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NSW GOVERNMENT

Catchment Management Plan

REPORT

Prepared for

Bega Valley Shire Council

11 August 2016

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elgin associates

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Nola Dummett – local historical accounts and photographs

Chris Nazer – records of estuary open and closed periods since 2007

EXECUTIVE SUMMARY

Bega Valley Shire Council (BVSC) received funding from the Office of Environment and Heritage (OEH) under the NSW Estuary Management Program to undertake a rapid catchment assessment (the 'Assessment') of Middle Lagoon.

The objectives of the Assessment were to:

- Identify catchment and foreshore issues currently impacting, or with the potential to impact, water quality and estuary health;
- Identify and recommend priority areas within the catchment for protection and targeted rehabilitation that will improve catchment condition and water quality of Middle Lagoon, and
- Preparation of this catchment management plan that highlights priority management areas and actions for protection and targeted rehabilitation that can be implemented as funding permits.

Elgin Associates in association with Riparian Engineering were engaged by BVSC to undertake the project, which involved multiple stages undertaken over a 16-month period from March 2015 to August 2016.

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This document is a preamble to the project and is structured to provide relevant background information and context to the project objectives and tasks undertaken. The document provides a summary of catchment and estuary physical characteristics including landforms and geology, vegetation communities (terrestrial and aquatic), current and historical land uses, and provides an overview of our current understanding of water quality and ecosystem health status of Middle Lagoon.

Catchment residents, the broader community and stakeholders (*i.e.* government agencies and others) were consulted throughout the project regarding issues affecting catchment condition and estuary health. Opinions regarding values and concerns for Middle Lagoon and the catchment were sought via an online questionnaire, email and phone. Subsequent information provided by the community and stakeholders was vital to undertaking field investigations where highlighted issues were examined and documented.

Field investigations of lower and upper catchment areas and the entire estuary foreshore were completed over a number of days and supplemented the preliminary assessment completed by Bega Valley Shire Council and Office of Environment and Heritage. In total, eight (8) priority management areas have been identified; all situated in the lower catchment area close to the estuary. Within each management area, at least one or more of the following issues is currently occurring - road surface erosion, natural stream bank erosion, degradation of riparian zone and/or sensitive coastal saltmarsh areas, and uncontrolled foreshore access.

Each of these issues is the result of past and present disturbances and considered to be either currently or have the potential to affect catchment condition and estuary water quality if not addressed.

A detailed description of each priority management area and each issue is provided in Appendix B.

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LIST OF ABBREVIATIONS AND ACRONYMS

DPI	NSW Department of Primary Industries
AHD	Australian Height Datum
BMAD	Bell Miner Associated Dieback – recognised as a key threatening process to *Eucalyptus* forest types due to the presence of over-abundant populations of psyllid insects (*Glycaspis* spp.) often with over-abundant Bell Miner birds (*Manorina melanophrys*) that out-compete bird species that predate on psyllid insects (Refer to NSW Scientific Committee 2008 – Final Determination)
EEC	Endangered Ecological Community
LALC	Local Aboriginal Land Council
LiDAR	Light Detection And Ranging
m^2	Metres squared
MHWS	Mean High Water Springs
OEH	Office of Environment and Heritage
N/A	Not Applicable
RCA	Rapid Catchment Appraisal
RMS	Roads and Maritime Services
SELLS	South East Local Land Services
SLR	Sea Level Rise

INTRODUCTION

1 BACKGROUND AND PROJECT OBJECTIVES

Middle Lagoon has significant ecological, recreational and socio-economic values all of which are reliant on good water quality. The water quality of the estuary is highly dependent on land-use practices and catchment disturbance, both past and present. Catchment management issues such as natural and man-made erosion, intensive land-use, and unsealed roads can all impact on water quality via increased sediment and nutrient inputs. Furthermore, as Middle Lagoon is not subject to regular and / or significant tidal flushing, water quality of the lagoon is more sensitive to catchment inputs compared to permanently open, well-flushed estuaries, and as such is vulnerable to catchment disturbances.

Bega Valley Shire Council (BVSC) received funding from the Office of Environment and Heritage (OEH) under the NSW Estuary Management Program to undertake a rapid catchment assessment (the 'Assessment') of Middle Lagoon.

The objectives of the Assessment were to:

- Identify catchment and foreshore issues currently impacting, or with the potential to impact, water quality and estuary health;
- Identify and recommend priority areas within the catchment for protection and targeted rehabilitation that will improve catchment condition and water quality of Middle Lagoon, and
- Preparation of this catchment management plan that highlights priority management areas and actions for protection and targeted rehabilitation that can be implemented as funding permits.

Elgin Associates in association with Riparian Engineering were engaged by BVSC to undertake the project.

1.1 SCOPE OF WORK AND PROJECT TIMELINE OVERVIEW

The project involved multiple stages undertaken over 16-month period from March 2015. A summary of the project stages and scope of work completed is provided below.

Project Stage	Date/s	Scope of Work
1	March – April 2015	• Preliminary analysis of lower catchment and foreshore issues completed by BVSC and OEH
2	July - August 2016	• Elgin Associates engaged to work on project • Data acquisition and desktop analysis • First round of Community and Stakeholder Consultation - Distribution of consultation plan and online questionnaire
3	August – February 2016	• Rapid catchment assessment – field site inspections
4	December 2015 –	• Preparation and submission of Draft catchment

	February 2016	management plan
5	March 2016	• Second round of Community and Stakeholder Consultation – Drop-In Session, Tanja Hall
6	March-May 2016	• Draft report review
7	August 2016	• Submission of Final catchment management plan

Stage 1 [March-April 2015] - Preliminary analysis of lower catchment and foreshore issues was undertaken by BVSC and OEH in a series of field inspections conducted in March 2015. These data including photographs were compiled and provided for project use.

Stage 2 [July-August 2015] - Elgin Associates engaged to deliver Stages 2-7 of the project. Stage 2 included data acquisition and desktop analysis including review of available spatial datasets (*i.e.* cadstre, land tenure and property, aerial imagery, LiDAR), previous reports and preliminary analysis completed during Stage 1. A GIS project database was developed to contain all the spatial and environmental information. The GIS was used to identify potential erosion areas throughout the catchment. Erosion types identified included head cuts on catchment streams, erosion on unsealed roads, bank and roadside embankments, and erosion from old logging snig tracks.

A consultation plan was prepared and distributed to catchment landholders and stakeholders for the purpose of raising awareness of the project objectives and seeking input to the project. Input from landholders, stakeholders and the wider community was received via phone, email with majority of feedback provided via an online questionnaire. Information gathered during this initial consultation period was used to prepare for field site inspections.

Stage 3 [August 2015 – February 2016] - Field site inspections of upper and lower catchment, and estuary foreshore areas were undertaken over multiple days during a 6-month period to assess erosion and other catchment issues (*i.e.* stock impacts, lack of riparian vegetation, *ad hoc* foreshore access, unsealed roads, wetland degradation, illegally constructed weirs). Inspections were undertaken on crown lands as well as private properties building upon preliminary work completed in Stage 1 by BVSC and OEH. All issues currently impacting or with the potential to impact on estuarine health were documented and photographed. Issues on private lands and potential remedial options were discussed with relevant landholders where possible at the time of inspection.

Stage 4 [December 2015 – February 2016] - A draft catchment management plan was prepared with findings of field site inspections compiled as a list of priority issues (High, Medium and Low), described and documented with management actions recommended to mitigate impacts on estuary health a key component of the report. The catchment was divided into a number of priority management areas with a map showing the location of each issue prepared for each area. The risk of high conservation areas (*i.e.* endangered ecological community, protected species) under threat from erosion processes or other issues was considered during the preparation of the catchment management plan. As well, the implications of predicted sea level rise with regard to high conservation areas located on estuarine foreshore and lower freshwater reaches was considered in the assessment. Draft report submitted to BVSC and OEH for review.

Stage 5 [March 2016] – A second round of community and stakeholder consultation was undertaken in March 2016 at Tanja Hall where community members and stakeholders were invited to attend a drop-in session to review a series of maps showing the Priority Management Areas and issues affecting Middle Lagoon catchment.

Stage 6 [March – May 2016] – Receipt of BVSC and OEH draft report review comments.

Stage 7 [August 2016] – Final version of Catchment Management Plan report submitted.

1.2 STUDY AREA

The study area included the catchment and estuary foreshore areas of Middle Lagoon. The catchment of Middle Lagoon and its proximity within the Bega Valley Shire is shown in **Figure 1**.

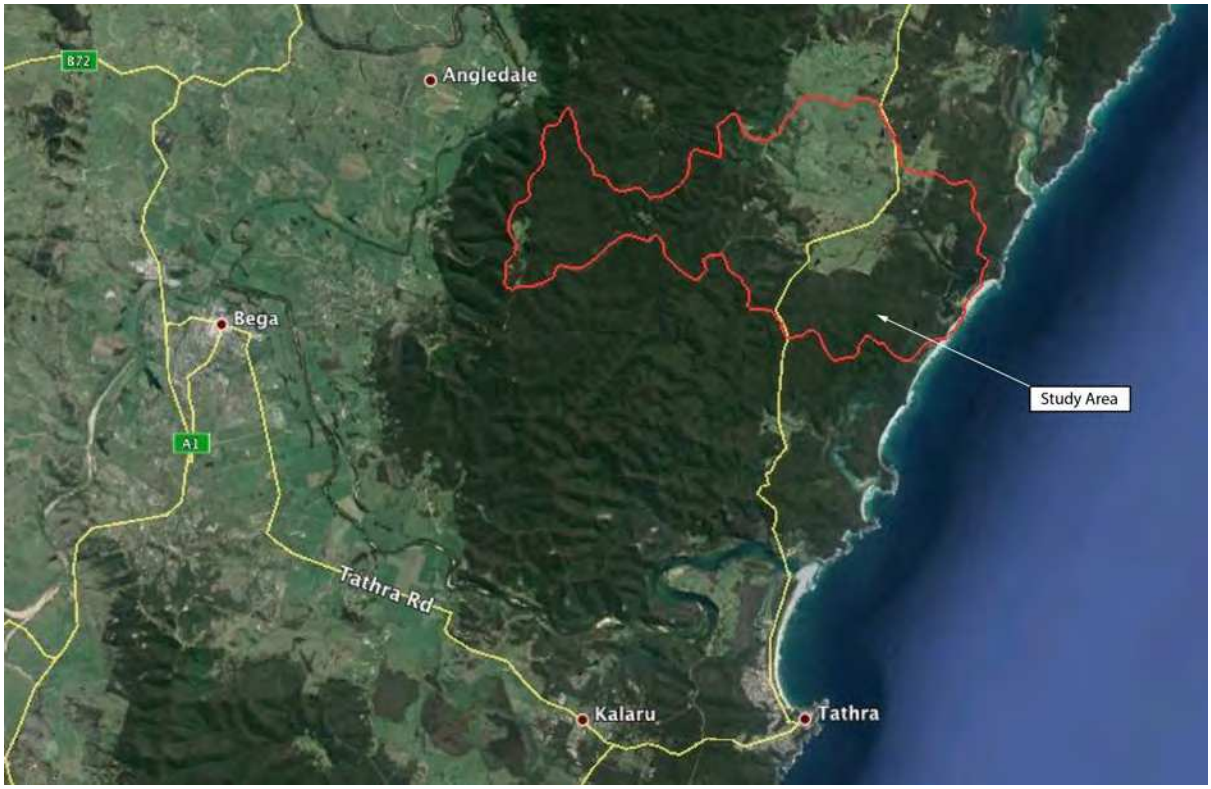

Figure 1. Catchment Area of Middle Lagoon.

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2 CATCHMENT AND ESTUARY PROFILE

The Middle Lagoon catchment is 27.3 km^2 in area bounded by the ridgelines of Dr George Mountain Road, Mt Peter firetrail and Gillards Beach Road to south, Dr George firetrail to the west, with the northern catchment boundary comprising road sections of Sandy Creek firetrail, Worlands Road, Fields Road, Tathra-Bermagui Road and Haighs Road. Majority of the catchment (approx. 72%) remains forested although large areas have been disturbed by historical forestry operations. Approximately 28% of the catchment has been cleared for agricultural uses.

Sandy Creek is the primary catchment stream whose headwaters originate on the eastern slopes of Dr George Mountain at an approximate elevation of 290m above sea level. Sandy Creek drains approximately 75% of the total catchment, the creek meandering for majority of its flow through the forests of Mimosa Rocks National Park before reaching the lower catchment where it flows adjacent to, or through private property situated on the alluvial floodplain. Booths Creek, the main tributary stream of Sandy Creek, drains approximately 25% of the total catchment that includes a small proportion of well-vegetated hill slope with majority of the sub-catchment area cleared for agriculture. Both creeks are characterised by typically low flows with many private water storages situated along drainage lines throughout the catchment that restrict natural base flow stream conditions. As a result, freshwater inflows to Middle Lagoon are typically low but can be very high under high rainfall flood condition events. The confluence of Sandy Creek and Booths Creek is located at the upper estuary surrounded by private land just to east of Tathra-Bermagui Road.

Middle Lagoon has a waterway size, including saltmarsh areas, of 0.6 km^2 (OEH 2016a). The estuary is a shallow, saline coastal lagoon classified as a semi-mature, wave-dominated, intermittent estuary (Roy *et al.* 2001). Estuary maturity refers to its stage of sediment infilling. Sandy Creek and its main tributary Booths Creek are the primary sources of fluvial sediment supply with a number of smaller streams draining the hill slopes to the north and south of the lagoon. The estuary basin is elongate and parallel to the coastline with a central island landform dividing the estuary into a north and south basin as shown in **Figure 2**.

Wave action is a dominant force influencing the geomorphology of the estuary, which is characterised by a sand barrier at its mouth enclosing the central basin (Roy *et al.* 2001). The sand barrier creates a constricted ocean entrance that becomes intermittently closed to the ocean for prolonged time periods. In NSW these types of estuaries are commonly referred to as ICOLLs – *intermittently closed or open lakes or lagoons*.

ICOLLs are characterised by a broad range of ecological conditions that include tidal flows when open to ocean, a variable salinity regime, and variable water levels that has had significant implications for the estuarine communities they support. Historically, catchment landholders have managed the entrance of Middle Lagoon since the late 1800s to maintain lower lagoon water levels and prevent inundation of low-lying agricultural lands. However, in more recent times the estuary entrance has been permitted to open naturally, although the entrance is still occasionally subject to illegal artificial openings by members of the community. Further discussion regarding the intermittent nature of the estuary entrance is provided in Section 2.5 below.

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Figure 2. Simplified geomorphological model of Middle Lagoon (from Elgin 2014).

A brief summary of Middle Lagoon and Catchment characteristics is provided in **Table 1** below.

Table 1. Summary of Middle Lagoon and Catchment Characteristics	
Estuary waterway size: 0.6 km^2	**Catchment Area:** 27.3 km^2 28% cleared (7.7 km^2), 72% forested (19.6 km^2), 54% Mimosa Rocks National Park (14.7 km^2), 44% Private Land tenure (12.03 km^2), 2% Crown Land (0.57 km^2)
Primary Inflows: Sandy Creek and its main tributary Booths Creek Sandy Creek sub-catchment area 20.6 km^2 (approx. 75% of total catchment) Booths Creek sub-catchment area 6.7 km^2 (approx. 25% of total catchment)	
Estuary type: Semi- mature, Saline coastal lagoon	
Estuarine vegetation: Saltmarsh 0.052 km^2, *Ruppia megacarpa* 0.211 km^2 *Ruppia*, also known as sea tassel, is often the dominant macrophyte in brackish water estuaries that are closed to the ocean for long periods.	
Catchment land-uses: Rural residential, agricultural grazing, recreation.	
Commercial activities: The estuary is available to commercial fishing as part of NSW Region 7 - Estuary General Fishery.	

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Endangered Ecological Community (EEC) types: The catchment contains seven (7) vegetation types listed as EECs types under the *NSW Threatened Species Conservation Act 1995* (TSC Act) including - Coastal saltmarsh, Freshwater wetlands, Bangalay Sand Forest, Lowland Grassy Woodland, River-flat Eucalyptus Forest, Swamp Schlerophyll Forest and Littoral Rainforest.	
Estuary open – closed period (%): Closed 80% of time, Open 20% of time.	
Entrance Opening Policy: none	
Water Quality:	• Moderate levels of nutrients. Mean nitrogen and phosphorous levels generally exceeding guideline limits. • Seasonal algal blooms common. • Highly variable salinity regime with waters ranging from brackish to marine conditions.

2.1 CATCHMENT GEOLOGY AND LANDFORMS

The predominant substrate comprising the Middle Lagoon catchment is Ordovician metasediments. These are sedimentary rocks including slate, siltstone, shale and greywacke that have been altered by metamorphic processes of folding, faulting and later intruded by granite and gabbro by volcanic activity during the Devonian period. Dr George granite outcrops on the western margin of the catchment. The Ordovician metasediments are relatively resistant to erosion, compared, for example, to weathered granitic substrates, and give rise to shallow soils of fairly low fertility. These are characteristic of the Sandy Creek sub-catchment whose soils are classed as yellow podzolics and more prone to erosion compared to the Cretaceous Tanja Syenite complex that underlies the Booth Creek sub-catchment that is characterised by mixture of soloths, yellow podzolic and chocolate soils. Extensive areas of Quaternary alluvial sand and gravel deposits are distributed around the foreshore and west of the lagoon.

2.2 LAND TENURE AND LAND-USES

Catchment land tenure and land-use has largely been determined by the catchment soil type characteristics and their suitability for agriculture. Private land tenure is mostly concentrated in the lower catchment area that is characterised by more fertile soils for agricultural use and includes the lower slopes and alluvial floodplain of Sandy and Booths Creeks. A number of private land holdings also exist in the upper catchment surrounded by National Park. Private land tenure represents approximately 44% of the total catchment area, with Mimosa Rocks National Park comprising 54% and crown land approximately 2% of catchment area. (**Figure 3)**.

Majority of land in the Booths Creek sub-catchment has been cleared for agriculture owing to its more fertile soils compared to the poorer soils of Sandy Creek sub-catchment that remains mostly forested and is part of Mimosa Rocks National Park.

Summary of catchment land tenure:

- Mimosa Rocks National Park (14.7 km^2) - 54% of catchment area
- Private Land tenure (12.03 km^2) – approx. 44% of catchment area

- Crown Land (0.57 km^2) – approx. 2% of catchment area

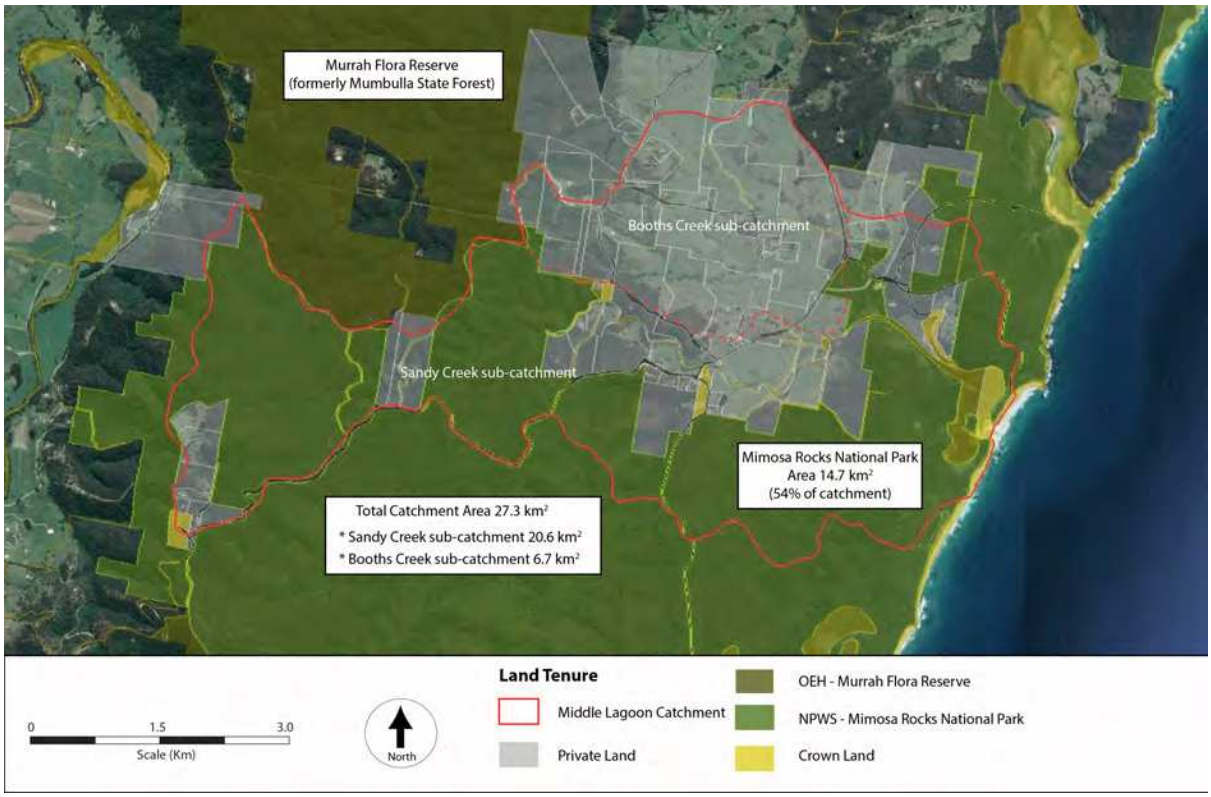


Figure 3. Middle Lagoon Catchment Land Tenure

2.2.1 HISTORICAL CATCHMENT DISTURBANCE AND EFFECTS OF DISTURBANCE

In general, European settlement of catchments has introduced substantial changes to the landscape including:

- Clearing of catchment vegetation for forestry, construction of road networks, and land for farming and housing; and
- Degradation of riparian vegetation by clearing for development, thinning for views, trampling by stock, and invasion by exotic pest species.

Cleared and disturbed catchments have less capacity to reduce the volume and rate of surface runoff under moderate to high rainfall events. Furthermore, the effects of human induced disturbance on catchment condition can be further exacerbated by natural stochastic events such as bushfire. Catchment disturbance typically results in increased rates of catchment and bank erosion and thus increased infilling of alluvial floodplains, fluvial deltas and shallow mud basins of estuaries via surface runoff.

Sediment supply and with it, nutrients and organic materials are important for the productivity of estuaries. However, excess supply of sediments and nutrients can be detrimental to the overall health of the estuary. Excess sediment and nutrient supply can lead to increased turbidity, and increased primary productivity by algae. Over long-term, persistent poor water clarity due to re-suspension of sediment fines and consistently high levels of nutrients can have a detrimental impacts on seagrass communities as algal flora outcompetes and becomes more dominant over

seagrasses. Loss of seagrass community has negative flow-on effects for estuarine fish populations. In addition, persistent and prolific growth of algae can lead to episodes of low levels of dissolved oxygen in the water column and this can be harmful to aquatic fauna and is often a cause of fish-kills.

The history of disturbance in the Middle Lagoon catchment includes large areas of the lower catchment that have been cleared for agriculture and areas subject to selective timber harvesting operations since the early years of European settlement up until the late 1970s and the associated network of unsealed road and snig-tracks. There are approximately 51.7 km of unsealed roads within the catchment (excluding unmapped old forestry roads) and it is acknowledged that unsealed roads and their associated runoff controls (*i.e.* mitre drains) can be a significant contributor of dispersible sediment fractions to catchment streams (Croke *et al* 2006). Other historical catchment disturbance includes land clearing gold mining and episodic wildfire events, and these are briefly discussed below.

Discovery of Gold in Sandy Creek sub-catchment

Alluvial gold was first discovered in the Nelson catchment in 1872 that triggered a local goldrush in Nelson catchment and adjacent Sandy Creek sub-catchment. Sandy Creek proved to be the richest source of alluvial gold with mining activity including the digging up and excavation of the creek bed continuing until the early 1900s.

Fire Disturbance

Wildfires in the catchment contribute to erosion of the hill slopes with fire resulting in a reduction of vegetation cover, leaf litter and loss of soil crust community that provide a protective layer to the surface soils during rainfall events. The history of fire disturbance in the Middle Lagoon catchment since 1978 includes the 1980/81 major fire event where a proportion of Sandy Creek sub-catchment and adjacent Nelson Lagoon catchment was burnt (NPWS 2011).

2.3 CATCHMENT VEGETATION

2.3.1 UPPER CATCHMENT VEGETATION

The upper catchment comprises dry, relatively steep ridges, and narrow, deeply incised gullies and the riparian zone along Sandy Creek. The dry ridges support various dry shrub forest communities, particularly *Far South Coast Foothills Dry Shrub Forest,* dominated by *Corymbia maculata* (spotted gum), *Eucalyptus tricarpa* (red ironbark), *Eucalyptus bosistoana* (coast grey box) and *Eucalyptus longifolia* (woolybutt). Towards the western end of the catchment *Eucalyptus sieberi* (silvertop ash) and *Eucalyptus agglomerata* (blue-leaved stringybark) are prominent. Downslope towards the margins of the moist gullies *Eucalyptus cypellocarpa* (monkey gum) is the dominant eucalypt species above a predominantly fern groundcover.

Southeast Warm Temperate Rainforest grows on the floors of the moist, relatively fire-protected gullies tributary to Sandy Creek. Characteristic species in this species-rich community are *Szygium smithii* (lillipilli), *Backhousia myrtifolia* (grey myrtle), *Myrsine howitteana* (muttonwood), *Eupomatia laurina* (bolwarra), *Doryphora sassafras* (sassafras), *Ficus coronata* (sandpaper fig), and *Pomaderris cinerea.*

The vegetation community in the narrow riparian zone of Sandy Creek above the tidal and high stand limit [a community not described by Tozer *et al.* (2010) and best described as 'gallery rainforest' as the formation is known in Victoria] has significant rainforest elements but also a number of species restricted to alluvial sites subject to recurrent flood disturbance, such as *Tristaniopsis laurina* (kanooka), *Lomatia myricoides*, and *Commersonia fraseri* (blackfellows hemp). *Eucalyptus botryoides* (bangalay) and *Eucalyptus elata* (river peppermint) occur as emergents. Clumps of *Lomandra longifolia* grow in the streambed proper and must have a substantial role in consolidating gravel bars.

2.3.2 LOWER CATCHMENT – CLEARED LAND

The Tanja locality, representing majority of the lower catchment area, was intensively settled during the late 1800s (the Tanja schoolhouse established in 1878) following the passage of the *Crown Lands Alienation Act 1861* (NPWS 2011). A large proportion of the lower catchment particularly the gently rolling country of Booths Creek was cleared of natural vegetation cover by the end of the century. The alluvial flats and richer soils of the Tanja Syenite complex would have been particularly attractive to settlers.

Given the extent of clearing and that much of the woody vegetation now present has been planted it is difficult to determine what the original vegetation might have been. Several isolated occurrences of the endangered ecological community (EEC) *Lowland Grassy Woodland in the South East Corner bioregion* have been mapped in this zone (**Figure 4**). This community is described as being characterised by an overstorey that is usually dominated by *Eucalyptus tereticornis* (Forest Red Gum), often with *Eucalyptus globoidea* (White Stringybark) and/or *Angophora floribunda* (Rough-barked Apple) and other eucalypts at some sites. The understorey often includes an open stratum of small trees dominated by *Acacia mearnsii* (Black Wattle), *A. implexa* (Hickory Wattle) or *Exocarpos cupressiformis* (Native Cherry) and an open shrub stratum that commonly includes *Bursaria spinosa, Cassinia spp.* and/or *Ozothamnus diosmifolius.* The grassy ground cover is dominated by *Themeda australis* (Kangaroo Grass), *Microlaena stipoides* (Weeping Grass), *Eragrostis leptostachya* (Paddock Lovegrass) and *Echinopogon ovatus* (Forest Hedgehog Grass) with forbs such as *Dichondra repens* (Kidney Weed), *Desmodium varians* (Slender Tick Trefoil), *Hydrocotyle laxiflora* (Stinking Pennywort), *Hypericum gramineum* (Small St John's Wort), *Glycine clandestina* and the fern *Cheilanthes sieberi* (Poison Rock Fern). It is quite plausible that this was the predominant community across the now cleared land. A comparable tract of richer soils at Goalen Head, in this case on gabbro substrate, supported *Lowland Grassy Woodland in the South East Corner bioregion.*

2.3.3 ESTUARY FORESHORE

A diverse range of vegetation communities occurs in the lower catchment areas closer to the shores of Middle Lagoon. These include *Far South Coast Foothills Dry Shrub Forest* on the dry ridges and *Southeast Warm Temperate Rainforest* in the moist gullies.

More significantly, seven EECs have been mapped in the lower catchment (OEH 2013), majority occurring on the foreshore of, or in close proximity to the estuary as shown in **Figure 4**. These include *Coastal Saltmarsh, Bangalay Sand Forest, Littoral Rainforest, Freshwater Wetlands on Coastal Floodplains, River-flat Eucalypt Forest on Coastal Floodplain, and Swamp Sclerophyll Forest*

on Coastal Floodplains. In addition Freshwater Wetland has been mapped adjacent to Sandy Creek near Tanja junction. Some of these EECs are of very restricted extent, and some community identifications appear to have been made without the benefit of ground-truthing field surveys to confirm mapping. Verifying the distribution and extent of EECs was outside the scope of this study however some notes regarding the EECs were recorded during field inspections. Comments regarding the occurrence and/or significant floristic components within of each of the six EECs is provided in **Table 2.**

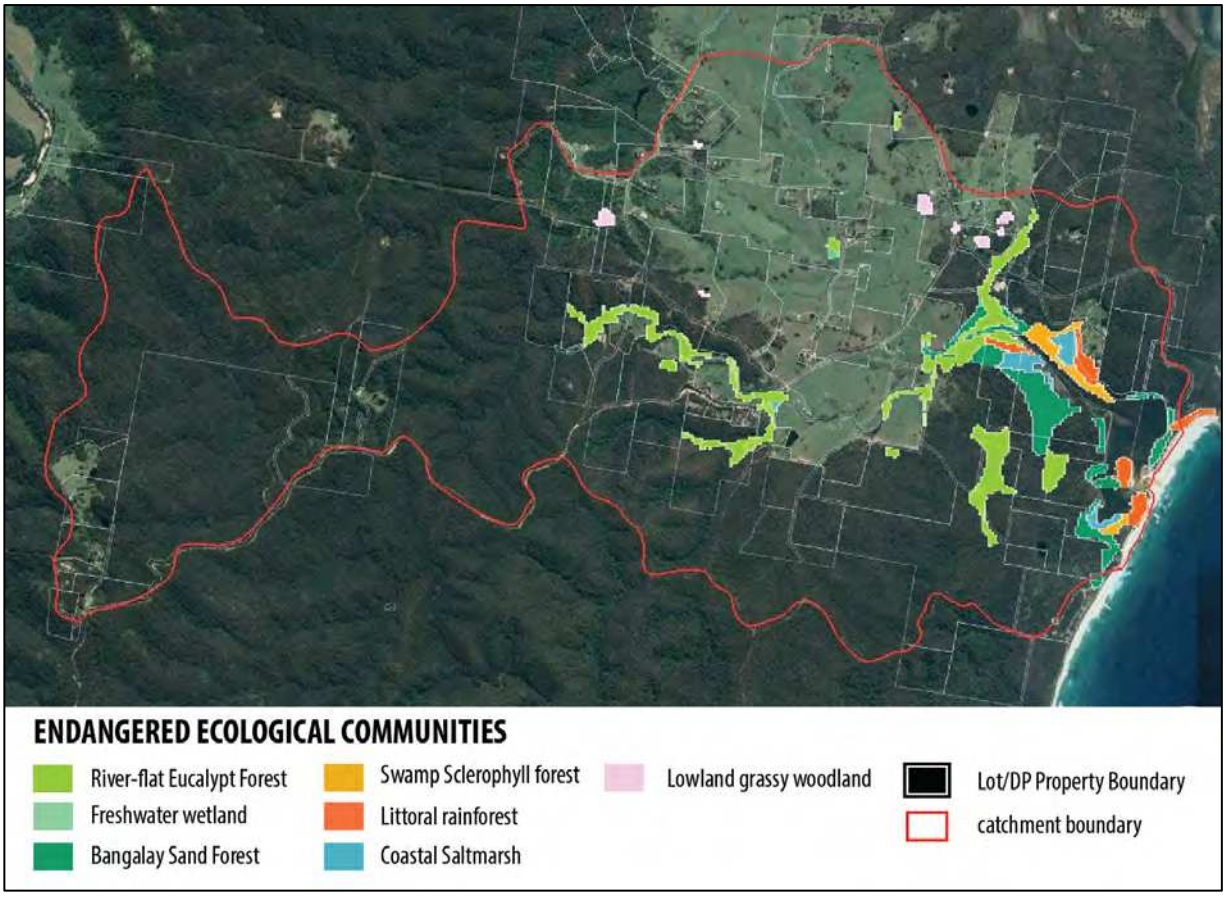


Figure 4. Distribution and extent of endangered ecological communities in Middle catchment. (*Note* - mapping from OEH 2013 and has not been verified in this study).

2.3.4 OTHER RARE AND SIGNIFICANT FLORA

In addition to the seven EECs listed in Middle Lagoon catchment, a number of rare and threatened plant species listed under *NSW Threatened Species Conservation Act 1995* (TSC Act) or otherwise regionally significant plant species are also known from the catchment. These include:

- *Ozothamnus turbinatus* (coast everlasting), an erect daisy shrub that is only known from SE region NSW. A population occurs at the mouth of Middle Lagoon on dunes and coastal cliffs and represents the currently known northern limit of the species on the coast.
- A few individuals of *Livistona australis* (cabbage tree palm) are located near Middle beach and together with a number of other small populations in Mimosa Rocks National Park, represent the southern limit for the species, which is regarded as regionally uncommon (NPWS 2011).

- Two species endemic to Dr George Mountain and that might be expected to occur at the western margins of the catchment include *Acacia georgensis* (Bega wattle), listed as vulnerable, and the rare *Eucalyptus specatatrix* (NPWS 2011). However, their presence was not confirmed in this assessment.
- The regionally significant *Acacia pedina* has a very restricted distribution, only known to occur between Bermagui and Tathra (Kodela and Tame 1999). It is present around the Middle lagoon shore, predominantly occurring just above the high tide level.
- Other rare plants found in the vicinity of Dr George Mountain include the vulnerable *Leionema carruthersii, Leionema ralstonii* and *Haloragodendron* sp. Wet forests growing on fire-protected aspects of Dr George Mountain contain the vulnerable species upright pomaderris (*Pomaderris virgata*) (NPWS 2011).

Table 2. Summary of Endangered Ecological Communities mapped in Middle Lagoon catchment with notes regarding the occurrence of each ECC.

