KIAMA MUNICIPAL COUNCIL

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

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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.

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.

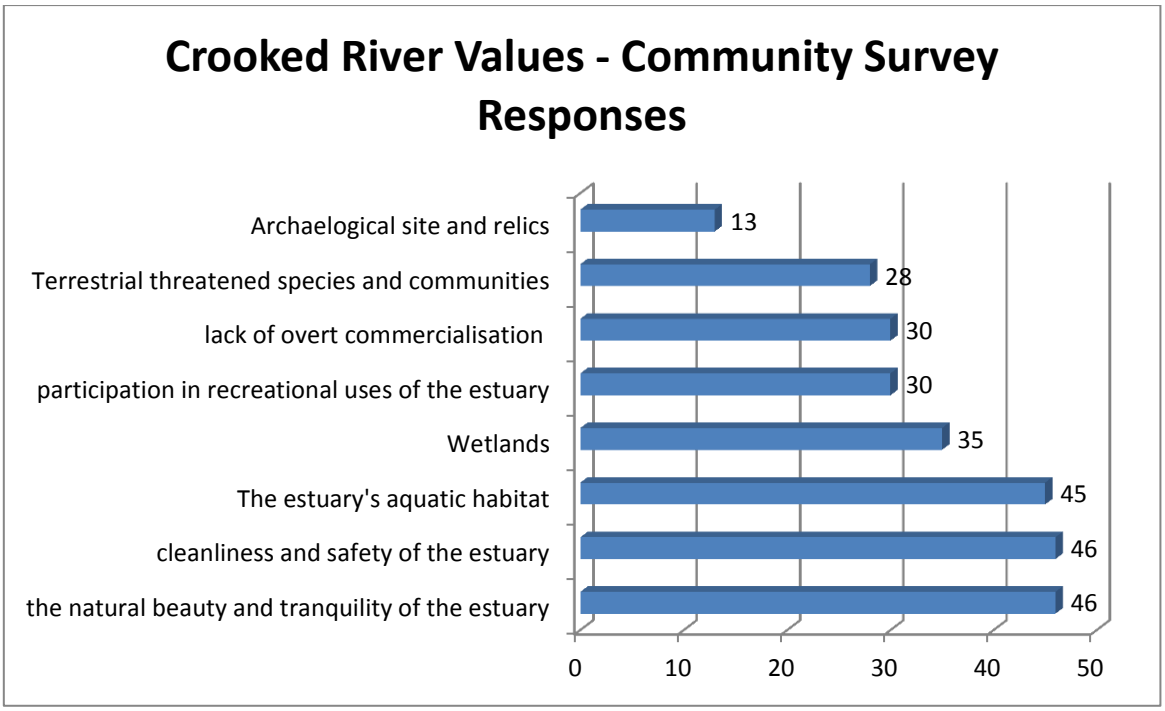
Union Creek riparian works in Elambra Estate

3. CONSULTATION ACTIVITIES FOR THE CROOKED RIVER COASTAL ZONE MANAGEMENT PLAN

3.1 COMMUNITY SURVEY

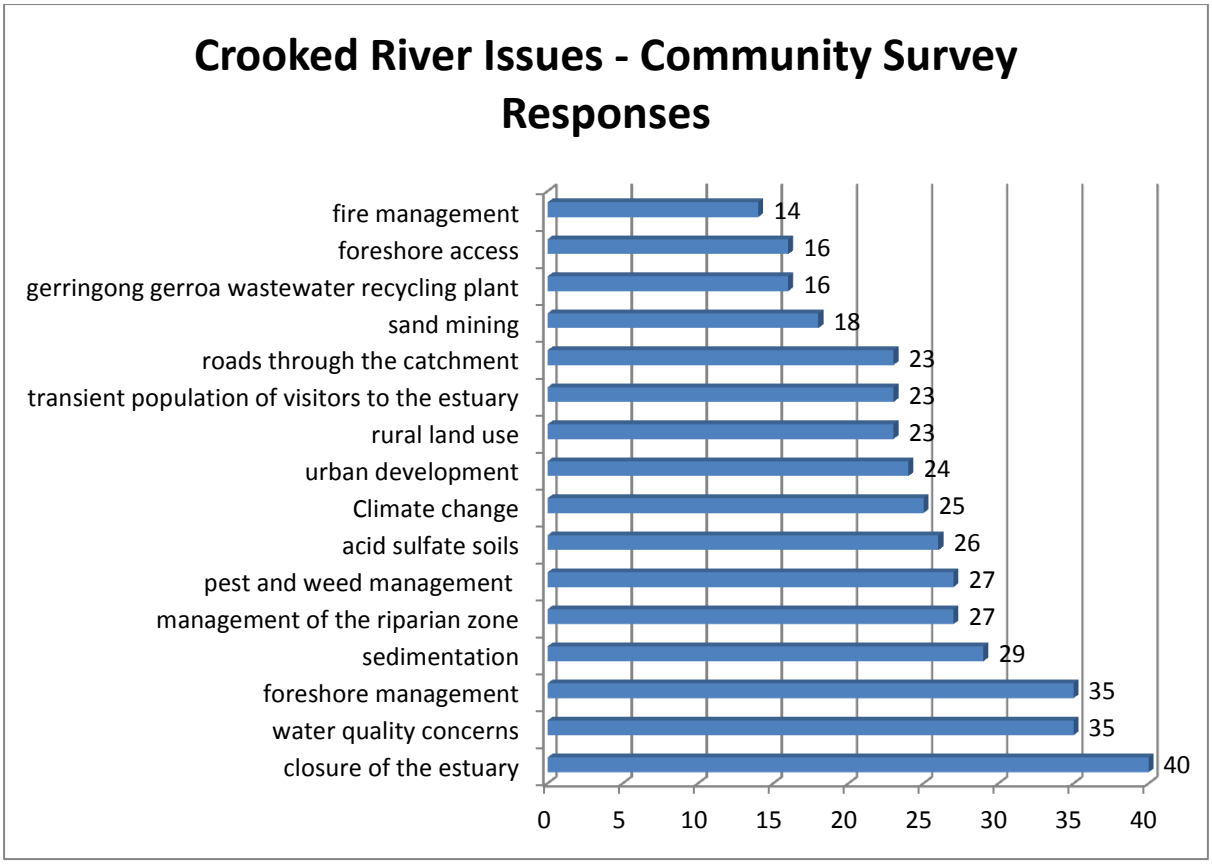
A survey relating to the review of the Crooked River Estuary Management Plan 2003 was distributed to the catchment area via letter box drop, and made available on-line for completion on Council's website. Fifty three survey responses were received from community members during the response period.

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

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.

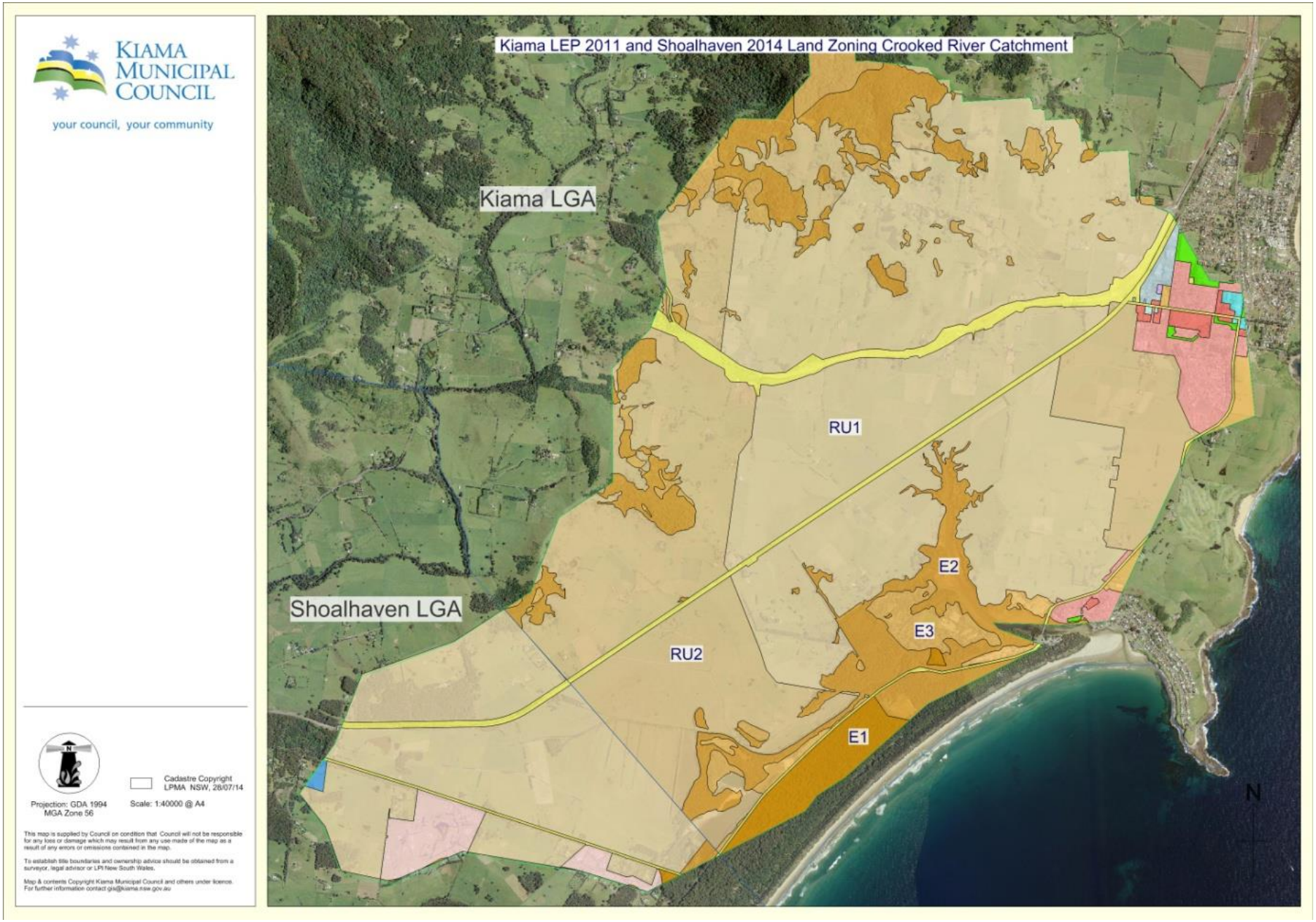


Figure 2: Land Use Zoning in Crooked River catchment

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

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.

