways 5.5km out to sea and includes the ocean floor, most coastal estuaries, many large river beds and coastal wetlands.

- The NSW Office of Environment and Heritage – National Parks and Wildlife Service, is responsible for the management of Seven Mile Beach National Park estate, conserving and enhancing the important vegetation and providing access and facilities to the general public. The Office of Environment and Heritage also provides grant funding and technical support to councils in the preparation of CZMPs and floodplain management plans through its Coast and Estuaries Programs.

- The NSW Local Land Services (LLS) is the newly formed department bringing together technical and advisory knowledge from Livestock and Pest Authorities, Catchment Management Authorities and some agricultural advisory services from the Department of Primary Industry. The Local Land Services is focused on farmers, landholders and the community across rural and regional NSW. The core responsibilities of LLS will be to bring together agricultural production advice, biosecurity, natural resource management and emergency management into a single organisation.

- Sydney Water Corporation owns the Gerroa WRP, operated by Veolia Water. The WRP treats waste water from the Gerringong and Gerroa townships to an advanced tertiary level and irrigates recycled wastewater on a farm property within the catchment.

- The NSW Department of Primary Industries – Fishing and Aquaculture, regulates recreational fishing, investigates fish kills, and manages invasive aquatic species and species listed as threatened under the *Fisheries Management Act 1994*. They also have a role in assessing proposed developments which could harm the aquatic environment, providing advice and consent conditions as part of the process.

- The NSW Environment Protection Authority regulates licensed industries in the Crooked River catchment including the Cleary Brothers Sand Mine, the former Gerroa Waste Depot and the Gerroa WRP, as well as providing environmental controls and regulation on state managed projects such as the Gerringong to Berry Princes Highway upgrade.
- NSW Roads and Maritime Service is responsible for the upgrade of the Princes Highway between Gerringong and Berry, including ensuring sediment and erosion controls are in place

during the planning and construction phase and runoff and stormwater detention infrastructure post construction.

- Sydney Trains, (formerly Railcorp) are responsible for managing the rail infrastructure, train services and maintaining the rail corridor running through the Crooked River catchment.

2. Review of Crooked River Estuary Management Plan 2003 Actions

Of the 97 actions outlined in the previous CREMP 2003, 26 actions were fully completed, 53 actions are ongoing or partially complete and 18 actions were incomplete or had no action. Some of the incomplete actions are still relevant as they pose a threat to the health of Crooked River, and these have been carried over into the Crooked River CZMP to hopefully gain more effort or funding in the future.

The detailed assessment of the management actions, their status, and reasons as to why they may not have been implemented can be seen in Appendix 1.

To assist with the prioritisation of management actions under the CRCZMP the issues have been aligned under management areas which reflect the CZMP Guideline objectives regarding estuary health, climate change impacts and community uses of the coastal zone. These areas are:

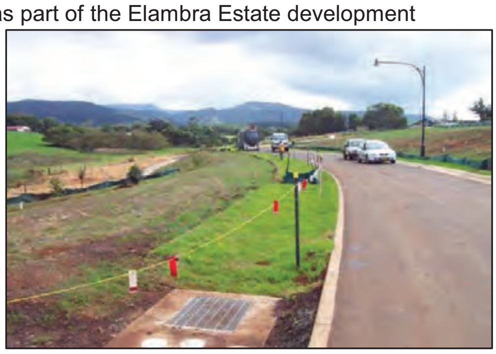
- management of catchment inputs
- estuary processes
- management of aquatic and terrestrial biodiversity
- balancing community uses and ecological values
- governance and Implementation.

2.1 Summary of Completed Actions

A number of the major CREMP 2003 actions that have been completed are listed below: (Refer to Appendix 1 for the full assessment of the actions under the CREMP 2003.)

- gross pollutant traps (Enviropods) installed in stormwater drains in Burke Parade Gerroa and Elambra Estate Gerringong.
- catchment caretakers program implemented in Gerroa and Gerringong
- wetland / riparian improvements completed as part of the Elambra Estate development
- entrance opening policy position developed by Kiama Council
- townships of Gerringong and Gerroa connected to sewer.

It must be noted that a number of the actions identified in the CREMP 2003 are ongoing and will continue to be ongoing due to the nature of the issues they are trying to address. For example some of the actions relating to weed control, water quality monitoring and development controls.



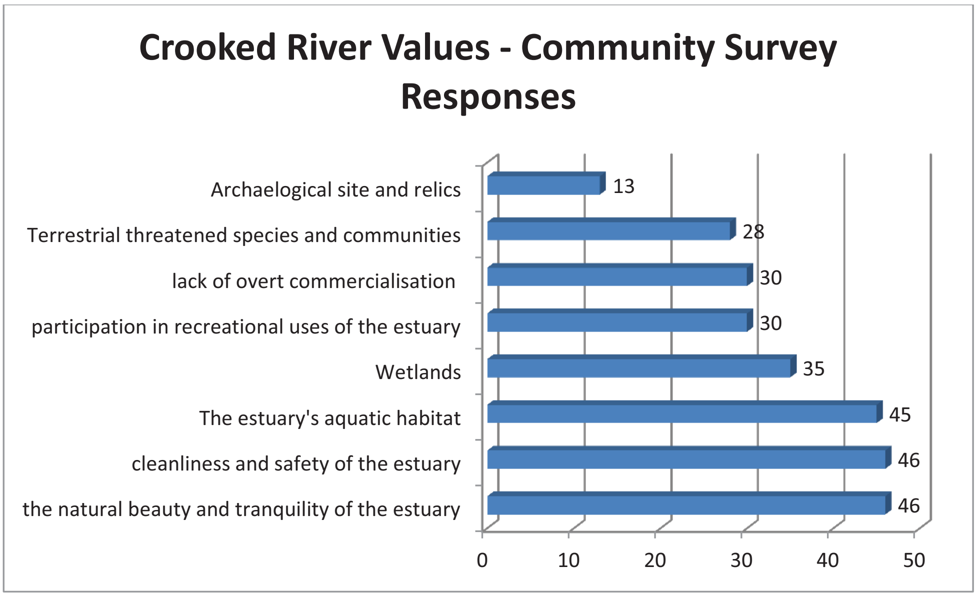
Union Creek riparian works in Elambra Estate

3. Consultation Activities for the Crooked River Coastal Zone Management Plan

3.1 Community Survey

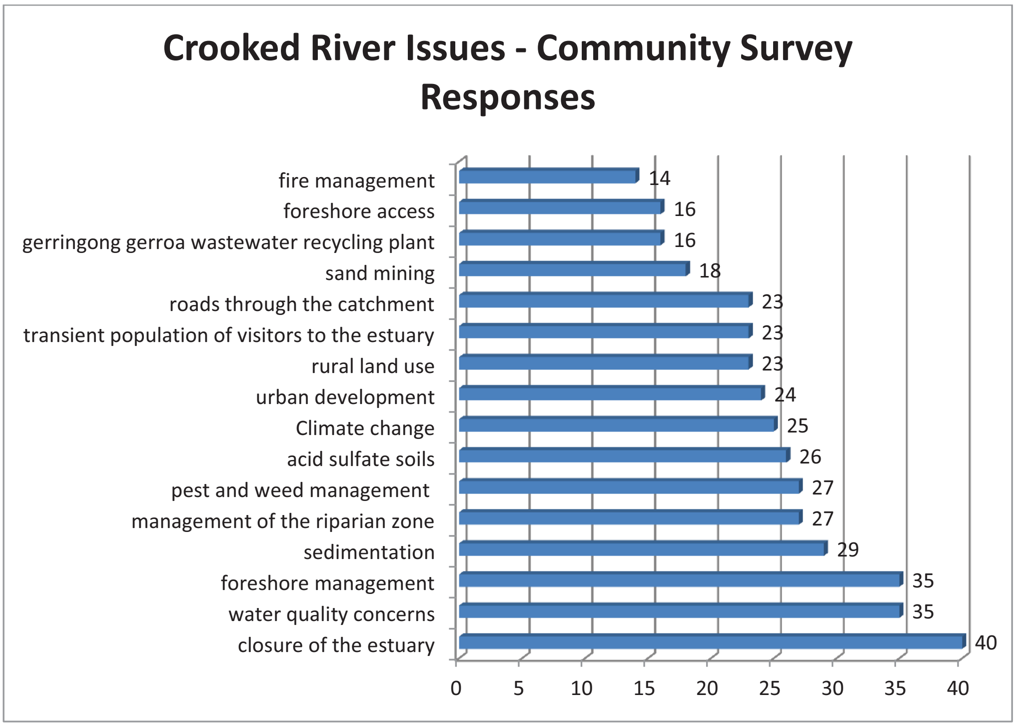
A survey relating to the review of the Crooked River Estuary Management Plan 2003 was distributed to the catchment area via letter box drop, and made available on-line for completion on Council's website. Fifty three survey responses were received from community members during the response period.

The following graph provides a summary of the community survey responses relating to the values for the Crooked River estuary.



As well as identifying the values that the community rated as important for the Crooked River estuary, there were a number of issues which were identified. Many of these issues were similar or the same as those identified in the consultation for the CREMP 2003. The issues are summarised in the following graph which illustrates the major issue of concern for the respondents was the closure of the entrance. This reflects the original community survey undertaken for the Crooked River Estuary Management Plan 2003. Many of the comments relating to other issues centered around:

- concerns over water quality and the potential for sewage overflow from the Gerroa WRP and holiday parks and poor water quality for swimming when the entrance is closed
- sedimentation of the river, with a perception that this is being caused by the sand mining and agricultural activities within the catchment, and is being exacerbated by the road bridge
- runoff from rural and urban areas and the new highway impacting on water quality
- foreshore management, acid sulfate runoff and climate change were less commented on but raised by a few survey respondents as issues for future management



The Crooked River Coastal Zone Management Plan Review Committee was presented with the results of the community survey, and discussed the main issues from their perspective as representatives of the catchment community. A range of issues were identified and have been listed below:

- there were concerns that not enough was done regarding the recent fish kill in Blue Angle Creek, to determine the cause of the incident. A collaborative approach to dealing with the issue into the future was identified for inclusion in the CRCZMP
- in-filling west of the road bridge was identified as needing further research to determine if there was anything exacerbating the in-filling and the source of the sediment
- education in the community around the entrance opening policy position of council, and why estuaries are not artificially opened unless in exacerbating circumstances
- maintaining access and amenity to the beach via the footbridge and potential to move the boat ramp to a more suitable location
- drainage of low lying land and land use practices increasing sedimentation rates needs to be dealt with under the CRCZMP
- educating the community on the Aboriginal significance and cultural heritage of the area, including collection of oral history of areas within the Crooked River catchment.

3.2 Government and Non Government Stakeholder Engagement

Government and non-government stakeholders attended a meeting at Kiama Council chambers in July 2013 to discuss the issues raised via the community survey, provide organisational perspectives on the issues, identify any other issues within their sphere of influence and to suggest potential management strategies to achieve the objectives of the CRCZMP.

Representatives from NSW Department of Primary Industries (Fisheries), NSW Office of Environment and Heritage, Sydney Water Corporation / Veolia Water and Cleary Brothers all provided valuable input into the issues identified in the Crooked River Catchment.

Some of the key management issues are identified in more detail below:

- entrance management should be maintained to allow a natural opening regime wherever possible, if trigger values are to be considered for artificial opening it should be because of risk to human health
- NSW Fisheries can put out temporary signage when the entrance is closed warning of risks and penalties for opening the entrance illegally
- communicate the entrance management policy position to catchment stakeholders to enhance community understanding
- develop a water quality report card which is simple and communicates relevant information
- monitor and enforce sediment control measures in urban areas and construction sites
- commit to ongoing weed control and revegetation in areas of Bailey's Island similar to works being undertaken in Seven Mile Beach Reserve
- investigate potential for best practice demonstration site to be established in catchment regarding land use and riparian management;
- work with landholders to control stock access to the foreshore and banks of the main channel of the Crooked River and its tributaries;
- revegetate / erosion control mitigation in Blue Angle Creek where there is erosion occurring in the holiday park
- work collaboratively on dealing with acid sulfate soil runoff in the catchment, and put forward research proposals to University of Wollongong and other research institutions where appropriate.

4. Summary of Estuary Processes

4.1 Physical Characteristics

The key physical characteristics of the Crooked River estuary are outlined below in Table 1.

Characteristics	Data	Notes
Catchment area	31.99 km^2	
Estuary area	0.28 km^2	Estuary area, volume and depth measured at 0.6m Australian Height Datum (AHD) as described in Roper et al. 2011
Estuary volume	141 ML	Based on areas at 0.6m AHD (Roper et al 2011)
Average depth	0.54 m	Estimated by dividing the total volume at 0.6m AHD by the total surface area of the estuary including mangrove areas but excluding saltmarsh (Roper et al 2011)
Seagrass extent	0.046 km^2	Based on 2005 mapping as part of Comprehensive Coastal Assessment
Mangrove extent	0.008 km^2	
Saltmarsh extent	0.017 km^2	

Table 1: Physical Characteristics of Crooked River Estuary

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4.2 Geomorphic Evolution

The Crooked River estuary is classified as a mature riverine barrier estuary according to the Roy et al. (2001) model, because of the estuaries advanced stage of natural infilling. Barrier estuaries are described as being separated from the open sea by a sub-aerial barrier of marine sand. There is evidence of a small tsunami or exceptionally large storm, in the form of an extensive marine sand sheet in the upper fill area which is likely to be the result of an overwash event in the late Holocene. The small accommodation space of the Pleistocene embayment appears to have rapidly infilled to its present state and the estuary may have become river dominated as early as 2000 years ago (Switzer pers comm., 2003).

The sediments of the Crooked River catchment relate directly to the volcanic geology types. Silt and clay-rich sediments occur in much of the vertically accreted floodplain areas, as these sediments weather from the volcanic and volcani-clastic rocks of the catchment. Heavy rain occasionally flushes the estuary, carrying much of the fine sediment to sea. Thus sediments of the estuary are generally mixed quartz and lithic muddy sands and muds, which give the estuary a ‘murky’ appearance during wet weather (Switzer pers comm, 2003).

River dominated estuaries such as Crooked River infill with fluvial sediment to form deltas. These deltas prograde seaward to form shoals, sub embayments and a series of bifurcating distributary channels. Mature riverine estuaries such as the Crooked River are characterised by sinuous channels discharging to the sea, with smooth levee banks and floodplain deposits covering the former basin (Roy et al, 2001). The Crooked River is at this semi mature to mature stage of infilling, and a single channel flanked by levee and floodplain deposits is clearly visible in aerial photographs. The entrance is frequently closed to the sea as part of the natural process of the estuary.

Analysis of the sources of modern sediment and their movement patterns and cycles conducted by Dunwoodie 2004 revealed that marine sands occur from the entrance up to about 1 kilometre upstream from the road bridge, with estuarine sandy muds dominating the upper estuary.

4.3 Current Land Use and Zoning

The Crooked River estuary is highly valued as an area of natural beauty, which is relatively undisturbed and supports recreational activities for locals and tourists. Many community responses have raised concerns over ongoing water quality and sedimentation which can affect not only estuary health, but recreational amenity as well. The ecological health of the Crooked River estuary is heavily influenced by inputs from the largely cleared catchment areas, which can input nutrients, sediments and faecal contaminants during high flow events. Historically, higher inputs have also occurred at certain times of year depending on land use practices such as fertilizer application and activities such as drain clearing have the potential to mobilize sediments and organic matter which can affect the main estuary water quality.

Whilst the main Crooked River estuary generally maintains good water quality throughout the year, however poor water quality can be experienced following rainfall when catchment runoff can flush nutrients and faecal contaminants into the estuary. When the mouth of the river is open these pollutants are flushed out to sea, but build up of nutrients and faecal contaminants can occur when the mouth is closed to the sea, due to a combination of marine sand building up at the river mouth and reduced flow conditions during below average rainfall conditions. The estuary is well flushed by tides when open to the ocean, and has a reported flushing time of 4.2 days (OEH, 2011).

Kiama Council’s Local Environment Plan 2011, and Shoalhaven Local Environment Plan 2014 define Land Use Zones as described by the NSW Department of Planning Standard Instrument LEP Program, which allows councils and other consent authorities to manage the way in which land is used. Figure 2 illustrates the land zoning within the Crooked River catchment, and Table 2 identifies the percentage of land the different zonings occupy within the catchment boundaries. As can be seen from the land zoning table, the majority of the catchment is zoned as RU1 Primary Production (50.62%) and RU2 Rural landscapes (23.49%). Combined with the environmental zonings E2 Environmental Conservation (10.57%) E3 Environmental Management (4.73%) and E1 National Parks and Nature Reserve (1.81%), these two broad land use zoning areas cover over 90% of the catchment area. The remaining zones relate to areas of road and rail infrastructure and the urban areas of Gerringong and Gerroa.

Primary production is an important part of the Kiama and Shoalhaven Local Government Area's identity. These land use practices, coupled with high rates of land clearance within the catchment can put pressure on estuary health from increased nutrient input, sedimentation and faecal bacterial contamination. It is essential that the CRCZMP recognizes the importance of agricultural productivity within the catchment and the resulting impacts on ecosystem health, and proposes strategies and management actions which can maintain and improve estuary ecosystem health whilst supporting the needs of agricultural operations and recreational users.

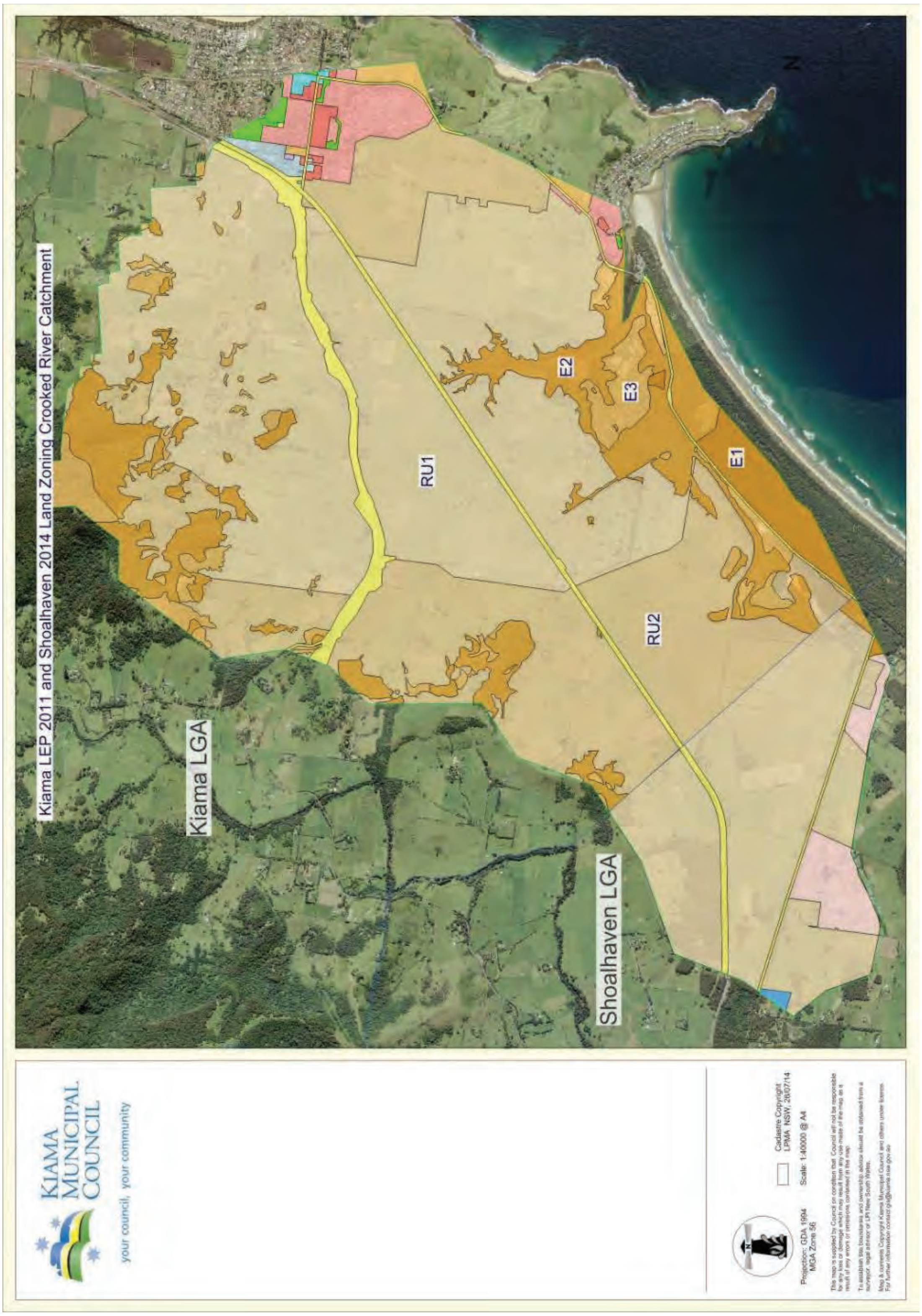

Figure 2: Land Use Zoning in Crooked River catchment

Land use Zone	Area m^2 in KMC LGA	Area m^2 in SCC LGA	Total Area Crooked River Catchment	% of total catchment area
B1 – Neighbourhood Centre	6,674	-	6,674	0.02%
B2 – Local Centre	33,774	-	33,774	0.11%
B7 – Business Park	95,684	-	95,684	0.30%
E1 – National Parks and Nature Reserve	557,078	10,482	567,560	1.81%
E2 – Environmental Conservation	3,282,315	38,404	3,320,719	10.57%
E3 – Environmental Management	1,485,912	-	1,485,912	4.73%
IN2 – Light Industrial	3,506	-	3,506	0.01%
R2 – Low Density Residential	745,008	-	745,008	2.37%
R3 – Medium Density Residential	113,464	-	113,464	0.36%
R5 – Large Lot Residential	-	520,981	520,981	1.66%
RE1 – Public Recreation	80,982		80,982	0.26%
RU1 – Primary Production	11,635,695	4,262,102	15,897,797	50.62%
RU2 – Rural Landscape	7,378,064		7,378,064	23.49%
RU4 – Primary Production small lots	-	26,951	26,951	0.09%
SP2 – Fire station	2,283	-	2,283	0.01%
SP2 – Town Hall	323	-	323	0.00%
SP2 – Railway	273,840	112,436	386,276	1.23%
SP2 – Classified Roads	673,749	67,413	741,162	2.36%
Total	**26,368,351**	**5,038,769**	**31,407,120**	

Table 2: Land Use Zoning within the Crooked River Catchment

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4.4 Climate and predicated Climate Change

4.4.1 Regional Climate

The closest Bureau of Meteorology (BOM) weather station to the Crooked River is located at the Kiama Bowling Club, which is approximately 12 kilometres to the north. This station has been keeping weather records since 1897. Local Toolijooa landholder Bryan Sharpe of 'Nyora' who owns land on the western bank of the Crooked River has also been keeping rainfall records since 1967, which is collated by the BOM at its climate data online portal. Table 3 below summarises the temperature data from the Kiama Bowling Club station and the rainfall data taken at Toolijooa.

Statistics	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Mean Rainfall	134.8	162.3	160.4	122.3	107	132.8	65.1	75.2	75.2	99.7	111.5	87.9	1393.2
Lowest	25	10.1	11	5	0.4	6.8	1	3.4	6.6	0	17.6	5.4	644.5
Highest	398.3	484.4	510.4	561.8	423	621.8	249.2	545	231.8	428.2	321.4	305	2258
Mean Temp	25.2	25.2	24.3	22.3	20.1	17.7	16.9	18.2	20	21.8	22.4	24.3	
Highest monthly mean	27.1	27.8	26	23.7	21.6	19.7	18.2	20.2	21.9	25.4	24.1	26.7	
Lowest monthly mean	23	23.2	22.7	20.5	19.1	16.8	15.8	16.9	18.1	20.1	20.9	22.6	

Table 3: Climate statistics for the Crooked River region (note: data changes with updated rainfall statistics)

As can be seen from the statistics in Table 3, the wettest months are from January to June. The hottest months are January and February and the coldest month is July.

4.4.2 Climate Change

Climate change is a challenge for the future management of the coastal environment, and the predicted impacts will change the way humans are able to interact with and utilise the estuary and wider catchment area. The NSW DECCW 2010[3] produced a report on the impacts of climate change on the biophysical environment in NSW which included the following predictions for the Illawarra region:

Expected physical responses

- Sea level is virtually certain to rise.
- Increased evaporation is likely to lead to drier conditions in spring and winter.
- Run-off is likely to decrease moderately in spring but increase substantially in summer.
- Short term hydrological droughts are projected to become more severe, while medium and long term droughts are projected to become less severe.
- Flooding behaviour is likely to change. The combination of sea level rise and catchment driven flooding is likely to increase flood frequency, height and extent in the lower portions of coastal floodplains.
- Fire regimes are likely to change, but changes to fuel availability are uncertain.

Impacts on land

- Rising sea level is virtually certain to increase coastal recession. Sea level rise and storms are virtually certain to increase coastal inundation and erosion causing additional recession of erodible coastline.
- Increased sediment shedding due to higher rainfall is likely to change river channels and cause sediment inundation in coastal floodplains.
- Stream bank erosion is likely to increase. Increased rainfall in summer and more intense storms are likely to lead to increased run-off to streams in the summer months, producing stream bank erosion, particularly where greater flow is coupled with higher water tables in lower floodplain areas and declines in bank stabilising vegetation.
- Acid sulfate soil problems are likely to continue in the short term, but reduce over the longer term. It is likely that the initial rise in sea level will cause saline waters to inundate some areas with acid sulfate soils, leading to a structural decline of the soil.
- Organic matter in soils are likely to increase in most areas, but decline in some coastal swamps.
- Sea level rise, flooding and increased rainfall are likely to affect Aboriginal cultural heritage values.

Impacts on settlements

- Sea level rise is virtually certain to threaten many settlements near estuaries and beaches
- Most property boundaries referenced to high water mark will change.
- Existing coastal protection structures are extremely likely to be affected.
- Major roads and other infrastructure are very likely to be affected. Sewage infrastructure known to be currently at risk includes Gerroa WRP.
- Flooding from urban streams is likely to increase.
- Sea level rise is virtually certain to increase flooding risks near the coast.
- The combined effects of sea level rise, increased flood flows and higher water tables are likely to cause saline waters to inundate some agricultural coastal plains. Agriculture on some low lying areas is likely to become unsustainable.
- Water supplies are likely to be affected by hydrological changes.

Impacts on ecosystems

- Sea level rise is likely to threaten coastal ecosystems. Rising water tables and saltwater intrusion are likely to affect lowland ecosystems in the coastal zone.
- Sea level rise is likely to threaten some estuarine communities. Sea level rise and shoreline retreat are likely to induce a large-scale modification or loss of intertidal and sub-tidal ecosystems as water depth, turbidity, sedimentation, pH, temperature and salinity change. Seagrasses are likely to be displaced from some of their current extent and their ability to re-colonise is difficult to predict. Mangroves and saltmarshes are also likely to be displaced, but new mangrove habitat should form in other places including areas currently occupied by saltmarsh. Changes in the species composition of estuarine invertebrate communities is likely to adversely affect estuarine food webs and result in decline in some fish populations.
- Climate change is likely to reduce migratory shorebird habitat and populations.
- Altered fire regimes are likely to cause widespread changes in many ecosystems.
- Highly fragmented ecosystems are likely to come under added pressure from climate change.

The predicted effects of climate change over the longer term are wide ranging and serious. To develop appropriate management strategies for this CZMP it was necessary to consider actions related to a problem which is already occurring and/or which could be exacerbated by climate change impacts in the shorter term. For the Crooked River estuary these include:

- Increased evaporation and an increase in short term hydrological droughts is likely to increase the chances in the short term of exposing acid sulfate soils to the atmosphere, and hence increase the risk of acid sulfate runoff.
- Increased sediment shedding and stream bank erosion due to changes in storm intensity is likely to occur within the catchment, potentially leading to increased infilling of the Crooked River basin.
- More research is needed to identify both the potential effect of salt water intrusion from a rise in water tables on mangrove and saltmarsh extent within the catchment, as well as determining the effect on productive agricultural land.
- Coastal hazards assessments will be required to determine future potential exposure of infrastructure and property to the effects of sea level rise and climate change impacts, particularly from storm surge and shoreline recession.

4.4.3 Predicted Sea Level Rise

As part of its Stage 1 coastal management reforms, the NSW Government announced that councils would have the flexibility to determine their own sea level rise projections to suit their local conditions and would no longer prescribe state wide sea level rise projections for use by councils. Prior to these reforms, the NSW Government had released a Sea Level Rise Policy Statement 2009, which adopted sea level rise benchmarks of 0.4m by 2050 and 0.9m by 2100 relative to 1990 levels.

In the absence of any Kiama specific sea level rise projections, Kiama Council has adopted the benchmarks as described in 2009 by the former NSW Government policy, until further research is available. Simple inundation modeling was undertaken to determine likely scenarios for 2050 and 2100 in relation to tidal conditions due to sea level rise. The tidal plots comparing Crooked River estuary tides and ocean tides are shown in Figure 5. These show that when the tide enters into the Crooked River estuary there is very little attenuation of the high tide, however the low tide appears to be greatly attenuated.

Consideration for mapping of the propagation of the sea level into the Crooked River was determined by looking at the exceedance data for the Jervis Bay tide gauge, as this data was unavailable for the Port Kembla tide gauge.

The Mean High Water Spring (MHWS) level was chosen to be mapped as this corresponded with an annual exceedance of 10%, which means that this would represent a fairly common occurrence. Coincidentally the Highest Astronomical Tides (HAT) in the sea level rise scenarios at 0.4m and 0.9m correspond closely to the AHD levels of 1.5m and 2.0m, making it easy to compare both MHWS and HAT levels for 2050 and 2100.

Furthermore, modelling of the catchment showed that up to 1.5m AHD there is very little variation in the inundation level. At 2m there is nearly a doubling of the area of inundation compared with 1.5mAHD (J Floyd OEH, pers comm. 2013). Table 4 describes the estimated tidal inundation heights at 2050 and 2100 for the MHWS level and the Highest Astronomical Tide (HAT).

Tidal Plane	**Current tide m AHD**	**2050 for Crooked River mAHD (+0.4m)**	**2100 for Crooked River mAHD (+0.9m)**
Mean High Water Springs (MHWS)	0.63m	1.03m	1.53m
Highest Astronomical Tide (HAT)	1.13m	1.53m	2.03m

Table 4: 2050 and 2100 MHWS and HAT for Crooked River Estuary

In the medium term to 2050, the more severe impact of inundation is likely to come from the closed berm conditions and interaction with rainfall which will occur in the Crooked River catchment in the future. A maximum berm height of 1.9m AHD for the Crooked River was determined as part of the Crooked River Flood Study Ocean Tail Water Control report, prepared by the Snowy Mountains Engineering Corporation in 2002. This means that without even considering the rise in sea level, the maximum berm height is already near the predicted highest astronomical tide for 2100 under the 0.9m sea level rise scenario.

Given this Plan is looking at effects of tidal inundation as a result of sea level rise, the scope of considering flooding from closure due to the berm levels is more appropriate for more detailed consideration in the floodplain management plan and coastal hazard studies which are to be developed in the future. Figures 3 (a), (b) and (c) have been included to indicate likely areas which may be impacted by the predicted tidal inundation at 1.5m and 2.0m AHD. It must be noted that this is a preliminary assessment, and detailed modeling, validation and cleansing of the LiDAR data to identify and remove errors has not been undertaken as part of this process.

It is apparent from the 2.0m AHD inundation map, that there is a potential for inundation of existing infrastructure and agricultural land. It will be particularly important in the near future to research in more detail catchment flooding levels and predicted effects of coastal hazards, and to develop appropriate future management options for mitigation and adaptation for both infrastructure and agricultural activities.

Figure 3 (a): Crooked River tidal inundation mapping 1.5m

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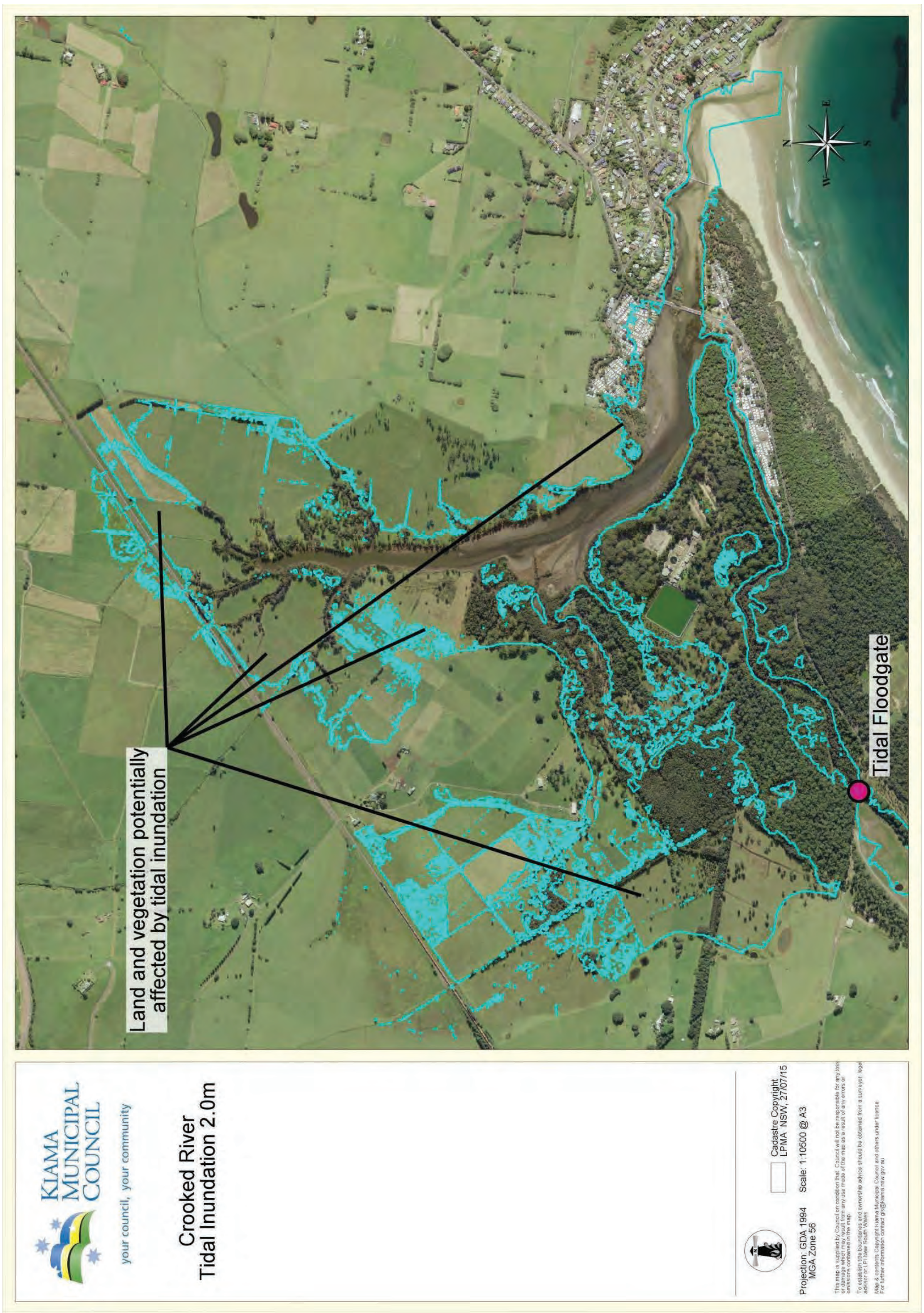

Figure 3 (b): Crooked River tidal inundation mapping 2.0m Map 1

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Figure 3 (c): Crooked River tidal inundation mapping 2.0m Map 2

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4.5 Estuarine Hydrodynamics

4.5.1 Flooding

The Crooked River originates with an elevation of around 300-400m AHD at Currys Mountain, as a number of secondary streams and tributaries, flowing in a south easterly direction into coastal floodplains before discharging into the ocean via the estuary. The Crooked River floodplain includes the low-lying areas to the south west of Gerringong, generally between Toolijooa Road or the Princes Highway and the railway line (RTA, 2010). There have been substantial drainage works in the area to drain the low lying flood plain to improve agricultural productivity. An extensive area of low lying swamps and swales border the Crooked River along its lower reaches. These areas which are generally at an elevation of less than 2m AHD, have slopes of less than 0.5% and are characterised by poor draining soils with a high water table at or near the surface. These areas provide a flood fringe storage area in which some flood volume is stored but which provide minimal flood conveyance because of shallow flow and high hydraulic resistance (Evans and Peck 2005). Crooked River broadens substantially as it enters the estuary proper and towards the outlet to the ocean at the northern end of Seven Mile Beach.

The entrance conditions at the mouth of the river are a key factor determining flood levels in the river. In the absence of flood conditions, water level in the river will primarily be controlled by sea level, but will be elevated slightly above sea level because of the hydraulic retardance of the entrance bar. In a major flood, the floodwater will scour a channel through the sand shoal at the entrance of the river. The rate of development of the scour channel and the final size of the channel will govern the peak flood level in the Crooked River. The process of scour is, in turn governed by the ocean level at the time that the flood occurs. The relative timing of the peak ocean level and the peak flood flow will dictate the resulting flood level in Crooked River and Foys Swamp (Evans and Peck 2005).

Due to the flood gates on the Blue Angle Creek, flooding conditions in Foy's Swamp are largely governed by rainfall in the catchment, with the prevailing ocean levels and entrance conditions of lesser importance (Evans and Peck 2005). The same study also finds that Foy's Swamp has a very large storage capacity relative to the surrounding catchment and it would be expected that within that catchment, impacts from a range of flood levels between common and rare floods would be relatively minor.

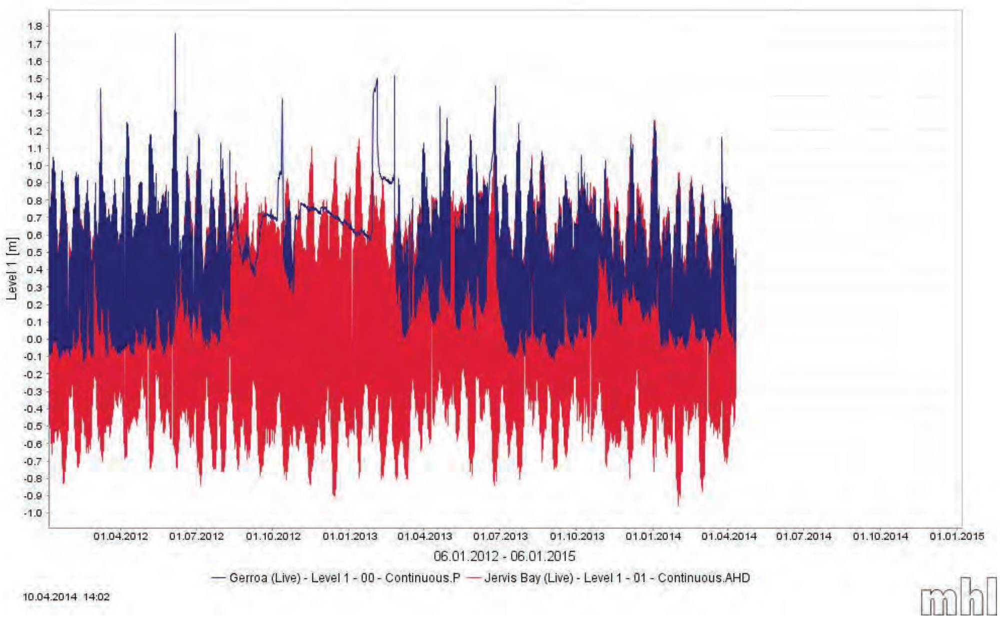
The flood study undertaken as part of the development of the Gerroa WRP found that flooding in the Crooked River is generally predicted to be contained within the wide downstream sections of the creek, but spills out across the flat flood plain when it runs north west along the eastern side of the railway line.

Anecdotally, minimal inundation does occur along parts of the foreshore of the Holiday Park fronting the northern bank of the Crooked River and the pedestrian underpass for Crooked River Road is periodically under water (Figure 4). As well as inundation, flood waters have particular impact in the scouring of creek / river banks. A recent incident following a major rain event occurred in the Blue Angle Creek in February 2014 (right), where scouring of the channel exposed the bank sediments to the atmosphere and washed large amounts of organic matter into the creek. Subsequent oxygen demand of the decaying matter and natural sulfate reducing bacteria most likely were responsible for low dissolved oxygen conditions, a sulphurous odour and a small number of fish mortalities.

Figure 4: Flooding of the pedestrian underpass at the Crooked River Road Bridge, Gerroa in January 2012

4.5.2 TIDES

A tidal environment influences the Crooked River estuary when the entrance is open, and due to the river's in-filled nature, tides are enhanced. This facilitates the deposition of marine sediments in the lower reaches of the estuary, leading to sometimes extended periods of closure. Whilst the tidal range of the Crooked River is at times significantly less than the ocean, it appears from the water level gauge data that the high tide propagates into the estuary at near 100% of the ocean tide. This is demonstrated in Figure 5, which is the Crooked River water level gauge data, overlaying the HMAS Creswell (Jervis Bay) ocean tide gauge data. A flushing time of 4.2 days (OEH 2011), means that Crooked River is relatively well flushed when compared with other Intermittently Closed and Open Lakes and Lagoons (ICOLLs).



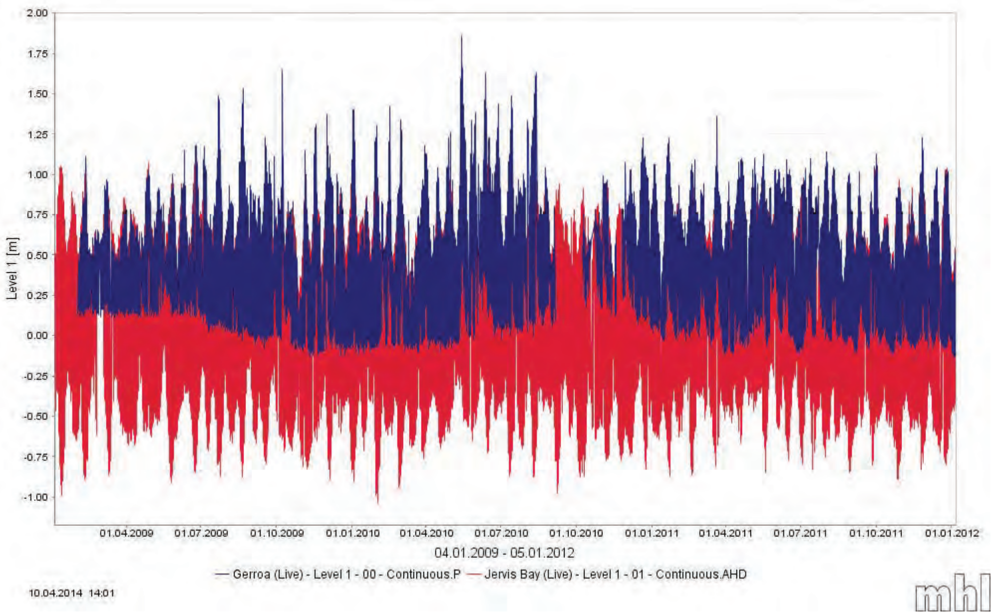


Figure 5: Crooked River water level gauge data overlaying HMAS Creswell ocean tidal gauge data

4.5.3 Entrance Condition and Estuary Opening

The Crooked River has been classified as a 'barrier estuary', under the Roy (1984) classification system for estuaries in NSW. Barrier estuaries are described as being separated from the open sea by a sub-aerial barrier of marine sand. The water body is connected to the sea by a sinuous narrow channel that attenuates a tidal range in the estuary basin. Tidal gauge data displayed in Figure 5 suggests that the main estuary basin generally receives the full high tide, but is attenuated to approximately 50% of the full tidal range, due to the estuary being perched, not draining below about 0m AHD or mean sea level.

The Crooked River estuary is relatively small and shallow and strongly tidal, with periods where the estuary is closed to the sea by a berm at its entrance. Climatic irregularities and the effects of El Nino and La Nina on fluctuating periods of flood and drought have had an impact on the Crooked River catchment, mainly on sedimentation rates and entrance conditions. In periods of low discharge, (drought), sedimentation at the entrance can result in entrance closure, while in periods of high discharge, (floods), heavy rainfall within the catchment often results in the opening of the mouth as well as inundation of floodplain areas within the catchment.

The Crooked River estuary has been described in a study by Dunwoodie (2004) as in an advanced stage of evolution, due to the shallow nature of the entire estuary, and the continuing sedimentation within the estuary. However according to Switzer (pers comm. 2004), the Crooked River appears to be in a state where its evolutionary progression has been stalled between the semi-mature and mature stage of its evolutionary progression. This is mainly due to the entrance closure of the estuary as a result of the low hydraulic head of the river and the subsequent shoaling at the entrance. This sediment is then scoured out of the estuary during floods, however it will promptly return during dry periods. Therefore the cycle of sedimentation and scour has resulted in the Crooked River failing to reach a full stage of maturity, where the river would be characterised by an open river entrance (Switzer pers comm., 2004)

Manly Hydraulics Laboratory have maintained a water level gauge on behalf of the OEH since 2 February 1999. Entrance closure and opening has been identified from observing the stop and start of a tidal signal from the available graphed data (D Weicek OEH, 2015). Table 5 identifies closure and opening of the Crooked River entrance, however for 3 periods (denoted with a * in the table) it is not clear whether or not the entrance closed due to the relatively short duration. There are also periods over the last 15 years where data has not been collected by the gauge, so it is possible that closures may have been missed, but it is considered unlikely due to the relatively small number of data gaps and the short time period of these gaps.

Entrance closure date	Entrance opening date	Water level height at opening	Closure duration	Open duration
16/06/2001	10/07/2001	1.21	~ 1 month	~ 2.5 years
21/11/2001	4/02/2002	1.56	~ 2.5 months	~ 4 months
30/06/2002	29/04/2003	1.47	~ 10 months	~ 5 months
5/05/2003	13/05/2003	1.26	~ 1 week	~ 1 week
9/09/2003	23/11/2003	1.43	~ 2.5 months	~ 4 months
1/03/2004*	7/03/2004*	0.91	~ 1 week	~ 3 months
31/05/2005	26/06/2005	1.21	~ 1 month	~ 14.5 months
10/04/2006	6/06/2005	1.5	~ 2 months	~ 10 months
29/10/2006*	5/11/2006*	0.83	~ 1 week	~ 16.5 months
17/11/2006	27/02/2007	1.56	~ 3.5 months	~ 2 weeks
18/09/2012	12/10/2012	1.38	~ 3 weeks	~ 5 years
28/10/2012	24/02/2013	1.51	~ 4 months	~ 4 months
18/06/2013*	24/06/2013*	1.3	~ 1 week	~ 4 months

Table 5: Periods of identified entrance closure and opening from the Gerroa water level recorder situate in the Crooked River

Between February 1999 and May 2015, 13 separate periods of entrance closed conditions have been identified, with the closure ranging from 1 week to 10 months, but typically in the order of a few weeks to months. The total duration of closed entrance conditions compared to the full record equates to approximately 15% of the time. The duration the entrance stays open ranges from 1 week to around 5 years, but is typically for a period of several months to over a year. This data indicates that the Crooked River is a predominantly open ICOLL (D Weicek OEH, 2015).

It should also be noted that a significant portion of the data has been recorded during a period of exceptionally dry conditions (2000-2009), where other ICOLLs on the South Coast experienced longer and more frequent periods of closed conditions. This may bias the degree of entrance closed to entrance open conditions for the Crooked River and hence the above recent data may not be an accurate reflection of average entrance conditions over a longer time scale. The full Crooked River entrance state analysis can be seen in Appendix 4.

4.5.4 Crooked River Entrance Opening Policy Position

Following the development of the CREMP 2003, and the subsequent study by Dunwoodie 2004, Kiama Municipal Council developed the Crooked River Entrance Opening Policy Position. The full policy position is included as Appendix 2.

The Crooked River Estuary Management Committee investigated the need for a formal entrance opening policy for Crooked River, and concluded at the time that the footpath under the Crooked River Road Bridge and the lower portion of the Holiday Park on the northern side of the river will be flooded, but no permanent dwellings were at risk.

The Kiama Municipal Council Policy Position adopted in 2005 stated that:

- Council's Policy Position is that Crooked River Entrance system be allowed to open naturally, unless there are extenuating circumstances, as flooding is not a threat to any permanent dwellings in the catchment; and
- This Policy position be included in the review of the Crooked River Estuary Management Plan.

The issue of the entrance closing is still a concern in the wider community, and there have been incidents of illegal opening of the estuary entrance. One such instance on 4 February 2013 led to the sand around the boat ramp at the mouth of the Crooked River being washed away, demonstrating not only that unmanaged opening of the entrance can cause ecological damage, but can also affect different user groups who utilise the facilities at the Crooked River entrance. The water level gauge data also shows that this artificial opening only led to a partial draining of the estuary, and not a reinstatement of tidal flow, with the full opening of the system occurring on 24 February 2013 following heavy rainfall. This is depicted in Figure 6.

There is still a perception in some areas of the community that the entrance of the river should be permanently open to the ocean to enhance flushing, and should be dredged to return the channel depth. This shows that there is still work to be done in communicating how systems like the Crooked River naturally function, and how the past opening and removal of sand at the entrance has been quickly returned.

The Entrance Management Policy Position of Kiama Municipal Council was developed after the CREMP 2003, and was identified to be included in the review of the CREMP 2003. The Policy Position will need to be reviewed by the relevant agencies in the future to identify whether there are any new extenuating circumstances under which the estuary may be opened and to identify if circumstances around decision making have changed. This should be considered in the context of threat to human/estuary health as flooding of assets has been identified as not being a consideration for opening of the entrance due to no permanent dwellings being at threat.

This may include adding in clauses such as:

> "Artificial opening may be required to address extreme water quality issues such as contaminant spills where it may be desirable to provide some 'draining' of the river. However, it is not considered practical to include triggers to address a broad range of potential water quality scenarios within the entrance opening policy. A range of factors would need to be considered during a water quality crisis, including:
>
> (a) environment and public health risks posed by the water quality issue
> (b) the extent to which artificial opening will mitigate the water quality issue
> (c) consequent environmental and public health risks along the adjoining coastline following artificial opening of the river."

The Entrance Opening Policy does not include trigger values for water quality issues, and it is recommended that any water quality crisis is assessed on an individual basis. If artificial opening is considered an appropriate option to address a water quality crisis, then Council will engage with the appropriate regulatory and advisory bodies in the NSW Office of Environment and Heritage and NSW Fisheries to determine the best course of action.