EEC Name	Comments
Coastal Saltmarsh	Extensive areas of *Coastal saltmarsh* occur around Middle lagoon. It is the characteristic variant form typical of ICOLLs that experience prolonged, non-tidal, high stand phases with *Tecticornia arbuscula, Austrostipa stipoides, Gahnia filum* all being absent. The extended duration of recent water high stands has impacted on saltmarsh and other fringing vegetation. In addition to the large tracts of dead *Melaleuca ericifolia* there is evidence of the death of such species as *Bolboschoenus* and *Juncus krausii,* presumably having been unable to tolerate the duration, depth and perhaps salinity of the recent high stands. Nevertheless a wide range of saltmarsh species are present and there is abundant evidence of recent recolonisation by saltmarsh taxa that include species of *Mimula, Atriplex, Cotula, Alternanthera, Selleria, Leptonella, Chenopodium, Juncus krausii, and Phragmites australis.*
Freshwater Wetlands on Coastal Floodplains	*Freshwater Wetlands on Coastal Floodplains* occur on private land on the alluvial flats at the head of the lake. Patches are small and are subject to stock grazing.
Bangalay Sand Forest	*Bangalay Sand Forest* is quite extensive on the sandy substrates that surround the lagoon. The community has been affected by recent prolonged water high stand phases with substantial tracts of near-shore vegetation dying. While prolonged water high-stands are the most probable cause of tree death in this community, this is not the only factor operative. Numerous dead large *Eucalyptus botryoides* were observed well above the high stand level on the southern side of Sandy Creek and the lagoon. It is postulated that the most probable cause of mortality of these Bangalays (*Eucalyptus botryoides*) could be attributed to the syndrome of Bell Minor Associated Dieback (BMAD). *Bangalay Sand Forest* is highly vulnerable to weed invasion

	but the stands in this catchment are in good condition.
River-flat Eucalypt Forest on coastal floodplain	Mapped as being quite extensive along creeks and drainage lines. The identification is questionable however, since un-cleared river flats are of negligible extent in the catchment and few of the key indicator species are present. The current vegetation along stream banks is best characterised as a form of gallery rainforest (Refer discussion in Section 2.3.1).
Swamp sclerophyll forest on coastal floodplains	Mapped as occurring as several small patches around the estuary. The community has suffered from recent prolonged water high stands that have resulted in the mortality of large tracts of *Melaleuca ericifolia*.
Littoral Rainforest	*Littoral Rainforest* has been mapped as five discrete patches but it is doubtful whether significant areas of this community exist in this catchment. Those mapped close to the ocean are more accurately classified as *Bangalay Sand Forest.* The small pockets of rainforest in gullies around the lagoon shores are best classified as *Southeast Warm Temperate Rainforest.*
Lowland Grassy Woodland	Eight discrete patches mapped in the lower catchment – none inspected. This community is likely to have once been widespread across the Tanja Syenite complex of the Booths Creek sub-catchment.

2.3.5 LAND-USE CHANGES AND NATURAL REGENERATION PROCESSES

Many large properties in the Tanja region that were actively farmed from the late 1800s through the 1900s have since been sub-divided into smaller rural private land holdings. Subsequently, some of the owners of these smaller land parcels are no longer engaged in farming practices. In recent years, there has been substantial re-vegetation of once-cleared private land areas within the lower catchment, comprising both extensive planting by landowners and natural regrowth of native species, especially pioneer species such as *Acacia* spp. South East Local Land Services (SE LLS) continues to work with a number of private landholders in the Booths Creek sub-catchment to rehabilitate stream frontages and improve the condition of the riparian corridor in the Booths Creek sub-catchment. The long-term view of the rehabilitation work is to provide the foundational structure for landscape-scale biodiversity corridors, improve stream health and water quality by reducing erosion potential and build resilience to floods, droughts, and threat of fire and weed infestation (SE LLS 2015).

A few examples of naturally regenerating riparian vegetation exist within crown reserve adjacent to watercourses. One such example includes that occurring along Sandy Creek at the Tanja junction bridge. A major flood event in 2010 swept away much of the vegetation at this site. The response has been rapid recolonisation by typical local streambank species, especially *Commersonia fraserii* (blackfellows hemp), a good illustration of the resilience of local native vegetation when not subject to grazing pressure by livestock.

2.3.6 WEED ISSUE

With the exception of a minor and now well-controlled infestation of bitou bush (*Chrysanthemoides monilifera* subsp. *rotundifolia*) on the dunes at Middle lagoon, weeds are largely restricted to the cleared and farmed land in the catchment.

Blackberry is quite widespread along creek lines in the farmland and is probably the most serious weed threat present in this catchment, given its capacity to swiftly envelope large tracts of land, harbour vermin and impede stock access to water.

The many other weed species present include *Senecio madagascariensis* (fireweed), *Cirsium vulgare* (sword thistle), *Gomphocarpus fruiticosus* (swan plant), *Verbena bonariensis* (purpletop), *Araujia sericifera* (moth vine), and *Agapanthus praecox* that are typical of longer-settled areas and disturbed sites.

2.4 COASTAL GEOMORPHOLOGY

Middle Lagoon is characterised as a wave dominated estuary (OzCoasts 2016, Roy *et al* 2001) and the geomorphic evolution of the estuary most likely follows that of other estuaries found on the south coast of NSW as described by Sloss *et al* (2007) and is briefly described below.

During the peak of the last ice age, approximately 12,500 years ago, the estuary was originally a river valley with a well-developed floodplain. This river valley was drowned by rising sea levels approximately 7,000 years ago, with beach sands pushed towards the coast leading to the formation of the barrier dune system that created the estuary.

Over the last 7,000 years the Estuary as been subject to continuous deposition from both the catchment and coastal environment. This has led to the formation of distinct estuarine zones (**Figure 5**), which include the: upper estuary; middle estuary; north and south basins; and the entrance.

- Lower reaches of Sandy Creek and Booths Creek comprise the upper estuary with current creek channels formed during the Quaternary. These channels are flooded with brackish waters when the berm at the entrance is at its maximum height.
- The middle estuary is dominated by fluvial sediments sourced from the catchment and deposited during flood events. It is estimated that these fluvial sediments have propagated into the middle estuary over the last 2,500 years, forming levee banks that bound the estuary channel. Estuarine back swamps have formed behind the levee banks
- The estuary channel extends almost all the way to the entrance. The majority of the bed level of the channel is likely perched above the low tide level. This means that even when the estuary entrance is open there is very little tidal flushing of the estuary channel and lower estuary.
- The north and south basins adjacent to the entrance of the lagoon are bounded by old Quaternary coastline and hilllsope to the west, and the by the Holocene sand dunes to the east that form Middle Beach.
- The entrance of the estuary, is a much younger deposit, and is subject to periodic erosion caused by waves, and flood flows during severe storm events. As such the boundary of this area is ambulatory, being subject to continuous erosion and deposition and changes to its morphology.

INTRODUCTION

The evolution of Middle Lagoon is almost mature, and depositional units within the estuary are generally much higher than that of both neighboring or nearby Nelsons Lagoon and Cuttagee Lake. This means that -

- Tidal flows in the lagoon are small and tidal flushing is limited, even when the entrance is fully open as observed in late January 2016.
- As the estuary is not subject to regular and / or significant tidal flushing, water quality of the lagoon is more sensitive to catchment inputs compared to permanently open, well-flushed estuaries, and as such is vulnerable to catchment disturbances.
- When the entrance is fully open, the organically enriched bed sediments of the estuary channel and estuarine back swamps are exposed to the air. Consequently the oxidation of exposed bed sediments often results in formation of hydrogen sulphide odours.
- Sedimentary units within the estuary are mapped and described in detail by Troedson and Hashimoto (2008).

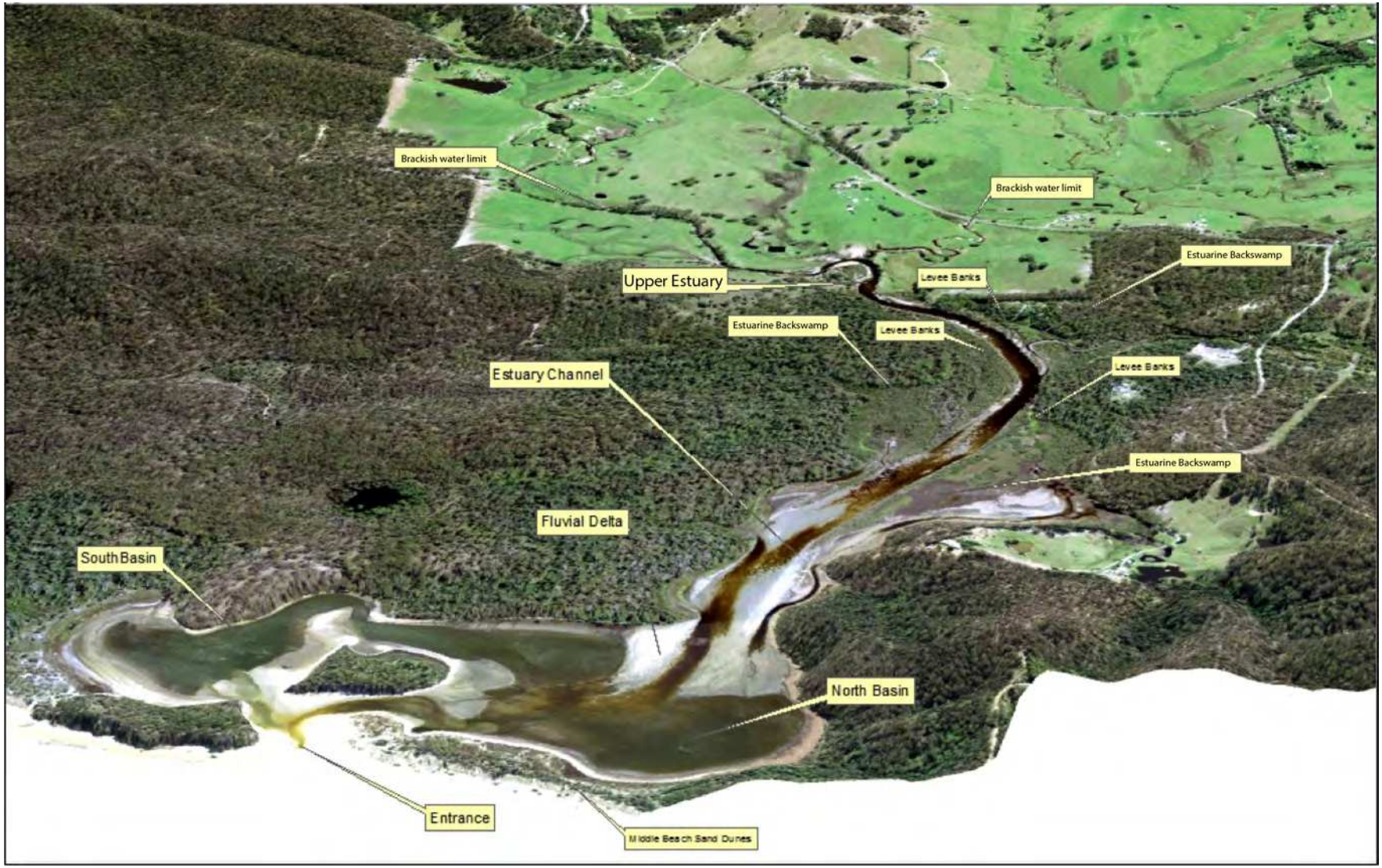


Figure 5. Geomorphological zones of Middle Lagoon.

2.5 ESTUARY ENTRANCE – OPEN AND CLOSED REGIME

The entrance of Middle Lagoon intermittently opens and closes to the ocean. Factors contributing to the intermittent nature of the estuary entrance include coastal sediment transport processes, climatic factors such as rainfall (among others), catchment size and limited freshwater inflows to maintain a permanently open ocean entrance, which becomes blocked by beach sands.

Water levels of the estuary are being monitored by OEH and Bega Valley Shire Council to gain a better understanding of the maximum height attained by the entrance berm during closed periods and the duration of entrance open periods. Preliminary data collected over the 4-month period from October 2015 to February 2016 shows the entrance opened twice over that period with the berm height reaching 1.98 mAHD and 2.066 mAHD prior to being breached (**Figure 6** and **Table 3**). The occurrence of two entrance openings over a 4-month period is likely an atypical trend and was due to the above average rainfall recorded over that period.

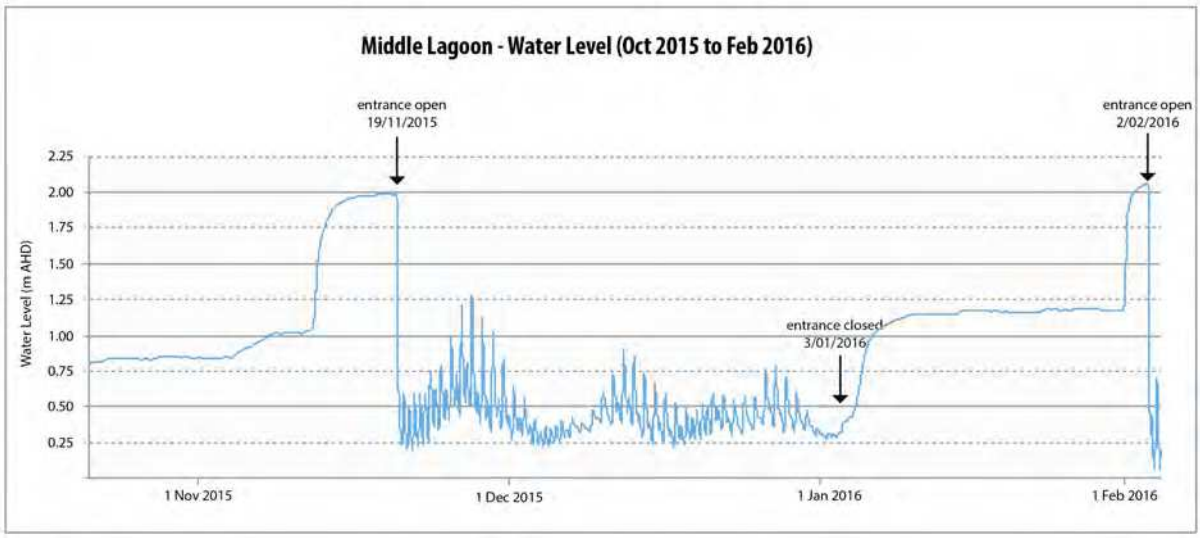


Figure 6. Middle Lagoon Water Levels (mAHD) from October 2015 to February 2016 (*data courtesy of MHL and OEH*).

Other data available for interpretation regarding the opening and closing regime of the lagoon include observations collected over a 6-year period (2010 to 2016) by local Tanja resident C. Nazer. Analysis of the time series data and observations suggest the following characteristics about the behavior of the estuary entrance:

- Entrance opening periods are on average approximately 44 days duration. Over the past six-year period (2010 to 2016), entrance open periods have ranged from 17 to 74 days with the entrance generally opening naturally once per year (**Table 4**). In addition to natural opening events, assisted artificial (and illegal) opening of the entrance has been common over this time period with the lagoon entrance being open on more than one occasion in years 2014 (two openings) and 2015 (three openings). The estuary is subject to tidal flows during open periods, however the tidal prism can vary significantly depending on the capacity and tidal efficiency of the entrance.

- Sand is supplied to the entrance from nearshore coastal sand transport and overtime becomes progressively cut-off off from tidal flows when the berm reaches approximately 0.8 to 1.0m AHD. Once blocked by beach sands the entrance closures are on average approximately 224 days duration. Over the past six years closed periods have ranged from 30 to 777 days (**Table 4**).
- During closed periods, lagoon standing water levels can exceed 2.0m AHD resulting in inundation of low-lying foreshore areas. Prolonged entrance closures such as the 777-day event that occurred between May 2012 and June 2014 and associated high water stands are not unnatural but can have a detrimental effect on foreshore vegetation with most tree, shrub and graminoid species unable to survive such long periods of inundation of brackish waters.
- In the period between October 2015 and February 2016 the maximum height attained by the entrance berm was 2.066 mAHD (**Table 3**). Previously, the entrance berm height has been modeled at 2.5 mAHD (*Refer Appendix D in* DLWC 2000). Monitoring estuary water levels of Middle Lagoon will continue to provide a better understanding of berm heights and duration of open and closed periods. Council does not intend to develop an entrance management policy for Middle Lagoon with the lagoon being allowed to open and close naturally.
- The entrance opens naturally when water levels in the estuary exceed the height of the berm. This generally occurs after a large rainfall event. The gradual and then sudden rise of water levels following catchment rainfall events triggering a breach of the entrance berm is shown in **Figure 6**.

A summary of Middle Lagoon entrance open and closed periods observed since 2007 and entrance berm heights where known is provided in **Tables 3** and **4**.

Table 3. Summary of Middle Lagoon entrance open – closed periods and water levels (2010 to 2016).

Entrance Open/Closed	Date [1]	Days Duration	Weeks Duration	Comment	Water Level (m AHD) at Opening [2]
open	17/02/2010	56	8.0		
closed	14/04/2010	467	66.7		
open	25/07/2011	59	8.4		
closed	22/09/2011	161	23.0		
open	1/03/2012	61	8.7		
closed	1/05/2012	777	111.0		
open	17/06/2014	74	10.6	Opened artificially	

closed	30/08/2014	98	14.0		
open	6/12/2014	41	5.9		
closed	16/01/2015	154	22.0		
open	19/06/2015	17	2.4	Opened artificially	
closed	6/07/2015	51	7.3		
open	26/08/2015	29	4.1		
closed	24/09/2015	56	8.0		
open	19/11/2015	45	6.4		1.983
closed	3/01/2016	30	4.3		0.3
open	2/02/2016	28	4.0		2.066

[1] Dates of open and closed periods provided by C. Nazer (Middle Lagoon Resident)

[2] Water level data from OEH and MHL.

Table 4. Statistical summary of Middle Lagoon entrance open – closed period

	Average duration (days)	Min duration (days)	Max duration (days)	Total Days	% Time
Entrance Openings	44	17	74	410	19%
Entrance Closures	224	30	777	1794	81%

Based on data collected over 6-year period, *17 February 2010 to 2 February 2016*

2.5.1 ECOLOGICAL SIGNIFICANCE OF OPEN-CLOSED REGIME

The intermittent open and closed entrance of Middle Lagoon (*i.e.* not permanently open to the ocean with a constant tidal regime) has had significant implications for the vegetation communities it supports around it shores and in its waters. A suite of species that require a tidal regime and that are present in nearby permanently open estuaries such as Nelson Lagoon, are absent from Middle Lagoon. These include mangroves (*Avicennia marina*) and the saltmarsh species *Limonium australe* (sea lavender)*, Tecticornia arbuscula, Austrostipa stipoides* and *Gahnia filum. Avicennia marina* (grey mangrove) seedlings do colonise the lagoon foreshore during entrance open phases with several seedlings evident in February 2016 (*pers. obs.* authors – **Figure 7**) but will always die-off once the entrance closes and lagoon waters become brackish.

Historically the lagoon entrance has been managed by a number of catchment landholders for a period of at least 70 years (*pers. comm.* N. Dummett, October 2015 – **Figure 8**), with the practice of artificially opening the entrance probably occurring since the late 1800s. The historical management practice of regularly opening the lagoon entrance maintained lower water levels in the estuary to provide regular access to low-lying lands for grazing and other agricultural uses. However, a consequence of artificial opening the lagoon entrance to regulate water levels has been the colonisation of foreshore areas by vegetation and tree species typically restricted to higher areas.

INTRODUCTION

Contemporary management of Middle Lagoon is the combined responsibility of NPWS, DPI Fisheries, DPI Lands and BVSC whose management policy regarding the lagoon entrance is that of – 'no artificial intervention'. In more recent times (at least past decade), Middle Lagoon has been allowed to open to the ocean naturally with estuary water levels remaining higher for naturally longer periods – typically up to 12 months and longer. As a result of water levels resuming a more natural pattern and high water stands becoming more prolonged at higher elevations, many of the tree, shrub and graminoid species that had colonised the low-lying foreshore areas are now dead or dying. This vegetation response extends well up into the lower reaches of Sandy and Booths Creek. The species primarily affected include *Melaleuca ericifolia,* and *Eucalyptus* trees such as *Eucalyptus bosistoana* (grey box), *E. longifolia* (woollibutt) and *E. botryoides* (bangalay), where these have been growing at low levels near the shores. There is also evidence of graminoids *Juncus kraussii* (sea rush) and *Bolboschoenus* sp. having been drowned in places, unable to tolerate the duration, depth and perhaps salinity of the recent high stands.

The foreshore vegetation of Middle Lagoon is currently undergoing a distribution shift back to what is natural according to the broader range of water levels and salinity regime associated with longer entrance closures. With anticipated rise in sea-levels expected by year 2100, further shifts in foreshore vegetation distribution are likely (further discussed in Section 4).

Figure 7. Ecological implications for the intermittent nature of Middle Lagoon. Grey mangrove (*Avicennia marina*) seedling that has opportunistically colonised the western foreshore of the lagoon during an entrance open phase (*left image*). An example of a dead stand of *Melaleuca ericifolia* on the southern foreshore of Middle Lagoon.

Figure 8. Historical management of the Middle Lagoon ocean entrance – circa 1950s (*photos courtesy of N. Dummett*).

2.6 ESTUARINE VEGETATION

Middle Lagoon supports a variety of estuarine macrophytes with greatest diversity of species found in the fringing saltmarsh community. Lagoon waters are characterised by a highly variable salinity ranging from 10 to 37 ppt, although lagoon waters are typically brackish (<20 ppt). Consequently, the lagoon supports, at times, extensive areas of *Ruppia* sp. (tassel-weed) and smaller localised patches of *Zostera* seagrass. In the most recent assessment of estuarine vegetation cover (Creese *et al.* 2009), these macrophytes were estimated to collectively cover 0.211 km^2 in area (**Figure 9**). Saltmarsh community fringes discrete areas of the estuary edge and is estimated to cover 0.052 km^2 in area (Creese *et al.* 2009). The largest area of saltmarsh is located on private land adjacent to the Sandy Creek channel.

The lagoon also supports a variety of macroalgae and is at times affected by large abundances of a few fast growing, opportunistic species, symptomatic of eutrophication. Seasonal blooms of macroalgae have included the green algae *Chaeotomorpha* sp. and *Ulva* sp. (as synonym *Enteromorpha* sp. as reported by Wiecek 2001) with spring-summer blooms of the red alga *Gracilaria chilensis* recorded in 2011 and 2012 (Elgin 2014).

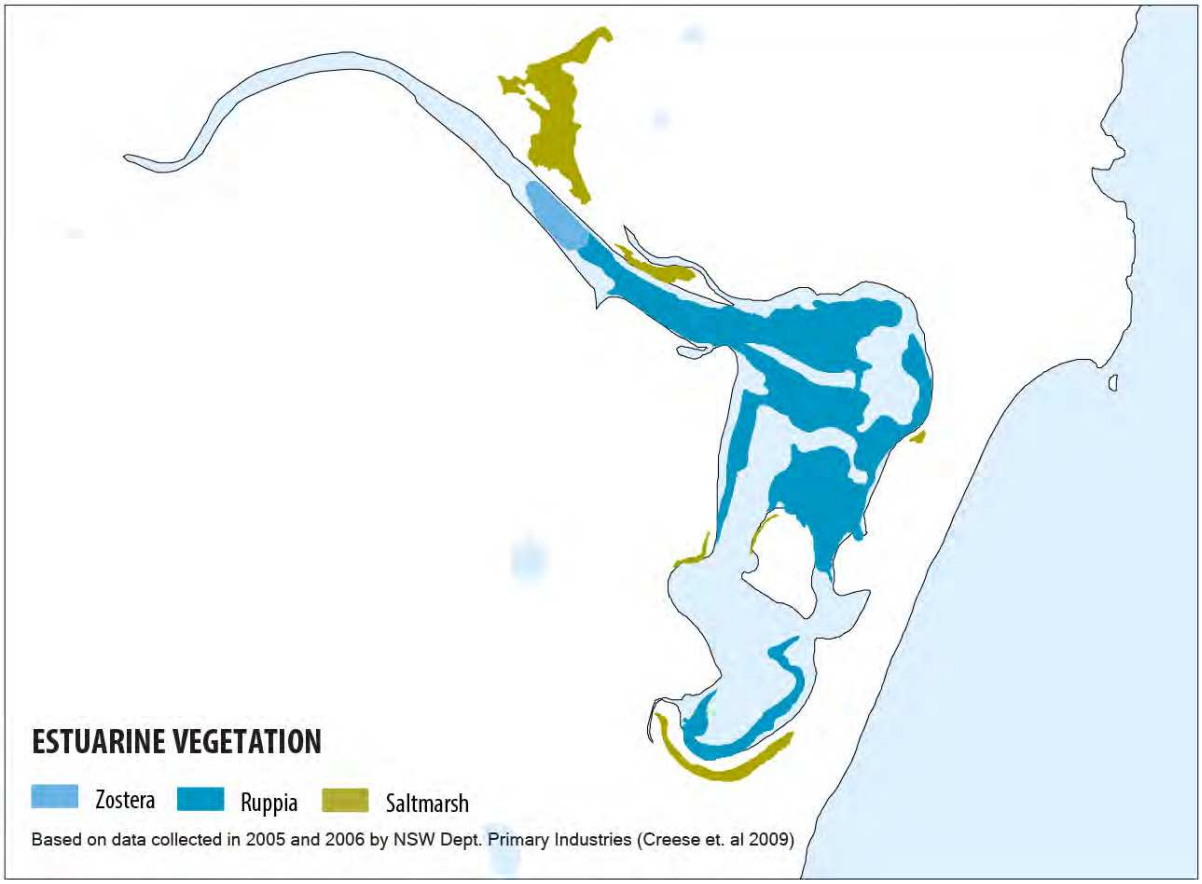


Figure 9. Estimated spatial extent of estuarine habitats of Middle Lagoon (from Creese *et al.* 2009 - based on aerial imagery from March 2005 and field survey March 2006).

2.7 WATER QUALITY AND ESTUARINE ECOSYSTEM HEALTH

2.7.1 WATER QUALITY

Assessments of water quality and ecosystem health of Middle Lagoon include studies undertaken by Wiecek (2001) and more recently by council (2010-2013).

The study by Wiecek (2001) investigated the water quality and trophic status of Middle Lagoon. This included monitoring a suite of physico-chemical water quality parameters as well as eutrophication indicators chlorophyll-*a* and macroalgal abundance. The study found that Middle Lagoon had levels of nutrients (TN, TP, ammonium) consistently exceeding the ANZECC guidelines and at periods was affected by high chlorophyll *a* concentration and high abundance of macroalgae, symptomatic of eutrophication. Wiecek (2001) observed signs of improved water quality when the lagoon was open to the ocean for more than a one-month period with reduced levels of nutrients and improved water clarity. Wiecek (2001) classified Middle Lagoon as a mesotrophic to borderline eutrophic system concluding that the ICOLL is naturally prone to the effects of eutrophication given that its catchment was relatively intact (*i.e.* <30% cleared). The study highlighted that for some ICOLLs such as Middle Lagoon, anthropogenic influences act with the natural vulnerability of a system to contribute to water quality degradation and symptoms of eutrophication. Further land use change in the catchments of such systems will only lead to further degradation.

INTRODUCTION

A more recent water quality assessment was undertaken by BVSC over the three-year period 2010 to 2013 (Elgin 2014) to gain a better understanding of the variable water quality conditions of the estuary with data collected during periods when the estuary entrance was open and closed, and following significant rainfall events. Estuary health was assessed in terms of eutrophication indicators including microalgal abundance (as chlorophyll a), water clarity (as turbidity) and water column nutrients.

The water quality conditions of Middle Lagoon can be summarised as having:

- Typically high levels of dissolved oxygen (DO);
- High to moderate water clarity (*i.e.* low turbidity);
- Highly variable salinity (**Figure 10**);
- Elevated levels of nutrients which regularly exceed recommended guideline limits for the protection of estuarine aquatic ecosystems; and
- Seasonal blooms of macroalgae and periodic blooms of microalgae are common, though not considered a serious threat to ecosystem health.

These water quality trends are generally evident irrespective of the entrance being closed or open. Water clarity and surface water salinity do decline during closed periods although water clarity was not strongly influenced by entrance open-closed status. Factors influencing water column salinity include the status of the entrance, amount of catchment inflow and climate (*i.e.* evaporation). The highly variable salinity of the lagoon between 2010 and 2013 is shown in **Figure 10**.

Depth profiling indicated that wind advection and hydraulic turbulence caused by flood flows were effective water column mixing processes in the absence of tidal flushing with water quality parameters generally uniform throughout the water column.

Overall, water quality of Middle Lagoon ranges between 'fair' and 'good' based on data collected from 2010 to 2013 (Elgin 2014).

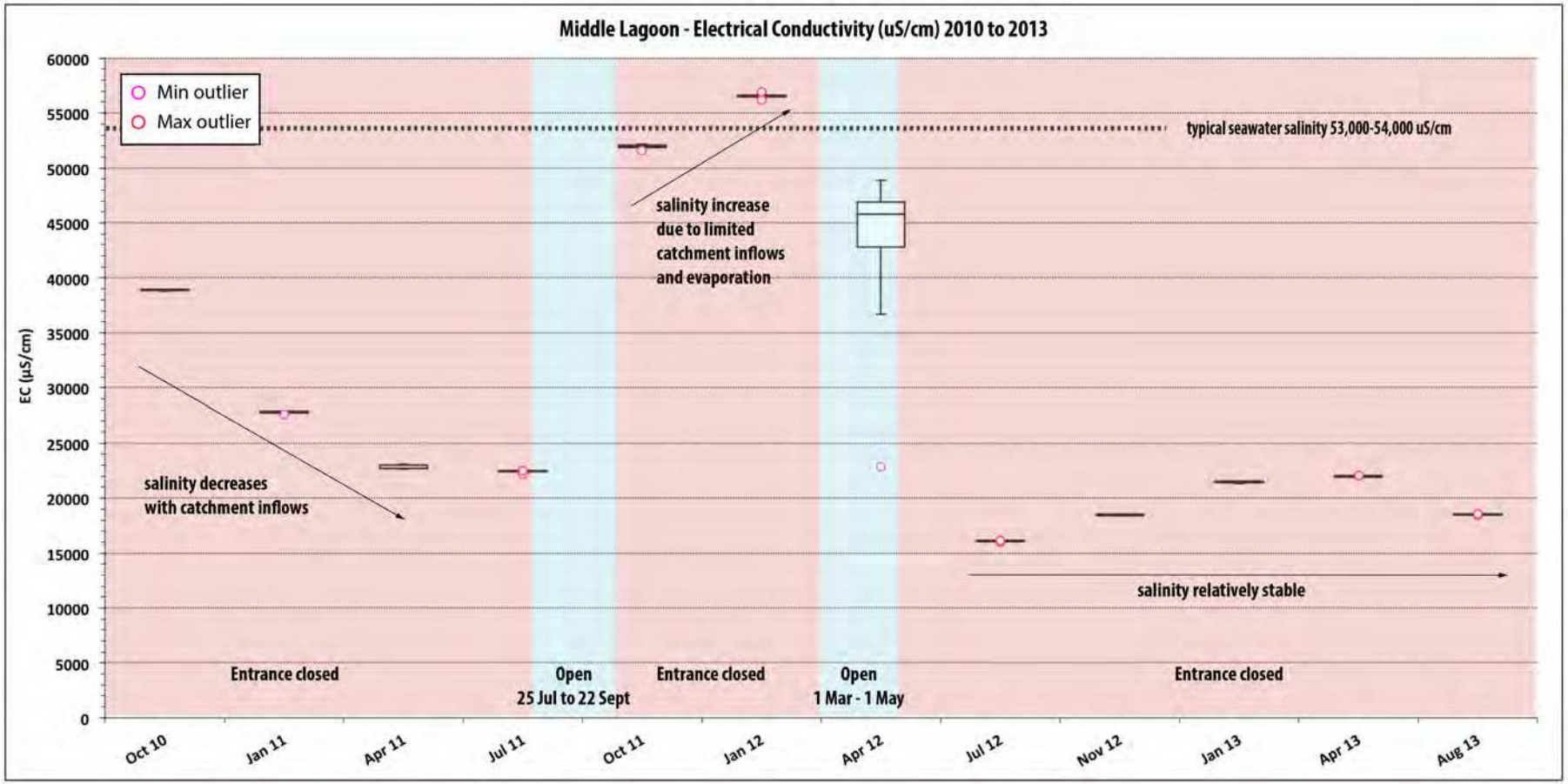


Figure 10. Variable salinity of Middle Lagoon observed over the period 2010 and 2013.

2.7.2 ESTUARINE ECOSYSTEM HEALTH

In NSW, estuary ecosystem health is based on a suite of ten (10) indicators that address state-wide coastal issues including eutrophication, habitat availability and fish assemblages. Indicators represent elements of the structure, function and composition of estuarine ecosystems and are summarised in **Table 5** below. Detailed information regarding the adopted indicators is provided in *Assessing the condition of estuaries and coastal lake ecosystems in NSW* (Roper *et. al.* 2011).

Table 5. Environmental indicators used to assess estuarine ecosystem health in NSW

Issue	Indicator
Eutrophication	microalgal abundance as phytoplankton determined by chlorophyll *a*;
	macroalgal abundance;
	water clarity as turbidity
Habitat Availability	extent of seagrass
	extent of mangroves
	extent of saltmarsh
Fish Assemblages	species diversity and composition
	species abundance
	nursery function
	trophic integrity

In 2010, a comprehensive assessment of estuarine ecosystem health for Middle Lagoon and the pressures acting upon it was completed as part of statewide estuary health reporting (DECCW 2011). The assessment provided Middle Lagoon with an overall condition index of 4.0 (out of 5), rated as being good based on three of six estuarine health indicators including extent of seagrass, extent of saltmarsh and fish assemblages. No data was available for chlorophyll *a*, macroalgae or turbidity and consequently the overall assessment was provided with low confidence. Seagrass and saltmarsh extent were rated as 'very good' with an estimated increase of at least 10% cover over the 20-year period between 1985 and 2006. The assessment also provided Middle Lagoon with an overall pressure index of 3.9 (out of 5), rated as having low to very low pressure in terms of pressure indicators – population, freshwater flows, disturbed habitat and tidal flows. Cleared land, sediment and nutrient inputs, and extractive fishing were rated as a moderate pressure.

In 2014, a subsequent assessment of ecosystem health was provided based upon eutrophication indicators only (microalgal abundance, turbidity and nutrients). In terms of eutrophication indicators, Middle Lagoon was provided a condition index of 4.0 (out of 5.0), rated as being in good condition (Elgin 2014) with results summarised in an Ecosystem Health Report Card (**Figure 11**).

MIDDLE LAGOON ESTUARY

ECOSYSTEM HEALTH REPORT CARD 2010-13

Ecosystem health was assessed using indicators of eutrophication including microalgal abundance (as chlorophyll a), water clarity (as turbidity) and water column nutrients. The assessment is based on data collected from the north and south basin (Zones 1 & 2) on a seasonal basis over the 3-year period, spring 2010 to winter 2013.