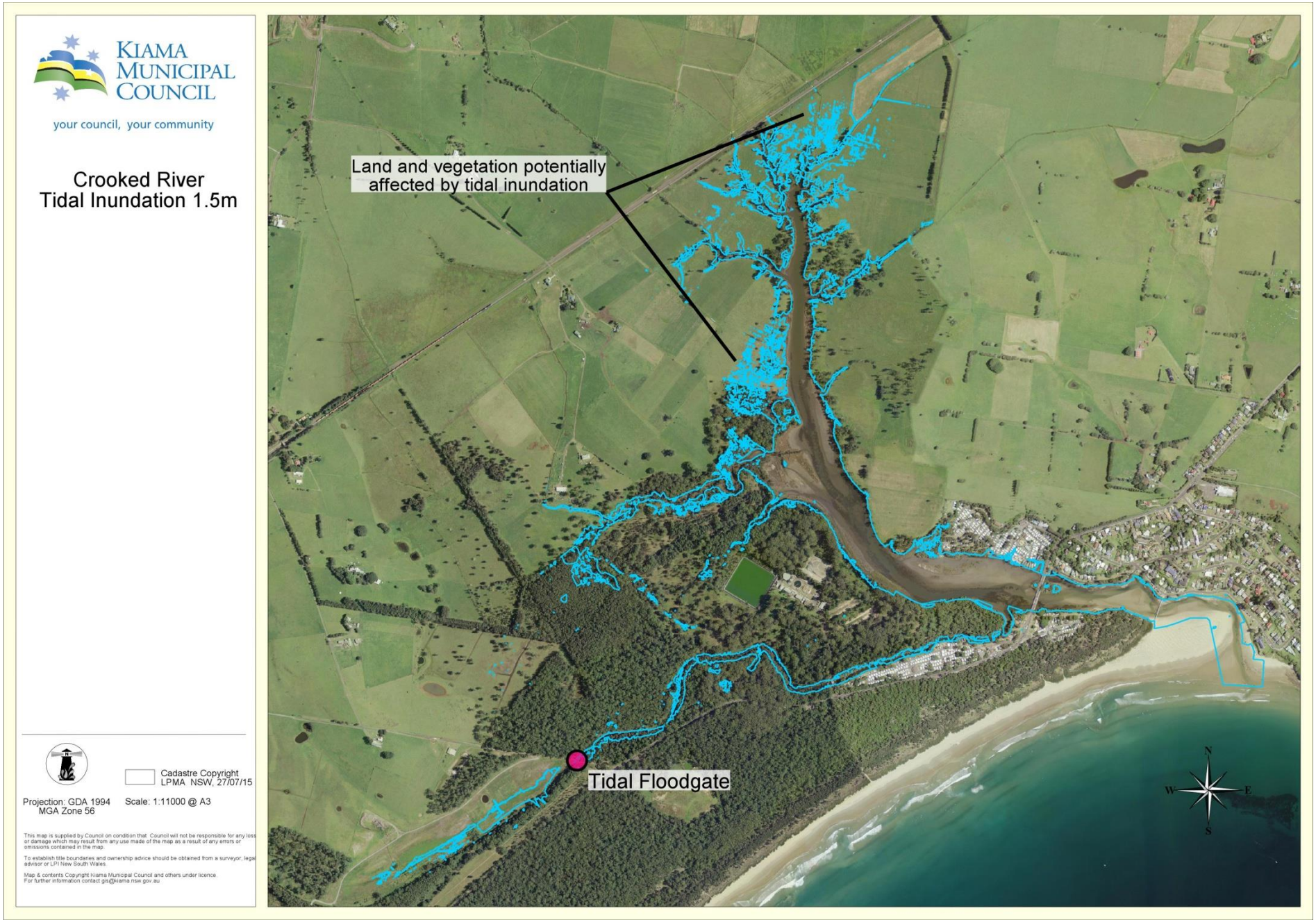


Figure 3 (a): Crooked River tidal inundation mapping 1.5m

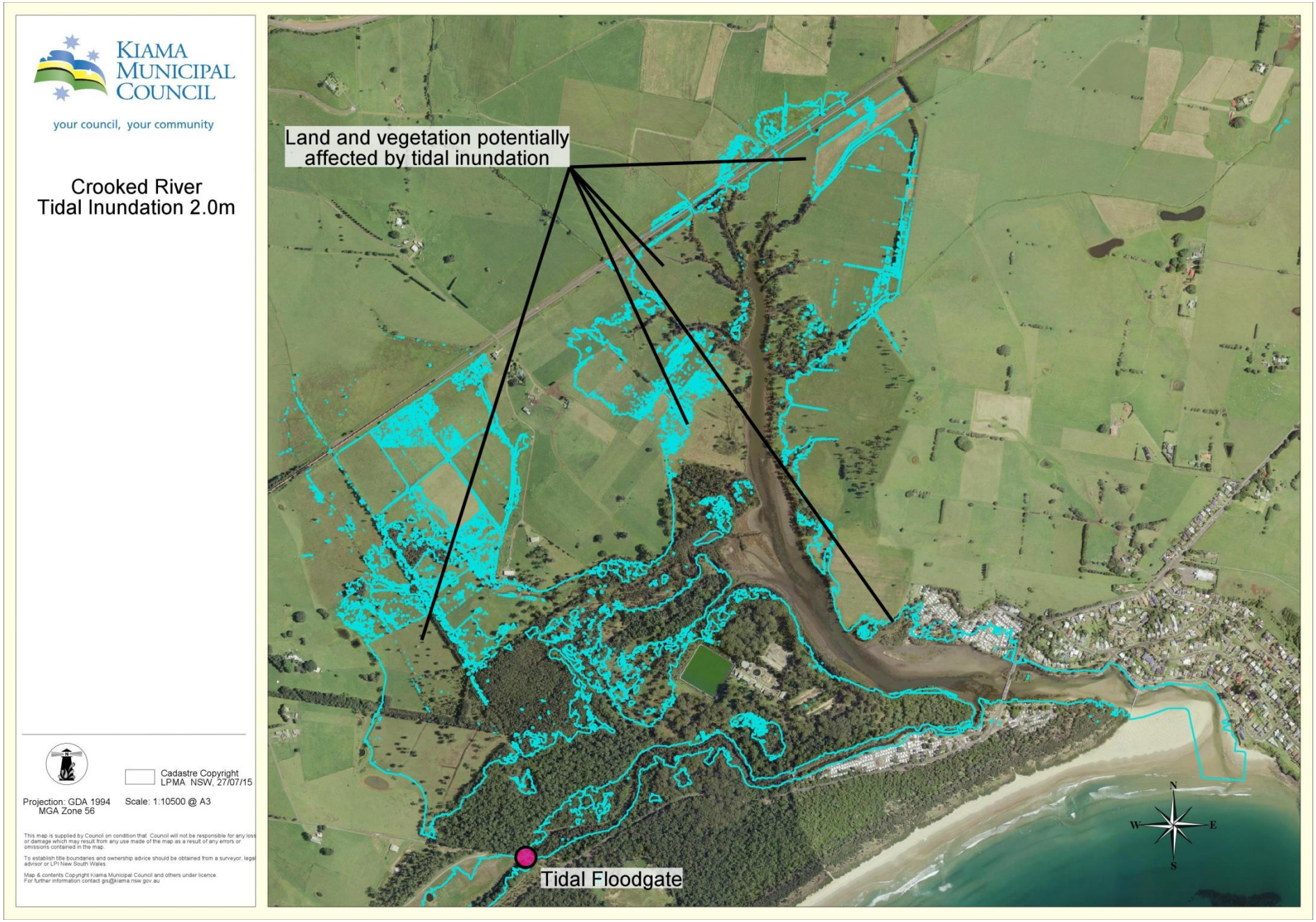


Figure 3 (b): Crooked River tidal inundation mapping 2.0m Map 1

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

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.

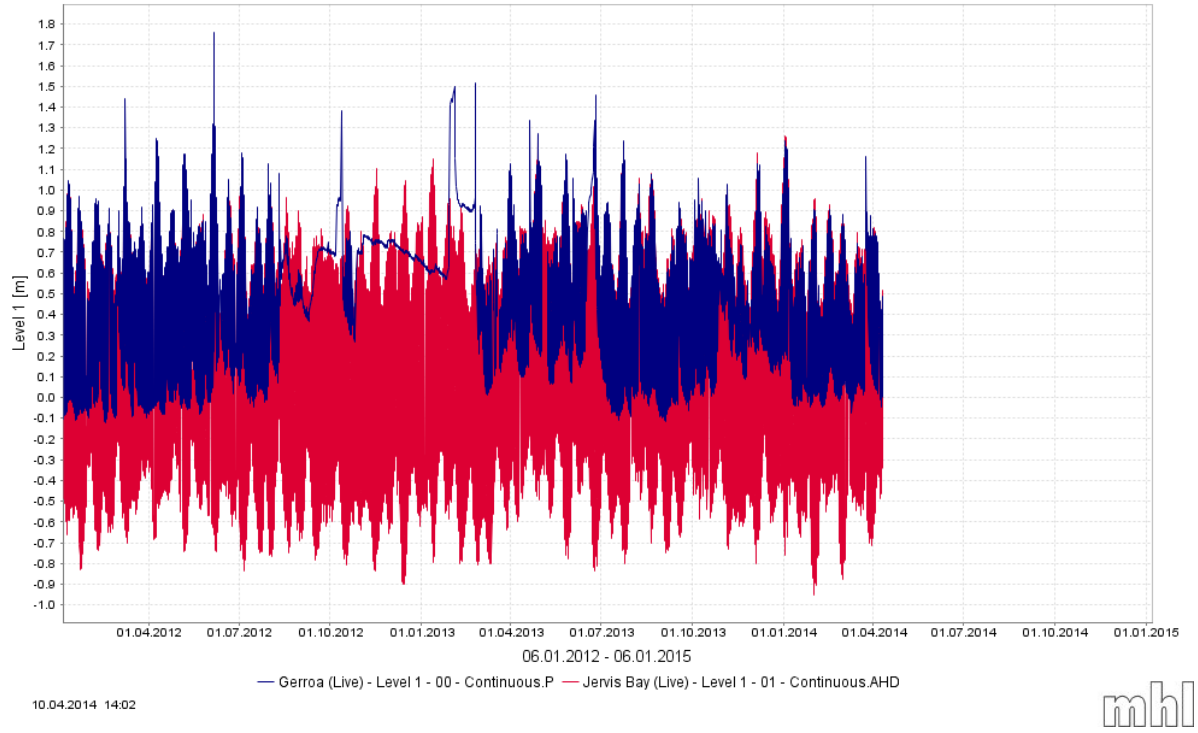
The flood study undertaken as part of the development of the Gerroa WRP found that flooding in the Crooked River is generally predicted to be contained within the wide downstream sections of the creek, but spills out across the flat flood plain when it runs north west along the eastern side of the railway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



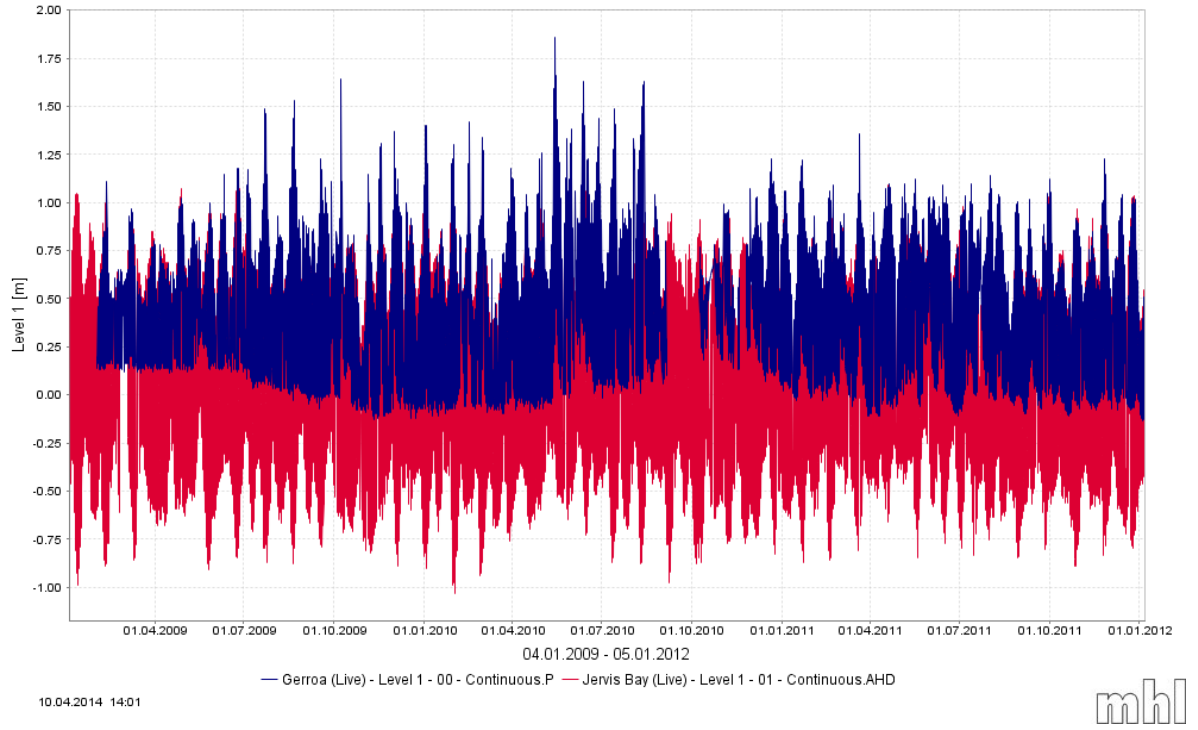


Figure 5: Crooked River water level gauge data overlaying HMAS Creswell ocean tidal gauge data

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.

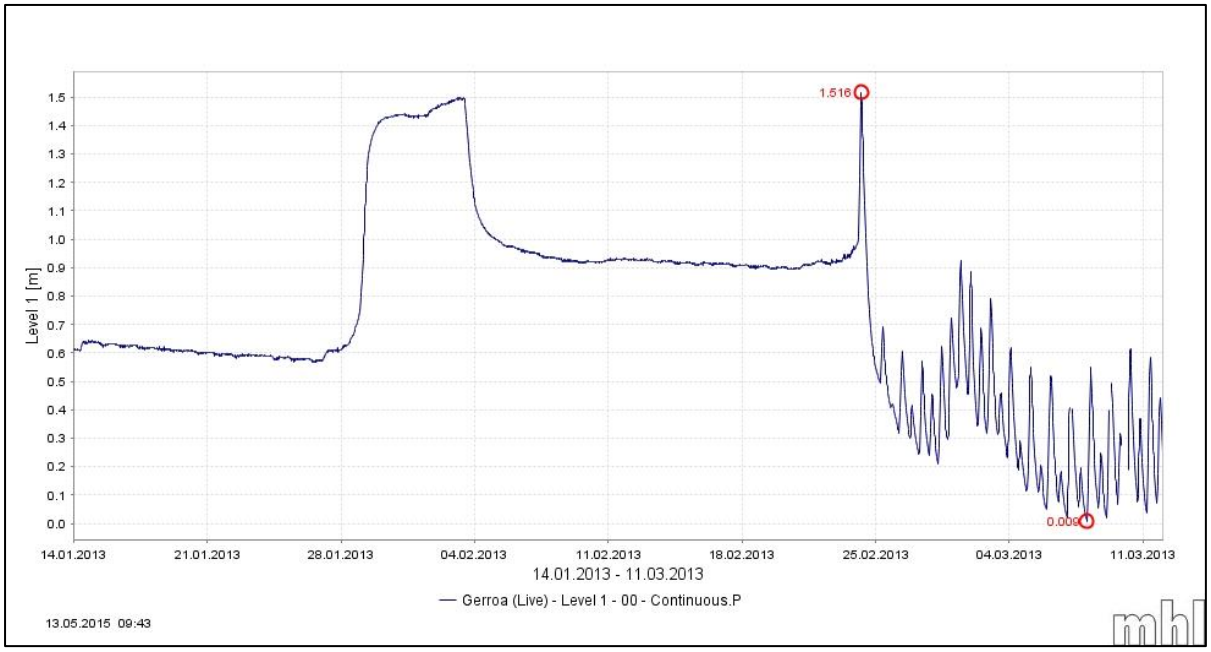


Figure 6: Crooked River artificial opening event February 2013

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.