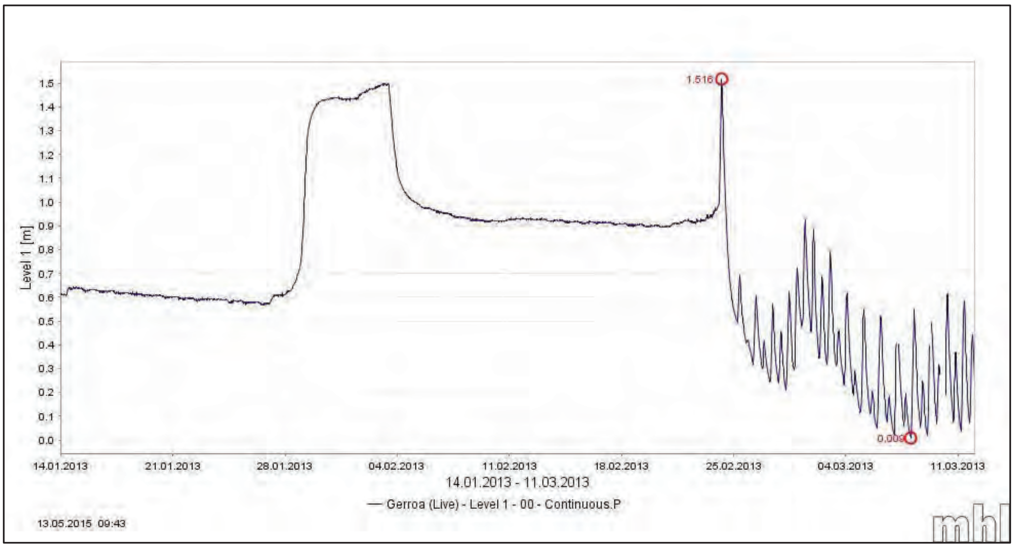


Figure 6: Crooked River artificial opening event February 2013

4.6 SEDIMENTATION

A tidal environment influences the Crooked River estuary when the entrance is open, and due to the river's infilled nature tides are enhanced, which facilitates the deposition of marine sediments in the lower reaches of the estuary. Dunwoodie 2004 also suggests the marine sediments which are deposited in the sediment channel bodies to the east and west of the road bridge, may result from storm activity during which large waves wash over into the estuary, depositing marine sediment as well as being transported from Seven Mile Beach sand dunes by the action of onshore winds. However, tides appear to be the main depositional mechanism for marine sands into the estuary when the entrance is open. At such times the sediment is deposited and reworked into the existing sediment bodies.

Dunwoodie states that the erosion and weathering of the geology of the upstream catchment appears to have had a minor impact upon the sedimentation of the estuary. However he identifies the erosion of the sandsheet in the banks of the creeks and river as a possible source of the sediment. At the present time the impacts of erosion of the sandsheet are minimal, however if the creek and river banks are not managed appropriately, there is the potential for significant quantities of sand to be added to the estuary.

The sandsheet would have once completely filled the estuary, and the modern channel would have cut through the sandsheet. The area of estuary that may have been infilled by the sandsheet would most likely be about $750m^2$. Since little of this sand has been flushed out of the estuary, it may indeed still be contributing to the shoaling and sedimentation.

Sedimentation, shoaling and flooding of the Crooked River estuary has been raised by community members as an area of concern. Theories relating to the infilling and sedimentation of the estuary include the building of the road bridge in 1983, marine and fluvial processes operating within the estuary and upstream land use practices that contribute sediment through erosion.

The building of the Gerroa road bridge in 1983 has been suggested as the reason for the build-up of sediment in the lower part of the Crooked River estuary. This argument is based on the belief that when the bridge was built, the clinker, ballast and rocks that were all used in the construction were never removed. Dunwoodie (2004) found the remaining ballast rock materials, which are now buried by sediment, have had a minimal effect on the build-up of sand around the bridge, as sediment has continued to move up the estuary and accumulate in the sediment bodies west of the road bridge.

Therefore, the materials that were left behind after construction were most likely not large enough to provide an impediment to marine sediment moving up the estuary as infilling continued on the western and the eastern sides of the road bridge after construction. Analysis of aerial photographs concluded that shoaling was prevalent in the Crooked River estuary in 1949 and 1963, including west of the existing road bridge, even before the construction of the current road bridge. A proposed hydrographic survey through this CZMP will provide a comparison for the previous hydrographic survey undertaken in 2001, and could provide the impetus for further exploration of this theory.

Dredging of the sediment from the channel downstream of the Gerroa road bridge has been undertaken in the past. However, the dredged areas were observed to infill rather quickly (often 3-5 years) after the removal of sand shoals (Reinfelds, 2001; Williams, 2003). This supports the concept that the areas of the lower estuary are infilled mainly by marine-derived sediments that move up the estuary, which is well documented from other similar estuaries. A series of aerial photography from 1949 to present has been included in Appendix 6, detailing changes in the catchment over time.

Another reason suggested by Dunwoodie 2004, for the low fluvial input into the Crooked River estuary, is the low gradient of many of the estuary's tributaries. The low stream gradients result in a decrease in the potential scouring and erosion that may occur after heavy precipitation, as the streams are longer and the flow slows as it moves out onto the alluvial flats.

Any increase in hydraulic efficiency through channelisation, flood mitigation works, increased hard surface runoff and removal of macrophyte beds within creek channels has the possibility to mobilise sediment. The RTA 2010 study found that freshwater habitat within the area around the Princes Highway upgrade was considerably degraded. Channel substratum was often dominated by loose accumulations of soft sediments, covering and infilling interstitial spaces of underlying substrata. This indicates historical and ongoing mobilisation of sediments from the disturbed catchment into the waterways, although its contribution to the main sediment bodies in the estuary are unknown.

The upgrade of the Princes Highway through the Crooked River catchment proposed some realignment of waterways and an increase in the hard surface areas creating runoff within the catchments. These are proposed to be dealt with by following established guidelines for river rehabilitation and installation of sediment control basins during construction and permanent spill and sedimentation basins for the treatment of pavement runoff and spill control during operation (RTA 2010b).

5. Summary of Estuary Values

As with the community and stakeholder survey from the CREMP 2003, the majority of values identified and statements offered relate to four main themes:

- the natural beauty and tranquility of the estuary
- cleanliness and safety of the estuary
- participation in recreational uses of the estuary
- lack of large scale development in the catchment.

These values are going to be relevant for the future management of the catchment and estuary, and are summarised below and expanded upon in the following section.

5.1 Social and Recreational Values

- Crooked River estuary is considered an area of significant natural beauty and relatively pristine state.
- The community values the clean and safe environment and considers the estuary as a place of tranquility and opportunity for all to access.
- Crooked River provides the community and visitors alike an opportunity to participate in a range of recreational activities including fishing, kayaking, bird watching and picnicking.
- There is prime agricultural land within the catchment, supporting dairy, grazing and horticultural activities.
- The Crooked River estuary and adjacent Seven Mile Beach are major tourism destinations and are important for the local economy.

5.2 Cultural Values

- Crooked River estuary and catchment has a number of sites and areas of significance to Aboriginal culture and history.
- Non-Aboriginal historic sites relate to the timber getting, dairy and agricultural heritage of European settlement of the area.

5.3 Environmental Values

- The Crooked River estuary supports a high diversity of bird life and many threatened and endangered species of flora and fauna are found throughout the catchment.
- There are a number of Endangered Ecological Communities (EECs) found within the estuary itself and the surrounding catchment including Coastal Saltmarsh, Swamp Oak Floodplain Forest and Bangalay Sand Forest.
- The Crooked River estuary provides important nursery and habitat areas for fish and other aquatic species.
- It is of local and regional ecological importance to maintain the health of the wetland areas within the Crooked River estuary.

6. Ecosystem Health Status and Pressures

Identifying the pressures on a particular coastal estuary is important for understanding both the health and vulnerability of that system. Recognising these pressures and endeavoring to resolve them through applying coordinated management priorities and actions involving all catchment stakeholders, is essential for the management plan to be effective in maintaining estuary health into the future.

The following section provides a summary of key estuary features and some new data and research which has been completed since the original CREMP 2003 was developed.

6.1 State of the Catchments Report 2010

The NSW Office Natural Resources Monitoring Evaluation and Reporting (MER) program provides information on natural resource condition and trends within catchments along the NSW coast. The MER program, coordinated by the Office of Environment and Heritage, collects data for NSW estuaries and reports on estuary ecosystem health, which feeds into the overall statewide condition target for estuaries and coastal lakes. Key indicators include water quality (*chlorophyll a* and turbidity), estuarine vegetation extent and fish populations.

The latest MER condition assessment for the Crooked River estuary was reported in the 'State of the Catchments 2010, report for estuaries and coastal lakes in the Southern Rivers region'.

The overall condition index for the Crooked River estuary was assessed as 'Very Good', averaged over condition scores for water quality parameters, which were both 'Good', and seagrass and saltmarsh extent which were also assessed as 'Good'. Macroalgae, mangrove and fish data was not available for the State of the Catchments assessment.

Table 6 summarises the information in the SOC 2010 report which identified pressures on the Crooked River estuary and assigned scores for each of the pressures to come up with an overall score.

Indicator	Pressure Score	Pressure index rating	Pressure indicator notes
Cleared land	1	Very High	≥68.5% cleared
Population	2	High	41-<264 head per km
Sediment input	2	High	80-<600 % increase from natural
Nutrient input	2	High	150-<400 % increase from natural
Freshwater flow	3	Moderate	Catchment runoff 11.9-<21.9% increase
Disturbed habitat	5	Very Low	<4.1% of perimeter disturbed
Tidal flow	2	High	Entrance Opening 1.4-<1.9m AHD
Fishing	5	Very Low	<2.0 tonnes per km^2

Table 6: Pressure indicators for the Crooked River catchment Source: Roper et al (2011)

6.2 Catchment Modelling Data

The NSW Office of Environment and Heritage have recently completed updated catchment nutrient export modeling for the Crooked River catchment. This modeling has been based on the Coastal Eutrophication Risk Assessment Tool (CERAT), which was developed to assist Council's to identify and prioritise land use planning decisions in the context of protecting the health of estuaries in NSW.

The spatial and temporal scales of the existing estuary models (in CERAT) have been updated to give a finer landscape scale overview of the Crooked River catchment. The models provide estimates of the contribution to the estuary of a number of parameters including phosphorus, nitrogen and total suspended solids, as well as estimating surface water flows and hill slope erosion. This modelling estimates the catchment exports considering factors such as land use, climate, rainfall, soil type and ground and surface water inflows.

Figures 7(a, b & c) show the spatial results of the modelling undertaken for the Crooked River catchment for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN), provided by the NSW OEH 2015.

The model shows that there are areas within the catchment which are predicted to contribute high areas of suspended solids and nutrients, particularly around the area between Toolijooa and Willowvale, the urban areas of Gerringong, Gerroa and the rural residential subdivisions in the Shoalhaven LGA. The reason for these areas being identified by the model are related to the existing land use including irrigated agriculture, viticulture, dairy farming, grazing and is also amplified in certain areas by the topography, soil type and hydrology. The modelled data also identifies the sand mining / quarrying as a high exporter of nutrients and suspended solids, however this does not consider the conditions placed on the operation by the Environmental Protection Licence and the actual monitoring data for the site. For maps including hill slope erosion and surface flow please see appendix 7.

It should be noted that this model is a predictor of sediment and nutrient export to the Crooked River estuary and does not consider the risk posed from other sources such as acid sulfate runoff. It should also be recognized that CERAT is a model providing estimates which have been calibrated based on generalised land use data and does not quantify the actual export of nutrients and sediments. This data would need to be collected, ground truthed and provided for input into the model to provide a more accurate representation of actual pollutants entering the system. The aim of this modelling data is to provide an overall comparison of the risks throughout the catchment which can be used to guide prioritization of activities and management actions to achieve the best results for estuarine health.

The modelling data depicted in Figures 7 (a-c), is clearly showing that priority areas for investment of funding, resources and engagement to reduce diffuse pollutants should be targeted in the Toolijooa and Willowvale areas. This is important for achieving best value for available money and resources when determining projects and management actions aimed at reducing nutrient and sediment inputs into the Crooked River estuary.

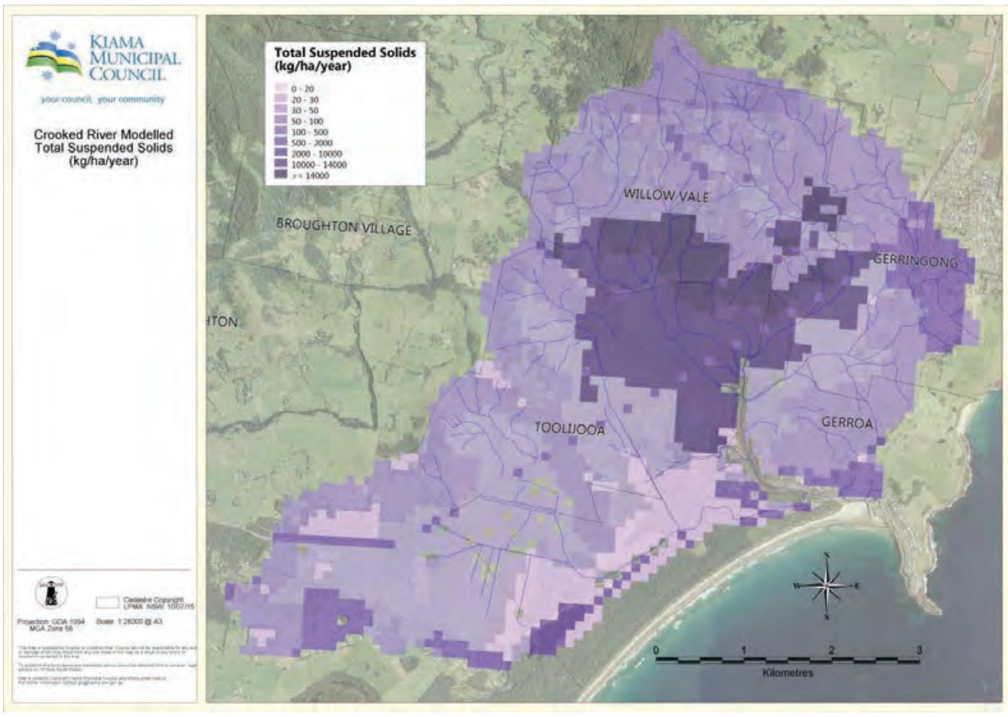


Figure 7 (a): Modelled export of Total Suspended Solids

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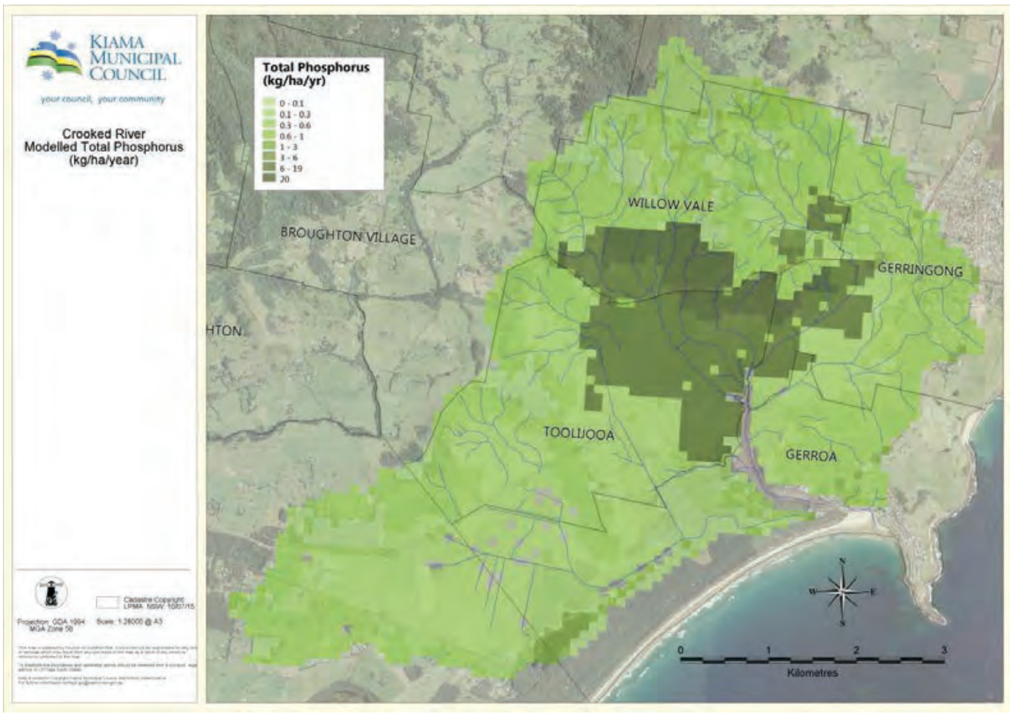

Figure 7 (b): Modelled export of Total Phosphorus

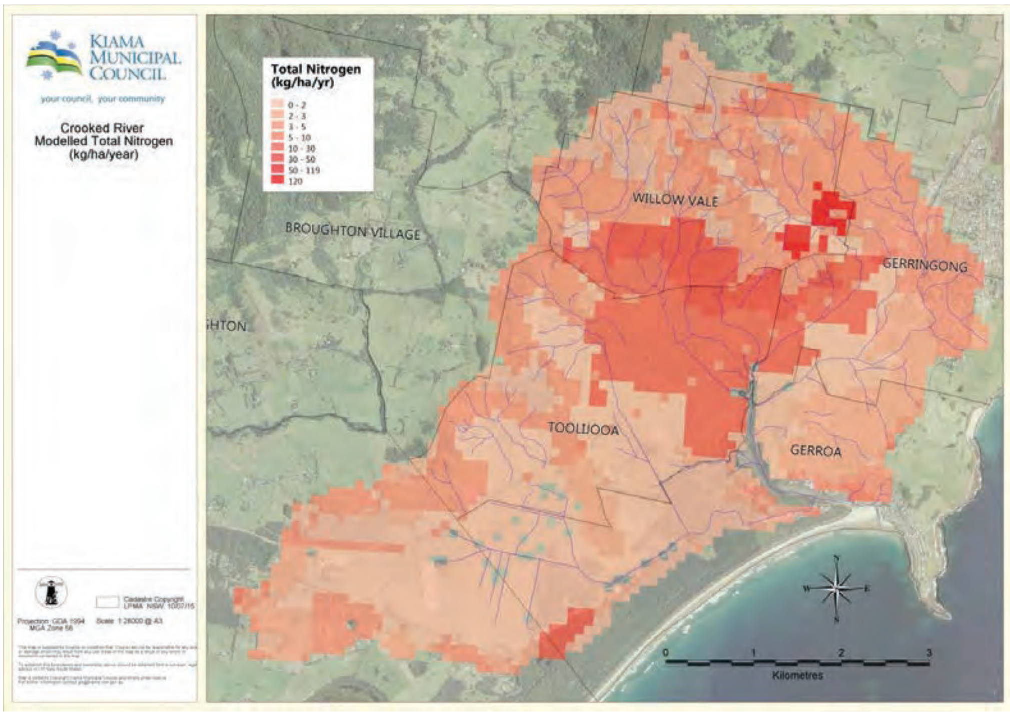

Figure 7 (c): Modelled Export of Total Nitrogen

NSW Office of Environment and Heritage have also prepared diffuse pollution risk mapping that shows the Crooked River sub-catchments and the comparative level of risk (high, medium, low) to the water quality and ecological health of the river. Diffuse pollution risks are depicted in Figure 7 (d). The low, medium or high rankings are based on a standard risk analysis framework of likelihood and consequence. Likelihood data represents the ecological response of the Crooked River waters in terms of *chlorophyll a* and turbidity parameters, as determined from the updated CERAT models.

This modelling could be utilized as part of a risk based decision making framework for considering the impacts on estuarine health of a proposed development This would be particularly relevant where the existing land use will be replaced with a potentially more intensive land use, for example urban development replacing agricultural activity. This would then identify the need for higher standards in terms of controls placed on a particular development to reduce the likelihood of impacts on the health of the Crooked River estuary.

The Illawarra Shoalhaven Regional Plan has identified a number of actions to guide biodiversity management in the Illawarra including 'A*ction 5.4.3 Implement a risk based decision making framework to manage water quality and waterway health for all coastal lakes and estuaries in the region where development is planned, with priority given to listed sensitive lakes and estuaries'.* In recognizing the relationship between the regional growth plan and this CZMP, a management action has been included to facilitate the use of the risk based mapping to inform future development and land use planning proposals.

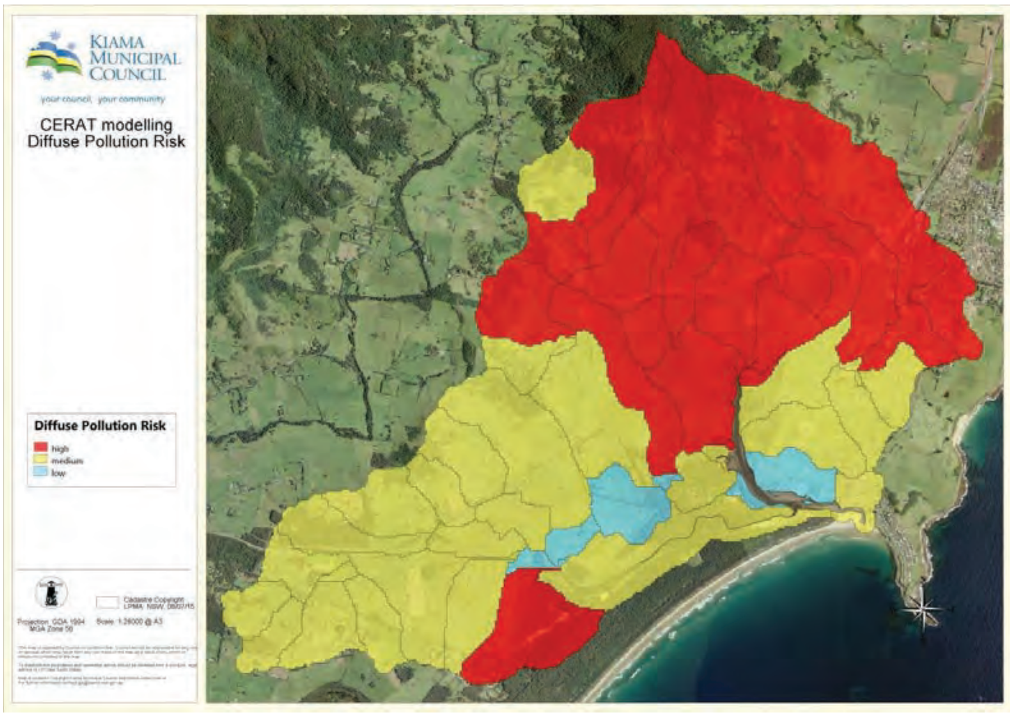

Figure 7 (d): Modelled diffuse pollution risk for Crooked River catchment

6.3 Water Quality

Many of the responses to the community survey indicated that water quality for recreational pursuits and during times when the river was closed to the ocean was an issue of concern.

Being a heavily modified catchment, the water quality in the Crooked River is influenced greatly by run-off and entrance condition. Previous water quality studies and investigations have reported levels of nitrogen, phosphorus and faecal coliforms above ANZECC (2000) guidelines. There are various contributors to these nutrient and faecal contaminants including rural land use, fertiliser application, Onsite Sewage Management Facilities (OSMFs), urban stormwater run-off and erosion and sedimentation of catchment soils.

Crooked River at times can exhibit poor water quality, particularly following rainfall events when it receives substantial contaminant loading including nutrients and bacteria. The lower reaches of the estuary are tidally flushed within a relatively short time frame following a rainfall event, however the upper reaches of the estuary can remain nutrient enriched due to poor flushing under low flow conditions.

Regular water quality monitoring is undertaken by KMC, Sydney Water Corporation and Cleary Brothers as part of licence conditions associated with their current or former operations within the catchment. There is a long history of water quality data from the Crooked River which has continually identified nutrient enrichment, faecal contamination and low dissolved oxygen issues associated with certain times of year and climatic conditions. The following provides a brief summary of recent water quality monitoring that has been undertaken in the catchment area.

NSW Monitoring Evaluation and Reporting Program, including Kiama Municipal Council sampling for 2006/07

A monthly water quality monitoring program was undertaken in 2006/2007 by KMC and provided data which was combined with the sampling under the NSW MER program to complete the State of the Catchments Report 2010. As discussed in Section 6.1, the Crooked River rated 4.5 out of 5 for ecosystem health, relying on *chlorophyll a* and turbidity results as indicators. The pressures identified in the report showed that cleared land, population, sediment input and nutrient input were all rated high to very high. The overall pressure score given to Crooked River estuary was 2.8 out of 5, with 1 being very high and 5 being very low.

Chlorophyll a has been utilised as an indicator of estuary health as an expression of available nutrients contributing to phytoplankton growth. Whilst Crooked River has many potential sources of nutrient input, in general *chlorophyll a* levels were under trigger levels of 2.9ug/L (NSW OEH, 2013) with a mean value of 1.7ug/L, 75th percentile of 2.2ug/L and a maximum recorded value of 25ug/L (OEH, 2011). There were no instances exceeding the worst expected value (WEV) of 30ug/L. There were 80 samples analysed for the Crooked River in the MER technical report.

The State of the Catchments 2010 report, whilst comprehensive, did not consider faecal coliform results as part of the assessment, as this measure is usually more associated with recreational activities and primary and secondary contact indicators. Results from the KMC sampling program in 2006/07 showed 50% compliance for both Crooked River sample sites for primary contact, and 66% and 100% compliance at the sample sites for secondary contact.

2012-14 Water quality sampling by Kiama Municipal Council and Sydney Water Corporation

Results from sampling conducted by Kiama Council over the summer of 2013-14 as part of the review of the CREMP show that at times the faecal coliform and *chlorophyll a* levels in the estuary are high. Higher levels are seen more often towards the back of the estuary and are more than likely due to the relatively longer flushing time compared with the middle and lower reaches of the estuary.

Chlorophyll a results showed that of the 17 monthly samples collected and analysed, 5 samples exceeded the 2.9ug/L trigger value. All except one of those *chlorophyll a* samples was taken in Zone 3, at the upper limit of the estuary. The maximum *chlorophyll a* sample was 14ug/mL which is half the worst expected value of 30ug/L, as determined by the Office of Environment and Heritage MER strategy. The sampling zones for the 2013-14 sampling can be seen in Figure 8.

Results from faecal coliform sampling showed that 70% of samples were below primary contact levels of 150 cfu /100mL, and 76% of samples were below secondary contact levels of 1000 cfu/100mL. The elevated levels of faecal coliforms occurred on four out of the 17 sampling occasions. Two of these elevated readings were from Zone 3 at the back of the estuary, and the only occurrence of elevated levels in Zone 1 coincided with a rainfall event when all three zones were elevated.

Monthly sampling by Sydney Water as part of the water quality monitoring for the Gerroa WRP over a 12 month period in 2012-13 showed that in the Crooked River 42% of samples were below 150 cfu / 100mL and 81% of samples were below 1000 cfu / 100mL. Sampling in Blue Angle Creek from the same program showed 75% below 150 cfu / 100 mL and 100% below 1000 cfu / 100mL. It should be noted that the analysis of the Sydney Water data has been compiled by Kiama Council during production of the CRCZMP, the sampling data can be found in Appendix 3. For a more detailed analysis of the water quality monitoring program undertaken by Sydney Water you can request a copy of the document '*Gerringong Gerroa Sewerage Scheme Water Quality Investigation 2012'*, available from Sydney Water. The report does note that in contrast to the tested effluent from the WRP, the background river water quality was much more variable and of higher values of faecal coliforms. Total Nitrogen, Total Phosphorus and Faecal coliform box plots taken from the report can be seen in Appendix 3.

With all the water quality sampling that has and is occurring in the Crooked River estuary as part of different NSW EPA licence conditions, there is an opportunity for a coordinated monitoring and reporting system to be implemented, or at the very least have easily accessible reporting of results for public information.

The Sydney Water (2012) Water Quality Investigation found that some of the data being collected as part of meeting the license conditions for the WRP was not comparable due to different sites used in the before and after assessments. A Sydney Water Corporation sampling team currently carries out the sampling of these sites relating to the licence conditions, and should improve the comparability and consistency of water quality data in the future.

2014-15 Monitoring Evaluation and Reporting program sampling

The NSW OEH Monitoring, Evaluation and Reporting program was engaged to conduct sampling in the Crooked River between December 2014 and March 2015.

Chlorophyll a results showed that of the 12 samples collected and analysed, 4 samples exceed the 2.9 ug/L trigger value identified by the MER program (see Appendix 3). Only 2 zones were sampled as part of this program, which align with the zones 2 and 3 identified in Figure 9. The maximum *chlorophyll a* value recorded was 10.27 ug/L and corresponded with the zone in the upper estuary. The following figures show a comparison of the different Council and MER program sampling data for the Crooked River estuary, the full data set can be found in Appendix 3.

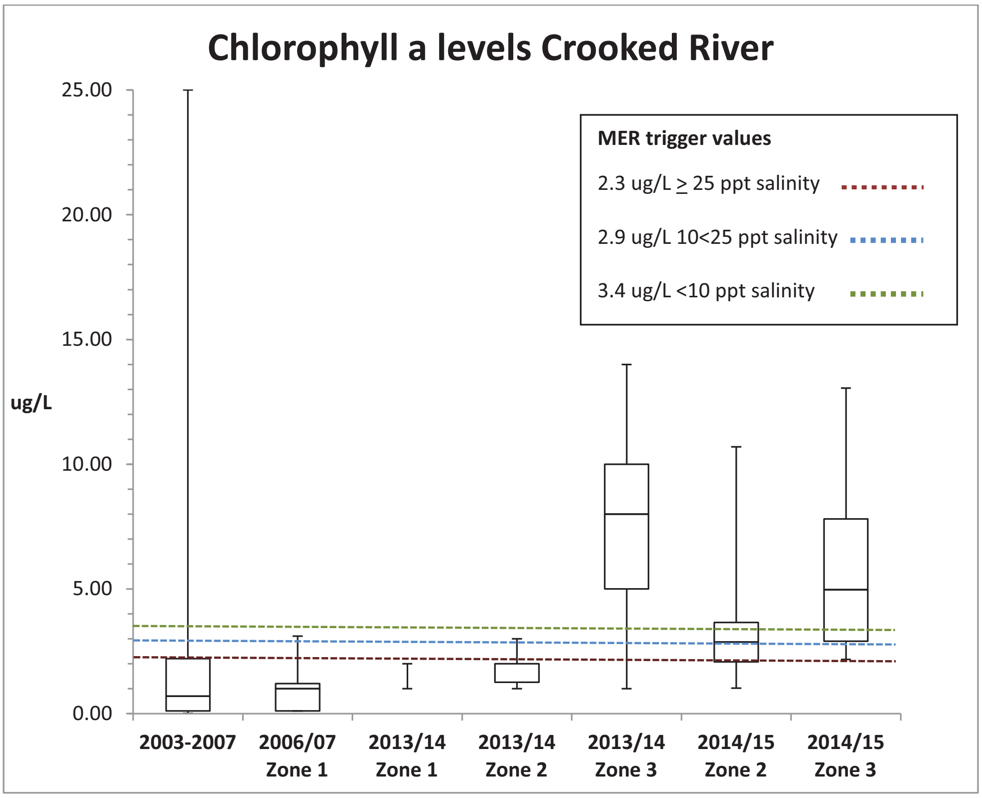

Figure 8 (a): Chlorophyll a levels Crooked River

This figure demonstrates the different *chlorophyll a* levels in the different areas of the river. Zone 1 relates to the lower part of the estuary near the mouth of the river, Zone 2 relates to the mid estuary and Zone 3 relates to the upper estuary. The 2003-2007 data is the combined data reported in the Technical Report Series for the State of the Catchments Report 2010, which is a combination of the 2006-07 Council data and the sampling by the MER program from 2003. The 2006/07 data has also been separated into its own box plot to demonstrate the effect of combining sampling data across zones and across years.

As can be seen when they have been separated into the 3 sampling zones, the *chlorophyll a* levels are higher in the mid and upper estuary, which is to be expected due to the greater influence of the ocean water in the lower estuary. This snapshot data identifies there are issues in the upper part of the river with elevated *chlorophyll a* levels above NSW MER trigger values for estuary health. Further sampling would be required to provide more confidence to the data, however this sampling indicates that the reduction of nutrients into the Crooked River estuary should be a primary focus for landholders and government agencies to ensure the ongoing health of the estuary.

Figure 8(b) represents the sampling data from the NSW MER Technical Report Series for the state of the catchments report, the 2006/07 Kiama Council sampling data and the 2014/15 MER sampling. The data shows that at times the Crooked River has high levels of turbidity, particularly in the upper part of the estuary.

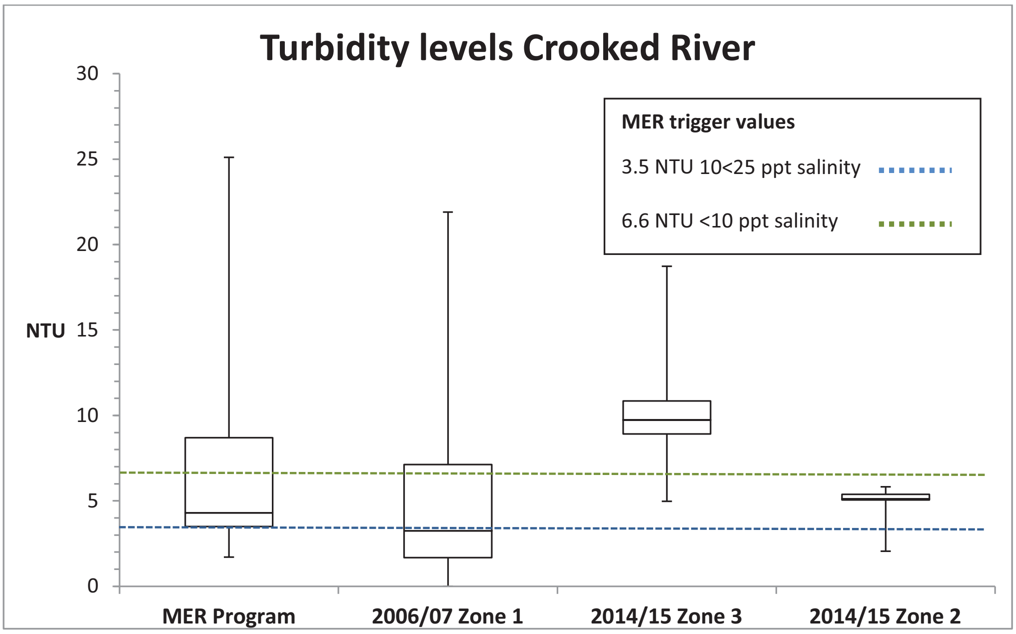

Figure 8(b): Turbidity levels in Crooked River

The recent sampling shows that the lower part of the estuary is generally above the MER guidelines for turbidity for salinity levels between 10 and 25ppt, and the upper estuary is also above the recommended trigger value for both salinity levels below 10 ppt and between 10 and 25 ppt. It should be noted that there were only 6 sampling runs conducted in the 2014/15 MER program, compared with 12 samples from 2006/07 and 11 samples for the MER program statistics for the Technical report series.

Figures 8(c) and 8(d) have been included below to show a comparison of the total nitrogen and total phosphorus levels between the 2006/07 Council program and the 2014/15 MER program, which only sampled for these parameters in the upper estuary (Zone 3). As is demonstrated by the limited sampling data, total phosphorus levels in the lower and upper estuary are above ANZECC guidelines (0.03mg/L) for most samples. Total nitrogen levels are also generally above ANZECC guidelines (0.3mg/L). The water sampling data in Appendix 3 also contains information on rainfall in the week of sampling. This shows a strong relationship between elevated nutrient levels and rainfall. It should be noted that the 2014/15 MER sampling program was conducted over a particularly wet summer for the Gerroa area.

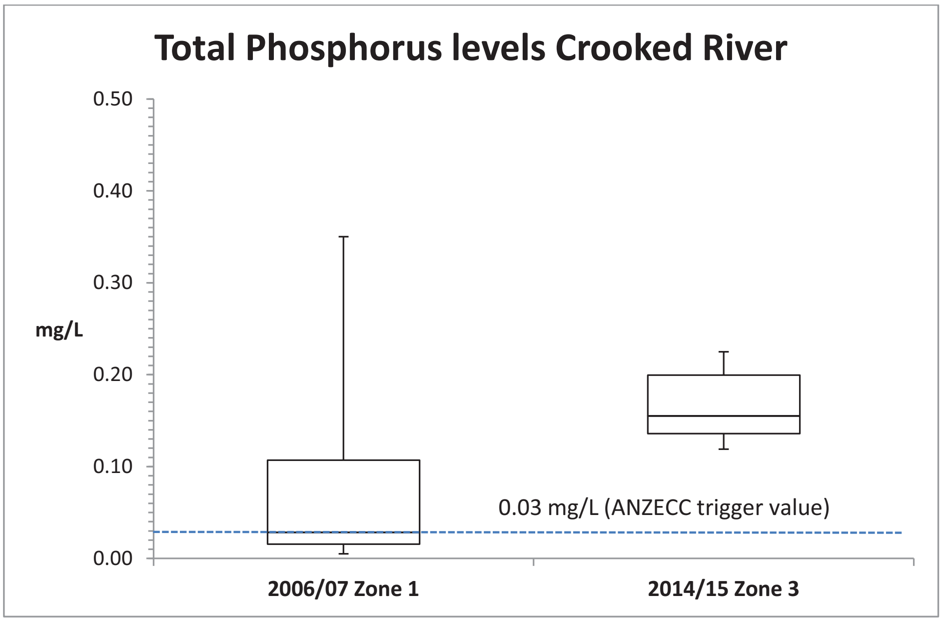

Figure 8(c): Total phosphorus levels in Crooked River

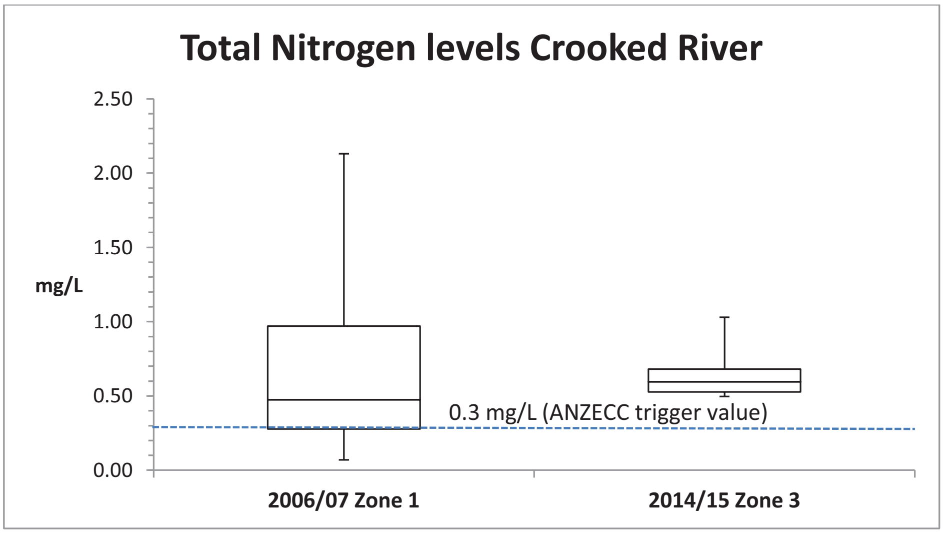

Figure 8(d): Total Nitrogen levels Crooked River

Figure 9: Sampling Zones involved with the 2013-14 Estuary Health Monitoring

Water quality sampling by Roads and Maritime Service

The Roads and Maritime Service (formerly Roads and Traffic Authority), had an aquatic ecology and water quality assessment completed as part of the preparation for the Gerringong to Berry upgrade of the Princes Highway. Field sampling was also conducted in 2009 to gather data on aquatic habitat, biota and water quality of the tributaries and main channel of the Crooked River which would be affected by the upgrade of the highway.

At this time it was reported that levels of phosphorus within the Crooked River drainages frequently exceeded the ANZECC threshold values for the protection of aquatic ecosystems (AWT, 1999, The Ecology Lab 1999, 2007). The likely source of these nutrients was fertilisers applied to improve grazing pasture and manure. Crooked River was within the ANZECC threshold limits for a range of organochlorine pesticides, oxides of nitrogen and trace elements, although it exceeded guidelines for copper and chloride and recorded concentrations of oil and grease and suspended solids that were much higher than samples taken in nearby Broughton Creek drainage (The Ecology Lab 2007).

Also the sampling results indicated that during periods of low rainfall, sites within the Crooked River were frequently below the ANZECC lower limits for dissolved oxygen. Low dissolved oxygen values can be caused by low flow condition and/or high in-stream organic loads. An earlier study by The Ecology Lab 1999, had also recorded low dissolved oxygen levels from sites within the Crooked River.

Surface and groundwater monitoring for the former Gerroa Landfill and Night Soil Depot

Since the closure in 2003 and rehabilitation of the Gerroa Landfill and Night Soil Depot in 2005, monitoring of surface and groundwater quality has been undertaken continuously in accordance with EPA licence conditions in the locations identified in Figure 10.

This has produced a measurable improvement to the local groundwater and surface water systems, according to the Annual Surface and Groundwater Monitoring Report for 2013-14 (KMC, 2014). The annual report came to the following conclusions:

- The rehabilitation of the landfill mound and night soil depot has produced a measurable improvement to the local groundwater quality. The improvement to local surface water quality is not clear.
- The key landfill indicator (ammonia-nitrogen) shows a decreasing / stabilising trend in several shallow wells and deep wells located next to the landfill mound and former night soil deposits.
- Elevated concentrations of nutrients in particular ammonia, continue to be detected in some shallow and deep groundwater.
- Concentrations of ammonia were reported below ANZECC guidelines for some onsite and offsite wells, and previously elevated ammonia concentrations at some wells in 2009-10 have substantially decreased in the 2012-13 and 2013-14 monitoring period.
- Concentrations of total phosphorus in the shallow / deep groundwater is generally variable, with a variably increasing trend at two shallow and two deep wells down gradient and north of the former night soil depot.
- Nutrient (ammonia) concentrations within surface water samples collected at downstream locations in Blue Angle Creek are variable and similar to previous years. An exceedance was noted at two sampling sites in August 2013 and February 2014. Based on low ammonia results from groundwater monitoring wells in close proximity to the creek, high ammonia concentrations in the surface water may be attributed to potential upstream sources (agriculture) or poor quality estuarine water transported by the tide.
- The landfill capping system reduces rainfall infiltration into the buried waste, reducing leachate generation and diverting runoff from the 3ha capped mound onto the aquifer, causing dilution and attenuation of the residual leachate.
- It is interpreted that surface and shallow groundwater quality, pending contribution of other sources, may meet the ANZECC guidelines in the next few years (2015).
- The deep groundwater quality, (below 3 mAHD), below the landfill mound will require a longer timeframe (3+years), to show improvements due to lack of flushing in the basal parts of the aquifer.

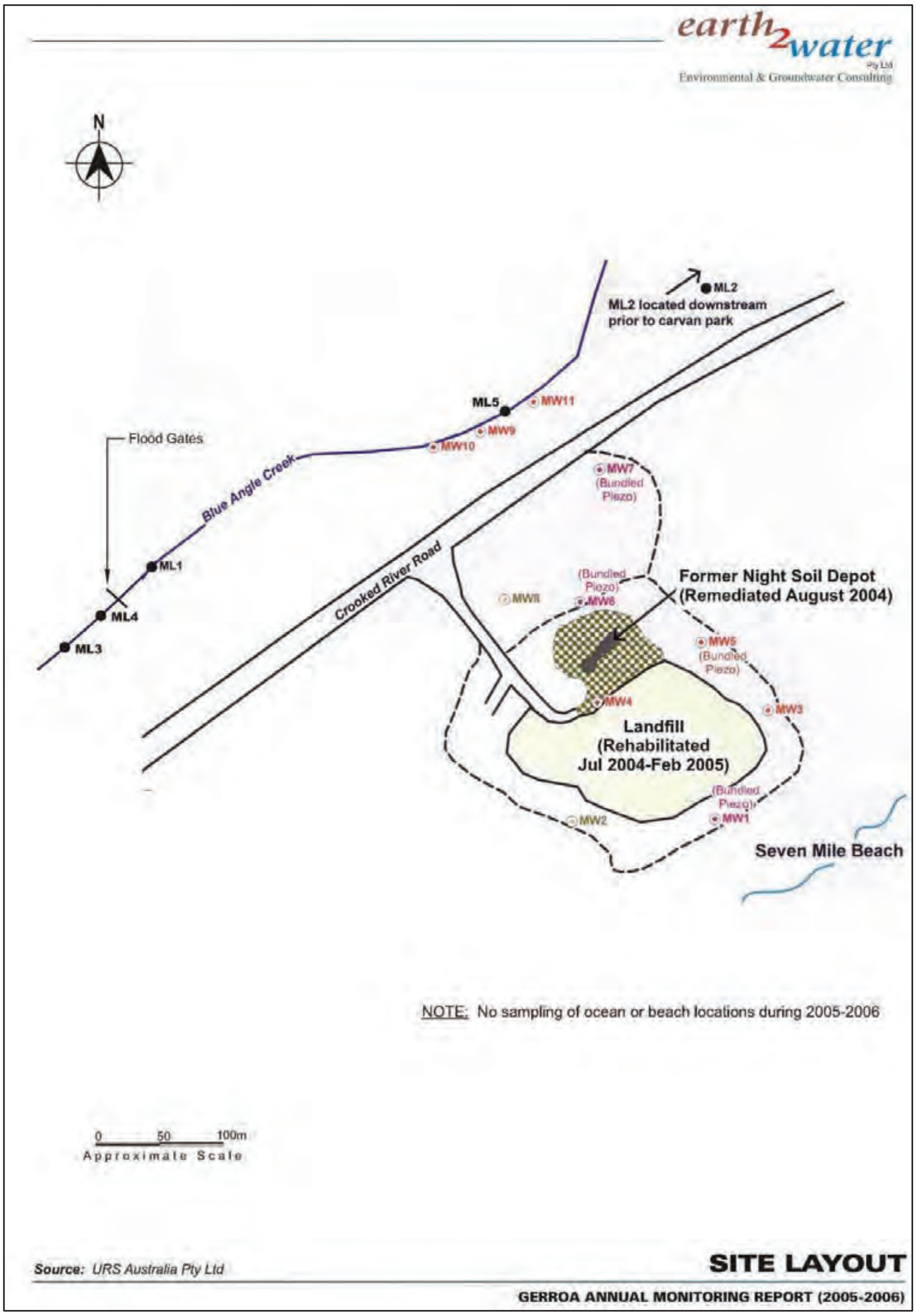

Figure 10: Monitoring locations for Gerroa Waste Depot (Source Gerroa Annual Monitoring Report 2005-06)

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Groundwater and dredge pond sampling for Cleary Brothers sand mining operation

Cleary Brothers undertakes monthly groundwater level monitoring and quarterly analyte testing in line with their development consent conditions. They also undertake sampling in the dredge pond on a monthly basis for pH and conductivity and quarterly basis for other analytes.

According to the annual Gerroa Sand Resource Annual Environmental Management Report for 2013-14 there are stable water quality trends in the groundwater, and all indications are that the sand mining operation is having very little effect on the groundwater system in the area. Several analytes have been identified as exceeding the objective levels provided by the development consent, but these are in line with the levels which have historically been found at the site. The report also noted that in general the analytical results for the surface water in the dredge pond when compared with the objective levels in the development consent are low, and show that the water is of high quality. There were exceptions to the trend including elevated levels of phosphorus, nitrogen, *chlorophyll a*, faecal coliforms and algae. The surrounding land uses are identified as having the potential to influence the raised levels of phosphorus, nitrogen, *chlorophyll a*, algae and faecal coliforms, rather than the actual sand mining operation itself.

The report also notes that there are no specific requirements for surface water quality in the Environmental Protection Licence, other than with regard to discharge from the dredge pond overflow. The overflow pipe is licensed in case of extreme weather in which flood water can drain to the adjacent Foy's Swamp. To date the report states that the pond water has never required use of the overflow pipe.

Future water quality analysis and reporting

As identified previously in this report, there is no integrated approach to water quality analysis and reporting and in some cases, follow up monitoring has been undertaken which cannot be directly compared with historical data. The development and implementation of an integrated water quality testing and / or analysis and reporting program has been identified as a priority action. This will then provide a more readily comparable and accurate report on the water quality trends of Crooked River and its catchment areas over time. Targeted sampling of sub catchments during low flow and following catchment events will also provide important data relating to sources of pollutants and magnitudes of contribution to the estuary. This can be used to target further support and education to landholders in these catchments to try to reduce pollutants entering the estuary.

6.4 Erosion

Many of the estuary foreshores are exhibiting signs of erosion, some areas showing slow progressive recession of the shoreline and/or undermining of existing riparian vegetation (Figures 11a and 11b). Whilst in many areas this is a natural part of river bank behavior and there is a vegetated riparian zone which helps to mitigate the erosion, there are areas where little or no riparian vegetation is present. This leaves these areas more vulnerable to the effects of wind, wave and tidal/flood current erosion, and damage by livestock. There are also areas within the estuary such as stretches of Blue Angle Creek where heavy rains have caused channel erosion and exposure of anoxic sediments leading to low dissolved oxygen issues in the water column. A recent event occurring in February 2014 introduced organic matter and exposed anoxic sediment in the main creek channel below the tidal flood gate, leading to a rapid decrease in dissolved oxygen concentrations and subsequent impacts on fish, invertebrates and amenity of the creek.

Given the nature of some of the areas of concern, engineering expertise will be required to determine the major causes and potential solutions to specific problems associated with the bank erosion. Some of the areas of concern in the Blue Angle Creek have the potential to undermine or affect areas of the Seven Mile Beach Holiday Park operations and should be a targeted priority for future action (Figures 11c, 11d and 11e). The areas of concern are identified in the Figure 12 map, which is a high use and high profile areas. Some of the causes could be related to the removal of emergent macrophytes and riparian vegetation to access areas of the creek for recreational purposes.

Formalising access and creating riparian buffer zones may deal with some of the issues. It is expected that a mix of hard (10d) and soft engineering solutions will be required to provide the best outcome for asset protection and ecological and habitat value.

