MIDCOAST council

MANNING RIVER ESTUARY & CATCHMENT

ISSUE ANALYSIS REPORT 2021

Annexure I

Forward

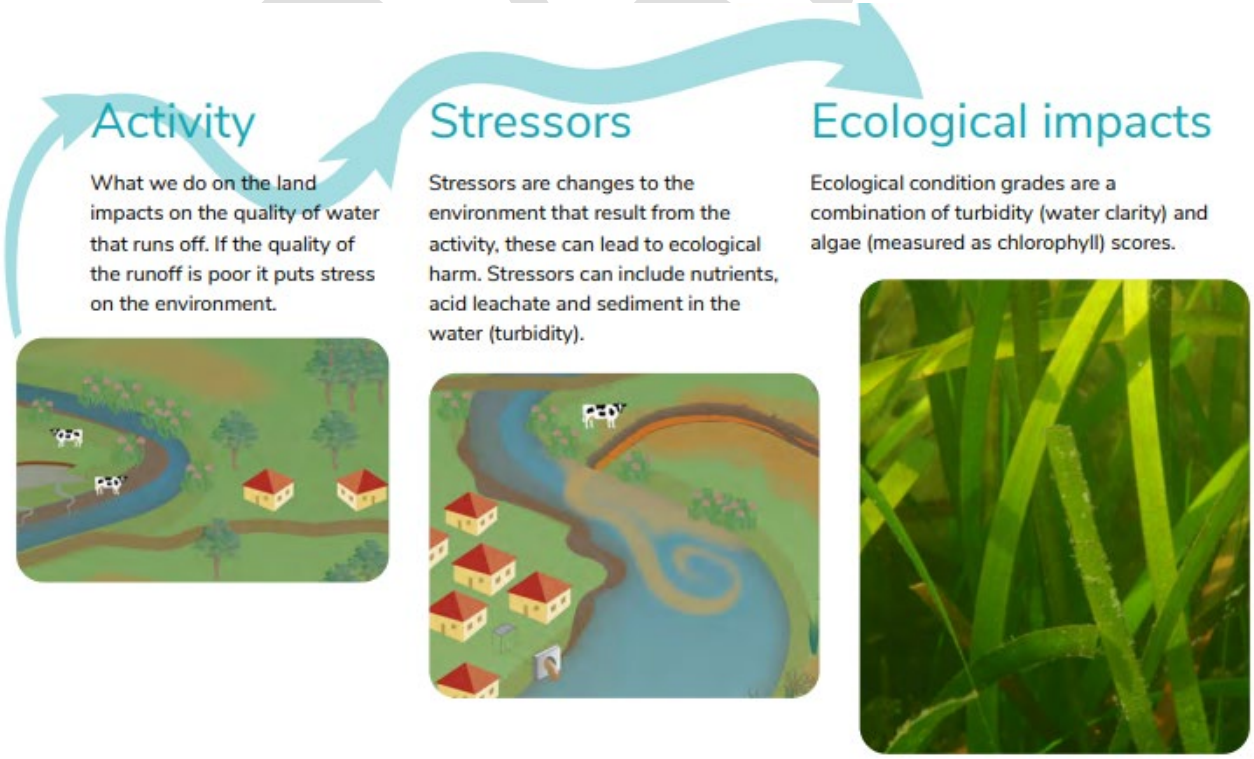
This document brings together a series of issue papers prepared to inform the Manning River Estuary and Catchment Management Program (ECMP).

Issues were identified via the Manning Threat and Risk Assessment, along with input from the ECMP Reference Group. The project team then prepared this series of issue papers and hosted 13 discussion groups with stakeholders who had detailed local, scientific or traditional knowledge to contribute. Participants at the discussion groups represented the Technical Advisory Group, CMP Reference Group, delivery partners from Council and state agencies, Aboriginal stakeholders and community representatives. The process for developing and consulting on the issue papers is provided in Appendix 1.

The issue papers examine activities, stressors and impacts, as shown in figure 1 below. The discussion groups identified stakeholders, existing management options, what's working and what's not, opportunities and management options.

Opportunities and management options developed through this process went through a series of iterations and refinement to become the final program of Management Actions in the Manning River ECMP.

Figure 1: analysis of activities, stressors and ecological impacts



Contents

1. Agricultural Impacts

This Issue Analysis paper covers a range of risks to ecosystem health from agriculture including diffuse-source run-off pollution; degradation of riparian and marine vegetation by stock; and soil degradation.