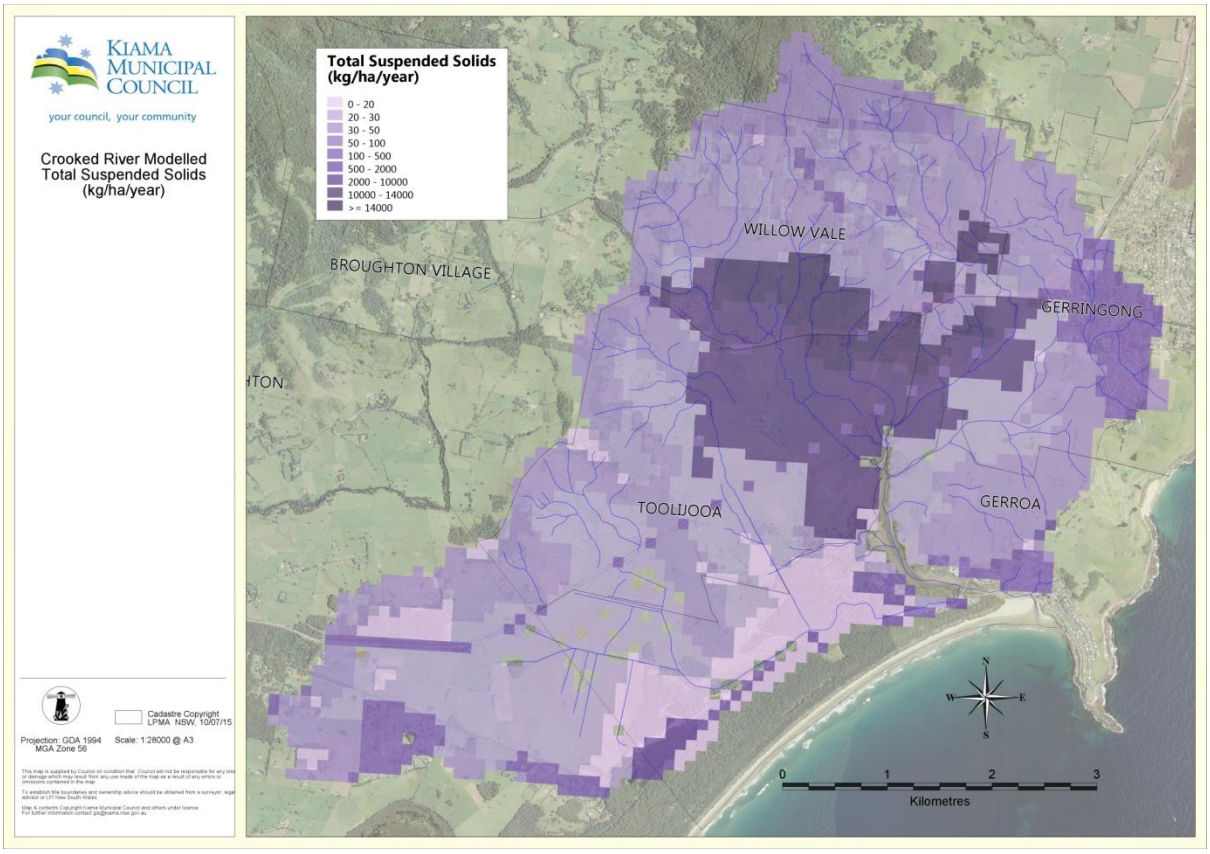


Figure 7 (a): Modelled export of Total Suspended Solids

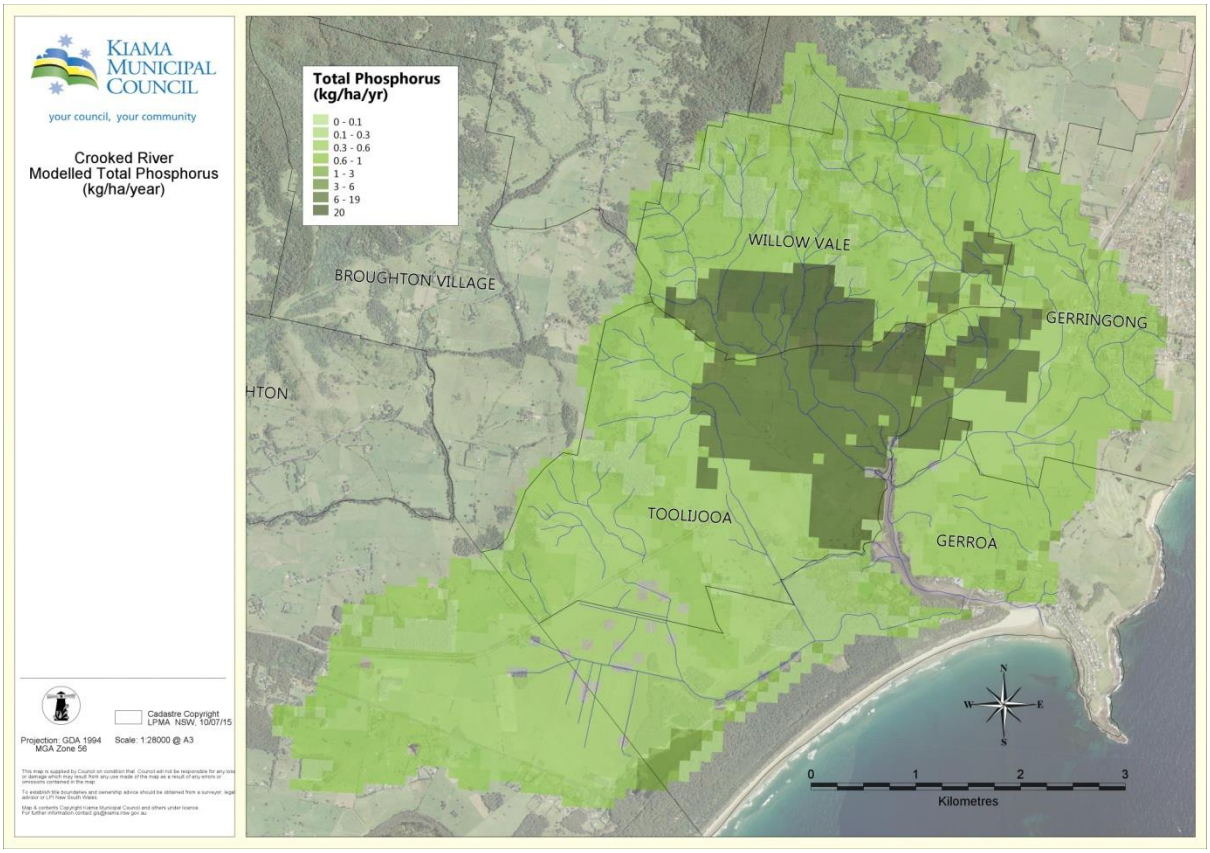


Figure 7 (b): Modelled export of Total Phosphorus

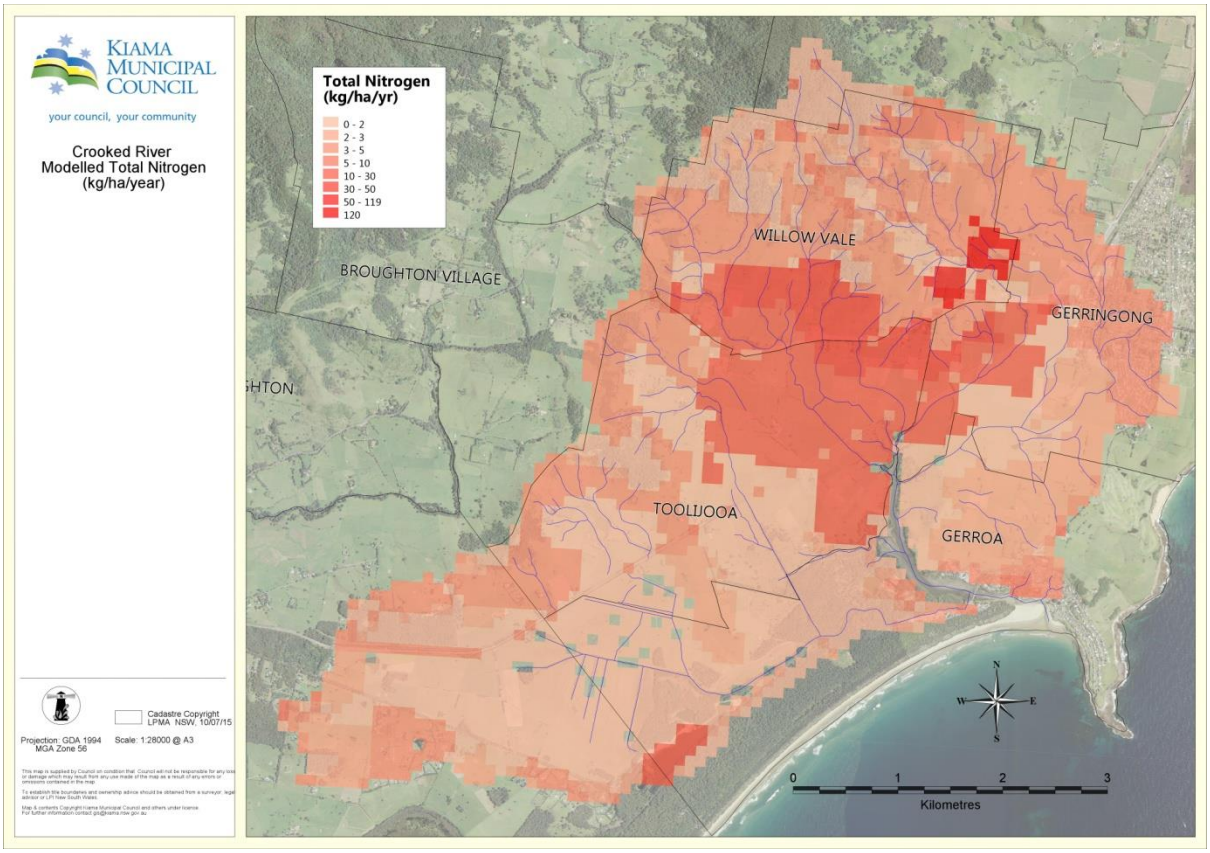


Figure 7 (c): Modelled Export of Total Nitrogen

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 '*Action 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.

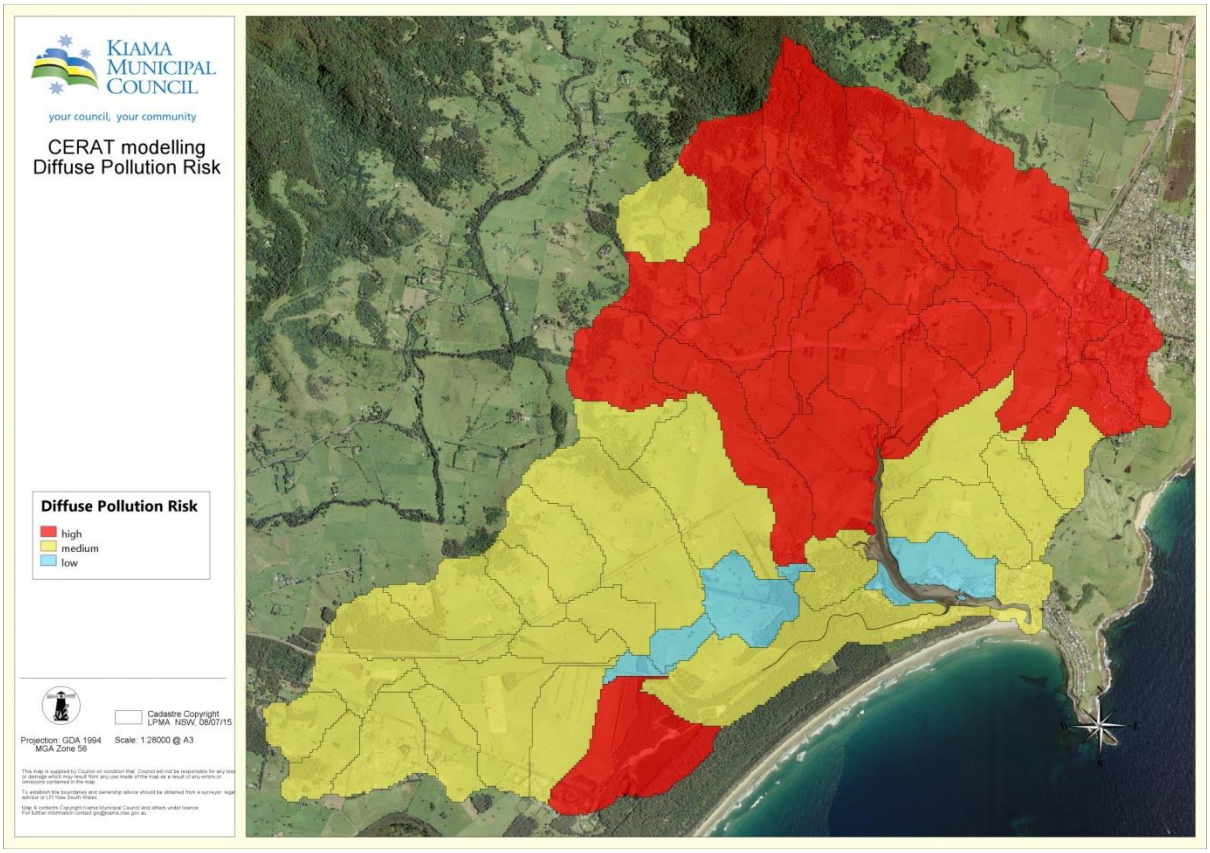


Figure 7 (d): Modelled diffuse pollution risk for Crooked River catchment

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.