Figure 11(a) Upper estuary bank erosion

Figure 11(b) Mid estuary bank erosion

Figure 11(c): Areas of exposed bank in Blue Angle Creek

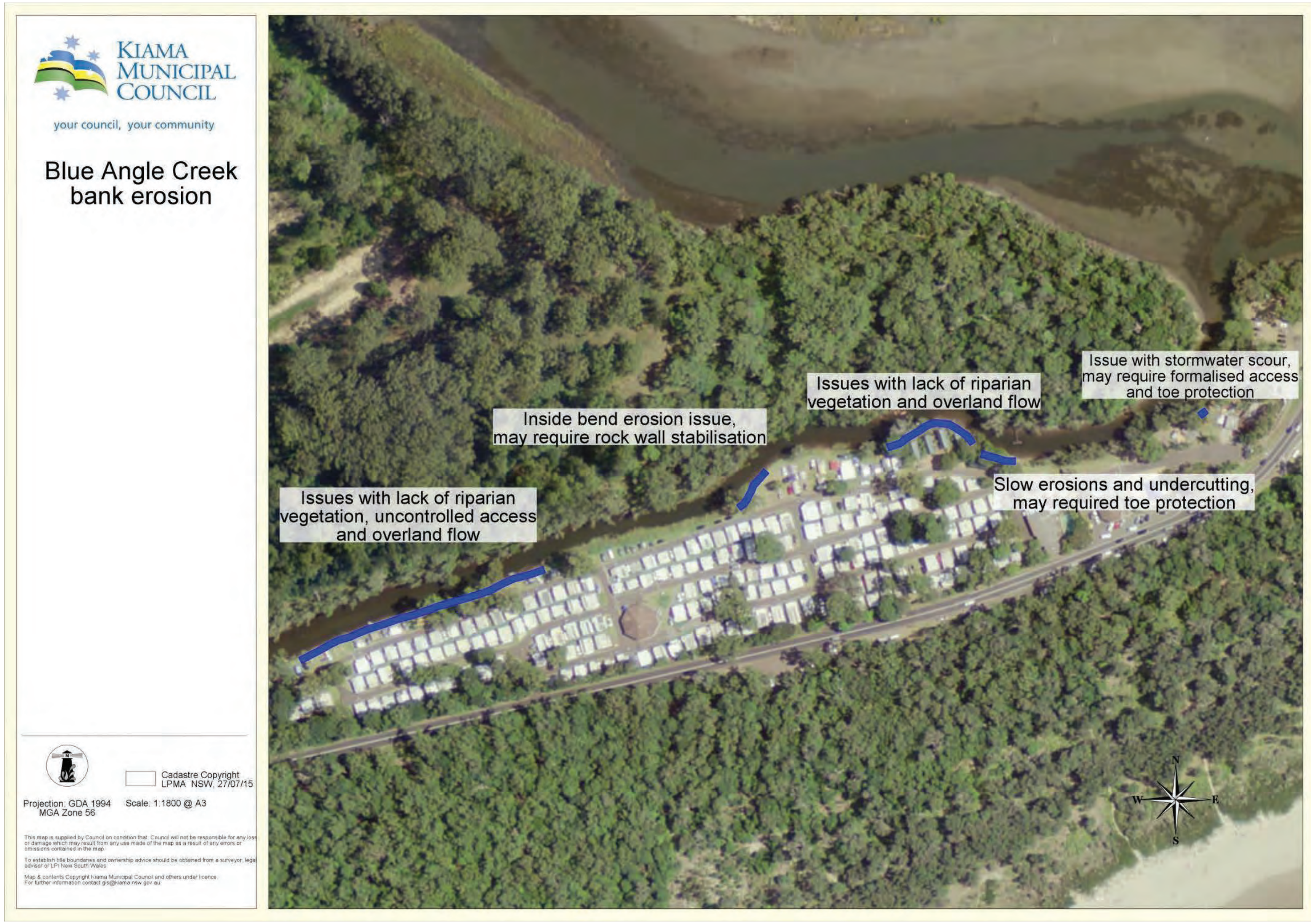

Figure 12: Foreshore erosion areas in Blue Angle Creek and Crooked River

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Figure 11(d): Erosion occurring in Blue Angle Creek

Figure 11(e): Erosion occurring in Blue Angle Creek (photo D.Weicek 2015)

6.5 VEGETATION

6.5.1 ESTUARINE VEGETATION

Estuarine vegetation generally refers to seagrass, mangroves and plants contained within the saltmarsh communities. Seagrass occurs in the intertidal and sub-tidal 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 briefly inundated on high tides. In an estuary, reference to riparian vegetation generally includes vegetation occurring above the high tide level and generally does not include estuarine vegetation.

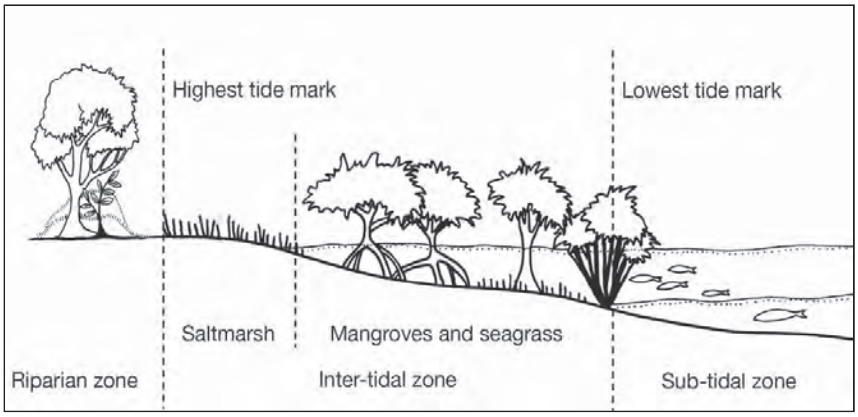

Figure 13: Estuarine Vegetation Zones, Sourced OEH Waterwatch Estuary Manual Fact Sheets

The Crooked River has a relatively small estuarine area compared with its total catchment size, and has relatively small areas of saltmarsh and mangrove stands compared with the size of the estuary. Creese RG, Glasby, West and Gallen (2009), reported on mapped habitats of NSW estuaries undertaken by the Department of Planning Comprehensive Catchment Assessment in 2005. It is reported there was 0.046km^2 of seagrass beds, 0.008km^2 of mangrove and 0.017km^2 of saltmarsh within the Crooked River estuary. Figure 14 shows the estuarine habitat mapped in 2005, projected over 2013 aerial photography. It is apparent that the distribution of seagrass has changed markedly since the 2005 mapping, and a repeat mapping exercise similar to the CCA assessment could provide more indication of the actual difference in area between 2005 and present. An analysis of the chronological aerial photography could also provide insight into the variation in distribution over time and potential causes of this variability.

The Crooked River estuary is usually open to the sea, and therefore the lower parts of the estuary are predominantly marine. Saltmarsh is listed as an Endangered Ecological Community in the *NSW Threatened Species Conservation Act 1995*, and seagrass and mangrove habitat are protected in NSW and require a permit from NSW DPI to undertake works or activities that may harm them.

Seagrasses

Seagrasses are highly productive areas of an estuary and play a vital role in ecosystem health, providing habitat for fish and other aquatic fauna, reducing erosion, cycling nutrients from sediments and providing a food source for fish and other aquatic fauna. The only species of seagrass found in the Crooked River is Eel grass (*Zostera capricorni*). In shallow estuaries such as the Crooked River, seagrasses are particularly sensitive to changes in sedimentation, turbidity and nutrient levels.

In 1998, a data compilation study was undertaken using time series photos from 1949 to 1997 of the Crooked River to determine whether changes to the areas where seagrasses were located had occurred. This study indicated that seagrass beds had declined substantially in 1977 and 1980. The level of seagrasses remained low throughout the 1980's but by 1997 had recovered to approximately their 1949 extent. A compilation of aerial photography from 1949 to present has been included in Appendix 6, showing the estuary and Foy's swamp area.

No further analysis has been undertaken to assess variability of the seagrass habitat within the estuary, and possible links between catchment conditions and sea grass decline or increase. The need to undertake further research has been identified as a priority action. Observations in the field in July 2015 identified that the seagrass in the lower part of the estuary downstream of the road bridge was in healthy condition with no sign of epiphytic algal growth, however just upstream of the Gerringong Gerroa STP the epiphytic algal growth on the seagrass was particularly evident.

Saltmarsh

Saltmarsh is a community of plants listed as an Endangered Ecological Community under the *NSW Threatened Species Conservation Act 1995*. This community grows at the highest tide level where it is frequently exposed for long periods of time. Saltmarsh is particularly important for the estuarine food chain, providing habitat and breeding areas for invertebrates, and feeding and foraging areas for fish species and shorebirds. Saltmarsh is particularly susceptible to sea level rise, as it is expected that as sea levels rise, the saltmarsh will struggle to migrate into previously unoccupied areas, particularly if constrained by adjacent incompatible land uses or built structures.

There is only $0.017km^2$ of salt marsh identified in the Crooked River catchment which generally occurs in the mid to lower estuary and appears to be confined by terrestrial vegetation, the holiday park on the northern side of the river and the steeper banks in the upper estuary.

Some of the areas where saltmarsh is located are fenced to restrict stock access; however there are still areas below the high water mark where stock have gained access, as indicated in Figure 15. The need to address this issue has been identified as a priority action.

There were concerns raised by NSW Fisheries about the potential invasion of saltmarsh by the weed species *Juncus acuta*, which can take over saltmarsh areas and out compete the naturally occurring *Juncus krausii.* The weed is prevalent in some areas of the adjoining LGA and future introduction of the species into the estuary is possible. Field observations conducted by Council and OEH officers did not find any *Juncus acuta* in riparian and salt marsh areas within the estuary. This will be something to watch for in the future.

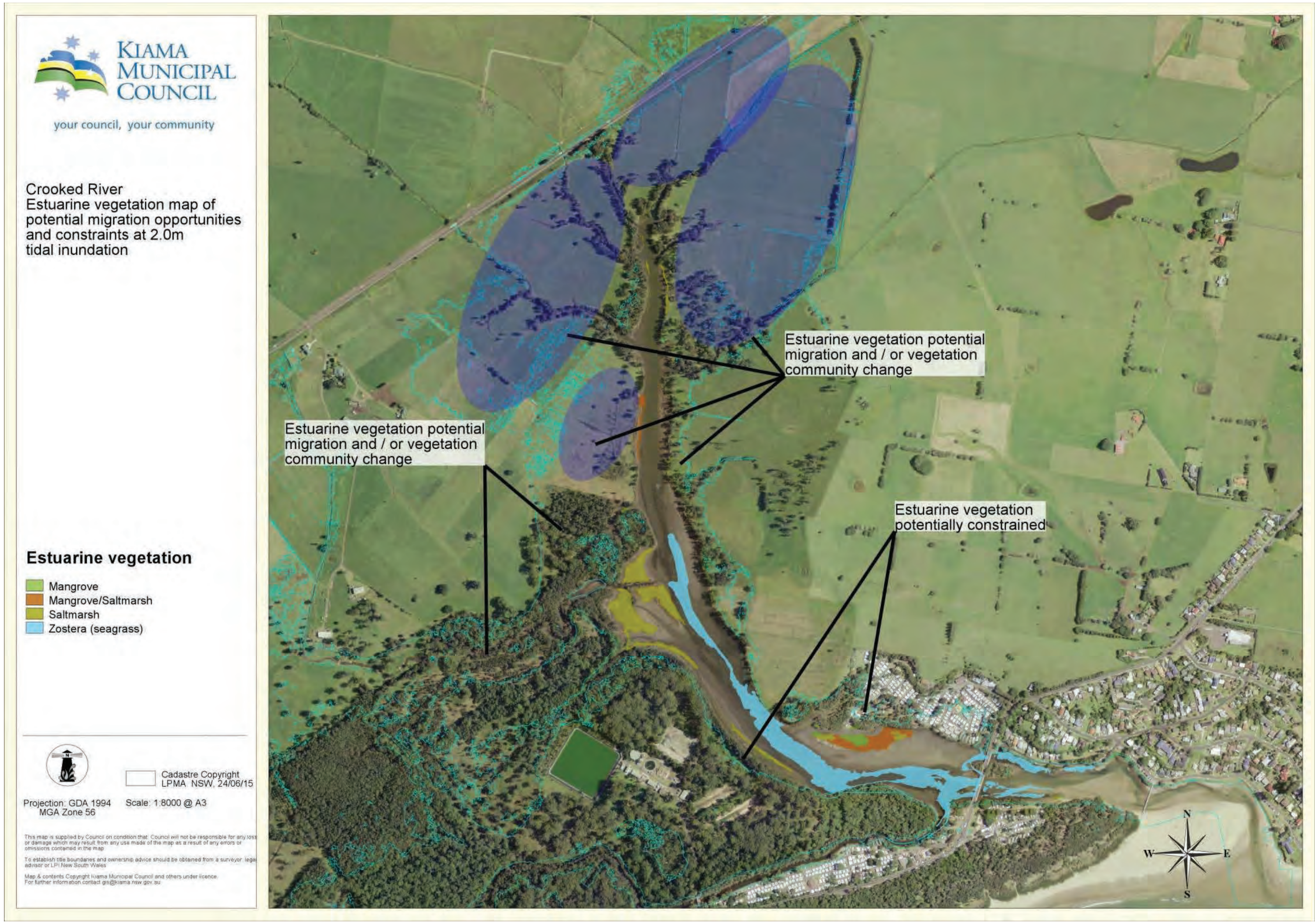

Figure 14: Crooked River Estuarine Habitat Mapping and potential constraints and migration opportunities. Habitat mapping provided by NSW Department of Primary Industries, from mapping undertaken by the NSW Department of Planning, Comprehensive Coastal Assessment undertaken in 2005

Figure 15: Evidence of stock access to the main Crooked River channel

Mangroves

Figure 14 identifies the location of mangroves located in the Crooked River system as mapped by West (2005). During the 2013-14 ecosystem health monitoring undertaken by Kiama Council, mangroves within the Crooked River estuary were observed to be in various states of health (Figure 16). There were many small mangroves observed, with some looking in a dead or dying state, more than likely due to extended periods of inundation when the Crooked River has been closed to the sea. It was also noted in field observations by Council and OEH officers in July 2015 that whilst there are a number of dead mangroves present throughout the system, there are also many semi mature mangroves which appear to have been established for a number of years throughout the system which are not captured in the estuarine habitat mapping.

Figure 16: Sporadic mangroves in the mid estuary of the Crooked River

6.5.2 Impacts on Estuarine Vegetation due to Sea Level Rise

It is expected that a rise in average sea levels associated with climate change, will result in the landward recession of fringing estuarine wetland systems. The location of saltmarsh and mangroves are principally controlled by tidal range. Predicted sea level rise by 2050 will see even the highest astronomical tide constrained mostly within the bank of the system (see Figure 3 a, b & c). It is expected that in the short to medium term the vegetation extent will also be constrained to current distribution. There are a number of barriers in the lower part of the estuary to migration of these vegetation types, including roads and built infrastructure, however there is little saltmarsh and mangroves presently in this area as can be seen from Figure 14. The coastal plains further up the estuary, provide adequate areas for these vegetation types to migrate into, however this is currently productive agricultural land and there is a risk of conflict between productive land use and advancing mangroves and saltmarsh areas. Further research will be required to assess the likely impact of sea level rise on not only estuarine vegetation communities but also on the surrounding agricultural lands and how these areas should be best managed into the future.

The floodplain area around the upper estuary is considered prime agricultural land, and maintaining this area as productive land will not necessarily be in conflict with achieving estuary health outcomes. However there is the likelihood in the longer term that some productive land will become less viable due to saline intrusion. This emphasizes the importance of preserving the agricultural land currently available, as pressure for alternative land uses will continue in the future. Future revisions of this CZMP will need to consider a range of potential management options for the areas potentially impacted by saline intrusion. These management actions could include:

- Doing nothing, and allowing saline intrusion to gradually modify the fringing floodplain land;
- Artificial intervention to reduce the impact of saline intrusion further upstream;
- Buy back of land or landholder agreements to allow the gradual colonisation of fringing wetlands in response to sea level rise. This could involve implementing rehabilitation activities for wetland and riparian areas and filling agricultural drains to restore more natural floodplain elevation or a combination of actions. This approach could consider rezoning of land, identification of buffer zones and SEPP 14 wetland areas

Due to the timeframes involved these issues will not be considered as management actions for the current Crooked River CZMP, however have been flagged as a future consideration.

6.5.3 Riparian Vegetation

Riparian vegetation can be described as the vegetation occurring above the high tide level bordering a watercourse. Riparian vegetation performs a number of important functions both ecological and physical. These functions include:

- bank stabilisation
- maintenance of soil structure through addition of organic matter and root propagation
- nutrient filtering from surface and ground water entering the estuary/watercourse
- land use buffering
- lowering in stream water temperature
- habitat provision for both terrestrial and aquatic fauna.

The Crooked River estuary has large tracts of riparian vegetation in its lower reaches in the Seven Mile Beach Reserve and Gerroa WRP property. The mid and upper estuary verges have riparian vegetation of varying width surrounding the majority of the estuary, however there are two notable areas where there is virtually no riparian vegetation. These areas are potential future fencing and revegetation projects for the Local Land Services and catchment landholders to undertake, subject to support and funding for these initiatives. These two areas are identified in Figure 17. As well as establishing connectivity in these areas, it is important for projects focused on weed control and additional stock exclusion fencing and revegetation activities to be implemented throughout the catchment. These projects will add to the overall resilience of the freshwater tributaries and Crooked River estuary by increasing riparian buffer widths which will contribute to reducing the identified high nutrient levels and faecal contamination which periodically occurs in the main estuary body.

Figure 17: Crooked River main channel riparian revegetation opportunities

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6.5.4 Terrestrial Vegetation

The Crooked River catchment contains a number of patches of remnant vegetation in various states from relatively undisturbed vegetation through to highly disturbed. Most are fragmented vegetation patches, although there are large areas of connected vegetation in the Seven Mile Beach Reserve and towards the escarpment in the upper reaches of the catchment. There are a number of vegetation patches which are considered Endangered Ecological Communities (EECs) listed under the *Threatened Species Conservation Act 1995*, these are mapped in Figure 18. There are also a number of threatened species of flora and fauna which have been recorded within the Crooked River catchment, or are considered likely to be found within certain vegetation communities. The list below identifies the Endangered Ecological Communities, and some of the threatened flora species which have been recorded in the Crooked River Catchment or are considered likely to be found within the catchment. These species and communities have been identified by various studies including Mills (2006) and the Roads and Maritime Service Flora and Fauna Assessment (2010), completed as part of the upgrade to the Princes Highway between Gerringong and Berry.

Endangered Ecological Communities

- Bangalay Sand Forest
- Illawarra Subtropical Rainforest
- Illawarra Lowlands Grassy Woodlands
- Littoral Rainforest
- Coastal Saltmarsh
- Swamp Schlerophyll Forest on Coastal Floodplains
- Swamp Oak Floodplain Forest
- Freshwater Wetlands on Coastal Floodplains

Threatened Species

- Illawarra Zieria (*Zieria granulata*)
- Illawarra Socketwood (*Daphnandra sp. C*)
- White flowered wax plant (*Cynanchum elegans*)
- Spiked Rice Flower (*Pimela spictata*)
- Australian Salt Grass (*Distichlis distichophylla*)
- Illawarra Irene (*Irenepharsus trypherus*)
- Rainforest Cassia (*Senna acclinis*)
- Illawarra Nightshade (*Solanum celatum*)
- Magenta Lily Pily (*Syzigium paniculatum*)
- Narrow Leafed Wilsonia (*Wilsonia backhousei*)
- Round Leafed Wilsonia (*Wilsonia rotundifolia*)

Despite largely disturbed surroundings, and a history of widespread land clearing, the Crooked River and the associated wetlands are considered an area of regional significance as they are home to several endangered, threatened and rare species of plants, birds, frogs and insectivorous bats (Reinfelds 2001). Given the extent of vegetation loss and habitat degradation across the Crooked River catchment, all stands of remnant vegetation, even when perceived to be degraded by exotics, have the potential to provide important habitat for both native flora and fauna (SWC 1996). In support of this the Kiama LEP 2011 has defined much of the remnant vegetation and EEC's as E2 Environmental Conservation or E3 Environmental Management zoning which restrict activities within these zones. The Illawarra Biodiversity Strategy developed in 2010-11, also aims to guide a program for biodiversity management for the three Illawarra Councils. The Strategy provides a clear set of priority actions to be undertaken by the Councils and identifies priority areas for investment to gain on-ground biodiversity improvement.

Figure 18: Endangered Ecological Communities of Crooked River catchment

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Crooked River is listed as one of three highest priority sites to guide investment in biodiversity via grant and internal funding in the Kiama LGA. The other highest priority sites are Minnamurra River and Jerrara Dam. Figure 19 below shows the Crooked River area identified as highest priority in the Illawarra Biodiversity Strategy.

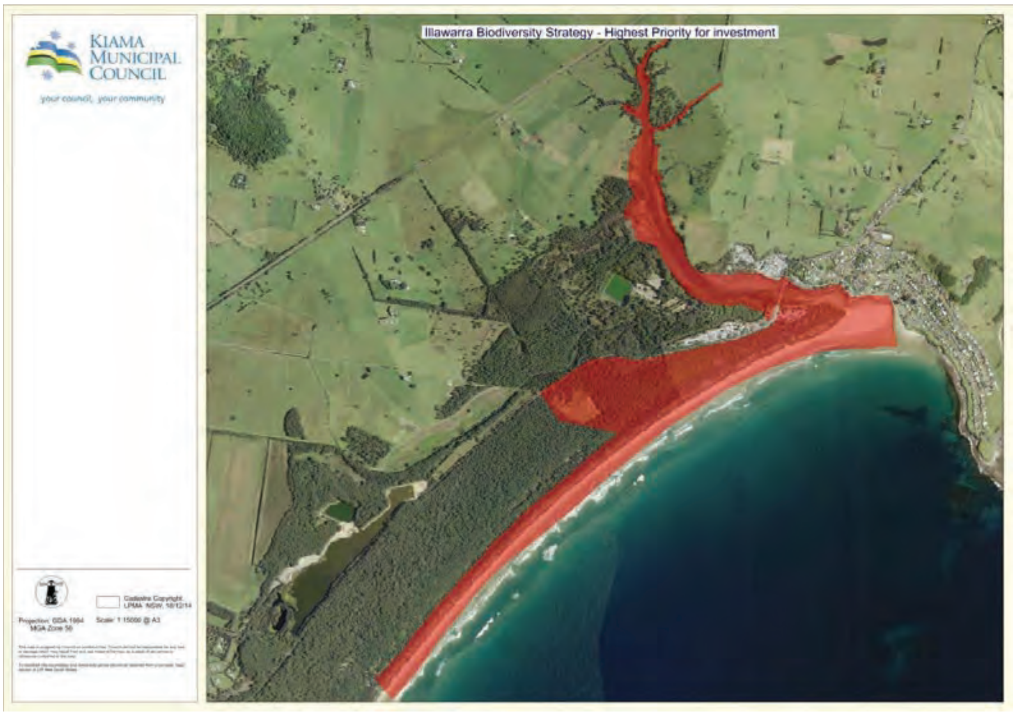

Figure 19: Illawarra Biodiversity Strategy - Highest Priority area for investment

Other state and regional planning documents, including the Illawarra Shoalhaven Regional Plan, the Illawarra Regional Strategy and the Southern River Catchment Action Plan have all identified the Crooked River estuary and catchment as an important area for investment for maintaining and improving biodiversity, including developing biodiversity corridors linking the escarpment vegetation to the vegetation communities on the coastal plain. These plans identify corridor linkages through the Seven Mile Beach National Park and Foys Swamp, which align with the requirements associated with the compensatory plantings identified in Figure 25. Continued effort from agency and private landholders should prioritise investment to rehabilitation of riparian corridors and linking fragmented remnant vegetation patches to enhance connectivity of fragmented vegetation and create linkages between escarpment and coast..

6.5.5 TERRESTRIAL WEEDS

Terrestrial weeds continue to be a problem within areas of the Crooked River catchment, with asparagus fern and lantana presenting particularly apparent and visually impactful examples along the estuary foreshore and throughout the Seven Mile Beach Reserve.

There has been significant investment and effort from the Illawarra Noxious Weeds Authority, National Parks, Seven Mile Beach landcare group, local landholders and Council in and around the Seven Mile Beach reserve, to clear asparagus fern and lantana infestations which have been degrading the Bangalay Sand Forest and Littoral Rainforest communities. Landholders are also undertaking weed control activities where they are encroaching on productive agricultural land. These weeds have been inhibiting the ability of native vegetation to naturally regenerate and provide an ongoing seed source for surrounding areas. Ongoing investment in this area should provide a basis for expansion of the area of EEC being actively managed within the catchment, and identification of future weed control and revegetation activities can build on the work that has already been done on both public and private land.

Weed management will continue to be an ongoing issue requiring substantial and sustained management effort and investment from all landholders and land managers within the catchment.

Lantana, Madeira vine, asparagus fern, bitou bush and coral trees are all particularly evident and identifiable weed species impacting on many areas of the Seven Mile Beach reserve and riparian areas of the Crooked River estuary. Other emerging weed threats which have been becoming more apparent in recent years include green cestrum in the beach / dune areas and increasingly in riparian areas and spiny burr grass which has been identified in Seven Mile Beach reserve. Problem areas which were identified on the catchment assessment are included in Figure 27.

6.6 Estuarine Fauna

6.5.1 Aquatic Biodiversity

Upper catchment

As part of the Gerringong to Bomaderry Bypass Highway Upgrade, Cardno Ecology Lab on behalf of the RMS completed field investigations in 2009 of aquatic habitats, biota and water quality in parts of the upper catchment of the Crooked River.

Freshwater sites within the Crooked River drainages have previously been assessed as providing minimal fish habitat (Class 3 Waterways, after Fairfull and Witheridge 2003), and occasionally as moderate fish habitat (Class 2 Waterways) on some sections of the Crooked River (The Ecology Lab, 2007 in RTA 2010). The more ephemeral drainage lines in the area, such as those that flow off Toolijooa Hill, have been considered unlikely to provide fish habitat (Class 4 Waterways), as they only flow during larger events, have poorly defined channels with few standing pools and are often colonised by pasture grasses (The Ecology Lab, 2007 in RTA 2010).

The report also identifies the 2 freshwater wetland areas (Willowvale and Gerringong wetlands) as both highly degraded. The majority of standing water within Willow Vale is contained within farm dams or open pondages without riparian vegetation. The Gerringong wetlands are predominantly creek swamp habitat on a degraded watercourse that passes through the outskirts of Gerringong.

A freshwater fish survey undertaken by The Ecology Lab in 1999 as part of the baseline data collection for the Gerringong Gerroa Sewage Scheme found 186 individuals from five families, representing seven species: Short finned Eel (*Anguilla australis*), Long finned Eel (*Anguilla reinhardtii*), Common jollytail (*Galaxias maculatus*), Empire Gudgeon (*Hypseleotris compressa*), Coxs Gudgeon (*Gobiomorphus coxii*), Striped Gudgeon (*Gobiomorphus australis*) and the introduced Mosquito fish (*Gambusia holbrooki*). A later survey in 2007 by the same organisation undertaken in the Crooked River caught only one Striped Gudgeon and a Long finned Eel was observed gulping air at the surface in response to low dissolved oxygen levels. This demonstrates the variable quality and availability of freshwater habitats within the Crooked River catchment and is an area which could be improved with coordination, investment and improved management.

Macroinvertebrate surveys as part of the 1999 study found 41 taxa across the Crooked River and Ooaree Creek cathcments. They found that consistent with results from water quality, the most common macroinvertebrates collected from pool habitat were Midge fly larvae (family Chironomidae), which are tolerant to pollution or degraded habitat. Crooked River was found to have a lower diversity, but higher total abundance of macroinvertebrates than the Ooaree Creek drainage (The Ecology Lab 1999).

Lower catchment

There are a large number of fish species that utilise estuarine waters at some time during their life cycle. The Crooked River estuary is considered to be major fish habitat (Class 1 Waterways), (Fairfull and Witheridge 2003). A survey conducted by The Ecology Lab 1999, of Werri Lagoon and Crooked River found the fish populations in the Crooked River were characterised by Luderick (*Girella tricuspidata*), Flat-tail mullet (*Liza argentea*), Sea mullet (*Mugil cephalus*), Tarwhine (*Rhabdosargus sarba*), Sand whiting (*Sillago ciliate*), Yellow finned leatherjacket (*Meuscheria trachylepsis*), Swan River goby (*Pseudogobius olorum*), Blue Groper (*Achoerodus viridis*) and Eastern King Prawn. The study underlines the importance of seagrass beds within the estuary, as it identifies that all of the species except the sand whiting are strongly associated with seagrass habitats.

The estuary is also renowned as a productive recreational fishery with commonly targeted species including Dusky Flathead (*Platycephalus fuscus*), Yellow fin bream (*Acanthopagrus australis*) and Luderick (*Girella tricuspidata*). On estuary health monitoring trips, Kiama Municipal Council staff observed schools of large mullet and luderick in the lower part of the estuary and Blue Angle Creek. There is no data available on fishing effort and the effect of recreational fishing on species abundance within the Crooked River.

6.5.2 Barriers to Fish Passage

In stream structures, such as the flood gate on Blue Angle Creek, were installed originally to stop the tidal inundation of Foy's Swamp, which would lead to the return of salt tolerant species in place of pasture grasses. Drainage and clearing of Foy's Swamp for agricultural purposes began in 1905, as described in a paper by John Colless (1963) entitled 'Land Development at Toolijooa on South Coast'. The floodgates provide an effective barrier to salt water intrusion, and allow the freshwater behind the floodgates to drain as the tide drops. One of the unfortunate consequences of flood gates is the barrier to fish passage to upstream reaches of the Blue Angle Creek. Certain fish species rely on being able to migrate from fresh to salt water (catadromous) to complete their breeding cycle such as the Australian Bass (*Maquaria novemaculeata*) and species of Australian Eels. There are no records of bass occurring in the Crooked River system, possibly due to the limited and largely degraded freshwater habitat available upstream of the estuary. The Blue Angle Creek floodgate still blocks fish passage to further habitat upstream of the flood gate for eels, mullet and other fish species.

Water quality is directly impacted by the presence of floodgate structures, predominantly by blocking water exchange. The stagnant water that is often found behind floodgates encourages the accumulation of organic matter, promoting high nutrient levels and episodic algal blooms as well as reducing water quality through low dissolved oxygen levels and low pH levels in drain water (Johnston et al 2003).

There is still an opportunity to assess the function and potential management options of the floodgates on Blue Angle Creek which could lead to an enhancement of aquatic habitat within the Crooked River and potentially assist in the management of acid sulfate runoff and poor water quality events. There would need to be a full analysis of the potential pros and cons, and cooperation between landholders and government agencies for this to take place. It was also identified in the CREMP 2003 that any alteration to the flood gate on Blue Angle Creek would require consideration of the disturbance or exposure of potential acid sulfate soils.

The Blue Angle Creek floodgate has been identified in the report '*The assessment and management of floodgates on the NSW South Coast' Report to the Natural Heritage Trust (2007),* as a high priority site for active management and this is supported by this CZMP. Any future opportunities to pursue the full or partial re-enstatement of a natural flow regime / wetland to Foy's Swamp should be pursued in cooperation with relevant state and local government agencies and landholders concerned.

6.5.3 Terrestrial Fauna

Several threatened and endangered fauna species have been recorded in the Seven Mile Beach, Foy's Swamp and Coomonderry Swamp areas (SWC, 1996). Flora and fauna reports have been completed for Cleary Brothers in 2005 and 2006 by Mills and Associates, who performed detailed surveys of the whole property, which forms a significant part of the Crooked River catchment. The fauna list was compiled from all previous studies at the property, and also cited fauna records from various papers and reports concerning the surrounding area. The list contained 204 species, including 33 mammals, 147 birds, 14 reptiles and 9 frog; including eight introduced mammal species and six introduced bird species.

The upgrade of the Princes Highway between Gerringong and Berry has also meant that detailed Fauna and Flora Assessments (2010) have been completed as part of the Review of Environmental Factors for the project. The review covered species recorded within a 10km radius of the study area, and species which could inhabit the area based on habitat preferences. A total of 80 animal species listed in the NSW *Threatened Species Conservation Act 1995* and/or the *Australian Environment Protection and Biodiversity Conservation Act 1999* or their potential habitat were recorded within a 10km radius of the study area. The report noted that based on the proximity of current and previous records and the presence of identified habitat preferences, potential habitat may exist within the study area for 44 threatened and 21 migratory animal species. The relative location of the Crooked River estuary to Coomonderry Swamp means that migratory species often utilize the mudflats and other areas of the Crooked River estuary. During the review of the CREMP 2003, it was noted by a committee member that he had observed groups of Japanese or Latham's Snip on multiple fishing excursions, walking along the bank of the estuary (pers comm., M.Gleeson 2015).

As reported in Mills (2006) and RMS (2010), previous studies have identified several threatened species that are known to occur or that could occur in the Crooked River catchment and nearby. Some of these species include:

- Green and Golden Bell Frog, reported on the Cleary Brothers property in the dredge pond. There are also records from Coomonderry Swamp, adjoining the Crooked River catchment boundary
- Regent Honeyeater, seen in the Seven Mile Beach National Park in 1993 and 1995
- Glossy Black Cockatoo; reported in Shoalhaven Heads in 1994
- Australasian Bittern occurs at Coomonderry Swamp and has been observed in the dredge pond at the sand mine property in January 2003
- Black Bittern has been cited once on Blue Angle Creek in July 1990
- Black necked Stork, recorded at Crooked River and Coomonderry Swamp, although records are over 30 years old
- Swift Parrot
- Powerful Owl, is present at Seven Mile Beach (Murphy 1998)
- Masked Owl; record of road kill near Gerroa in 1980
- Spotted Tailed Quoll, reported as road kill on the Seven Mile Beach Road in 1987
- Grey Headed Flying Fox
- Large Bentwing Bat, roost in caves and unnatural structure such as buildings and drains. Local habitat provides very likely foraging area
- Yellow bellied Sheathtail Bat, recorded in 1995 by Murphy (1998) in forest within Seven Mile Beach National Park
- Eastern False Pipistrelle
- Little Eagle

- Greater Broad-nosed Bat, recorded in 1995 by Murphy (1998), in forest within Seven Mile Beach National Park.

This list is by no means exhaustive, and demonstrates the importance of all habitat types in the Crooked River catchment, as it provides a variety of forage area and habitat for both resident and migratory fauna species. Both the Mills (2006) report and the RMS (2010) report are available on-line at the Cleary Brothers website and Roads and Maritime Service Gerringong Upgrade website, and provide more comprehensive details on the faunal biodiversity of the area.

6.7 ACID SULFATE SOILS

In the 1998 Estuary and Data Compilation Study, acid sulfate soils in the Foy's Swamp area were identified as an area of concern, but many of the drains in the lowland areas of the estuary could pose a threat to ecosystem health. The drains leading into the poorly flushed upper Crooked River estuary may have the potential for more serious implications on the health of the main estuary, and as such a study and management plan for acid sulfate soils in the Crooked River Catchment could be of benefit to reduce the risks to estuary health into the future. This would require the coordination, cooperation and participation of multiple property owners across the catchment.

In early October 2011, there was a fish kill incident which resulted in mature flathead and blackfish dying in Blue Angle Creek. The cause of death was suffocation due to aluminium build up on the gills of the fish. This is a common symptom of acid sulfate soil runoff, where aluminium is stripped from the soil by acid runoff and becomes soluble in the water column at pH levels below 5.5.

These incidents often occur after long periods of low rainfall where potential acid sulfate soils are exposed to the atmosphere due to the drop in the water table. Exposure of these normally waterlogged soils leads to iron sulphide oxidation, producing sulphuric acid. This acid can result in low pH water being flushed into the estuary when heavy rainfall occurs following long dry periods, flushing substantial quantities of low pH water and soluble aluminium into waterways.

Acid sulfate soils are predicted to become less of a problem as sea level rise gradually inundates and buffers the low lying areas within the catchment. This being said, it is likely that in the short term there will be instances where acid sulfate soils are exposed to the atmosphere, which in turn will create acid runoff, high levels of soluble aluminium within the water column and fish kills that generally follow such events. The 2011 acid sulfate runoff event in the Blue Angle Creek highlights the issue, and the careful planning and management that needs to occur to minimise the likelihood of these events happening into the future.

Acid sulfate soil runoff has occurred on multiple previous occasions in Blue Angle Creek and Figure 20 shows the potential acid sulfate soil risks within the Crooked River catchment.

Development of a strategy or management plan to deal with future potential acid sulfate run off events from the Blue Angle Creek should be a priority, given the past history of actual acid sulfate run off. Any management strategy will need to include an assessment of the role the flood gates on the creek play, and bring together land holders in the catchment to determine research avenues and cooperative actions to try to reduce the impacts and likelihood of future acid sulfate runoff. The process could follow the methodology implemented by Shoalhaven Council and UNSW in 2012, which undertook a strategic catchment wide prioritization of high acid producing drains and subsequent production of actions plans to reduce or eliminate acid drainage from each site. Any plans which are researched and developed should also include investigation of the potential re-enstatement of a natural or semi natural hydrological regime to Foy's Swamp.

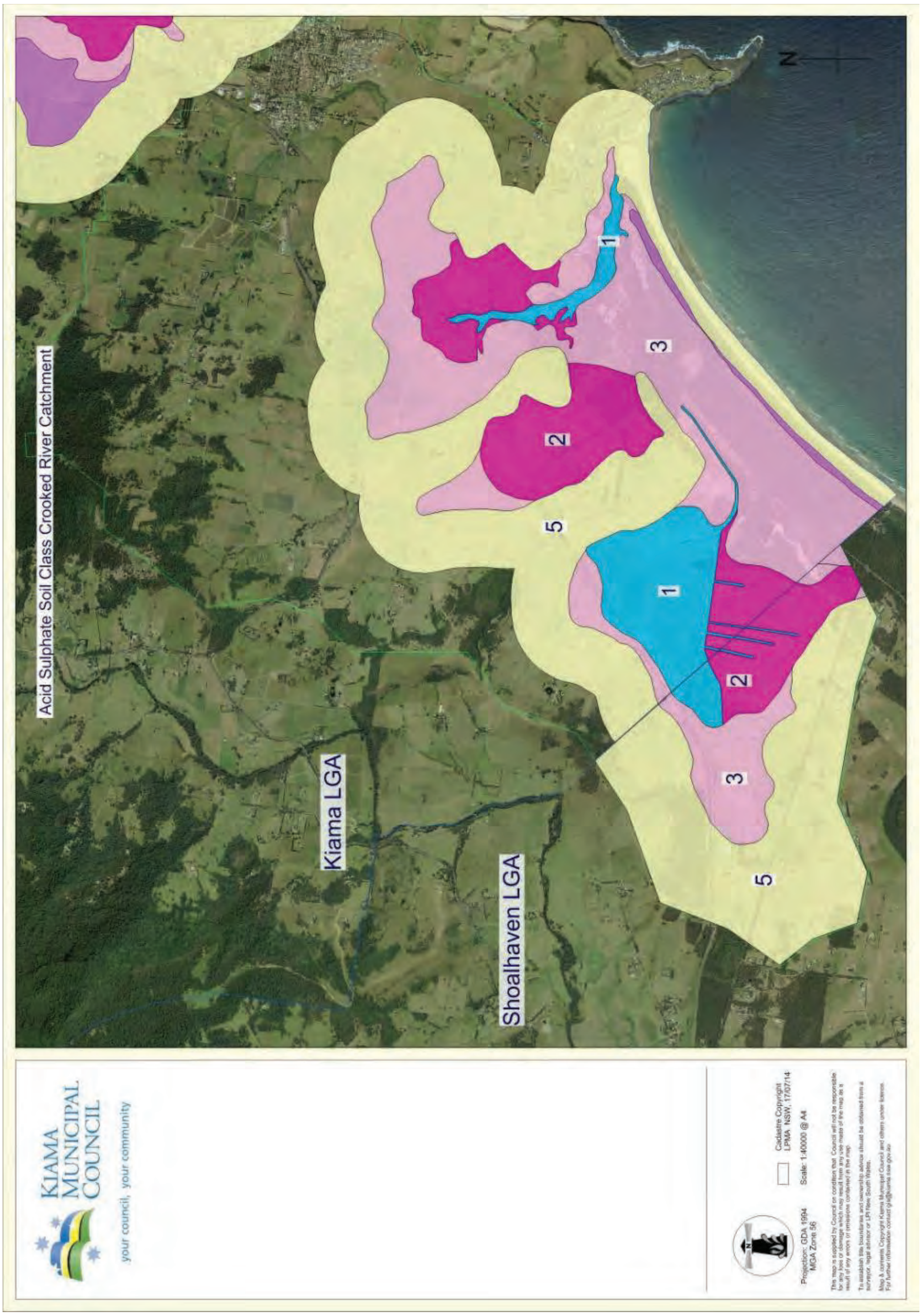

Figure 20: Acid sulfate soil map of Crooked River catchment

6.8 Urban Expansion, Storm Water and Drainage

Urban expansion and road upgrade projects can lead to pressure on natural ecosystems and estuarine processes by changing the hydrological characteristics of land, creating large areas of hard stand which are generally impervious and create increased runoff and increased runoff velocity. This stormwater runoff can contain pollutants which are more efficiently transported into the waterway, including litter, nutrients, sediment and hydrocarbons.

The Crooked River estuary has a very low percentage of land zoned for residential, commercial and industrial development. Recent development of Elambra estate and the upgrade of the Princes Highway are increasing the hard surface runoff area, particularly in the Union Creek catchment.

The information contained within Chapter 6 of the Review of Environment Factors (REF) for the Gerringong upgrade identifies changes to local hydrology as a potential threat during both the construction and operation of the highway upgrade. The upgrade also includes two creek realignments in the Crooked River catchment, and proposes a number of strategies and actions which will mitigate the effects on the local hydrology and reduce the impacts of sediment mobilisation, flooding impacts and erosion. It has been identified that on completion of the upgrade, there will be an increase in the amount of road runoff. This has been dealt with by appropriate sizing of drainage structures, which according to the REF will improve the existing flood impacts for road users. Pavement drainage is being incorporated into the highway upgrade to capture and treat runoff, including permanent spill and sedimentation basins, and the creek realignments will include compensatory riparian plantings, and reinstatement of channel morphology which mimics the natural state of the river in the realigned sections.

Development of Elambra estate has meant a change in land use for parts of the Union Creek catchment leading into the Crooked River. Union Creek has a very low stream gradient, as identified by Dunwoodie 2004, and this low gradient means there is a decreased risk for potential scouring or erosion that may occur after heavy rainfall, as the flow slows as it moves out onto the alluvial flats between Gerringong and Gerroa.

To deal with the change of land use and potential for environmental impacts associated with residential development of Elambra Estate, Kiama Council created Chapter 22 of Council's Development Control Plan 2012 dedicated to Elambra Estate – 'Chapter 22 – Site Specific Controls Elambra Estate'. Development controls include the requirement for onsite stormwater retention and re-use, all lots to be connected to sewer and dedication of riparian land abutting Union Creek is to be rehabilitated and dedicated to Council as public reserve. A Union Creek Plan of Management was also prepared, which detailed the requirements for the management of the riparian lands included in the Elambra Estate development including riparian plantings (Figure 21). The Union Creek Plan of Management can be viewed at Kiama Council's website www.kiama.nsw.gov.au, under the plans and policies section.

Figure 21: Riparian rehabilitation Elambra Estate

Kiama Council established the southern boundary of Gerringong in the LEP 2011, in consultation with the community and department of planning. This boundary can be seen in Figure 2 showing the Land Zoning in the current Kiama LEP 2011. At the time of review, consultation for the Draft Regional Growth and Infrastructure Plan was underway, and there was considerable concern in the community that the southern boundary which was adopted in the Kiama LEP 2011 would be extended further south. If this were to happen, the importance of stormwater controls and riparian land management would be extremely important not to enhance the delivery of pollutants to the Crooked River by increasing hydraulic efficiency of Union Creek. This plan supports strict controls on runoff from new developments in the Crooked River catchment, including best practice Water Sensitive Urban Design initiatives to minimize future water quality impacts.

As well as controlling volume and velocity of stormwater runoff from urban and highway areas, stormwater drains also have the potential to deliver volumes of litter and gross pollutants to the receiving waters. A number of 'enviropod' units have been installed in many of the drains in Elambra Estate and a number of drains in the Gerroa township. Ongoing monitoring and maintenance of these structures will be required to ensure efficient operation of the stormwater network and the capture and diversion of gross pollutants and sediment.

6.9 Waste Water Management

6.9.1 Gerroa Wastewater Recycling Plant

The Gerroa WRP was commissioned in 2002, and has been designed to meet an expected increase in population up to the year 2022 of 11,000. The NSW Ministers conditions of approval included conditions for a treated effluent reuse scheme, to negate the need for an ocean outfall. According to the 2011 census statistics, Gerringong, Werri Beach and Gerroa have a combined residential population of 4,634.

There have been concerns raised by the community over the treated wastewater irrigation and sewage overflow points associated with the Gerringong Gerroa Sewage Scheme (GGSS), and the potential to influence nutrient and faecal contamination levels within the estuary. The GGSS was commissioned in August 2002 and treats waste water to an advanced tertiary level. The wastewater recycling plant has been designed to re-use at least 80% of effluent and 100% of biosolids for agricultural purposes, and cater for an equivalent population of 11,000 and average dry weather flow of 2.2ML per day.

The Gerroa WRP has drastically reduced the potential for untreated effluent to enter the estuary through stormwater drains, effluent trenches and via seepage through the disposal of raw effluent at the former Gerroa Night Soil Depot. However, rural properties that cannot connect to the reticulated sewer system still operate onsite sewage management facilities (OSMFs) and Council routinely inspects these systems for faults in their operation according to the risk rating given to the OSMF.

Sydney Water Corporation owns a 150 hectare property adjoining the north western tip of the Crooked River estuary, of which 70 hectares is utilised for irrigation of the recycled effluent for pasture improvement. When water is unlikely to be used for irrigation due to seasonal conditions, water is discharged onto the sand dune systems at a rate of up to 0.8ML per day (Boake, 2009).

The location of sewer overflow points within the catchment has been identified as an area of concern by the community. Sydney Water Corporation is working with the holiday park on the northern side of the Crooked River to ensure that private pumping stations on the site are not creating an increased risk of sewer overflow due to storm water being pumped into the sewer system (J.Kidd pers comm. 2013). In 2013, Sydney Water Corporation issued letters requiring land holder actions to address this problem through their trade waste licensing. These actions are being tracked and most have been completed.

A report completed by Sydney Water Corporation in October 2012 titled, *'Gerringong Gerroa Sewerage Scheme Water Quality Investigation'*, was undertaken to assess data collected over the eight years of operation to determine whether effluent reuse and dune disposal of effluent from the Gerringong Gerroa Water Recycling Plant has affected or influenced:

- ground water quality of the irrigation farm or the plant site;
- water quality in the Crooked River; or
- water quality of the Blue Angle Creek

The full report is available from Sydney Water Corporation on request www.sydneywatercorporation.com.au.

The report identifies that NSW Ministerial conditions of approval are mandatory requirements and in this instance, monitoring, analysis and reporting of groundwater and river waters should be consistent, defensible and readily retrievable in order to meet the Ministers Conditions of Approval 46 (Sydney Water 2012).

The report does however identify that there have been inconsistencies in what and where data was collected, recognising that uniform data collection across boreholes and river sites has been difficult to obtain. It also strongly recommends that Sydney Water Corporation, in order to be able to prove compliance to the Ministers Conditions of Approval, investigate implementing a standardised system that meets the criteria for reporting. Correspondence from Sydney Water during the review of this plan indicates that the sampling and reporting system has been standardized as Sydney Water Corporation is now undertaking the sampling for both the Environmental Protection Licence and sampling points for the Ministers Conditions of Approval.

The data that was comparable across monitoring sites was analysed in this report and the following statements made:

- The production of consistent quality effluent was demonstrated out of routine six day effluent monitoring, that had a total of 2725 sample tests with only 16 exceedences of the Environmental Protection Licence limits 50th percentile between January 2004 and June 2011.

- Comparison of river water quality for the five listed parameters for estuarine waters of the ANZECC (2000) guideline values (total phosphorus, total nitrogen, pH, oxidised nitrogen and filterable reactive phosphorus) indicated both before and after periods exceedances occurred. This suggested no change occurred in river water quality from operation of the Gerroa WRP.
- Conclusions of the broad geographic AWT (1998) study of groundwater of the Crooked River catchment concluded nutrient and bacterial contamination was present at all bore hole sites sampled. Poor ground water quality of sites at the farm area were attributed to intensive dairy farming activities that had been undertaken prior to construction of the Gerroa WRP.
- Of the 13 ground water parameters with ANZECC (2000) guideline values for irrigation waters, only pH and faecal coliforms had a pattern of consistent exceedances across most sites. These exceptions were also recorded in the two sample periods before the plant was constructed for both the plant and farm sites. Where faecal coliform values exceeded guidelines, they were well above the exceedance values recorded in the plant effluent. Given the recorded low levels of faecal coliforms in the plant effluent it is clearly not the source of faecal coliforms detected in the ground water.
- The four summary analyses of pH, total nitrogen, total phosphorus and faecal coliforms sampled across the effluent, bore hole and river water for dry and wet weather data all reflected effluent quality was of consistent quality with minimal variation. The consistent quality met Environmental Protection Licence (EPL) values on all but a few occasions. In comparison river water and ground water were much more variable through time, including the period before operation of the plant.
- Ground water and river sites had values on most sampling occasions that were higher than EPL values for total phosphorus and faecal coliforms.
- The comparative assessment suggests irrigation of effluent and dune disposal of effluent is most likely to contribute to dilution of ground water, but dilution has not been sufficient for an obvious change in ground water to be detected.

As well as the analysis of the water quality parameters collected under the licence conditions for the operation of the Gerroa WRP, Sydney Water Corporation has confirmed that there have been no plant overflow from the Gerroa WRP and no pumping station dry weather overflow since the scheme began in 2002 (SWC at stakeholder meeting, 2013).

6.9.2 Onsite Sewage Management Facilities (OSMFs)

There are an estimated 146 Onsite Sewage Management Facilities (OSMFs) within the Crooked River catchment. The highest concentrations of the OSMFs are contained in the upper catchment areas of Blue Angle Creek, the upper catchment of Crooked River around Willow Vale and the flats around Toolijooa.

Treated effluent from OSMFs have high concentrations of nitrogen and phosphorus. Council requires landholders who cannot connect to the sewer to gain approval for the operation of OSMFs. The OSMFs are ranked by Council as high risk or low risk, according to site considerations including soil type, location relative to streams, type of system and potential loading. Council carries out inspections of the high risk systems on an annual basis, and low risk systems on a 4 yearly basis, according to its Onsite Sewage Management Strategy adopted in 2004.

Orders are issued to owners of OSMFs which are identified as faulty or where effluent discharge areas or trenches are assessed to have failed.

Figure 22 shows the OSMFs which are present in the Crooked River catchment. These maps have been collated using a combination of actual database information for the Kiama LGA and interpreting aerial photography for the area within the Shoalhaven LGA.