Estuary Information (OEH 2014, NLWRA 2001)

Catchment area: 27.3 km² (approx. 28 % cleared)
Estuary area: 0.6 km²
Estuary type: semi-mature, saline coastal lagoon
Entrance: intermittently open or closed, generally closed
Major tributaries: Sandy Creek, Booths Creek
Central basin average depth: 0.7 m

Surface waters were characterised by healthy levels of dissolved oxygen (DO), high water clarity and lows levels of microalgae majority of the time. Levels of DO declined slightly following the opening of the lagoon entrance, although not to levels detrimental to the health of aquatic fauna. The entrance opened naturally on two occasions during the monitoring period, in winter 2011 and autumn 2012 following heavy rainfall in the catchment. The openings were short-lived, with the entrance closing again within a six to eight-week period. Lagoon waters are influenced by tannins and salinity levels are highly variable ranging from brackish (EC ~16,000 µS/cm) to marine (EC ~56,000 µS/cm).

Water column nutrient levels regularly exceeded guideline limits with a mean Total Nitrogen concentration of 890 ug/L and a mean Total Phosphorous concentration of 26 µg/L. The lagoon was also periodically affected by a high abundance of microalgae and/or macroalgae.

Information regarding the distribution, extent and condition of estuarine vegetation presented here is based on data collected in 2005 and 2006 by NSW Department of Primary Industries (OEH 2010, Creese *et al.* 2009).

The ecosystem health assessment for the 2010-2013 period provided the estuary with an overall score of 4.0, the lagoon rated as being in good condition (Grade B) based on the eutrophication indicators chlorophyll *a* and water clarity.

For further detailed information about Middle Lagoon and Council's estuary health monitoring program, please refer to Estuary Health Monitoring Report Series Number 4 (Elgin 2014d).

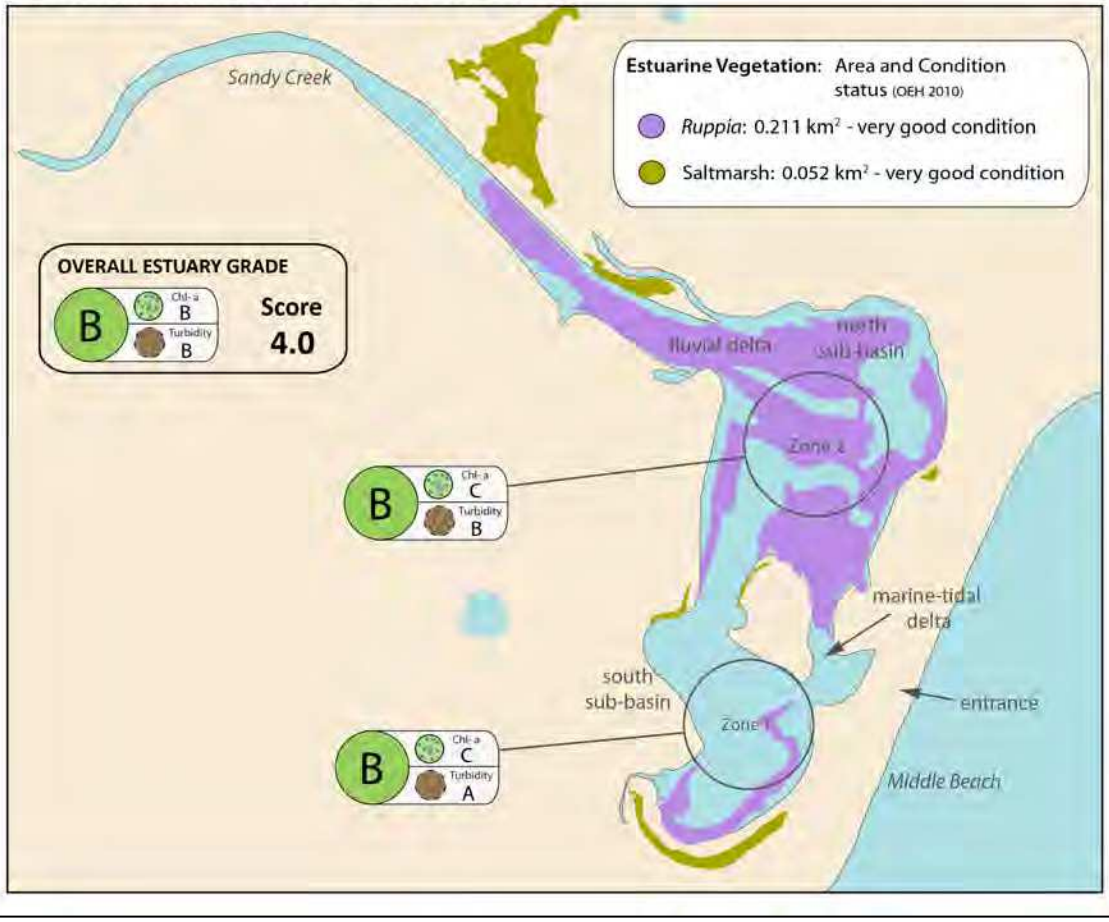


Figure 11. Ecosystem Health Report Card for Middle Lagoon (based on 2010-2013 WQ data)

3 CULTURAL HERITAGE

The Middle Lagoon catchment is part of country belonging to the Yuin people who have inhabited this region for at least 20,000 years (NPWS 2009). Oral tradition and physical evidence indicate the Yuin maintained a thriving society that incorporated sophisticated exchange patterns and rich social and ceremonial lives. Estuaries such as Middle Lagoon provided bountiful seafood resources including fish, shellfish and eels.

Middle Lagoon is significant to local Aboriginal people and it is acknowledged that the beach and lagoon areas contain extensive archaeological values (BVSC 2010). In regards to this matter, it is recommended that an archaeological survey be completed prior to commencing any works disturbing ground particularly in relation to actions recommended in this report. Surveys should be conducted by a qualified archaeologist in consultation with the Bega Local Aboriginal Land Council.

4 SEA-LEVEL RISE

The effect of predicted sea-level rise (SLR) associated with climate change was considered during this study in context of potential change to the estuarine environment, and in particular how SLR may affect areas of high conservation significance (*i.e.* EECs such as coastal saltmarsh community). A Digital Elevation Model (DEM) for Middle Lagoon was created using Arc GIS 10 to analyse various tidal levels and berm heights associated with predicted sea level rises.

In discussing the potential effect of predicted SLR on the estuary, it is important to note the estuary was formed as a consequence of global SLR approximately 7,000 years ago. Since that time, small variations in sea level of +/-1.5m have occurred relative to present day sea-levels on the southeast coast of Australia (White *et al* 2014; Sloss *et al* 2007). Hence, the estuary has adjusted to changes in sea level in the past. Consequently the main impact of SLR will likely be on the built environment and low-lying private and public assets. In particular, some access roads and agricultural grazing lands will likely become inundated more often.

The effects of SLR on Middle Lagoon were examined with respect to anticipated increased extent of estuary foreshore inundation associated with high water stand during entrance closed periods. As sea-level rises it is anticipated that there will be a concomitant increase in sand supply to the shoreline resulting in a corresponding increase in berm height at the estuary entrance (OzCoasts 2016b). Hence, the maximum height of the berm may increase by the corresponding maximum increase in sea level. High water stand of Middle Lagoon during entrance closed periods is presented in **Figure 12** comparing maximum berm height at present day sea-level with predicted maximum berm height for year 2100. The mapping was based on the following simplistic approach and is a useful preliminary assessment of SLR for this study:

4.1 EXISTING TIDAL ELEVATION

Mean High Water Springs (MHWS) for Middle Lagoon was based on the nearest tidal monitoring station of Port of Bermagui (OEH 2012).

MHWS (Bermagui) = 1.27 m (MHWS of Tidal Gauge) + (-0.714 m AHD [Elevation of Gauge])

= 0.556 m AHD

MHWS only applies when the entrance to Middle Lagoon is open and subject to large tidal flows.

When examining spatial data modelling of the DEM in ArcGIS, it is evident that majority of land surface in the estuary imagery exceeded 1.8 mAHD indicating that the entrance was closed at the time of LiDAR acquisition in 2008, and that standing water levels in Middle Lagoon was at least 1.8 mAHD at the time. Hence, tidal areas of Middle Lagoon were unable to be identified based on analysis of the DEM.

4.2 PREDICTED SEA-LEVEL RISE

CSIRO has developed a model for sea level rise for years 2030, 2050 and 2100 relative to 1990 (OzCoasts 2016b). Mapping presented in **Figure 12** (below) uses the high-end scenario of a 1.1m increase in sea level by 2100. The corresponding increase in MHWS relative to the Australian Height Datum (AHD) and predicted berm heights for years 2030, 2050 and 2100 are provided in **Table 6.**

It is important to note that BVSC has adopted a sea level rise policy for planning purposes that is consistent with the former NSW Government's SLR Policy and provides for an increase in mean sea level of 0.91m by 2100 above 1990 levels (BVSC 2013). There is still considerable uncertainty surrounding estimates of future SLR. Therefore, mapping presented in **Figure 12** shows a greater potential inundation of areas than what would be expected under a SLR scenario of a 0.91m increase above 1990 levels, and in terms of planning purposes, presents a more conservative approach using a higher estimate of future SLR.

Table 6. Predicted MHWS and maximum berm heights for Middle Lagoon based on maximum projected Sea-Level Rise (SLR)

Year	Sea-Level Rise Ozcoasts (2016b)	Predicted MHWS (AHD)	Predicted Max. Berm Height (AHD)
2030	0.2 m	0.756 m	2.7 m
2050	0.7 m	1.256 m	3.2 m
2100	1.1 m	1.656 m	3.6 m

2100 Sea-level Rise and Increase in MHWS

The digital elevation model enables calculation of the likely change in estuary tidal area due to a 1.1m increase in sea level by year 2100 compared to present day MHWS. However, the predicted increase in tidal level for year 2100 MHWS of 1.656m could not modeled for Middle Lagoon as the estuary water levels (due to entrance closure) at the time of LiDAR data capture exceeded the predicted increase in tidal level.

2100 Sea-level Rise and Increase in Berm Height

As sea-level rises it is anticipated there will be a concomitant increase in sand supply to the shoreline effectively resulting in a corresponding increase in berm height at the estuary entrance (OzCoasts 2016b). Hence, the maximum height of the berm will increase by the corresponding increase in sea

level. A present-day maximum berm height for Middle Lagoon has been modelled at 2.5 mAHD (DLWC 2000). Therefore, the maximum berm height for year 2100 is as follows:

Maximum Berm $_{2100}$ height =

2.50 mAHD (DLWC 2000) + 1.1 m = 3.6 mAHD

Based on analysis of the DEM, an increase in the maximum berm height to 3.6 mAHD would result in the periodic inundation of an additional area of 0.27 km^2 (**Figure 12**) during entrance closed periods. This is equivalent to a 24% increase in brackish water area compared to present-day.

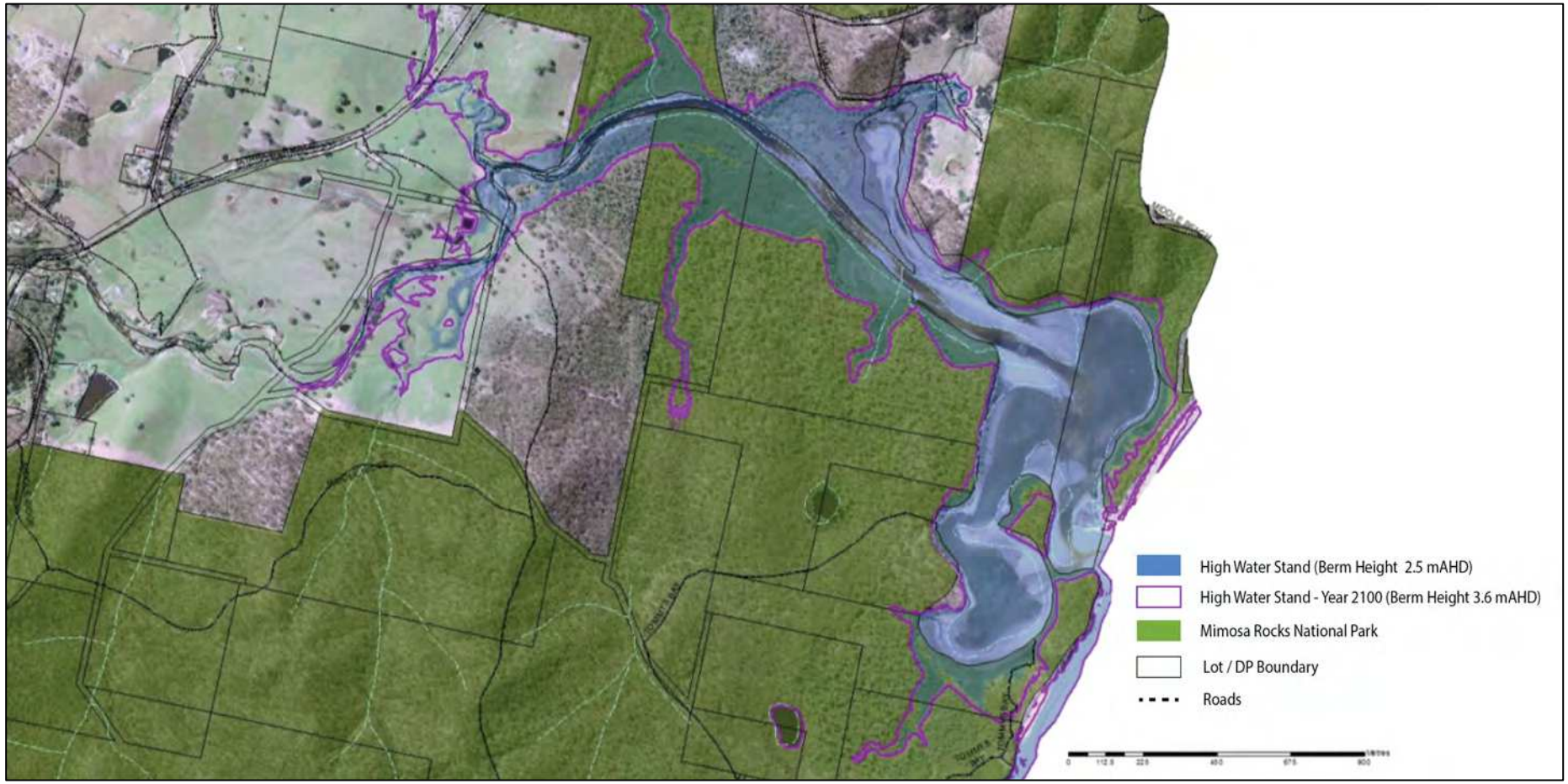


Figure 12. Middle Lagoon high water stand for maximum berm height of 2.5 mAHD compared to predicted maximum berm height of 3.6 mAHD associated with sea level rise for year 2100 (Ozcoasts 2016b).

4.3 LIKELY AND POTENTIAL EFFECTS OF SEA-LEVEL RISE ON MIDDLE LAGOON

Likely effects of a 1.1m sea-level rise on Middle Lagoon include:

- Tidal waters will extend further upstream;
- Periodic inundation of an additional area of 0.27 km^2 compared to present day during entrance closed conditions; and
- Existing low-lying roads, crossings and agricultural grazing lands will become inundated more often.

An increased sea-level may result in variable behaviour of the estuary entrance due to associated climatic changes. Two scenarios are possible:

1) the berm may be permanently breached and estuary may become tidally dominated; or
2) an increase in sea-level may translate to a corresponding increase in the berm height such that the entrance will behave in much the same way that it does today with an open-closed regime. The potential effects of each scenario are discussed below.

Under scenario 1, the estuary may become dominated by marine conditions similar to Nelson Lagoon. Mangrove communities may establish in shallow tidal areas that are currently occupied by fringing stands of *Melaleuca ericifolia*. The current extent of coastal saltmarsh will become permanently inundated and may be replaced over time with submergent macrophytes such as *Ruppia* spp. Saltmarsh communities will retreat where suitable opportunities for retreat exist. Seagrass meadows are likely to become more prevalent in the estuary assisted by an increase in marine tidal-delta.

Under scenario 2, the entrance will behave in the same way that it does today where the estuary will experience open and closed periods and the berm will be subject to breaching during flood events. The estuary will still experience a broad range of ecological conditions (*i.e.* variable salinity regime and periods of inundation) similar to present day levels. There is likely to be a shift in the distribution of vegetation communities relative to elevation requirements. Under this scenario, the total brackish area of the estuary is estimated to increase by approximately 24% when the entrance closes. The tidal area will also significantly increase during periods when the berm is breached. The estuary would likely behave in a very similar way to how nearby Cuttagee Lake operates today.

APPROACH AND OUTCOMES

5 COMMUNITY AND STAKEHOLDER CONSULTATION

Approach to Community and Stakeholder Engagement

The aim of consultation was to raise awareness and provide opportunity to community and stakeholders to input to the project regarding catchment and estuary values, management issues and concerns. Community and stakeholder consultation was important to prioritising erosion management areas for targeted rehabilitation, achieving a high level of understanding, involvement and overall acceptance of the proposed management recommendations.

The terms of reference for this project were specifically focused on addressing erosion and sedimentation issues for the protection and improvement of estuarine water quality values. However a number of other management issues such as limited boating access and estuary entrance closures and illegal openings were identified through consultation and are also documented.

Consultation was undertaken using a combination of the following methods:

- Distribution of letter and consultation plan to stakeholders and catchment residents;
- Online survey to gather input regarding catchment values and issues from community and stakeholders;
- Media release - BVSC website and ABC radio
- Meeting with stakeholder representatives and individual landholders;
- Monitoring and responding to email and telephone feedback; and
- Facilitation of community information session to present findings of catchment and estuary erosion issues and management recommendations (30 March 2016).

Distribution of Letter and Consultation Plan

A hard-copy letter including consultation plan explaining project objectives and seeking input to the project was sent to landholder residents within the catchment at the commencement of the project in July 2015. The consultation plan provided brief overview of catchment characteristics and ecological values including terrestrial vegetation communities of conservation significance, types and extent of estuarine vegetation, catchment land uses, commercial fishing rights and water quality. The consultation plan is provided in **Appendix A**.

A digital copy of the consultation plan was also distributed to key representatives of each of the following stakeholder agencies whose responsibilities are summarised in **Table 7**.

- Bega Local Aboriginal Land Council (Bega LALC)
- National Parks and Wildlife Service (NPWS)
- Bega Valley Shire Council and members of Coastal Committee
- Southeast Local Land Services (SELLS)
- Dept. of Primary Industries – Fisheries
- NSW Roads and Maritime Services (RMS)
- Dept. of Primary Industries – Lands (formerly Crown Lands)

Table 7. Summary of Stakeholder, Responsibility and Key contact representative

Stakeholder Agency	Contact
Bega Local Aboriginal Land Council (Bega LALC) As the State's peak representative body in Aboriginal Affairs, the NSW Aboriginal Land Council aims to protect the interests and further the aspirations of its members and the broader Aboriginal community. The Bega Local Aboriginal Land Council receives funding from this State body (from asset generated funds) to undertake projects and programs specific to the local community of the Bega land area that includes the catchment area of Middle Lagoon.	Glenn Wilcox Chief Executive Officer ceo_begalalc@commander.net.au
Bega Valley Shire Council (BVSC) Council is a local statutory authority with powers and responsibilities conferred from State and Federal Parliament. The main piece of legislation that details the powers of local councils is the *Local Government Act 1993*. Council provides a range of day-to-day services for our community and Bega Valley Shire Council is committed to ensuring that the Council and the community work in partnership to achieve the best outcome for the Shire. Responsible for a broad range of programs the Environment Section of the BVSC is involved in estuary, storm water, waste, water, sewage, weed and road management programs.	Kyran Crane Coastal Management Officer K.crane@begavalley.nsw.gov.au Daniel Murphy Coordinator of Environmental Management D.murphy@begavalley.nsw.gov.au
Department of Primary Industries - Lands (Lands) DPI Lands is responsible for the sustainable and commercial management of Crown land. Lands manages the development, marketing and sales of crown lands not required for public purposes. Various land uses are authorised by Lands including: waterfront occupations, commercial, grazing and agriculture, residential, sporting; community purposes, tourism, and industrial. It manages these Crown lands through a variety of methods such as licensing, leasing, sale and disposal of surplus crown and other state-owned lands. Lands also provide land information/status and land accounts services as well as a map and products sale centre.	Grant Merinuk grant.merinuk@crownlands.nsw.gov.au
Office of Environment and Heritage (OEH) The Office of Environment and Heritage works to protect and conserve the NSW environment, including the natural environment, Aboriginal country, culture and heritage and our built heritage, and manages NSW national parks and reserves. OEH develops and leads policy, reform and education in sustainability, biodiversity and native vegetation, coastal protection and Aboriginal cultural heritage.	Daniel Wiecek Senior Natural Resource Officer – Coasts and Estuaries (Southeast Region) daniel.wiecek@environment.nsw.gov.au

Department of Primary Industries - Fisheries Responsible for the management of recreational fishing, commercial fishing, aquaculture, habitat management, species protection, disease and pest management, research and compliance in NSW in accordance with the *Fisheries Management Act 1994*. Responsibility and jurisdiction over waterway areas up to mean high water mark.	Matt Proctor District Fisheries Officer Eden 02 4476 0100 matt.proctor@dpi.nsw.gov.au
National Parks and Wildlife Service (part of OEH) NSW has 879 national parks and reserves that protect a diversity of landscapes and cultural heritage sites while providing for public access to camping sites, walking tracks and picnic/BBQ facilities. NPWS is responsible for management of lands protected under the *NPW Act 1974* to mean high water mark of estuaries and ocean.	Kathryn Brown Ranger Mimosa kathryn.brown@environment.nsw.gov.au
NSW Roads and Maritime Services (RMS) RMS is responsible for management of network of state and national roads in NSW and associated infrastructure such as bridges, culverts and tunnels. RMS also manages navigable waterways, wharves and maritime safety aids for commercial and recreational boating.	Darren Hulm darren.hulm@rms.nsw.gov.au Graham Roche Environment Manager graham_roche@rta.nsw.gov.au
Southeast Local Land Services (SE LLS) Locally based and managed organisation with a Board of local people, reporting directly to the NSW Minister for Office of Environment and Heritage. It is a statutory body established under the *Catchment Management Authorities Act 2003* to facilitate and coordinate the management of natural resources in the southeastern NSW. SELLS responsibilities include involving local communities, farmers and other land managers, Landcare, government agencies, Aboriginal people, local government and industry in addressing the natural resource management issues facing the region. Through SELLS and its partnerships and programs, the NSW and Australian Governments provide funding for strategic on-ground works to help protect and restore natural resources across the landscape.	Andrew Taylor Senior Lands Services Officer andrew.taylor@lls.nsw.gov.au David McCreery Senior Lands Services Officer david.mccreery@lls.nsw.gov.au

5.1 ONLINE SURVEY QUESTIONNAIRE

An online survey questionnaire was developed to gain an overview of the catchment and estuary values important to the community. Survey respondents were asked specific questions focused on level of concern for estuarine water quality, catchment condition and the periodic closure of the estuary entrance.

Respondents were also asked to rank ten general catchment issues in order of greatest to least impact that they considered were negatively affecting catchment condition and water quality of Middle Lagoon. A copy of the online survey is provided in **Appendix A**.

The findings from the community survey is provided in the sections below.

5.2 COMMUNITY VALUES AND CONCERNS FOR MIDDLE LAGOON AND CATCHMENT

The online survey received a total of 32 respondents (16 resident landholders in the catchment, 15 community members located outside the catchment, and 1 stakeholder) who expressed their values and concerns for Middle Lagoon.

5.2.1 VALUES

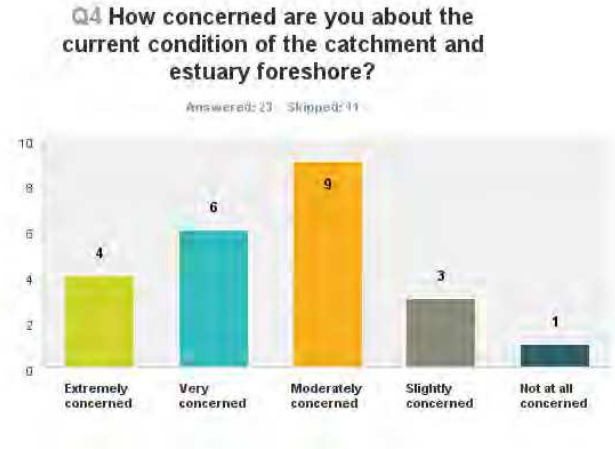
The consensus among survey respondents was that Middle Lagoon is valued most for its ecological and social values, followed by economic values associated with tourism and commercial fishing. A summary of the ecological, social, economic and other values provided by survey respondents are provided in **Table 8.**

Table 8. Community Values of Middle Lagoon

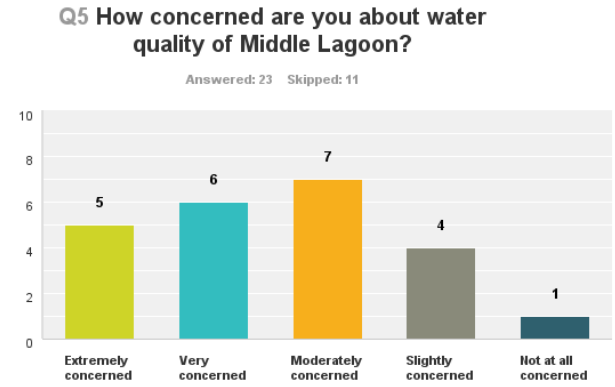
Ecological	Flora and fauna communities, birdlife, sea eagles, tidal flows when open, intermittent flood regime, aquatic habitats, fish nursery, good water quality, saltmarsh community, bio-luminescent organisms
Social	Kayaking and canoeing, fishing, prawning, swimming, bushwalking, picnics, camping
Economic	Direct and indirect tourism benefits to local businesses that rely on the ecological and social values (*i.e.* recreational opportunities) of the lagoon that attract visitors to area. Productive commercial fishery for fish, prawns, crabs and eels. Freshwater extraction from Sandy Creek for domestic use.
Other	Environmental aesthetic, pristine condition, isolation from human population and relatively low level of human interference, sustainable uses and minimal impacts

5.3 CONCERNS AND ISSUES

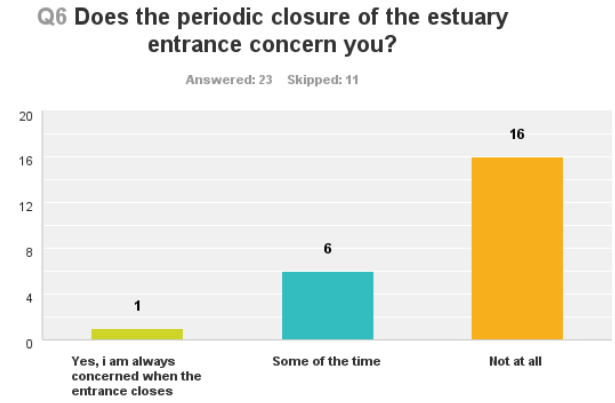
Survey respondents were asked to rank their level of concern for the current condition of the catchment and estuary foreshore, water quality of Middle Lagoon and whether the periodic closure of the entrance was a concern. While the questions were broad in nature, the responses provide a general indication of community sentiment regarding these matters with survey results provided in **Figure 13.**



Majority of survey respondents have some level of concern for current condition of the catchment and estuary foreshore



Majority of survey respondents are concerned about water quality



The periodic closure of the estuary entrance is not a concern for most survey respondents.

Reasons of concern include:

- Perceived decline in water quality;
- Higher risk of impacts to water quality during closed periods;
- Odours that occur when the entrance opens following a prolonged closure
- Indicates low rainfall and low catchment inflows

Figure 13. Community concerns for catchment condition, water quality and periodic closure of the estuary entrance.

APPROACH AND OUTCOMES

The two issues that were consistently ranked highest among survey respondents as having the greatest negative impact on the catchment condition and water quality of the estuary were:

1) Unfenced creek lines and stock impacts; and

2) Lack of riparian vegetation due to historical vegetation clearing.

The rank order of all ten issues is provided in **Table 9** based on the score averaging from all survey respondents. For instance, the closure of the estuary entrance was considered to be having a moderately high negative impact by survey respondents. Overall, however, the issue is considered to be having the least negative impact on catchment and estuary condition when compared to other issues. 4

Table 9. Ten general catchment issues ranked in order of greatest to least impact on catchment condition by survey respondents (only 38% of respondents completed)

Greatest Impact	1. Unfenced creek lines and stock impacts
	2. Lack of riparian vegetation due to historical clearing
	3. Poorly maintained unsealed roads
	4. Bank erosion
	5. Wetland degradation (freshwater or saltmarsh)
	6. Forestry practices
	7. Ad-hoc foreshore access
	8. Weed infestation
	9. Illegal drains or weirs
Least Impact	10. Estuary entrance closure

Note – Rankings based on score averages of 13 of 34 responses provided

APPROACH AND OUTCOMES

6 CATCHMENT AND FORESHORE EROSION ASSESSMENT

6.1 CATCHMENT TERRAIN AND POTENTIAL EROSION ASSESSMENT

A catchment terrain and potential erosion assessment was undertaken in Arc GIS 10. The assessment was undertaken using a digital elevation model (DEM) for the Middle Lagoon Catchment (**Figure 14**). The DEM was created using 0.5m LiDAR (Light Detection and Ranging) elevation data captured in 2008 and provided by Council for project use. LiDAR is able to detect subtle topographic features such as river terraces and river channel banks, and measure the land-surface elevation beneath the vegetation canopy. It is able to resolve spatial derivatives of elevation, and useful for detecting elevation changes between repeat surveys that enables better understanding of physical processes that shape landscapes.

Other GIS datasets including aerial images, soils, watercourses, roads, and land tenure were incorporated into the assessment. This data was then used to locate and estimate the extent of potential erosion for the following types:

- Road erosion
- Logging track erosion
- Embankment erosion
- Bank erosion
- Foreshore erosion
- Head cut and nick point erosion

Potential catchment erosion sites identified in the assessment are shown in **Figure 15** (attached). The length width and depth of erosion for various erosion types was measured from the DEM, Hillshade, and slope models inside Arc GIS 10. Analysis was also undertaken on soil types and proximity to a watercourse.

A catchment erosion assessment matrix (**Table 10**) was developed to characterise each potential erosion site. The assessment details the erosion type, sediment yield, threats caused by erosion, responsible landholder / agency, management priority (based on estimated sediment yield), and likely cause of erosion.

The results of the potential erosion assessment are contained in a GIS shapefile. Only selected sites were ground-truthed during field inspections as inspection of all areas was not achievable within the scope of this project. Many of the potential erosion sites exist within the upper catchment and were not validated by visual assessment. Further field investigation would be required to validate the current status of majority of potential erosion sites.

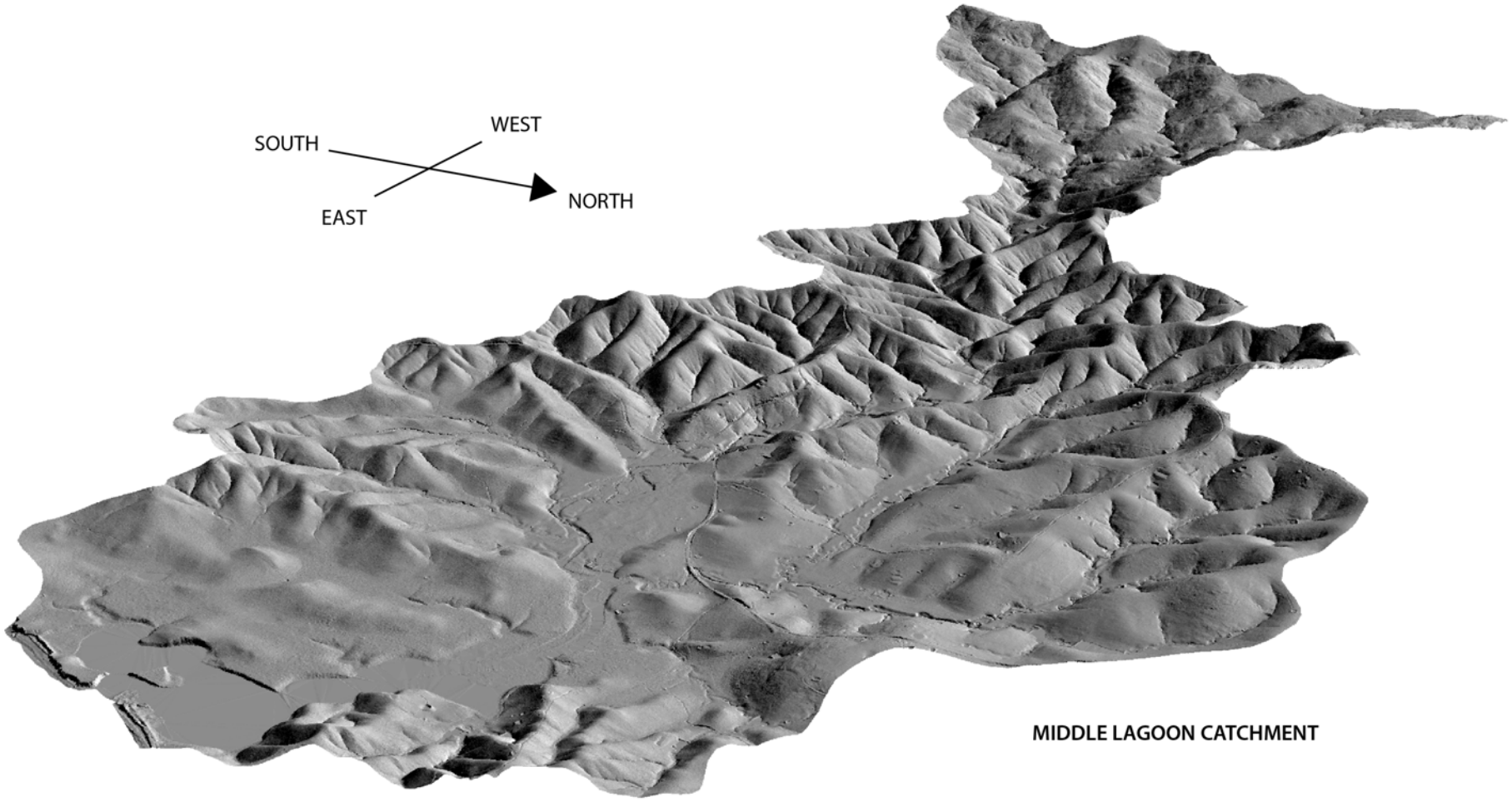


Figure 14. An enhanced Digital Elevation Model (DEM) and Hillshade model of Middle Lagoon Catchment.