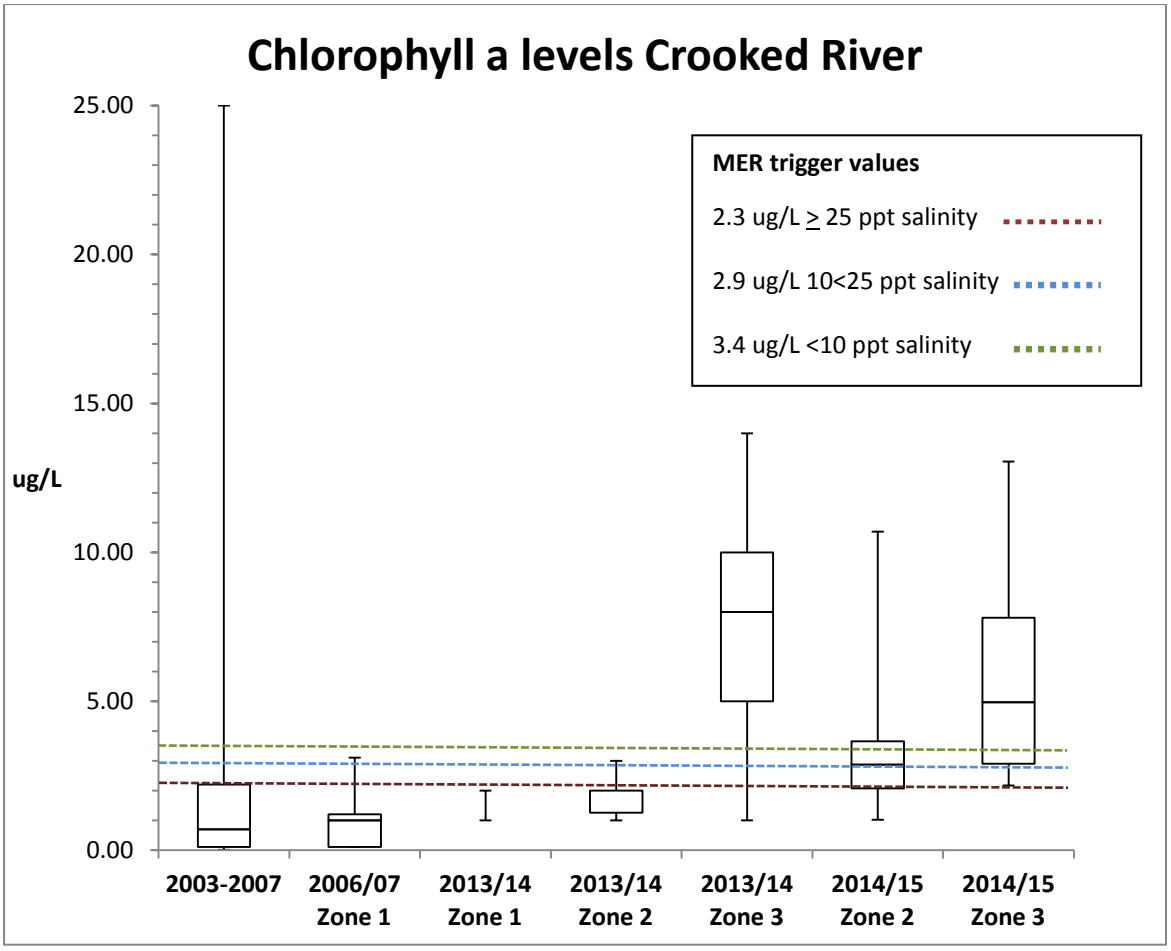


Figure 8 (a): Chlorophyll a levels Crooked River

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.

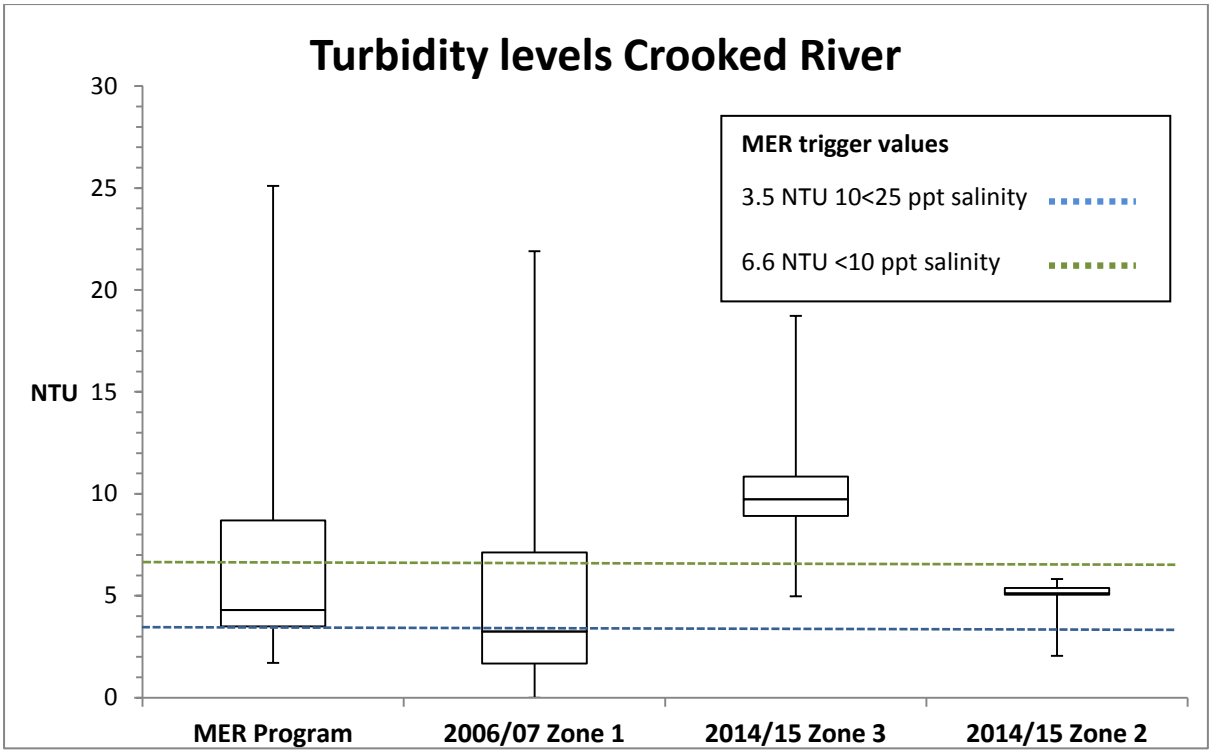


Figure 8(b): Turbidity levels in Crooked River

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.

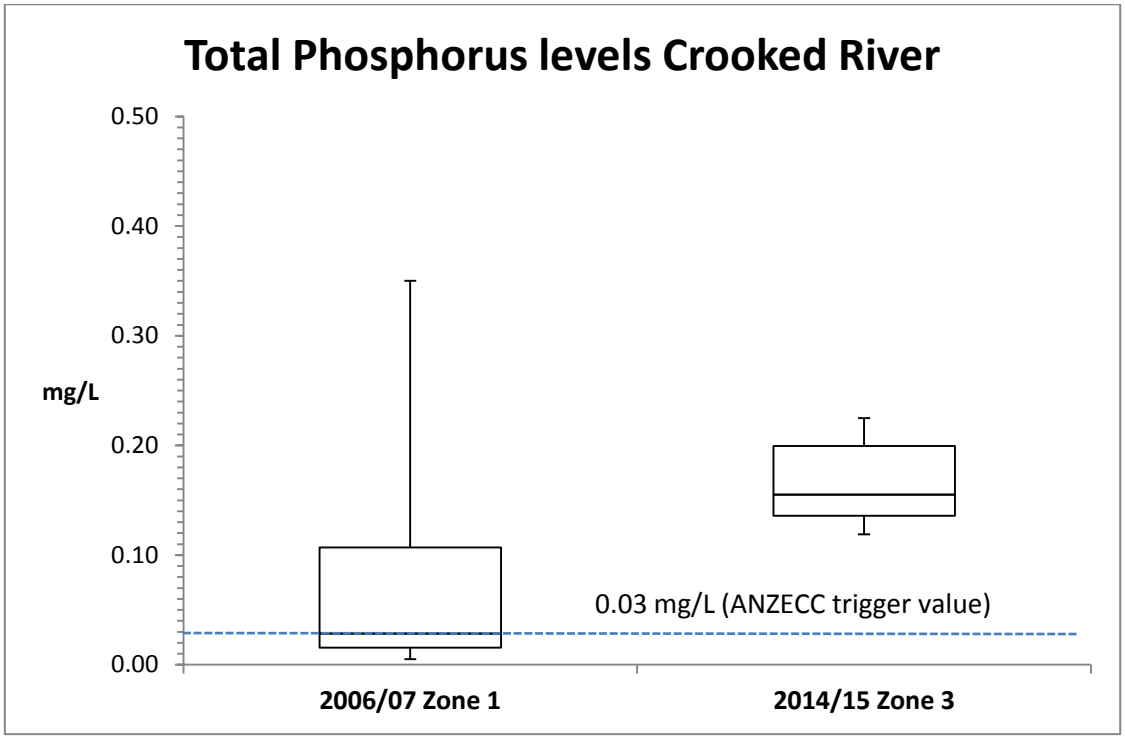


Figure 8(c): Total phosphorus levels in Crooked River

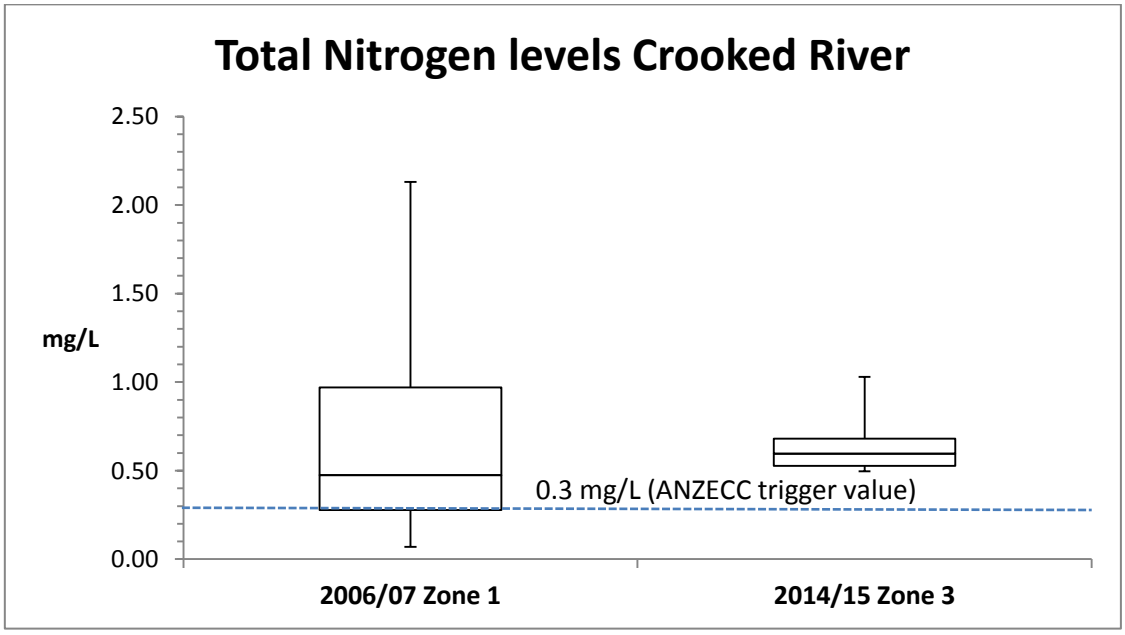


Figure 8(d): Total Nitrogen levels Crooked River

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.

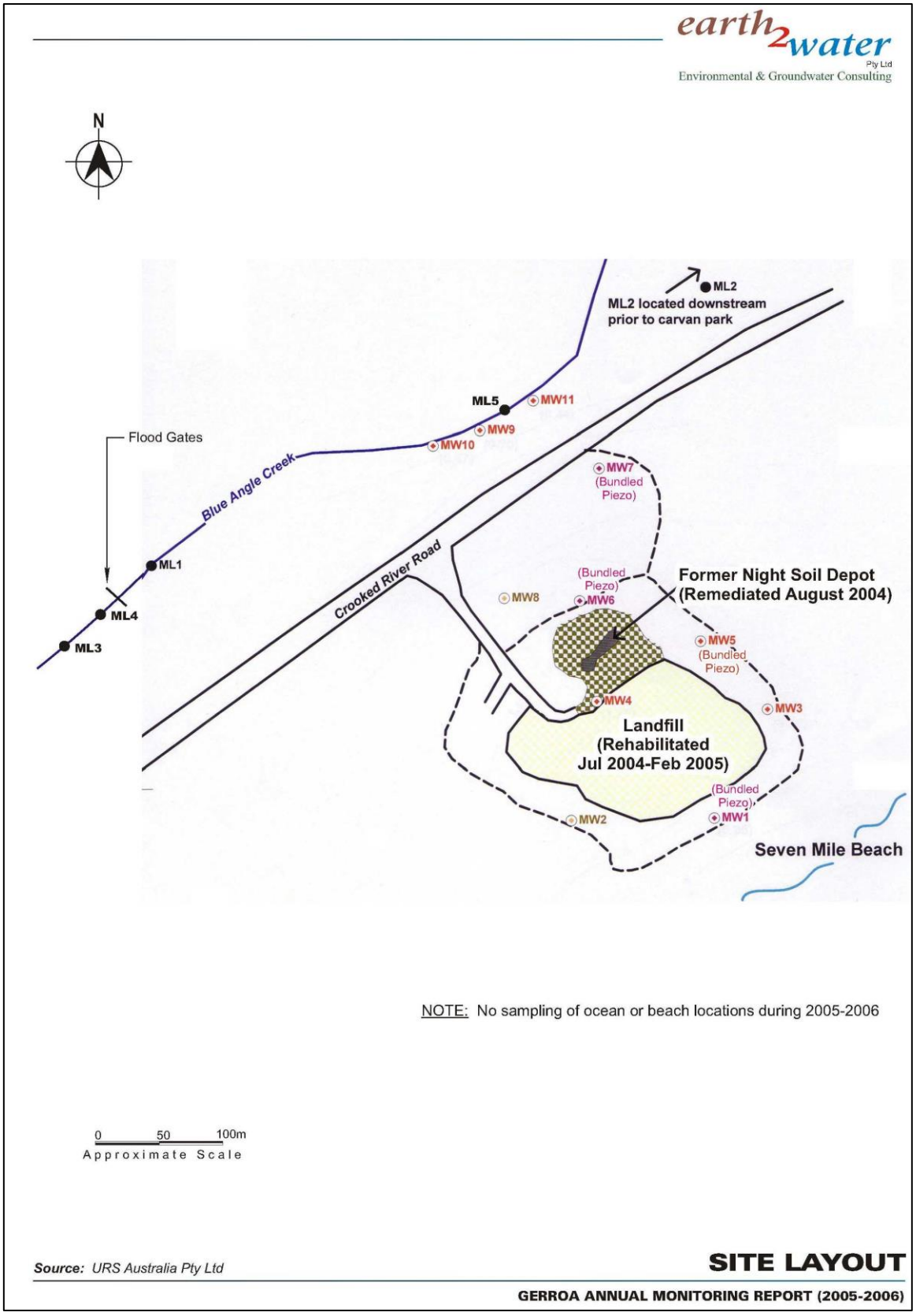


Figure 10: Monitoring locations for Gerroa Waste Depot (Source Gerroa Annual Monitoring Report 2005-06)