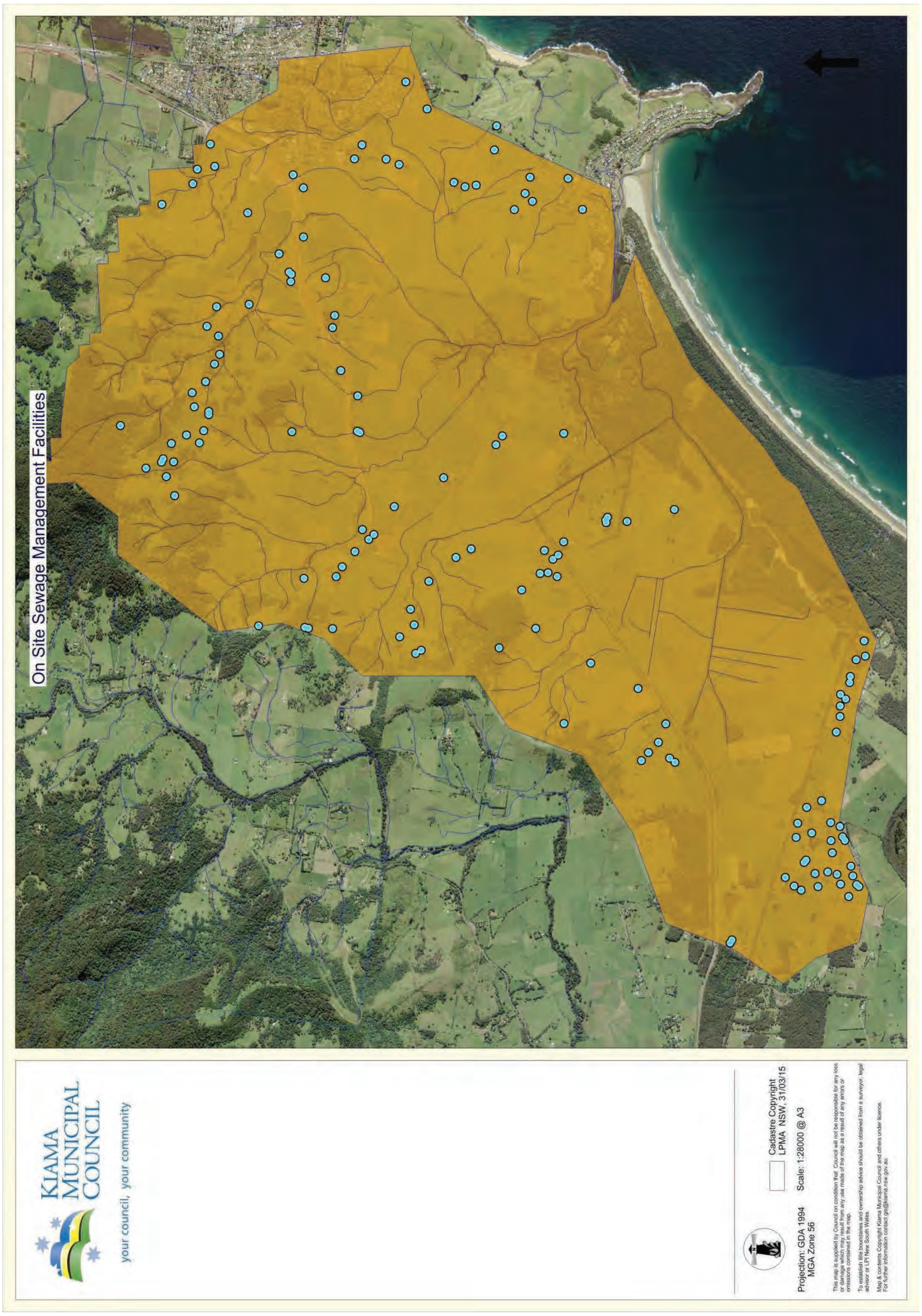

Figure 22: Onsite sewage management facilities in the Crooked River catchment

6.10 Agricultural Land Uses

Dairy farming and grazing are both historically important and major land uses in the Crooked River catchment, with just over 50% of the land zoned for primary production and 24% zoned as rural landscapes. Livestock access to riparian zones and wetlands was identified in the CREMP 2003 as a management issue, and is still a current management area where improvements can be achieved. There have been a number of areas of the estuary which have been fenced to restrict livestock access, however there are major tributaries such as Union Creek and the upper Crooked River where there is limited control over riparian access by stock, and / or riparian vegetation is sparse.

Ongoing pressure on estuary health from nutrient enrichment remains, which is contributed to by the largely agricultural land use within the Crooked River catchment. A NSW Department of Primary Industries '*Overview of the NSW Dairy Industry (2014)*' summarised the major natural resource management challenges for nutrient runoff and water quality from both effluent and fertilizer use as:

- Hotspots (laneways, feedpads, high traffic areas)
- Concentration of nutrients in re-use areas
- High residual levels of Phosphorus on many farms

The report indicated that about 35% of farmers prepare a nutrient budget for their farm and 68% of NSW farmers surveyed test the nutrient levels of their soils every 2-3 years.

Phosphorus levels have historically been high within the surface and ground water of the Crooked River catchment, due to historical and continued land use.

Overall in the Kiama LGA there has been a decrease in the number of dairies, which has in part been replaced by a few larger dairy operations, grazing, cropping and more diverse or 'boutique' primary production activities and rural lifestyle land uses. Gill (2008) in a study on '*Land Management and Land Cover on Land owned by Amenity Oriented Rural Landowners in the Jamberoo Valley*' cited various reports which detailed the decline of the dairy industry in NSW. In the Kiama LGA, growing beef cattle numbers since the early 1970's (ABS Agricultural Census 1971-2001) is likely evidence of one response to pressure in the dairy industry since the restructuring of the industry in 2000.

Diversification of the agricultural activities may lead to less intensive agricultural production, however there are opportunities for organizations such as Local Land Services to implement dairy effluent re-use projects on the remaining dairies in the catchment, and to facilitate and support improved riparian management projects including riparian fencing and revegetation projects in strategic locations within the estuary and its tributaries.

There have been concerns raised in the previous CREMP 2003, about the potential impact of changing rural land use including the potential for impacts associated with changed fertilizer and pesticide / fungicide use in the viticulture and agriculture sector. There have not been any water quality investigations or research into the effects of land use change on the Crooked River estuary, and this is a potential area to include in future research projects in partnership with industry and research institutions. The information coming from this area of research also has the potential to inform future reviews of Council Local Environment Plans and Development Control Plans in the context of the potential effects on estuary health.

There are significant barriers to the implementation of natural resource management (NRM) activities including increasing landholder age and physical capacity and economic means to fund works, not only to be able to afford to invest in such projects, but to maintain the areas after initial works are completed. These issues, as well as trying to achieve cross property or cross boundary benefits in terms of land management, are challenges which need to be addressed in the proposal and implementation of NRM projects.

The newly formed NSW Local Land Services (LLS) brings together technical and advisory knowledge from the Livestock Health and Pest Authorities, Catchment Management Authorities and some agricultural services from the Department of Primary Industries. Their major charter is to deliver customer focused services to farmers, landholders and the community across rural and regional NSW. South East Local Land Services will engage with their customers to provide expertise in agricultural production, biosecurity, emergency response and recovery, animal welfare, chemical residue management, natural resource management, movement of stock and other related services and programs. At the time of review of the CREMP 2003, NSW LLS was in its infancy, but initial discussions indicated that riparian protection projects and dairy effluent management projects would be part of the LLS service delivery model, and more importantly, supporting local agricultural businesses to remain economically viable into the future.

At the government and non government stakeholder meeting held in July 2013, Sydney Water Corporation representatives indicated that they would be interested in pursuing the potential establishment of 'demonstration' reaches for parts of the riparian and agricultural lands which make up the treated effluent irrigation area adjoining the Crooked River estuary. As this site is an leased operational farm and has Ministers Conditions of Approval regulating the irrigation of the recycled effluent, there would need to be support and agreement by all parties concerned.

The demonstration reach concept would undertake projects to improve estuary health outcomes such as stock exclusion, off stream watering and riparian revegetation project which would be utilized to promote these activities within the catchment. A potential site has been suggested in Figure 23, as well as identifying other tributaries which could be considered for demonstration reach projects. The demonstration reach concept provides an opportunity to kick start or build momentum for investment in natural resource management strategies within a catchment, through completion of small scale projects which can be utilized in field days and build community connection through communication of ideas and methodologies. These projects are generally funded through grant funding opportunities and supported through state government agencies such as South East Local Land Services and the Department of Primary Industry.

Photograph sourced from NSW DPI website showing the impact of stock exclusion fencing on riparian zones (Photo L.Bogie)

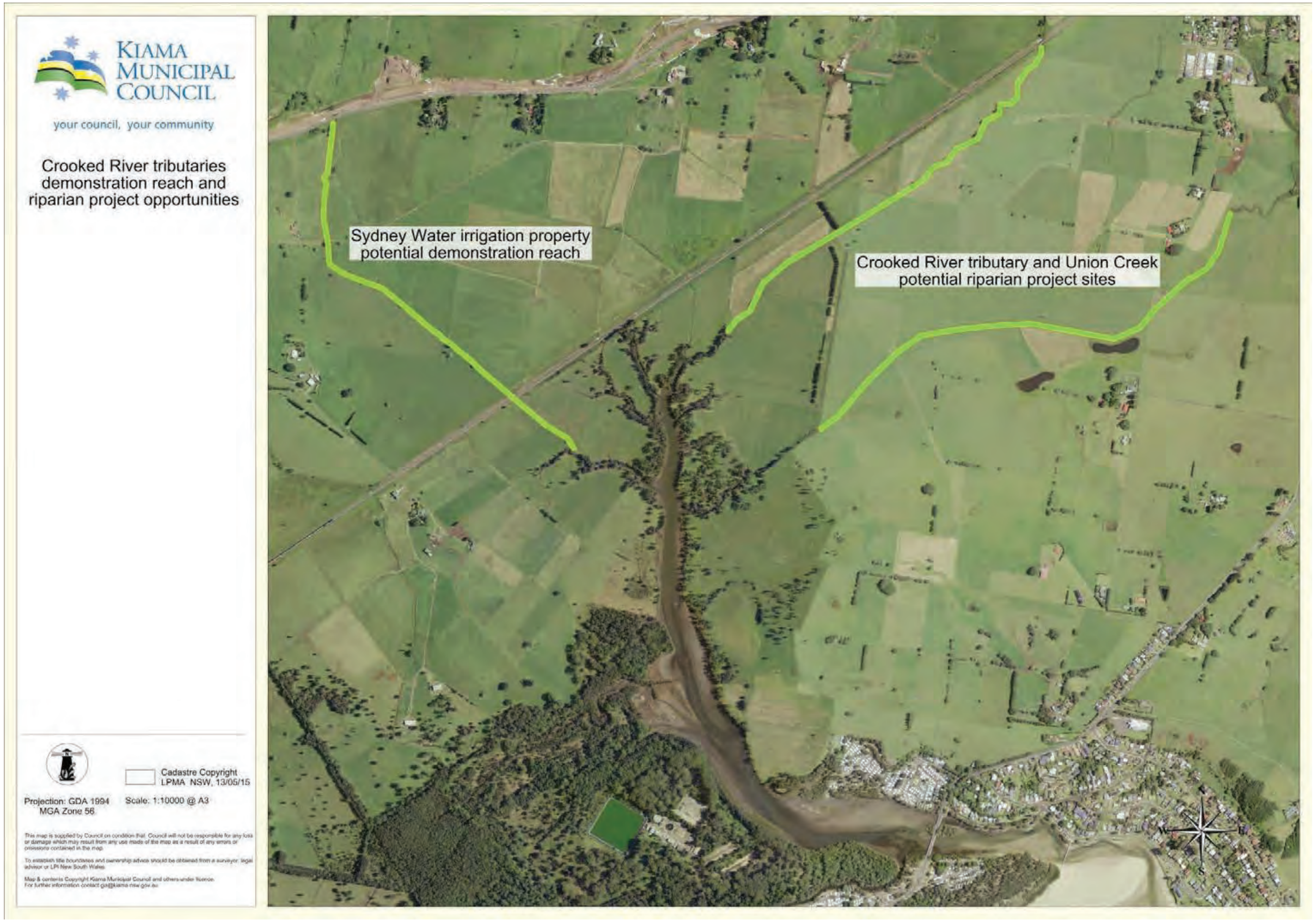

Figure 23: Potential riparian management demonstration reach, Sydney Water irrigation property and other tributaries, Crooked River

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6.11 Sand Mining

According to the Quarry Environmental Management Plan 2009, Cleary Brothers has operated the Gerroa Sand Mine, for approximately 50 years. Between 1990 and 2008 the quarry operated under a development consent granted by the Land and Environment Court. The sand mine has since been granted approval for the extension to their sand extraction activities, subject to conditions determined by the NSW Land and Environment Court. The approval allows for extraction until 31 July 2023, with strict rehabilitation and environmental monitoring and reporting conditions imposed. The approval for the extension to the sand mining activities, as well as the full Gerroa Sand Resource, Quarry Environmental Management Plan and annual environmental monitoring reports can be found on the Cleary Brothers website at http://www.clearybros.com.au/page/projects.

Weed control and revegetation activities continue to be implemented as required by the development consent, to compensate for the loss of endangered ecological community and other vegetation as a result of the sand mining activities. This includes the revegetation of 30 hectares of the property creating wildlife corridors and enhancing existing habitat as well as the protection and management of a further 56 hectares of high conservation value land on the site (Cleary Brothers Website, sourced November 2014).

Due to the sensitive nature of the vegetation communities remaining in the Crooked River catchment and particularly around the sand mining operation, conditions of consent for the sand mining operation require monitoring of the groundwater quality and levels to determine the effect on local hydrology and whether or not this is effecting the vegetation communities. This is included as part of the Annual Quarry Environmental Management Plan submitted to the Department of Planning and Environment.

In February 2014 a flood scour event in the Blue Angle Creek catchment led to oxygen depleted conditions and a small fish kill in the Blue Angle Creek below the flood gate. A field assessment by Council staff, Cleary Brothers representatives and Office of Environment and Heritage officers found the event to be naturally occurring, but exacerbated by the enhanced draining capacity of the cleared land above the floodgate. It was identified that the planting out of the compensatory corridor along Blue Angle Creek may assist to reduce the impact of flood scour in future. This planting is identified in Figure 24, and is identified to be completed as part of the consent conditions for the extension of the Gerroa sand mining operation. The compensatory plantings already underway on the Cleary Brothers site as part of the development consent conditions detailed in the Gerroa Sand Resource Quarry Environmental Management Plan (2009), can be seen outlined in Figure 25. This revegetation demonstrates how projects can be implemented to provide connection of fragmented vegetation patches across a landscape. These figures identify approximate locations of the revegetation activities and should not be used to determine if compensatory plantings have been carried out in compliance with the QEMP 2009 and consent conditions.

Figure 24: Future compensatory planting for Blue Angle Creek which will reduce the potential for flood scour

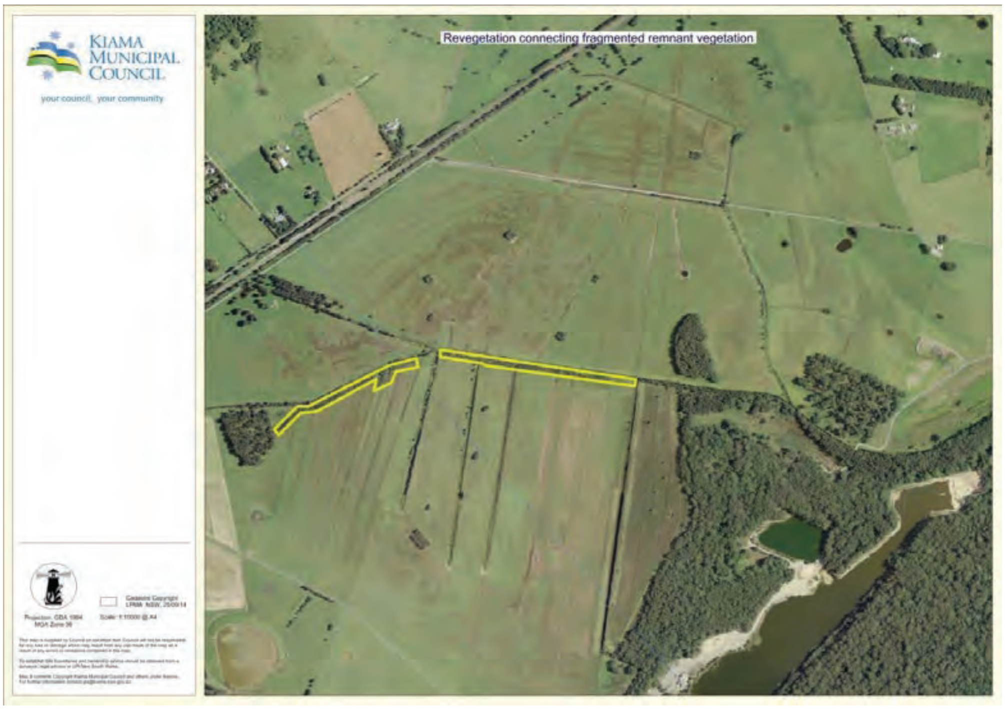

Figure 25: Compensatory plantings on Foy's Swamp

7. Community Uses and Cultural Heritage

Community access to, and use of the coastal zone including estuaries and rivers is recognized as being extremely important for health and well being. In the context of the CZMP, access refers to the ability of the general public to be able to utilize the public land that surrounds the estuary and the waterway itself. This section provides a brief overview of the community uses of the estuary

7.1 Amenity

The natural beauty and tranquility, safety and aquatic habitat of the Crooked River Estuary have rated highly amongst community values in both the 2003 and 2012 surveys. The Crooked River and adjacent Seven Mile Beach is an extremely popular area with locals and tourists for recreational pursuits and passive enjoyment. Maintaining these values and dealing with issues which threaten community enjoyment and interaction with the Crooked River are key for attracting tourism to the area and the continued ability for people to utilize the area for their enjoyment and well being. Peak visitor periods over the summer and Easter school holiday periods put pressure on surrounding amenities and the estuary itself, and it is important that issues which can impact the continued use and amenity of the river are identified and potential management actions are considered.

7.2 Recreational Uses

The Crooked River is valued highly by the community for its beauty and relatively natural state. Due to the infilled nature of the Crooked River estuary, and its relatively small area, there is very limited opportunity for motorised boating within the estuary. Recreational uses of the estuary generally include kayaking, fishing, bait gathering, swimming and passive recreation such as picnicking.

The Crooked River is a well known recreational fishing spot, and it is assumed that there is a high rate of fishing pressure placed on the system in peak periods due to the two holiday parks located on the estuaries banks.

Swimming activities generally occur in the very low part of the estuary, where there is good mixing of ocean and estuarine water. Water quality for primary and secondary contact activities is often unsuitable following rainfall, and can be exacerbated when the estuary is closed to the ocean. Beachwatch sampling has been undertaken on Seven Mile Beach since 2011/12, and all samples have shown excellent water quality, with a beach suitability grade of Very Good awarded every year including 2013/14. For Beachwatch results you can read the Beachwatch annual reports at http://www.environment.nsw.gov.au. After the 2015/16 sampling season, it may be pertinent to move the monitoring point to inside the river mouth where many families swim during the summer period.

7.3 Access

7.3.1 Pedestrian Access

Foreshore access to the Crooked River estuary is limited to the lower parts of the main estuary and lower parts of Blue Angle Creek from the Discovery Holiday Park and Seven Mile Beach Holiday Park, to the entrance on Seven Mile Beach. Access to Baileys Island is restricted, as the former footbridge across Blue Angle Creek has been removed, however due to shoaling at the mouth of the creek, public access can be gained at low tide to the southern bank of the Crooked River adjacent to the Gerroa WRP.

Given the relatively accessible foreshore in the lower part of the estuary, it is important to identify those areas in Blue Angle Creek and the main Crooked River channel which are suffering from bank erosion, and rectify these problems to ensure public access is maintained. This may however include limiting access to the foreshore in these problem erosion areas until the issue is addressed, or consolidating access to key points along the bank.

7.3.2 NAVIGATION

Even though the Crooked River is not compatible with motorised boats, there is a sand boat ramp located where the river meets Seven Mile Beach. This ramp provides a relatively sheltered launching location for small trailer boats to the ocean. Given the relatively exposed location of the Gerringong Boat Harbour boat ramp, the Crooked River boat ramp is an important asset for locals and tourists alike.

The estuary channel from the confluence of Seven Mile Beach upstream to the road bridge is generally narrow and quite shallow, and the marine sediment derived shoaling is particularly evident. Upstream of the road bridge the estuary broadens with the channel hugging the southern bank upstream of the Blue Angle Creek. The estuary shallows just upstream of the Gerroa WRP and at low tide, even kayak and canoe access can be difficult. The back half of the estuary increases in depth and remains navigable at both high and low tide up to the estuarine limit.

There is the opportunity to develop more formalized kayak / canoe launching facilities to assist in protecting bank areas and provide ease of access to the public. One proposed site is the current canoe / kayak access in the Seven Mile Beach Holiday Park. Currently an informal 'sand' beach area is utilized and is seasonally washed away by floods and tide. A properly designed formalized access would help protect the bank from erosional forces related to pedestrian access, flood and stormwater scour (Figure 26). Another potential location is at the end of Park Road Gerroa, near to the path under the road bridge.

Figure 26: Seven Mile Beach Holiday Park kayak launch site, stormwater outlet

7.4 Cultural And Heritage Environment

7.4.1 Aboriginal Heritage

The Gerroa area falls within the tribal area delineated by Tindale (1974) as Wodi Wodi, an area which extends from Wollongong to the north of the Shoalhaven and west as far as Picton, Marulan and Moss Vale. The Crooked River catchment area also crosses Local Aboriginal Land Council areas, the Jerrinja and the Illawarra. The estuary area falls within the Jerrinja LALC area and some of the upper catchment areas towards Gerringong fall within the Illawarra LALC area. There is relatively little information on Aboriginal Heritage specifically relating to the Crooked River estuary and catchment. According to the REF for the Princes Highway Gerringong Upgrade, there are a small number of references in official and ethno-historical documentation which indicate that the Crooked River estuary was a focus for Aboriginal occupation following European settlement of the Illawarra. Sydney Water Corporation (1996) briefly summarised several unpublished reports from the 1980's and 90's and provided a map of the approximate location of known Aboriginal heritage sites. The map indicates that there are a number of Aboriginal sites along the western foreshore of the estuary.

Through the 1840's and 1850's Aboriginal communities were increasingly impacted by the spread and consolidation of European settlement. In response, Aboriginal people either settled on the pastoral stations, in 'fringe camps' adjacent to European settlements, or were forced into adjacent rough and mountainous country(RTA 2007). Reports from the 1850's onwards suggest a trend in Aboriginal occupation and subsistence such that camps and most food gathering and hunting became concentrated along the coast. Permanent Aboriginal camps became established on Broughton Creek, Crooked River, around Jervis Bay and in a gully on the northern side of the Coolangatta Mountain on the Berry Estate (Egloff 1981 in RTA 2007).

Many Aboriginal sites have been located in the course of archaeological surveys within the Illawarra region. Site types include rock shelters with art and / or cultural deposits, grinding grooves, artifact scatters, scarred trees, coastal and estuarine midden sites and burials (Officer, 2006).

Shell middens are the most common Aboriginal site type to occur within the coastal landscape. These sites are generally located on rocky headlands and on coastal sand dunes adjacent to rock platforms or creek and estuary entrances. Further inland the most common site types to be encountered are small stone artefacts (Officer, 2006).

Previous studies in the Gerringong / Gerroa area have identified shell middens, artefact scatters and a burial site. Much of the archaeological work conducted in the Gerrringong / Gerroa locale has been carried out within the Cleary Brothers Blue Angle Creek property (Officer 2006).

In 1999, an archaeological assessment of the proposed Gerroa WRP site was completed as part of the Environmental Impact Statement for the proposal. Mcdonald Heritage Consultants identified various zones of archaeological sensitivity and five aboriginal scarred trees within the WRP site. Following this study a comprehensive program of archaeological subsurface testing was conducted by Navin Officer in 2000. Large numbers of stone artefacts were recovered from test pits within the Sydney Water land and proposed pumping stations. In March 2003, (Barber (2003) in Officer 2006) also identified one small pipi midden in a survey conducted for the upgrading of facilities at the Seven Mile Beach Holiday Park.

The archaeological assessment by Officer 2006 of the Cleary Brothers Sand Mine found that the sites were typical of the local area as identified in previous studies and the midden sites within the property were relatively poor in comparison to the midden and dense artefacts found to the north in the Gerroa WRP site. Sections of the Sydney Water land which contains the WRP have been preserved from development to protect and conserve these sites.

Future sea level rise may pose a risk to culturally significant sites within the Crooked River catchment and it will be important to work with the Local Aboriginal Land Council to determine appropriate management strategies for the conservation and protection of these sites. Potential actions could be education signage on the banks of the Crooked River which explain the cultural heritage significance of the area.

7.4.2 Non-Aboriginal Heritage

Exploration of the Kiama coast was carried out in October 1819, when Surveyor General John Oxley travelled by sea and Deputy Surveyor General James Meehan travelled by land in search of cedar. According to Bayley (1976) the cedar trees abounded in the forests amongst the fig trees and cabbage tree palms, where vines made it difficult to make the tracks along which the sawn planks were carried to the coast. By the 1820's the supply of cedar from the Illawarra and the Hunter Valley was nearing exhaustion (RTA, 2010c).

By the late 1830's the majority of the lower coastal plain between Gerringong and the mouth of the Shoalhaven River had been taken up as land grants. A road was cleared from Kiama in 1849, winding around the spurs to Mount Pleasant, then across the flats at Omega and up the ridge to the township and on to the Crooked River (RTA 2007). Gerringong was without a school until 1876, although schools were by then in existence at Omega, Foxground and Toolijooa. With the expansion of the diary industry, dairy factories were established in February 1888 at Gerringong, in January 1889 at Foxground and later the same year at Toolijooa (RTA, 2007).

The end of the Great War saw the development of 'Crooked River Village', (now Gerroa), at the north end of Seven Mile Beach which ended in Black Head. Returned soldiers made a 'convenient crossing for vehicular traffic' in 1920 when it was said private enterprise could make it one of the ideal tourist resorts of N.S.W (Bayley, 1976).

The area around Crooked River and the brush frontage along Seven Mile Beach provided excellent habitat for birds including swans and brush pheasants, and when shooting parties began visiting the area in 1923 Gerringong Council sought its proclamation as a bird sanctuary. At the same time it also required land for public reserves, whilst building lots were selling quickly. The beach became noted for motor car and cycle racing, with as many as 2000 spectators attending.

A footbridge was built across the lagoon in 1927. On the 11 January 1933 Seven Mile Beach was used by Sir Charles Kingsford Smith as the runway for the first commercial flight between Australia and New Zealand. This was the same year that a traffic bridge was suggested and the following year the footbridge was washed away by floods. The road bridge over Crooked River began to carry increasing traffic in the 1970's after the road was surfaced with bitumen. The current bridge was built by the Department of Main Roads (now Roads and Maritime Service), in 1983.

The non-aboriginal heritage sites within the Crooked River catchment are listed in Schedule 5 of the Kiama LEP 2011. All the heritage items listed are of local heritage significance, and include sites such the Old Gerringong Dairy Co-op, the Old Station Master's Cottage and a number of historic homesteads.

8 ESTUARY MANAGEMENT ISSUES AND OPTIONS

The information gathered and presented in the early part of the CZMP, has been used to identify the key management issues for the Crooked River Estuary. Information has been compiled considering the review of new scientific papers, water quality and estuary health data, recent environmental events, and identified community uses associated with pressures on the Crooked River estuary. Some of the key management issues addressed in this plan are shown in Figure 27.

The various management issues have been broken into key strategic areas:

6. Management of catchment inputs;
7. Estuary processes;
8. Management of aquatic and terrestrial biodiversity;
9. Balancing community uses, cultural heritage and ecological values;
10. Governance an Implementation

The existing approach and potential management options are discussed in the following section.

8.1 MANAGEMENT OF CATCHMENT INPUTS

Catchment inputs have the potential to impact upon estuary health, and efforts should be prioritized based upon minimizing the pollutant loads at the source. This can be achieved by focusing on land use practices, monitoring water quality parameters to detect trends and identifying and managing point source impacts. Catchment inputs are broken down into the following areas to simplify the identification of issues and potential management activities:

- Nutrient and faecal contamination sources
- Acid sulfate soil

The existing approach to managing, monitoring and identify changes in estuary health from catchment inputs can be summarized as follows:

Nutrient and faecal contamination sources

- Water quality sampling and reporting by licensed facilities within the catchment including the former Gerroa Landfill site, Cleary Brothers Sand Mine and the Gerroa WRP;
- Operation of OSSMs on rural properties which are inspected by Council as determined by their risk rating;
- Some dairy shed effluent management undertaken, no data on number of operations utilizing effluent settlement pond and re-use infrastructure;

Acid sulfate soils

- No overarching management of potential acid sulfate soils, except for major developments through the requirement for Acid Sulfate Soil Management Plans;
- Reactive investigation of acid sulfate soil runoff events;
- Floodgate on Blue Angle Creek stops tidal inundation of Foy's Swamp;
- Drainage channels maintained by landholders;

Potential additional management activities include:

Options	Description	Figure	Pros	Cons
Develop best practice demonstration sites for riparian land management within the Crooked River catchment	Riparian revegetation, stock exclusion and off stream watering projects	Figure 23 Action 1.1, 1.7, 3.3	Creates buffer between stock and direct water access Potential to attract interest from other landholders in the catchment Provides filtration for runoff Relatively low cost for implementation	Requires buffer area on productive land Funding support required Landholder acceptance required Ongoing maintenance requirements
Publishing estuary health data	Create and publish estuary health report cards to communicate with the community	Action 1.3	Easy to understand communication tool Provides broad trend analysis on water quality in the estuary	Annual water sampling required to complete the report cards Costs to sample on annual basis Not targeted to identify sources of nutrients and turbidity
Investigate poor water quality events and potential mitigation strategies	Work with landholders to determine appropriate management of recurring poor water quality events in Blue Angle Creek Conduct event based sampling to identify sub catchments with water quality issues	Figure 27 Action 1.5, 1.6	Potential to reduce impacts of runoff events Communication between land owners and government agencies to address the issues Provides important information for analysis of water quality trends	Hard to measure impact of mitigation measures Requires land owner cooperation Event based sampling only a snapshot Costs associated with event based sampling

Options	Description	Figure	Pros	Cons
Manage sources of agricultural effluent contamination	Develop engagement and remediation program with landholders to improve agricultural effluent management within the Crooked River catchment	Action 1.10	Engages agricultural sector in best practice management Deals with point source pollution Easily identifiable for engagement	Requires landholder acceptance and cooperation High cost and ongoing maintenance Requires funding assistance for landholders
Manage the cause and impact of acid sulfate runoff	Investigate acid sulfate runoff events in coordination with landholders and relevant government agencies Develop acid sulfate soil management plans for high risk sites within Crooked River catchment Investigate potential effect of reinstating natural flow regime in the Foy's Swamp to assist in managing acid sulfate runoff	Figure 20 Action 1.6, 1.11	Potential to reduce the occurrence of acid sulfate runoff Engages land owners in awareness of acid sulfate runoff issues Communication between landholders, government agencies and university expertise	Potential high cost to develop and implement specific management plan Requires landholder acceptance and cooperation Cross boundary / property action required to see results
Use risk based mapping (updated CERAT) to guide decision making relating to proposed land use change and development to ensure estuary health is maintained	Utilise the risk based mapping data provided by the updated CERAT model to guide decision making relating to appropriate management controls on development and land use change proposals	Action 1.12	This decision making aligns with recommendations in the Illawarra draft Regional Growth and Infrastructure Plan Provides important first pass information when looking at developments and land use change proposals	Hard to incorporate into decision making process May be difficult to gather on-ground data to test the modeled data

8.2 ESTUARY PROCESSES

Estuary processes such as tidal movement and flooding due to catchment rainfall are not easily controllable, as these are natural phenomenon. Management issues and strategies to combat these are aimed at mitigating impacts on human activities and infrastructure, whilst not affecting estuary health. The Crooked River intermittently closes to the ocean, and this process is part of the natural cycle of the estuary. Past occurrences of illegal opening of the estuary, and community pressure to open the estuary led Council to adopt a Crooked River Entrance opening policy position. This has not stopped the illegal opening of the system, the most recent being in February 2013. Erosion and sedimentation has also been raised by the community as important issues for the Crooked River.

The existing management approach to managing estuary processes can be summarized as follows:

- Council has adopted an entrance management policy position;
- Council works with Office of Environment and Heritage when opening of the estuary is required;
- Council is in the process of developing flood plain management plans for areas of the municipality, in accordance with the *Floodplain Management Manual;*
- Areas of bank recession in Seven Mile Beach Holiday Park on Blue Angle Creek, currently managed through small areas of revegetation and reactive ad hoc retaining wall infrastructure;
- Bank stabilizing rock walls have been installed in the lower part of the estuary in the Gerroa township fronting Burke Parade;
- Naturally occurring erosion in the main channel of the estuary undercutting trees downstream from Crooked River roadbridge;
- Bank erosion in the mid and upper parts of the estuary is occurring naturally, in some cases exacerbated by stock access and lack of riparian vegetation. Fencing to restrict stock has been put in place in the majority of the estuary but maintenance and upgrading is an ongoing issue; and
- Rock wall revetments have been placed along the foreshore in the lower estuary where community use and access is highest and public infrastructure is potentially at risk

Potential additional management activities include:

Options	**Description**	**Figure**	**Pros**	**Cons**
Manage erosion occurring on Council controlled and community land	Engage engineering expertise to assess and propose design plans for bank erosion occurring in Blue Angle Creek and Crooked River	Figure 11,12 Action 2.1	Reduces sedimentation of the Crooked River estuary Benefits assets which are at risk from erosion Can be used to formalize access to riparian area	High cost of rock wall stabilization and other engineering solutions A substantial flooding event may still result in erosion of the bank Maintenance of rock walls

Options	Description	Figure	Pros	Cons
Research sediment infilling sources and infill rate	Undertake hydrographic survey of the Crooked River estuary to determine change in sediment infill	Action 2.2	Provides actual data on infill rates Potential to identify sources of sediment which can be better targeted with management	High cost assumed May confirm what is already known
Manage erosion and sedimentation from urban development	Council to continue to monitor sediment and erosion controls on new developments	Action 2.3	Part of Council's ongoing role Reduces point source impacts from development sites	
Provide information on estuary entrance management	Publicise the estuary opening policy position of Council Temporary signage relating to the penalties for illegal opening of the Crooked River Develop material relating to the importance of the natural cycle of estuary entrance dynamics for the Crooked	Action 2.5, 2.6, 2.7	Part of Council's ongoing responsibility to provide information to the public Could stop the illegal opening of the Crooked River and potential adverse effects on infrastructure and ecosystem	Production of educational material does not transfer to changed behavior in all cases Coordination between agencies for temporary signage during closure of the entrance

8.3 MANAGEMENT OF AQUATIC AND TERRESTRIAL BIODIVERSITY

Threats to aquatic and terrestrial biodiversity come from a range of areas including development of land, land use practices, fragmentation of habitat, weed or feral animal impacts, and pedestrian access. Appropriate management of these threats should be implemented where appropriate, and the value and connectivity of terrestrial and aquatic ecosystems recognized within the Crooked River Catchment.

The existing management of aquatic and terrestrial biodiversity can be summarized as follows:

- Council has identified Seven Mile Beach Reserve as a high priority for investment for biodiversity enhancements and protection, and with Seven Mile Beach Landcare completes weed control activities over the approximately 35 hectare site annually;
- Whilst significant vegetation is being removed on the Cleary Brothers site, there are also large areas of vegetation which is required to be actively managed for biodiversity enhancement, and there are large areas of compensatory plantings required under their license conditions for the Gerroa Sand Mine;
- Weed control and vegetation enhancement activities undertaken on the Gerroa WRP site;
- Stock exclusion fencing of many riparian zones on rural agricultural properties abutting the Crooked River estuary;
- Riparian enhancement of parts of Union Creek as part of the development of Elambra Estate;

Potential additional management activities include:

Options	Description	Figure	Pros	Cons
Manage weeds on priority Council controlled, agency controlled and community land and other priority locations	Weed control activities implemented in Seven Mile Beach Reserve and other Council and agency controlled properties	Figure 27 Action 3.1, 3.2, 3.3	Increases resilience of native vegetation Facilitates natural regeneration Demonstrates agency and Council commitment to weed control	High cost of ongoing maintenance Funding assistance required Responsibility spread across multiple custodians
Develop riparian revegetation and stock exclusion projects	Engage with landholders who own riparian land on the Crooked River estuary and major tributaries to develop stock exclusion and riparian revegetation projects	Figure 17 Action 1.7, 3.6	Stops direct faecal contamination of waterways Provides vegetated buffer zone Limits stock damage to bank and wetland areas	Cost to implement and provide ongoing maintenance Landholder acceptance required Requires funding assistance for landholders

Options	Description	Figure	Pros	Cons
Investigate potential impacts of sea level rise on migration of salt marsh and mangrove communities	Update the estuarine mangrove, saltmarsh and seagrass mapping for the Crooked River estuary Propose research projects to be undertaken to investigate mangrove and saltmarsh migration	Figure 14 Action 3.4, 3.5	Provides ongoing data source to determine trends in estuarine vegetation Enhances communication between agencies and research institutions Provides information to inform land use planning for the future	Depends on departmental timeframes for re mapping of estuarine vegetation under the MER program Crooked River may not be a research priority

8.4 Balancing Community Uses, Cultural Heritage and Ecological Values

The issues around community uses relates mainly to the increased use of the estuary over holiday periods and the potential for increased impacts due to uncontrolled pedestrian access to riparian areas and increased potential for waste and litter impacts. There are also considerations for primary and secondary contact to waters containing elevated levels of faecal coliforms.

The existing management approach to balancing community uses and ecological values can be summarized as follows:

- Beachwatch sampling at Seven Mile Beach to determine beach suitability grades over the summer swimming season;
- Riparian areas in the Seven Mile Beach Holiday Park planted out to discourage informal access to the Blue Angle Creek;
- Providing community facilities in parks and reserves to encourage passive recreational activities; and
- Upgrade of the Crooked River foot bridge to improve ease of access across the Crooked River.

Potential additional management activities include:

Options	Description	Figure	Pros	Cons
Include potential impacts of sea level rise on agricultural lands in any future research proposals on sea level rise	Propose research projects in partnership with research institutions to investigate the potential impacts of sea level rise on the agricultural sector	Action 4.3	Provides information for landholders to make management decisions	May identify issues which affect future viability of land for agricultural production

Options	Description	Figure	Pros	Cons
Provide infrastructure which enhances community use of the Crooked River estuary	Investigate the potential for formalized kayak / canoe launching facilities	Figure 27 Action 4.4	Formalised access can provide protection for riparian areas Infrastructure likely to be popular with locals and tourists	Costs associated with maintenance of infrastructure in marine environment
Work to protect, conserve and recognise important cultural heritage sites and values	Work with the LALC to determine appropriate management for culturally significant sites in the Crooked River catchment	Action 4.2	Identifies, promotes and recognizes cultural significance of the area Cross communication and cooperation between agencies, community and representatives of LALC	

8.5 Governance and Implementation

Review of the CREMP 2003 and development of the Crooked River Coastal Zone Management Plan is the first step in identifying threats and pressure on estuary health and community uses. It is important to recognise that a CZMP requires cross government, department, stakeholder and community cooperation to achieve the identified actions within the management plan. To improve the opportunity for broader cooperation and communication it is important to establish some management actions within the CZMP which will be integral in achieving the goals and strategies of the plan.

The existing management approach is for state and local government, stakeholders and landholders within the catchment to communicate with each other in some capacity around specific issues, such as the review of the CREMP or upgrade of the Princes Highway. This process is sometimes ad hoc and can mean that important information is not disseminated to potential stakeholders, for example incentives for private landholders to implement stock exclusion and revegetation projects. The formation of the Local Land Services Department, with expertise in natural resource management, agronomy, biosecurity, livestock health and other services aimed at landholders means there is the opportunity to coordinate better communication with landholders relating to funding and support for activities which will assist in maintaining estuary health in the Crooked River.

Potential management activities include:

Options	Description	Figure	Pros	Cons
Improve strategic implementation of projects in the Crooked River catchment which are of benefit to estuary health, cultural significance and recreational activities	Develop agency and landholder committee to identify potential funding for works within the Crooked River catchment and oversee the implementation of the CRCZMP	Action 5.1	Improves communication between landholders, agencies, community Better utilization of resources and funding available for on ground works	Hard to get all stakeholders to meet on a regular basis Funding can be limited and inconsistent Resource intensive for lead agency
Employment of estuary health officer to coordinate activities identified within the Crooked River CZMP in conjunction with other estuaries and potentially across the Illawarra	Cross agency investment in an estuary health officer hosted by Council to coordinate and implement on ground activities related to the Crooked River CZMP. The position would need to be funded for a minimum 5 year period.	Action 5.2	Improves likelihood of on ground actions being undertaken Creates a consistent point of contact for agencies and landholders Brings together varied agency and landholders with interest and roles within the Crooked River catchment	Requires a MOU between agencies tied to funding and hosting of the position Funding cycles rarely long enough to guarantee position

9 THE CROOKED RIVER COASTAL ZONE MANAGEMENT PLAN

The potential management options have been discussed with community representatives, stakeholders and government agencies and prioritized considering a number of factors including:

- The likely success in resolving the management issue;
- Cost of implementation and potential funding;
- Expected level of community support for the action; and
- Potential environmental impact

The results of the management action prioritization exercise have been provided in Appendix 5.

9.1 MANAGEMENT ACTIONS AND IMPLEMENTATION PLAN

The recommended actions are described in the following management actions table. Management actions consist of research studies, investigations, education and on-ground works. Many of the actions require additional design, funding commitment and assessment prior to implementation.

The recommended management actions have been described in terms of:

- Description - a basic scope of works required;
- Priority - high medium or low or is an ongoing project;
- Responsibility – Lead agency, stakeholder or landholder responsible for implementing and / or supporting the management actions. In many cases multiple agencies, landholders and stakeholders will be listed recognizing the combined cooperative effort to gain implementation outcomes. Responsibility also identifies the agencies which are tasked with supporting these activities through grant and staff resources;
- Cost estimate - a very broad estimate of costs for implementation over the 10 year life of the plan is provided. Cost estimates provide a basis for government and non government agencies to allocate funding for projects within the catchment to assist land holders and land managers in their efforts to implement the CZMP activities;
- Potential funding - CZMP strategies and activities will require allocation of funding from multiple sources to achieve outcomes. These sources include local and state government, landholder and stakeholder contributions through both in-kind and monetary allocations; and
- Timing - Timeframes based on priorities developed in the CZMP have been identified for the 10 year life of the CZMP. Review of the plan throughout the 10 year life will be required to ensure management actions remain relevant and are being achieved;

Figure 27 identifies the key sites and proposed action for the Crooked River catchment which have been described in this CZMP, including bank stabilization, acid sulfate soil management, weed control, riparian management and stock exclusion, and recreational facilities.

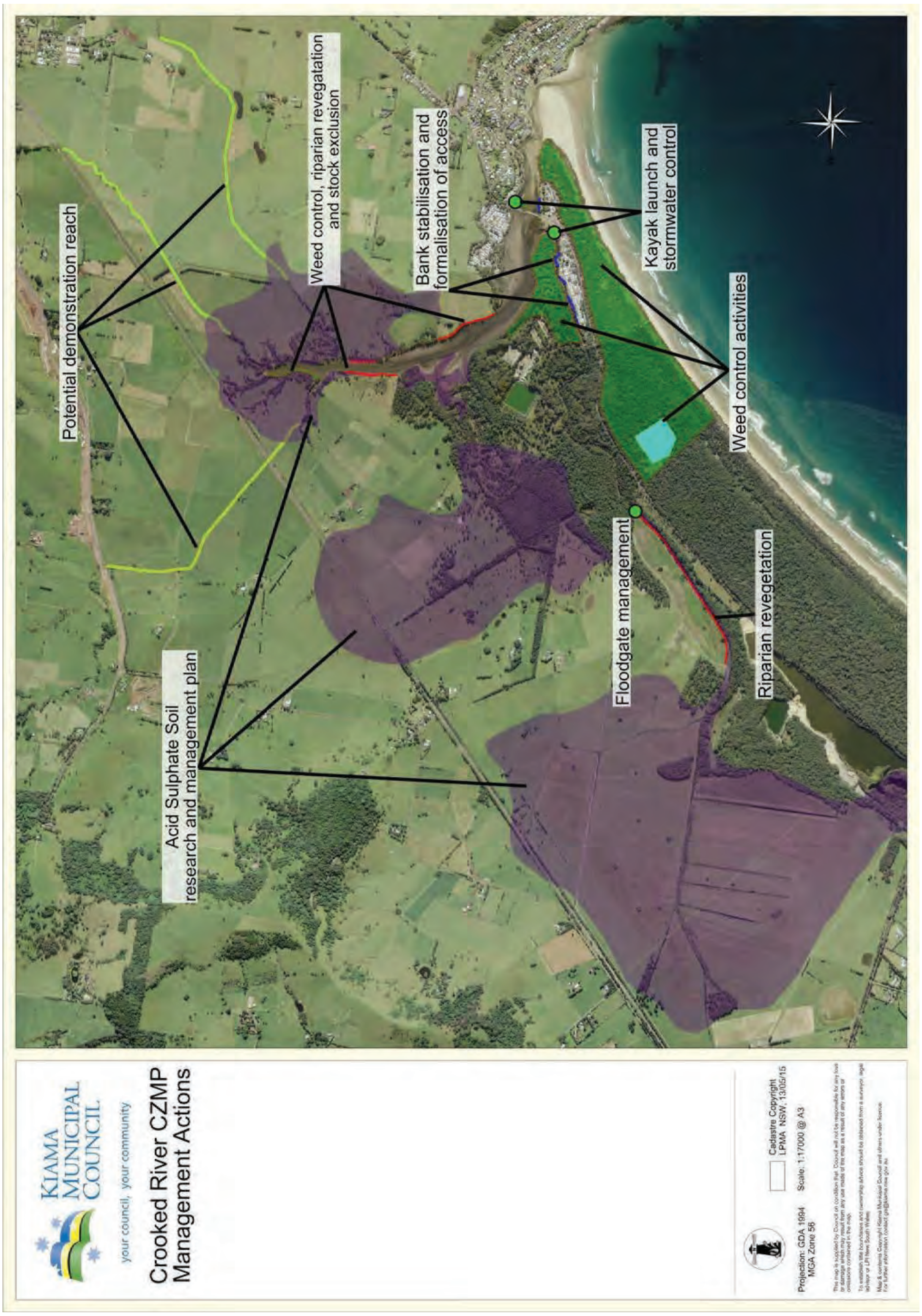

Figure 27: Key Crooked River Management Actions

Table 6: Management Actions for Crooked River Coastal Zone Management Plan

Management of Catchment Inputs						
Action		**Priority**	**Responsibility**	**Cost**	**Potential funding**	**Timing**
1.1	Develop a best practice riparian and aquatic environment management demonstration site on interested landholders properties within the catchment	High	Local Land Services, Sydney Water Corp private land holders	$30,000	Grant funding, Agency budget	3-5 years
1.2	Facilitate collection and collation of water quality information required to complete Estuary Health Report Cards	Medium	OEH, KMC	$10,000	Grant funding, Agency cost	2-3 years
1.3	Produce and publish Estuary Health Report Cards	Ongoing	KMC, OEH	Agency cost	Staff time	2-3 years
1.4	Ensure water quality monitoring results from licensed facilities within the Crooked River catchment are available for public access	Ongoing	KMC, Sydney Water Corp, Cleary Brothers	Agency cost	Staff time	Annual
1.5	Complete event based and targeted water quality sampling to identify areas to target for water quality improvements	Medium	KMC	$5,000	Agency budget, Staff time	Bi ennial
1.6	Work with landholders in Blue Angle Creek catchment to determine appropriate management of recurring poor water quality events including acid sulfate runoff and assessment of floodgate management options	High	KMC, OEH, NSW Fisheries, Cleary Bros, private land holders	Agency cost	Grant funding, Agency budget, Staff time	2-3 years
1.7	Deliver information and extension services to landholders within the Crooked River catchment that support farm profitability and land and water stewardship practices	Ongoing	LLS	Agency cost	Grant funding, Staff time	Annual
1.8	Carry out inspections of OSSMS in accordance with Council's On-site Sewage Management Strategy	Ongoing	KMC	Agency cost	Staff time	Annual
1.9	Identify risks and enact mitigation measures for pumping stations on private properties and yard gullies connected to the Gerroa WRP	High	Sydney Water Corp	Agency cost	Agency budget	1 year
1.10	Develop engagement and implementation program with landholders to improve agricultural effluent management within the Crooked River catchment	High	LLS, KMC	$60,000	Grant funding, Agency budget	1-3 years
1.11	Coordinate research into the development of management options / plan for high risk acid sulfate soil areas within the Crooked River catchment including consideration of potential effects of reinstating natural / semi	Medium	KMC, OEH, NSW Fisheries, UoW	$10,000	Grant funding, Agency budget	3-5 years

	natural tidal wetlands in Foy's Swamp					
1.12	Utilise diffuse pollution risk maps to guide decision making to ensure the ongoing protection of the Crooked River estuary from inappropriate development types	Ongoing	KMC	Agency cost	Staff time	Annual

Management of Estuary Processes

Action		Priority	Responsibility	Cost	Potential funding	Timing
2.1	Complete assessment and implement erosion control measures for the Blue Angle Creek in Seven Mile Beach Holiday Park	High	KMC, OEH	$80,000	Grant funding, Agency budget	1-3 years
2.2	Undertake a hydrographic survey to determine the rate of infill occurring in the Crooked River Estuary	Low	KMC, OEH	$30,000	Grant funding, Agency budget	5-10 years
2.3	Ensure erosion and sediment controls are established and monitored in new developments within the Crooked River catchment and best practice water sensitive urban design principals are included to ensure no increase in pollutants to the estuary	Ongoing	KMC	Agency cost	Agency budget	Annual
2.4	Complete flood management study for the urban areas of the Crooked River catchment	Ongoing	KMC, OEH	$60,000	Grant funding, Agency budget	3-5 years
2.5	Place temporary signage at the entrance to Crooked River when closed, informing of entrance opening policy position and the legal ramifications of illegal opening of estuary	Medium	KMC, Fisheries NSW	Agency cost	Agency budget	Annual
2.6	Review entrance opening policy position to include additional information relating to circumstances for consideration of artificial opening	Low	KMC, OEH	Agency cost	Staff time	3-5 years
2.7	Ensure entrance opening policy position is available on Council website, along with educational information about the importance of maintaining the natural cycle of opening and closure	Ongoing	KMC	Agency cost	Staff time	1-2 years
2.8	Monitor the ongoing effect of runoff from the Princes Highway upgrade on bank stability and sediment mobilisation around the runoff control infrastructure	Ongoing	KMC, RMS	Agency cost	Staff time	Annual

Management of Aquatic and Terrestrial Biodiversity

Action		Priority	Responsibility	Cost	Potential funding	Timing
3.1	Weed control activities undertaken in Seven Mile Beach Reserve and Gerroa Waste Depot	Ongoing	KMC	$40,000 (funded)	Agency cost, Grant funding	Annual
3.2	Weed control activities undertaken on Bailey's Island and Gerringong Gerroa WRP site	Medium	KMC, Sydney Water Corp	$10,000	Agency cost, Grant Funding	Annual
3.3	Implement weed control and revegetation projects for riparian zones on the Crooked River estuary foreshore and tributaries	Medium	LLS, private Landholders	$20,000	Grant funding	Biennial
3.4	Update mapping of seagrass, saltmarsh and mangrove vegetation in the Crooked River estuary	Medium	NSW Fisheries, OEH	Agency cost	Staff time	3-5 years
3.5	Research potential migration of saltmarsh and mangrove communities due to the impacts of sea level rise and work with landholders to develop appropriate strategies to manage the issues identified	Low	KMC, OEH, UOW	$5,000	Agency budget	5-10 years
3.6	Implement weed control and revegetation projects for riparian zones on upper catchment tributaries of the Crooked River, with priority placed on connectivity of fragmented vegetation patches, restricting stock access and controlling bank erosion	High	LLS, private Landholders	$20,000	Grant funding	Biennial

Management of Community Uses, Cultural Heritage and Ecological Values

Action		Priority	Responsibility	Cost	Potential funding	Timing
4.1	Conduct faecal contamination sampling in the Crooked River swimming area during the summer swimming season	Medium	KMC	$3,500	Agency cost	1-3 years
4.2	Work with LALC to research sea level rise and the potential management implications for culturally significant sites which may be affected	Medium	KMC, LALC	$5,000	Grant funding, Agency cost	5-10 years
4.3	Research potential impacts of sea level rise on agricultural lands within the Crooked River catchment	Medium	KMC, UOW	$5,000	Grant funding, Agency cost	5-10 years
4.4	Investigate feasibility of providing formalized canoe/kayak launching points in the lower estuary	Low	KMC, RMS	Agency cost	Staff time	5-10 years

Governance and implementation of the Crooked River Coastal Zone Management Plan						
Action		**Priority**	**Responsibility**	**Cost**	**Potential funding**	**Timing**
5.1	Develop an agency and landholder committee to identify and communicate potential funding for works within the Crooked River catchment and oversee the implementation of the Crooked River Coastal Zone Management Plan	High	KMC LLS, Sydney Water Corp, catchment landholders	Agency cost	Staff time	Annual
5.2	Employment of estuary health officer or similar position, to coordinate the implementation of on-ground activities for the Crooked River and other Coastal Zone Management Plans (including Minnamurra River and potentially other estuaries in the Illawarra)	Medium	KMC, LLS, OEH	$85,000 (full time) $50,000 (part time)	Grant funding, Agency budget	Annual

Table 7: Crooked River Coastal Zone Management Plan Implementation Plan

Action / Strategy		10 year funding cost	1	2	3	4	5	6	7	8	9	10
			2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1.1	Develop a best practice riparian and aquatic environment management demonstration site on interested landholders properties within the catchment	$30,000				$30,000						
1.2	Facilitate collection and collation of water quality information required to complete Estuary Health Report Cards	$30,000			$10,000			$10,000			$10,000	
1.3	Produce and publish estuary health report cards				Note 1			Note 1			Note 1	
1.4	Ensure water quality monitoring results from licensed facilities within the Crooked River catchment are available for public access		Note 1									
1.5	Complete event based and targeted water quality sampling to identify areas to target for water quality improvements	$25,000		$5,000		$5,000		$5,000		$5,000		$5,000
1.6	Work with landholders in Blue Angle Creek catchment to determine appropriate management of recurring poor water quality events including acid sulfate runoff and assessment of floodgate management options			Note 1	Note 1							
1.7	Deliver information and extension services to landholders within the Crooked River catchment that support farm profitability and land and water stewardship practices		Note 1									
1.8	Carry out inspections of OSSMS in accordance with Council's On-site sewage management strategy		Note 1									
1.9	Identify risks and enact mitigation measures for pumping stations on private property connected to the Gerroa WRP		Note 1									
1.10	Develop engagement and implementation program with landholders to improve agricultural effluent management within the Crooked River catchment	$60,000	$20,000	$20,000	$20,000							

Action / Strategy		10 year funding cost	1	2	3	4	5	6	7	8	9	10
			2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1.11	Coordinate research into the development of management options for high risk acid sulfate soil areas within the Crooked River catchment including consideration of potential effects of reinstating natural / semi natural tidal wetlands in Foy's Swamp	$10,000			$10,000							
1.12	Utilise diffuse pollution risk maps to guide decision making to ensure the ongoing protection of the Crooked River estuary from inappropriate development types		Note 1									
2.1	Complete assessment and implement erosion control measures for the Blue Angle Creek in Seven Mile Beach Holiday Park site	$80,000		$80,000								
2.2	Undertake a hydrographic survey to determine the rate of infill occurring in the Crooked River Estuary	$30,000					$30,000					
2.3	Ensure erosion and sediment controls are established and monitored in new developments within the Crooked River catchment and best practice WSUD principals are included to ensure no increase in pollutants to the estuary		Note 1									
2.4	Complete flood management study for the urban areas of the Crooked River catchment	$60,000			$60,000							
2.5	Place temporary signage at the entrance to Crooked River when closed, informing of entrance opening policy position and the legal ramifications of illegal opening of estuary		Note 1									
2.6	Review entrance opening policy position to determine if trigger point relating to risk to human health is necessary				Note 1							

Action / Strategy		10 year funding cost	1	2	3	4	5	6	7	8	9	10
			2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2.7	Ensure entrance opening policy position is available on Council website, along with educational information about the importance of maintaining the natural cycle of opening and closure		Note 1									
2.8	Monitor the ongoing effect of runoff from the Princes Highway upgrade on bank stability and sediment mobilisation around the runoff control infrastructure		Note 1									
3.1	Weed control activities undertaken in Seven Mile Beach Reserve and Gerroa Waste Depot		Note 1									
3.2	Weed control activities undertaken on Bailey's Island and Gerroa WRP site	$100,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
3.3	Implement weed control and revegetation projects for riparian zones on the Crooked River estuary foreshore	$100,000	$20,000		$20,000		$20,000		$20,000		$20,000	
3.4	Update mapping of seagrass, saltmarsh and mangrove vegetation in the Crooked River estuary				Note 1							
3.5	Research potential migration of saltmarsh and mangrove communities due to the impacts of sea level rise	$5,000					$5,000					
3.6	Implement weed control and revegetation projects for riparian zones on upper catchment tributaries of the Crooked River, with priority placed on connectivity of fragmented vegetation patches, restricting stock access and bank erosion	$100,000		$20,000		$20,000		$20,000		$20,000		$20,000
4.1	Conduct faecal contamination sampling in the Crooked River swimming area during the summer swimming season	$10,500	$3,500	$3,500	$3,500							

Action / Strategy		10 year funding cost	1	2	3	4	5	6	7	8	9	10
			2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
4.2	Work with LALC to research sea level rise and the need for management of culturally significant sites which may be affected	$5,000					$5,000					
4.3	Research potential impacts of sea level rise on agricultural lands within the Crooked River catchment	$5,000					$5,000					
4.4	Investigate feasibility of providing formalized canoe/kayak launching points in the lower estuary											
5.1	Develop an agency and landholder committee to identify and communicate potential funding for works within the Crooked River catchment and oversee the implementation of the Crooked River Coastal Zone Management Plan		Note 1									
5.2	Employment of estuary health officer or similar position, to coordinate the implementation of on-ground activities for the Crooked River and other Coastal Zone Management Plans (50% of fulltime equivalent)	$250,000			$50,000	$50,000	$50,000	$50,000	$50,000			
Total estimated 10 years implementation cost for CZMP		$900,500										

Note 1: Action can be achieved utilising current staffing and / or allocated resources as part of normal business of agency / stakeholder

All monetary values are estimates and many need to be incorporated into strategic and asset maintenance plans once the CZMP program has been accepted for implementation. Allocation of budget or application for grant funding of opportunities identified in this implementation plan will be the responsibility of the agency / agencies involved and will need to be adopted into their strategic and financial plans to guarantee implementation. The identification of monetary expenditure in the Crooked River CZMP does not tie the agency / landholder to the implementation of activity, it does however provide a strong justification for allocation of budget and / or resources to the particular management actions and provides strong support to grant funding applications for future projects.