1.1 Situational Analysis

Activity

Agriculture is a widespread and common land-use throughout the Manning River catchment and estuary. Dairy and beef grazing dominate, with localised areas of sheep and poultry farming. Approximately 12% of the catchment is classified as Grazing Modified Pasture in the NSW Land Use Map 2017.1 Stock intensity for cattle and sheep varies across the catchment as shown in **Error! Reference source not found.**1.[2] Based on Annual Stock Return data (2009-2018), relatively high stock numbers are found in the Barnard, Upper Manning, Barrington, Gloucester and Lansdowne subcatchments, with moderate stock numbers in the Nowendoc, Manning, Dingo Creek and Dawson. Poultry rates are highest in the North East and South West of the catchment, but are localised (Swanson 2020). While horses aren't included in stock intensity, there are some large equine properties in the Manning catchment with irrigated and fertilized pastures.

Socio-economic benefits

Agriculture in the MidCoast region is a significant employer and regional specialization forming part of the LGA's economic competitive advantage (MidCoast Regional Economic Development Strategy 2018-22). Dairy, beef and sheep farming contribute a combined annual gross revenue of $217 million to the MidCoast region.[3]

Community consultation for the Manning River Estuary and Catchment Program (CMP) revealed that farming is a way of life for many in the region, with multi-generational family connections to the land. Rural scenery associated with agricultural landscapes is also part of the Manning's regional identity. Farming contributes to employment, food security and export earnings. Rural produce is supplied to the local community through farmers' markets and retailers, and distributed to export markets. Members of the CMP Reference Group voiced their desire to continue dairying on the islands in the lower estuary.

[1] (Swanson R. , 2020)
[2] (MidCoast Council, 2020)
[3] (Saphere Group, 2018)

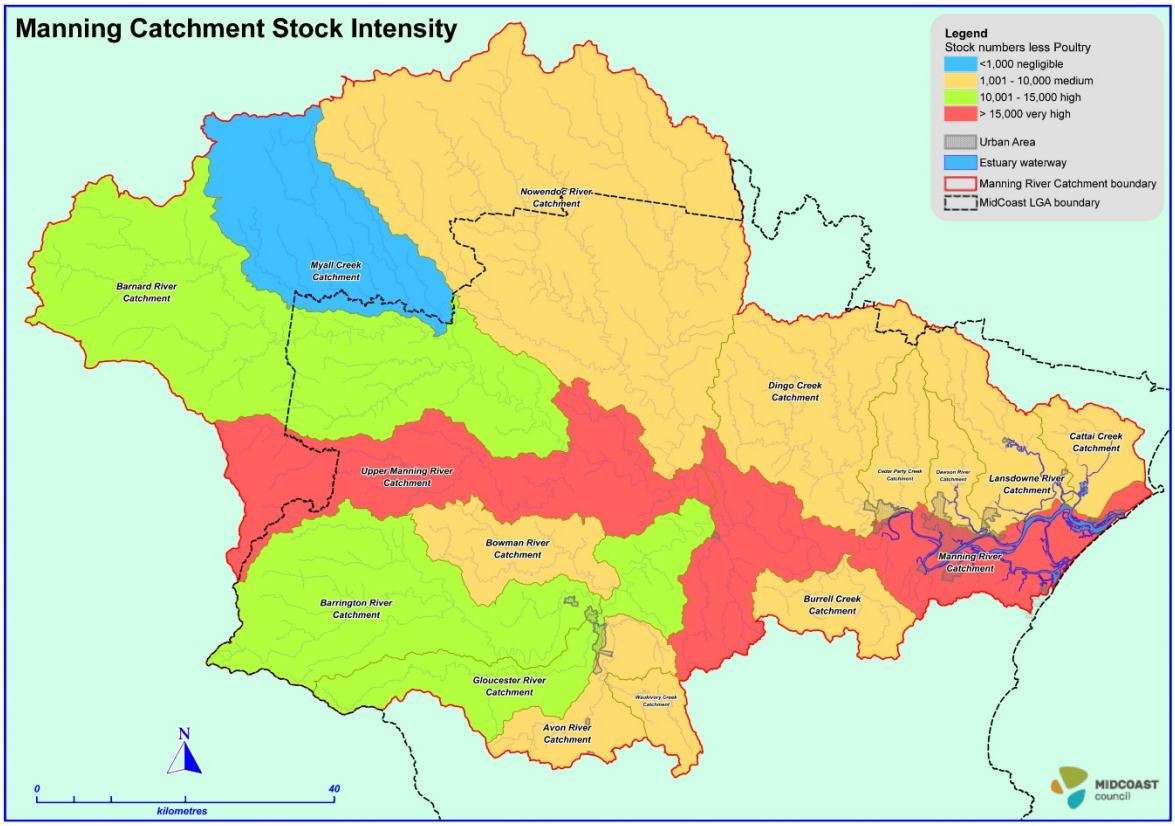


Figure 1: Stock intensity in the Manning catchment based on annual stock returns.