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

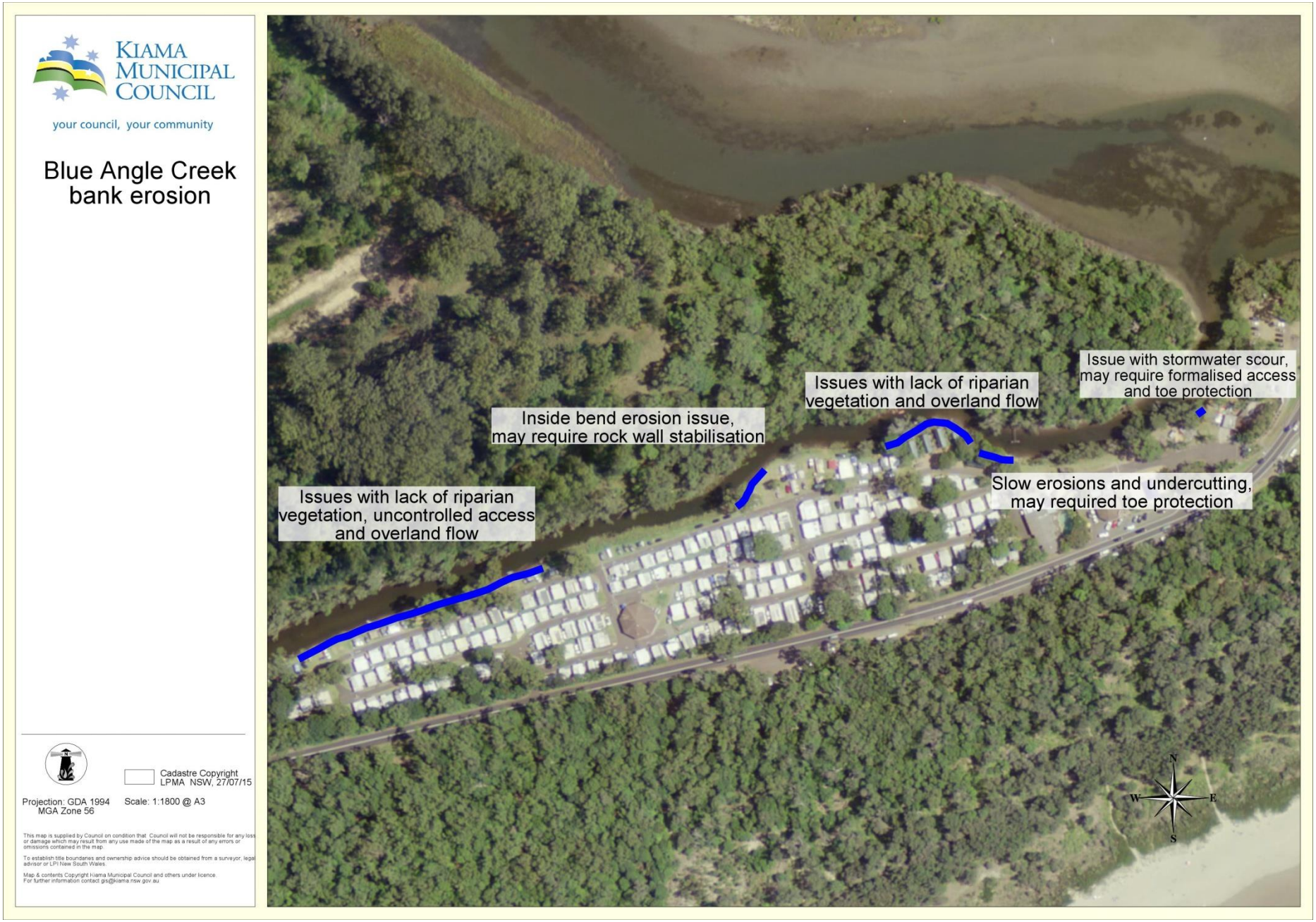


Figure 12: Foreshore erosion areas in Blue Angle Creek and Crooked River

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.

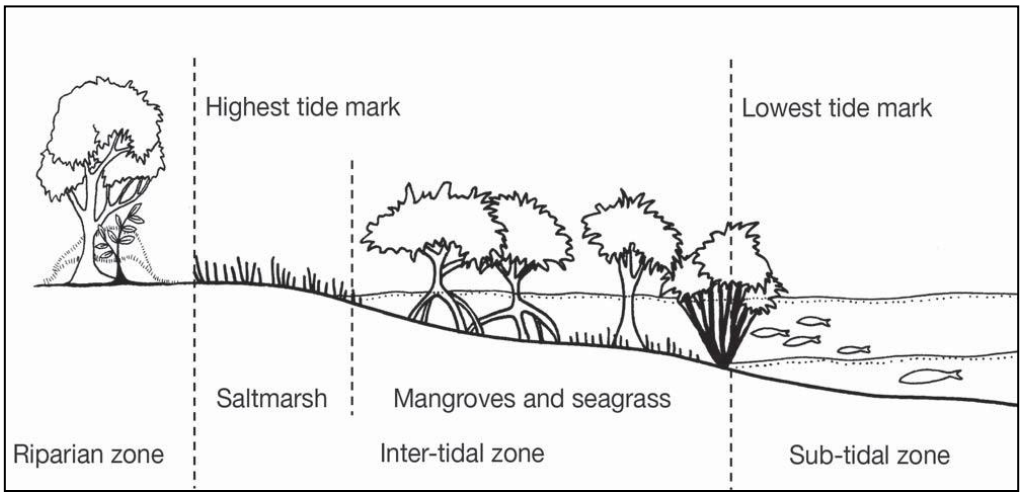


Figure 13: Estuarine Vegetation Zones, Sourced OEH Waterwatch Estuary Manual Fact Sheets

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.

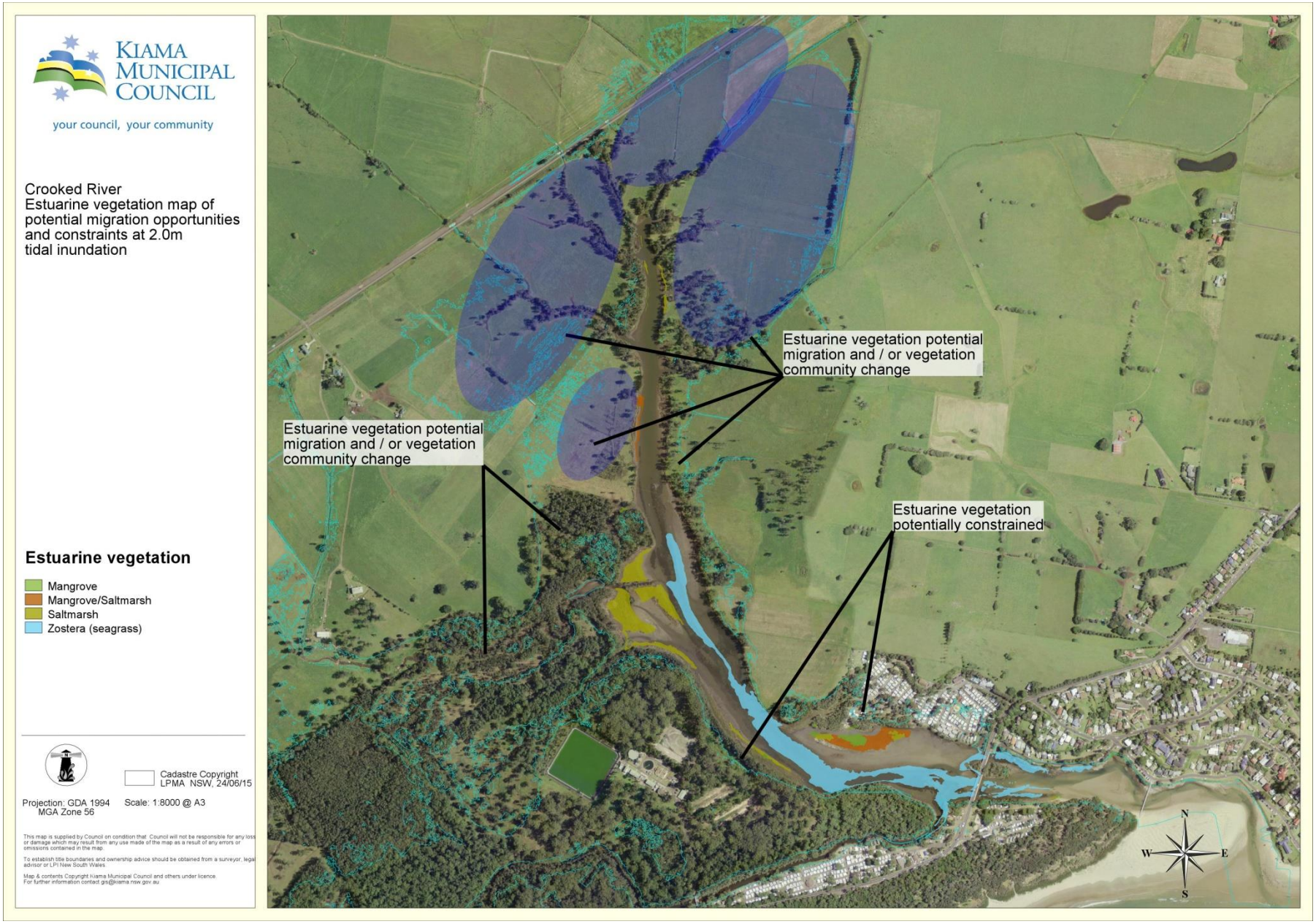


Figure 14: Crooked River Estuarine Habitat Mapping and potential constraints and migration opportunities. Habitat mapping provided by NSW Department of Primary Industries, from mapping undertaken by the NSW Department of Planning, Comprehensive Coastal Assessment undertaken in 2005

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.

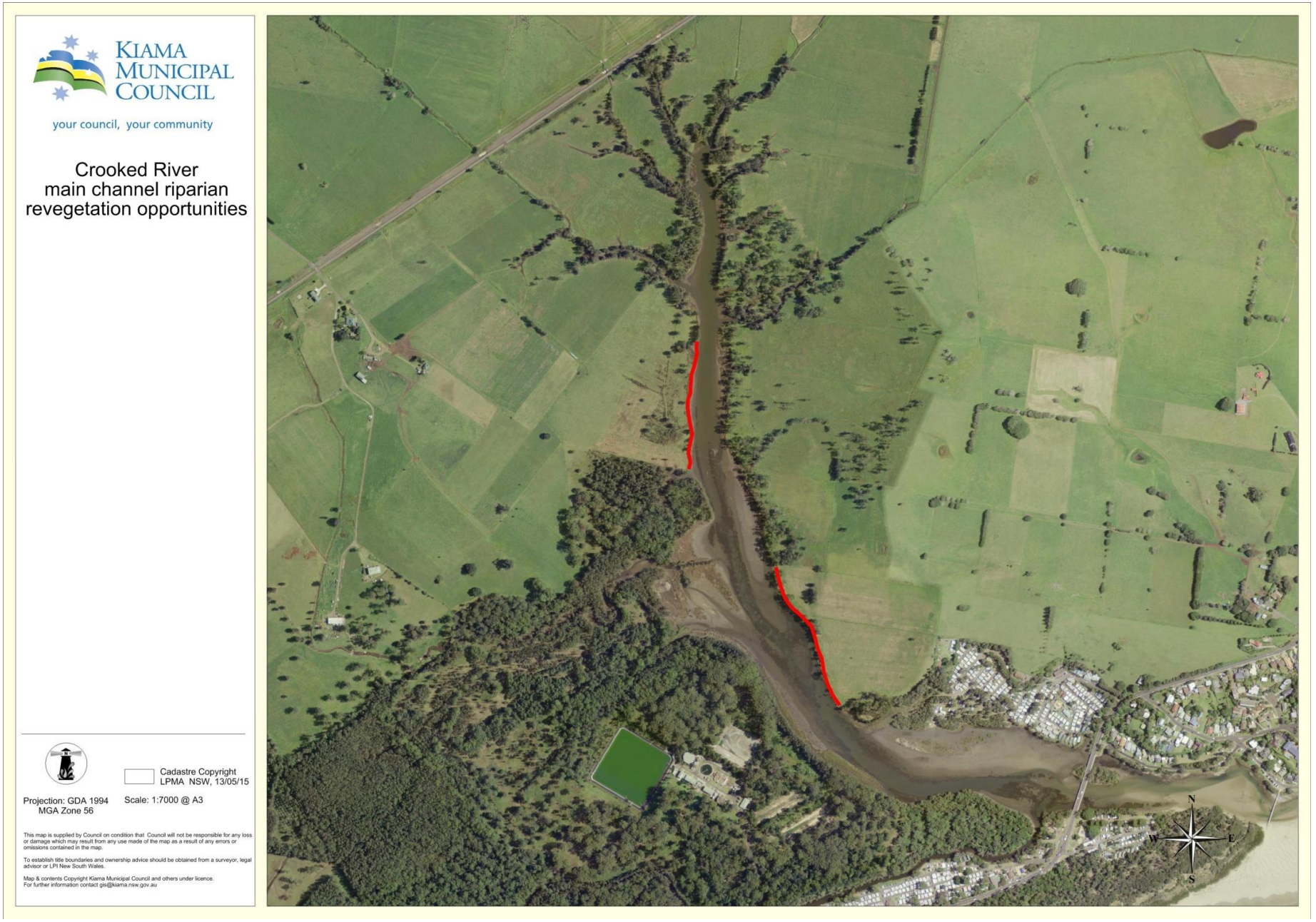


Figure 17: Crooked River main channel riparian revegetation opportunities

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

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.