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Appendix 1 – Assessment of CREMP 2003 Complete, Ongoing and Incomplete Actions

Action	Status	Recommendation	Reason for no action
1. A more strategic approach to data collection is required to measure compliance with the guidelines.	Ongoing. Monthly monitoring by Council at Gerroa Waste Depot rehabilitation site in line with EPA licence requirements. Cleary Brother monitoring in Blue Angle Creek in line with EPA licence requirements. Sydney Water monthly monitoring in Crooked River and Blue Angle Creek as part of licence requirements for the WRP.		
2. Analyse water quality data to highlight sources of impacts and recommend and implement appropriate remedial actions.	Ongoing by all bodies monitoring for licence requirements in the Crooked River.	Carry over action. Improved reporting and analysis of all organisations sampling in the Crooked River Catchment.	
3. Implement the most appropriate option for remedial works outlined in the "Management and Remediation Plan for the Gerroa Waste Disposal and Recycling Facility" report by URS (2003)	Ongoing. Remediation Plan implemented as required by NSW EPA.		
4. Continue to actively encourage sewer connections.	Ongoing, approximately 99% connected to sewer in catchment		
5. Incorporate water sensitive urban design for new urban areas.	Ongoing		
6. Monitor the use of Council's sediment and erosion control guidelines issued with development applications by developers.	Ongoing	Carry over action.	
7. Assess adequacy of guidelines and compliance measures.	Ongoing		
8. Retrofit appropriate infrastructure such as gross pollution and sediment traps and macrophyte basins on drainage paths from urban developments.	Complete. Gross pollutant traps installed in Elambra estate, some areas of Gerroa along Burke Parade.	Maintenance schedule required for GPTs.	

9. Develop a monitoring program to assess the contribution of each land use type to water quality in Crooked River.	Ongoing. OEH updating CERAT to inform land use contribution to water quality and identify problem areas.		
10. Develop DCPs and other planning controls to be considered in any application for rezoning of parcels of land adjacent to Crooked River and its tributaries.	Complete. Kiama DCP 2012 finalised. Elambra Estate has its own chapter and specific controls in the Kiama DCP 2012.		
11. Develop and implement an education program focusing on appropriate pesticide storage according to "Workcover Code of Practice for the safe use and storage of chemicals in agriculture".	Ongoing.EPA and DPI provides information to landholders on appropriate usage and disposal of chemicals on rural properties.		
12. Design an appropriate education program with assistance from EPA Cleaner Industries Unit.	complete, covered under the Catchment Caretakers program implemented in Gerringong - Gerroa		
13. Implement appropriate education materials for the program.	complete, covered under the Catchment Caretakers program		
14. Monitor and evaluate the success of the education campaign.	complete, covered under the Catchment Caretakers program		
15. Identify land management practices which improve water quality in Crooked River.	Ongoing. Support for Seven Mile Beach Landcare Group Activities and weed control and revegetation activities undertaken		
16. Design projects which interested Landcare volunteers may be able to assist with.	Ongoing, see above	Carry over action as part of weed control and revegetation activities in Seven Mile Beach Reserve.	
17. Investigate sources of financial and in-kind support for Landcare groups.	Ongoing, Council has allocated budget and sourced grant funding through to 2018 for weed control activities in Seven Mile Beach Reserve in support of the Seven Mile Beach Landcare Group.		

18. Identify the full range of impacts of visitors on the estuary by surveying the permanent residents and by observation of any obvious changes in the estuary area during peak tourist periods.	Completed as part of the Catchment Caretakers project in Gerringong Gerroa		
19. Distribute this information to relevant government agencies and community members to raise awareness of these impacts and to develop projects to assist to alleviate these impacts.	Complete		
20. Identify the current impacts of sand mining activities on water quality in Crooked River and Blue Angle Creek;	Ongoing. Consent conditions required under EPA licensing including annual monitoring and reporting.		
21. Implement planning controls and monitor compliance placed on these activities in the catchment.	Ongoing, monitoring by NSW EPA for licensed activities within the catchment. Council development controls and inspections by officers for compliance continues.		
22. Develop and implement a Water Sharing Plan for Crooked River catchment that identifies the maximum volume of water that can be extracted from Crooked River without impacting on water quality and aquatic ecosystems.	Ongoing. Responsibility of Office of Water. Crooked River covered by the Greater Metropolitan Region Unregulated Water sources Water Sharing Plan.		
23. Any stream improvement works along Union Creek should focus on wetland enhancement rather than channelisation	Complete, as part of Elambra Estate	Included in current plan identifying riparian projects as demonstration sites in Crooked River tributaries.	
24. Develop and implement an education program that identifies the estuary as a 'sensitive' and 'valuable' environment.	Complete, as part of the Catchment Caretakers program.	Action in new CRCZMP will incorporate publishing information on Council's website relating to estuary health and estuary function.	
25. Implement the program in the local community.	Completed, Catchment Caretakers grant final report summarises the project achievements.		

26. Monitor and evaluate the success of the program in raising awareness of the values and function of estuary systems.	Completed, as above.		
27. Erect appropriate signage to deter people from excessive removal of biota that would cause irreversible decline in biodiversity of the estuary environment.	No action	Discuss the implications for signage with Risk Management for incorporation into new CZMP	No budget allocation and reluctance to put up more signage than is already located around the estuary reserves. Limited impact of signs.
28. Provide support to local people who would monitor the visitor behaviour as being consistent with protection of the natural assets of the estuary.	No action, no further action		Unfeasible and not required. Residents report inappropriate and damaging behaviour to Council through the CRM system.
29. Management and restriction of public access to less sensitive parts of the riparian zone.	Ongoing action needs to be included as part of the strategy for dealing with erosion in the Blue Angle Creek.	Council maintains fencing and tracks in Seven Mile Beach Reserve, Private property is fenced and inaccessible. Formalising access identified in dealing with Blue Angle Creek erosion.	
30. Fencing to restrict livestock access to tributary drainage lines and the riparian zone.	Ongoing. Some fencing to restrict livestock access has occurred along the main river channel. There are still areas where cattle access the main river channel.	Carry over action, Local Land Services will provide advice and support to landowners who want to pursue riparian fencing.	
31. Incorporate 'buffer zone' strategies for an identified buffer zone width.	Complete. Riparian buffer zones required as part of the DCP.		
32. Examine local fire management plans and identify any inadequacies for revision.	Ongoing. Undertaken as part of Illawarra Bushfire Management Committee		
33. Implement zoning controls in the Kiama LEP to identify Crooked River estuary as a 'sensitive' environment.	Complete. Kiama LEP updated with sensitive land zoned as E2, E3 and important vegetation identified in the biodiversity layers.		

34. Implement riparian corridor management process.	Ongoing.	Carry over action. LLS to provide advice and support to landowners wanting to pursue riparian revegetation.	
35. Review current zoning.	Complete. Undertaken as part of the Kiama LEP 2011 development.		
36. Incorporate into zoning plans.	Complete. Undertaken as part of the Kiama LEP 2011 development.		
37. Act to remove exotic vegetation to allow enhancement of native species.	Ongoing	Carry over action. LLS to provide advice and support to landowners wanting to pursue riparian revegetation. Illawarra noxious weeds authority monitors and controls noxious weeds.	
38. Identify potential for disturbance of Acid Sulfate Soils in the vicinity of Foys Swamp.	Ongoing. Acid sulfate soils have been mapped. Blue Angle Creek water monitoring	Carry over action. Study into ASS in the catchment identified as a management action in CRCZMP.	
39. Conduct routine monitoring for Acid Sulfate Soils impact on Foys Swamp and water quality in Blue Angle Creek.	Ongoing, Cleary Brothers licence requirements and event monitoring by KMC.	Overall management plan to deal with ASS runoff identified as management action in the CRCZMP.	
40. Investigate purpose of tidal flood gates and address potential for natural water movement between Crooked River and Foys Swamp.	No action	Incorporate options into ASS study in conjunction with landholders.	Purpose of tidal flood gates is known. Private landholder responsible for structure and will need to be engaged to discuss managment options.
41. Manage all natural assets that are listed under the threatened species schedules of the Fisheries Management Act 1994.	Ongoing. Threatened species impacts taken into account in development applications process.		

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42. Survey catchment and inspect potential sediment source areas, for example land clearing, unsealed roads, informal access areas to the river and estuary.	Ongoing. Identified as part of the review	Identify areas of erosion on Seven Mile Beach Holiday Park and above the tidal flood gate in Blue Angle Creek. Gerringong to Berry bypass potential source. Management Action suggested to undertake hydrographic survey to determine rate of infill in estuary.	
43. Develop a monitoring program to assess sediment supply to the estuary and to decipher natural rates of sedimentation and infilling from anthropogenic sources.	Ongoing	Identified as research project for university student and also to undertake hydrographic survey.	
44. Assess current soil management practices in the catchment.	No action	This previous action will be accounted for if ASS management plan developed for high risk soils. DPI or UoW may look at this in the future.	Resourcing issue.
45. Assess the need for sedimentation basins and other control measures or changes to current management practices.	Ongoing. Planning and implementation of Elambra Estate development and upgrade of the Gerringong to Berry bypass.		
46. Identify significant drainage lines.	Complete. Mapped and identified under Kiama LEP 2011		
47. Construct sediment traps and ponds on drainage paths leading from major urban and infrastructure developments.	Completed as part of the Elambra Estate development and upgrade of the Gerringong to Berry bypass.		
48. Monitor sedimentation at stormwater outlets adjacent to development sites.	Ongoing. Council Environment and Health Officer respond to sediment and erosion control issues concerning development		
49. Identify significant drainage lines in urban areas of the catchment.	Complete. Natural drainage lines identified in the Kiama LEP 2011. All stormwater drainage within the municipality is being mapped in Council's asset system. Will be completed.		

50. Assess sediment levels at stormwater outlets.	No action		Resource issue no assessment has been undertaken, however this could be incorporated into a University study looking at sediment sources and infill rates.
51. Prioritise areas in need of sediment control, including retrofitting for urban areas.	Ongoing. GPTs installed in urban areas adjoining the Crooked River.		
52. Assess options for sediment control.	No action		Requires research to determine volume of sediment in Crooked River basin.
53. Design and implement best practice works.	Ongoing incorporated into the development approvals process.		
54. Identify farming practices contributing to erosion and sedimentation.	No action		Resource issue, farming practices which contribute to erosion and sediment are known, however resources to assist landholders to implement better practices need to be allocated by state government agencies including LLS and DPI.
55. Identify funding sources to assist sediment reduction.	Ongoing. Local Land Services responsible for delivery of agricultural support services and natural resource management grant funding.		
56. Distribute appropriate educational material regarding the impacts of different farming practices on erosion and sedimentation rates.	Ongoing. Local Land Services responsible for delivery of agricultural support services.		
57 Host community workshops with rural property owners.	Ongoing. Dairy industry seminar held as part of DPI dairy industry improvement program.		

58. Select appropriate sample sites to identify sources of sediment.	Ongoing. University of Wollongong student project undertaken addressing sediment in Crooked River.	Continue to work with UoW students to identify projects which research sediment dynamics in the Crooked River.	
59. Conduct regular and event based sampling.	Ongoing. Regular sampling in Blue Angle Creek by KMC, SWC and Cleary Brothers. Event based sampling conducted when complaints are lodged with Council.	Identified in the CRCZMP under targeted water quality monitoring.	
60. Design and implement a community education program.	Completed under Catchment Caretakers Program		
61. Evaluate the success of the education program in increasing the awareness of community members regarding the values of the estuary and sensitivity to catchment pressures.	Completed under Catchment Caretakers Program		
62. Develop Entrance Opening Policy which acknowledges the ecological and other environmental impacts of artificial opening and provides a contingency plan for emergency situations.	Complete. No mechanical opening of Crooked River entrance has been adopted as a policy of Council	Review of the entrance opening policy position may be required to update the wording to reflect the process for opening to occur under extenuating conditions.	
63. Erect appropriate signage to ensure adequate public awareness during periods of public health risk.	No action	May be considered under CRCZMP management action suggesting temporary signage about entrance opening when entrance is closed.	Other issues higher priority.
64. Prepare and implement a Floodplain Management Plan which allows for natural opening and closing of the estuary mouth.	Ongoing. To be completed subject to funding.	Carry over action, however floodplain management plan will look at conditions which cause threat to property and life, not entrance opening policy.	

65. All approved developments should comply with interim flood policy and the Flood Prone Lands Policy set out in the Floodplain Management Manual.	Ongoing		
66. Identify funding sources for implementation of the Floodplain Management Plan (see ENT 3).	Ongoing, funding source is the NSW Floodplain Management Program.		
67. Design and implement an education campaign to increase public awareness of flood risk within identified PMF and provide information about measures that can be taken on properties to reduce flood risk.	Not completed.		Floodplain management plans not completed yet, SES responsible for flood risk education, as well as communication and consultation undertaken in development of floodplain managment plan.
68. Consider closure and use of drop boards at the floodgate and at key locations along feeder drains in order to retard freshwater flows during wet weather conditions.	Not completed.	To be included as part of assessment of ASS risks within the Crooked River catchment.	Requires consent of flood gate owner and funding to undertake study or modelling.
69. Assess foreshore areas for indications of ‘sensitivity’ such as poor health of native vegetation, excessive weed growth and other signs of environmental stress.	No action, major foreshore areas on private land.	Carry over action as part of assessment of bank erosion areas in Crooked River and Blue Angle Creek.	To be incorporated into future actions
70. Develop and adopt a strategy to provide for protection of these areas by restricting public access to these areas.	No action		To be incorporated into future actions
71. Identify foreshore areas that are ‘less sensitive’ and that have the potential to accommodate some degree of public access.	Ongoing. Areas for public access restricted by large areas of private land. Council maintains fencing and access tracks through Seven Mile Beach Reserve.		
72. Facilitate access to these areas by providing a defined access trail or foreshore boardwalk.	Ongoing.		

73. Manage these areas appropriately, by raising public awareness of appropriate behaviour in an estuary environment (see NAT 1 and NAT 2).	No action		
74. Liaise with the local Waterways Authority, DIPNR and EPA to discuss restricted use of estuary by power boats due to environmental sensitivity.	No action, unlikely to be required due to infilling of estuary		Only likely if complaints are lodged if power boats become more common in Crooked River
75. Evaluate the feasibility and public desirability of an estuary foreshore walk.	No action		Bridge to Bailey's Island from Seven Mile Beach HP removed due to dangerous condition. No plans to reinstate.
76. Define the onground boundaries of the foreshore Crown Reserves.	No action.		Substantial cost involved with surveying.
77. Engage the Department of Lands to conduct a land status search through the Crown Lands Information database.	Ongoing as required.		
78. Liaise with local landholders and the Aboriginal community.	Ongoing. Council is trying to establish an Aboriginal reference group, but not specifically for Crooked River		
79. Design and implement an appropriate community education campaign.	Complete	Improve water quality monitoring reporting process and report estuary health report cards	
80. Evaluate the success of the education campaign in raising public awareness of STP operations.	Complete. Substantial connection of properties to sewer demonstrates success of program		
81. Complete and easy access by community members to all data relating to water quality.	Ongoing. SoE report reported on Streamwatch monitoring. Streamwatch now redundant in Crooked River catchment. Licensed premises in the catchment are required to make sampling data available in annual reports.	Improve water quality monitoring reporting process.	

82. Develop criteria for artificial opening of the estuary to be included in Entrance Opening Policy (EOP)	Complete. Entrance Opening Policy Position adopted by Council 2005.	Carry over action. Entrance opening policy to be reviewed to determine if change to wording required to better define extenuating circumstances.	
83. Develop an EOP which includes contingency plans to initiate in the event of an emergency situation which outlines the responsibilities of each relevant government department.	Ongoing, EOP developed will be reviewed in the future.		
84. Give notification of any WRP overflow to initiate EOP arrangements.	Ongoing. Required as part of the WRP operating licence. Reported on annually by SWC.		
85. Conduct a study of roads in Crooked River catchment to identify potential spill risk areas and to prevent runoff in environmentally sensitive areas.	Partly completed, Considered as part of the Gerringong to Berry upgrade to Princes Hwy.		
86. Distribute existing documentation to relevant authorities such as Kiama Council and landowners	Ongoing. Covered under Council's SoP and chemical certification of workers.		
87. Review road maintenance procedures.	Ongoing. Considered as part of the planning for road maintenance works through REF.		
88. Provide appropriate studies such as EIS for construction or relocation of roads in the catchment.	Ongoing. Studies undertaken as part of Princes Hwy upgrade		
89. Inform Council and local residents of the catchment of any plans to carry out work on the railway that has the potential to impact on the Crooked River catchment.	Ongoing as required. No carry over required.		
90. Plan to reduce any potential impacts on the catchment during work.	Ongoing as required. No carry over required.		

91. Undertake a study, in conjunction with the local Aboriginal community, documenting the oral history of Aboriginal occupation and use of the Crooked River area.	Not completed.	Carry over action.	No budget / resource allocation
92. Provide information to the local Aboriginal community as well as NPWS for recording in their database.	Ongoing. As required or as information is gathered through development assessment process or research.		
93. After consultation with the local Aboriginal community, incorporate relevant information into local historical documents recording landuse and occupation of the area.	No action	Carry over action.	No budget / resource allocation
94. Raise awareness of the findings of Council's consultant Heritage Advisor through media releases and educational materials targeted at local residents of the area.	Complete. Undertaken as part of the Kiama LEP 2011 development.		
95. Develop guidelines for consultation and archaeological survey where sites may be present.	Completed. Aboriginal Cultural Heritage Management Development Assessment Toolkit developed by Illawarra Councils		
96. Any development occurring in areas likely to contain sites should include assessment of the impact on Aboriginal heritage.	Ongoing		
97. Prepare a map of the zone's sensitivities to likely Aboriginal heritage sites and usage.	Partly completed, some work undertaken as part of the planning for the Gerringong to Berry Princes Hwy upgrade and the Development of the Aboriginal Cultural Heritage Management Development Assessment Toolkit.		

APPENDIX 2 – CROOKED RIVER ENTRANCE OPENING POLICY POSITION

Kiama Municipal Council Policy Position:
Artificial Opening of the Crooked River Entrance

Introduction

The Crooked River Estuary Management Committee has investigated the need for a formal Entrance Opening Policy for Crooked River, as has been prepared for the entrance of Werri Lagoon. The aims of such a policy would include that entrance opening follows as natural a regime as possible within the constraints of permanent dwelling inundation and flooding. The alternative is to adopt a Policy Position on the matter, if a full Policy is not considered necessary.

This information sheet outlines the outcomes of this investigation and the resulting 'Policy Position' on the matter of artificial opening of the Crooked River Entrance.

The entrance of the Crooked River at Gerroa occasionally closes to the ocean, which is a natural process of maturing estuaries and can be exacerbated by low rainfall levels.

The Crooked River Estuary Management Plan, which was adopted by Council in September 2003, identifies the issues associated with entrance closure and recommends that a Policy be developed. In 2002-2003, during preparation of the Estuary Management Plan, the entrance was closed for an extended period of time due to drought conditions and resulted in the artificial opening of the entrance by Council (with approval by the Department of Infrastructure Planning and Natural Resources) on 29 April 2003 due to flooding of Gerroa Shores Holiday Park.

As water quality monitoring during periods of closure did not identify water quality issues, it has been identified that the main issue associated with the entrance closure is minor flooding, particularly in the Gerroa Shores Holiday Park.

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Kiama Municipal Council Policy Position:
Artificial Opening of the Crooked River Entrance
(cont'd)

The Crooked River Estuary Management Committee has discussed the matter, including whether it is necessary to prepare a comprehensive Entrance Opening Policy like the recently adopted Policy for Werri Lagoon or whether a Policy Position of Council would be more appropriate due to the minor nature of the flooding issue, as compared to other estuaries such as Werri Lagoon.

Surveying of the area confirming that if the water level is half a metre over the footpath under the Crooked River Road Bridge (which is fairly exceptional), that the lower portion of the Caravan Park will be flooded, but no permanent dwellings will be at risk.

The Estuary Management Committee has requested that the Gerroa Shores Holiday Park should incorporate the re-location of the on-site caravans under threat to higher ground during any re-design of the park or simply raise the vans.

Following the results of the surveying, the Crooked River Estuary Management Committee decided that the system should be allowed to open naturally (as it generally does at such flood levels) and a formal Opening Policy is not required as flooding will not be an issue for permanent dwellings.

However, artificial opening of the entrance may be considered in extenuating circumstances, such as extreme flood event threatening dwellings, subject to approval by the Department of Lands and/or the Department of Primary Industries (Fisheries) .

Kiama Municipal Council Policy Position

In April 2005, Council adopted the following:

- Council's Policy Position is that Crooked River Entrance system be allowed to open naturally, unless there are extenuating circumstances, as flooding is not a threat to any permanent dwellings in the catchment.
- This Policy Position be included in the review of the Crooked River Estuary Management Plan.
- The community be advised of this Policy Position via the Kiama Independent and an information sheet be available at Council.

For more information, contact Kiama Municipal Council on 4232 0444.

Kiamasphere

Appendix 3 – Water Quality Results

NSW Office of Environment and Heritage, Monitoring, Evaluation and Reporting (MER) Program trigger values for estuary health

Estuary Class	MER Trigger Values	
	Chlorophyll a (ug/L)	Turbidity (NTU)
Lake	3.6	5.7
River - lower (salinity ≥ 25 ppt)	2.3	2.8
River - mid (salinity 10 to < 25 ppt)	2.9	3.5
River - upper (salinity < 10 ppt)	3.4	6.6
Lagoon	2.0	3.3

The NSW MER Program classifies the Crooked River as a river, not a lake or lagoon.

NSW MER Program sampling results from 2014/15 sampling

Date	Zone	Chlorophyll a (ug/L)	TP (ug/L)	TN (ug/L)	Turbid (NTU)	Salinity (ppt)	Rain in 7 days prior to sampling (mm)
04-Dec-14	3 (upper)	8.18	225.90	1030.00	8.73	21.93	52.4
04-Dec-14	2 (mid)	1.02			2.05	34.35	52.4
12-Dec-14	3 (upper)	3.25	158.70	658.00	4.97	19.96	44.4
12-Dec-14	2 (mid)	2.90			5.47	23.41	44.4
09-Jan-15	3 (upper)	13.05	213.00	526.00	18.73	26.94	133.4
09-Jan-15	2 (mid)	10.69			5.09	23.82	133.4
30-Jan-15	3 (upper)	2.17	151.50	687.00	9.49	7.43	12.4
30-Jan-15	2 (mid)	1.81			5.14	25.12	12.4
20-Feb-15	3 (upper)	6.67	119.60	497.00	11.14	22.98	6
20-Feb-15	2 (mid)	3.91			5.83	35.73	6
13-Mar-15	3 (upper)	2.78	131.00	533.00	9.98	26.02	50.4
13-Mar-15	2 (mid)	2.84			5.04	32.79	50.4

Crooked River Kiama Council Estuary Health Monitoring sampling results for 2013-14

Site	Date	Chlorophyll a (ug/L)	Faecal Coliform (cfu/100mL)
CRZ3 (upper)	13/11/2013	5	4800
CRZ3 (upper)	2/12/2013	8	72
CRZ3 (upper)	17/12/2013	10	10
CRZ3 (upper)	3/02/2014	14	14
CRZ3 (upper)	31/03/2014	1	2000
CRZ2 (mid)	13/11/2013	3	2100
CRZ2 (mid)	2/12/2013	2	6
CRZ2 (mid)	17/12/2013	2	0
CRZ2 (mid)	6/01/2014	1	0
CRZ2 (mid)	3/02/2014	2	10
CRZ2 (mid)	31/03/2014	1	230
CRZ1 (lower)	13/11/2013	2	1000
CRZ1 (lower)	2/12/2013	1	2
CRZ1 (lower)	17/12/2013	1	0
CRZ1 (lower)	6/01/2014	1	0
CRZ1 (lower)	3/02/2014	1	16
CRZ1 (lower)	31/03/2014	1	100

Sydney Water Corporation faecal coliform (cfu/100mL) sampling 2012-13

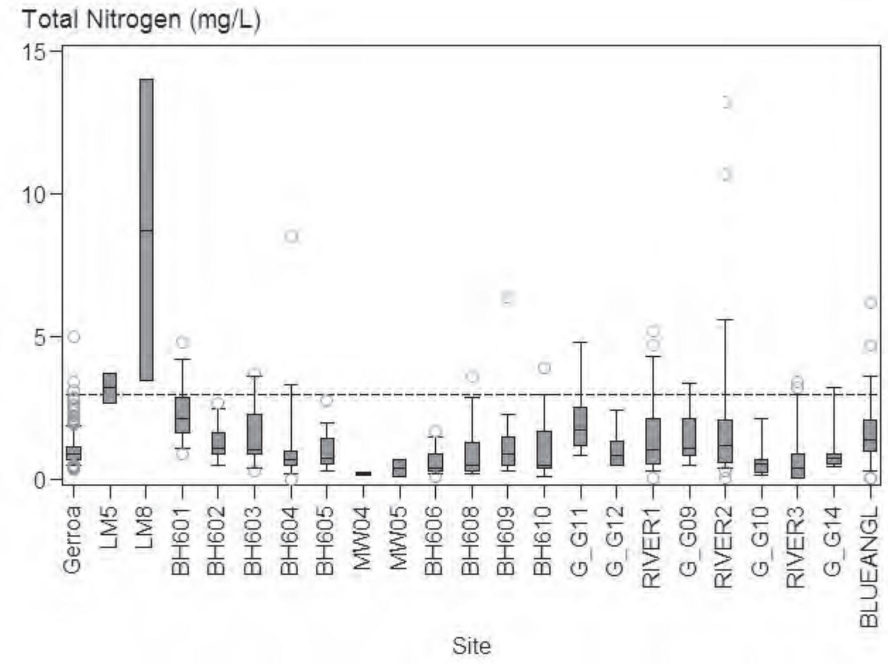
Sample Date	2/07/2012	2/08/2012	6/09/2012	10/10/2012	5/11/2012	5/12/2012	4/01/2013	21/01/2013	4/03/2013	8/04/2013	2/05/2013	5/06/2013
River 1	80	190	60	1300	38	52	1300	14	1600	360	1600	740
River 2	160	490	92	3200	20	42	970	240	740	1400	15000	420
River 3	30	22	4	48	6	10	640	140	560	360	180	310
Blue Angle	15	26	4	8	12	17	550	340	58	34	90	550

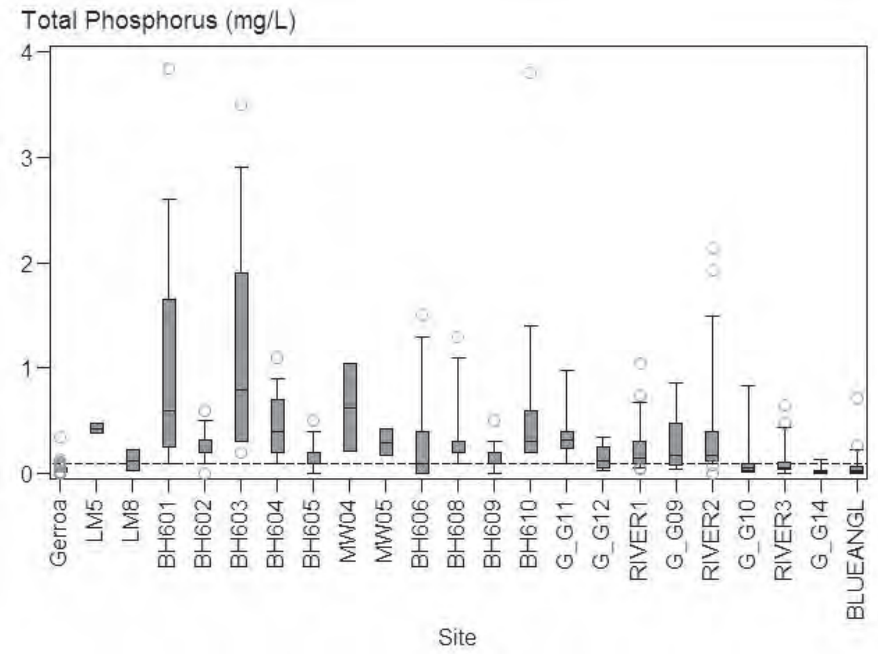
Crooked River Kiama Council Water Quality Data 2006/07

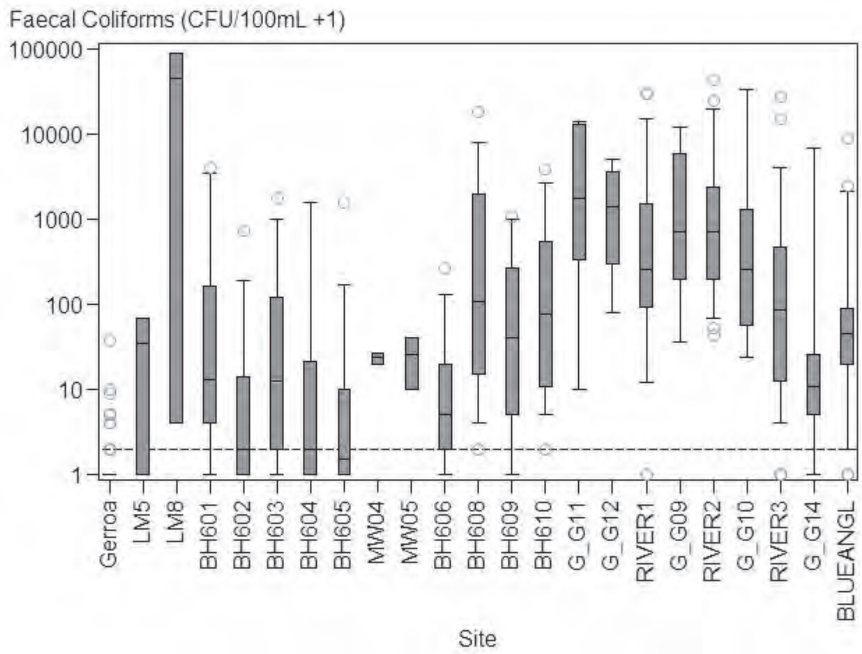
Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll a (ug/L)	Turb. (NTU)	Salinity (ppt)	Rain in 7 days prior to sampling (mm)
C1 - Crooked River 1 - Estuarine/River (road bridge)						
27-Jul-06	2.00	0.24	1.20	13.20	3.91	72.60
29-Aug-06	0.39	0.03	1.20	2.80	24.03	0.00
28-Sep-06	0.24	0.02	2.20	0.80	36.59	0.00
27-Oct-06	0.56	0.02	0.10	3.20	35.73	0.00
30-Nov-06	0.42	0.06	0.20	3.30	38.12	0.00
21-Dec-06	0.39	0.01	2.20	2.80	34.28	55.90
25-Jan-07	0.74	0.10	3.10	3.90	37.79	9.00
22-Feb-07	0.60	0.10	1.00	5.10	35.84	0.00
29-Mar-07	0.53	0.07	1.00	3.70	27.92	18.40
26-Apr-07	1.90	0.35	2.40	14.90	1.92	64.20
23-May-07	0.24	0.01	0.10	2.10	33.05	18.60
21-Jun-07	2.13	0.21	0.10	21.90	3.97	194.80

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll a (ug/L)	Turb. (NTU)	Salinity (ppt)	Rain in 7 days prior to sampling (mm)
C2 - Crooked River 2 - Estuarine/River (footbridge)						
27-Jul-06	1.60	0.14	0.10	13.50	6.11	72.60
29-Aug-06	0.07	0.01	0.10	0.00	35.56	0.00
28-Sep-06	0.25	0.02	1.00	0.20	34.91	0.00
27-Oct-06	0.28	0.01	0.20	4.10	37.56	0.00
30-Nov-06	0.27	0.02	0.10	0.00	38.78	0.00
21-Dec-06	0.29	0.01	1.20	1.30	34.54	55.90
25-Jan-07	0.76	0.06	2.20	2.10	38.00	9.00
22-Feb-07	0.65	0.03	1.20	3.50	36.37	0.00
29-Mar-07	0.32	0.03	1.20	1.80	32.79	18.40
26-Apr-07	2.10	0.35	1.20	14.70	2.43	64.20
23-May-07	0.18	0.01	0.10	0.90	35.36	18.60
21-Jun-07	1.85	0.16	0.10	19.10	4.31	194.80

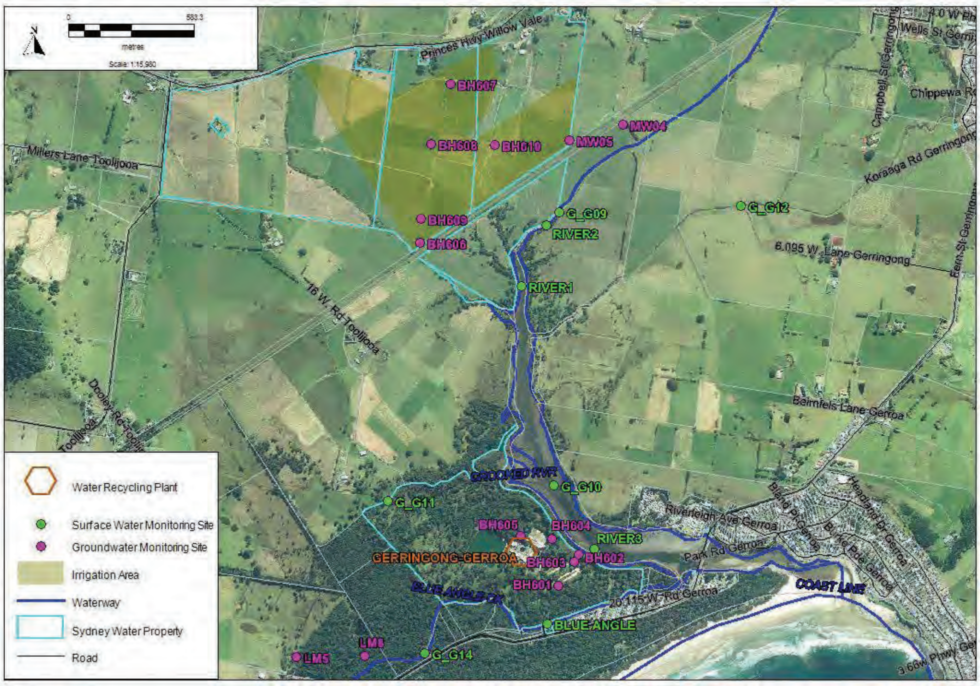
Sydney Water Corporation Total Nitrogen, Total Phosphorus and Faecal coliform box plots from the report 'Gerroa Sewage Scheme Water Quality Investigation Final Report 2012'







Faecal Coliforms (CFU/100mL +1)
100000
10000
1000
100
10
1
Gerroa
LM5
LM8
BH601
BH602
BH603
BH604
BH605
MW04
MW05
BH606
BH608
BH609
BH610
G_G11
G_G12
RIVER1
G_G09
RIVER2
G_G10
RIVER3
G_G14
BLUEANGL
Site



metres
BH607
BH608
BH610
MW05
MW04
BH609
BH606
G_G09
RIVER2
RIVER1
G_G12
CROOKED RIVER
G_G10
G_G11
BH605
BH604
RIVER3
GERRINGONG-GERROA
BH603
BH602
BH601
BLUE ANGLE
LM5
LM8
G_G14
COAST LINE
Water Recycling Plant
Surface Water Monitoring Site
Groundwater Monitoring Site
Irrigation Area
Waterway
Sydney Water Property
Road

APPENDIX 4 – CROOKED RIVER ENTRANCE STATE ANALYSIS FROM WATER LEVEL GAUGE 1999-2015

Crooked River Entrance State Analysis from Water Level Gauge 1999 - 2015

- MHL have maintained a water level gauge on behalf of OEH in the Crooked River since 4/2/1999, so there exists around 15 years of water level data (see figure 1 over page for full data set). At the time of installation the entrance was open.
- Entrance closure and opening has been identified from observing the stop and start of a tidal signal from the graphed data (see figure 2). This is generally easy to identify but there are three periods (identified by * in below table) where it is not fully clear due to the shortness of the closure, and while they are likely to be closures, these periods would benefit through checking with Council records and/or other information sources. In addition, there are a couple of short periods of time (~ 1 week) identified (not included in the below table) where tidal signals were briefly absent but do not display characteristics of typical closures and openings and are more likely data quality issues.
- There are small periods of time where no data has not been collected so there may be periods of closure that have been missed, but considered unlikely as there are not many of these periods and they are short.
- Between February 1999 and May 2015, 13 separate periods of entrance closed conditions have been identified, with closed conditions ranging from 1 week up to 10 months, but typically in the order of a few weeks to months. The total duration of closed entrance conditions compared to the full record equates to approximately being closed for 15% of the time.
- The duration that the entrance stays open for ranges from 1 week to around 5 years, but typically in the order of several months to over a year. The total duration of open entrance conditions for the full record equates to approximately being open for 85% of the time. This illustrates that Crooked River is a predominantly open ICOLL.
- The height of entrance opening ranges from 0.83 to 1.56 m AHD, but typically over 1.2m AHD.
- The lowest recorded height of entrance opening of 0.83 m AHD corresponds to the 2nd shortest period of entrance open conditions (~ 2 weeks).
- A significant portion of the data has been recorded during a period of exceptionally dry conditions (~2000 – 2009) where other ICOLLs on the South Coast experienced longer and more frequent periods of closed conditions. This may bias the degree of entrance closed to entrance open conditions for the Crooked, and hence the above may not be an accurate reflection of average entrance conditions over a longer time span.

Figure 1: Complete water level data set from the Gerroa water level gauge situated in the Crooked River.

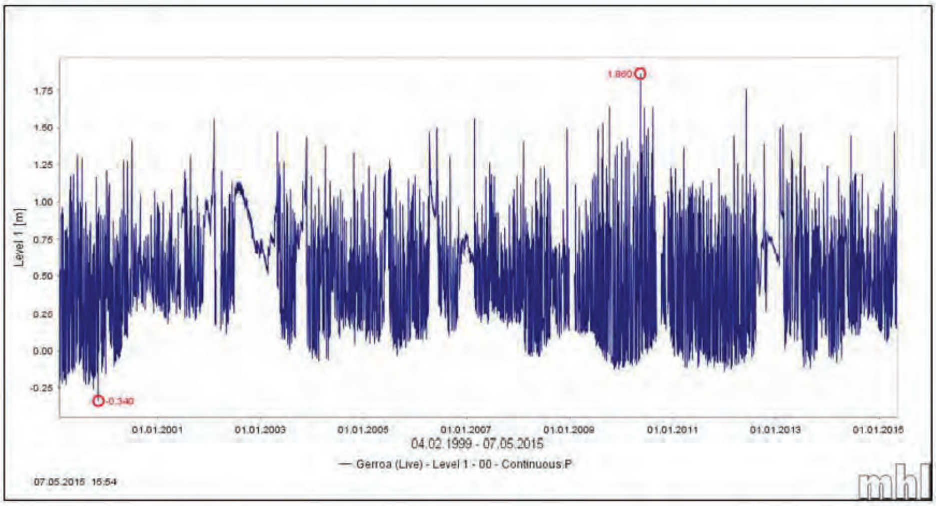
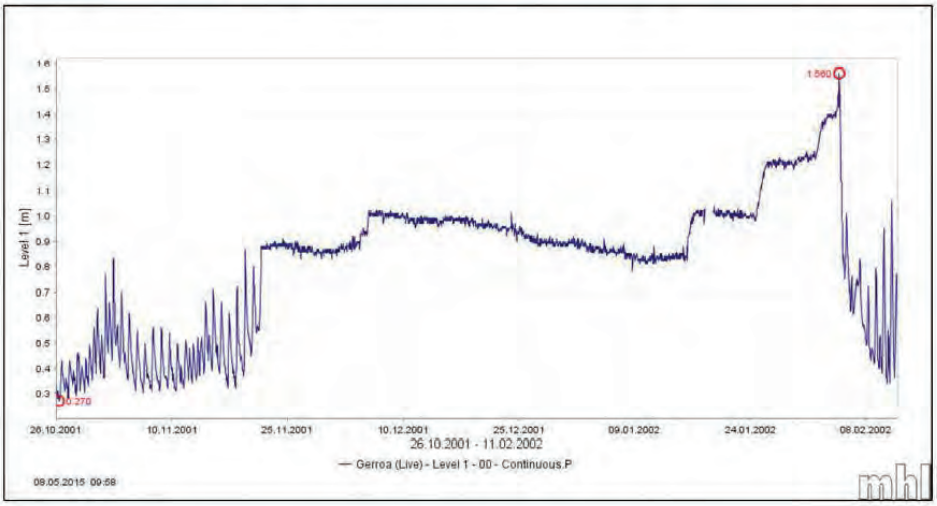


Figure 2: Example of a period of entrance closure identified from the loss of tidal signal.