Stressors

Activities associated with agriculture such as land-clearing, groundcover loss and soil degradation accelerate the rate of rainwater runoff and erosion, carrying sediments, nutrients, pathogens and agricultural chemicals into waterways of the catchment and estuary.[4]

Riparian vegetation plays a key role in reducing diffuse-source water pollution by slowing the rate of runoff, taking up nutrients and stabilising riverbanks. Stock graze on riparian vegetation and seek shade along the creeks, trampling soft banks and drinking from streams.[5] Stock degrade the riparian zone by disturbing the vegetation and soil, introducing weeds and increasing nutrients through defecation. Reductions in the extent, condition and connectivity of riparian vegetation increases the rate and impact of diffuse-source water pollution.[6]

[4] (NSW Government, 2009)
[5] (Swanson R. , 2019)
[6] (NSW Government, 2009)

Grazing and poor pasture management cause soil degradation including compaction, erosion and loss of soil structure and organics, which contribute to runoff by reducing the rate at which rainwater infiltrates into the soil.[7]

In the program of Rapid Site Assessments undertaken in the Manning catchment in 2019[8], uncontrolled stock access in the riparian and instream zones was found to be a widespread threat to stream and estuary health across the catchment.

A comprehensive Threat and Risk Assessment (TARA) was undertaken for the NSW Marine Estate Management Strategy.[9] Agricultural diffuse-source runoff was ranked as the third highest priority threat to environmental assets and the second highest priority threat to social, cultural and economic benefits at both the state-wide level and in the northern region, which includes the Manning.[10] Agricultural impacts including soil degradation, irrigation, run-off and cattle impacts on the riparian zone were also identified as a key issue by the Manning CMP Community Reference Group.

The preliminary spatial risk assessment for the Manning estuary and its catchment[11], highlighted that diffuse catchment runoff from agriculture is the driving force behind nutrients and sediments within the estuary as opposed to urban runoff. The final, calibrated spatial risk assessment[12] found that subcatchments posing the highest risk to estuary health and water quality from agricultural diffuse-source nutrients and sediments were the Lansdowne River and Cedar Party Creek, followed by subcatchments in the southwest (Upper Manning, Barrington, Gloucester, Avon and Manning) and northwest (Dingo Creek, Dawson River and Cattai Creek).

This is illustrated in the Estuary Health Risk Map (Figure 2 below) which provides the combined risk ratings for Total Suspended Solids, Total Nitrogen and Total Phosphorous associated with Modified Grazing Pasture land-use in the Manning catchment.[13] The full report can be viewed on Council's web site (Our Manning River web page).

[7] (Gloucester Shire Cuoncil, 2015)
[8] (Swanson R. , 2020)
[9] (BMT, 2017)
[10] (BMT, 2017)
[11] (MidCoast Council, 2020)
[12] (Swanson R. , 2019)
[13] (Swanson R. , 2019)

Updated Estuary Health Risk Map (Water Quality Risk Assessment)