Table 10. Sample output of Catchment Erosion Assessment (GIS Shapefile)

Site ID	Erosion Type	Estimated sediment yield	Treat to	Responsibility	Priority	Likely Cause
1	Head Cut	>1000 m^3	Watercourse & wetland destruction	NPWS	High	Natural Logging / Clearing
2	Road Erosion	>100 m^3	Road maintenance	Council	High	Design
3	Logging track erosion	>100 m^3	Hillslope drainage	State Forest	Low	Logging / Clearing
4	Embankment erosion	>100 m^3		Council	Medium	Soil
5	Bank erosion	>100 m^3	Loss of riparian land	Landholder	Medium	Non specific
6	Foreshore erosion	>10 m^3	Loss of riparian land	Council	Low	Non specific

Summary of Potential Erosion Assessment

- Many of the potential erosion sites were identified in the middle to lower catchment area including locations in both Sandy and Booths Creek sub-catchments. Many of the sites are located in vicinity of old logging roads and snig tracks in catchment areas now administered by National Park Wildlife Service.
- Potential bank erosion was identified in the lower freshwater reaches of Sandy and Booths Creek and these were subject to field inspections (see **Section 6.3** below).
- The assessment did not identify un-natural erosion of estuary foreshore based on 2008 LiDAR information.

6.2 ASSESSMENT OF EROSION FROM LOGGED CATCHMENTS

The potential erosion assessment identified many logging roads and snig tracks that have been constructed in the catchment from historical forestry operations, particularly in the upper catchment with example image shown in **Figure 16**. Soils in the upper Middle Lagoon catchment are classified as erosional soil landscapes (DLWC 1999). This means that soils are extremely sensitive to disturbance and are particularly prone to erosion when they are disturbed. Constructed logging roads, tracks, and snig tracks are vulnerable to erosion, especially when runoff concentrates in these depressions, and without appropriately functioning runoff controls, begin to behave like first order drainage lines. Sediments may be mobilised from the surfaces of unsealed roads in even low to moderate rainfall events. These areas are likely to continue to erode until they reach the underlying bedrock or dense clays.

Erosion of logging roads and snig tracks may be a dominant source of sediment supply to the estuary. Certainly there is evidence of excessive and recent sediment deposition on the fluvial delta of Middle Lagoon, which may be from identified potential erosion sites in the upper catchment. However, further assessment would need to be undertaken to estimate the amount of sediment sourced from the upper catchment that is supplied to the Estuary.

Most of the potential erosion sites found in the upper catchment erosion are difficult to access and it may not be practical to remediate, but at least these sites should be inspected to assess actual erosion. Also, major unsealed roads and trails may need to be regularly maintained and inspected by the relevant authority, particular adjacent watercourse crossings.

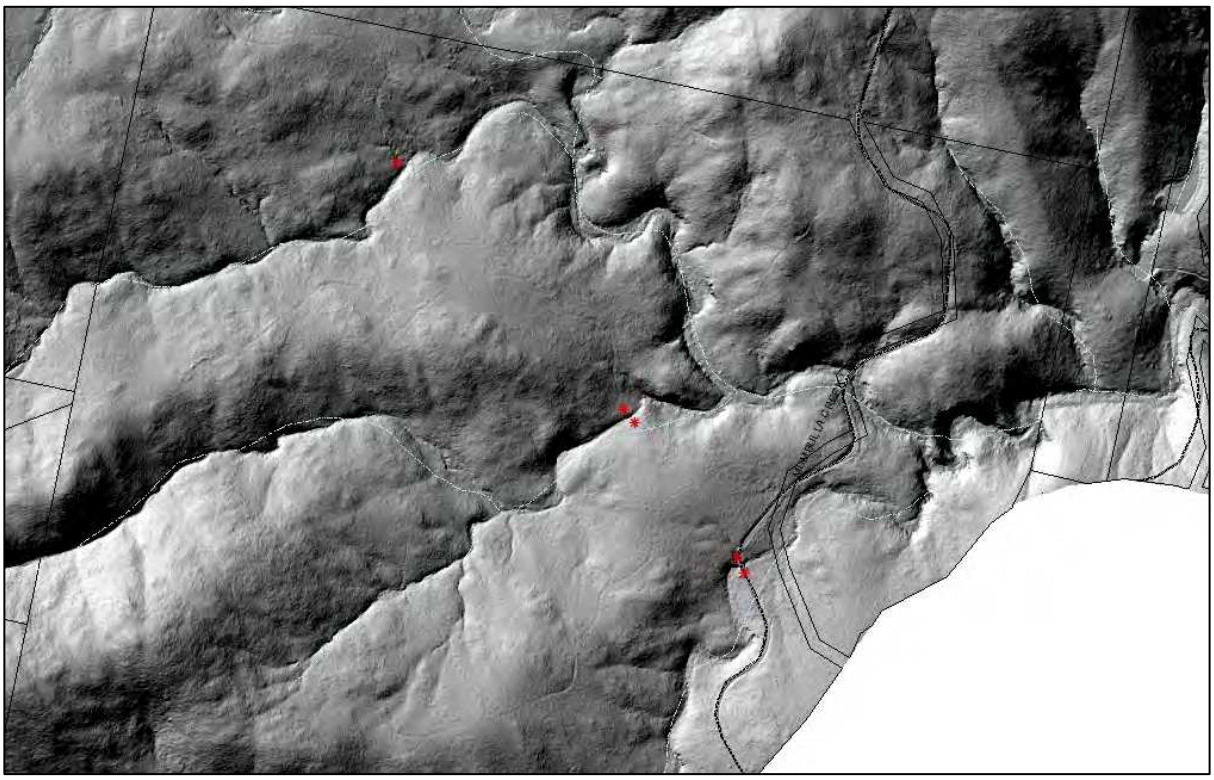


Figure 16. Example of historical forestry logging roads and snig tracks (red asterisks) identified on the enhanced DEM and slope analysis in upper catchment adjacent to Mumbulla Creek Road.

6.3 FIELD INSPECTIONS OF POTENTIAL EROSION ISSUES

Field inspections to assess potential erosion issues in the Middle Lagoon catchment were undertaken on 2 September 2015, 29 October 2015, 14 February 2016, 8 March 2016 and 31 March 2016.

Stream banks of the lower freshwater reaches of Sandy and Booths Creek and foreshore banks across the whole estuary were inspected for erosion. Where erosion is active, the assessment took into consideration fluvial geomorphology, hydraulic environment and geotechnical characteristics of the sediments at each site. Erosion of the banks was assessed in the context of the following criteria:

- stratigraphy of bank sediments
- geotechnical strength of banks sediment
- height of eroded banks
- proximity of large trees to eroding banks and potential for bank collapse
- stability of channel bedforms (pools and riffles)

A brief summary of the field inspections of is provided in sections below.

6.4 HEAD CUTS

A number of head cuts on streams tributary to Sandy Creek were identified in Mimosa Rocks National Park and ground-truthed by field inspection (**Figure 17**). Inspections confirmed that these head cuts were highly active and subject to further erosion after high rainfall events. Well-established vegetation including mature *Eucalyptus* trees does not appear to arrest the rate of erosion (**Figure 18**). Ongoing erosion of these sites represent one of the highest risk and incidence of sediment erosion observed in the catchment, with estimates of up to 2,000 m^3 of sediment already eroded from the channelization of alluvial deposits. It is unclear what proportion of this sediment is deposited in the estuary or whether deposition occurs further downstream and is yet to reach the estuary. However, there is high probability that the finer dispersible fraction of the sediment distribution makes it way to the estuary. These areas are discussed in more detail in Priority Management Area 8 (**Appendix B**).

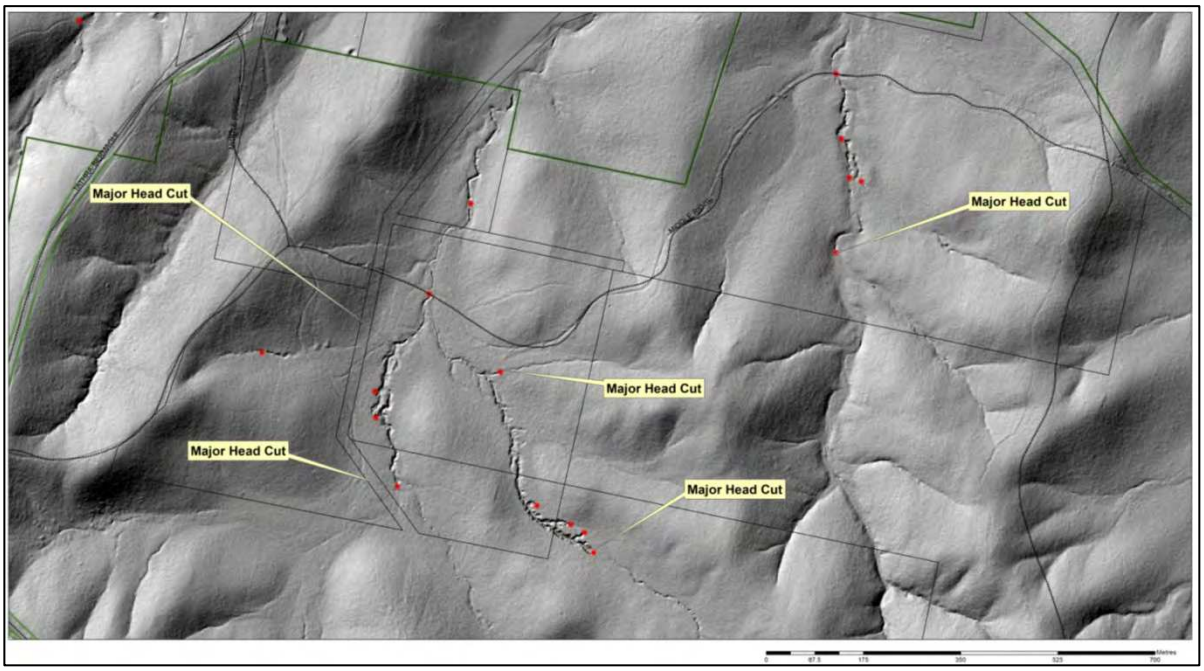


Figure 17. Location of head cuts and serious creek bank erosion identified in the forested area of Sandy Creek sub-catchment using LiDAR.

Figure 18. Example of active head cut in forested setting of Sandy Creek sub-catchment.

Active head-cut on second order stream in forested setting (*left image*). Gully formation due to migration of the head-cut up the drainage line. A natural process in areas with highly erodible soils such as Sandy Creek sub-catchment (*right image*).

6.5 STREAM BANK EROSION OF LOWER REACHES

Moderate bank erosion was observed along the lower reaches of Sandy and Booths Creek. These creeks are typically low energy creeks although subject to episodic high velocity flows following significant rainfall events. Observed bank erosion is linked to these episodic high intensity rainfall events coinciding with entrance berm breaches on low tide resulting in further increased stream power and erosion potential. This would typically occur when the peak flow/ rainfall in catchment

coincides with the entrance being breached at low tide, and the berm height is close to its maximum height of 2.5 mAHD. Prior to the berm being breached, flood flows are dammed up in the estuary and channel velocities are relatively low. When the berm collapses, it leads to a rapid increase in the hydraulic slope of the water surface in the estuary, and flood flows become concentrated within the bankfull channel, causing episodic erosion. Although these events were not directly observed in this investigation, local residents have described exceptionally high channel velocities occurring during these types of rainfall events. These events have also been described as being unpredictable and reported loss of farm infrastructure (*i.e.* fences and timber crossings) and observed incidences of bank erosion.

Erosion of bank toes is occurring along the lower reaches of Sandy Creek undermining the stability of large *Eucalyptus* trees (**Figure 19**). Undermined trees are highly susceptible to wind blow, as shear stress created by the wind eventually leads to localised bank collapse as the large tree falls in to the creek (**Figure 20**). These trees supply large woody debris to the creek and estuary, which provide valuable instream refuges and habitat for aquatic flora and fauna. Large woody debris also helps to enhance the geomorphic character and condition of the creek and estuary by exerting strong influence on channel hydraulics and sediment transport and deposition.

Figure 19. Example of bank toe erosion occurring along lower reach of Sandy Creek.

Figure 20. Natural process of tree collapse occurring along lower Sandy Creek supplying large woody debris (LWD) to creek and estuary.

6.6 EROSION AROUND BOX CUVERT AT BOOTHS CREEK

Localised erosion near and adjacent to the box culvert at Booths Creek is evident (**Figure 21**). This is caused by the hydraulic jump over the box culvert down to the naturally lower elevation of the creek. Local residents report extremely high velocities and erosion during high rainfall events. The existing rock chute and adjacent rock revetment require maintenance to mitigate further bank erosion. This issue is further described in priority management area 4 (**Appendix B**).

Figure 21. Localised bank erosion occurring adjacent to the rock chute at the box culvert outlet on Booths Creek.

6.7 ASSESSMENT OF UN-SEALED ROAD NETWORK

Middle Lagoon catchment includes approximately 51.7km of unsealed road network (excluding logging extraction tracks) representing 0.9% of total catchment area. These road surfaces likely represent a significant contributor of dispersible sediment fractions to catchment watercourses and appropriate maintenance of the roads and their runoff controls are vital to protecting the water quality values of catchment streams.

A limited assessment of sections of the unsealed road network was undertaken in accordance with the *Managing Urban Stormwater - Soils and Construction Volume 2C Unsealed Roads* (DECC 2008).

Three high to medium sites were identified where road and runoff control maintenance is required to protect catchment stream and estuary values from erosion impacts. These include:

- Road and roadside embankment erosion of lower Dr George Mountain Road (Refer **Appendix B** - Priority Management Area 1)
- Inappropriate road maintenance deteriorating road surface condition (Refer **Appendix B** - Priority Management Area 5)
- Erosion of Barrabooka Road with sediment and gravel input to watercourse (Refer **Appendix B** - Priority Management Area 7)

7 CATCHMENT MANAGEMENT ISSUES

7.1 PRIORITY MANAGEMENT AREAS AND ISSUES

Eight (8) priority management areas have been identified, all situated around the lower catchment as shown in **Figure 22**. Within each management area, at least one or more of the following issues is currently occurring - road surface erosion, natural stream bank erosion, degradation of riparian zone and/or sensitive coastal saltmarsh areas, and uncontrolled foreshore access.

Each of these issues is the result of past and present disturbances and considered to be either currently or have the potential to affect catchment condition and estuary water quality if not addressed.

A summary of the issues including brief description, the issue threat, responsible stakeholder/ landholder for addressing issue, and actions recommended for treatment of issue are provided in **Table 12** below.

Further detailed description of each priority management area and issues is provided in **Appendix B.**

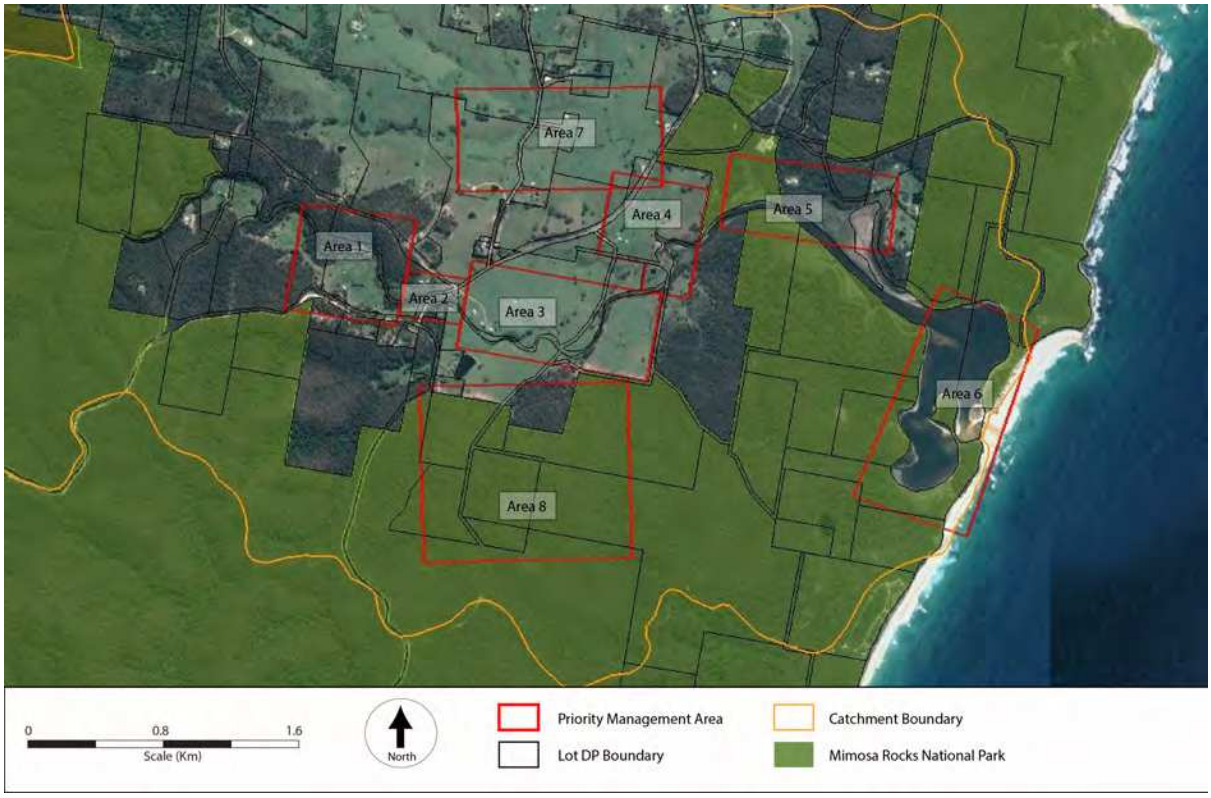


Figure 22. Overview of priority management area locations for Middle Lagoon catchment.

7.2 PRIORITIES

The recommendations have been assigned a priority, which represents the following indicative timeframe for implementation.

High Priority	Within 1 year
Medium Priority	Year 1 to 3
Low Priority	Year 4 to 6

These priorities are subject to availability of Council's or relevant stakeholder operational budgets to undertake recommended actions. For some recommendations, the availability of State and Commonwealth funding grants will affect implementation of priorities.

8 OTHER GENERAL ISSUES

8.1 LIMITED BOATING ACCESS

Limited access to the foreshore for launching small vessels for recreational and commercial fishing was raised as an issue during the consultation period. Some community members question the suitability of the estuary for use by motored vessels. However, the estuary is currently available to commercial fishing under Region 7 of the NSW Estuary General Fishery and commercial fishers must be able access the estuary. Currently, boating access for commercial fishermen is limited to a poorly maintained NPWS management track that continues to degrade over time. Current access to the

estuary foreshore is provided via the NPWS Tanja depot. This issue is further addressed in Priority Management Area 5 (**Appendix B)**.

8.2 ESTUARY ENTRANCE CLOSURES

Prolonged closures of the estuary entrance has been raised as an issue of concern by some community members with rising water levels inundating private land and low-lying sections of roads, and the perceived impact that closures may be having on estuarine water quality, and sustainable commercial fishing.

As discussed in **Section 2.5.1**, the entrance of Middle Lagoon has historically been managed by catchment landholders for a period of at least 70 years to regulate estuary water levels. In more recent times, the entrance has been permitted to open naturally though attempts are still made by persons to artificially open the entrance. Opening the entrance of an estuary requires a permit from DPI Fisheries and it is an offence for a member of the public to carry out this activity. To do so attracts heavy penalties of up to $220,000 per offence.

Artificial opening an estuary can have many ecological implications including –

- Rapid lowering of water levels exposing sediments and estuarine vegetation. This exposure can cause release of offensive odours (hydrogen sulfide gas);
- Depending on level of dissolved oxygen in the water, fish kills may occur; and
- Altered salinity regime and water inundation level. While estuaries that have periodic closures naturally experience a broad range of salinity and water levels, more frequent opening of an estuary can lead to shifts in the structure and distribution of riparian vegetation communities and estuarine macrophytes.

The issue of illegal openings of the entrance is further addressed in Priority Management Area 6 – **Appendix B.**

With regards to water quality and sustainable fishing concerns during closed periods, the following recommendations are made –

- That Council make available to the community available relevant water quality monitoring information and/or consider implementing a regular water quality monitoring program for Middle Lagoon.
- That DPI Fisheries provide some educational materials and/or catch data regarding the Middle Lagoon fishery to demonstrate the sustainability of the fishery and address community concerns.

Table 12. Summary of Middle Lagoon catchment priority management issues and recommended actions for treatment

Management Area	Issue #	Issue Description	Threat To	Priority (H/M/L)	Responsibility	Action/Recommended Treatment
1	1.1	Road and roadside embankment erosion	Bank stability, sedimentation of watercourse, WQ	High	RMS/BVSC	Erosion of Dr George Mountain road and the roadside embankments continue to supply dispersible sediment fractions that pose a threat to nearby Sandy Creek. A number of stormwater pipes direct roadside runoff to the slopes of private lands where grassed paddocks would act to filter sediment fines. However surface runoff from the lower section of road flows down to Tathra-Bermagui road and on to Sandy Creek. Recommend stablising roadside embankments using batter blankets (as per Group A control measures in DECC 2008), constructing sediment detention basins at road stormwater outlets (as per Group B control measures in DECC 2008) and or using bales of straw to contain sediments at the base of roadside embankments. Consider sealing the lower section of Dr George Mountain Road.
2	2.1	Road embankment erosion	WQ, embankment maintance	Low	DPI Lands/BVSC	Minor erosion of roadside embankment of Tathra-Bermagui Road contributing dispersible sediment fractions to watercourse. Recommend stablising roadside embankments using batter blankets and construction of a small sediment detention basin/trap to prevent excess sediments from entering watercourse (as per Group B control measures in DECC 2008).
2	2.2	Perception of riparian zone dominated by weeds	None	Low	DPI Lands/BVSC	Tanja Junction bridge provides good example of naturally regenerating riparian vegetation community typical of *EEC River-Flat Eucalyptus Forest* and typical of what may regenerate naturally along the lower freshwater reaches of Sandy Creek if stock impacts are removed from the riparian zone. Tree canopy includes Acacia mearnsii, Eucalyptus spp, and dense stands of Commersonia regenerating on riparian margins that were disturbed during floods of 2010. Instream aquatic vegetation is indicative of freshwater conditions including Typha, Persicaria, Nastursium. Recommendation to include signage promoting educational awareness of EEC River-Flat Eucalyptus Forest and typical vegetation of lower Sandy Creek.
3	3.1	Minor to moderate bank erosion and slumping with stock access to streamside zone	Bank stability, sedimentation of estuary, WQ	High	Private Land Lot 11 DP1092225, SE LLS	Work with landholder to fence off the streamside zone to exclude stock from the watercourse. Encourage landholder to use water troughs for stock. Investigate opportunities to revegetate the riparian zone with appropriate species.
3	3.2	Riparian vegetation limited to canopy trees with vegetation absent along large reaches of the creek	Bank stability, sedimentation of estuary, EEC River Flat Eucalyptus Forest	High	Private Land Lot 11 DP1092225, SE LLS	Work with landholder to increase the width of riparian buffer, re-establish canopy and understorey vegetation typical of EEC River Flat Eucalyptus Forest using strategy of assisted natural regeneration. Species would need to consider variable salinity regime and periods of inundation (Refer species list). Fencing requirements needs to take into consideration flood events.

Table 12. Summary of Middle Lagoon catchment priority management issues and recommended actions for treatment

Management Area	Issue #	Issue Description	Threat To	Priority (H/M/L)	Responsibility	Action/Recommended Treatment
4	4.1	Erosion of streambank during episodic high flow events	Bank stability, sedimentation of estu	High	Private Land Lot 2 DP1105244, SE LLS	Streambanks of Booths Creek immediately downstream of the Tathra- Bermagui Road culvert being eroded by high velocity flows during episodic storm events. Recommended treatment includes maintenance of the stormwater pipes where Booths Creek naturally flows to alleviate flow force. Work with landholder to improve the riparian vegetation cover that will provide increased bank protection during high flow events.
4	4.2	Limited riparian vegetation along streambank with stock access to streamside zone	Bank stability, Visual aesthetic	High	Private Land Lot 2 DP1105244, SE LLS	Riparian vegetation absent or limited to sparse stands of *Melaleuca ericifolia* that are doing a reasonable job of stablising the bank where present. Landholder is receptive to addressing the problem of bank erosion by re-establishing riparian buffer but also intends to continue grazing this area. Species would need to consider variable salinity regime and periods of inundation (Refer species list). Fencing requirements would need to consider periods of inundation and flood events.
4	4.3	Bank and bed erosion at rock chute outlet	Box culvert, Tathra-Bermagui Road, bed and bank stability	High	DPI Lands, RMS, BVSC	Repair rock chute which may include need for redesign and extension of existing rock revetment to disperse high velocity flows. Landholder would like to move stock from the western to eastern side of property via the box culvert and rock chute to avoid the need to cross Tathra-Bermagui Road. Repair to rock chute may consider use of cement stablised sand for bed protection but also provide even surface for use as a stock crossing.
4	4.4	Road embankment concentrates stormwater flows though box culvert during high rainfall events	Box culvert / Tathra Bermagui Road / bed & bank erosion	High	DPI Lands, RMS, BVSC	Construction of the Tathra-Bermagui Road embankment across the floodplain and placement of box culvert in an elevated position above the natural drainage of Booths Creek is likely to be contributing to the build-up of floodwaters on the western side of the embankment during high rainfall events. This issue may be exacerbated when flood levels in Sandy Creek are high prior to the sand berm at the entrance being breached, causing Booths Creek floodwaters to back-up. When the berm at the entrance is breached, the roadside embankment acts like a dam wall, concentrating flow through the box culvert, leading to potentially very high velocities that cause downstream erosion of Booths Creek. A potential treatment includes maintenance of rock chute at a high flow outlet of box culvert to improve dispersion of velocity water. Additionally there is a need to investigate whether additional engineering designs at the box culvert, and maintenance of the low-flow stormwater pipes at Booths Creek may assist in natural drainage. Further engineering investigation is required.
4	4.5	Riparian vegetation degraded and limited to canopy trees with vegetation absent along large reaches of the creek	Bank stability, sedimentation of estuary, EEC River Flat Eucalyptus Forest	High	Private Land Lot 2 DP1105244, SE LLS	Work with landholder to increase the width of riparian buffer, re-establish canopy and understorey vegetation typical of EEC River Flat Eucalyptus Forest using strategy of assisted natural regeneration. Species would need to consider variable salinity regime and periods of inundation (Refer species list). Fencing requirements needs to take into consideration flood events.

Table 12. Summary of Middle Lagoon catchment priority management issues and recommended actions for treatment

Management Area	Issue #	Issue Description	Threat To	Priority (H/M/L)	Responsibility	Action/Recommended Treatment
5	5.1	Inappropriate road maintenance deteriorating road surface condition	Road stability, coastal saltmarsh, landholder access	Medium	DPI Lands/BVSC adjacent to Private Lands Lot 1381 DP854091 & Lot 1382 DP854091	Landholder manages the unsealed road with appropriate use of blue-metal to stabilise the surface and creation of runoff controls. NPWS road maintenance crew disrupt and damage stable road surface with unecessary grading resulting in poor runoff controls and further erosion. Work with landholder and NPWS road maintenance to implement effective road management and runoff controls along this 150m section of unsealed road.
5	5.2	Uncontrolled foreshore access via sensitive saltmarsh community	Coastal saltmarsh community	Medium	DPI Lands/BVSC, Private Land Lot 6 DP259588	Recreational users of Middle Lagoon accessing the foreshore via the coastal saltmarsh creating informal tracks through Private Lands and parking cars along narrow roadside verge. Landholder would prefer public access to the foreshore via NPWS designated and managed tracks. Signage to raise awareness of sensitive saltmarsh community and that access to estuary is not encouraged.
5	5.3	Large stand of dead Eucalypyus trees on southern side of estuarine channel	Visual aesthetic	Low	NPWS	A large stand of dead Eucalypt trees (many are Bangalays - Eucalyptus botryoides) exists on the southern side of Sandy Creek channel. Some tree deaths, those in low-lying areas, are attributed to prolonged inundation when the estuary entrance has been closed but majority of dead trees exist above the water high stand and the most probable cause of death for those trees can be attributed to Bell Miner Associated Dieback (BMAD). Recommend community education and or signage that explains the background history of artificial entrance opening of Middle Lagoon and the influence that practice has had on vegetation distribution and that some of the tree dieback is a natural process in response to the lagoon resuming its natural opening and closing regime. Further explanation of the issue of BMAD in the coastal forests of Mimosa Rocks National Park (Refer Action 7 in Section 5.1.4 (NPWS 2011) would also be valuable.
5	5.4	Potential for bank damage associated with launching small vessels	Bank stability	Low	NPWS	Foreshore access point currently used by commercial fishermen to launch small vessels under an access agreement with NPWS via the Tanja depot. Investigate options to protect the bank for vessel launching and retrieval if this location is to be the main foreshore access point for commercial fishermen.
6	6.1	Artificial opening of the estuary entrance	Natural hydrodynamic regime of estuary, estuarine flora, fish recruitment	High	DPI Fisheries, NPWS, DPI Lands, BVSC	Development of educational signage to be erected near the entrance that explains the unique ecology of Middle Lagoon as an ICOLL and potential harm to estuarine ecology due to artificial opening of estuary entrance (i.e. shifts in estuarine vegetation communities, potential fish kills, loss of fish recruitment, altered salinity regime)

Table 12. Summary of Middle Lagoon catchment priority management issues and recommended actions for treatment

Management Area	Issue #	Issue Description	Threat To	Priority (H/M/L)	Responsibility	Action/Recommended Treatment
6	6.2	Degraded foreshore area on western side of lagoon associated with informal camp and boat launching area	Native vegetation via introduction of weeds	Medium	NPWS	NPWS management track from Gillards Beach campground to western foreshore of Middle Lagoon is in poor condition and not maintained. The track is primarily used by NPWS and commercial fishermen though not useable in wet conditions. NPWS intend to install a locked gate to further limit track use with commercial fishermen granted permission to continue estuary access via NPWS depot off Haighs road. Liaise with NPWS regarding plans to install a locked gate on the management track at Gillards Beach Road to limit track use. Work with NPWS to monitor the natural regeneration of vegetation at the degraded foreshore to ensure weeds do not become an issue.
6	6.3	Motorbike access to coastal saltmarsh community	Coastal saltmarsh	Medium	NPWS	• Liaise with NPWS to inform of recent damage to EEC coastal saltmarsh by motorbikes and that access was likely via Tommy's Bay Walk. Identify potential access routes other than Tommys Bay Walk that may be used by motorbikes and block-off. • Use bollards and or fencing to limit Tommys Bay Walk to pedestrian traffic only (if not already done) and or consider fencing the southern perimeter of estuary to prevent foreshore access by motorbikes.
7	7.1	Wetland area unfenced with stock access causing potential damage to herbaceous wetland flora	Wetland flora and function	High to Medium	Private Land Lot 241 DP1093825, Lot 321 DP870998 and Lot 82 DP810431, SE LLS	Work with landholders to protect natural values of wetland areas from stock impacts and enhance the function of wetland to slow water flows. Fencing may not be practical in all areas due to potential damage during flood events. Alternative solutions to improving wetland areas may include discussion with landholders to implement stock management to graze wetland areas only during dry periods to minimise damage, and or use of off-stream stock watering troughs. Current landholders are commencing a project with SE LLS to improve the condition of the drainage line including re-establishing riparian vegetation and fencing to exclude stock access.
7	7.2	Erosion of Barrabooka Road with sediment and gravel input to watercourse	Sedimentation of watercourse	Medium	Crown Road [DPI Lands/BVSC]	Implement road maintenance to improve storm-water runoff controls to prevent erosion of road surface and deposition of gravel to Davis Creek watercourse.
7	7.3	Artificially constructed drain that has negatively impacted on floodplain wetland	Wetland flora and function	Low	Private Land Lot 211 DP852166, SE LLS	Artificial drains have been historically constructed through floodplain wetlands to improve condition of pasture to detriment of wetland flora. These drains can also be subject to erosion issues. The current landholder is working with SE LLS to improve the condition of the drainage line including re-establishing riparian vegetation and fencing to exclude stock access.
7	7.4	Riparian vegetation absent along large reaches of Booths Creek and tributary streams due to historical land clearing	Bank stability, sedimentation of watercourse, EEC River Flat Eucalyptus Forest, visual aesthetic	Low	Private Land Lot 241 DP1093825 and Lot 2 DP1105244, SE LLS	Work with landholders to re-establish canopy and understorey vegetation typical of EEC River Flat Eucalyptus Forest using strategy of assisted natural regeneration. Species would need to consider periods of inundation (Refer species list) and fencing requirement need to take into consideration flood events.

Table 12. Summary of Middle Lagoon catchment priority management issues and recommended actions for treatment

Management Area	Issue #	Issue Description	Threat To	Priority (H/M/L)	Responsibility	Action/Recommended Treatment
8	8.1	Severe erosion, slumping of banks, loss of freshwater wetland	Bank stability, sedimentation to watercourse, stability of management track, loss of freshwater wetland	High	NPWS	Example of an active head-cut on a minor stream in a forested setting which has formed a deep incised gully approximately 400m long. Natural erosion process that shows examples of undercutting, lateral bank erosion and slumping due to highly erodible, sodic soils in the Sandy Creek sub-catchment. Difficult to treat due to scale of problem. Recommended actions include a collaborative research project for university to study what may have been the initial cause/s (i.e.historical logging practices) and what potential actions could be undertaken to halt or slow down process. Monitor head-cut progression as freshwater wetland and nearby management track under direct threat as the head-cut migrates further upstream.
8	8.2	Moderate creek bed and bank erosion migrating upstream, causing erosion similar to head-cut	Bank stability, sedimentation to watercourse	Medium	NPWS	Moderate creek bed erosion leading to the erosion of creek bed and banks. These sites can be stabilised with rock / log structures or by the natural recruitment of Large Woody Debris that is strategically placed. Sites would need to be regularly inspected.