Danny Wiecek
Senior Natural Resource Officer – Coast and Estuaries

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APPENDIX 5 – MANAGEMENT ACTION PRIORITISATION

	Management Action	Likely success	Cost	Community support	Enviro benefit	Total	Priority
1.1	Develop a best practice riparian and aquatic environment management demonstration site on interested landholders properties within the catchment	3	4	4	5	16	High
1.2	Facilitate collection and collation of water quality information required to complete Estuary Health Report Cards	4	2	4	1	11	Medium
1.3	Produce and publish estuary health report cards						Ongoing
1.4	Ensure water quality monitoring results from licensed facilities within the Crooked River catchment are available for public access						Ongoing
1.5	Complete event based and targeted water quality sampling to identify areas to target for water quality improvements	4	2	4	2	12	Medium
1.6	Work with landholders in Blue Angle Creek catchment to determine appropriate management of recurring poor water quality events including acid sulfate runoff and assessment of floodgate management options	4	2	5	5	16	High
1.7	Deliver information and extension services to landholders within the Crooked River catchment that support farm profitability and land and water stewardship practices						Ongoing
1.8	Carry out inspections of OSSMS in accordance with Council's On-site sewage management strategy						Ongoing
1.9	Identify risks and enact mitigation measures for pumping stations on private properties and yard gullies connected to the Gerroa WRP	5	5	5	4	19	High

1.1	Develop engagement and implementation program with landholders to improve agricultural effluent management within the Crooked River catchment	4	2	5	5	16	High
1.11	Coordinate research into the development of management options / plan for high risk acid sulfate soil areas within the Crooked River catchment	3	2	4	4	13	Medium
1.12	Utilise diffuse pollution risk maps to guide decision making to ensure the ongoing protection of the Crooked River estuary from inappropriate development types						Ongoing
2.1	Complete assessment and implement erosion control measures for the Blue Angle Creek in Seven Mile Beach Holiday Park	5	1	5	5	16	High
2.2	Undertake a hydrographic survey to determine the rate of infill occurring in the Crooked River Estuary	4	1	4	1	10	Low
2.3	Ensure erosion and sediment controls are established and monitored in new developments within the Crooked River catchment						Ongoing
2.4	Complete flood management study for the urban areas of the Crooked River catchment						Ongoing
2.5	Place temporary signage at the entrance to Crooked River when closed, informing of entrance opening policy position and the legal ramifications of illegal opening of estuary	4	3	3	4	14	Medium
2.6	Review entrance opening policy position to include additional information relating to circumstances for consideration of artificial opening	5	4	4	2	15	Low
2.7	Ensure entrance opening policy position is available on Council website, along with educational information about the importance of maintaining the natural cycle of opening and closure						Ongoing

2.8	Monitor the ongoing effect of runoff from the Princes Highway upgrade on bank stability and sediment mobilisation around the runoff control infrastructure						Ongoing
3.1	Weed control activities undertaken in Seven Mile Beach Reserve and Gerroa Waste Depot						Ongoing
3.2	Weed control activities undertaken on Bailey's Island and Gerringong Gerroa STP site	4	2	3	4	13	Medium
3.3	Implement weed control and revegetation projects for riparian zones on the Crooked River estuary foreshore and tributaries	4	2	4	4	14	Medium
3.4	Update mapping of seagrass, saltmarsh and mangrove vegetation in the Crooked River estuary	4	4	4	1	13	Medium
3.5	Research potential migration of saltmarsh and mangrove communities due to the impacts of sea level rise and work with landholders to develop appropriate strategies to manage the issues identified	3	3	3	1	10	Low
3.6	Implement weed control and revegetation projects for riparian zones on tributaries of the Crooked River, with priority placed on connectivity of fragmented vegetation patches, restricting stock access and controlling bank erosion	4	3	4	5	16	High
4.1	Conduct faecal contamination sampling in the Crooked River swimming area during the summer swimming season	5	3	4	2	14	Medium
4.2	Work with LALC to research sea level rise and the need for management of culturally significant sites which may be affected	4	3	4	1	12	Medium
4.3	Research potential impacts of sea level rise on agricultural lands within the Crooked River catchment	4	3	4	1	12	Medium

4.4	Investigate feasibility of providing formalized canoe/kayak launching points in the lower estuary	3	3	3	1	10	Low
5.1	Develop an agency and landholder committee to identify and communicate potential funding for works within the Crooked River catchment and oversee the implementation of the Crooked River Coastal Zone Management Plan	5	4	4	3	16	High
5.2	Employment of estuary health officer or similar position, to coordinate the implementation of on-ground activities for the Crooked River and other Coastal Zone Management Plans (including Minnamurra River and potentially other estuaries in the Illawarra)	3	2	5	4	14	Medium

Likely Success	1 to 10	Low Priority
Poor likelihood 1, high likelihood 5	11 to 15	Medium Priority
	16-20	High Priority

Cost

High cost 1, Low cost 5

Community / Stakeholder Support

Low level support 1, High level support 5

Environmental impact / benefit

Low environmental benefit 1, High environmental benefit 5

APPENDIX 6 – AERIAL PHOTOGRAPHY COMPILATION CROOKED RIVER CATCHMENT

Crooked River Estuary 1949

Estuary open to the ocean

Large sediment beds apparent in mid estuary

Seagrass appears to be present throughout the estuary upstream of the road bridge

No caravan parks present

Large sections of the upper estuary foreshore and catchment cleared, as pre present day

Entrance channel alignment along the northern foreshore

Crooked River Estuary 1963

Estuary barely open to the ocean

Seagrass appears to be present in the lower estuary around Blue Angel Creek, reduction in extent of seagrass in the mid to upper estuary

Development of southern and northern caravan park sites apparent

Crooked River Estuary 1969

Seagrass appears to be present through much of the estuary

Estuary closed to the ocean by wide sand berm

Development of both southern and northern caravan parks clearly visible

Crooked River Estuary 1979

Estuary open to the ocean

Seagrass appears to be sparse throughout the system, most noticeably around mid to lower estuary

Crooked River Estuary 1987

Entrance closed to the ocean

Seagrass appears to be present in the mid and upper parts of the estuary

Crooked River Estuary 1993

Estuary open to the ocean

Sediment beds apparent in the mid estuary

Seagrass visible around Blue Angle Creek in mid to lower estuary, appears to be absent from mid to upper estuary

Clearing on the future Gerroa Wastewater Recycling Plant site apparent

Landfill site very visible

Further extension of northern caravan park

Crooked River Estuary 1999

Entrance open to the ocean

Sediment beds apparent in the mid estuary]

Crooked River Estuary 2003

Estuary practically closed to the ocean

Gerroa Sewage Wastewater Recycling Plant built

Landfill site under remediation

Seagrass appears to be present in the mid and lower estuary

Crooked River Estuary 2012

Estuary open to the ocean

Dune vegetation noticeably close to the foot bridge at Burke Parade

Gerroa WRP site vegetation re-established by Gerroa Environment Protection society apparent

Seagrass beds visible in the mid and lower estuary

Noticeably turbid in the upper estuary

Foys Swamp 1949

Largely intact, northern part starting to get drained

Foys Swamp 1963

Drains evident through middle of the swamp

Foys Swamp 1969

Clearing of Swamp started

Foys Swamp 1974

Most of swamp clear, sand mining starting

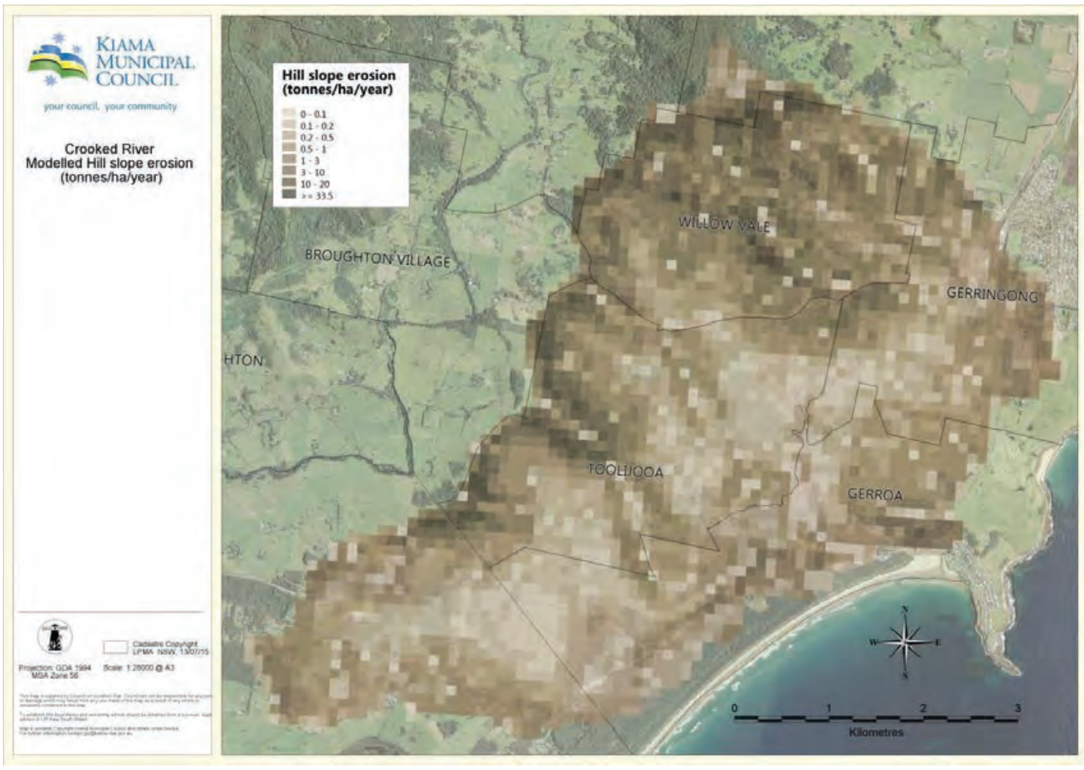
Foys Swamp 1979

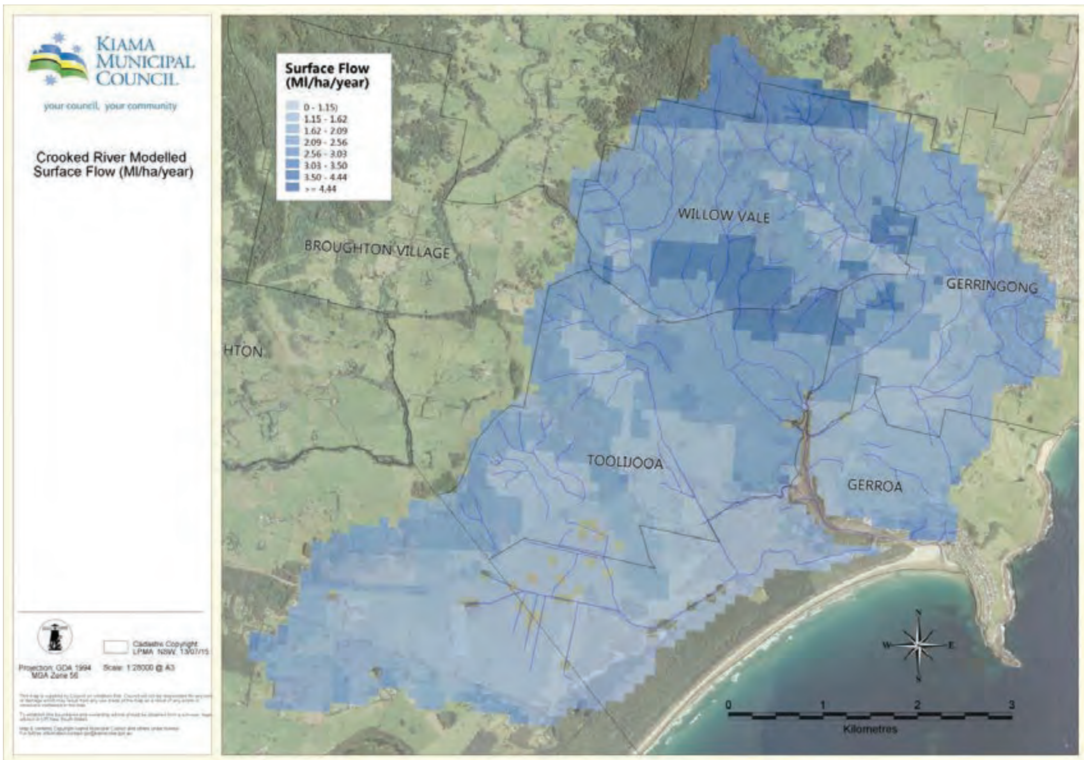
Foys Swamp 1999

Foys Swamp 2012

Sand mine extended to almost current extent.

APPENDIX 7 – CATCHMENT MODELLING





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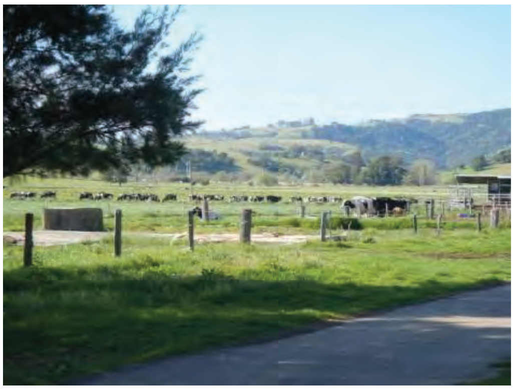
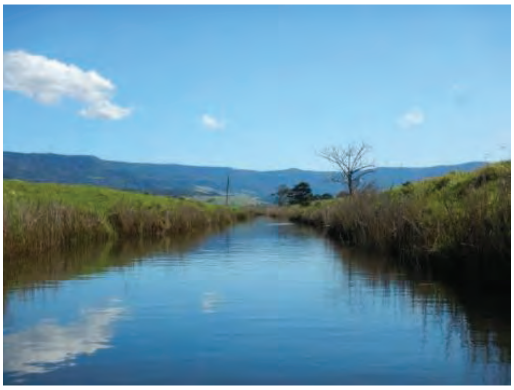
Coastal Zone Management Plan for the Minnamurra River Estuary

June 2015

Coastal Zone Management Plan for the Minnamurra River Estuary

Kiama Municipal Council has prepared this document with financial assistance from the NSW Government through the Office of Environment and Heritage. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage

Prepared on behalf of Kiama Municipal Council by Hydrosphere Consulting.

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Minnamurra Estuary Management Plan Review Committee - Councillor Andrew Sloan, Councillor Mark Honey, Councillor Kathy Rice, Errol McLean, Graham Pike, Grant Merinuk, Cliff Mason, Andrew Wilson

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;

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

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

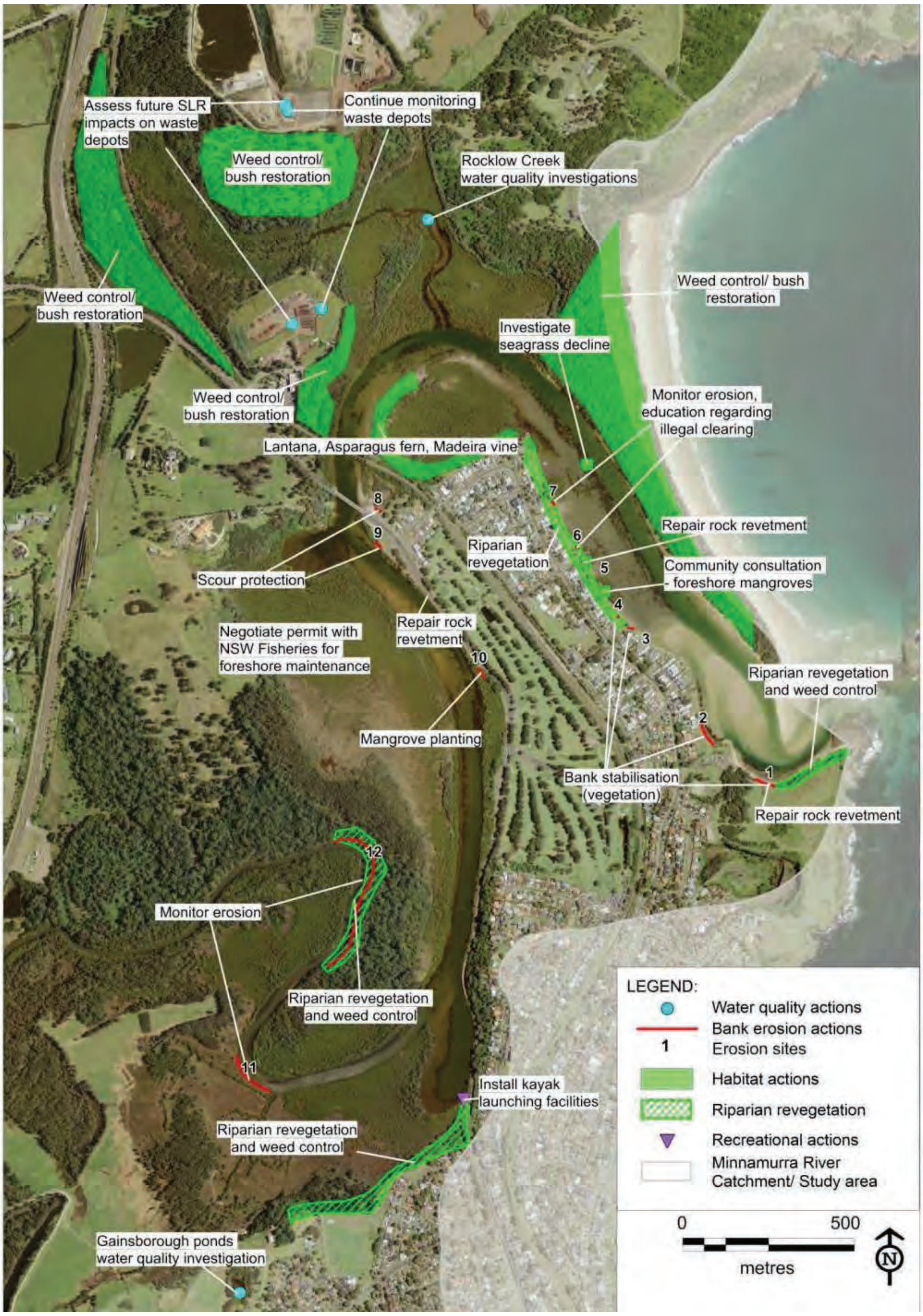


Figure 1: CZMP Management Actions – Lower-Mid Estuary

Note – Site 5 rock revetment has been repaired

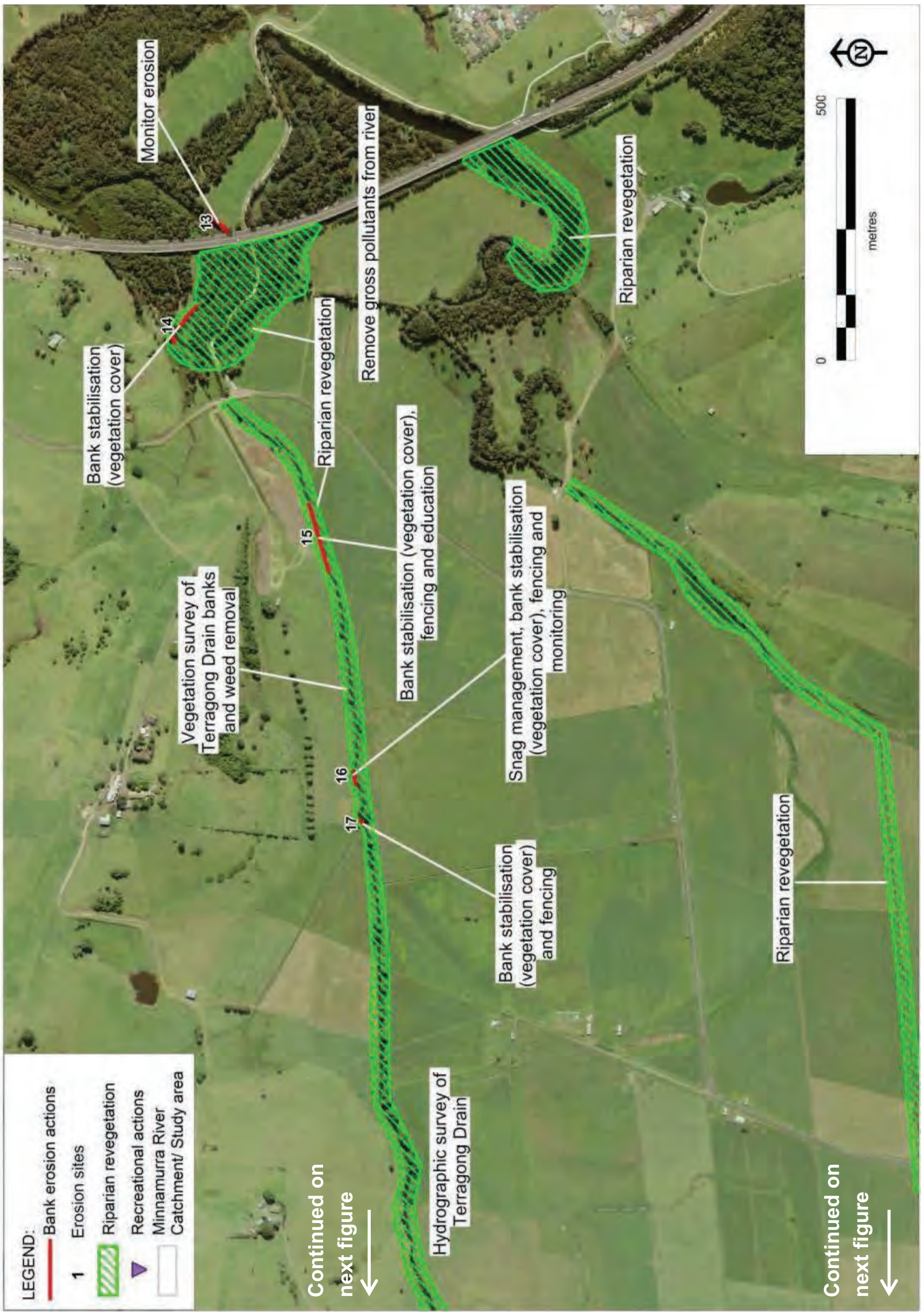


Figure 2: CZMP Management Actions – Upper Estuary and Terragong Swamp

Hydrosphere Consulting

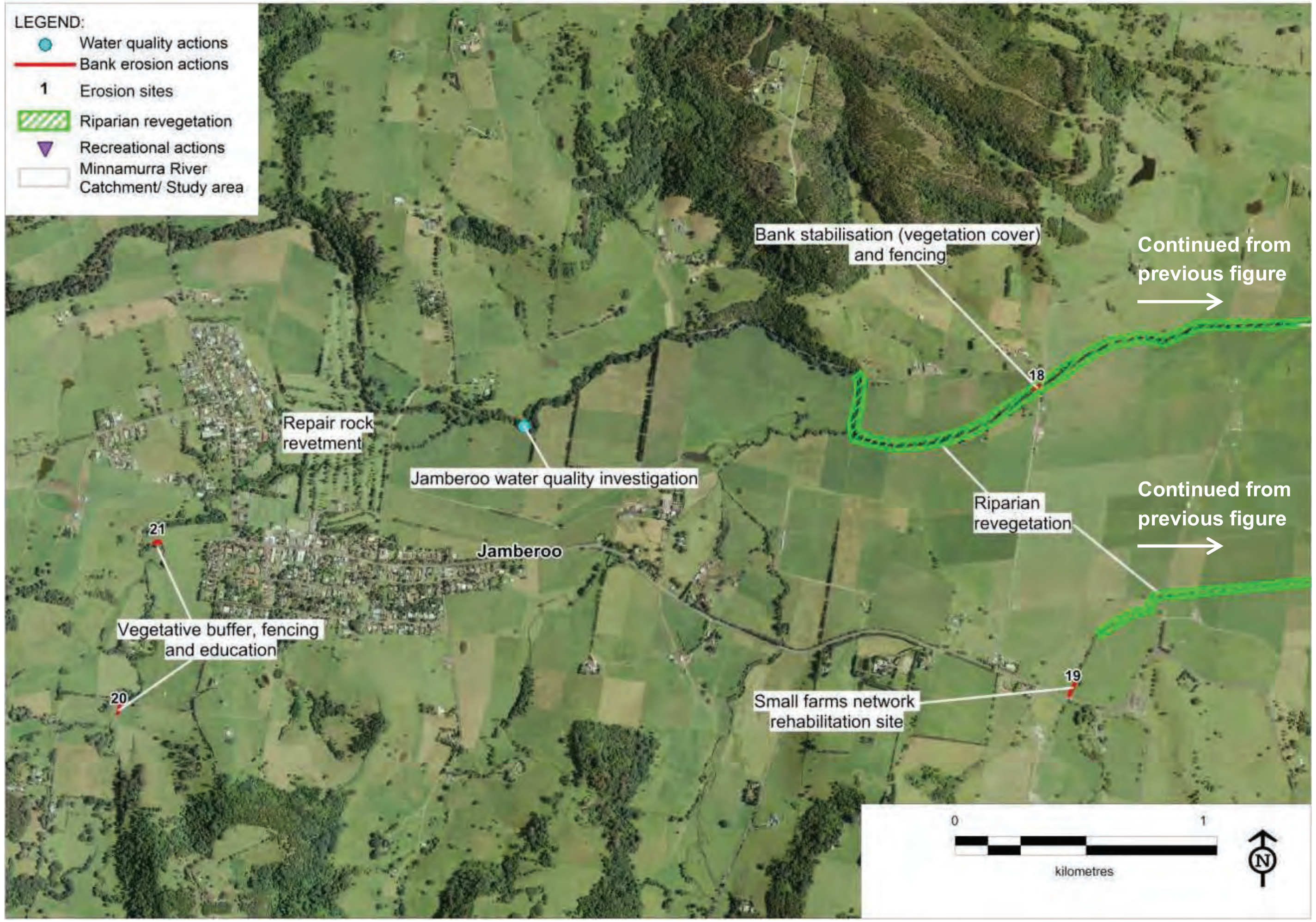


Figure 3: CZMP Management Actions – Jamberoo

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.

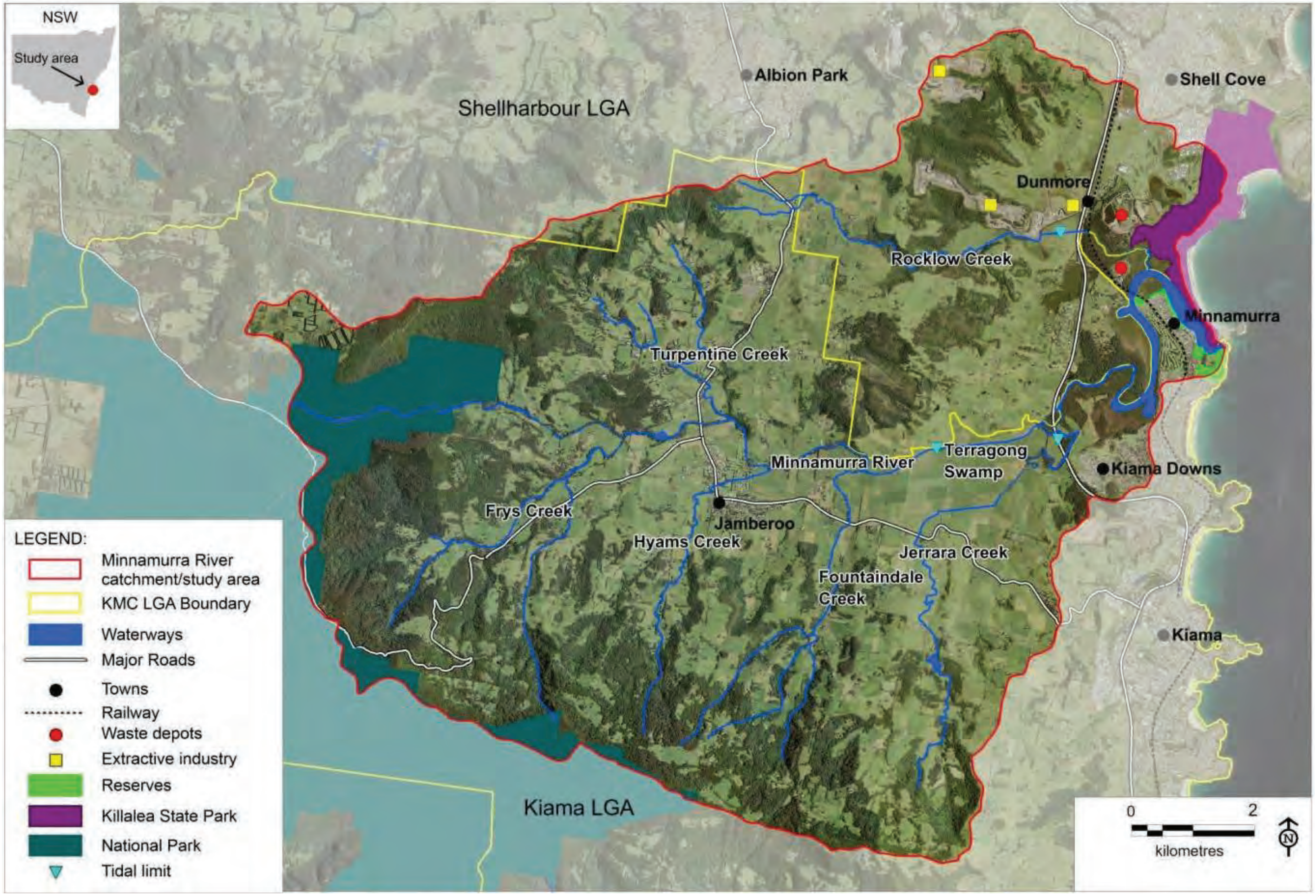


Figure 5: The Minnamurra River CZMP study area (Minnamurra River Catchment) and key features

Hydrosphere Consulting

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.

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

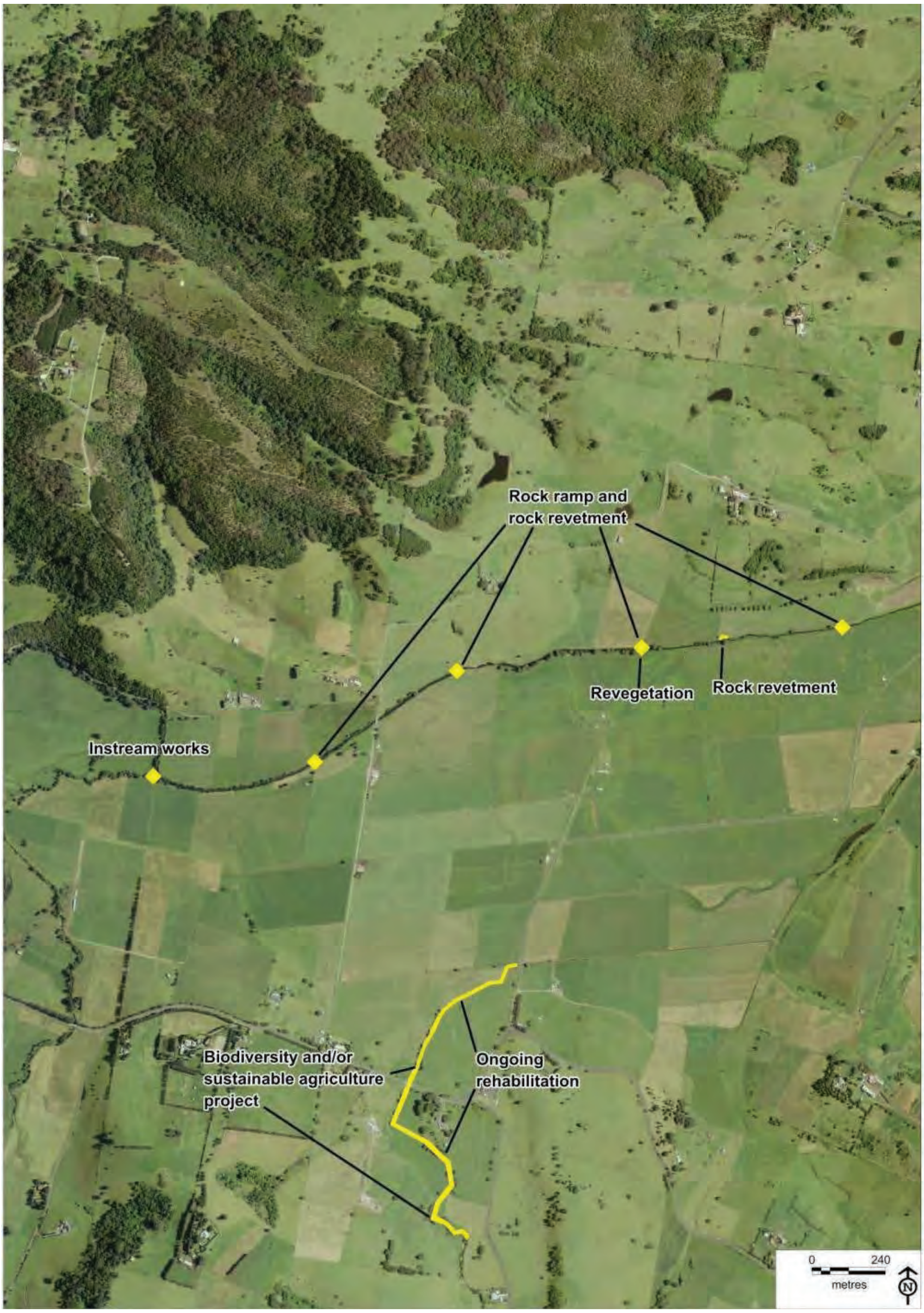


Figure 10: Locations of on-ground works implemented in mid-reaches of the Minnamurra River and Terragong Swamp

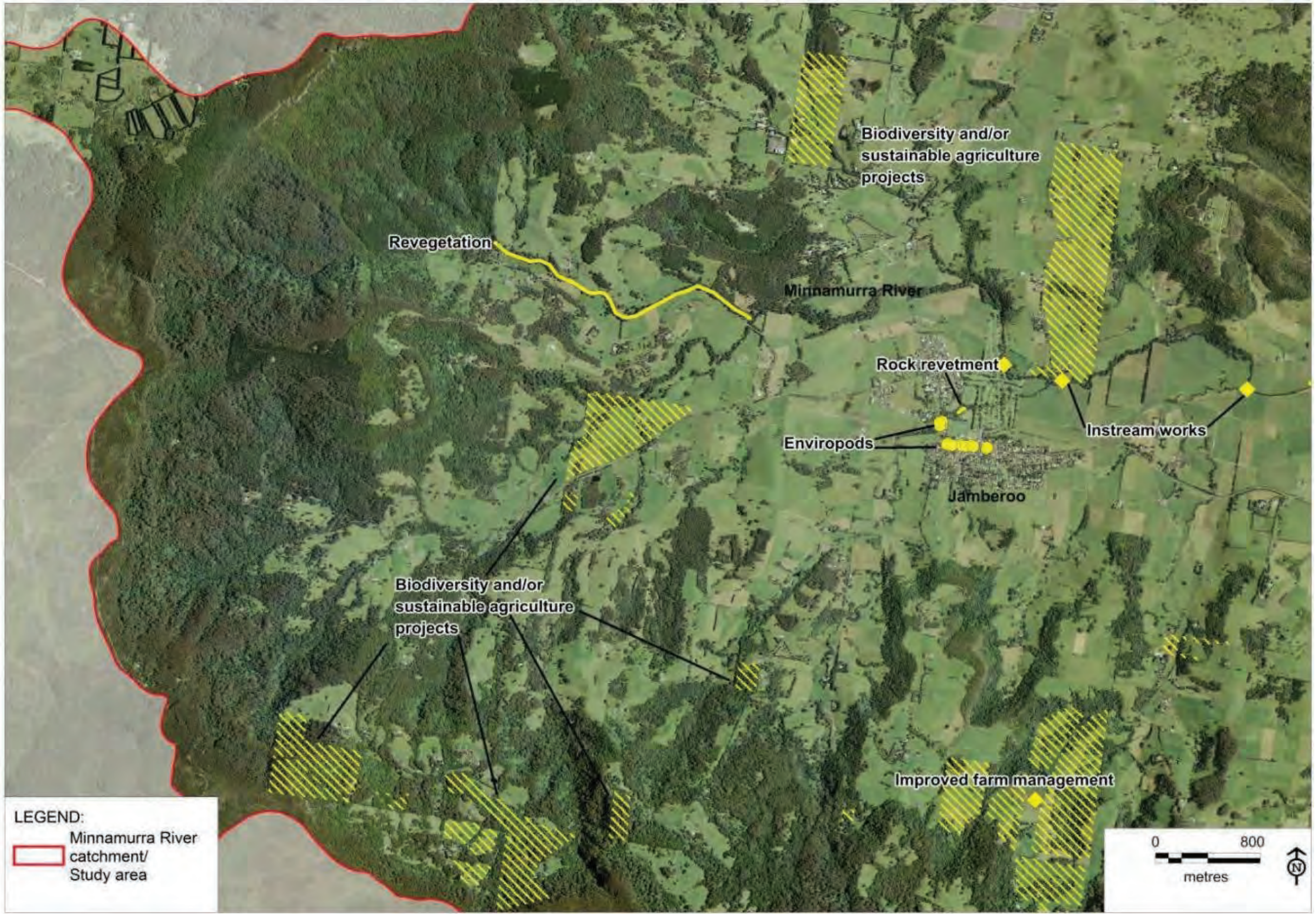


Figure 11: Locations of on-ground works implemented in upper catchment

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.

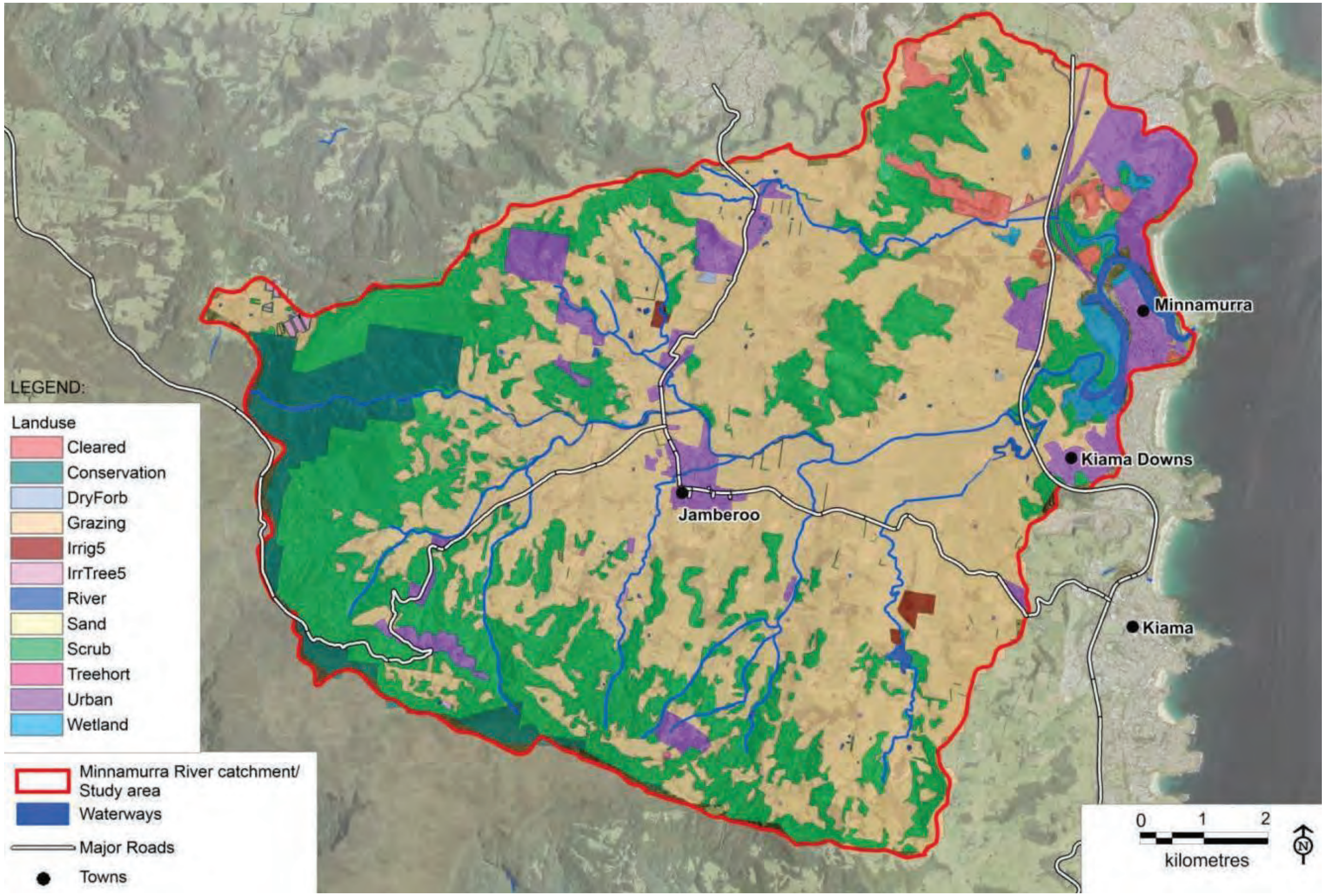


Figure 12: Major land uses of the study area

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

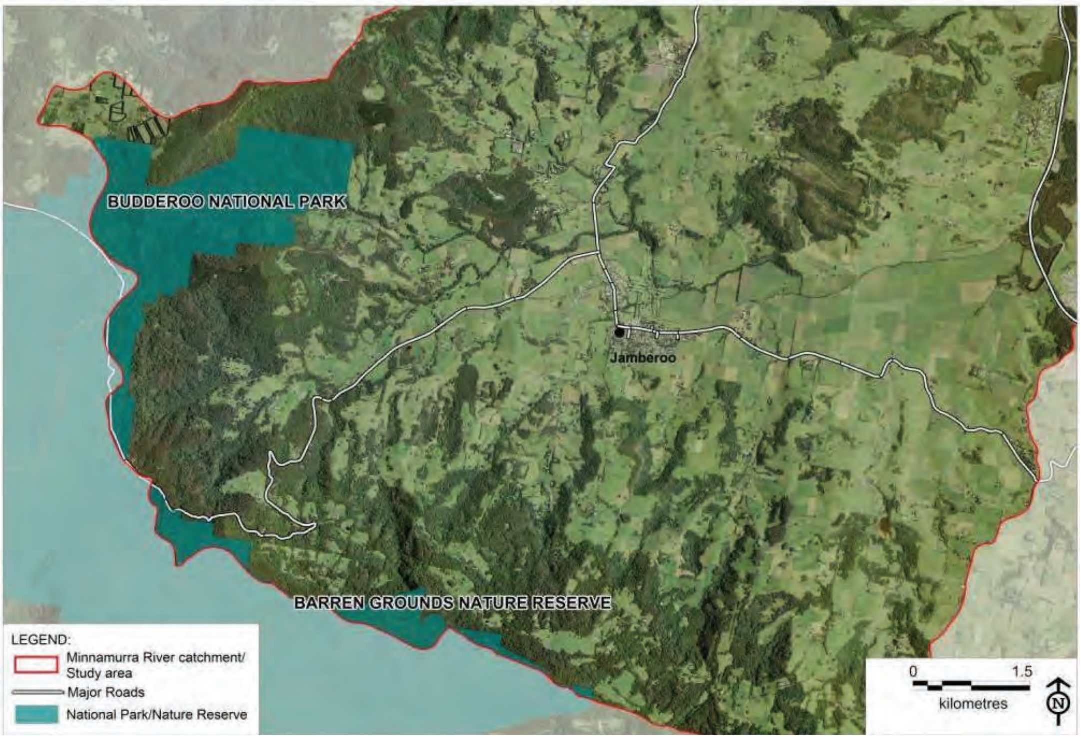


Figure 14: National Parks and Nature Reserves within the Minnamurra River Catchment

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.

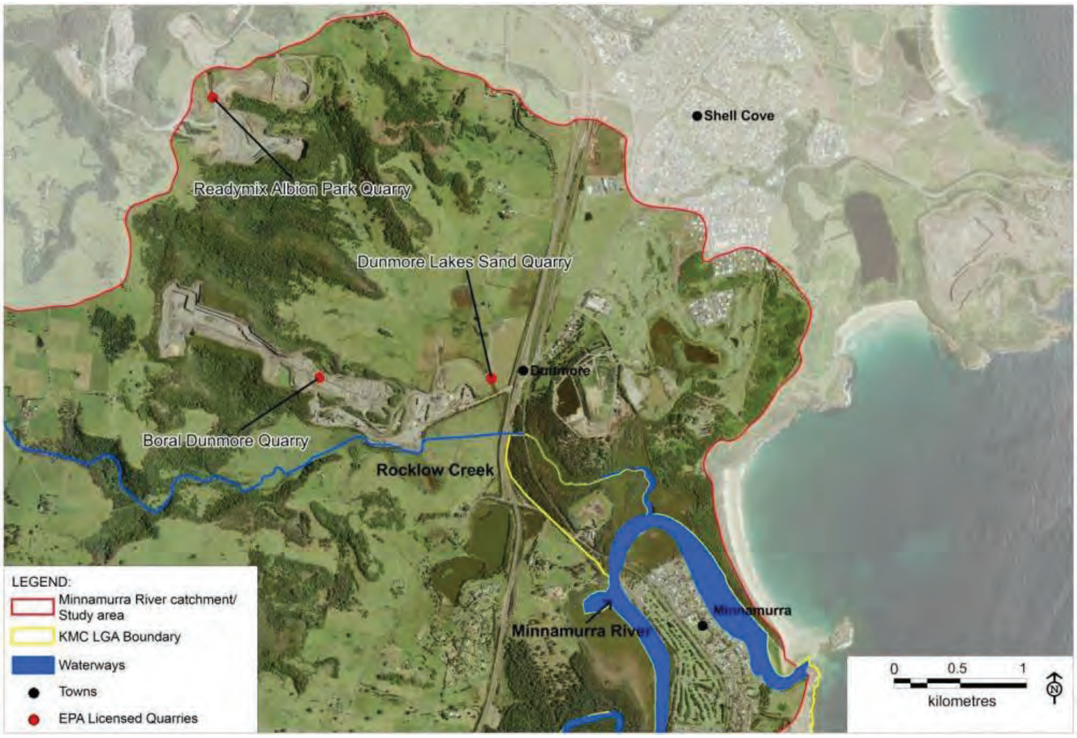


Figure 16: Extractive industry locations

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.

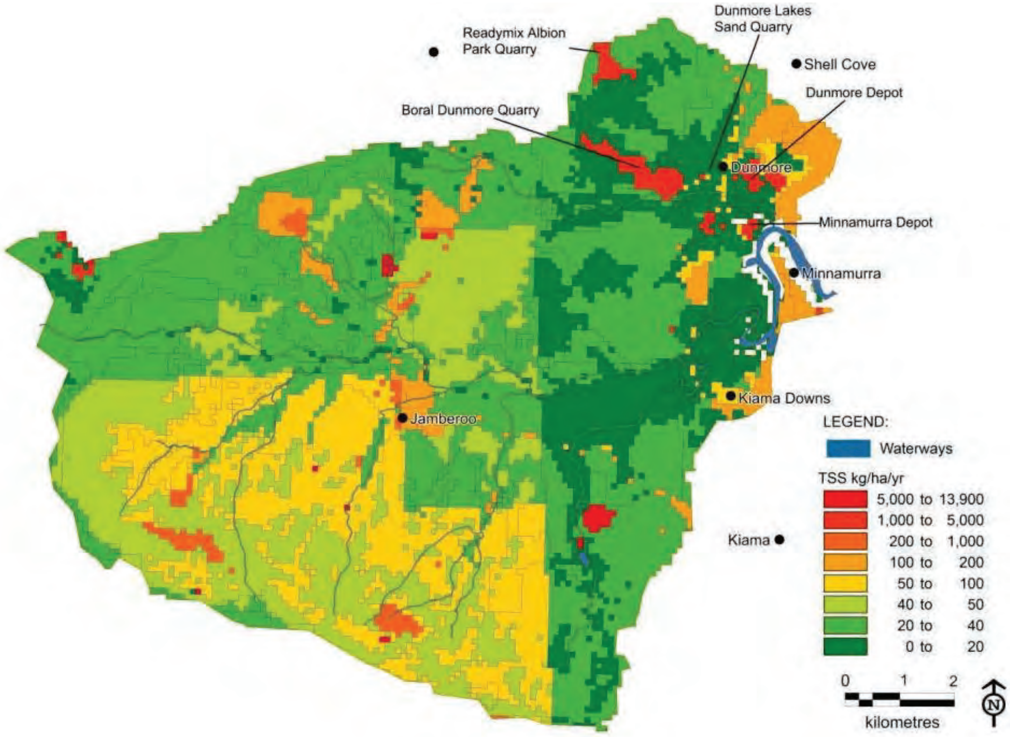


Figure 20: Modelled TSS load

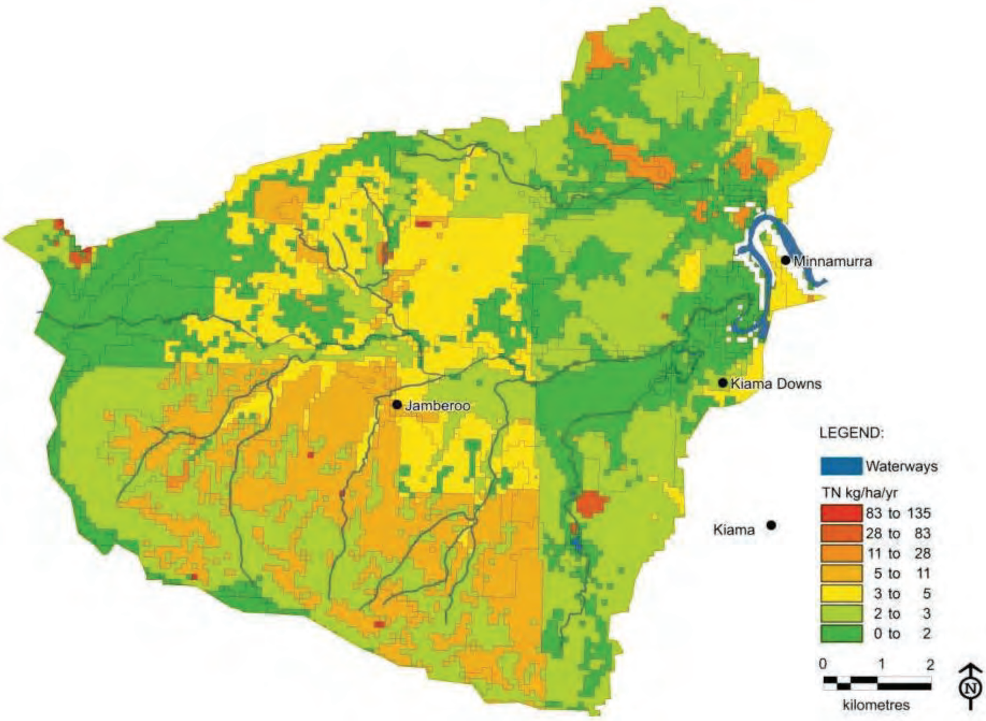


Figure 21: Modelled TN load

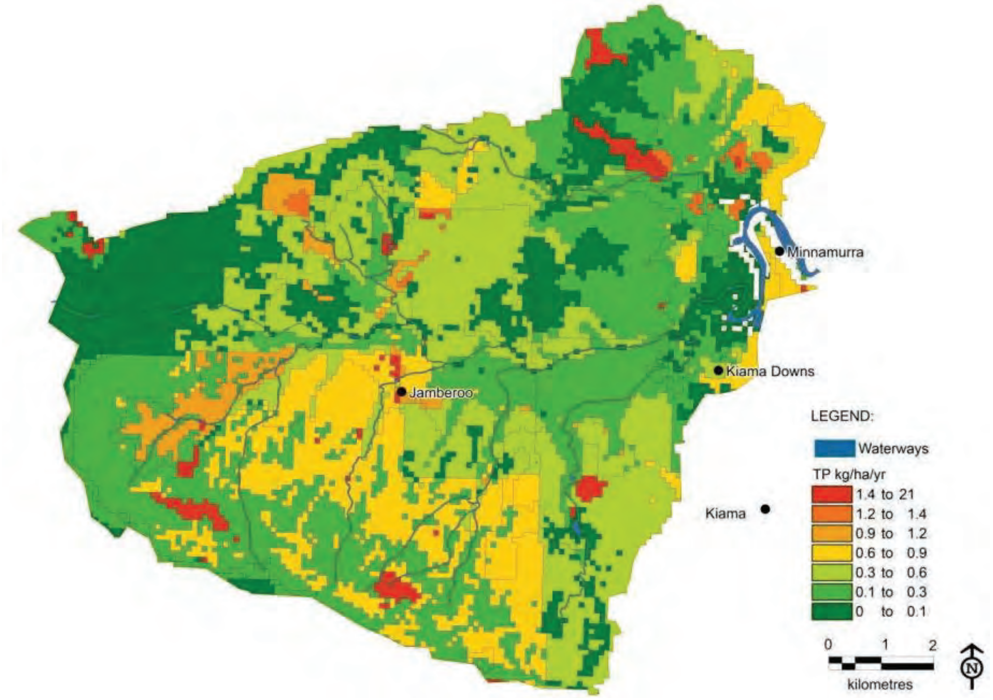


Figure 22: Modelled TP load

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).