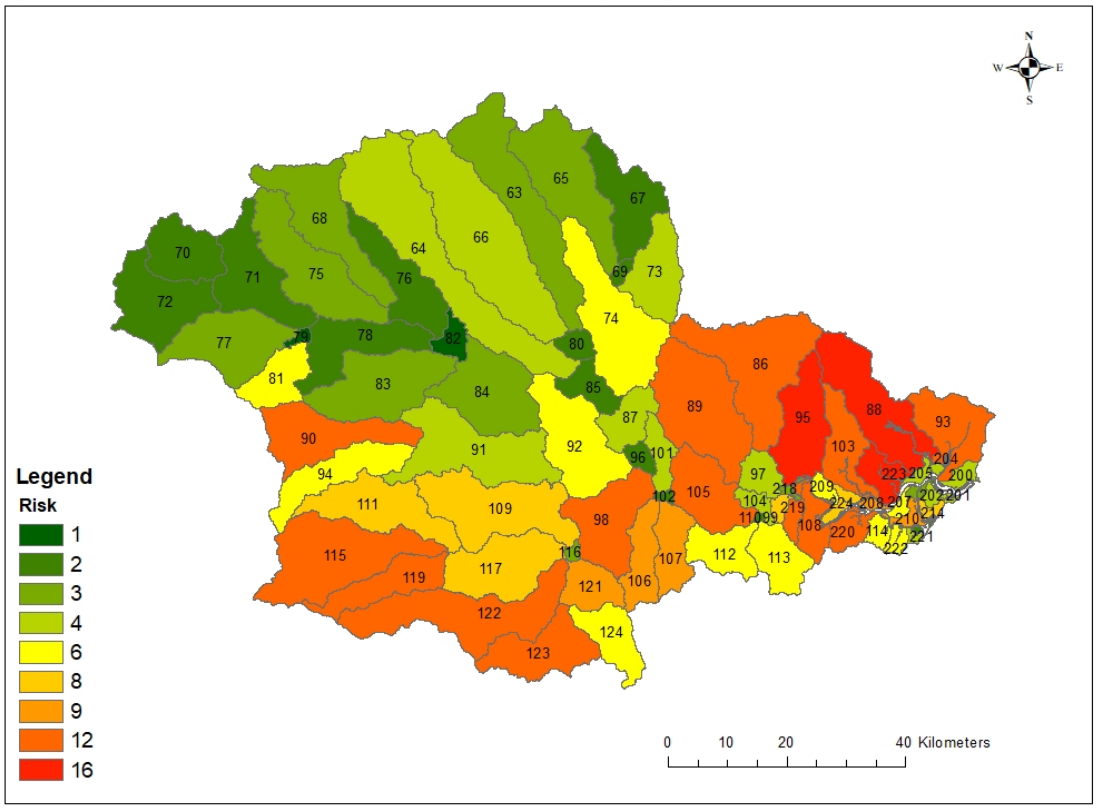


Figure 2: Risk ratings for TSS, TN and TP pollution associated with agricultural diffuse-source runoff in the Manning catchment.[14] The red coloured subcatchment number 88 is the Lansdowne River, and 95 is Cedar Party Creek

Stock manure on streambanks and in adjacent pastures is a potential source of pathogens to waterways. Pathogens from stock pose a risk to human health. In the spatial risk assessment, Swanson assessed the risk of pathogens from stock manure on water quality for oyster aquaculture and potable water.[15] The risk analysis is based on total stock numbers and stock densities in each subcatchment for beef cattle, dairy cattle, horses and sheep.

The subcatchments with the highest risk for pathogens arising from stock for drinking water and oyster aquaculture are shown in Table 1 below.

Dingo Creek (86) was found to pose a Very High Risk of pathogen impact on drinking water quality. Dingo Creek on average supplies up to 15% of flows to Manning River, just upstream of the offtake for Bootawa Dam. Seven subcatchments in the Gloucester, Barrington and Upper Manning posed a High Risk to drinking water quality. These subcatchments are shown in Figure 3.

[14] (Swanson R. , 2019)
[15] (Swanson R. , 2019)

Table 1: Pathogen risk from stock intensity on drinking water and aquaculture

Community value	High risk subcatchments
Drinking water quality	Dingo Creek (86), Manning River (99, 105), Barrington River (117), Gloucester River (98, 122)
Aquaculture	Oxley Island (203), Mamboo Island (204), Jones Island (205), Lansdowne River (88,223) Cattai Creek (93)

The numbers refer to numeric codes for each subcatchment assigned by the Energy, Environment and Science group of DPIE.

Islands in the estuary along with subcatchments in the Lansdowne River and Cattai Creek were found to pose the highest risk for stock pathogens to aquaculture, as shown in Figure 4.

Climate-change modelling for the Manning region predicts an increase in extended drought conditions, as well as increased severity and intensity of extreme weather events including storms and floods (Adapt NSW). More frequent and prolonged drought has potential to exacerbate soil degradation through loss of pasture cover and soil carbon. More extreme weather events will accelerate the rate of runoff and diffuse-source water pollution during high rainfall events.

Cattle impacts on the riparian zone and instream condition are widespread throughout the catchment.[16]

[16] (Swanson R. , 2020)