Note - Refer to Appendix B for detailed description of Issues and Recommended Actions

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LIMITATIONS

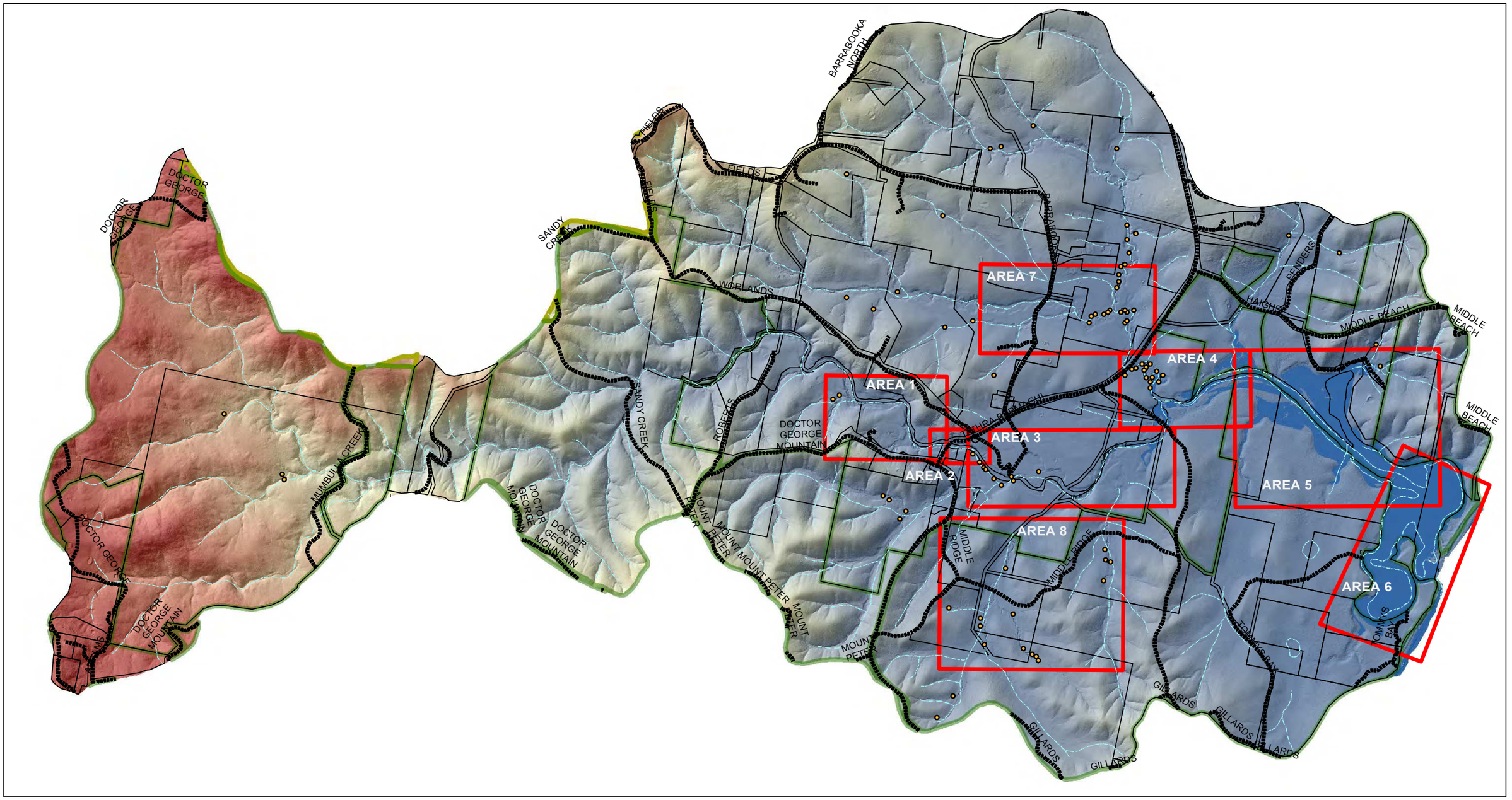
10 LIMITATIONS

Elgin Associates Pty Ltd has prepared this report for the sole use of BVSC in accordance with generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the original proposal dated 22 May 2015.

The methodology adopted and sources of information used by Elgin Associates are outlined in this report. Elgin Associates has made no independent verification of this information beyond the agreed scope of works and Elgin Associates assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to Elgin Associates was false.

This report was prepared between October 2015 and August 2016 and is based on the conditions encountered and information reviewed during that period up to the time of preparation. Elgin Associates disclaims responsibility for any changes that may have occurred after this time. Opinions and recommendations contained in this report are based upon information gained during desktop study and fieldwork and information provided from government authorities' records and other third parties. The information in this report is considered to be accurate at the date of issue and reflects at the site at the dates sampled. This document and the information contained herein should only be regarded as validly representing the site conditions at the time of the fieldwork unless otherwise explicitly stated in a preceding section of this report.

This report should be read in full together with all other reports referenced by this report. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Potential Erosion Area
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Priority Management Areas
- Average Water Level 2.0 m AHD
- Mimosa Rocks National Park
- State Forest

Elevation (m) Value

High : 312.937

Low : 0.243

POTENTIAL EROSION ASSESSMENT
PRIORITY MANAGEMENT AREAS 1 to 8

Riparian engineering

GDA 94 Zone 55

Sheet No.

Sheet 1 of 10

FIGURE 15

Analysis By: Tim Dilworth
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Checked by: Nick Yee

Date: 18 February 2016

APPENDIX A

Stakeholder and Community Consultation

- **Consultation Plan**
- **Online Questionnaire**

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E. council@begavalley.nsw.gov.au

ABN. 26 987 935 332
DX. 4904 Bega

12 August 2015

[applicant name]
[applicant address1]
[applicant address2]
[applicant address3]

CONSULTATION PLAN – Middle Lagoon Catchment

Dear Landholder/Stakeholder/Resident,

Bega Valley Shire Council (BVSC) has received funding from the Office of Environment and Heritage to conduct a rapid catchment assessment of Middle Lagoon.

The assessment has several objectives including:

- To identify catchment and foreshore issues currently impacting, or with the potential to impact, water quality and estuary health; and
- To identify priority areas within the catchment for protection and targeted rehabilitation that will improve catchment condition and water quality of Middle Lagoon.

Middle Lagoon has significant ecological, recreational and socio-economic values all of which are reliant on good water quality. The water quality of the estuary is highly dependent on land-use practices and catchment disturbance. Catchment management issues such as natural and man-made erosion, intensive land-use, and unsealed roads can all impact on water quality via increased sediment and nutrient inputs. Water quality impacts can be further exacerbated when the estuary entrance is closed.

The assessment of Middle Lagoon will utilise rapid visual assessment methodology to identify catchment and estuary foreshore issues that are currently, or have the potential to impact on water quality and estuary health. The primary outcome from the assessment will be actions documented in a catchment management plan that will highlight priority areas for protection and targeted rehabilitation that can be implemented as funding permits.

Local consultancy Elgin Associates has been engaged by BVSC to conduct the project.

As a landholder/resident, or stakeholder with an interest in Middle Lagoon and its catchment catchment, we would like to hear your thoughts regarding how you value the lagoon but also your concerns about the current condition of the catchment and estuary foreshore. You can provide your input to this project via a number of ways – via online survey using the weblink: https://www.surveymonkey.com/s/Middle_Lagoon

Or by contacting project manager Nicholas Yee directly on mobile 0400365234 or email nick.yee@elgin.com.au

Field inspections by Elgin Associates will commence in September 2015. Access to catchment areas via your property may be required. A further consultation period will be convened in late 2015 to present the information gathered during the field inspections.

Middle Lagoon has a waterway size (including saltmarsh areas) of 0.6 km^2 and a catchment area of 27.3 km^2. Majority of the catchment is forested with 54% located within the Mimosa Rocks National Park and 28% of the catchment cleared for agricultural grazing/rural residential uses. The estuary is primarily used for recreation with fishing, swimming and canoeing the main activities although the estuary is available to commercial fishing.

Middle Lagoon is a shallow, saline coastal lagoon whose entrance is closed to the ocean for prolonged time periods. Historically Middle Lagoon has been permitted to open naturally and is not currently subject to an entrance management policy. The duration of entrance openings range from approximately six to eight weeks with the estuary closed for 90% of the time.

The Healthy Rivers Commission (2002) classified NSW estuaries according to their perceived conservation value and management orientation. This was based on factors including a lake's natural sensitivity, current condition of the waterbody and catchment, as well as patterns of settlement, future opportunities for development, and potential for restoration and rehabilitation. Under this framework, Middle Lagoon was assessed as having extreme natural sensitivity and was classified for significant protection. Its physical and geomorphic characteristics making the lagoon highly vulnerable to catchment disturbance and is among a group of small, shallow estuaries that are most likely to be affected by further land use change and catchment disturbances.

Snapshot Summary of Middle Lagoon and Catchment Characteristics	
Estuary waterway size: 0.6 km^2	**Catchment Area:** 27.3 km^2 28% cleared (7.7 km^2), 54% National Parks (14.7 km^2)
Primary Inflow: Sandy Creek and its main tributary Booths Creek	
Estuary type: Semi- mature, Saline coastal lagoon	
Estuarine vegetation: Saltmarsh 0.052 km^2, *Ruppia megacarpa* 0.211 km^2 *Ruppia*, also known as sea tassel, is often the dominant macrophyte in brackish water	

estuaries that are closed to the ocean for long periods.	
Catchment land-uses: Rural residential, agricultural grazing, recreation.	
Commercial activities: The estuary is available to commercial fishing as part of Estuary General Fishery.	
Endangered Ecological Community (EEC) types: The catchment contains seven (7) vegetation types listed as EECs types under the *NSW Threatened Species Conservation Act 1995* (TSC Act) including - Coastal saltmarsh, Freshwater wetlands, Bangalay Sand Forest, Lowland Grassy Woodland, River-flat Eucalyptus Forest, Swamp Schlerophyll Forest and Littoral Rainforest.	
Estuary open – closed period (%): Closed 90% of time, Open 10% of time.	
Entrance Opening Policy: none	
Water Quality:	• Mean nitrogen and phosphorous levels generally exceeding guideline limits. • Seasonal algal blooms common. • Highly variable salinity regime with waters ranging from brackish to marine conditions.

Regards

Kyran Crane
Coastal Management Officer

Rapid Catchment Assessment - Middle Lagoon

Bega Valley Shire Council (BVSC) has received funding from the Office of Environment and Heritage to conduct an assessment of Middle Lagoon and its catchment.

Middle Lagoon has significant ecological, recreational and socio-economic values all of which are reliant on good water quality. The water quality of the estuary is highly dependent on land-use practices and catchment disturbance.

Catchment management issues such as natural and man-made erosion, intensive land-use, and unsealed roads can all impact on water quality via increased sediment and nutrient inputs. Water quality impacts can be further exacerbated when the estuary entrance is closed.

The assessment of Middle Lagoon will utilise rapid visual assessment methodology to identify catchment and estuary foreshore issues that are currently or have the potential to impact on water quality and estuary health. Actions from the assessment will be documented in a catchment management plan that will highlight priority areas for targeted protection and rehabilitation.

Local consultancy Elgin Associates has been engaged by BVSC to conduct the project.

This survey is designed to seek your initial input regarding catchment management and estuary foreshore issues you feel are important for Middle Lagoon. As a landholder, stakeholder or community member who values Middle Lagoon, thank you for participating in our survey. Your input is vital.

Your responses will be used to help inform field inspections that will be conducted by Elgin Associates during late winter-early spring 2015.

Rapid Catchment Assessment - Middle Lagoon

* 1. Are you a resident landholder, stakeholder or community member interested in Middle Lagoon?

* 2. Which stakeholder group do you represent?

- [ ] Bega Aboriginal Land Council
- [ ] Biamanga Trust
- [ ] Office of Environment and Heritage
- [ ] Bega Valley Shire Council
- [ ] Forestry Corporation of NSW
- [ ] South East Local Land Services
- [ ] Department of Primary Industries
- [ ] NSW Roads and Maritime
- [ ] NSW Crown Lands
- [ ] Other (please specify)

Middle Lagoon has significant ecological, social and economic values.

Ecological values include flora and fauna communities, hydrology and tidal flows, intermittent flood regime due to periodic closure of the entrance, water quality and variable salinity. Social values include all recreational activities (i.e swimming, kayaking, fishing, boating, hiking, 4wD, camping). Economic values may include rural water source for stock and domestic supply, oyster farming, forestry or tourism associated benefits.

3. What do you value most about Middle Lagoon and its catchment?

Ecological values	
Social values	
Economic values	
Other values	

* 4. How concerned are you about the current condition of the catchment and estuary foreshore?

- Extremely concerned
- Very concerned
- Moderately concerned
- Slightly concerned
- Not at all concerned

* 5. How concerned are you about water quality of Middle Lagoon?

- Extremely concerned
- Very concerned
- Moderately concerned
- Slightly concerned
- Not at all concerned

* 6. Does the periodic closure of the estuary entrance concern you?

- Yes, i am always concerned when the entrance closes
- Some of the time
- Not at all

7. Please describe why the periodic closure of the estuary entrance concerns you?

* 8.

What issues do you feel are negatively affecting the condition of the catchment and water quality of Middle Lagoon?
Rank in level of importance to you (*e.* #1 = has the greatest negative impact.....#8 = least negative impact)

- Unfenced creek lines and stock impacts
- Lack of riparian vegetation due to historical vegetation clearing
- Weed infestation
- Ad hoc foreshore access
- Poorly maintained unsealed roads
- Wetland degradation (i.e/ freshwater or saltmarsh)
- Bank erosion
- Illegal drains or weirs (i.e. barriers to fish passage)
- Estuary entrance closure
- Forestry practices

9. Please provide other information regarding Middle Lagoon catchment management issues that you feel are important.

Rapid Catchment Assessment - Middle Lagoon

Please register your interest in this project by leaving your contact details. Your contact details and input will be kept private and will not be disclosed to any third party. All information will be deleted at the conclusion of the project.

10. Address

Name	
Address	
City/Town	
State/Province	
ZIP/Postal Code	
Email Address	
Phone Number	

APPENDIX B

Middle Lagoon Catchment – Priority Management Areas

APPENDIX B

Priority Management Area 1

Area Description and Issue Synopsis

The management area includes lower Sandy Creek bounded by the slopes of Worlands Road to the north and the slopes of Dr George Mountain Road to the south. Sandy Creek is surrounded by private lands and the riparian zone along reaches within this area are generally well vegetated. The management issue in this area is to address ongoing erosion of the unsealed Dr George Mountain Road and the roadside embankments. A proportion of sediment fines from Dr George Mountain Road are transported in surface runoff during each high rainfall event with some sediments captured in mitre drains but some also transported further downslope to Tathra-Bermagui Road where it poses a direct threat to sedimentation of Sandy Creek.

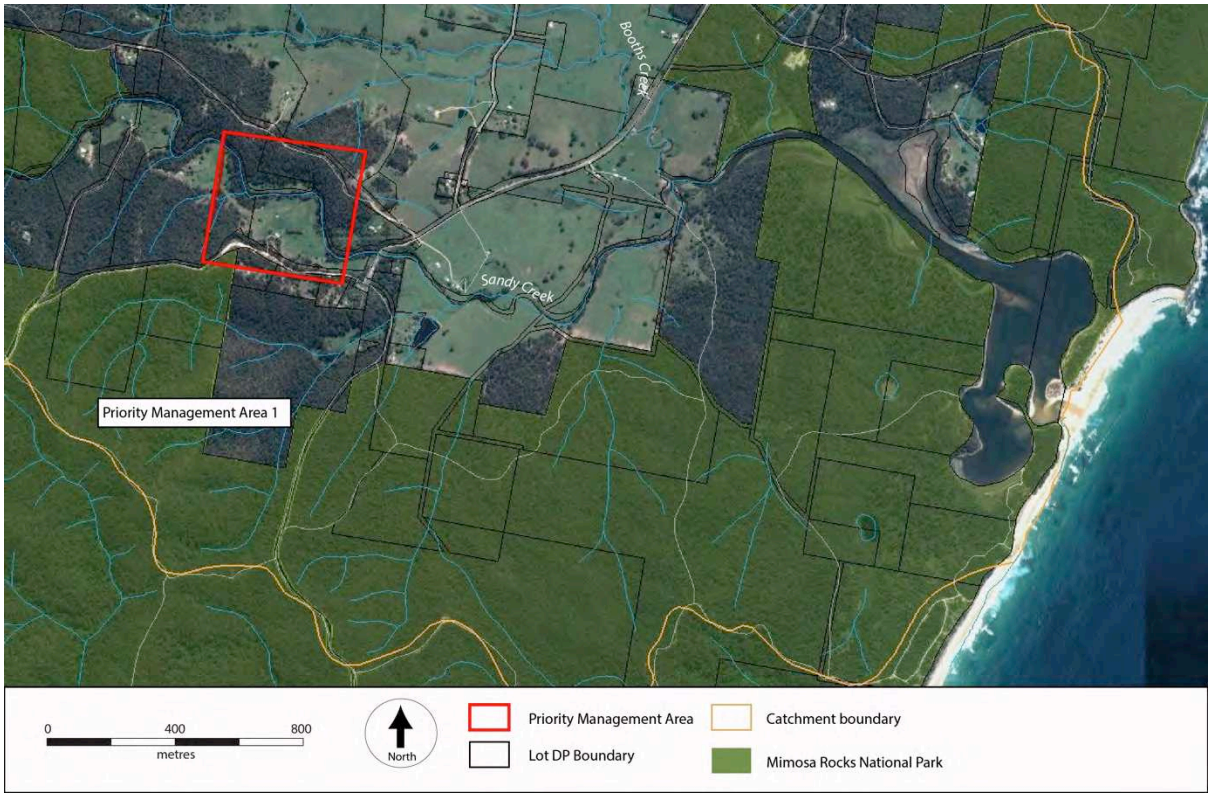


Figure B1 Location of priority management area 1.

High priority issue that requires attention include:

- **Issue 1.1** Road and roadside embankment erosion

Each issue is described with recommended actions for treatment provided in sections below.

Issue 1.1: Road and roadside embankment erosion

HIGH PRIORITY

Site Address [Responsibility]: Crown Road and Crown Land reserve [DPI Lands/BVSC] (Refer **Map B1**).

Lat/Long Coordinates: Road section between points **-** 36°38'35.06"S, 149°57'48.38"E and 36°38'39.95"S, 149°58'13.18"E

APPENDIX B

Issue Description: The unsealed Dr George Mountain Road is a key road corridor linking the coast to Bega and is an important alternative road corridor during times of flood when the Bega–Tathra Road is inundated at Jellat Jellat flats. The road is generally maintained in good condition with the maintenance schedule involving surface re-grading with some road sections further stabilised with addition of blue-metal road base. However, the regular disturbance caused by road maintenance results in new loose sediments that may be transported in surface runoff. Mitre drains are designed to remove surface road runoff and capture any dispersible sediment fractions. However, once mitre drains have reached capacity and or become blocked with leaf litter, surface runoff carrying dispersible sediment fractions is inadvertently diverted back to the road. Consequently, increased surface runoff flows pose further threat to road surface stability.

Erosion of the roadside embankments and lower 700m section of Dr George Mountain Road (**Map B1**) continue to supply dispersible sediment fractions that pose a threat to nearby Sandy Creek. Road surface runoff management along this road section includes three storm-water pipes and at least nine mitre drains. Two stormwater pipes and majority of mitre drains direct road surface runoff to the crown road reserve on the northern side of Dr George Mountain road. Sediment deposition is evident below each stormwater pipe outlet with sediment fractions also delivered further downslope to private land, which is below the crown road reserve. Siltation barriers to contain sediment within the crown road reserve are damaged and no longer functional (**Figure B2**). Downslope private lands are comprised of grassed paddocks, which would act to filter sediment fines and mitigate potential impacts to water quality of Sandy Creek. A third storm-water pipe directs road surface runoff to the table drain below the roadside embankment on the opposite side of the road (**Figure B3**). From this pipe outlet, surface runoff flows the remaining section of Dr George Mountain Road, approximately 400m in length, which has few runoff controls and erosion is evident. In addition, majority of the mitre drains along the lower road section of Dr George Mountain Road are full of sediment and require maintenance.

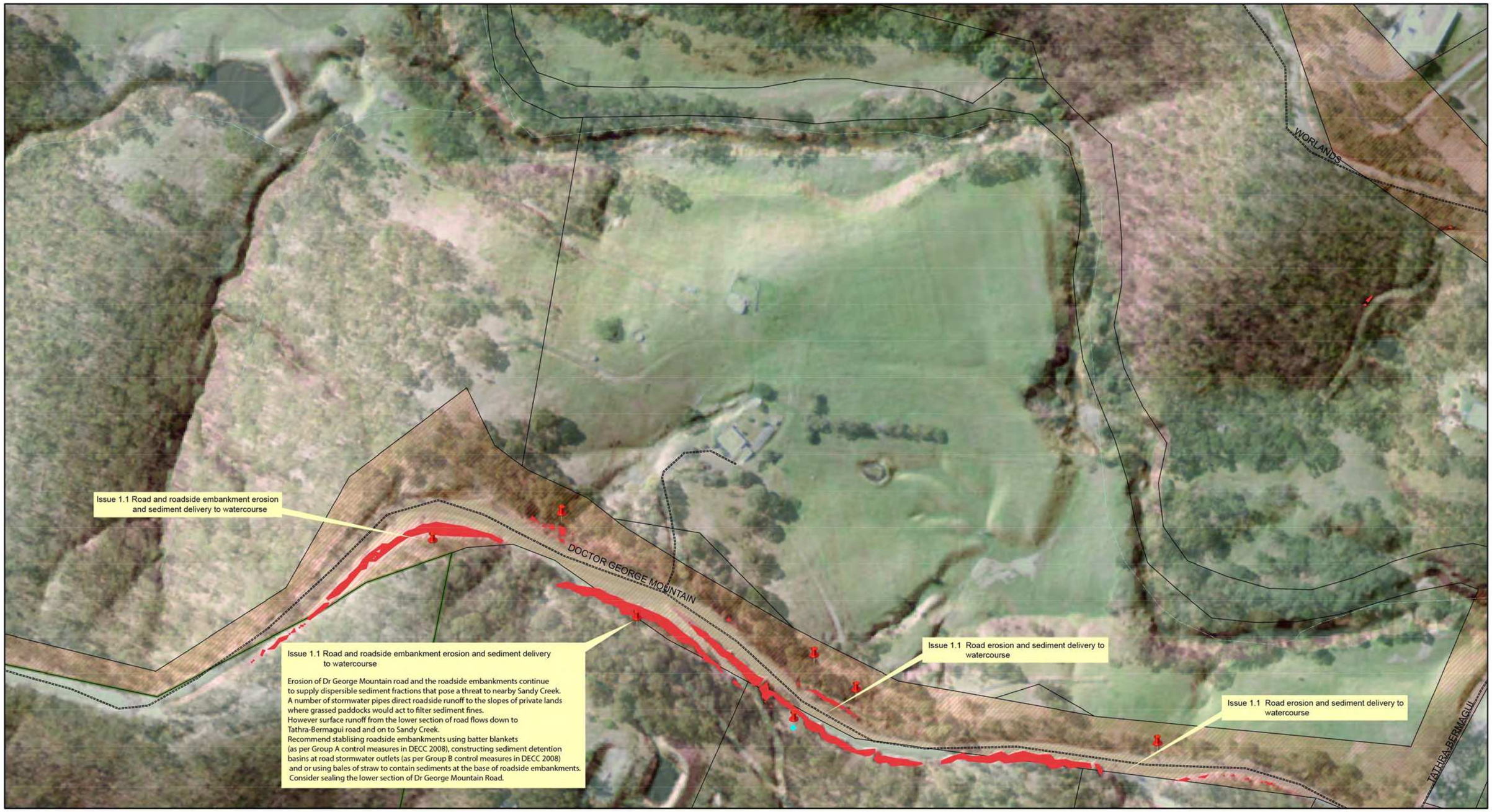
Recommended Treatment Action/s:

- Recommend stabilising roadside embankments using batter blankets (as per Group A control measures in DECC 2008). In some road sections, bales of straw may be used to help contain sediments at the base of roadside embankments on the southern side of Dr George Mountain Road;
- Construct sediment detention basins at road stormwater outlets (as per Group B control measures in DECC 2008); and
- Consider sealing the lower section of Dr George Mountain Road including appropriate stormwater runoff controls.

APPENDIX B

Figure B2 Example of a hillslope and unstable roadside embankment of Dr George Mountain Road that continues to erode and supply dispersible sediment fractions during rainfall events (*left image*). Road surface runoff is directed to the crown road reserve via two stormwater pipes where sediment deposition below pipe outlets is evident. Siltation barrier below one of the pipe outlets is damaged and no longer functional with sediment being delivered further downslope to private land (*right image*).

Figure B3 Third storm-water pipe outlet (along the 700m road section) that discharges to roadside drain below embankment (*left image*). From the pipe outlet, road surface runoff flows a further 400m to Tathra-Bermagui Road (*right image*).



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Potentail Eroding Bank / Embankment
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Mimosa Rocks National Park
- Crown Road Reserve

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 1

GDA 94 Zone 55

Riparian engineering

Map B1

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Sheet No.
Sheet 3 of 10

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 2

Area Description and Issue Synopsis

The area includes the junction of Dr George Mountain road and Tathra-Bermagui Road and the single lane timber bridge over Sandy Creek. Low priority issues in this area include erosion of roadside embankment and perception that the riparian zone of Sandy Creek upstream and downstream of the bridge is dominated by exotic weed species.

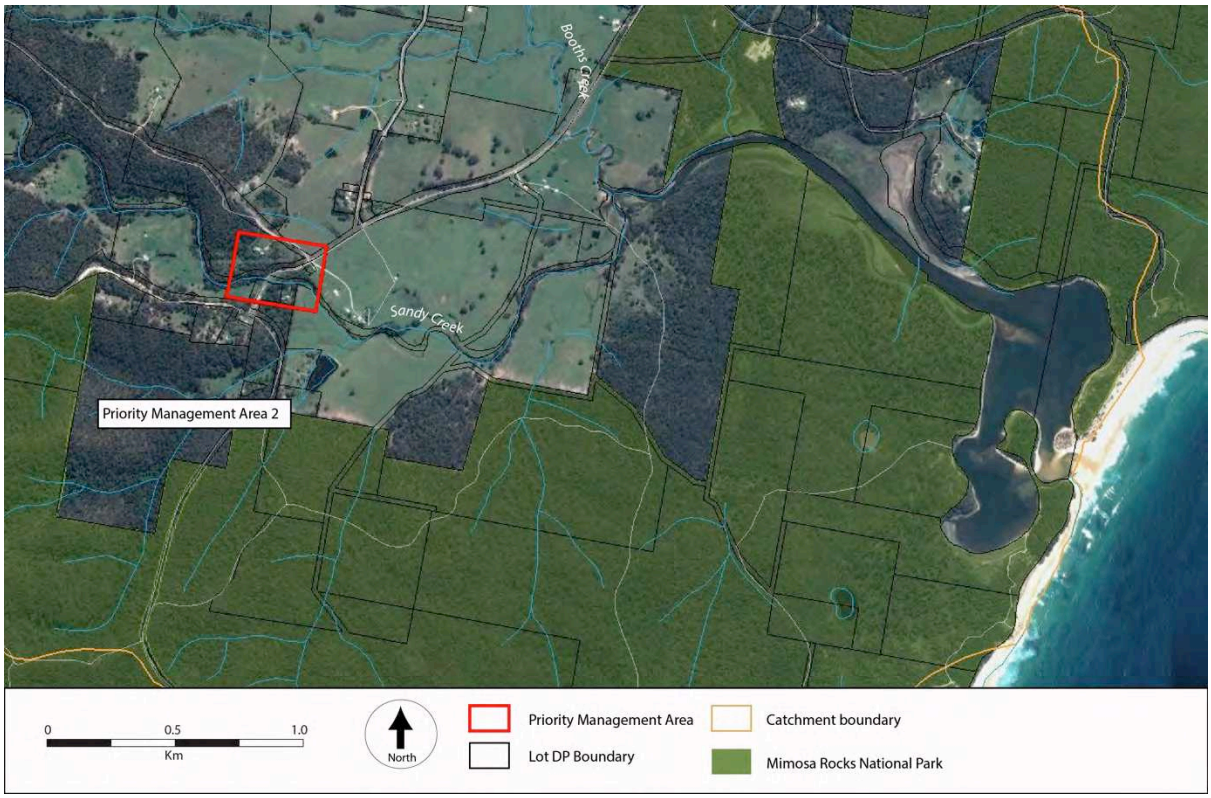


Figure B4 Location of priority management area 2.

Low priority issues that require attention include:

- **Issue 2.1** Minor erosion of roadside embankment and sediment delivery to watercourse
  Issue 2.2 Perception of riparian zone dominated by weeds

Each issue is described with recommended actions for treatment provided in sections below.

Issue 2.1 Minor erosion of roadside embankment and sediment delivery to watercourse

LOW PRIORITY

Site Address [Responsibility]: Tathra-Bermagui Road [RMS/BVSC] (Refer **Map B2**).

Lat/Long Coordinates: 36°38'33.27"S, 149°58'22.71"E

Issue Description: Minor erosion of roadside embankment of Tathra-Bermagui Road immediately south of Worlands Road (**Figure B5**) is contributing dispersible sediment fractions to Sandy Creek during high rainfall events.

Recommended Treatment Action/s:

- Recommend stabilising roadside embankment using batter blankets and construction of a small sediment detention basin/trap to prevent excess sediments from entering watercourse (as per Group B control measures in DECC 2008).

Figure B5 View of roadside embankment and verge towards Worlands Road (*left imag*e). The view from the roadside embankment and verge towards the Tanja junction bridge (*right image*).

Issue 2.2 Perception of riparian zone dominated by weeds

LOW PRIORITY

Site Address [Responsibility]: Crown Reserve [DPI Lands] (Refer **Map B2**).

Lat/Long Coordinates: 36°38'35.33"S, 149°58'18.54"E

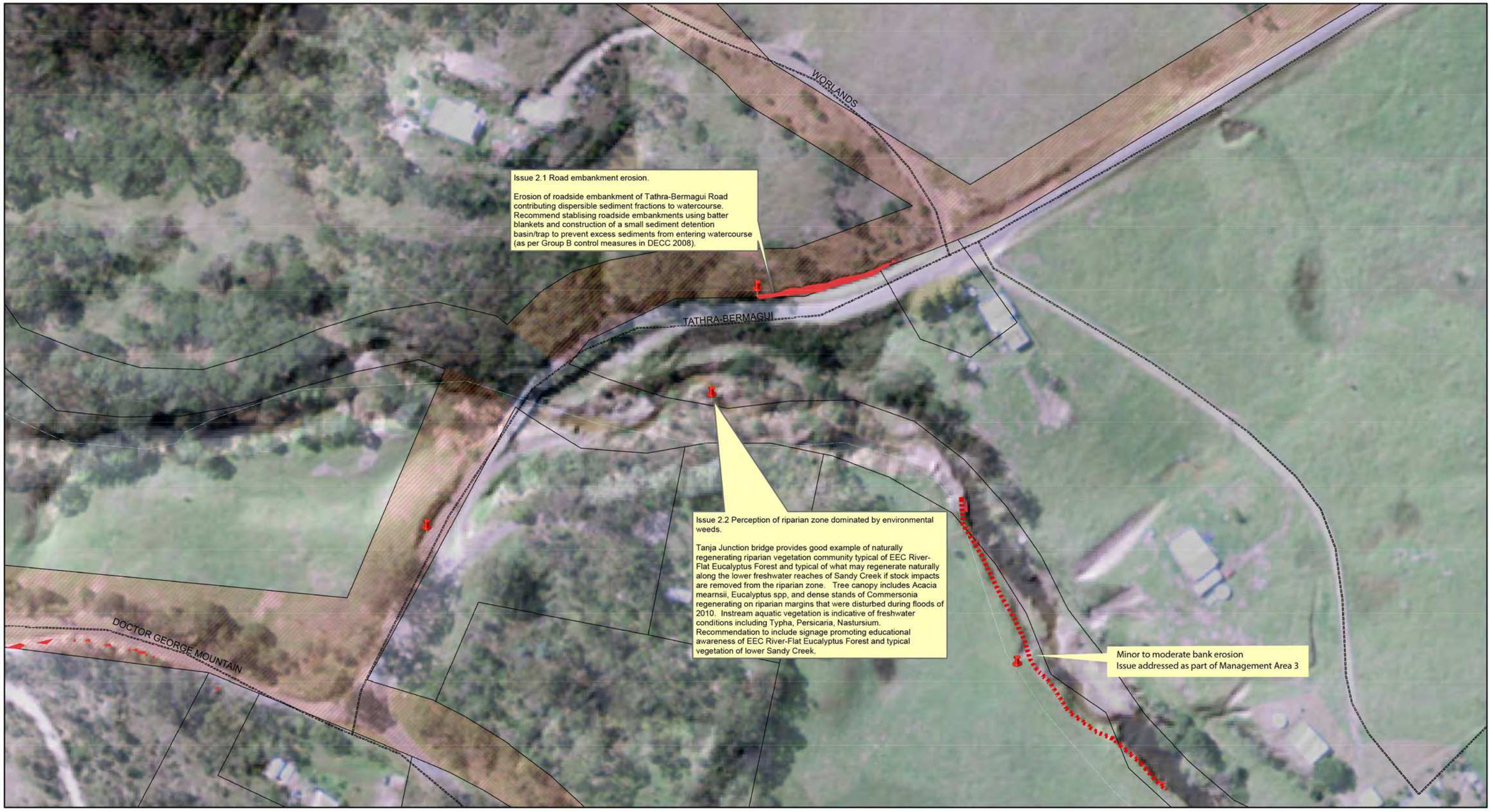
Issue Description: Sandy Creek at Tanja Junction bridge (Tathra-Bermagui Road) provides a good example of naturally regenerating vegetation community typical of lower freshwater reaches of Sandy Creek. The vegetation has been mapped as EEC *River-flat Eucalyptus Forest* although there is perception that the riparian zone is dominated by exotic species. Tree canopy includes *Acacia mearnsii, Eucalyptus* spp, and dense stands of *Commersonia* (black-fella hemp) are regenerating on riparian margins that were disturbed during significant flood events in 2010. Instream aquatic vegetation is indicative of freshwater conditions including *Typha, Persicaria, Nastursium*. This vegetation community is what may regenerate naturally along the lower freshwater reaches of Sandy Creek if stock impacts are removed from the riparian zone.

Recommended Treatment Action/s:

- Consider including signage promoting educational awareness of EEC *River-Flat Eucalyptus Forest* and naturally regenerating vegetation of lower Sandy Creek.

APPENDIX B

Figure B6 View of the Sandy Creek vegetation community (*left imag*e). A dense stand of *Commersonia* has naturally regenerated on the right bank of Sandy Creek following flood disturbance in 2010 (*right image*).



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Bank Erosion
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Crown Road Reserve
- Potentail Eroding Bank / Embankment

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 2

Riparian engineering

GDA 94 Zone 55

Sheet No.
Sheet 4 of 10

Map B2

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 3

Area Description and Issues Synopsis

The area includes the floodplain of lower Sandy Creek where the stream meanders through private land before joining with Booths Creek downstream (**Figure B7**). Tidal flows and brackish waters influence the lower reaches of Sandy Creek with low-lying floodplain areas experiencing prolonged periods of inundation when the estuary entrance is closed. A stand of dead *Melaleuca ericifolia* and numerous dead large *Eucalypts* that had colonised lower stream bank areas provide evidence of recent prolonged estuary high stands.

The property has been used for agriculture since the late 1800s with a timber mill previously operating on the property. The streamside zone is unfenced with stock able to access the watercourse. Minor to moderate bank erosion and bank slumping is evident in localised areas. Riparian vegetation is limited to large canopy trees representing remnant *River-flat Eucalyptus Forest* community with vegetation absent along large stretches of bank. Large woody debris (LWD) is present in lower Sandy Creek providing fish habitat and some bank protection.