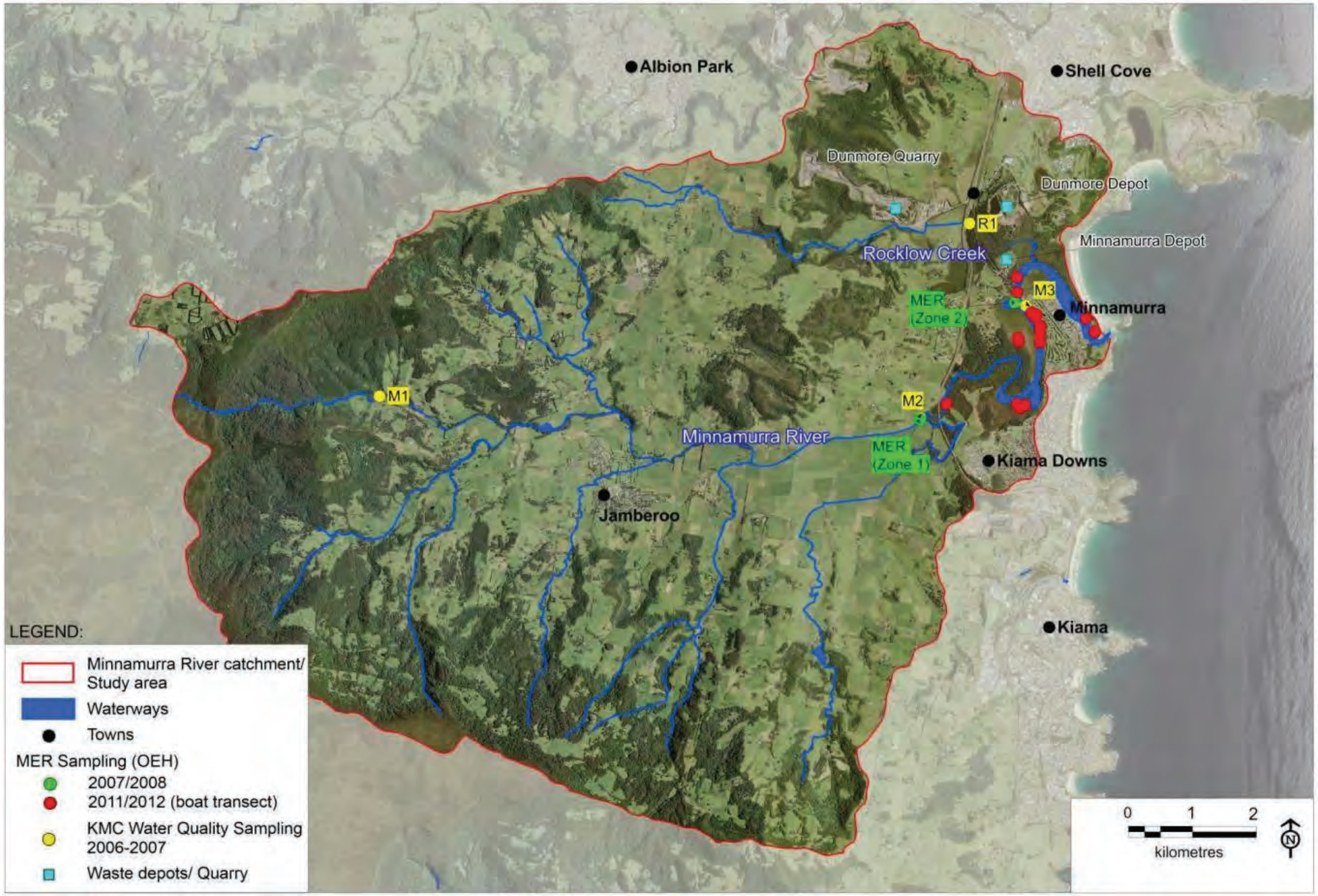


Figure 23: Recent water quality sampling sites within the Minnamurra River Catchment

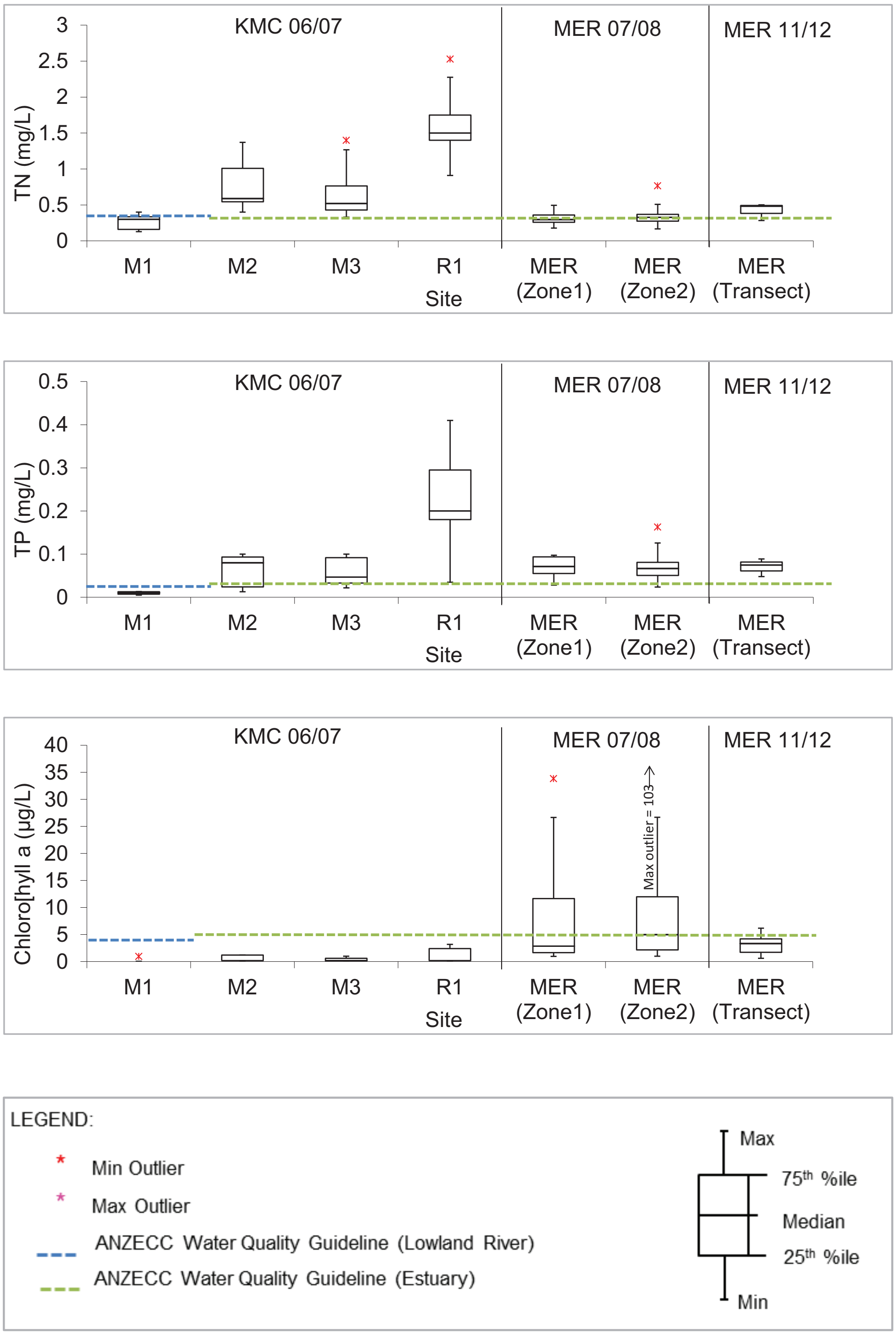


Figure 24: Nutrient and Chlorophyll a results for the Minnamurra River Catchment from 2006/07 (KMC), 2007/08 (OEH) and 2011/12 (OEH)

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.

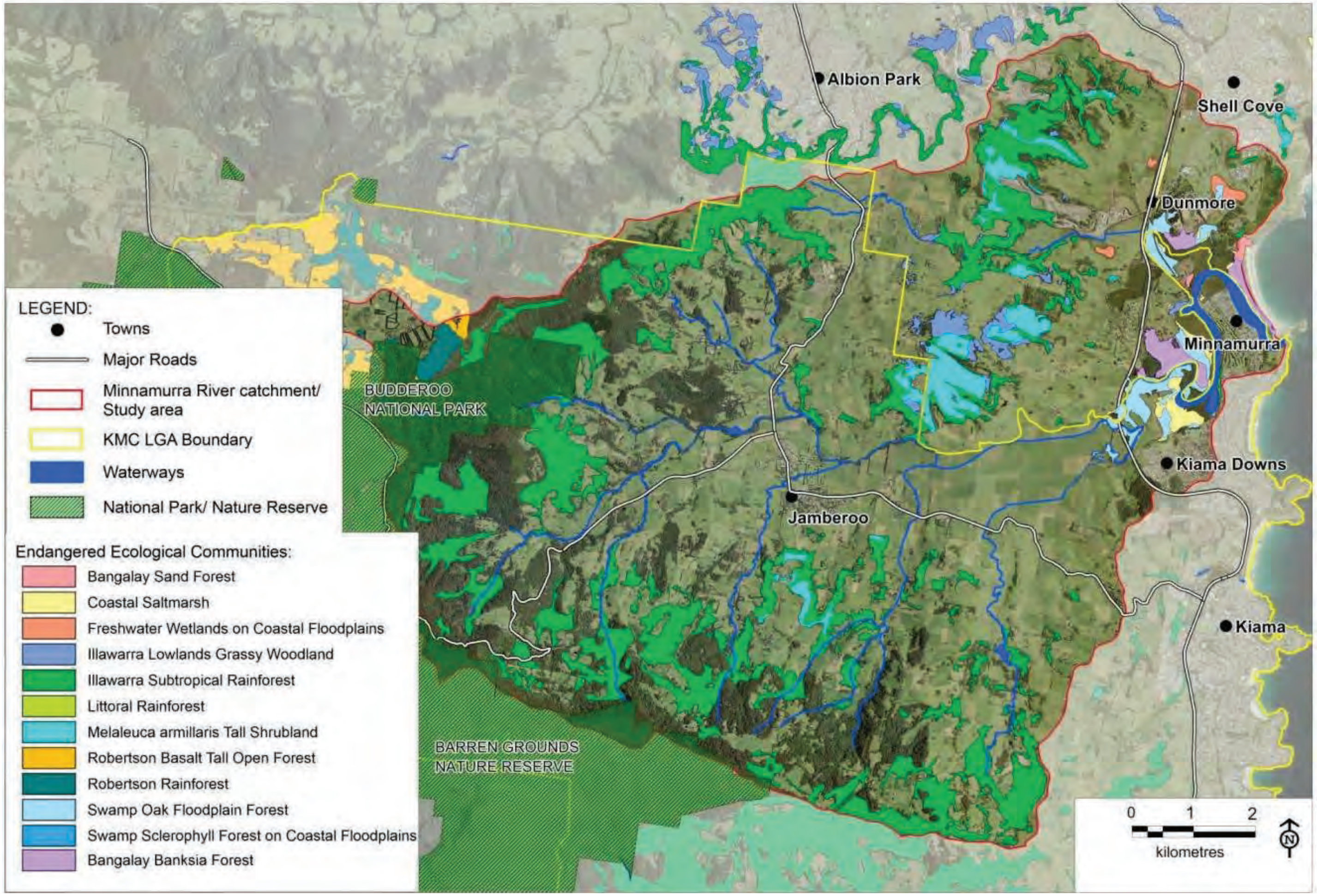


Figure 25: Endangered Ecological Communities in the Minnamurra River Catchment mapped by KMC and SCC

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.

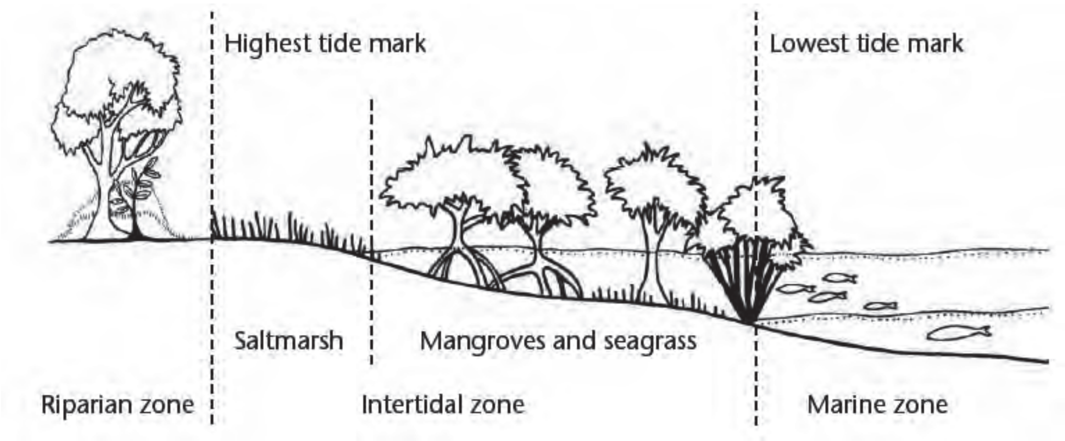


Figure 26: Zonation of estuarine vegetation

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.

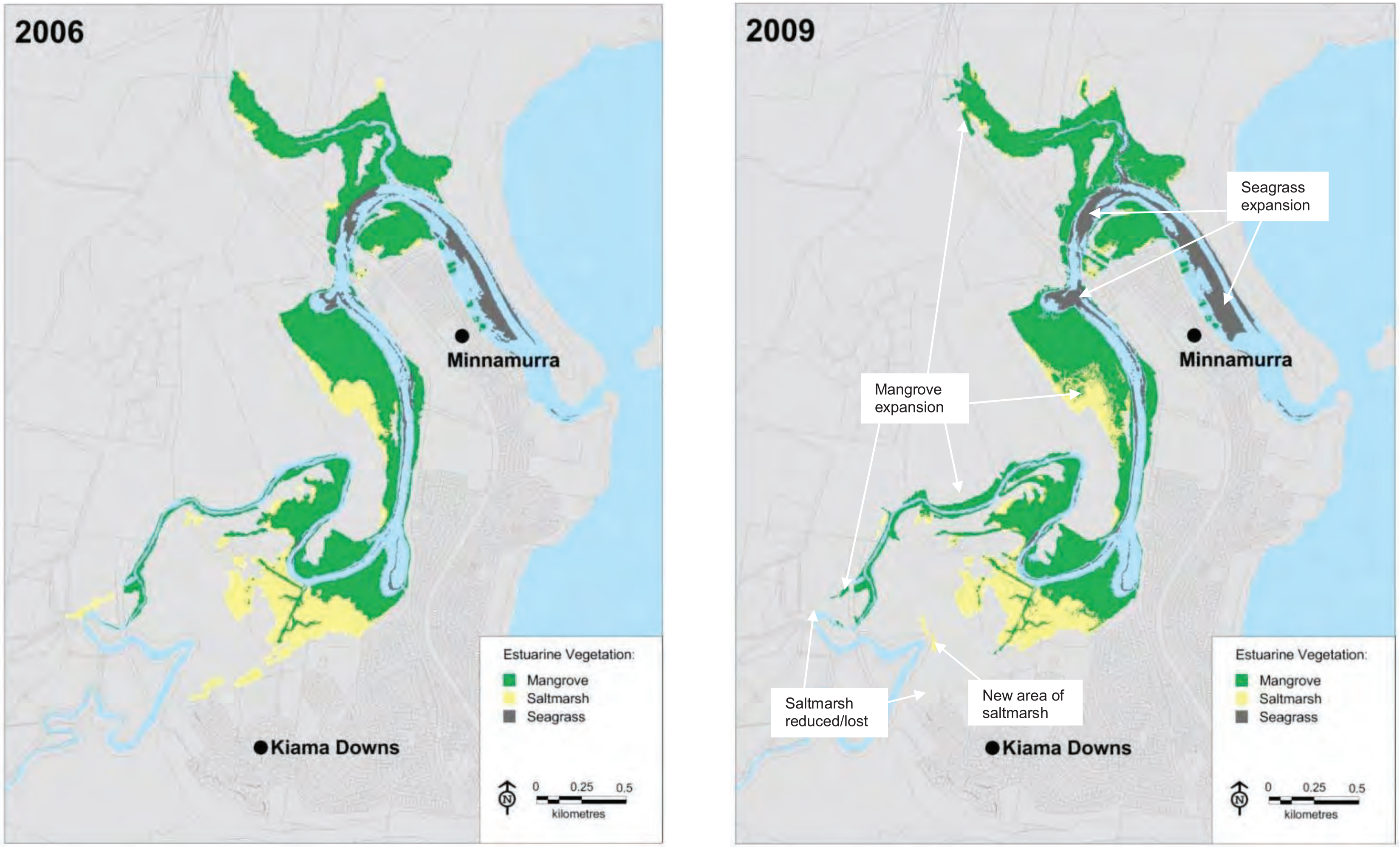


Figure 27: Estuarine macrophytes 2006 (left) and 2009 (right) (mapping provided by KMC)

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.

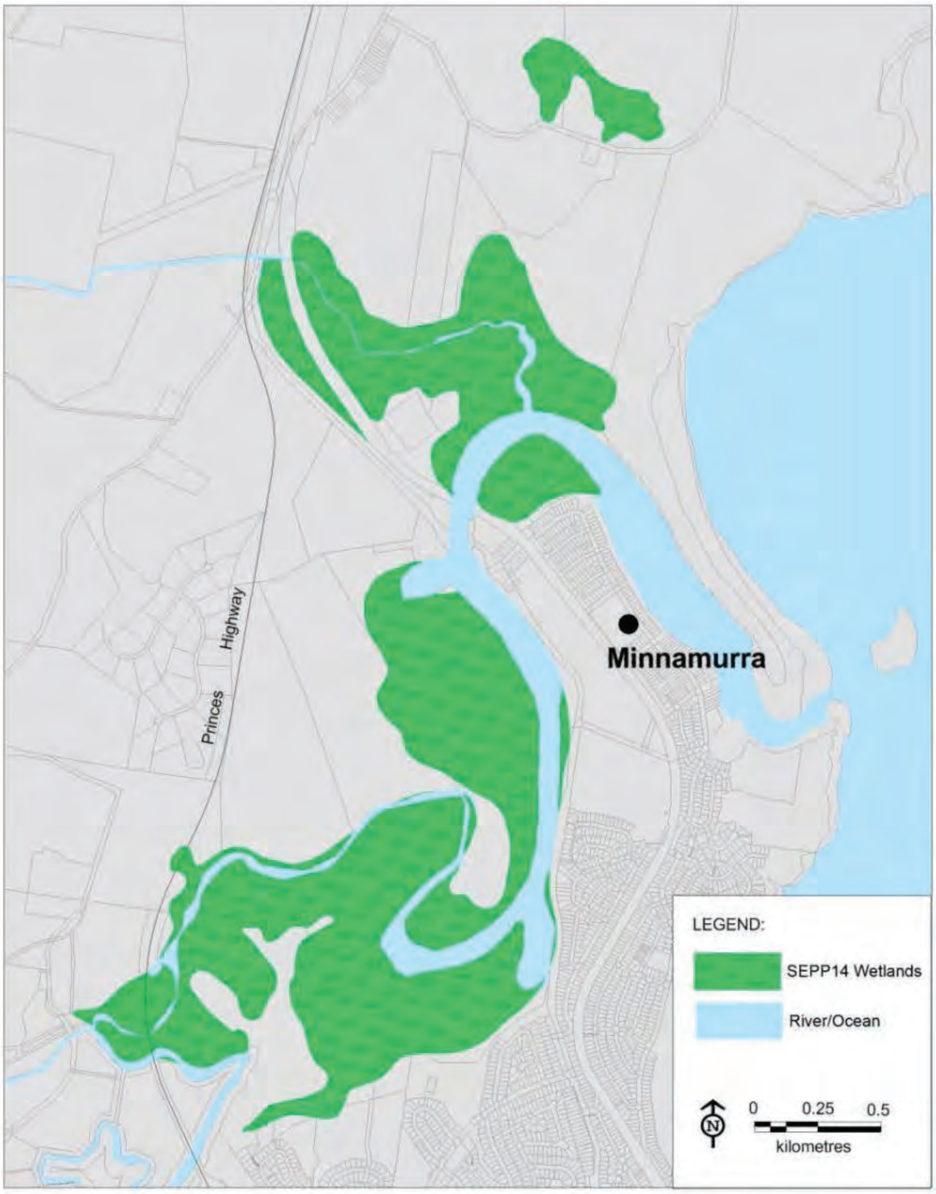


Figure 28: SEPP 14 Wetlands

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

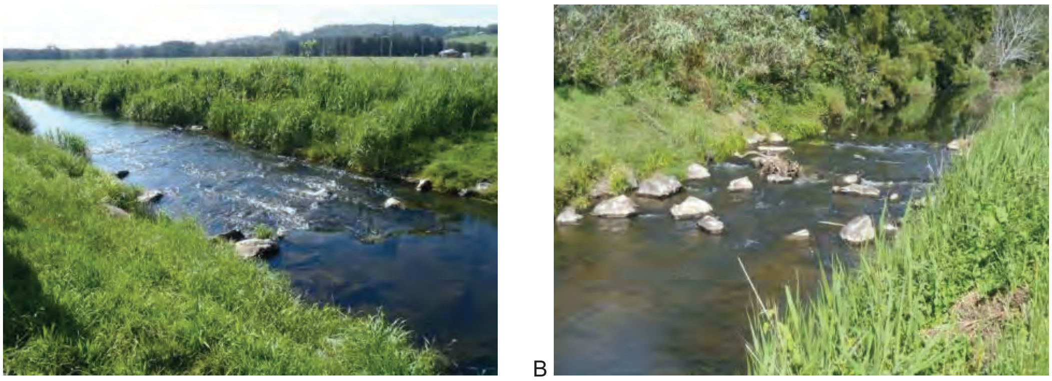
The 1995 EMP proposed several options for the control of bank erosion through the Terragong Swamp. The options included;

- 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

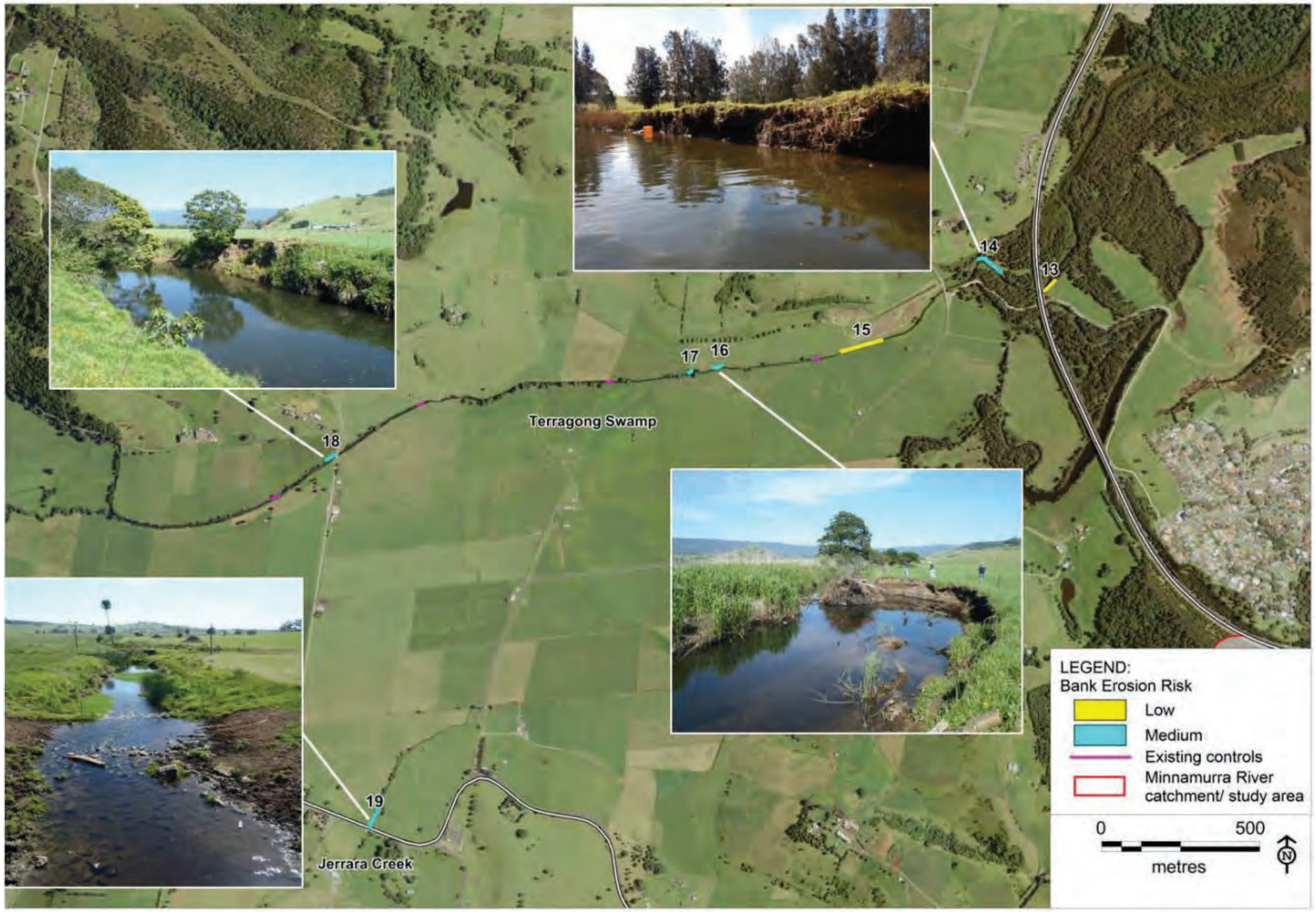


Figure 34: Locations of bank erosion sites in the upper estuary and lower Terragong swamp

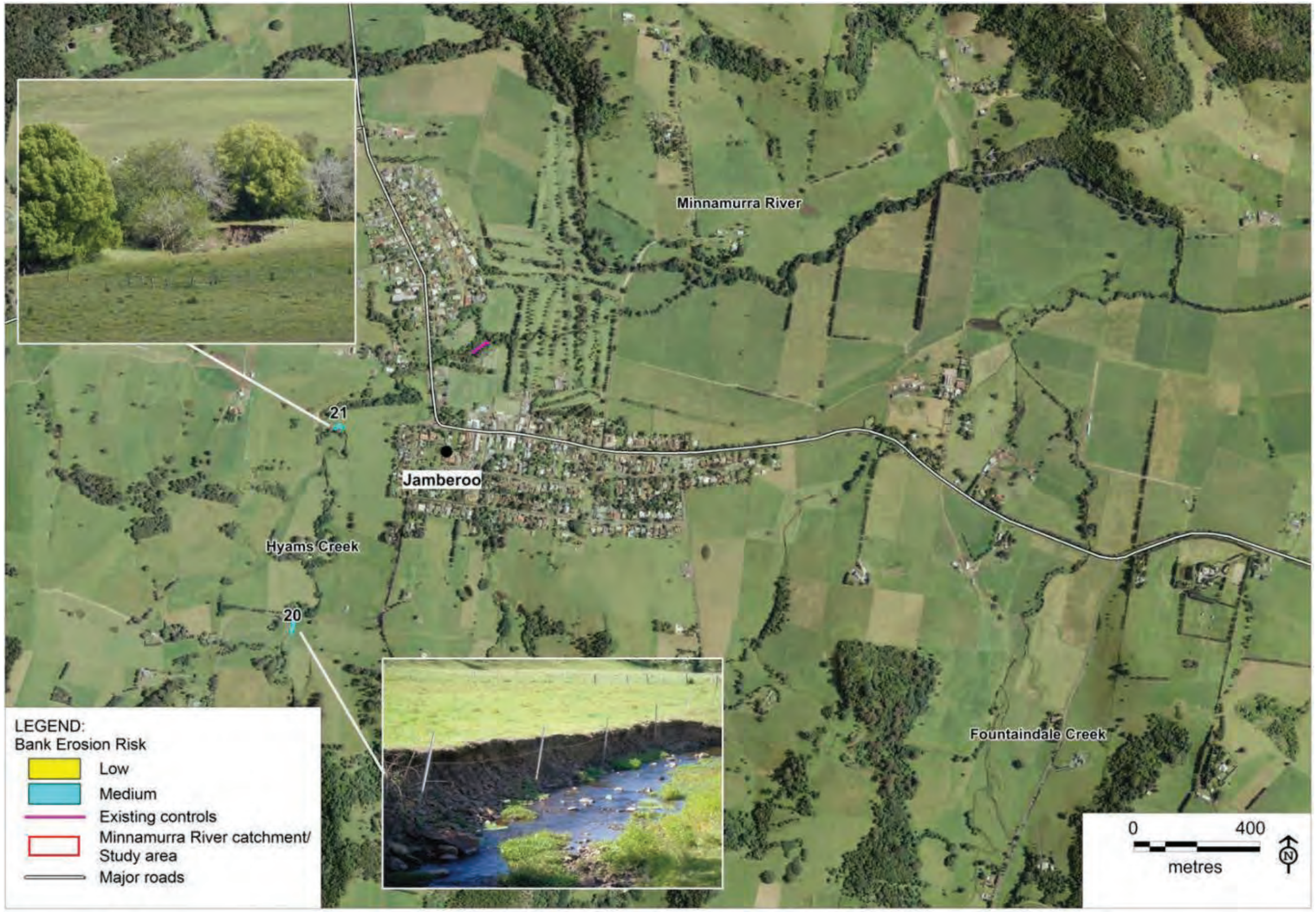


Figure 35: Locations of bank erosion sites in Hyams Creek

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.

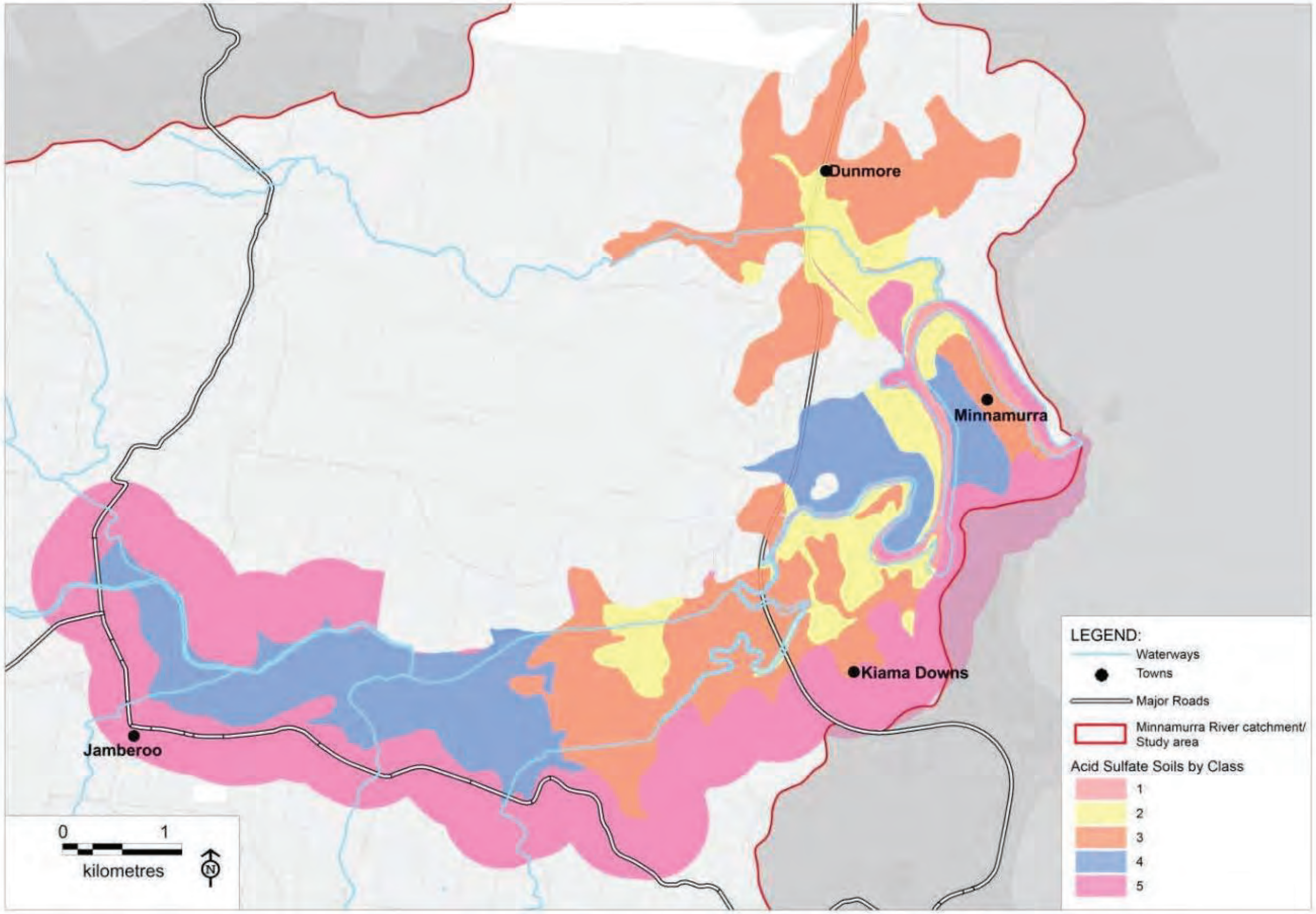


Figure 37: ASS Risk Maps

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

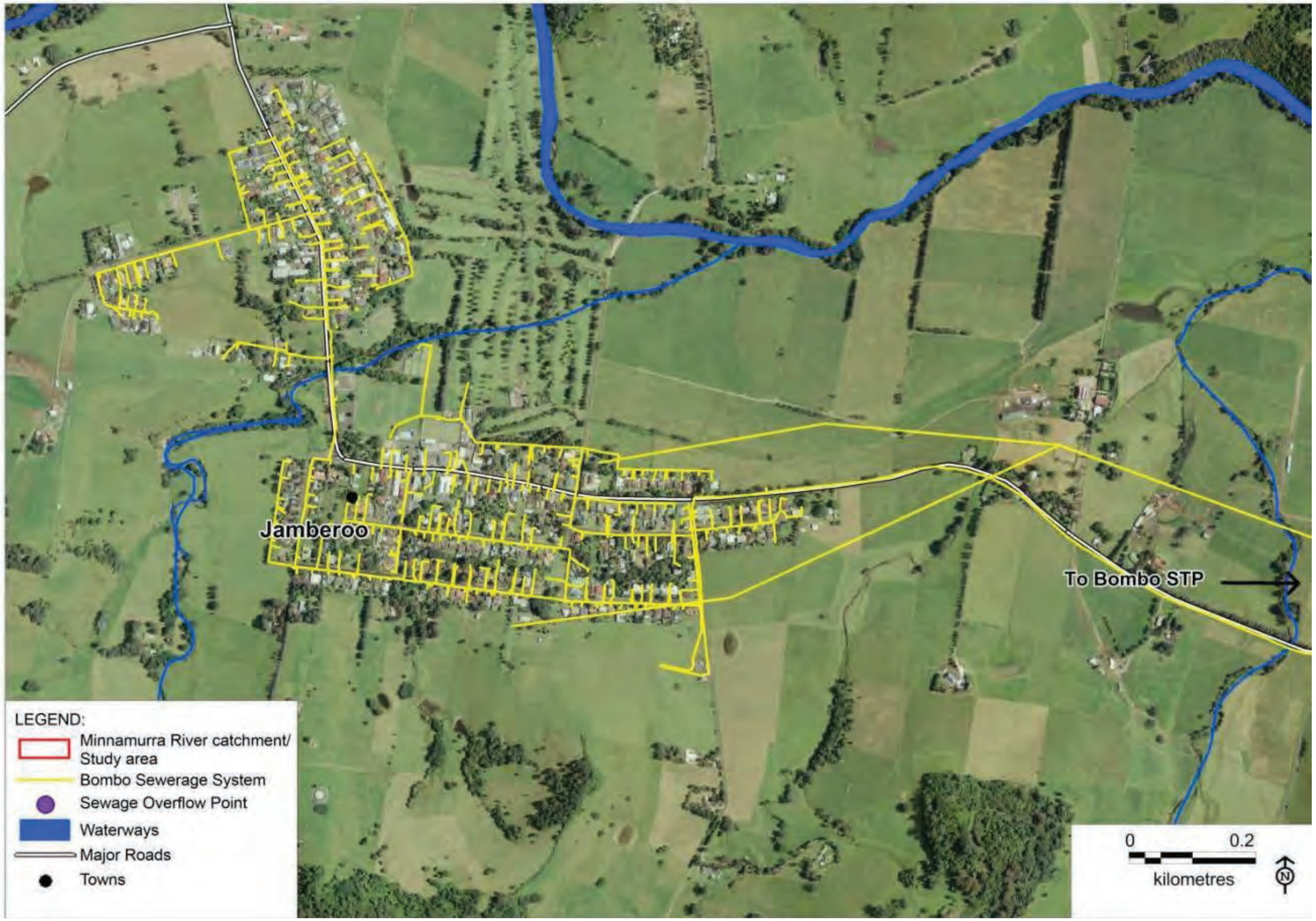


Figure 41: Jamberoo sewerage system

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.

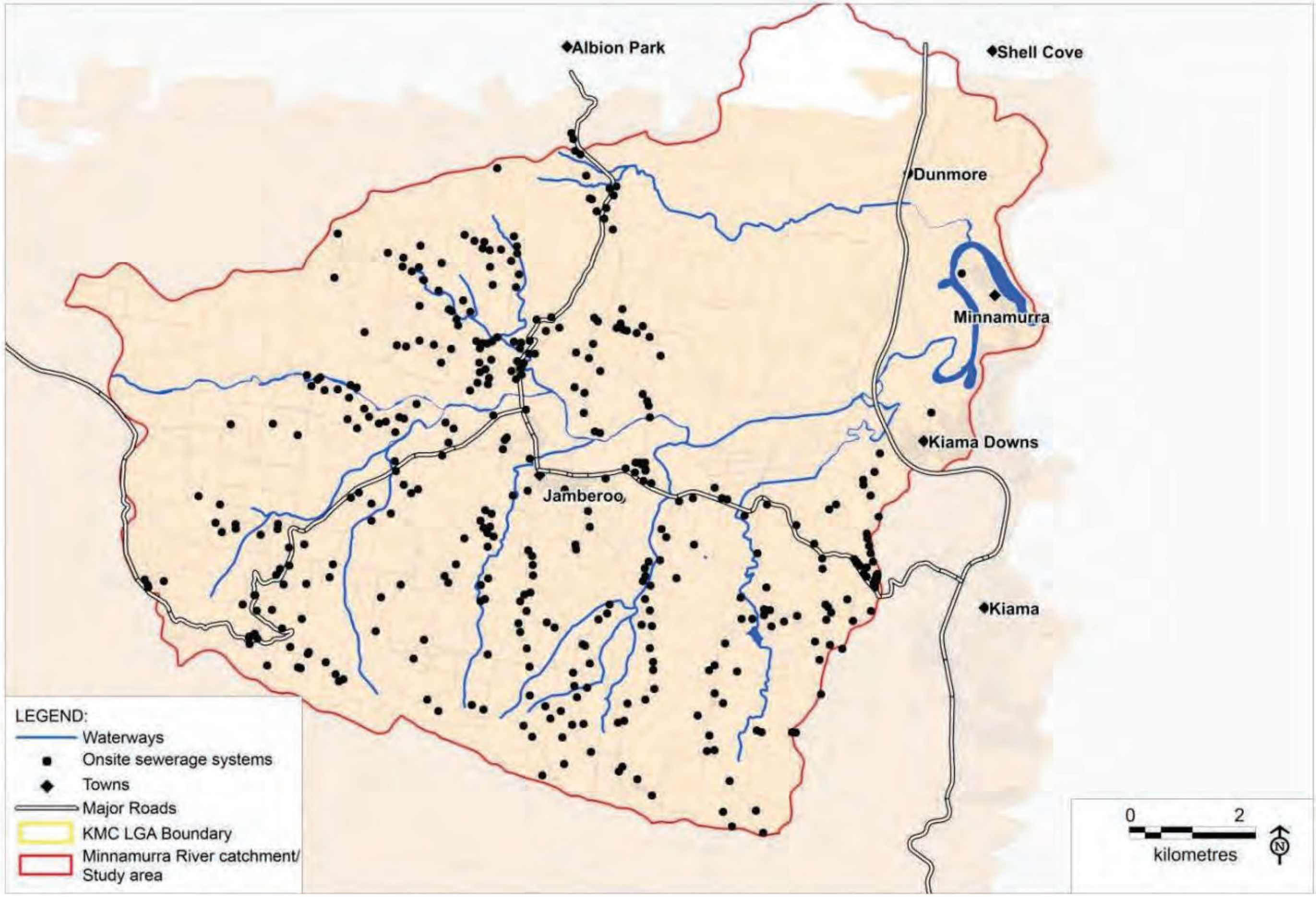


Figure 42: On-site sewerage systems in Kiama LGA

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.

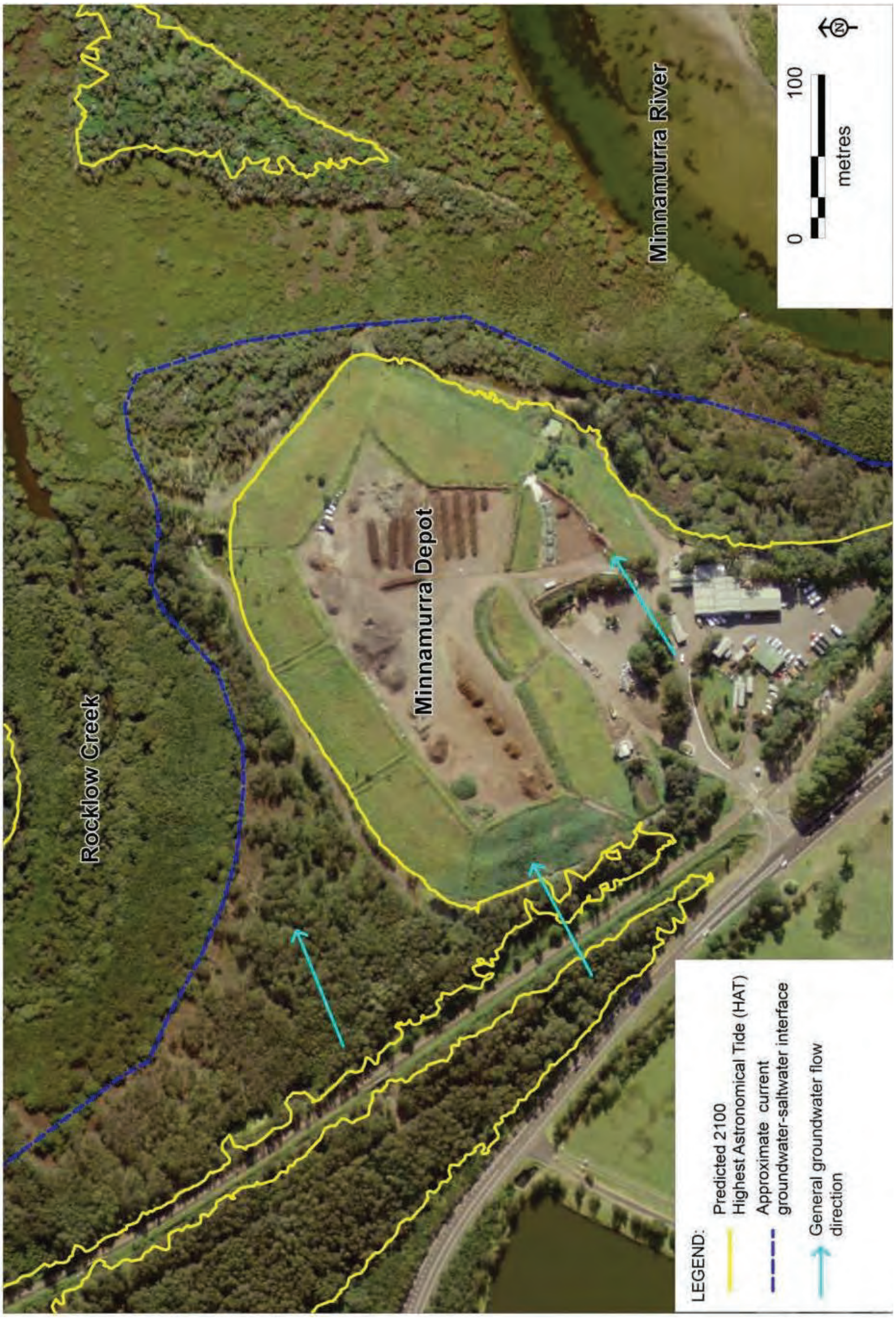


Figure 45: Predicted 2100 highest astronomical tide at Minnamurra Depot

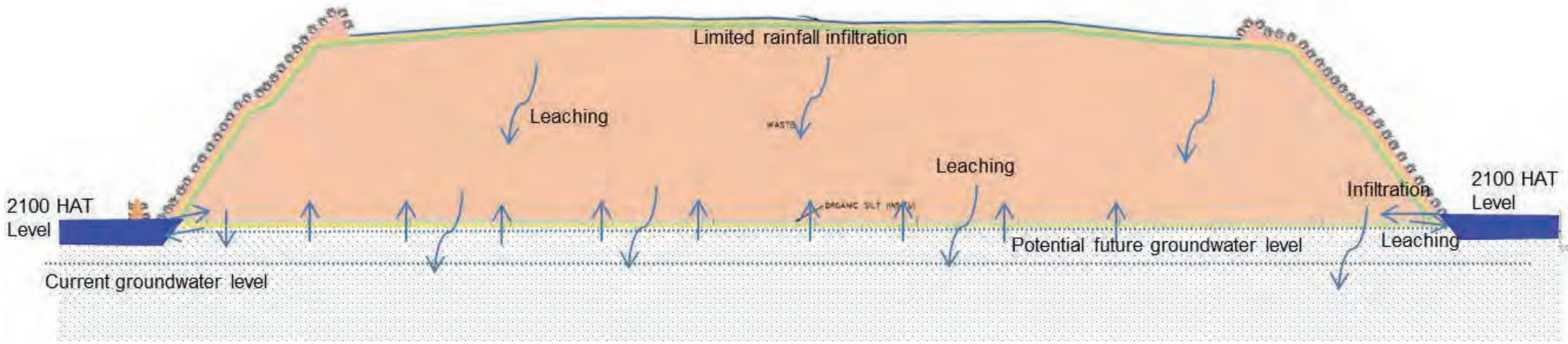


Figure 46: Potential effects of sea level rise on Minnamurra Depot landfill mound

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.

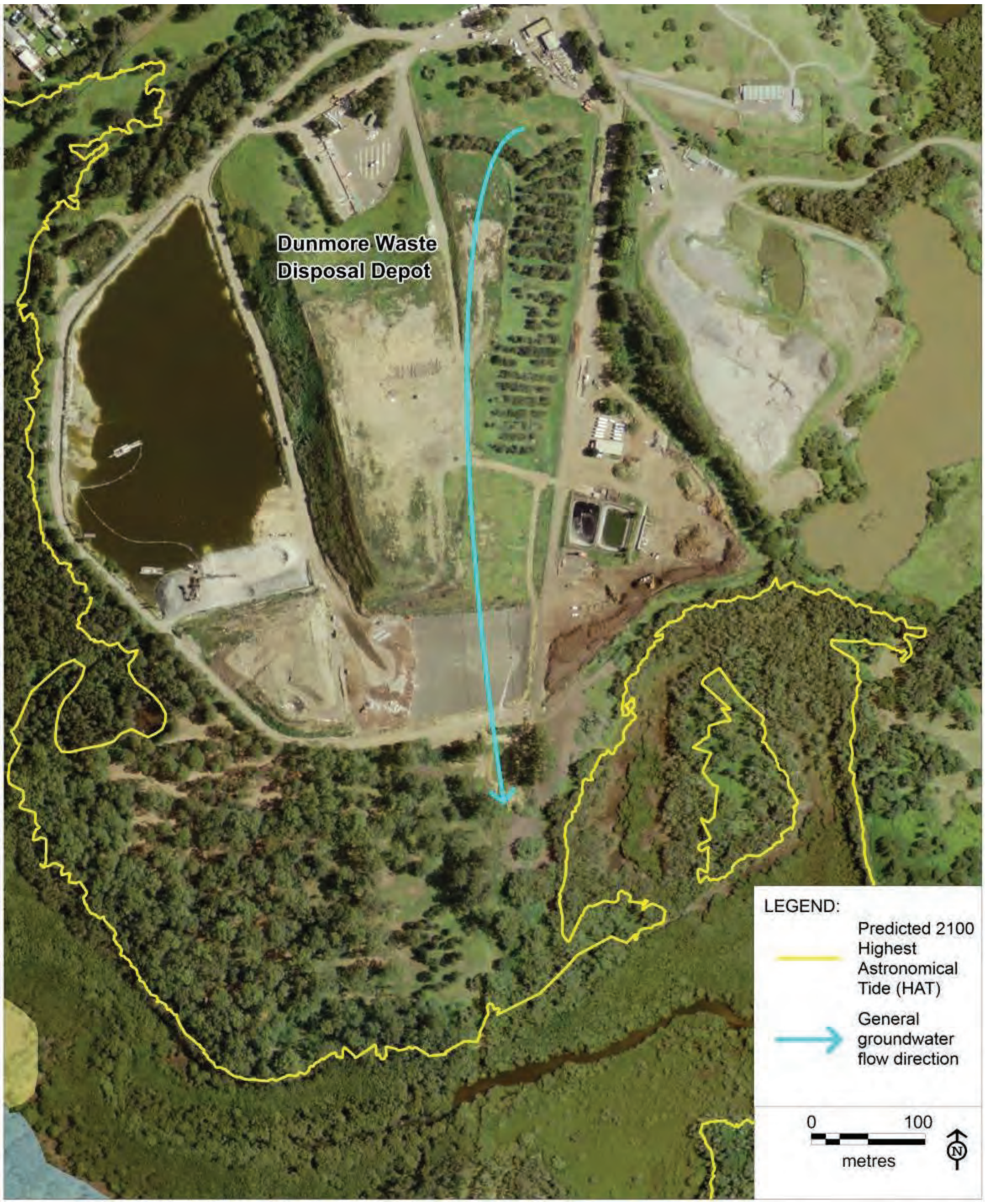


Figure 47: Predicted 2100 highest astronomical tide at Dunmore Depot

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).