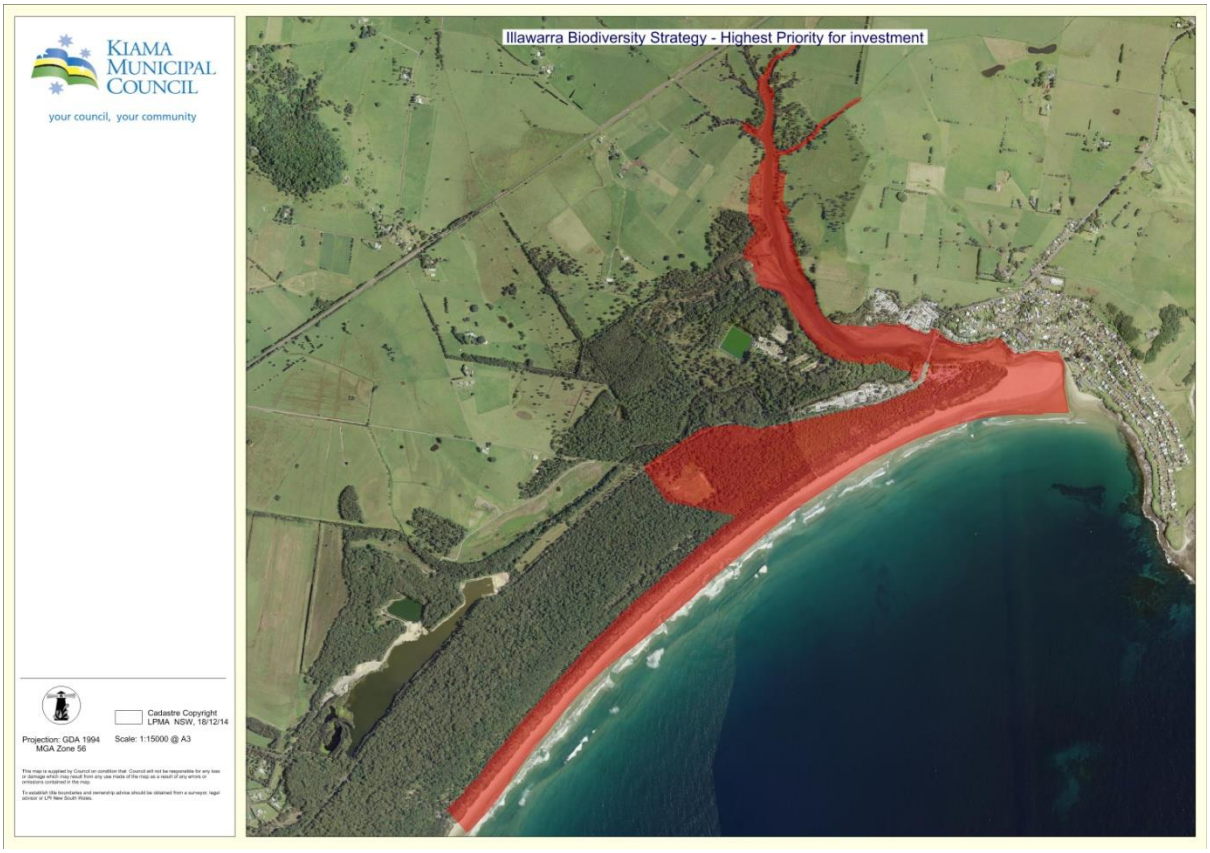


Figure 19: Illawarra Biodiversity Strategy - Highest Priority area for investment

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.

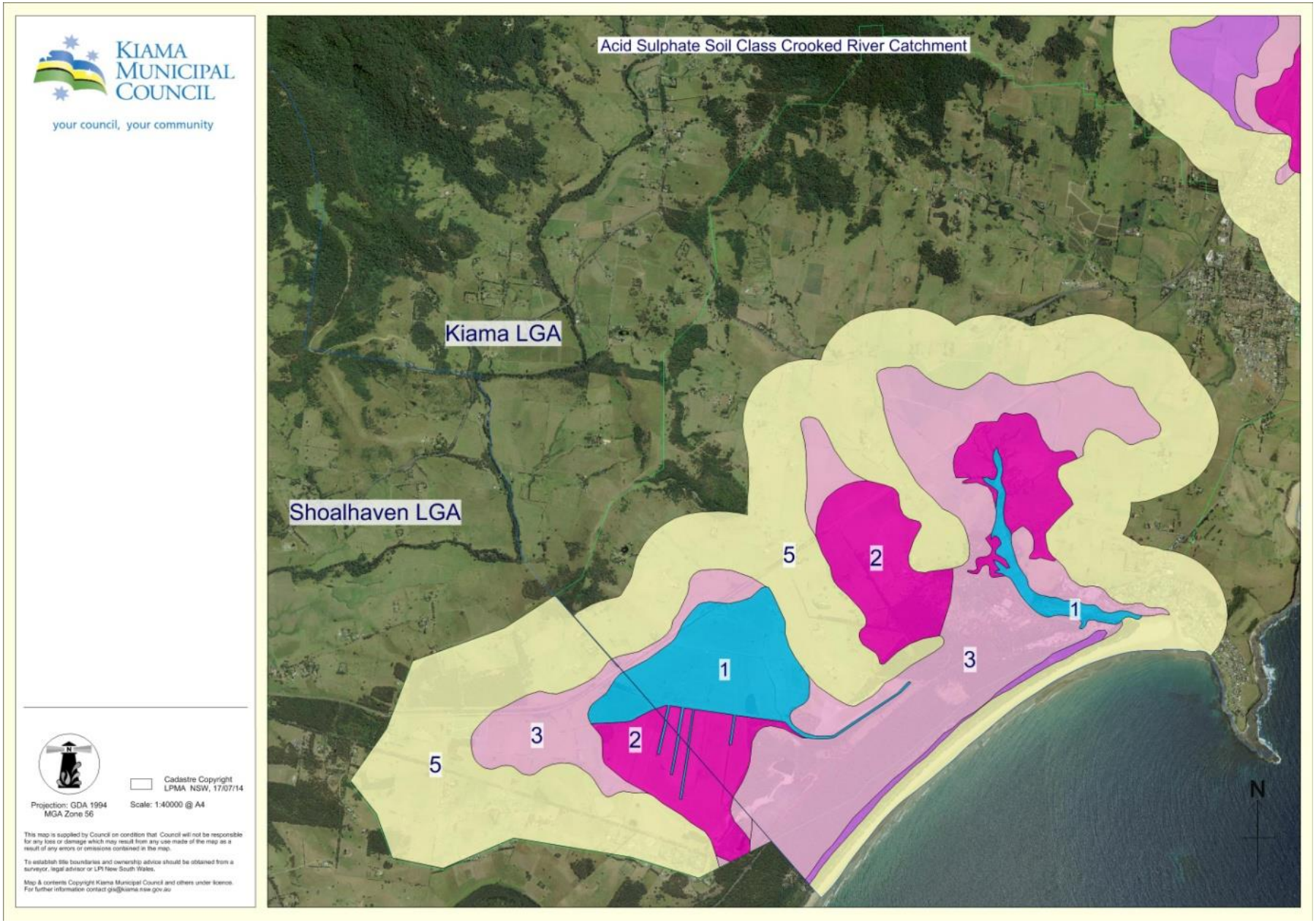


Figure 20: Acid sulfate soil map of Crooked River catchment

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.

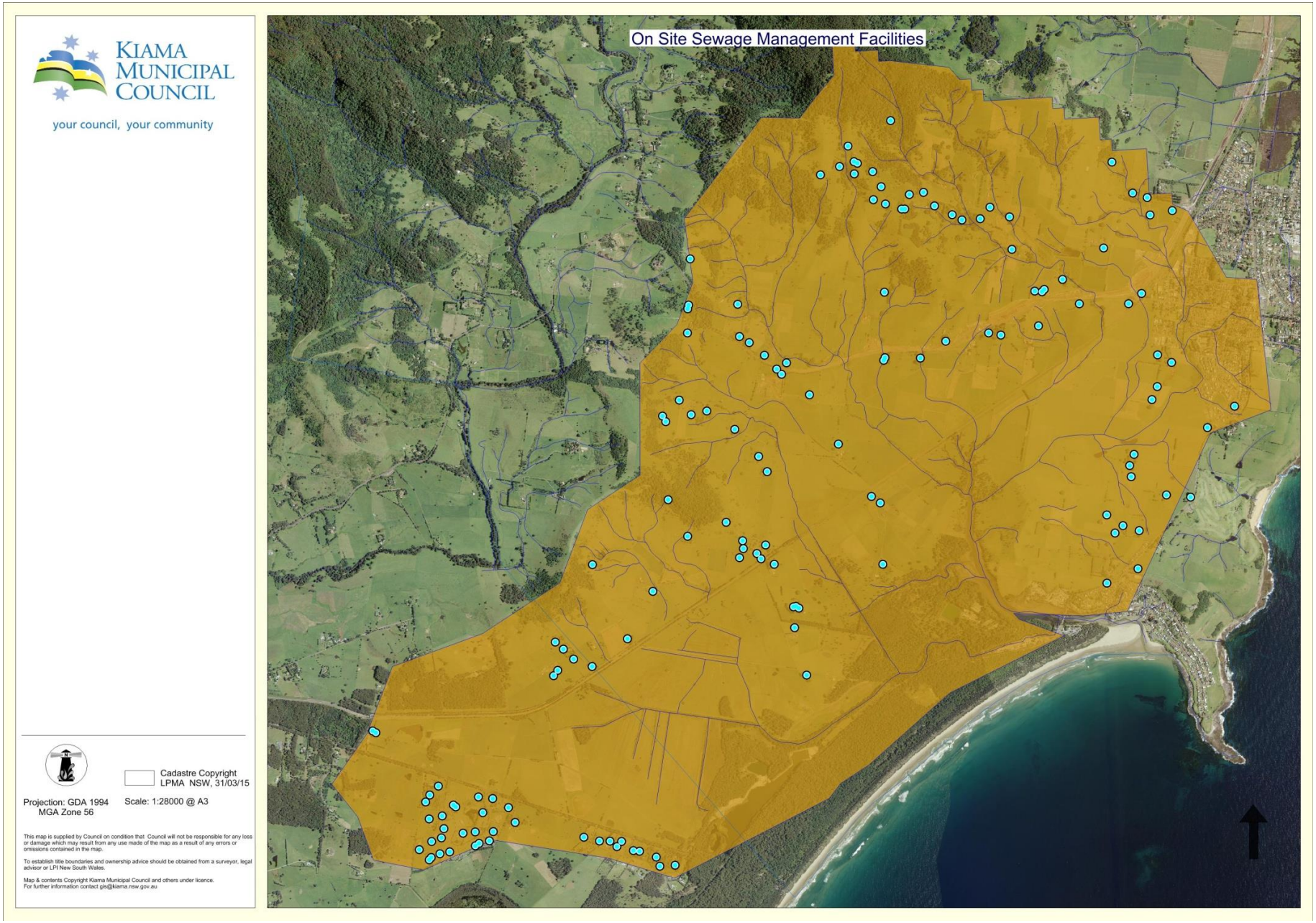


Figure 22: Onsite sewage management facilities in the Crooked River catchment

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)

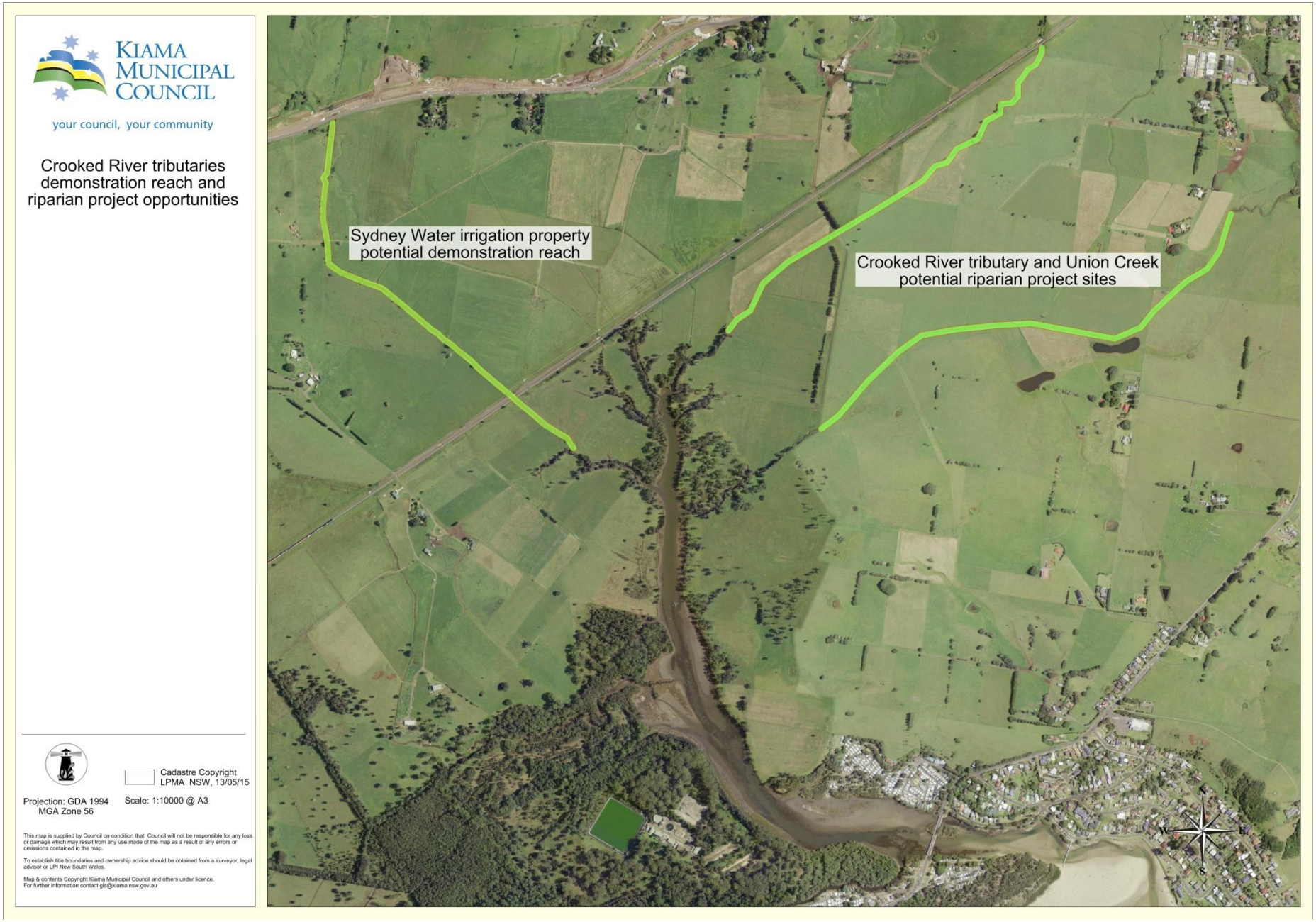


Figure 23: Potential riparian management demonstration reach, Sydney Water irrigation property and other tributaries, Crooked River