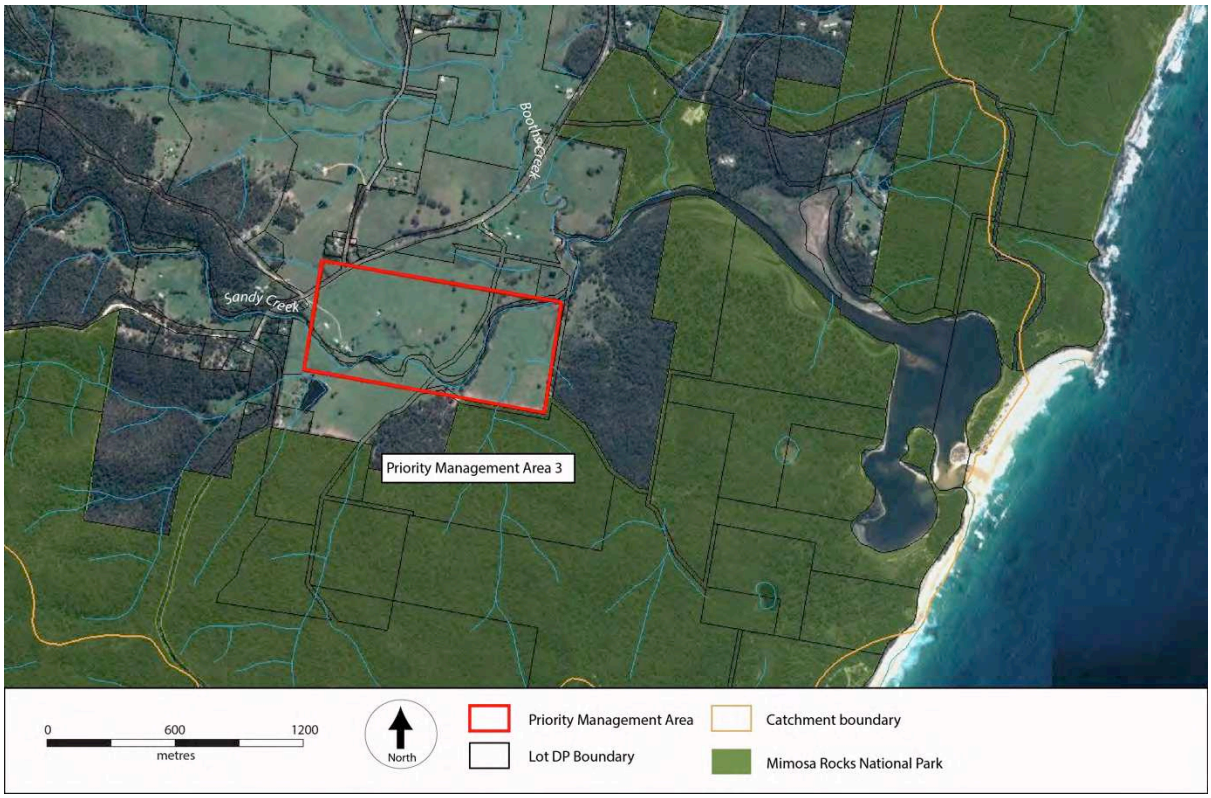


Figure B7 Location of priority management area 3.

High priority issues that require attention include:

- **Issue 3.1** Minor to moderate bank erosion and slumping with stock access to streamside zone
- **Issue 3.2** Riparian vegetation limited to canopy trees with vegetation absent along large reaches of the creek

Each issue is described with recommended actions for treatment provided in sections below.

APPENDIX B

Issue 3.1 Minor to moderate bank erosion and slumping with stock access to streamside zone

HIGH PRIORITY

Site Address [Responsibility]: Private Land [Lot 11 DP1092225, SE LLS] (Refer **Map B3**).

Lat/Long Coordinates: Multiple locations along reach between points 36°38'36.42"S, 149°58'24.70"E to 36°38'45.25"S, 149°58'50.48"E

Issue Description: The freshwater reaches of Lower Sandy Creek are characterised by a series of connected pools and wetlands indicative of low stream velocity environment. Pools are well vegetated with a range of emergent aquatic macrophytes including *Myriophyllum* sp, *Juncus* sp., *Eleocharis sphacelata*, and *Alisma plantago-aquatica*. Riparian vegetation is largely limited to canopy trees including an isolated stand of remnant *Casuarina cunninghamii* with Eucalypts becoming more prevalent downstream. Understorey vegetation is limited to small stands of *Melaleuca*, *Callistemon, Juncus and Lomandra* confined to the active channel with stock grazing to the top of bank currently maintaining a streamside zone clear of understorey vegetation. Riparian vegetation is absent along several long reaches of the creek with pasture grasses the primary vegetation providing bank stability.

Current stocking rates are low with impacts to the streamside zone in terms of bank erosion and slumping minor to moderate. However stock impacts to creek water quality are evident in low flow pools where water-colour is brown due to suspended load. Benthic algal mats are present in lower Sandy Creek indicative of nutrient impacts to the creek. Current landholder has expressed concerns regarding the dead Eucalypt trees (Bangalays) along the tidally influenced reach of Sandy Creek. Tree deaths are attributed to prolonged periods of inundation when the estuary entrance was closed. The landholder would like to re-establish riparian tree cover in these areas although successful improvement and revegetation of the riparian zone would require stock to be excluded from streamside zone. For lower Sandy Creek, species to be considered for revegetation works would need to be tolerant to prolonged periods of inundation of brackish to saline water.

Recommended Treatment Action/s:

- Work with landholder of Lot 11 DP1092225 to fence off the streamside zone to exclude stock from the watercourse and implement use of water troughs for stock.
- Work with landholder to investigate opportunities to re-establish riparian vegetation along bare banks and improve condition of the riparian zone where understorey vegetation is absent.

APPENDIX B

Figure B8 Stock access to the streamside zone and watercourse contributes to diminished water quality of Sandy Creek (*left image*). Example of freshwater reach of Sandy Creek and floodplain with riparian vegetation absent (*right image*).

Figure B9 Example of lateral bank erosion that has been caused by water flows from an overland drainage line and a pre-cursor bank disturbance. Improved riparian understorey and groundcover vegetation would help to prevent this type of erosion from occurring (*left image*). Downstream view of lower Sandy Creek with dead *Eucalypts* in the distance due to prolonged inundation. (*right image*).

Issue 3.2 Riparian vegetation limited to canopy trees with vegetation absent along large reaches of the creek

HIGH PRIORITY

Site Address [Responsibility]: Private Land [Lot 11 DP1092225, SE LLS] (Refer **Map B3**).

Lat/Long Coordinates: 36°38'33.61"S, 149°59'3.52"E

Issue Description: The riparian zone of lower Sandy Creek is unfenced with stock able to graze to top of bank and enter the creek bed. Riparian vegetation is limited to isolated large canopy trees with understorey strata absent. This area of Sandy Creek has been mapped as the EEC *River Flat Eucalyptus Forest* although few of the key community indicator species are present at the site. The primary disturbance factor contributing to the absence of shrub and understorey vegetation is

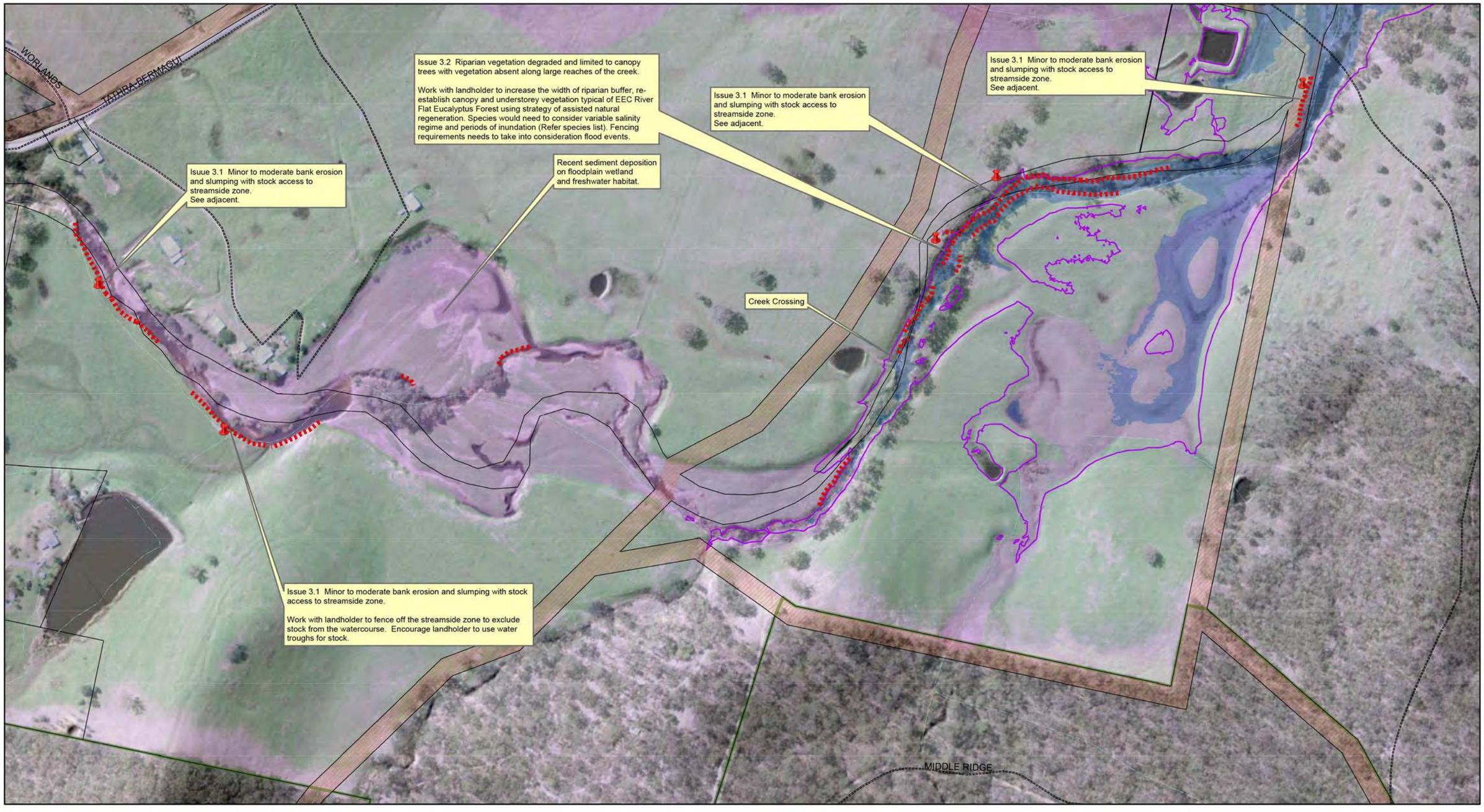
trampling and grazing impacts by stock.

The landholder has expressed interest in re-establishing riparian tree cover although successful improvement and revegetation of the riparian zone would require stock to be excluded from streamside zone. For lower Sandy Creek, species to be considered for revegetation works would need to be tolerant to prolonged periods of inundation of brackish to saline water.

Recommended Treatment Action/s:

- Work with landholder of Lot 11 DP1092225 to investigate opportunities to re-establish riparian vegetation along bare banks and improve condition of the riparian zone where understorey vegetation is absent. Refer to conceptual drawing for typical river restoration treatment (**Appendix C**) and recommended species list (**Appendix D**).

Figure B10 Example of riparian zone where understorey vegetation is absent and bank disturbance due to stock impacts is evident (*left image*). Typical condition of the riparian zone along lower Sandy Creek limited to canopy trees with shrub and understorey vegetation absent (*right image*).



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Bank Erosion
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Crown Road Reserve
- Water Level (Max. Berm 2.5 m AHD)
- Herbaceous Wetland Flora / Pasture Grasses
- Mimosa Rocks National Park

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 3

Riparian engineering

GDA 94 Zone 55

Sheet No.

Sheet 6 of 10

Map B3

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 4

Area Description and Issues Synopsis

The area includes the floodplain and lower reaches of Booths Creek extending from the western side of Tathra-Bermagui Road and includes the area surrounding the confluence of Booths Creek and Sandy Creek. Fluvial and estuarine processes operate in this area with the dominant process dependent on whether the lagoon entrance is open or closed. When the entrance is closed water levels rise, brackish water conditions migrate further upstream and low-lying land becomes inundated. When the entrance is open, water levels remain low until the entrance closes again.

The current landholder family has used the property for agriculture since at least the late 1940s including cropping (beans and corn) and grazing. Historical management of water on the property has included the installation of a timber weir (now dilapidated) on Booths Creek to prevent the intrusion of brackish water upstream and artificial opening of the lagoon entrance to maintain lower water levels in this area of the property.

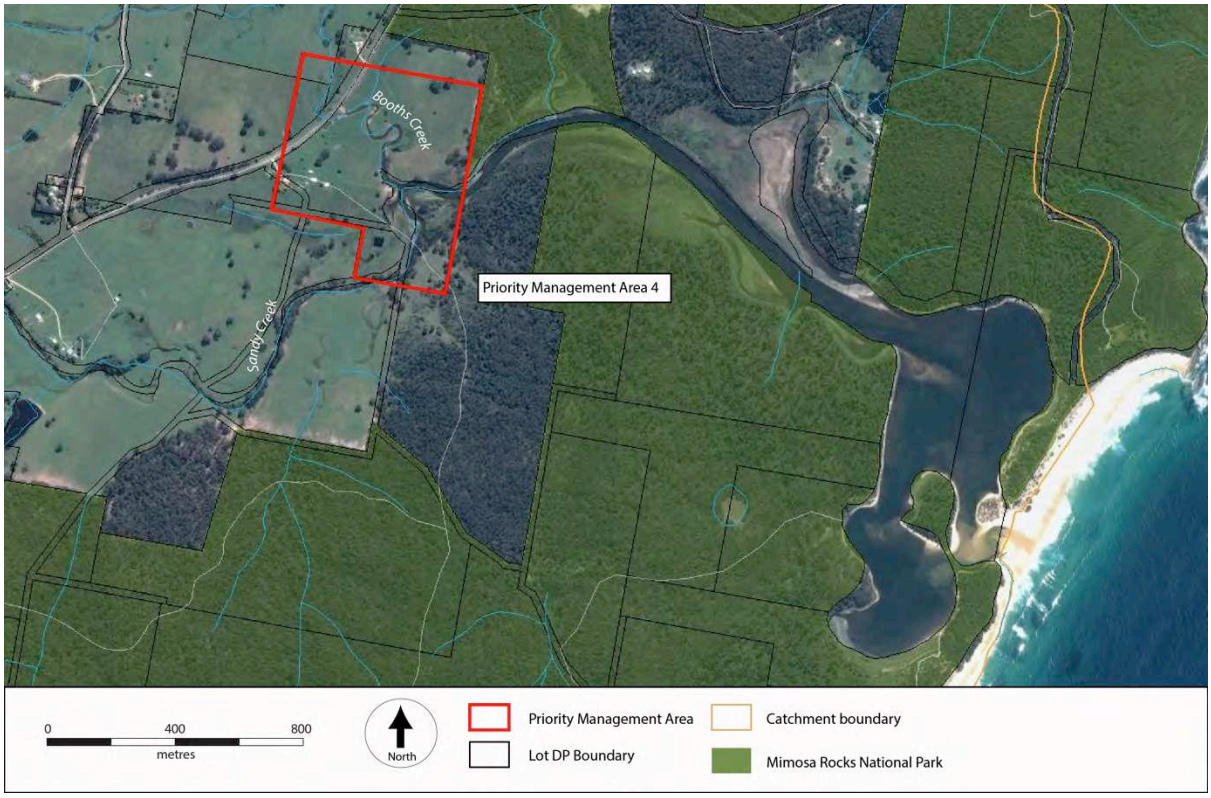


Figure B11 Location of priority management area 4.

High priority issues that require attention include:

- **Issue 4.1** Erosion of stream bank during episodic high flow events
- **Issue 4.2** Limited riparian vegetation along stream bank with riparian zone unfenced with stock access to watercourse
- **Issue 4.3** Bank erosion at rock chute outlet
- **Issue 4.4** Road embankment dams up stormwater in high rainfall events
- **Issue 4.5** Riparian vegetation degraded and limited to canopy trees with vegetation absent

along large reaches of the creek

Each issue is described with recommended actions for treatment provided in sections below.

Issue 4.1 Erosion of stream bank during episodic high flow events

HIGH PRIORITY

Site Address [Responsibility]: Private Land [Lot 2 DP1105244, SE LLS] (Refer **Map B4**).

Lat/Long Coordinates: 36°38'15.97"S, 149°59'8.61"E

Issue Description: Erosion to the stream banks of Booths Creek immediately downstream of the Tathra-Bermagui Road occurs during episodic high flow events. The construction of the Tathra-Bermagui Road across the Booths Creek floodplain has likely contributed to some of the erosion issues currently observed on Booths Creek. The culvert, whilst of sufficient size, has been positioned upstream of the natural flow drainage and is elevated above the creek. Consequently, during high flow events large volumes of water accumulate on the western side of Tathra-Bermagui Road before reaching the threshold to spill over the culvert. The Tathra-Bermagui Road acts like a dam-wall concentrating high stream-flow energy through the culvert and down into a meandering section of Booths Creek that would not naturally be subjected to such high velocity flows. Large granite boulders have been used to construct a rock chute at the culvert spillway to protect the creek bed with boulders also placed along bank sections immediately downstream of the culvert. Some boulders have been shifted by floodwaters from the active channel up onto the floodplain providing some evidence of the high velocity and force of stream flows during high rainfall events. There is risk that ongoing high flow events may erode through the bank to short-circuit the meander bend, with landholder at risk of loosing large area of land and contributing a large amount of sediment to the estuary.

Recommended Treatment Action/s:

- Maintenance of the low-flow stormwater pipes at the natural alignment of Booths Creek.
- Work with landholder to improve the riparian vegetation cover over lower Booths Creek that will provide increased bank protection during high flow events.
- Mitigation of bank erosion problem may also require further engineering investigations and re-design of the rock chute outlet to disperse stream-flow energy.

Figure B12 Large granite boulders placed at the culvert outlet for bed protection (*left image*). The

hydraulic jump caused by the culvert has led to development of a scour pool where flows enter Booths Creek and erosion of the opposite bank. Boulders have been placed along the creek banks in an effort to stabilise the banks from the episodic high flows that occur (*right image*).

Issue 4.2 Limited riparian vegetation along stream bank with riparian zone unfenced with stock access to watercourse

HIGH PRIORITY

Site Address [Responsibility]: Private Land [Lot 2 DP1105244, SE LLS] (Refer **Map B4**).

Lat/Long Coordinates: 36°38'16.07"S, 149°59'9.51"E

Issue Description: The riparian zone of Booths Creek is unfenced with stock permitted to graze to top of bank and enter the creek bed. Very little natural vegetation exists along banks with riparian vegetation limited to isolated stands of *Melaleuca ericifolia, Juncus* spp., and pasture grasses. Improving vegetation cover of the riparian zone would improve bank stability and help to protect the banks from erosive forces during high flow events. The landholder is receptive to remedial works being undertaken to improve the condition of the riparian zone but also intends to continue grazing the alluvial flats and immediate riparian lands surrounding Booths Creek. Re-establishing vegetation along the banks would be difficult if stock is not excluded from the streamside zone. However, fencing requirements would need to consider periods of inundation and damaging episodic flood flows. Species to be considered for revegetation works would also need to be tolerant to prolonged periods of inundation of brackish to saline water with *Melaleuca ericifolia* and species indicative of *Swamp Sclerophyll Forest* and *Bangalay Sand Forest* communities likely to be most appropriate.

Recommended Treatment Action/s:

- Work with landholder to investigate opportunities to re-establish riparian vegetation along bare banks and improve condition of the riparian zone where understorey and canopy vegetation is absent. Refer to conceptual drawing for typical river restoration treatment (**Appendix C**) and recommended species list for upper estuary area (**Appendix D**).
- Rehabilitation of the riparian zone of lower Booths Creek will need to consider long periods of inundation and waters of variable salinity.
- Explore potential provisions available to landholder to offset the exclusion of stock from this area to allow riparian vegetation to re-generate.
- Recommend landholder use water troughs so cattle do not need to enter watercourse

APPENDIX B

Figure B13 View of lower Booths Creek from Tathra-Bermagui Road showing riparian zone absent of vegetation and stock access to top of bank (*left image*). View over the meander bends showing general absence of natural riparian vegetation (*right image*).

Figure B14 Example of a low-lying area devoid of vegetation with bare earth exposed. This area becomes inundated when the estuay entrance closes (*left image*). Example of current condition of riparian zone of lower Booths Creek where some vegetation exists with isolated stands of *Melaleuca ericifolia* limited to the active channel and remains of dead *Melaleuca* (*right image*).

Issue 4.3 Bank and bed erosion at rock chute outlet

HIGH PRIORITY

Site Address [Responsibility]: Watercourse [DPI Lands, BVSC, SE LLS] (Refer **Map B4**).

Lat/Long Coordinates: 36°38'15.74"S, 149°59'6.55"E

Issue Description: Episodic high flow events at the box-culvert have caused disturbance to the rock chute with bed sediments now exposed with potential risk of further erosion. The rock chute may need to be re-designed to better disperse stream power. Furthermore, the landholder has expressed desire to move stock between western and eastern sides of property via the box culvert to avoid dangerous practice of walking stock over Tathra-Bermagui Road. However, the rock chute in its current form prevents the movement of stock via the box culvert.

Recommended Treatment Action/s:

- Repair rock chute, which may include need for redesign and extension of existing rock revetment to disperse high velocity flows.
- Repair and maintenance of the rock chute may consider use of cement stabilised sand for bed protection but also provide even surface for use as stock crossing.

Figure B15 The rock chute outlet below the box-culvert (*left image*). Example of the large boulders comprising the rock chute and disturbance to bed sediments occurring during high flow events (*right image*).

Issue 4.4 Road embankment concentrates stormwater flows through box culvert during high rainfall events

HIGH PRIORITY

Site Address [Responsibility]: Tathra-Bermagui Road [RMS, DPI Lands, BVSC] and private land [Lot 2 DP1105244] (Refer **Map B4**).

Lat/Long Coordinates: 36°38'16.43"S, 149°59'4.43"E

Issue Description: The construction of the Tathra-Bermagui Road across the Booths Creek floodplain and placement of the box culvert in an elevated position above the natural flow drainage of Booths Creek is likely to be to be contributing to the build-up of floodwaters on the western side of the embankment during high rainfall events (**Figure B16**). This issue may be exacerbated when flood levels in Sandy Creek are high prior to the sand berm at the entrance being breached, causing Booths Creek floodwaters to back-up. When the berm at the entrance is breached, the roadside embankment acts like a dam wall, concentrating flow through the box culvert, leading to potentially very high velocities that cause downstream erosion of Booths Creek. A potential treatment includes maintenance of rock chute at a high flow outlet of box culvert to improve dispersion of velocity water. Additionally there is a need to investigate whether additional engineering designs at the box culvert, and maintenance of the low-flow stormwater pipes at Booths Creek may assist in natural drainage. Further engineering investigation is required.

APPENDIX B

Recommended Treatment Action/s:

- Undertake regular inspection and maintenance of the stormwater pipes at the natural flow alignment of Booths Creek to remove debris and ensure stream flows (**Figure B17**).
- Implement maintenance at the rock chute outlet to improve dispersion/reduction of stream flow velocity during high flow events.
- Investigate the need for additional engineering designs at the box-culvert as required.

Figure B16 Example of how the road embankment acts like a dam wall causing floodwaters to build-up on the western side of Tathra-Bermagui Road (*photos courtesy of N. Dummett*, 15 February 2010).

Figure B17 The view of Booths Creek natural alignment above the stormwater pipes (*left image*). The upstream view of Booths Creek natural alignment from the box culvert looking towards the stormwater pipes (*right image*).

Issue 4.5 Riparian vegetation degraded and limited to canopy trees with vegetation absent along large reaches of the creek

HIGH PRIORITY

Site Address [Responsibility]: Private Land [Lot 2 DP1105244, SE LLS] and crown reserve [DPI Lands] (Refer **Map B4**).

APPENDIX B

Lat/Long Coordinates: 36°38'29.82"S, 149°59'14.44"E

Issue Description: The riparian zone of lower Sandy Creek is unfenced with stock able to graze to top of bank and enter the creek bed. Riparian vegetation is limited to isolated large canopy trees with understorey strata absent. The site is partially private land and crownland that is characterised by a number of large dead *Eucalyptus* trees and dead stands of *Melaleuca ericifolia* whose demise is attributed to recent prolonged periods of inundation when the estuary entrance was closed. This area of Sandy Creek has been mapped as the EEC *River Flat Eucalyptus Forest* though although key community indicator species are no longer present at the site.

The landholder has expressed interest in re-establishing riparian tree cover although successful improvement and revegetation of the riparian zone would require stock to be excluded from streamside zone. For lower Sandy Creek, species to be considered for revegetation works would need to be tolerant to prolonged periods of inundation of brackish to saline water.

Recommended Treatment Action/s:

- Work with landholder of Lot 2 DP1105244 and DPI Lands to investigate opportunities to re-establish riparian vegetation along bare banks of Sandy Creek and improve condition of the riparian zone where understorey vegetation is absent. Refer to conceptual drawing for typical river restoration treatment (**Appendix C**) and recommended species list (**Appendix D**).

Figure B18 Example of riparian zone of lower Sandy Creek where natural vegetation is largely absent and that could be improved by rehabilitation efforts (*left image*). The riparian zone of Sandy Creek looking upstream to the adjoining property that is characterised by large canopy trees with understorey vegetation absent (*right image*).

Issue 4.4 Road embankment concentrates stormwater flows though box culvert during high rainfall events.

Construction of the Tathra-Bermagui Road embankment across the floodplain and placement of box culvert in an elevated position above the natural drainage of Booths Creek is likely to be contributing to the build-up of floodwaters on the western side of the embankment during high rainfall events. This issue may be exacerbated when flood levels in Sandy Creek are high prior to the sand berm at the entrance being breached, causing Booths Creek floodwaters to back□up. When the berm at the entrance is breached, the roadside embankment acts like a dam wall, concentrating flow through the box culvert, leading to potentially very high velocities that cause downstream erosion of Booths Creek. A potential treatment includes maintenance of rock chute at a high flow outlet of box culvert to improve dispersion of velocity water. Additionally there is a need to investigate whether additional engineering designs at the box culvert, and maintenance of the low-flow stormwater pipes at Booths Creek may assist in natural drainage. Further engineering investigation is required.

Issue 4.3 Bank and bed erosion at rock chute outlet.

Repair rock chute which may include need for redesign and extension of existing rock revetment to disperse high velocity flows.

Issue 4.2 Limited riparian vegetation along streambank with stock access to streamside zone.

Riparian vegetation absent or limited to sparse stands of Melaleuca ericifolia that are doing a reasonable job of stablising the bank where present. Landholder is receptive to addressing the problem of bank erosion by re-establishing riparian buffer but also intends to continue grazing this area. Species would need to consider variable salinity regime and periods of inundation (Refer species list). Fencing requirements would need to consider periods of inundation and flood events.

Issue 4.1 Erosion of streambank during episodic high flow events.

Streambanks of Booths Creek immediately downstream of the Tathra- Bermagui Road culvert being eroded by high velocity flows during episodic storm events. Recommended treatment includes maintenance of the stormwater pipes where Booths Creek naturally flows to alleviate flow force. Work with landholder to improve the riparian vegetation cover that will provide increased bank protection during high flow events.

4.1 Erosion of streambank during episodic high rainfall events. See adjacent.

Issue 4.5 Riparian vegetation degraded and limited to canopy trees with vegetation absent along large reaches of the creek.

Work with landholder to increase the width of riparian buffer, re-establish canopy and understorey vegetation typical of EEC River Flat Eucalyptus Forest using strategy of assisted natural regeneration. Species would need to consider variable salinity regime and periods of inundation (Refer species list). Fencing requirements needs to take into consideration flood events.

Booths Creek

TATHRA-BERMAGUI

Booths Creek

Middle Lagoon Estuary Channel

Sandy Creek

0 55 110 220 330 440 Metres

MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Bank Erosion
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Crown Road Reserve
- Mimosa Rocks National Park
- Water Level (Max. Berm 2.5 m AHD)
- 2100 Sea Level Rise (Berm Height 3.6 m AHD)

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 4

GDA 94 Zone 55

Riparian engineering

Map B4

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Sheet No.
Sheet 7 of 10

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 5

Area Description and Issue Synopsis

The area includes the tidal channel of Sandy Creek and the fluvial depositional zone of the lagoon characterised by levee bank formation along the main channel that enclose several extensive saline wetland areas. Majority of EEC coastal saltmarsh community is located in this management area, a large portion of which is located on private land. Stands of dead *Melaleuca* and *Eucalyptus* trees fringe saltmarsh areas and provide a conspicuous reminder of the transition foreshore vegetation is currently undergoing due to the lagoon entrance being allowed to resume its natural open and closed regime. The estuary foreshore is subject to increased periods of inundation due to prolonged high water stands associated with the entrance closure. The area includes NPWS and private land tenure with road maintenance and uncontrolled foreshore access issues the requiring attention.

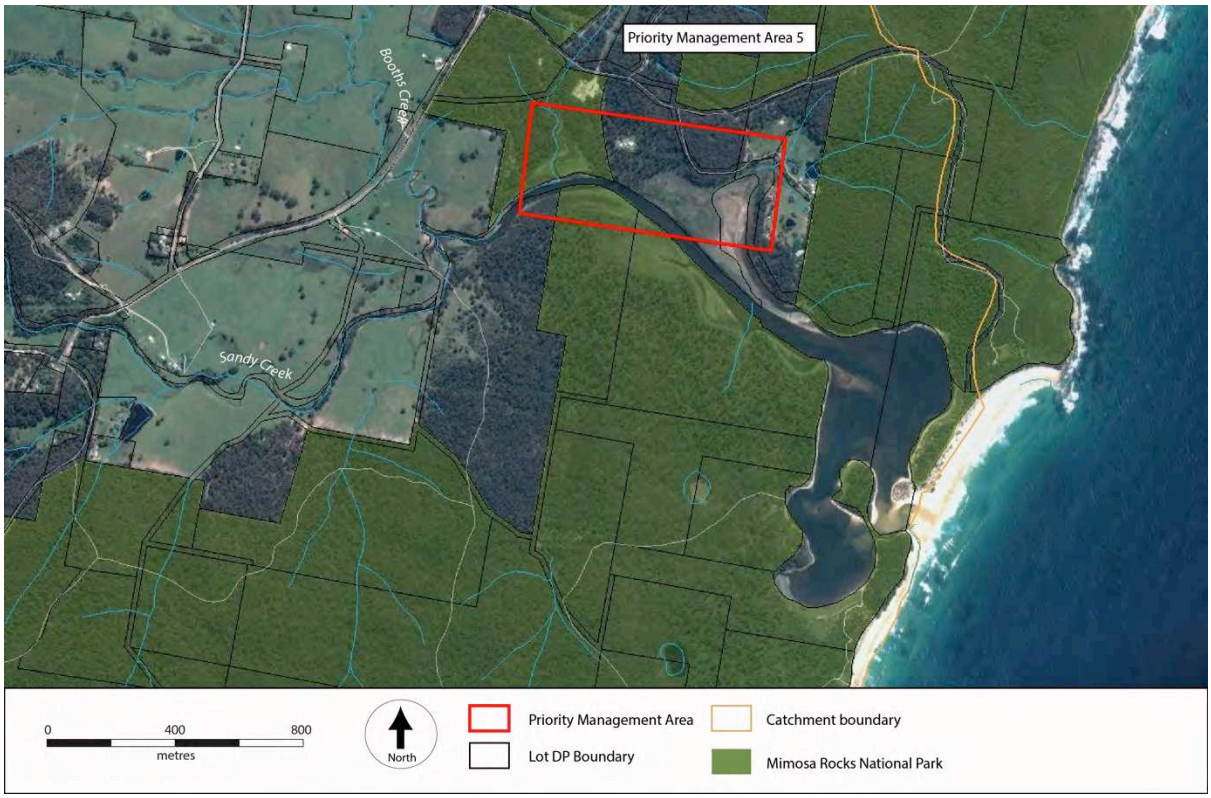


Figure B19 Location of priority management area 5.

Medium priority issues that require attention include:

- **Issue 5.1** Inappropriate road maintenance
- **Issue 5.2** Uncontrolled foreshore access via sensitive saltmarsh community

Low priority issue that requires attention include

- **Issue 5.3** Large stand of dead Eucalyptus trees on southern side of estuarine channel
- **Issue 5.4** Potential for bank damage associated with launching small vessels

Each issue is described with recommended actions for treatment provided in sections below.

APPENDIX B

Issue 5.1 Inappropriate road maintenance deteriorating road surface condition

MEDIUM PRIORITY

Site Address [Responsibility]: Private Land [Lot 6 DP259588], Crown Road [DPI Lands/NPWS/BVSC] (Refer **Map B5**).

Lat/Long Coordinates: 36°38'15.76"S, 149°59'58.57"E

Issue Description: A short section of unsealed road approximately 150m long with moderate slope is in fair condition though inappropriate road maintenance is deteriorating road surface condition. The crown road alignment passes through private lands (Lot 6 DP259588) and crown land reserve before ending at the boundary to private lands (Lot 1381 DP854091 and Lot 7004 DP1054068). A 50m section of the road becomes inundated by approximately 100mm depth during high water stands when the lagoon entrance is closed. The landholder (Lot 1381 DP854091 and Lot 7004 DP1054068) at the end of the road currently undertakes regular road surface maintenance with appropriate use of blue-metal to stabilise road surface and creation of effective run-off controls. However, landholder efforts to improve the road surface are disturbed by NPWS road maintenance crew who continue to grade this section of the road removing the stabilising blue-metal. This process eventually results in further erosion and a poorer road surface with dispersible sediment fines being transported to the saltmarsh community.

Recommended Treatment Action/s:

- Work with landholders and NPWS road maintenance crew to implement effective road management and runoff controls along this 150m section of unsealed road, including use of blue-metal to raise a 50m section of road surface above the high water stand when the lagoon entrance is closed.
- Install siltation controls at the bottom of the slope to minimise sediment fines entering the saltmarsh.

Figure B20 Moderately sloping section of crown road requiring improved surface runoff controls and improved maintenance schedule undertaken in liaison with landholders (*left image*). The mitre drain at the base of the road slope increasing in size with dispersible soil fractions entering the saltmarsh in high rainfall events (*right image*).

APPENDIX B

Issue 5.2 Uncontrolled foreshore access via sensitive saltmarsh community

MEDIUM PRIORITY

Site Address [Responsibility]: Private lands [Lot 6 DP259588], crown reserve [DPI Lands] (Refer **Map B1**).

Lat/Long Coordinates: 36°38'15.72"S, 150° 0'0.99"E

Issue Description: Recreational users of Middle Lagoon accessing the foreshore via coastal saltmarsh creating informal tracks through private lands and parking cars along narrow roadside verge with increasing frequency. As the road is immediately adjacent to the lagoon it provides easy access point for canoeists and kayakers. Despite this section of the road being on private land, those wishing to access the lagoon are using it as a carpark with increasing frequency. Landholder who owns land and landholders who rely on the road would prefer public access to the foreshore via NPWS designated and managed tracks.