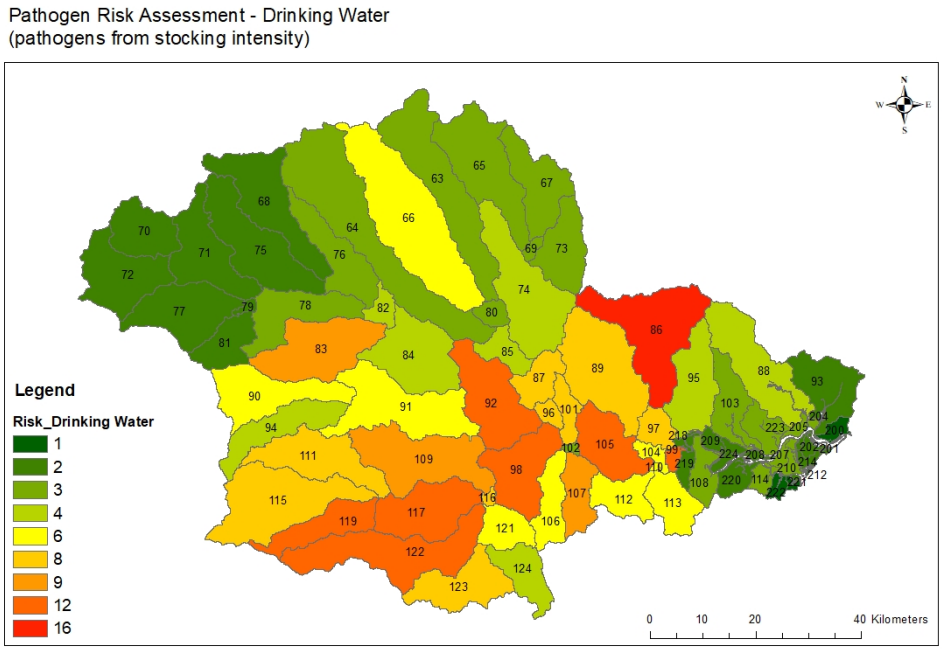


Figure 3: Risk assessment of pathogens from stock intensity on drinking water quality[17]

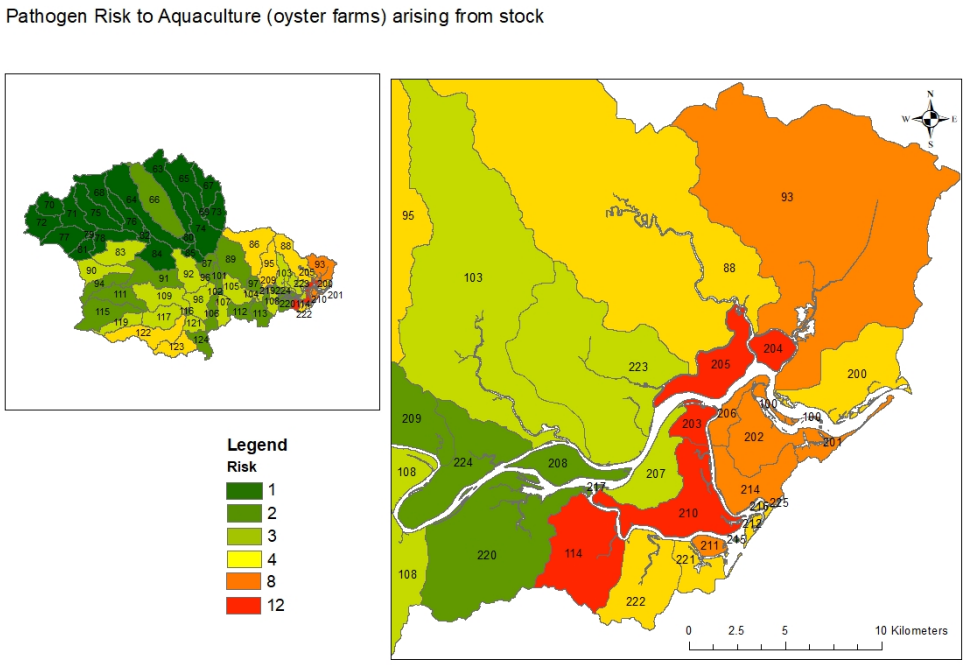


Figure 4: pathogen risk to aquaculture/oyster farms posed by stock intensity in surrounding subcatchments.

Impacts

Key impacts of agricultural diffuse-source run-off on catchment and estuary values are shown in Table 1 below[18]

	Priority problem	Key impacts to address
1	Sediment levels exceeding ANZECC Guidelines	• smothering of aquatic ecosystems • increased water infrastructure maintenance costs
2	Nutrient levels exceeding ANZECC Guidelines	• nuisance weed growth and harmful algal blooms • increased water treatment costs • reduced fishery production (commercial and recreational)
3	Pathogen levels exceeding ANZECC Guidelines	• reduced fishery production (aquaculture, commercial and recreational fishing) • human health impacts from aquatic recreation

Table 1: Key impacts associated with water pollution from diffuse-source runoff.

In the Manning, potable water supply is a critical use. High rates of nutrients and sediments increase water treatment costs including energy and chemicals. Investigations by MidCoast Water were reported in the Manning River Catchment Management Program.[19] These investigations showed water quality problems with high levels of turbidity and nutrient loads particularly associated with high flows. Peaks in turbidity generally showed a close correlation to peaks in flow. Peaks in phosphorus levels mobilised by sedimentation have a longer recovery period, and levels can remain above ideal pumping levels after turbidity has become acceptable[20]

The Manning River Catchment Management Program reports research by Thurtell (2007 p.9), which also suggests that nutrients are transported into waterways at high flows, positing that "this is likely to be the result of erosion, the transport of animal wastes, fertilisers and detrital material."