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

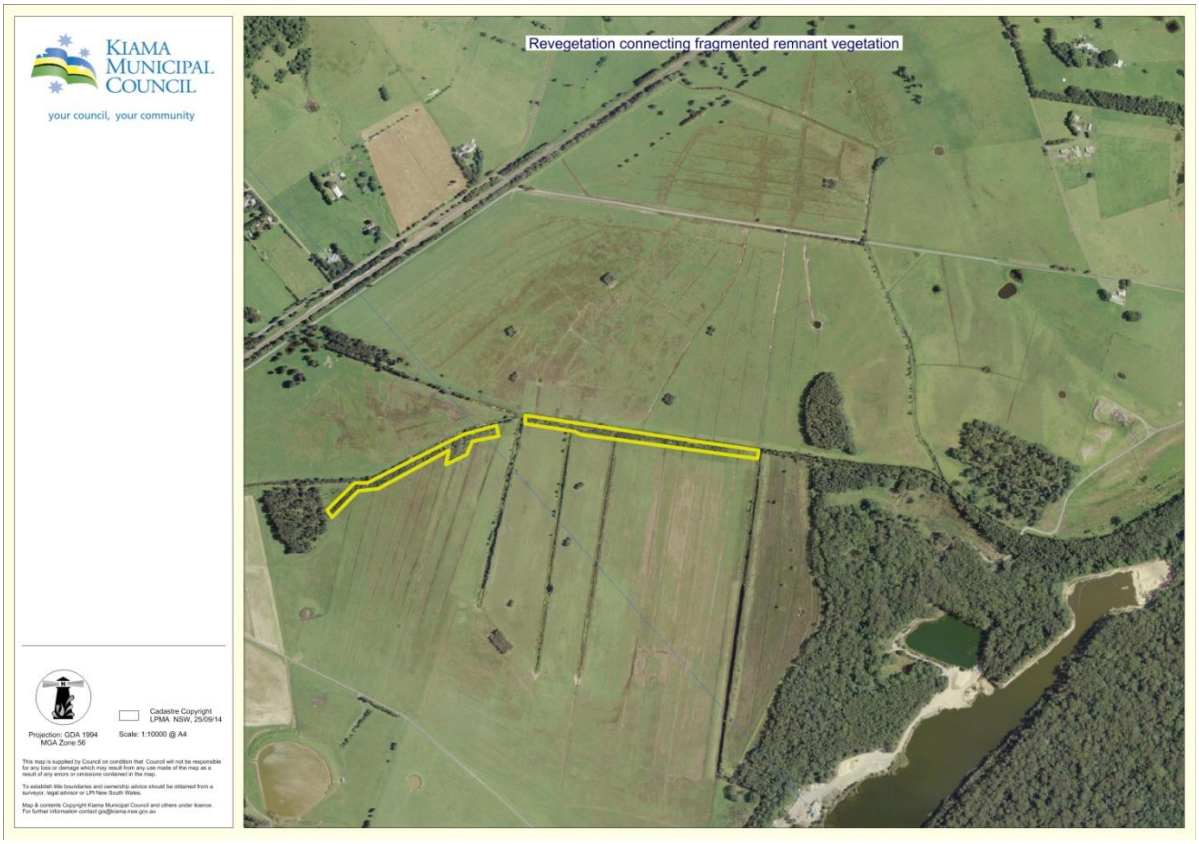


Figure 25: Compensatory plantings on Foy's Swamp

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.

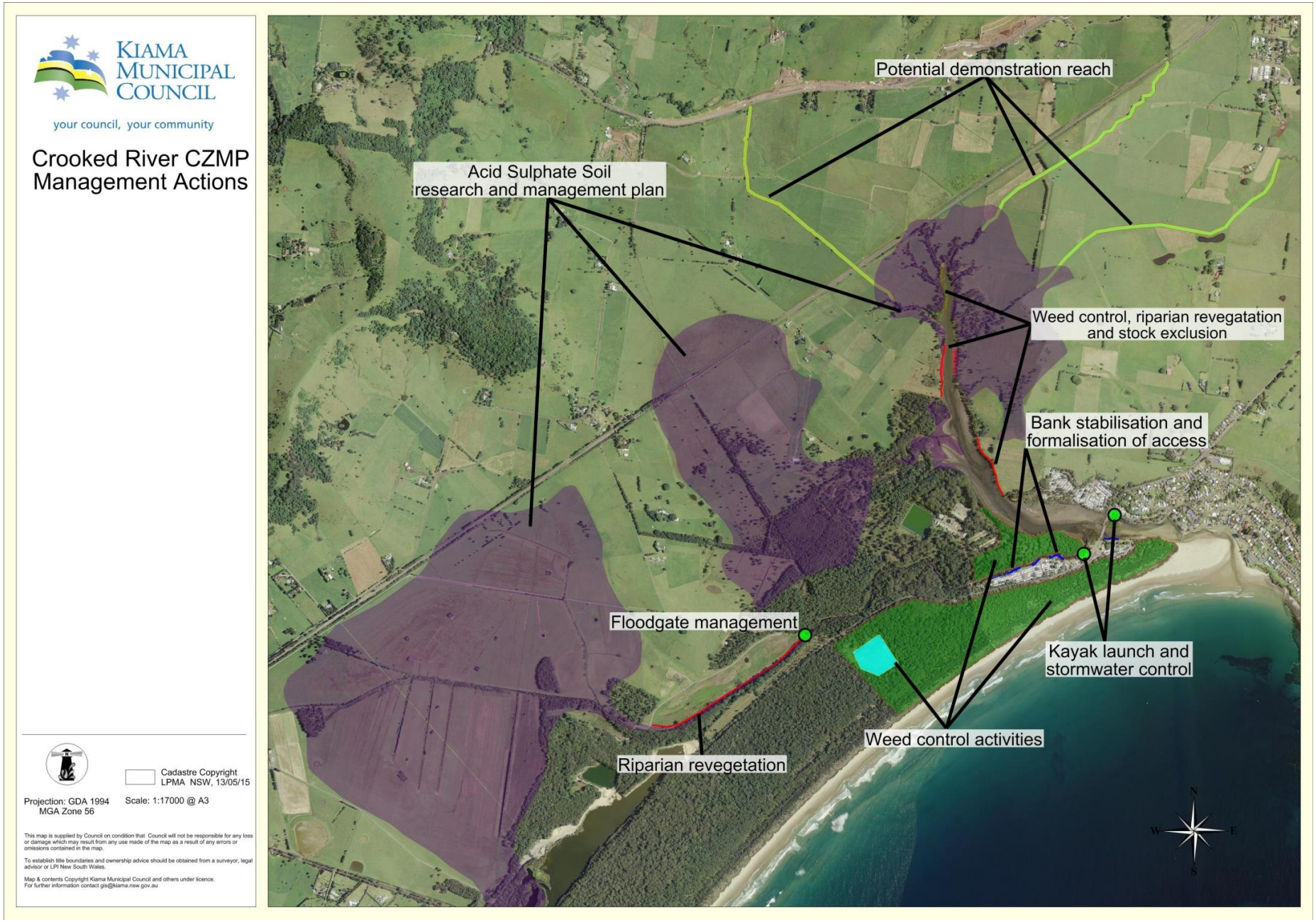


Figure 27: Key Crooked River Management Actions

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.		

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

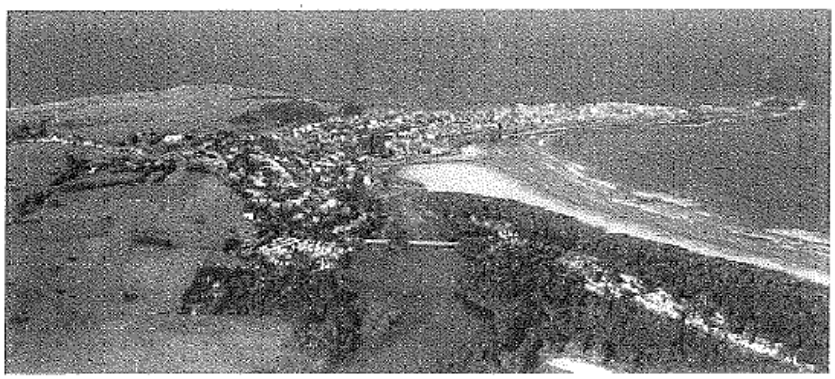
The Crooked River Estuary Management Committee has investigated the need for a formal Entrance Opening Policy for Crooked River, as has been prepared for the entrance of Werri Lagoon. The aims of such a policy would include that entrance opening follows as natural a regime as possible within the constraints 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.

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

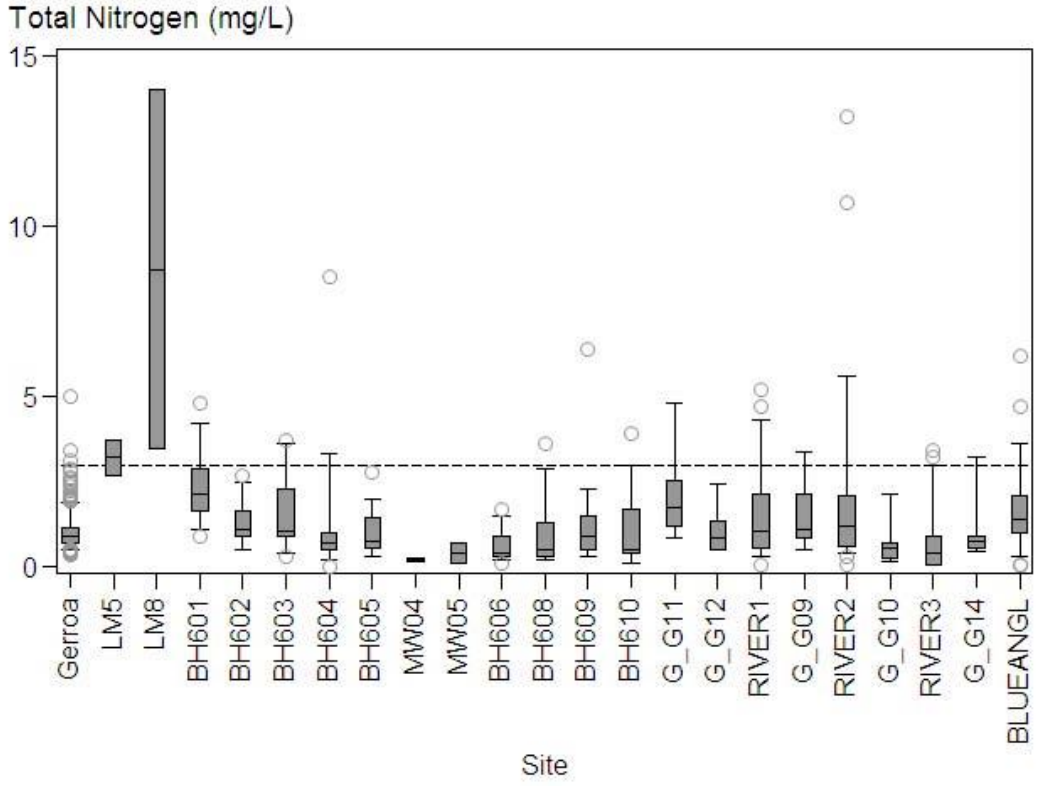
Sample Date	2/07/2012	2/08/2012	6/09/2012	10/10/2012	5/11/2012	5/12/2012	4/01/2013	21/01/2013	4/03/2013	8/04/2013	2/05/2013	5/06/2013
River 1	80	190	60	1300	38	52	1300	14	1600	360	1600	740
River 2	160	490	92	3200	20	42	970	240	740	1400	15000	420
River 3	30	22	4	48	6	10	640	140	560	360	180	310
Blue Angle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