Recommended Treatment Action/s:

- Signage to raise awareness of sensitive saltmarsh community and that access to estuary at this location is not encouraged.

Figure B21 Overview of the issue location with respect to private land and crown land reserve (*left image*). Informal access to lagoon foreshore via private land (*right image*).

Issue 5.3 Large stand of dead *Eucalyptus* trees on southern side of estuarine channel

LOW PRIORITY

Site Address [Responsibility]: Estuary foreshore [NPWS] (Refer **Map B5**).

Lat/Long Coordinates: 36°38'40.81"S, 150° 0'9.36"E

Issue Description: A large stand of dead *Eucalyptus* trees (many are Bangalays - *Eucalyptus botryoides*) exists on the southern side of Sandy Creek channel. This represents one of many areas where dieback is evident around the lagoon foreshore. Some tree deaths, those in low-lying areas, can be attributed to prolonged inundation when the estuary entrance has been closed but many dead trees exist above the water high stand and the most probable cause of death for those trees can be attributed to Bell Miner Associated Dieback (BMAD). Extensive stands of dead *Melaleuca*

ericifolia are also present around the lagoon foreshore. *Melaleuca* can tolerate several years of continuous inundation before tree death occurs. Extended periods of low water levels due to drought can also cause tree mortality.

Recommended Treatment Action/s:

- Community education and or signage that explains the background history of artificial entrance opening of Middle Lagoon and the influence that practice has had on vegetation distribution and that some of the tree dieback is a natural process in response to the lagoon resuming its natural opening and closing regime.

Further community education and explanation of the issue of BMAD in the coastal forests of Mimosa Rocks National Park (Refer Action 7 in Section 5.1.4 (NPWS 2011) would also be valuable.

Figure B22 Approximate foreshore areas where tree dieback (*Eucalyptus* and *Melaleuca*) has occurred (*left imag*e). Example of dead *Eucalyptus* trees on lagoon foreshore (*right image*).

Issue 5.4 Potential for bank damage associated with launching small vessels

LOW PRIORITY

Site Address [Responsibility]: Estuary foreshore [NPWS] (Refer **Map B5**).

Lat/Long Coordinates: 36°38'17.28"S, 149°59'30.97"E

Issue Description: NPWS management track via the NPWS Tanja Depot providing access to the estuarine channel and is currently used by commercial fishermen to launch small vessels under an access agreement with NPWS. The narrow unsealed track follows the western side of a drainage line to the estuary. Part of the track has been elevated above a low-lying wetland and drainage area using gravel with installation of a stormwater pipe to maintain low-flow connectivity. The track ends at the foreshore that is part of a depositional levee bank environment of the lagoon, with the levee bank crest elevated above the saline wetland area immediately to the north. The reed *Phragmites australis* is the dominant vegetation along and below the bank crest. Levee bank is composed of cohesive sandy-clay sediments with moderate natural erosion occurring.

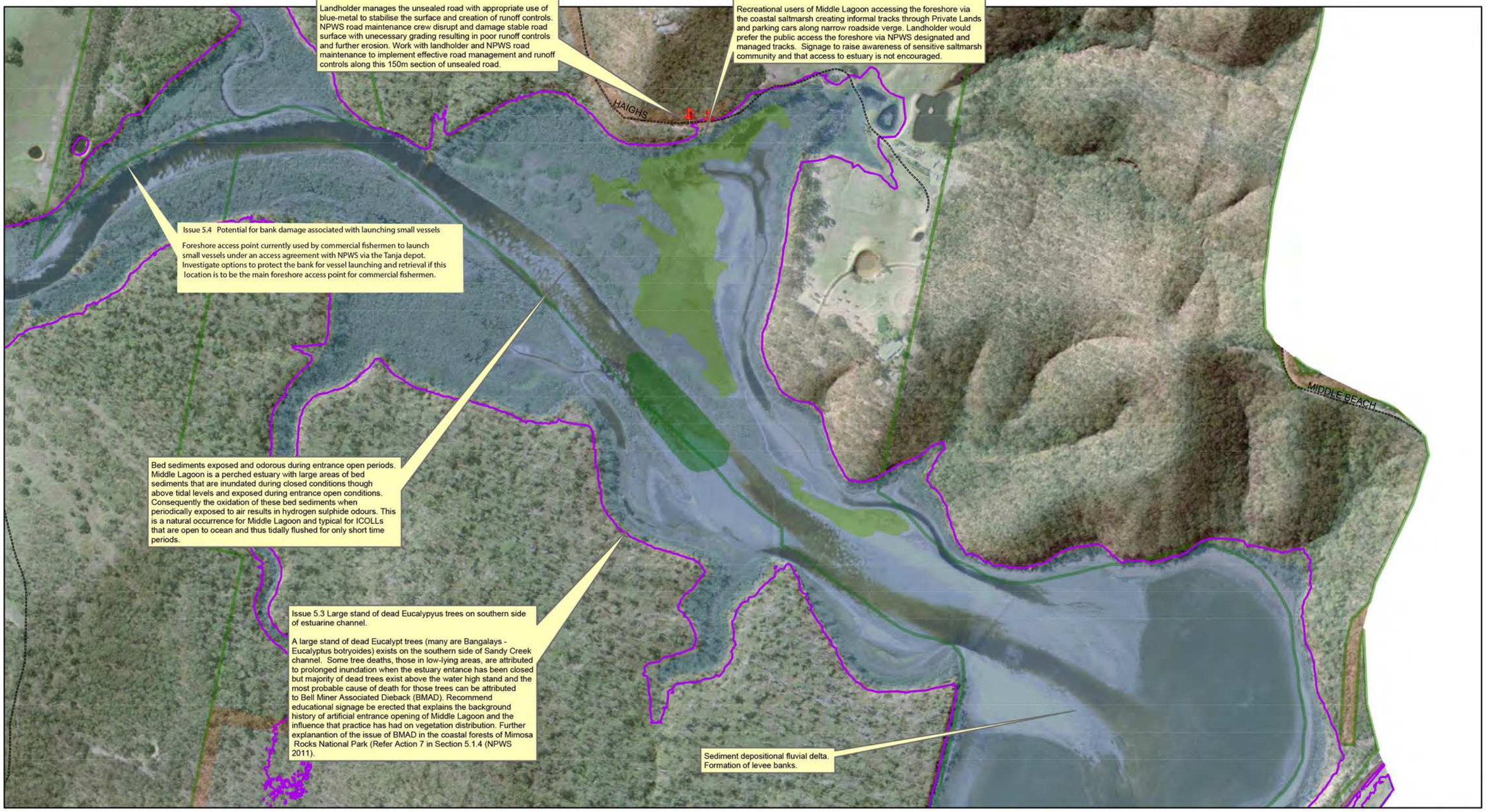
The primary issue is related to ongoing access and potential for bank damage associated with launching small trailerable motorboats by commercial fishermen at this location. The levee bank is

steep and boat launching and retrieval is feasible during high water levels. However, access is difficult during low water levels with vessels likely requiring winching over the bank. Minor impact to bank vegetation (*Phragmites australis)* is evident where vessel launching and retrieval has been occurring. NPWS are obliged to permit commercial fishers to use this foreshore access point to launch their vessels as alternative access points via other NPWS management tracks are in poor condition and not currently maintained by NPWS. If this site continues to be the main foreshore access point for launching small vessels then options to protect the bank for vessel launching and retrieval are required.

Recommended Treatment Action/s:

- Investigate options to protect the bank for vessel launching and retrieval if this location is to be the main foreshore access point for commercial fishermen.

Figure B23 NPWS management track terminating at the lagoon foreshore (*left imag*e). Wheel ruts forming on the bank where boat launching has been occurring (*right image*).



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Saltmarsh
- Zostera
- Bank Erosion
- Road
- Crown Road Reserve
- Water Level (Max. Berm 2.5 m AHD)
- 2100 Sea Level Rise (Berm Height 3.6 m AHD)
- Mimosa Rocks National Park

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 5

GDA 94 Zone 55

Riparian engineering

Map B5

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Sheet No.
Sheet 7 of 10

Checked by: Nick Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 6

Area Description and Issue Synopsis

This area includes the entrance to Middle Lagoon and the estuary broadwater comprised of a northern and southern sub-basin known as Dorl Bay and Tommy's Bay respectively (**Figure B24**). The lagoon foreshore to mean high water mark (MHWM) is part of Mimosa Rocks National Park and managed by NPWS with the estuarine waterway below MHWM the responsibility of DPI Fisheries.

The lower estuary is the most popular area for recreation providing a protected and safe waterway for swimming, fishing, and canoeing. Public access is provided to the north-eastern foreshore via a 200m long track from the main visitation area and Middle Beach carpark. Road access to the lagoon foreshore includes NPWS management tracks to the western and southern ends of the estuary from Gillards Beach campground.

The entrance to Middle Lagoon intermittently opens and closes and the ecology of the lagoon is intrinsically linked to its open-closed regime. The entrance is generally closed and typically only opens for short periods of 3 to 6 weeks before closing again. Historically the lagoon entrance has been managed by a number of catchment landholders for a period of at least 70 years (*pers. comm. N. Dummett*, October 2015), with the practice of artificially opening the entrance probably occurring since the late 1800s. A consequence of the long-term practice of opening the lagoon entrance to regulate water levels has been the colonisation of foreshore areas by vegetation and tree species typically restricted to higher areas.

Management of Middle Lagoon is the responsibility of NPWS, DPI Fisheries, DPI Lands and BVSC whose policy regarding the lagoon entrance is that of – 'no artificial intervention'. In more recent times, Middle Lagoon has been allowed to open to the ocean naturally with estuary water levels remaining higher for naturally longer periods – typically up to 12 months and longer. As a result of water levels resuming a more natural pattern and high water stands more prolonged, many of the tree and shrub species that had colonised the low-lying foreshore areas are now dead or dying. The foreshore vegetation of Middle Lagoon is currently undergoing a distribution shift back to what is natural according to the broader range of water levels and salinity regime.

APPENDIX B

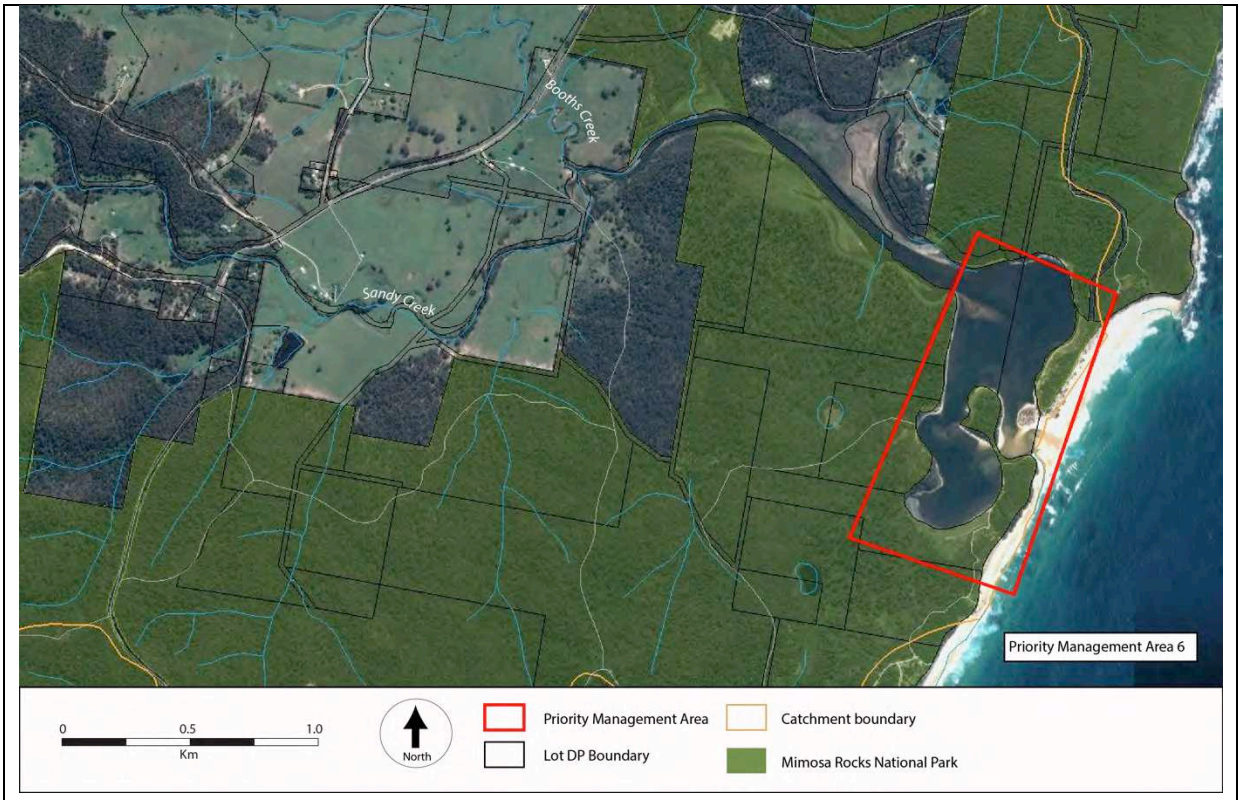


Figure B24 Location of priority management area 6.

High priority issue that require attention include:

- **Issue 6.1** Artificial opening of the estuary entrance

Medium priority issues that require attention include:

- **Issue 6.2** Degraded foreshore area on western side of lagoon associated with informal camp and boat launching area
- **Issue 6.3** Motorbike access to coastal saltmarsh community

Each issue is described with recommended actions for treatment provided in sections below.

Issue 6.1 Artificial opening of the estuary entrance

HIGH PRIORITY

Site Address [Responsibility]: Crown land [DPI Lands, DPI Fisheries, NPWS, BVSC] (Refer **Map B6**).

Lat/Long Coordinates: 36°38'59.11"S, 150° 0'30.65"E

Issue Description: The entrance to Middle Lagoon intermittently opens and closes and the ecology of the lagoon is intrinsically linked to its open-closed regime. The entrance is generally closed and typically only opens for short periods of 3 to 6 weeks before closing again. Historically the lagoon entrance was managed by a number of catchment landholders for a period of at least 70 years (*pers. comm. N. Dummett*, October 2015), however the practice of artificially opening the entrance by earlier landholders was probably occurring since the late 1800s. The entrance was opened by digging out the sand berm with use of shovels and or horse and dray (**Figure B25**). The historical management practice of regularly opening the lagoon entrance maintained lower water levels in the

estuary to provide regular access to low-lying lands for grazing and other agricultural uses. However, a consequence of artificial opening the lagoon entrance to regulate water levels has been the colonisation of foreshore areas by vegetation and tree species typically restricted to higher areas.

Management of Middle Lagoon is the responsibility of DPI Fisheries, DPI Lands, NPWS and BVSC whose policy regarding the lagoon entrance is that of – 'no artificial intervention'. There is now generally broad public understanding of the ecological sensitivities of ICOLLs and that opening the entrance of an ICOLL is prohibited and a prosecutable offence under *Fisheries Management Act* 1994 (Refer Part 7 Section 201). In more recent times, Middle Lagoon has been allowed to open to the ocean naturally with estuary water levels remaining higher for naturally longer periods – typically up to 12 months and longer. As a result of lagoon water levels resuming a more natural pattern and high water stands more prolonged, many of the tree and shrub species that had colonised low-lying foreshore areas are now dead or dying. The foreshore vegetation of Middle Lagoon is currently undergoing a distribution shift back to what is natural according to the broader range of water levels and salinity regime.

Recommended Treatment Action/s:

- Development of educational signage to be erected near the entrance that explains the unique ecology of Middle Lagoon as an ICOLL and potential harm to estuarine ecology due to artificial opening of estuary entrance (*i.e.* shifts in estuarine vegetation communities, potential fish kills, loss of fish recruitment, altered salinity regime).
- Previously DPI Fisheries have erected signage to inform persons that opening the entrance is a prohibited and prosecutable offence. Consider implementing permanent signage to minimise risk of illegal artificial openings.

Figure B25. Historical management of the Middle Lagoon ocean entrance – circa 1950s (*photos courtesy of N. Dummett*).

APPENDIX B

Figure B26 Signage erected near the entrance of Middle Lagoon in 2012 warning persons that opening the estuary is prohibited and prosecutable offence with heavy penalties of up to $110,000 for individual and $220,000 for corporations.

Issue 6.2 Degraded foreshore area on western side of lagoon associated with informal camp and boat launching area

MEDIUM PRIORITY

Site Address [Responsibility]: Estuary foreshore [DPI Lands, NPWS] (Refer **Map B6**).

Lat/Long Coordinates: 36°38'55.45"S, 150° 0'13.38"E

Issue Description: A NPWS management track from Gillards Beach Road provides access to the western foreshore of Middle Lagoon where there is an informal camp. Areas of the foreshore are degrading from uncontrolled use. The track has historically been used by fishermen to launch small vessels and continues to be the primary foreshore access point for commercial fishermen. However the track is currently in very poor condition and not being actively maintained by NPWS. When funding permits, NPWS intend to install a locked gate at the track entrance to further limit use and restrict public use (*pers. comm.* K. Brown, NPWS, Oct 2015). Foreshore access is an important issue to commercial fishermen who are currently permitted to fish the lagoon under Region 7 of the NSW Estuary General Fishery. Consequently, NPWS are obliged to permit alternative and continued access via the Tanja Depot off Haighs Road in lieu of access via other established tracks.

Recommended Treatment Action/s:

- Liaise with NPWS regarding plans to install a locked gate on the management track at Gillards Beach Road to limit track use.
- Work with NPWS to monitor the natural regeneration of vegetation at the degraded foreshore to ensure weeds do not become an issue.

APPENDIX B

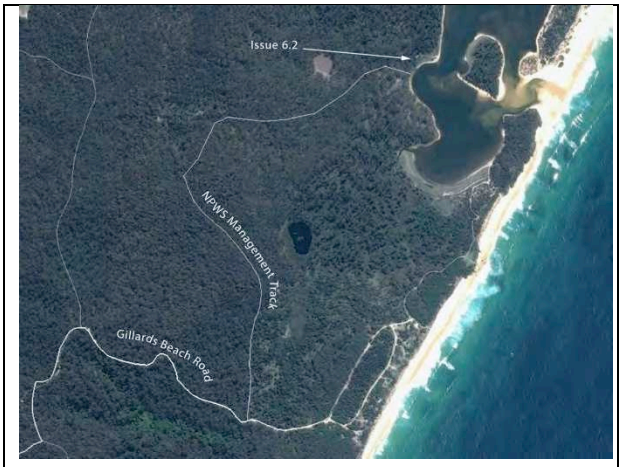


Figure B27. NPWS management track that provides access to the western side of Middle Lagoon (*left imag*e). Foreshore access at western side of lagoon via NPWS management track used to launch small vessels (*right image*).

Issue 6.3 Motorbike access and damage to EEC coastal saltmarsh community

MEDIUM PRIORITY

Site Address [Responsibility]: Estuary foreshore [DPI Lands, NPWS] (Refer **Map B6**).

Lat/Long Coordinates: 36°39'11.18"S, 150° 0'13.09"E

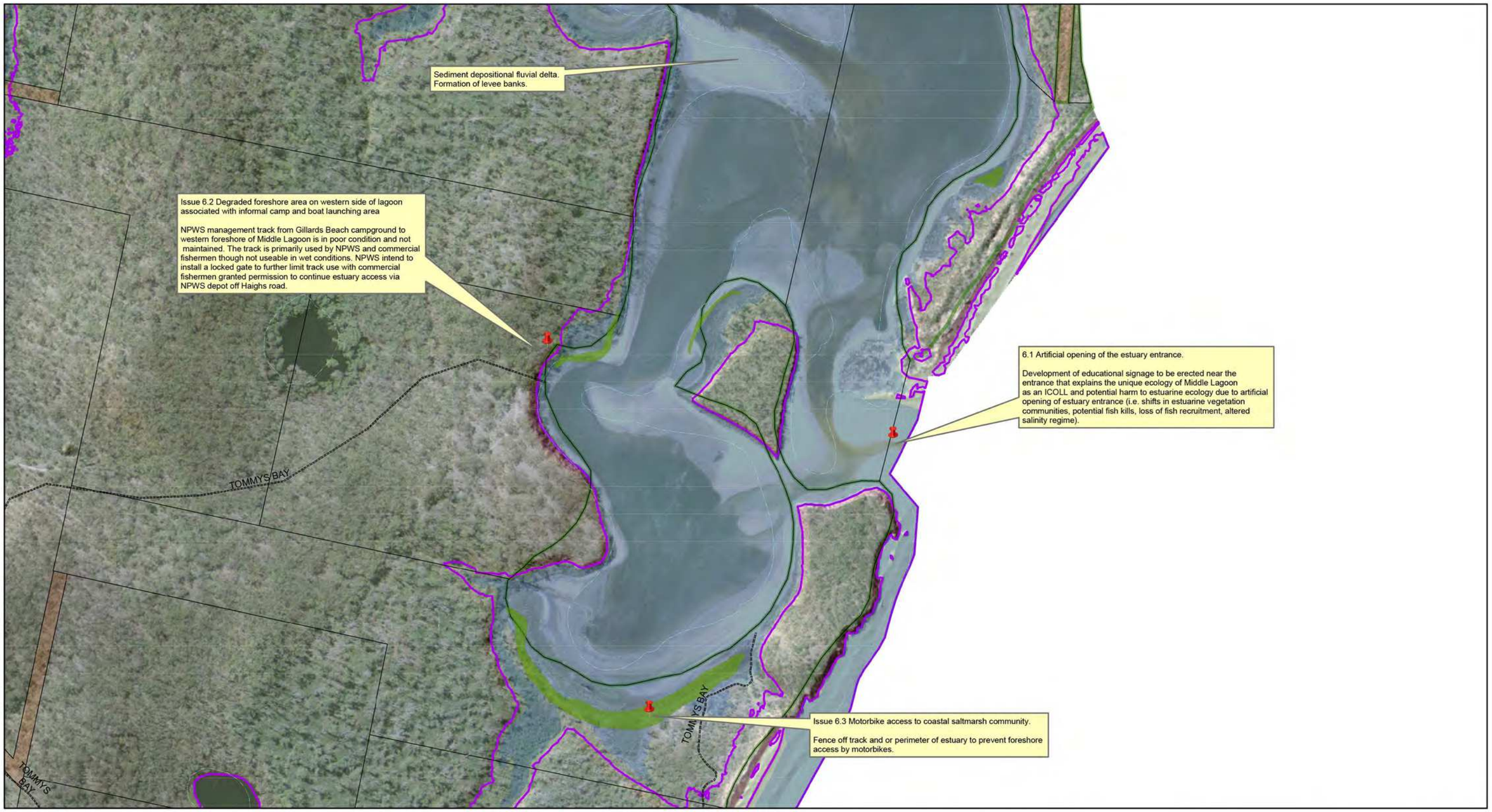
Issue Description: A NPWS management track exists behind the foredune from Gillards Beach day-use area providing access to the southern end of Middle Lagoon. NPWS are in process of formalising this former vehicular track as a loop-walking track known as 'Tommy's Bay Walk' (NPWS 2011). The track winds through the endangered ecological community (EEC) *Bangalay Sand Forest* before opening onto the foreshore of Tommy's Bay, which is characterised by a large extent of EEC *Coastal Saltmarsh* community. Recent disturbance and damage to the saltmarsh community by motorbikes is evident in form of tyre tracks that have created scars through the vegetation community. It is probable that motorbikes accessed the foreshore via the Tommy's Bay walking track though not confirmed.

Recommended Treatment Action/s:

- Liaise with NPWS to inform of recent damage to EEC coastal saltmarsh by motorbikes and that access was likely via Tommy's Bay Walk. Identify potential access routes other than Tommys Bay Walk that may be used by motorbikes and block-off.
- Use bollards and or fencing to limit Tommys Bay Walk to pedestrian traffic only (if not already done) and or consider fencing the southern perimeter of estuary to prevent foreshore access by motorbikes.

APPENDIX B

Figure B28 The southern end of Middle Lagoon is characterised by a large extent of coastal saltmarsh community (*left imag*e). Evidence of recent impacts to saltmarsh community likely due to motorbikes (*right image*).



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Saltmarsh
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Crown Road Reserve
- Water Level (Max. Berm 2.5 m AHD)
- 2100 Sea Level Rise (Berm Height 3.6 m AHD)
- Mimosa Rocks National Park

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 6

Riparian engineering

GDA 94 Zone 55

Sheet No.
Sheet 8 of 10

Map B6

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 7

Area Description and Issue Synopsis

This area includes the lower freshwater sections of Booths Creek and tributary streams including Davis Creek (**Figure B29**). The area is characterised by low gradient slopes and alluvial floodplain that become inundated during high rainfall events. Drainage lines include extensive wetland areas where stream flows are naturally slow and soil moisture retained. The area is entirely under private land tenure with current land-use primarily for cattle grazing. The streamside zone is virtually devoid of natural remnant vegetation with much of the original vegetation likely cleared when the area was settled in the late 1800s. Riparian vegetation is degraded and limited to isolated stands of a few scattered trees. In-stream vegetation includes a range of reeds, rushes and herbaceous wetland species that appear in reasonable condition given that stock currently access and graze wetland areas. A number of landholders are currently undertaking projects with SE LLS to protect the streamside zone from potential impacts associated with stock grazing and these are shown in **Figure B29**.

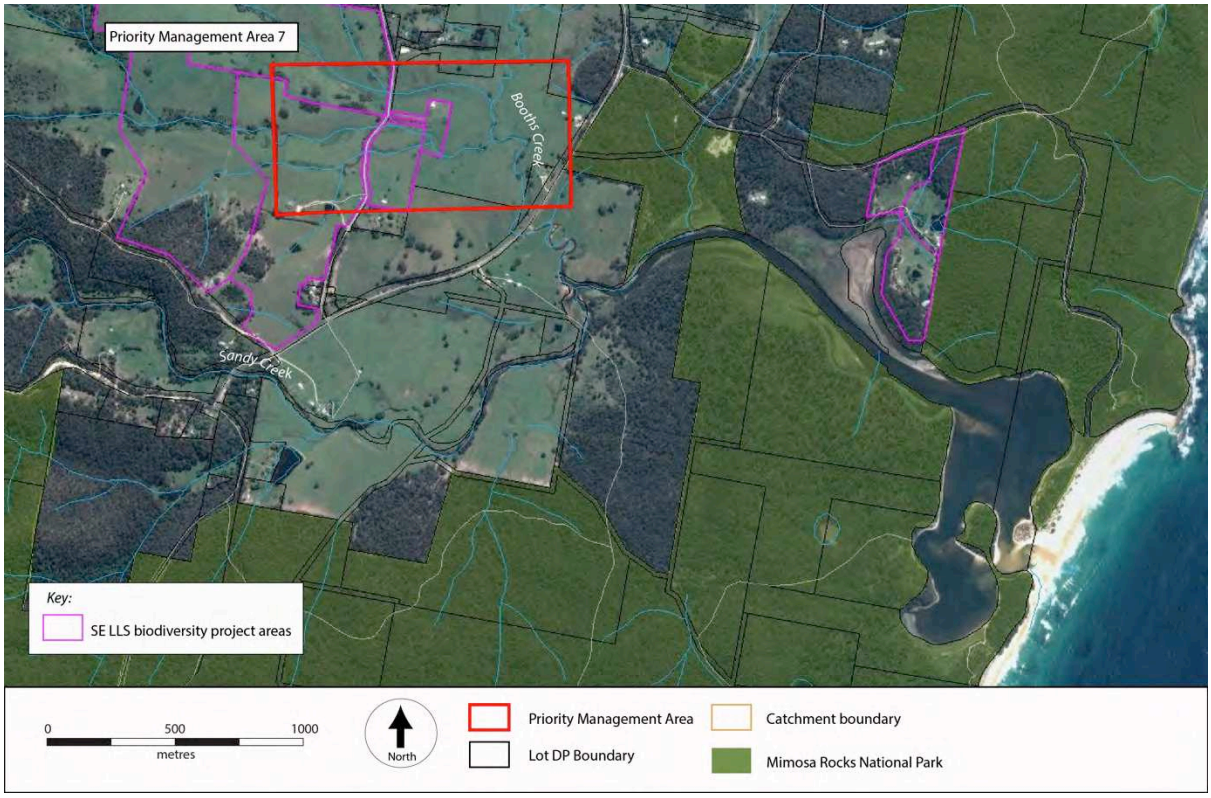


Figure B29 Location of priority management area 7.

Medium to High priority issues that require attention include:

- **Issue 7.1** Wetland area unfenced with stock access causing potential damage to herbaceous wetland flora
- **Issue 7.2** Erosion of Barrabooka Road with sediment and gravel input to wetland

Cont'd over page.

APPENDIX B

Low priority issues that require attention include:

- **Issue 7.3** Artificially constructed drain that has negatively impacted on floodplain wetland
- **Issue 7.4** Riparian vegetation absent along large reaches of Booths Creek and tributaries due to historical land clearing

Each issue is described with recommended actions for treatment provided in sections below.

Issue 7.1 Wetland area unfenced with stock access causing potential damage to herbaceous wetland flora

MEDIUM-HIGH PRIORITY

Site Address [Responsibility]: Private lands [Lot 82 DP810431], private lands [Lot 321 DP870998], private lands [Lot 241 DP1093825], Tanja Biodiversity Corridor Project [SE LLS](Refer **Map B7**).

Lat/Long Coordinates: [36°38'4.03"S, 149°58'35.25"E]; [36°38'4.39"S, 149°58'51.11"E]; [36°38'6.02"S, 149°58'55.67"E]

Issue Description: Davis Creek, a tributary stream of Booths Creek, has a sub-catchment area of 2.74 km^2 (10% of total catchment area of Middle Lagoon). Davis Creek and its minor streams drain the well-vegetated slopes and subsequent grazing lands below Fields Road and Worlands Road. Headwaters start at an elevation of approximately 171m and descend 3.85km through private lands to the confluence with Booths Creek at an elevation of 6m. A number of dams are located along the drainage lines of the Davis Creek system and stream flows are ephemeral. The lower reaches of Davis Creek and its tributary streams are natural wetland areas well defined by the distribution of wetland flora including *Juncus* spp., *Carex* spp. and *Typha* sp.

These wetland areas have an important role in the function of the catchment watershed in slowing stream flows, assisting the deposition of suspended solids and improving water quality. They also have inherently high natural biodiversity values providing vital habitat for insects, amphibians, reptiles and birds. Davis Creek wetlands extend over a number of adjoining private properties upstream and downstream of Kellys Bridge on Barrabooka Road whose land-uses currently include cattle grazing. Wetland areas are unfenced with stock able to graze through the wetlands and along drainage lines with potential damage to herbaceous wetland flora.

Recommended Treatment Action/s:

- Work with landholders along the Davis Creek wetland system to protect natural values of wetland areas from stock impacts and enhance the function of wetland to slow water flows. Fencing may not be practical in all areas due to potential damage during flood events.
- Alternative solutions to improving wetland areas may include discussion with landholders to implement stock management strategy to graze wetland areas only during dry periods to minimise potential damage, and or use of off-stream stock watering troughs.
- Note that South East Local Land Services (SE LLS) will commence work with landholders of Lot 82 DP810431 in 2016 to fence the drainage line to exclude stock access and undertake a replanting program to rehabilitate the riparian zone.

APPENDIX B

Figure B30 Downstream view of Davis Creek drainage line from Kellys Bridge at Barrabooka Road with cattle grazing in the wetland area (*left image*). A tributary drainage line to Davis Creek defined by the presence of wetland plants including *Juncus* spp. (*right image*).

Issue 7.2 Erosion of Barrabooka Road with sediment and gravel input to wetland

MEDIUM PRIORITY

Site Address [Responsibility]: Crown Road [DPI Lands/BVSC] (Refer **Map B7**).

Lat/Long Coordinates: Road section between points - 36°38'11.80"S, 149°58'39.23"E and 36°37'57.28"S, 149°58'43.63"E

Issue Description: Road surface of Barrabooka Road has been stabilised with blue-metal gravel though current road runoff controls are not sufficient with erosion of the road surface occurring during high rainfall events. Water flows generated during high rainfall events transport gravel to the lowest road elevation point at Kellys Bridge with gravel deposits impacting on Davis Creek and adjacent wetland areas.

Recommended Treatment Action/s:

- Implement road maintenance to improve storm-water runoff controls to prevent erosion of road surface and deposition of gravel to Davis Creek watercourse.

Figure B31 Gravel deposits transported to Kellys Bridge from Barrabooka road surface runoff after recent heavy rainfall event (*left image*). Gravel deposits accumulating in roadside drain adjacent to

Davis Creek watercourse (*right image*).

Issue 7.2 Artificially constructed drain that has negatively impacted on floodplain wetland

LOW PRIORITY

Site Address [Responsibility]: Private land [Lot 211 DP852166] (Refer **Map B7**).

Lat/Long Coordinates: 36°37'55.37"S, 149°58'32.73"E

Issue Description: Artificial drains have been historically constructed through floodplain wetlands to improve condition of pasture to detriment of wetland flora. These drains can also be subject to erosion issues.

Recommended Treatment Action/s:

- No action required. The current landholder is working with SE LLS to improve the condition of the drainage line including re-establishing riparian vegetation and fencing to exclude stock access.

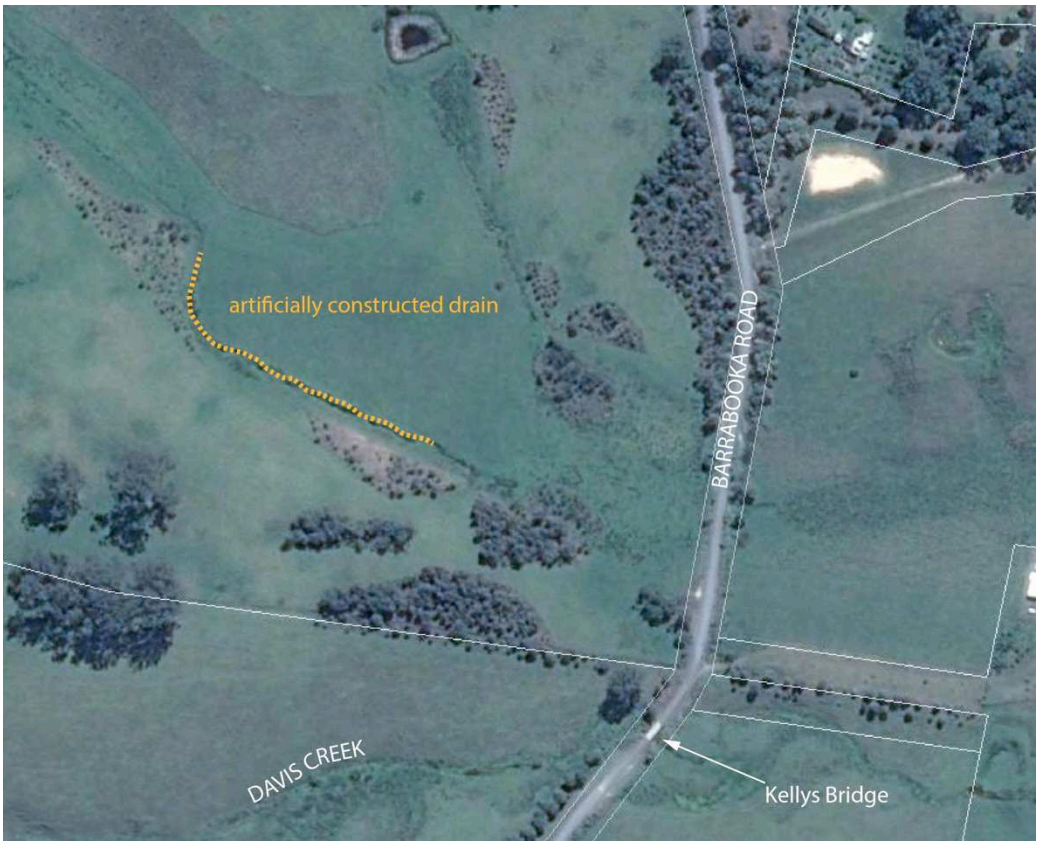


Figure B32 Location of an artificially constructed drain through a floodplain wetland that is now undergoing rehabilitation works.