Detailed monitoring on the Barrington River in 2008-10[21] found that in dry weather, the Barrington River was producing one-third of the nitrogen load of the Lower Manning, which was consistent with the high percentage contribution of flow from the Barrington. Phosphorus levels in the upper Barrington were much higher than in the mid Barrington (0.06-0.11 compared to 0.025-0.038 mg/L), and can be attributed to agricultural disturbances. Phosphorous levels in the Barnard were similar to the mid Barrington, however at much lower flows.

[18] (NSW Government, 2009)
[19] (Midcoast Water, 2011)
[20] (Midcoast Water, 2010)
[21] (Midcoast Water, 2010)

This varies slightly from earlier research (in a dry period) which found the Avon River (in the Gloucester sub-catchment) and Dingo Creek to have the highest nitrogen levels in the Manning Catchment, and the Avon to have the highest phosphorus levels, followed by the Barnard, Bakers Creek and the Lower Manning.[22]

From 2010 MidCoast Water started intensively monitoring the Barnard River upstream of Mackay. Preliminary results suggest extremely high (1600 NTU) turbidity for moderately low flows when compared to the Barrington River[23]

Tourism and recreation is also impacted by degradation of swimming sites and loss of scenic amenity.

1.2 Stakeholders

Management agencies

Lead: Hunter Local Land Services

Partners: MidCoast Council; DPIE Department of Agriculture

Community Stakeholders

MidCoast Dairy Advancement Group; Women in Dairy, Young Farmers Network, Biodynamic farmers, Economic Development Council, Growers Markets.

1.3 Existing Management Approach

The current scale of actions to mitigate agricultural impact is not considered to be commensurate with the scale of diffuse source runoff.[24]

Hunter Local Land Services operates an agricultural extension program including incentive grants when funds allow. Projects to reduce diffuse-source water pollution include stock-exclusion fencing to protect riparian vegetation and providing off-stream water-points and alternative shade; as well as introducing rotational grazing to improve pasture cover.

HLLS worked with selected dairy farmers to develop and implement effluent management plans in the lower Manning.

There has been ad-hoc projects to exclude stock from riparian zones and protect banks from erosion via rock revetment and fillets in the lower Manning.

Legislative controls are in place to manage agricultural pathogens, pesticides and chemicals, but compliance and monitoring are weak.

[22] (Thurtell, 2007)
[23] (Watkins, 2011)
[24] (MidCoast Council, 2020).

1.4 Knowledge Gaps

- Export rates of nutrients and sediments under different management regimes and current rates of adoption
- Impact of climate change on catchment hydrology and therefore diffuse pollutant transport into the Manning Estuary
- Current and future land capability/Suitability of areas of Catchment and Estuary for various land use (e.g. dairy areas contracting, loss of grazing areas due to SLR in floodplain)
- How to tackle private vs public benefit
- Future water security

1.5 What's working, what's not?

The next three sections are based on discussions with the Manning River Estuary CMP Reference Group (May 2020), and a stakeholder discussion group (August 2020).

What's working?

- Increasing demand for information and training in Regenerative Agriculture and Rehydrating the Landscape, across Australia and locally. For example, a regenerative agriculture field day on the theme of soil health held in March 2020 was attended by over 300 farmers.
- Private conservation agreements on environmentally sensitive land.
- Council acquisition and remediation of agricultural land for conservation (e.g. Glen Almond, Cattai Wetlands).
- Environmental field officers and incentive programs: consistent interest from farmers over time for catchment management projects (e.g. through Hunter Local Land services, Landcare, former MidCoast Water). Farmers have demonstrated good will and stewardship.
- Whole-of-farm and holistic management training offered by Landcare has worked well (210 participants). Need to continue with this kind of training due to turn over of landholders and reinforce the messages.
- New farmers/landholders want to feel part of a community. Landcare and Sustainable Farming Groups appeal to them. They are amenable to doing the right thing by the environment and often have more funds available for conservation.

What's not working?