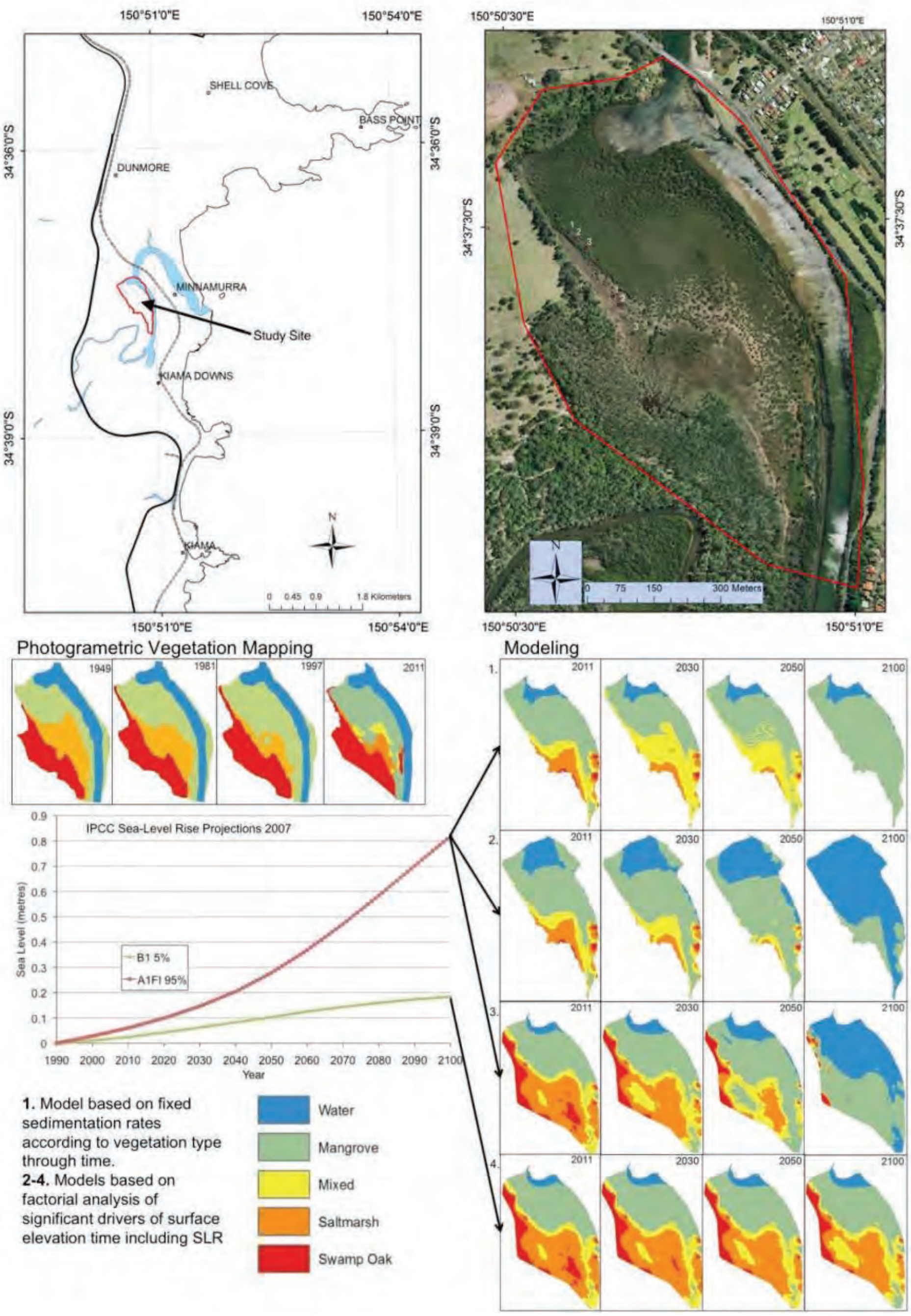


Figure 49: Top - Location of study site in the Minnamurra River Estuary (Source: Oliver et al., 2012) Bottom - Summary of changes to wetland vegetation at a monitored site in the Minnamurra River

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.

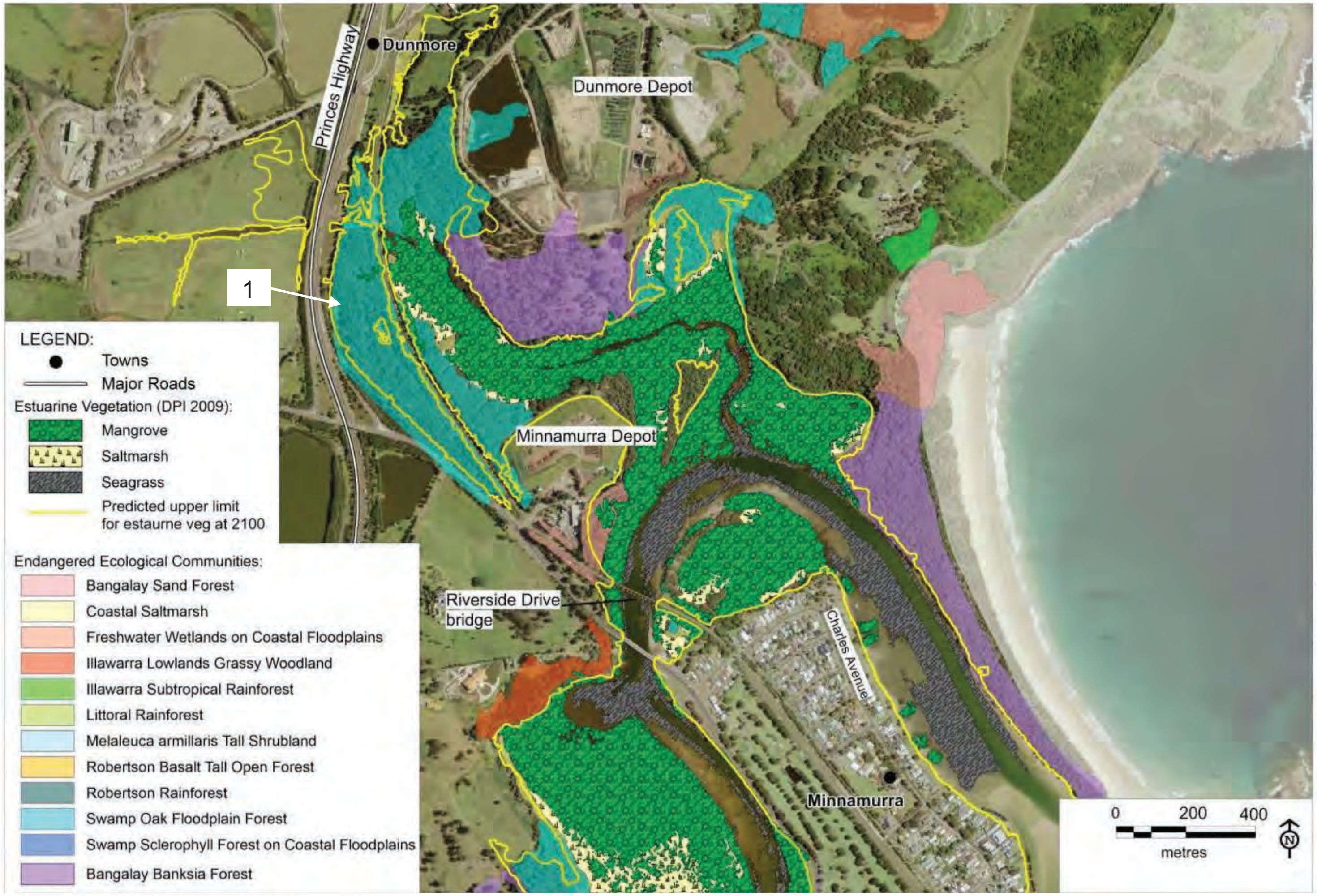


Figure 50: Potential areas for migration of estuarine vegetation types with sea level rise – lower estuary

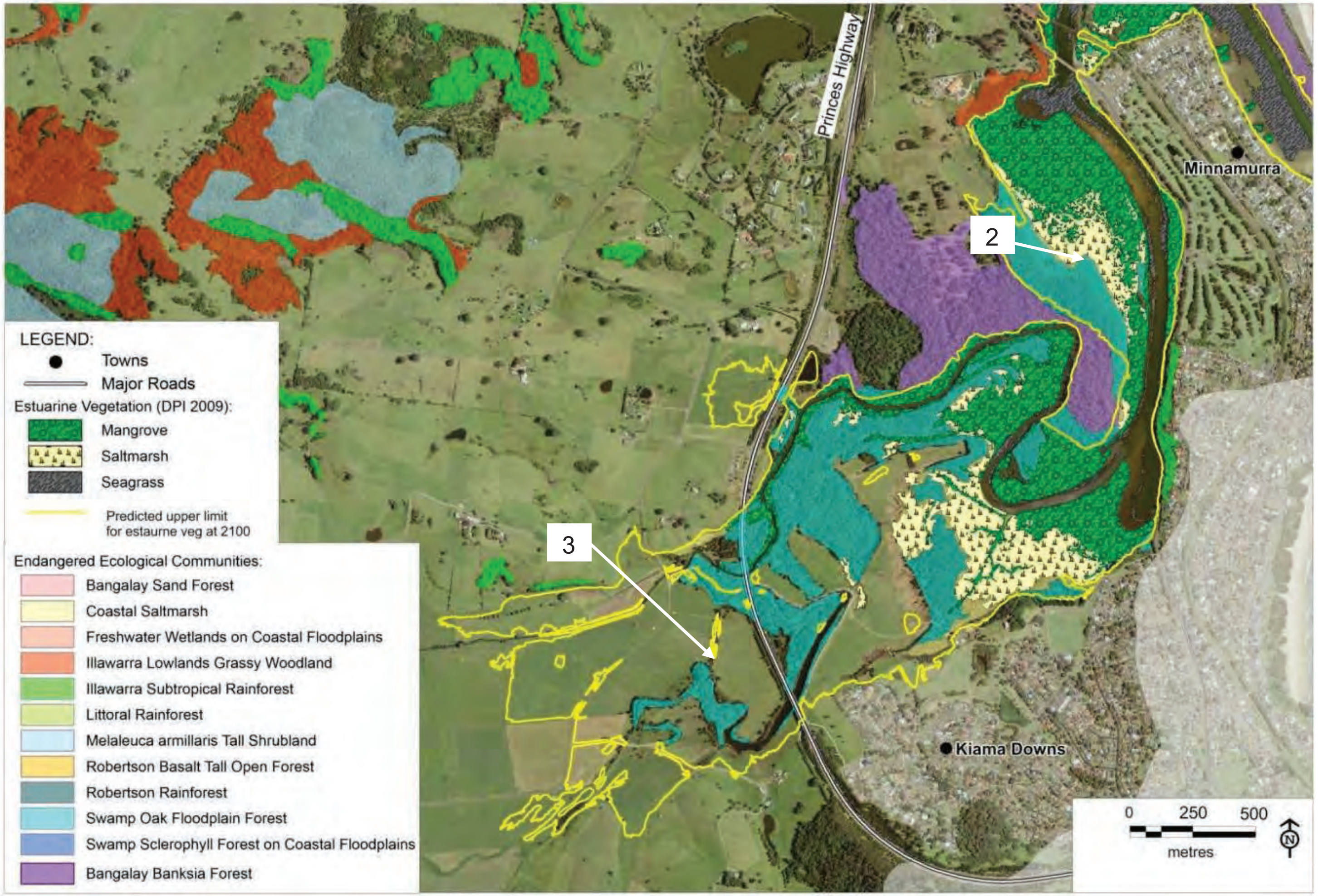


Figure 51: Potential areas for migration of estuarine vegetation types with sea level rise – mid and upper estuary

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.

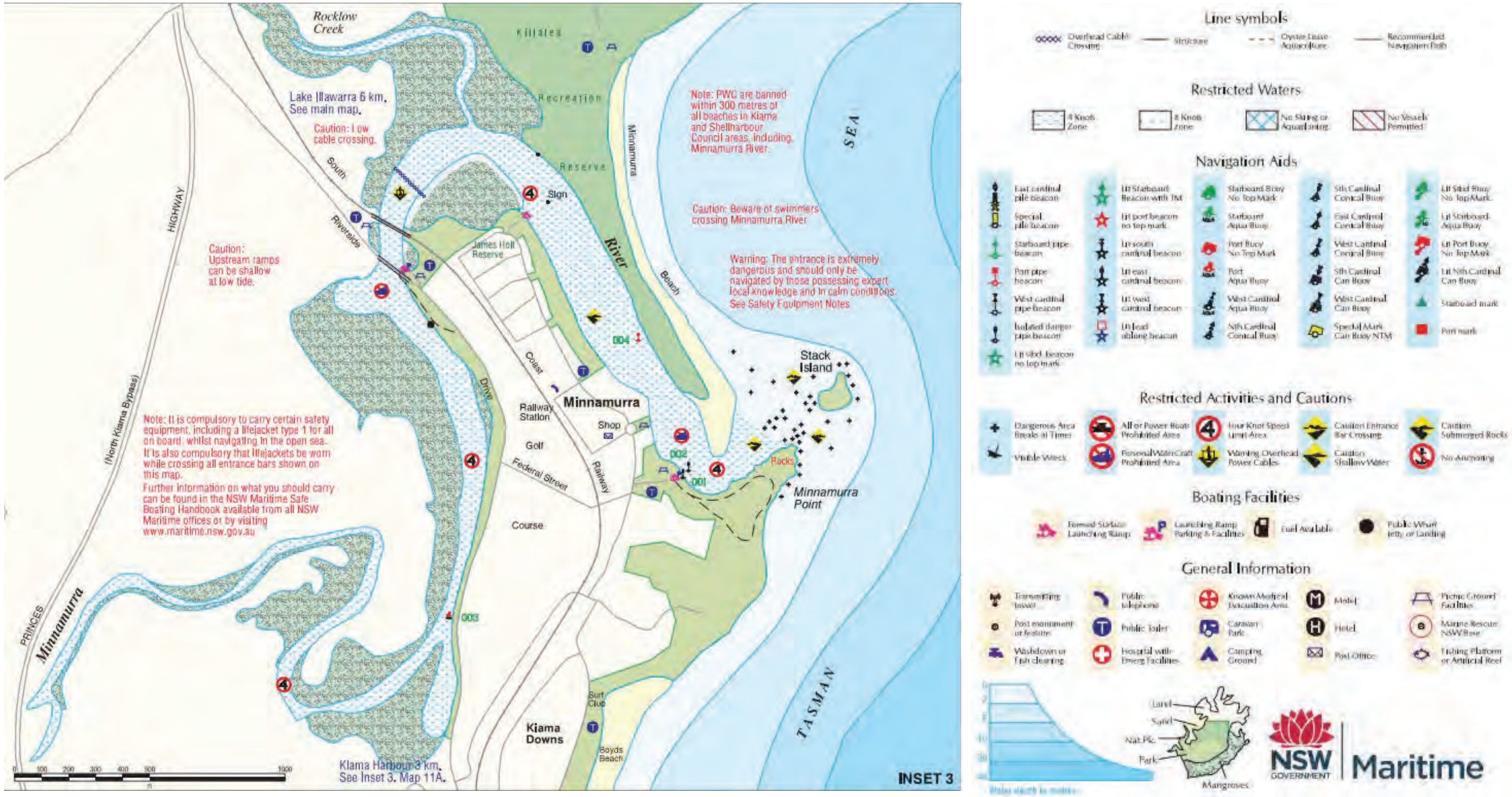


Figure 53: Minnamurra River Boating Map

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

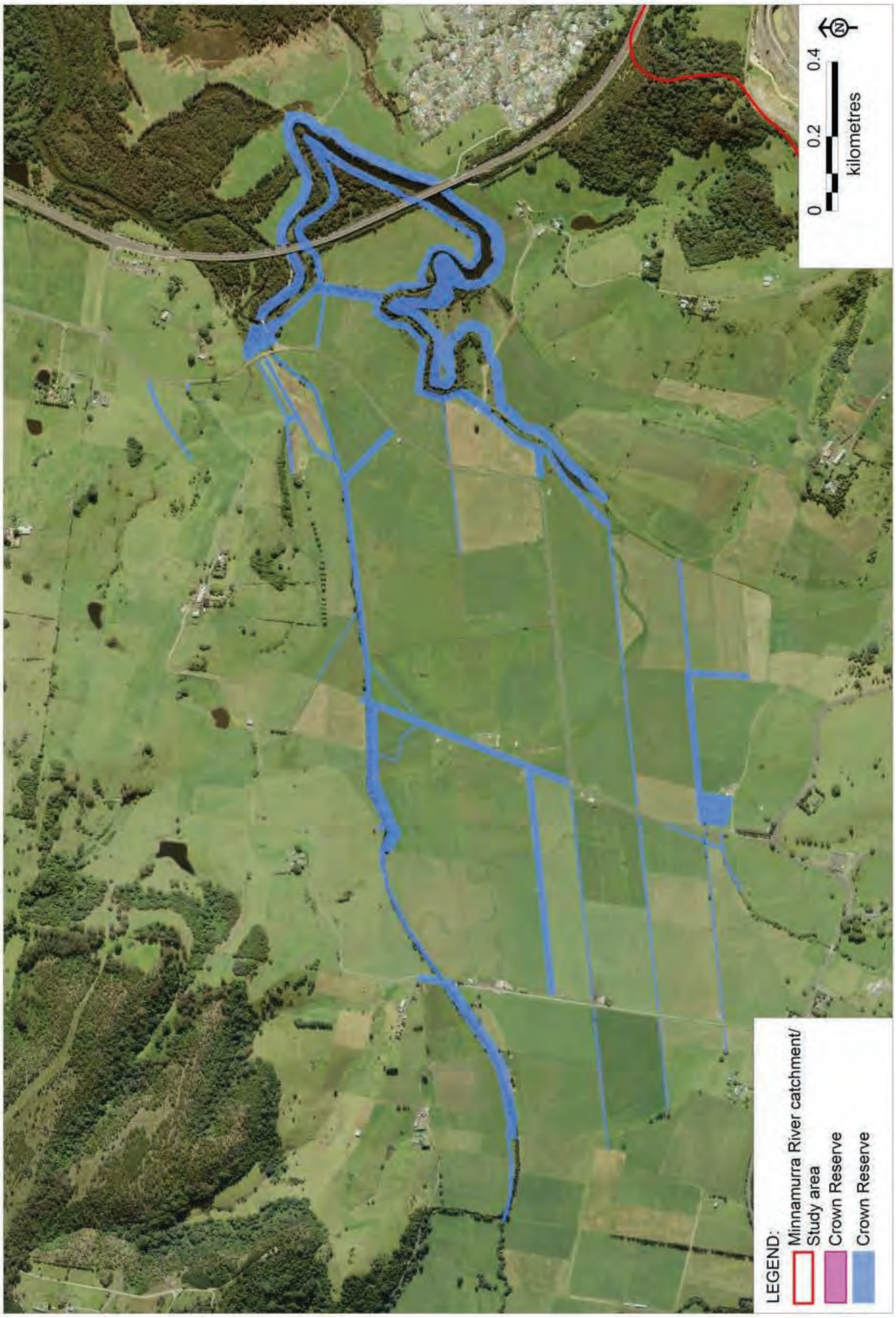


Figure 55: Terragong Swamp riverfront land tenure

Hydrosphere Consulting

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

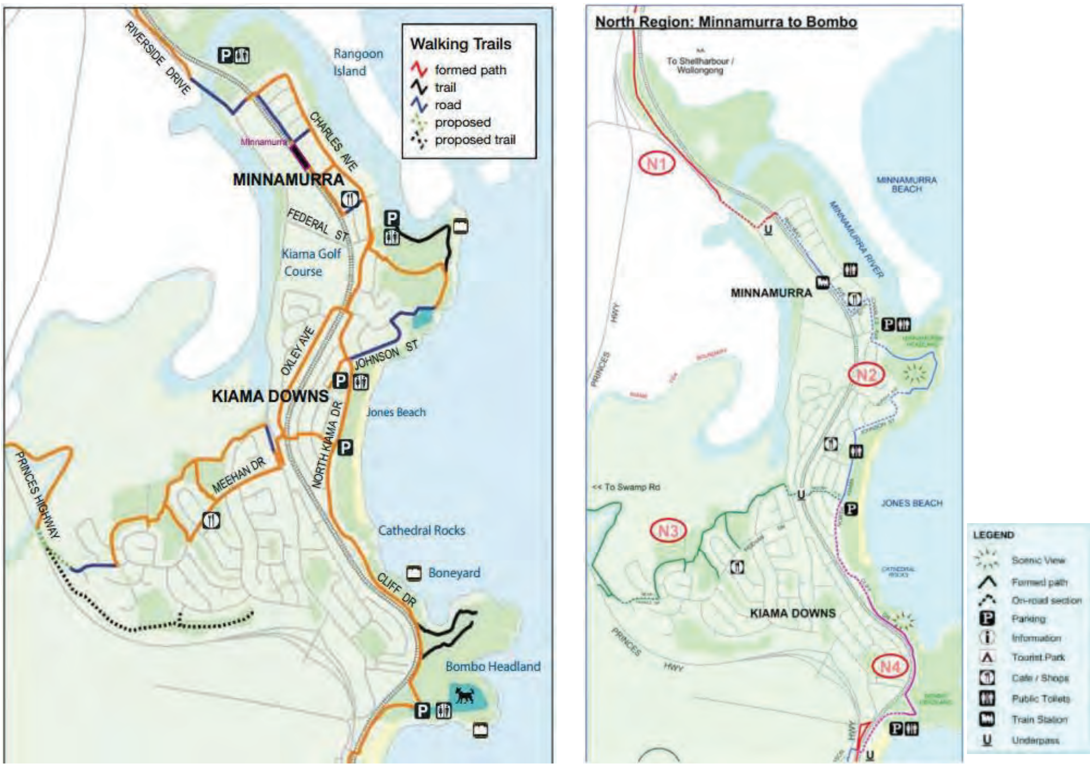


Figure 56: A: Walkways and B: Cycle Paths

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.

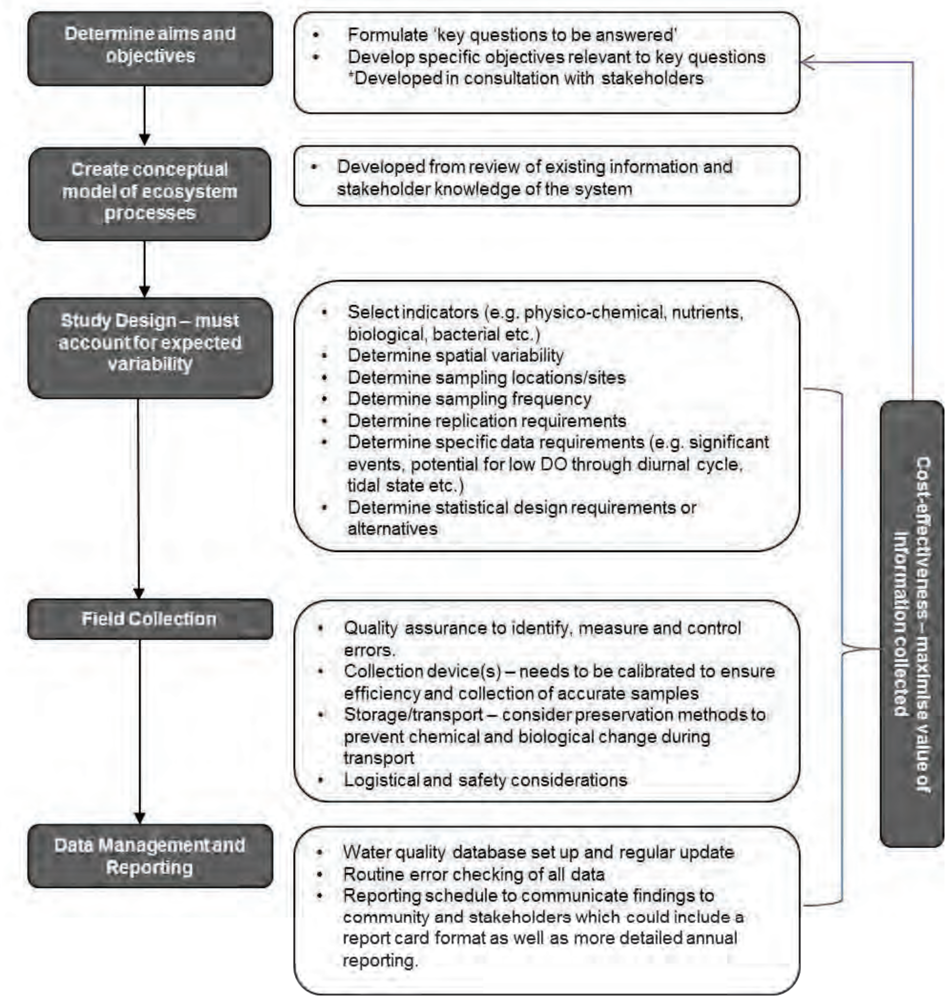


Figure 58: Framework for sampling program design

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:
    - o 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.

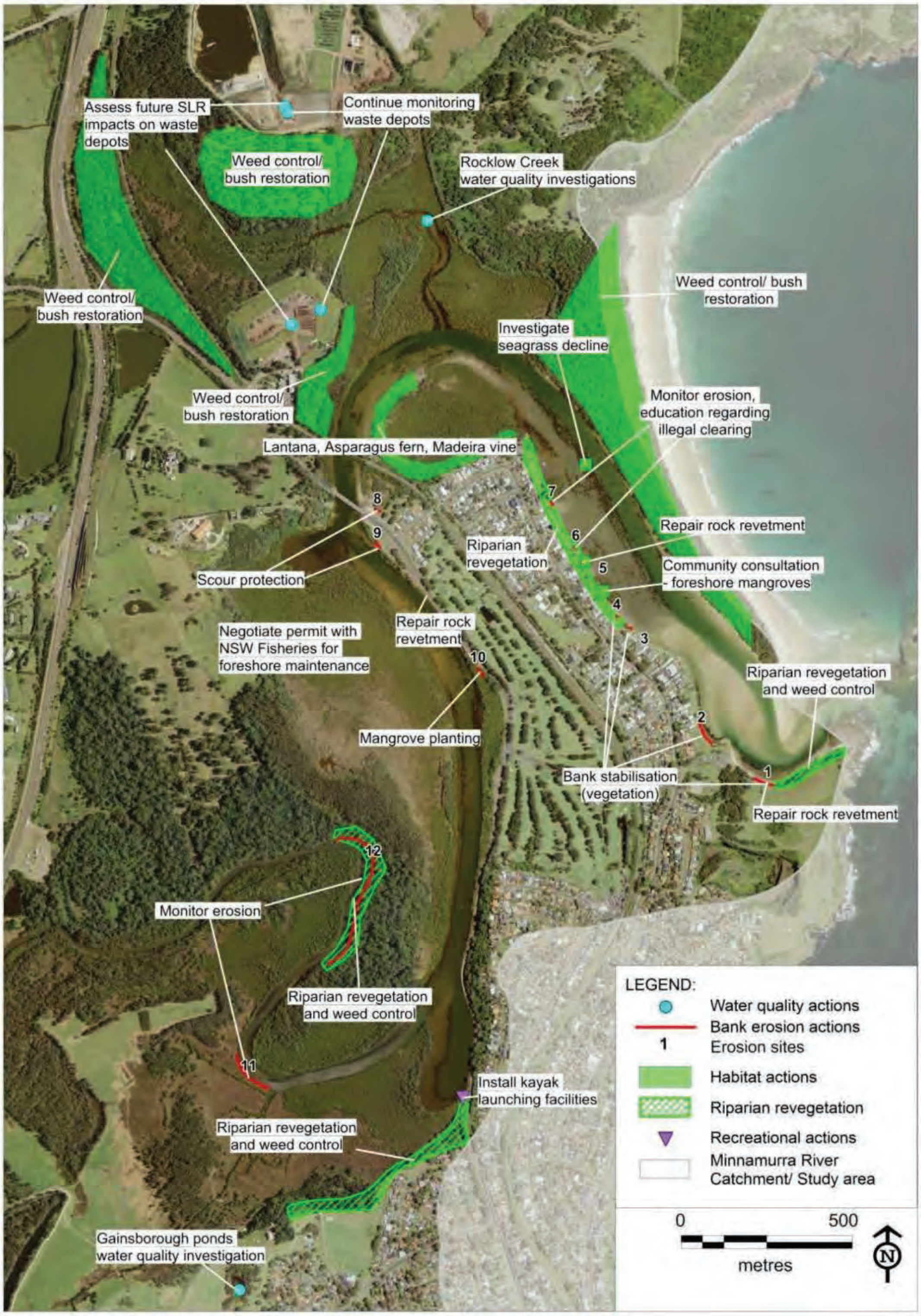


Figure 61: CZMP Management Actions – Lower-Mid Estuary

Note – Site 5 rock revetment has been repaired

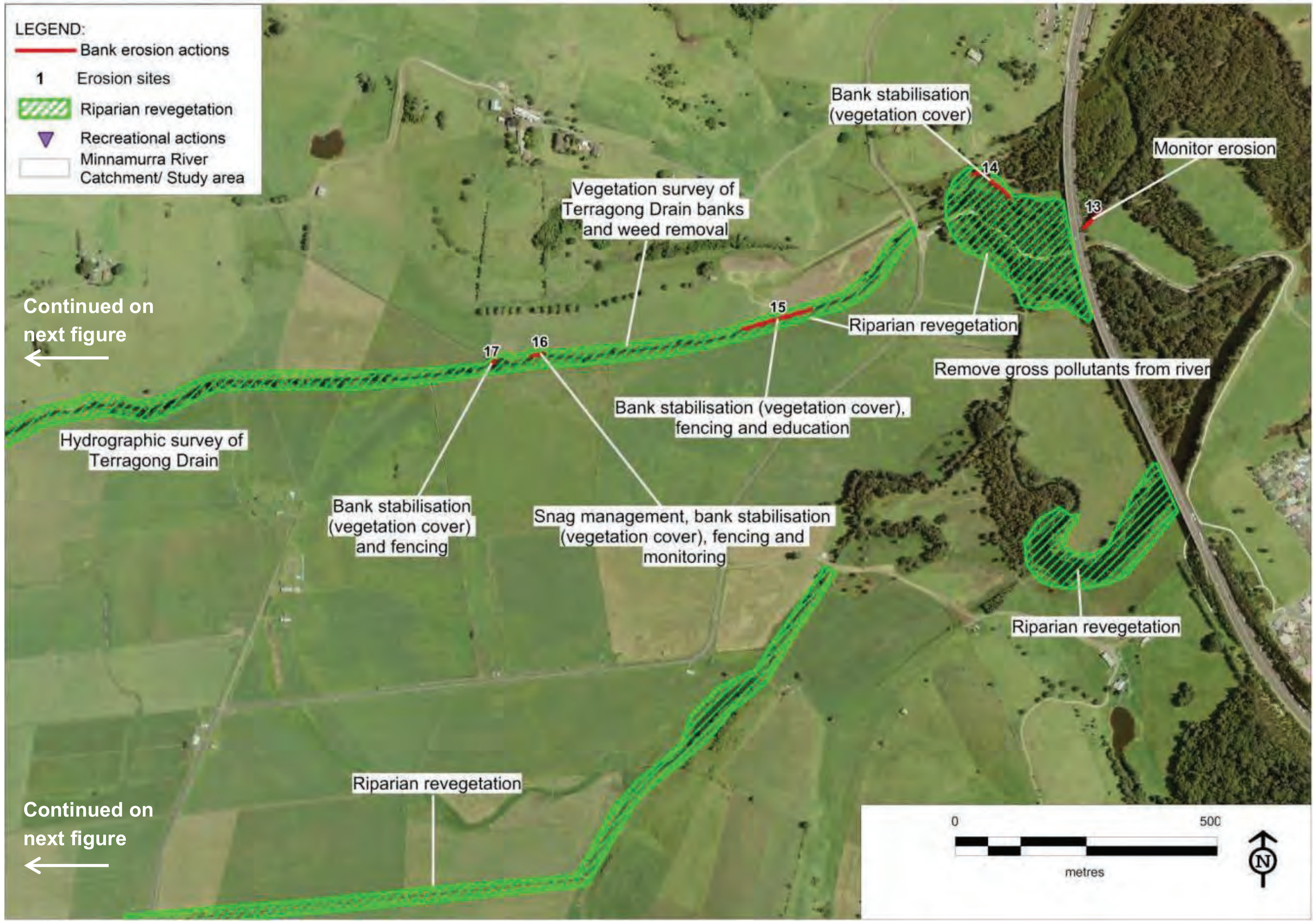


Figure 62: CZMP Management Actions – Upper Estuary and Terragong Swamp

Hydrosphere Consulting

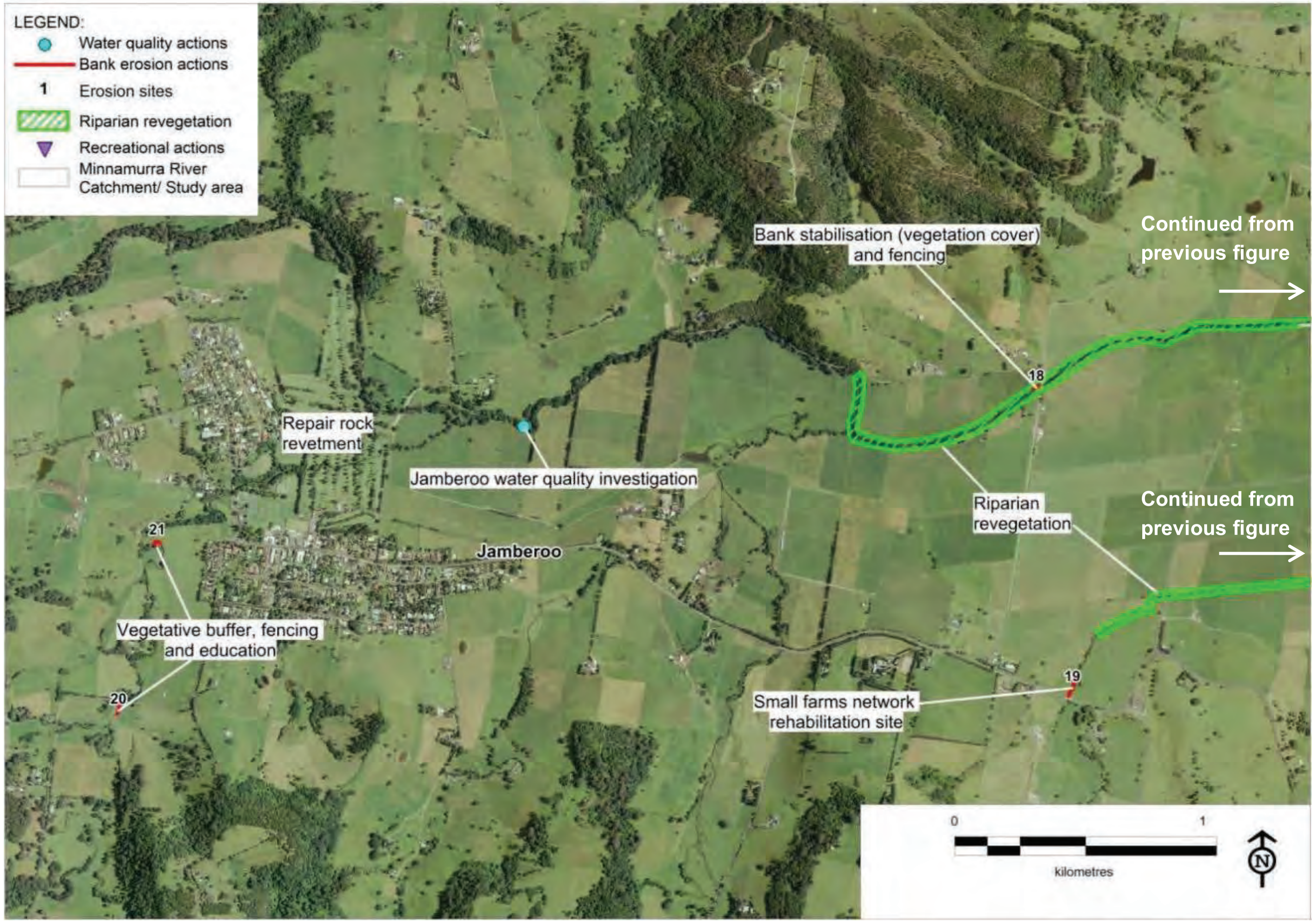


Figure 63: CZMP Management Actions – Jamberoo

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.

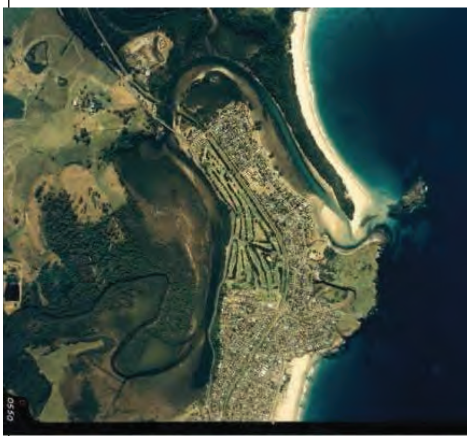
Action (numbering generated for this document)		Responsible Body (2003 EMP Review)	Priority (2003 EMP Review)	Outcome of Action	Comments
Recreation					
46	Implement proposal for fishing jetty and connection under Princes Highway bridge.	KMC	High	Fishing jetty / shared pathway connection under bridge 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.

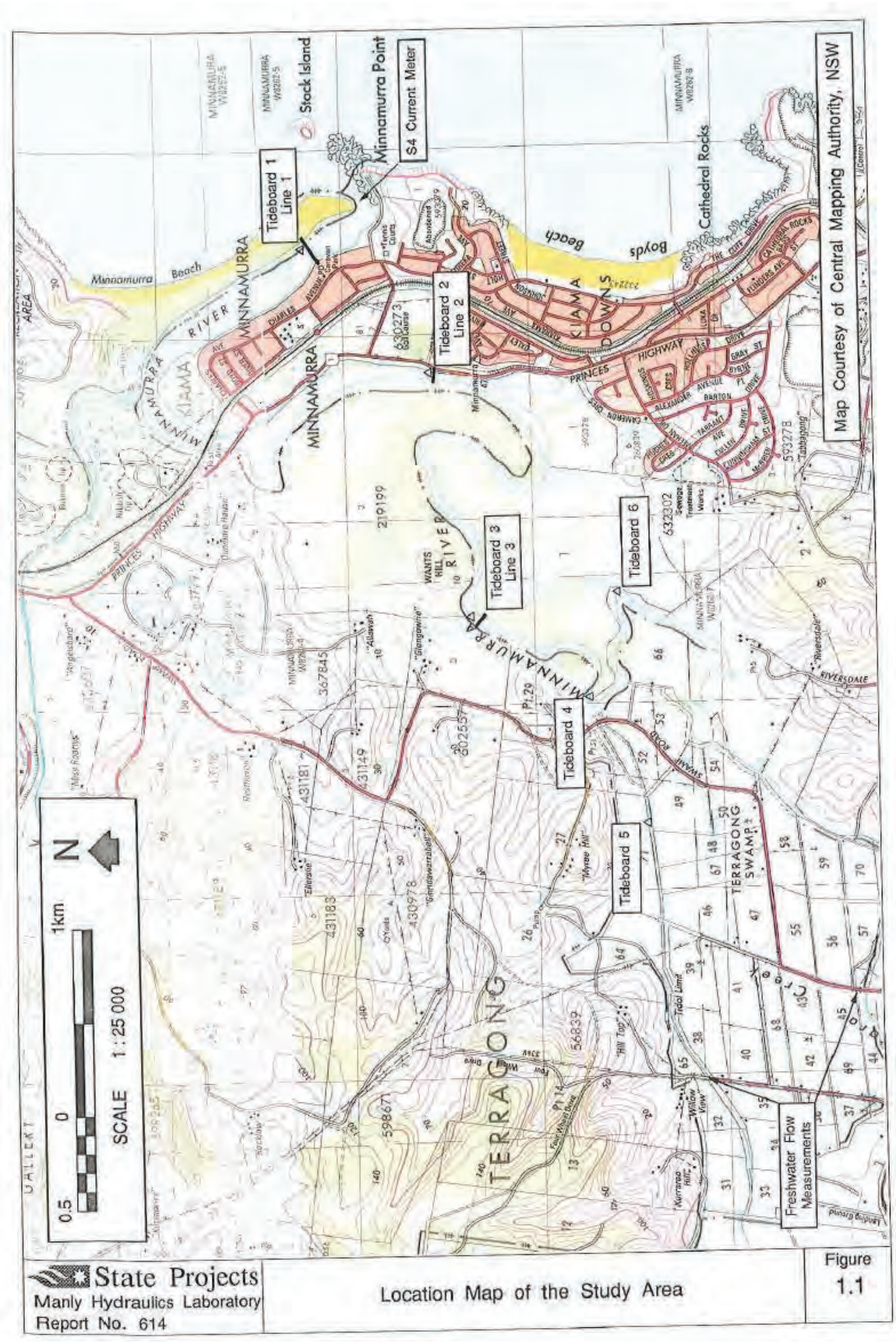
Table 23: Comparison of aerial photography of the Minnamurra River entrance

	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)



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Manly Hydraulics Laboratory
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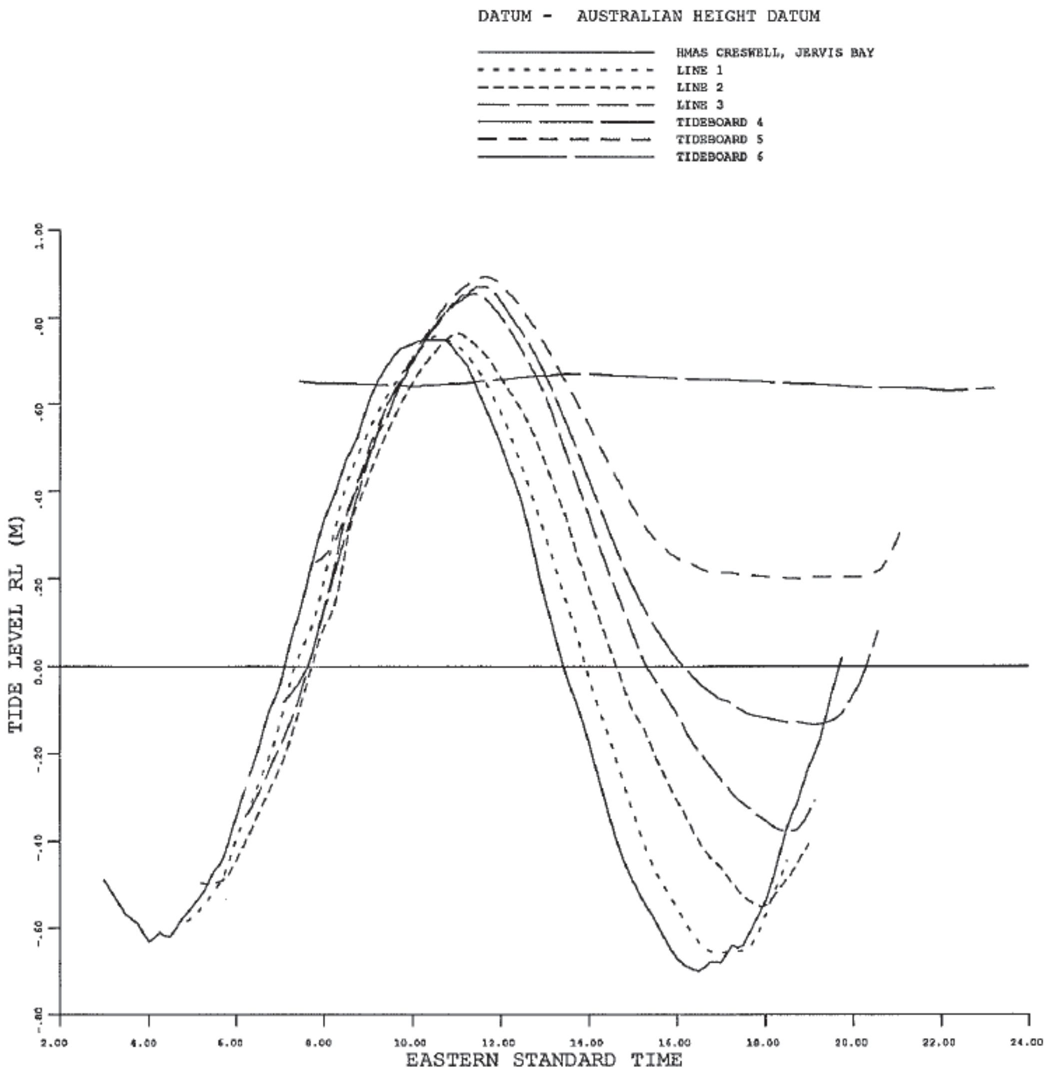
Location Map of the Study Area

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.

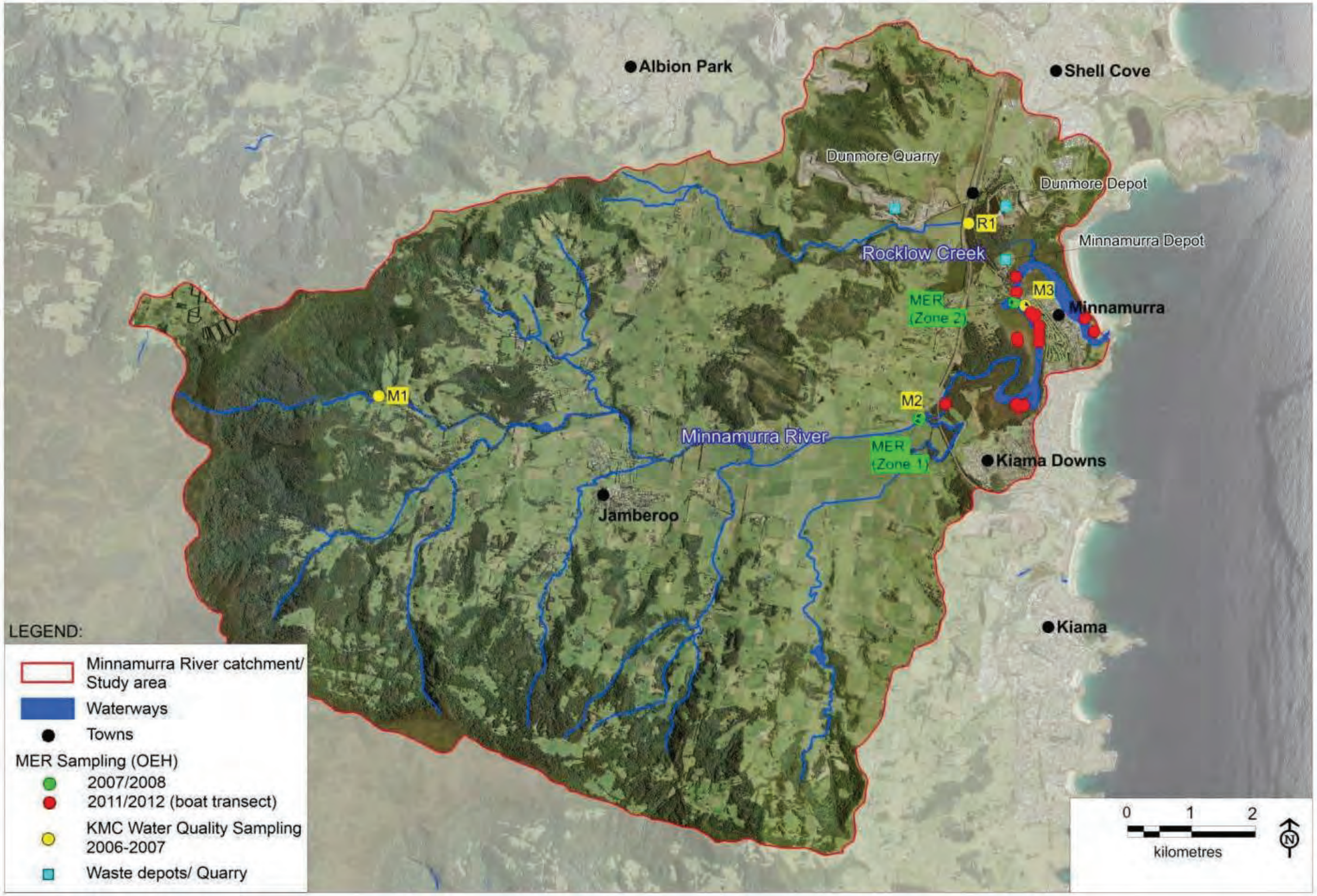


Figure 64: Recent water quality sampling sites within the Minnamurra River Catchment

Hydrosphere Consulting

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.

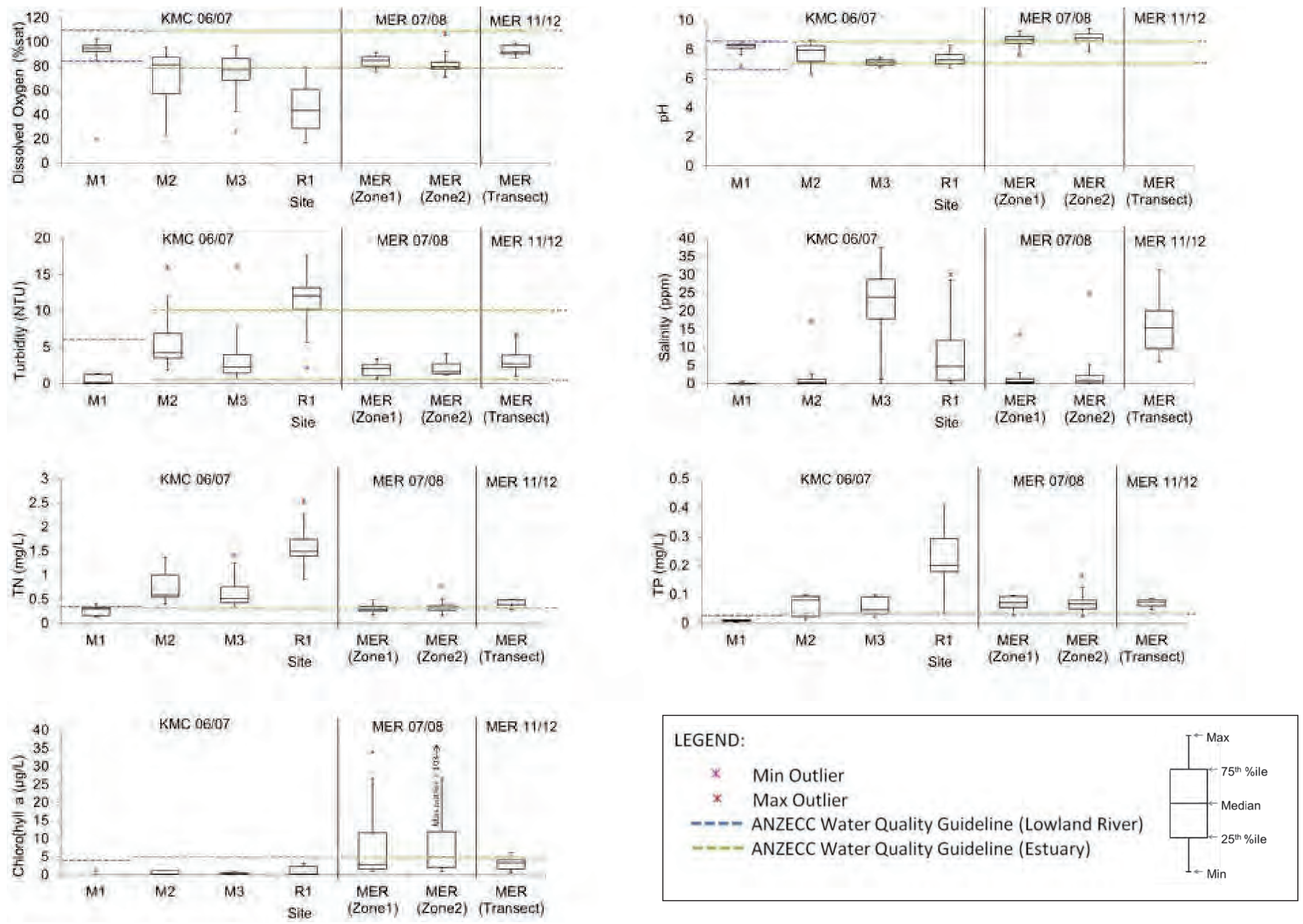


Figure 65: Water quality results for the Minnamurra River Catchment from 2006/07 (KMC), 2007/08 (OEH) and 2011/12 (OEH)

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		LIKELIHOOD (observed erosion): 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

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

Hydrosphere Consulting

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: o structural works, such as levees, detention basins, flood gates and improved flow conveyance o flood warning systems o evacuation management o 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.