Issue 7.3 Riparian vegetation absent along large reaches of Booths Creek and tributary streams due to historical land clearing

LOW PRIORITY

Site Address [Responsibility]: Private lands [Lot 241 DP1093825 and Lot 2 DP1105244] [SE LLS] (Refer **Map B7**).

APPENDIX B

Lat/Long Coordinates: [36°37'53.91"S, 149°59'3.07"E], [36°38'11.03"S, 149°59'6.23"E]

Issue Description: Lower freshwater section of Booths Creek and tributary streams meander through private lands that are primarily used for agricultural grazing. The streamside zone is largely devoid of natural remnant vegetation that has been historically cleared since the area was first settled in late 1800s. Booths Creek is unfenced with cattle able to access the watercourse. Erosion issues appear to be minor although efforts could be made to improve the condition of the riparian vegetation that would benefit the overall natural values of creek and improve resilience of the creek banks during high flow events. A number of landholders located on upstream tributaries are currently undertaking projects with SE LLS to rehabilitate the streamside zone. Rehabilitation of lower Booths Creek to re-establish tree and understorey cover would represent a linkage to those existing projects and generate an overall improved outcome for the condition of Booths Creek sub-catchment.

Recommended Treatment Action/s:

- Work with landholders to re-establish tree canopy and understorey vegetation typical of EEC *River Flat Eucalyptus Forest* using strategy of assisted natural regeneration. Species used for plantings would need to tolerate periods of inundation (Refer species list – **Appendix D**) and fencing requirement need to take into consideration flood events.

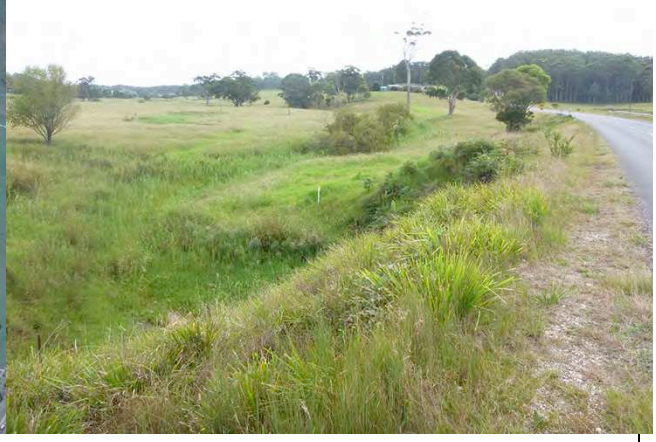


Figure B33 Overview of lower freshwater section of Booths Creek showing general absence of tree cover and riparian vegetation along the creek (*left image*). The view of Booths Creek upstream from Tathra-Bermagui Road showing a riparian zone largely devoid of trees (*right image*).

Issue 7.3 Artificially constructed drain that has negatively impacted on floodplain wetland

Artificial drains have been historically constructed through floodplain wetlands to improve condition of pasture to detriment of wetland flora. These drains can also be subject to erosion issues. The current landholder is working with SE LLS to improve the condition of the drainage line including re-establishing riparian vegetation and fencing to exclude stock access.

Issue 7.4 Riparian vegetation absent along large reaches of Booths Creek and tributaries due to historical land clearing.

Work with landholders to re-establish canopy and understorey vegetation typical of EEC River Flat Eucalyptus Forest using strategy of assisted natural regeneration. Species would need to consider periods of inundation (Refer species list) and fencing requirement need to take into consideration flood events.

Issue 7.2 Erosion of Barrabooka Road with sediment and gravel input to watercourse

Implement road maintenance to improve storm-water runoff controls to prevent erosion of road surface and deposition of gravel to Davis Creek watercourse.

Issue 7.1 Natural wetland surrounded by pasture, unfenced with stock access and potential damage to herbaceous wetland flora.

Work with landholders to protect natural values of wetland areas from stock impacts and enhance the function of wetland to slow water flows. Fencing may not be practical in all areas due to potential damage during flood events. Alternative solutions to improving wetland areas may include discussion with landholders to implement stock management to graze wetland areas only during dry periods to minimise damage, and or use of off-stream stock watering troughs. Current landholders are commencing a project with SE LLS to improve the condition of the drainage line including re-establishing riparian vegetation and fencing to exclude stock access.

Issue 7.4 Riparian vegetation absent along large reaches of Booths Creek and tributaries due to historical land clearing.
See adjacent.

Issue 7.1 Wetland area unfenced with stock access causing potential damage to herbaceous wetland flora

Landholders working with SE LLS to imporve condition of drainage line including re-establishing riparian vegetation and fencing to exclude stock access

Issue 7.1 Natural wetland surrounded by pasture, unfenced with stock access and potential damage to herbaceous wetland flora.
See adjacent.

BARRABOOKA

TATHRA-BERMAGUI

0 50 100 200 300 400 Metres

MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Road
- Rivers and Creeks
- Lot/DP Boundary
- Crown Road Reserve
- 2100 Sea Level Rise (Berm Height 3.6 m AHD)
- Herbaceous Wetland Flora / Pasture Grasses

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 7

Riparian engineering

GDA 94 Zone 55

Sheet No.
Sheet 9 of 10

Map B7

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX B

Priority Management Area 8

Area Description and Issues Synopsis

The area is located in Mimosa Rocks National Park to southwest of Middle Lagoon and is part of the Sandy Creek sub-catchment. The area is characterised by forested slopes with first and second order streams that originate at the southern boundary of the catchment at Gillards Beach Road at elevations ranging between 70 and 90m. Sandy Creek sub-catchment is characterised by yellow podzolic soils (metasediments and granites) that are more prone to erosion compared to those of Booths Creek sub-catchment that are mixture of soloths, yellow podzolic and chocolate soils. This area provides multiple examples of natural erosion processes occurring on minor streams in a forested setting. It should be noted that this area was subject to disturbance associated with historical logging prior to becoming part of Mimosa Rocks National Park. Erosion examples include active head-cuts, undercutting, and slumping due to bed instability, a natural process that is difficult to treat and likely represents a major ongoing contribution of dispersible sediment to the estuary during high flow events.

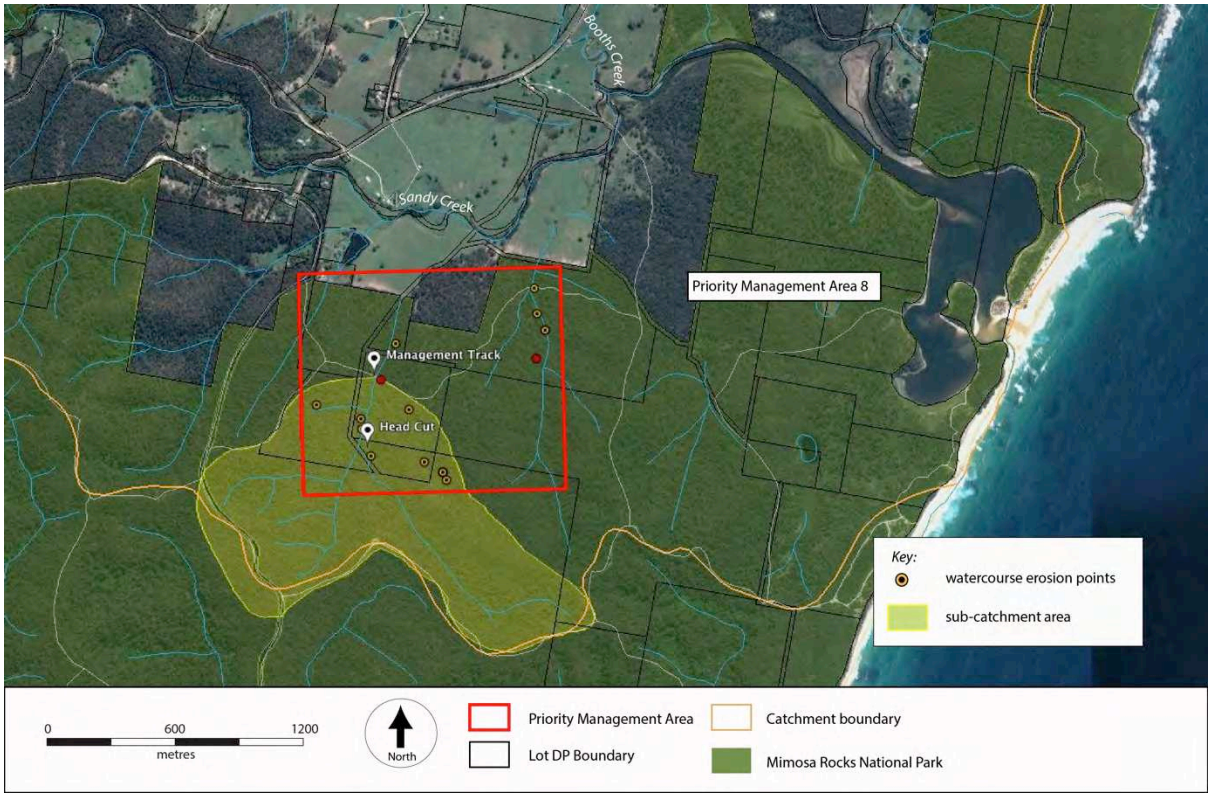


Figure B34 Location of priority management area 8.

High priority issues that require attention include:

- **Issue 8.1 Severe erosion, slumping of banks, example of active head cut**

Each issue is described with recommended actions for treatment provided in sections below.

Issue 8.1 Severe erosion, slumping of banks, example of active head cut

HIGH PRIORITY

APPENDIX B

Site Address [Responsibility]: Mimosa Rocks National Park [NPWS] (Refer **Map B8**).

Issue Description: Potentially serious erosion problems were identified in multiple zones along minor streams in this management area (as shown on **Figure B34**, and refer **Map B8**) using high resolution LiDAR aerial imagery. One of these streams was inspected to ground-truth the desktop assessment and to better understand the potential scale of the issue that is occurring across the catchment, in particular Sandy Creek sub-catchment.

A 400m long reach of an unnamed second order stream was inspected. The reach is bounded by NPWS management tracks at either end with the bottom of the reach at an elevation of approximately 36m. The catchment area to the bottom of the reach is estimated to be 1.2 km^2 as shown in **Figure B34**. Erosion along this reach is moderate at the lower reach to severe in the middle to upper reach with well developed gully up to 3m deep, lateral bank erosion, undercutting and bank slumping evident (**Figures B35 & B36**). Bank instability is leading to collapse of mature trees that further destabilise the banks. The migrating active head-cut that was inspected is located at lat -36.654901°, long 149.974579°. A short distance separates the head-cut to a freshwater wetland, which is then bounded by a NPWS management track. Further migration of the head-cut will lead to loss of the wetland and will then pose a direct threat to the management track.

Possible cause and or contributing factors for this type of erosion include highly erodible, dispersive soils, historical logging and land clearing practices, and changes in sea level and water levels of the estuary leading to increased hydraulic gradients.

Recommended Treatment Action/s:

- This is a natural process and would be difficult to treat due to the scale of the problem. Potential options may include a collaborative research project with a university to further investigate the significance of the process – spatially and temporally, and identify factors that may be exacerbating the process, and what potential actions could be undertaken to halt or slow down process.
- Monitor head-cut progression as nearby management track under direct threat as the head-cut migrates further upstream.

Figure B35 Active head-cut on second order stream in forested setting (*left image*). Gully formation due to migration of the head-cut up the drainage line. A natural process in areas with highly erodible soils such as Sandy Creek sub-catchment (*right image*).

APPENDIX B

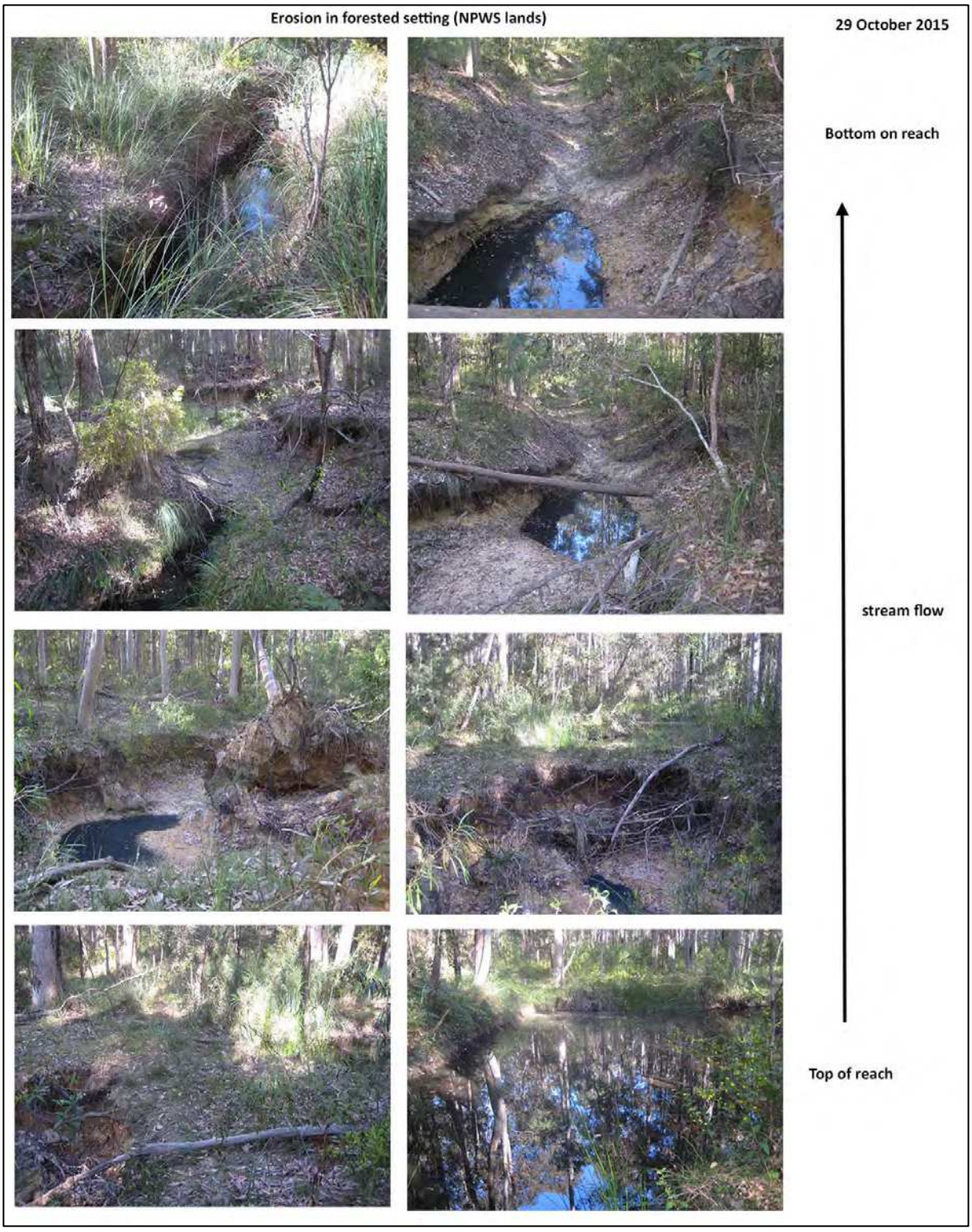
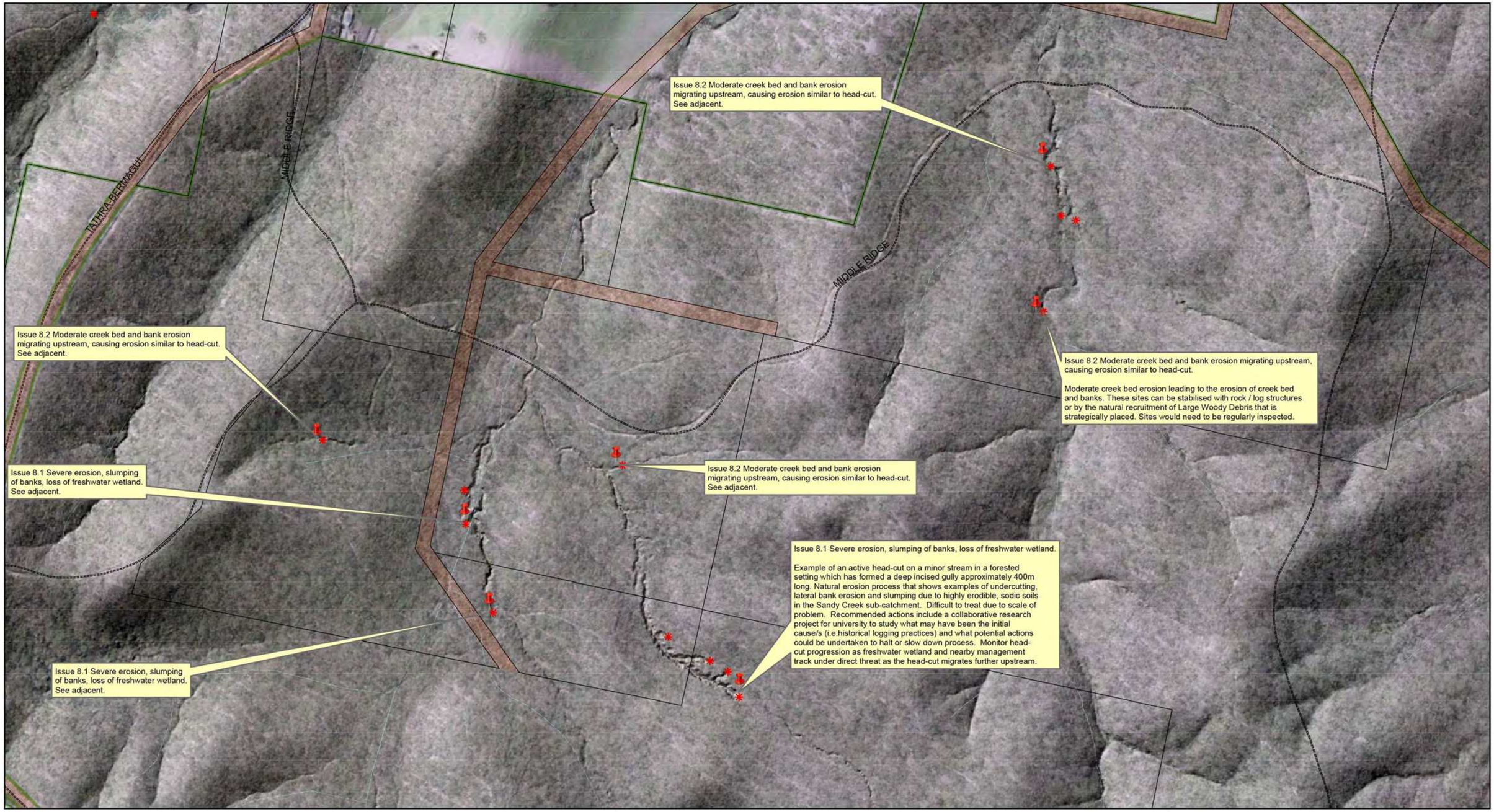


Figure B36 Sequential images of erosion impacts occurring along a 400m reach of a second order stream in forested setting (as described above).



MIDDLE LAGOON CATCHMENT MANAGEMENT PLAN

Legend

- Issues
- Crown Road Reserve
- Rivers and Creeks
- Potential Erosion Area
- Mimosa Rocks National Park

MIDDLE LAGOON PRIORITY MANAGEMENT AREA 8

Riparian engineering

GDA 94 Zone 55

Sheet No.
Sheet 10 of 10

Map B8

Analysis By: Tim Dilworh
River & Coastal Engineer MIE CPEng Aust, NER, RPEQ

Checked by: Nicholas Yee

Date: 18 February 2016

APPENDIX C

Conceptual Drawings of Typical Treatments

- **Lower Estuary**
- **Upper Estuary**
- **Lower Freshwater**

LOWER ESTUARY FORESHORE

Tidal Areas (saline waters)

A range of diverse vegetation communities occurs close to the shores of Middle Lagoon. Two of these vegetation communities include *Far South Coast Foothills Dry Scrub Forest* and *Southeast Warm Temperate Rainforest*.

More significantly, a number of Endandered Ecological Communities occurr on, or in close proximity to the estuary foreshore. These include Coastal Saltmarsh, Bangalay Sand Forest, and Swamp Sclerophyll Forest on Coastal Floodplains.

Tree, shrub and graminoid species listed here are recommended for rehabilitation works.

Vegetation Structure

Large Trees

Corymbia maculata (Spotted gum)
Eucalyptus agglomerata (White stringybark)
Eucalyptus bosistoana (Grey box)
Eucalyptus tricarpa (Red ironbark)
Eucalyptus paniculata (Grey ironbark)
Eucalyptus botryoides (Bangalay)

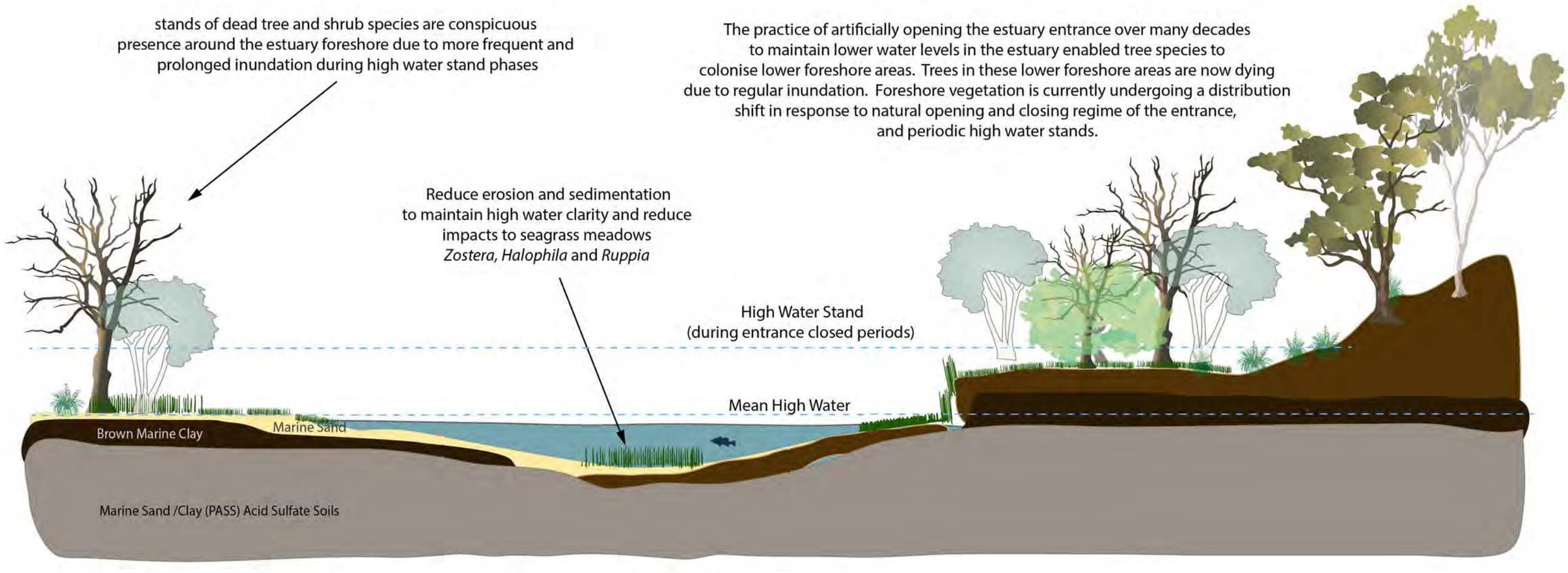
Shrubs/Mid-size trees

Melaleuca ericifolia (Swamp paperbark)
Pittosporum undulatum
Myoporum acuminatum (Boobialla)

Graminoids

Lomandra longifolia
Bolboschoenus sp.
Juncus krausii

Saltmarsh/ Saline wetland sp.



This conceptual drawing is a general guide for vegetation structure of lower estuarine foreshore of Middle Lagoon.
Specific sites would require investigation and planning prior to undertaking works.

RIPARIAN ZONE OF UPPER ESTUARY

Below tidal limit

Plants growing in this estuarine-riparian zone must contend with a degree of saline influence and periods of inundation of varying duration during high water stands when the estuary is closed to the ocean.

Stream banks in this zone are composed of alluvial material and assisted natural regeneration of areas where ripairan vegetation is absent or where erosion is an issue is recommended.

Tree, shrub and graminoid species listed here already occur in this zone and are recommended for rehabilitation works.

Vegetation Structure

Large Trees

Eucalyptus botryoides (Mahogany)

Shrubs/Mid-size trees

Melaleuca armillaris (Honey myrtle)
Acacia floribunda
Acacia mearnsii (Black wattle)
Myoporum acuminatum (Boobialla)

Graminoids

Lomandra longifolia
Juncus krausii

Saltmarsh/ Saline wetland sp.

Re-establish a continuous fringe of riparian vegetation along open banks

Tree collapse is a natural process that creates fish habitat but also disturbs the streambank causing sediment to enter the estuary. Trees growing at the top of banks showing signs of failure may be coppiced by arborist to reduce wind shear force. Expansion of riparian buffers also reduces wind shear on individual trees.

Fence off riparian buffers from grazing to protect vegetation and minimise damage to streambank

Maximise width of riparian setbacks

dead tree and shrub species are a conspicuous feature of the upper estuary foreshore due to more frequent and prolonged inundation during high water stand phases

High Water Stand
(during entrance closed periods)

Mean High Water

Brown Alluvium

Brown Marine Clay

Marine Sand /Clay (PASS) Acid Sulfate Soils

This conceptual drawing is a general guide for riparian vegetation structure of the upper estuary of Middle Lagoon.
Specific sites would require investigation and planning prior to undertaking works.

RIPARIAN ZONE OF LOWER CATCHMENT

Freshwater environment above tidal limit

A relatively wide range of species could be used for reahbilitating sites located in this zone. For high energy sites prone to erosion in flood events, recommend the planting of *Tristaniopsis laurina* (kanooka), *Commersonia fraseri* (black fellows hemp) and *Lomandra longifolia*.

Commersonia fraseri is a fast-growing post-disturbance coloniser that has been observed to form dense stands on banks in wake of major flood events. Both *Tristaniopsis* and *Lomandra* grow within the stream beds and play and major role in consolidating streambed sediments.

Large Trees

Eucalyptus botryoides (Mahogany)
Backhousia myrtifolia (Grey myrtle)
Eucalyptus cypellocarpa (Monkey gum)
Eucalyptus elata (River peppermint)
Szygium smithii (Lillipilli)

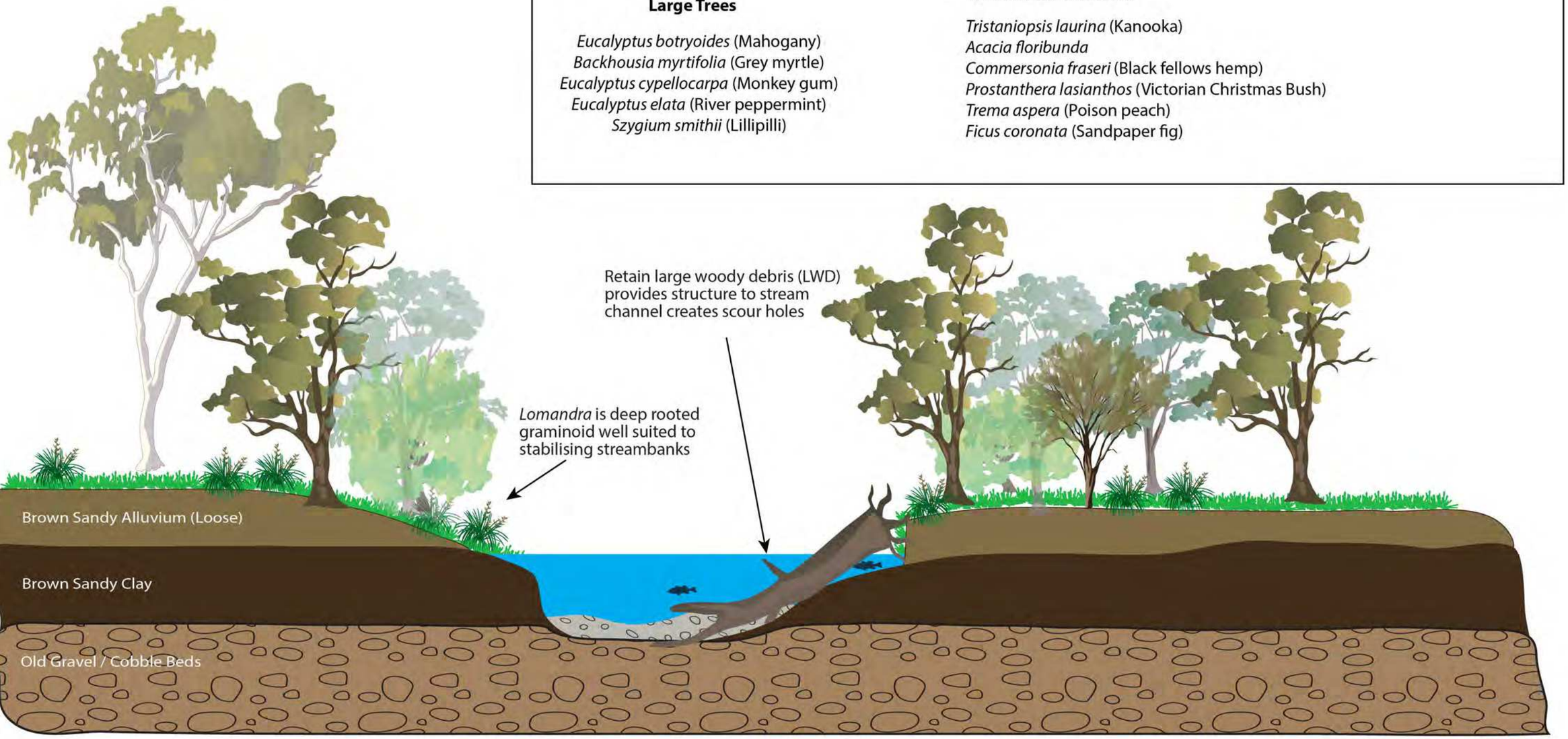
Vegetation Structure

Shrubs/Mid-size trees

Tristaniopsis laurina (Kanooka)
Acacia floribunda
Commersonia fraseri (Black fellows hemp)
Prostanthera lasianthos (Victorian Christmas Bush)
Trema aspera (Poison peach)
Ficus coronata (Sandpaper fig)

Graminoids

Lomandra longifolia



This conceptual drawing is a general guide for riparian vegetation structure of the lower catchment of Middle Lagoon.
Specific sites would require investigation and planning prior to undertaking works.

APPENDIX D

List of Plant Species recommended for Rehabilitation Works

A preliminary list of plant species is provided here grouped in accordance with the three types of management sites for which rehabilitation planting may be undertaken. The three sites include:

- Lower estuary foreshore
- Riparian zone of upper estuary below tidal and high stand limit
- Riparian zone of upper estuary above tidal and high stand limit

The species list provided is indicative only and ***no species should be selected for any specific site without a careful assessment of the species likely to have once been present there***.

Careful species selection is required so as to harmonize new plantings within existing distribution patterns. Seed of local provenance should always be used for propagation so as to preserve genetic integrity.

In general, a minimalist approach is desirable with only species being planted that are likely to be slow to re-colonise a site naturally. Local natural vegetation has great resilience and a strategy of assisted natural re-generation generally produce better, more aesthetically satisfying outcomes than deliberate interventions.

Lower estuary foreshore	
Corymbia maculata (spotted gum)	Large tree
Eucalyptus agglomerata (white stringybark)	Large tree
Eucalyptus bosistoana (grey box)	Large tree
Eucalyptus tricarpa (red ironbark)	Large tree
Eucalyptus paniculata (grey ironbark)	Large tree
Pittosporum undulatum	Medium tree
Melaleuca ericifolia	Shrub
Myoporum acuminatum (boobialla)	Shrub
Lomandra longifolia	Graminoid

APPENDIX D

Riparian zone of Upper estuary below tidal limit	
Plants growing in this zone must contend with a degree of saline influence. Stream banks in this zone are composed of alluvial material. The following shrub, tree and graminoid species are recommended:	
Acacia floribunda	Shrub
Melaleuca ericifolia	Shrub
Myoporum acuminatum (boobialla)	Shrub
Acacia mearnsii (black wattle)	Medium tree
Eucalyptus botryoides (mahogany)	Large tree
Lomandra longifolia	Graminoid
Juncus krausii	Graminoid

Riparian zone of Upper estuary above tidal limit	
A relatively wide range of species could be used for sites in this zone. For high energy sites prone to erosion in flood events, recommend the planting of *Tristaniopsis laurina* (Kanooka), *Commersonia fraseri* and *Lomandra longifolia. Commersonia fraseri* is a fast-growing post-disturbance coloniser that has been observed to form dense stands on banks of Sandy Creek (Middle Catchment) and Cuttagee Creek in the wake of major flood events. Both *Tristaniopsis laurina* (Kanooka) and *Lomandra longifolia* grow within the stream beds. They have the capacity to survive major flood events and a play a major role in consolidating streambed sediments. The following shrub, tree and graminoid species are recommended:	
Acacia floribunda	Shrub
Prostanthera lasianthos (Victorian Christmas bush)	Shrub
Trema aspera (poison peach)	Shrub
Tristaniopsis laurina (Kanooka)	Medium tree
Backhousia myrtifolia (grey myrtle)	Large tree
Commersonia fraseri	Medium tree
Ficus coronata (sandpaper fig)	Medium tree
Eucalyptus elata (river peppermint)	Large tree
Eucalyptus botryoides (mahogany)	Large tree
Eucalyptus cypellocarpa (monkey gum)	Large tree
Szygium smithii (lillipilli)	Medium to Large tree
Lomandra longifolia	Graminoid