- Manning farmers don't have the cultural experience or knowledge about how to manage during drought conditions in the Manning due to our experience in a milder climate. Farms were overstocked during the drought. Farmers didn't look ahead and know when to de-stock.
- What happens on the land has the biggest impact on the river and estuary. Improving land management is the key rather than focusing on the river.
- Erosion and sediment loss from farm paddocks remain an issue, demonstrated by the sediment build-up in farm dams being cleaned out during the drought.
- Landscape is drying out: "Gumboots used to be part of the school uniform in Nowendoc. They're no longer needed due to changes in hydrology within the landscape."
- Rate of run-off is increasing. "A landholder at Caffreys Flat said in his father's day, when it rained in Gloucester he had 2-3 days to pull his pumps out of the river. Now it takes 12-24 hours. The rate of run-off has increased dramatically."
- Engagement with horse owners is a gap. Horses can be intensive and have a large impact: irrigation and erosion.
- Public land – Crown, RMS – allowing cattle into riparian zone.
- Absence of regulation relating to nutrient discharges from farms, use of fertilisers etc. NZ recently introduced reforms with controls on nitrogen pollution and farm practices.
- Modification of the riparian areas is impacting significantly on potable water supply due to loss of banks and sedimentation. Flood peaks are higher and ongoing sediment load is higher.
- There is significant potential to improve pastures using regenerative farming methods. Paddocks of the lower Manning look like lawn even after good rain.
- There is community pressure on Council to reduce rural lot sizes – needs to be managed carefully.
- Potential impact of land-clearing on local water cycle and microclimate.

1.6 Opportunities

Regenerative farming and rehydrating the landscape have been championed by members of the Manning River Estuary CMP Reference Group, noting the considerable interest in amongst cohorts in

the district including young farmers, hobby farmers and agribusiness. Comments during consultation (May 2020) include:

- *"Soil-for-life research shows improved profitability and wellbeing from regenerative farming."*
- *"Provide credible regenerative farming advice, info on benefits and methods and where to get it."*
- *"There's opportunity to transform the dairy industry. You could produce such nutrient-dense food (butter, yoghurt, other value added dairy) off low input, multi-species pasture systems which retain moisture and build carbon'. Re-visioning what is possible in these landscapes seems really important."*

The principle of regenerative agriculture and regenerative pastoralism is to enhance natural ecosystem services, resulting in sustainable production, an improved natural resource base, healthy nutrient cycling, increased biodiversity and resilience to change.[25]

Rehydration of the landscape involves reinstating more natural biophysical landscape functions and processes, to improve water reliability and soil organic content while reducing reliance on high-cost artificial inputs.[26]

Early adopters are reporting success with these practices. Government bodies and academics are beginning to support practice change by documenting credible scientific evidence on the impact and repeatability of regenerative agriculture practices on the physical, chemical and biological health of the soils and the associated long-term economic, environmental and social benefits.

A member of the Reference Group also discussed new farm practices being introduced by young graduates:

- *"I'm really enjoying seeing young people coming through and changing our practices. views have changed through a lifetime living on the land: 3rd and 4th generation producers are modernising our thinking. The old timers are dropping away and the young ones are combining a lot of agricultural science and coming onto properties with a better array of farming methods."*
- *"People are becoming more aware of the importance of maintaining groundcover. They're moving away from the old UK methods and responding to local conditions: using less water, less chemicals. Practicing low tillage, restricting run-off."*
- *"We're noticing the benefits as a group – the ones who are struggling to come up to speed with the new types of thinking are being shown the economic benefits and environmental benefits by the people across the fence. Its farmers talking to farmers.*

[25] (WA Department of Primary Industries and Regional Development, 2019)
[26] (Hurditch, 2015)

They're not getting bullied. It's a positive movement, we need education to spread the word to newcomers into the industry."

An issue-based discussion group with key stakeholders was held on 11 August 2020, which identified the opportunities shown below.

- Continue to deliver incentive and engagement programs to promote the benefits of the actions that will improve catchment health and farm productivity (e.g. fencing riverbanks to keep cattle within property boundaries)
    - Share a vision but don't be too prescriptive. Encourage people to engage individual and innovative ways then share knowledge and experience
    - Encourage and support young farmers who have had high levels of training, encourage peer on peer learning - authorities are the last step.
    - Council promote property planning via website.
    - New landholder booklet with contact lists, legislation, farm planning.
    - Farmers markets opportunity to provide information to farmers and reach new farmers
    - Maintain continuity of catchment management efforts to bridge the knowledge gap when funding cycles impact on engagement opportunities. Focus magazine could be a place to promote agricultural stories
    - Use local media for stories showcasing good agricultural practice e.g. Focus magazine. Maintain agricultural extension promoting sustainable farming as a field of expertise in the Manning through face to face, sustainable farming groups etc.
    - Promote Holistic farm management, whole farm planning and management through extension, support, demonstration farms.
    - Build expertise in regenerative methods to improve soil health: healthy soils can improve water infiltration, erosion. Building the soil sponge will also buffer or mitigate the impacts of climate change.
    - Promote the role of trees and native vegetation in the agricultural landscape. Trees create rain. Whatever we can do to encourage trees would be good - even crop trees, fodder trees or timber trees within farming systems, not just natives.
    - The CMP team could join meetings at the fire sheds to discuss fixing estuary issues."