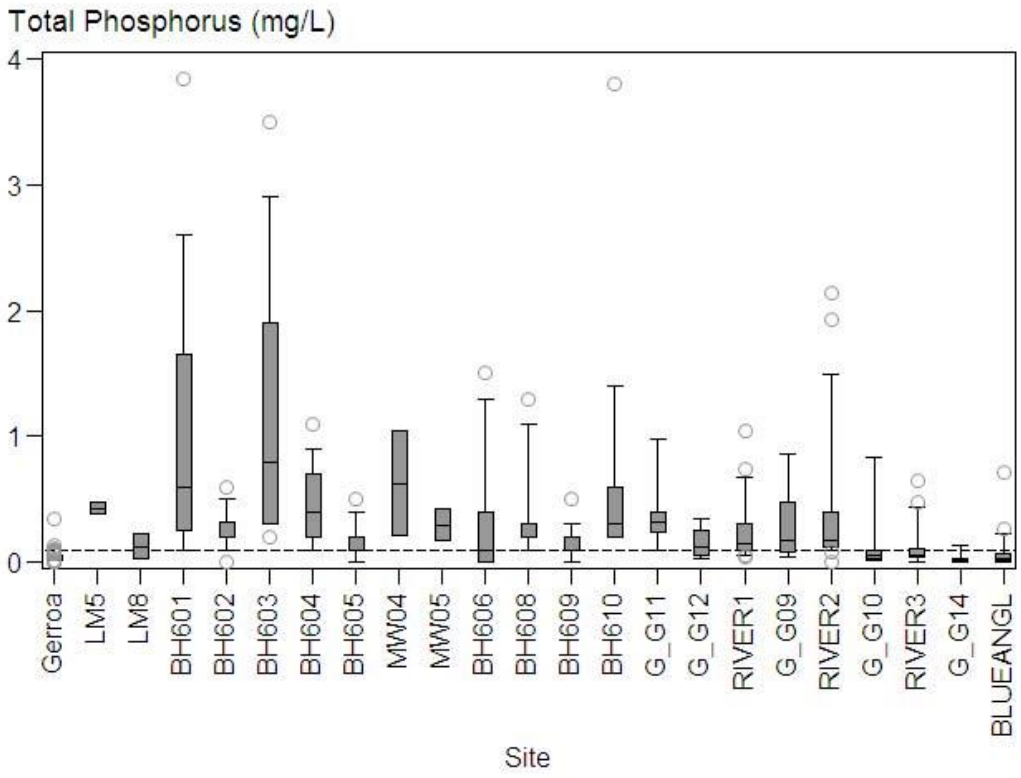
Crooked River Kiama Council Water Quality Data 2006/07

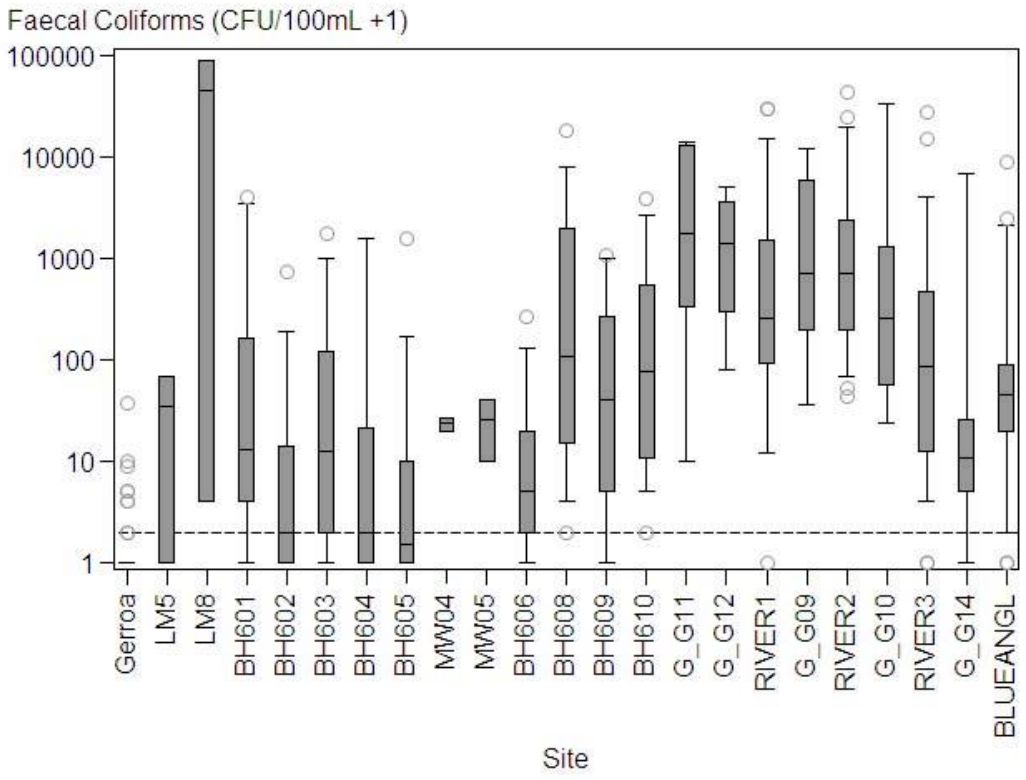
Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll a (ug/L)	Turb. (NTU)	Salinity (ppt)	Rain in 7 days prior to sampling (mm)
C1 - Crooked River 1 - Estuarine/River (road bridge)						
27-Jul-06	2.00	0.24	1.20	13.20	3.91	72.60
29-Aug-06	0.39	0.03	1.20	2.80	24.03	0.00
28-Sep-06	0.24	0.02	2.20	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

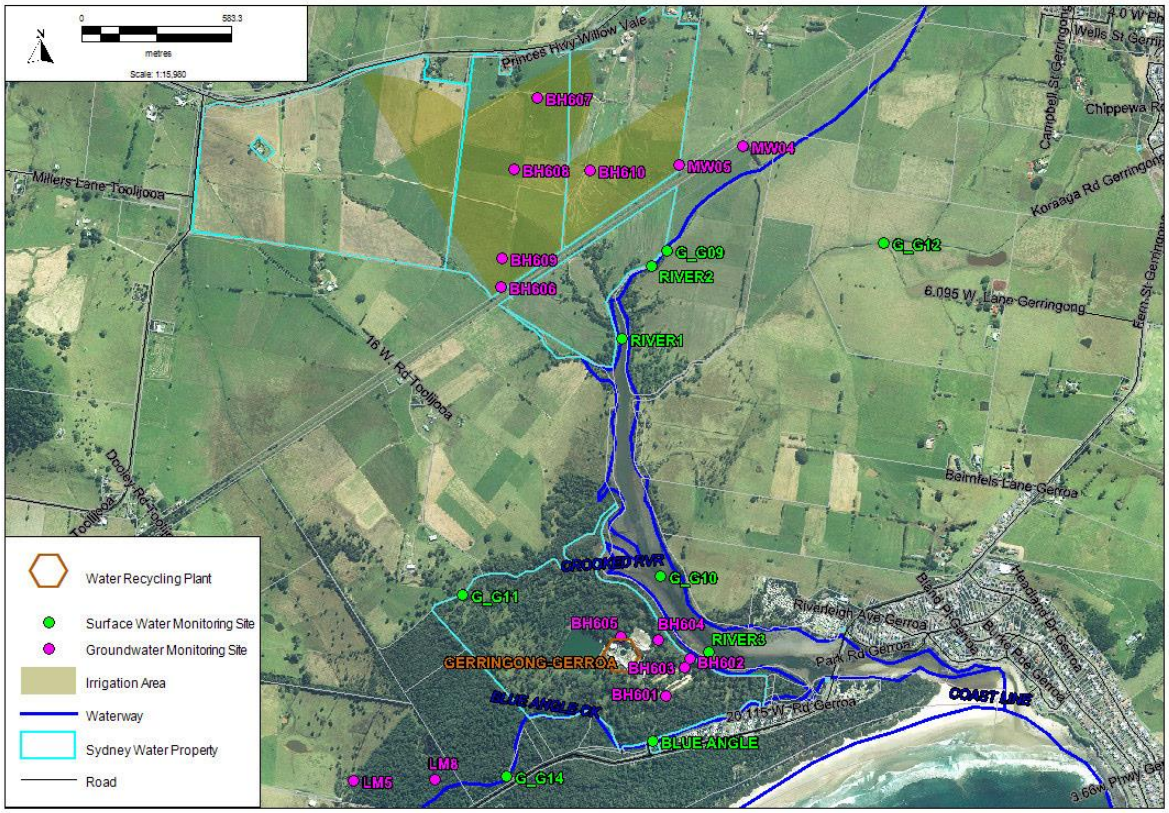
Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll a (ug/L)	Turb. (NTU)	Salinity (ppt)	Rain in 7 days prior to sampling (mm)
C2 - Crooked River 2 - Estuarine/River (footbridge)						
27-Jul-06	1.60	0.14	0.10	13.50	6.11	72.60
29-Aug-06	0.07	0.01	0.10	0.00	35.56	0.00
28-Sep-06	0.25	0.02	1.00	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


Water Recycling Plant
Surface Water Monitoring Site
Groundwater Monitoring Site
Irrigation Area
Waterway
Sydney Water Property
Road
BH607
MW04
BH608
BH610
MW05
BH609
G_G09
RIVER2
BH606
G_G12
RIVER1
G_G10
G_G11
BH605
BH604
RIVER3
BH603
BH602
BH601
BLUE ANGLE
LM8
LM5
G_G14
Princes Hwy Willow Vale
Millers Lane Toolijooa
16 W. Rd Toolijooa
Koraaga Rd Gerringong
6.095 W Lane Gerringong
Belmfels Lane Gerroa
Riverleigh Ave Gerroa
Park Rd Gerroa
COAST LINE

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.

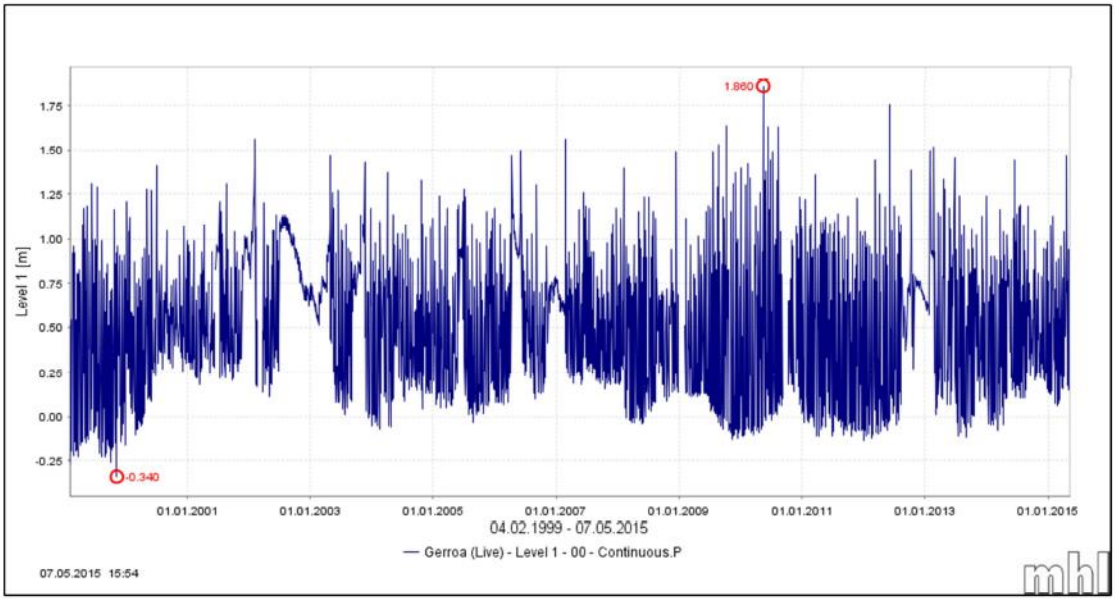
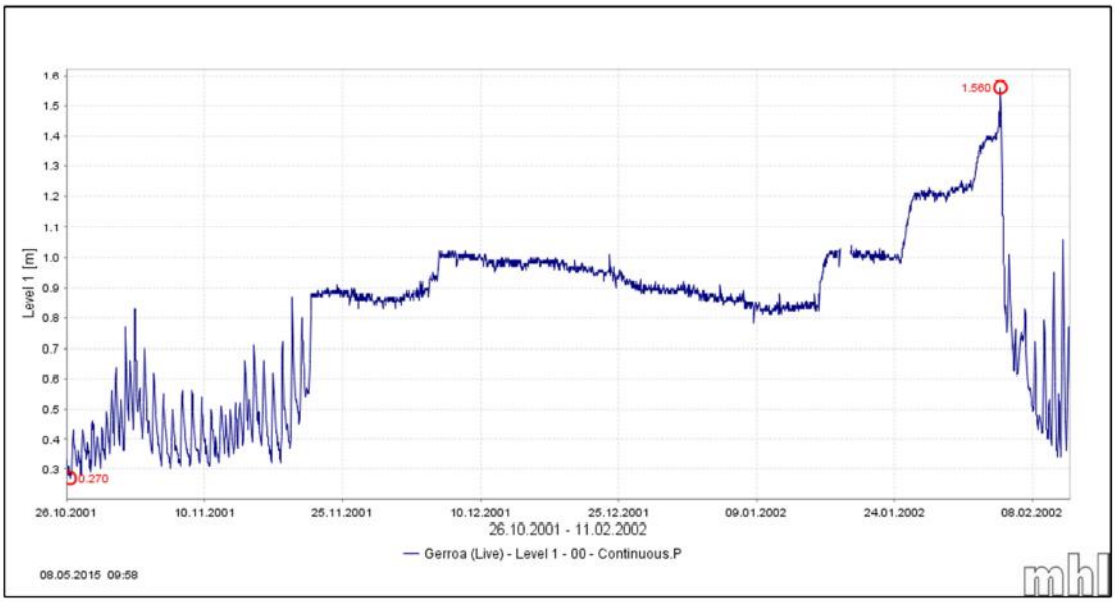


Figure 2: Example of a period of entrance closure identified from the loss of tidal signal.



Danny Wiecek
Senior Natural Resource Officer – Coast and Estuaries

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

Poor likelihood 1, high likelihood 5

1 to 10	Low Priority
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