- Work with the large commercial more traditional farmers to maintain productivity while managing environmental impacts.
- Support more sustainable technologies on productive farms e.g. Smiths Farm in the Myall should be supported.
- Advocate to improve management of public land (Crown land, RMS) for conservation e.g. impose licence conditions on farmers using their land.
- MCC is working on a new Local Environment Plan (LEP) and reviewing zoning and development controls. Opportunity to improve environmental outcomes.
- Offer rate relief to encourage people to achieve environmental outcomes identified through the Rural Strategy being developed by MCC.
- As estuarine farmland becomes less viable, convert to natural areas (e.g. wetlands). Demonstrates how the results yield increased estuarine productivity for aquaculture, fish etc.
- Vacant lots in Wingham could be acquired and used as demonstration sites.
- Build the link between premium produce, a healthy environment and sustainable farming practices (e.g. Tasmania, King Island). We see the "Manning Valley naturally" signs coming into the area, let's strengthen this brand and bring our farming practices into line with the values we hold for our spectacular natural environment.
    - Integrate economic development with environmental outcomes particularly with high intensity farms: value-add to products with clean environment branding.
    - Farmers practicing good environmental stewardship can get a premium price on their produce, for example through organic or biodynamic certification or the new Land to Market system. Investigate opportunities to build a local brand (e.g. Farm to Fridge) or co-op with best practice guidelines to develop a reputation for good land stewardship and premium produce.

1.7 Management Options

The following management options were identified through consultation with the Reference group (May 2020) and the issue-based discussion group (11 August 2020).

Planning

- Use the Rural Strategy, Local Environment Plan (LEP) and DCP to encourage appropriate land use, reduce agricultural impacts and improve environmental outcomes.

Capacity Building

- Continue to deliver behaviour change engagement programs across the catchment.
    - Use flexible approaches relevant to the demographic, farm type, size, level of risk for the location or type of farm (e.g. tailor whole farm management to meet responsive to farmer needs; productivity plus environmental outcomes).
    - Support farmer-to-farmer learning
    - Package communication for different target audiences.
    - Run an outreach program with property visits. Maintain extension staff/catchment officers to resource this approach.
    - Link engagement to current issues e.g. drought and water security to encourage off stream watering, fence off dams and include watering points from dams.
    - Provide technical advice on installation of dams to reduce their potential impact.
    - Education about options for management of land identify and promote triggers for management e.g. ground cover triggers for allowing cattle into fenced riparian areas.
    - Support the sustainable farming program long term? Use the CMP as a way of sourcing funds for land management, technical and engagement advice for landholders.
    - Talk about, educate and inform people about ecosystem services, what the river gives to us and what we need to do to protect it.
    - Work more with farmers, Landcare to promote a transition to regenerative farming.
    - Educate new arrivals, targeting property buyers in high priority areas.
- Offer incentive programs for riparian management, especially in high value areas (e.g. in the tidal zone). Maintain finance to support this approach.
    - Design projects to meet their individual needs for management. Highlighting benefits for the farmer.
    - Focus on 'whole reach' fencing by working with connected properties.
    - Offer stewardship payments for landholders for best practice management of farming land.

- Improve clarity on what 'best practice' looks like including a range of options for different types of farms.
    - Define and promote best practice targets for nutrients, buffer zones, management of weeds on riverbanks, ground cover levels – especially when the farms have river frontage.
    - Provide credible regenerative farming advice, info on benefits and methods and where to get it.

Operations

- Develop a program to build the link between premium produce, a healthy environment and sustainable farming practices (e.g. Manning Valley Naturally).
- Do a demonstration project rationalising the number of drainage channels in the floodplain and changing the profile. Replace many small, deep channels with a few wide, shallow, laser-levelled drains that can be grassed with pasture cover. It could reduce acid leachate and improve productivity of the farms on lower reaches of the Manning.

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2. Biodiversity Loss

This Issue Analysis paper focusses on conservation of aquatic dependent fauna, and fauna that depends on the riparian zone of the Manning River catchment and the estuary. Related CMP Issue Papers include *Vegetation Management* and *Coastal Wetlands*.

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2.1 Situation Analysis

Wildlife conservation was a major theme in community surveys undertaken in August 2019 for the Manning River Estuary and Catchment Management Program (CMP)[27]. Comments included:

> *"I love the wildlife the estuary supports – birds, fish, dolphins, crabs, islands..."*
>
> *"Water is life…we share the river as a central part of the wild ecosystem that provides habitat for wildlife from iconic animals to the tiniest microbes."*
>
> *"My vision for the Manning catchment is healthy, abundant biological populations of plants, animals and macroinvertebrates."*

The high value placed on wildlife conservation was reflected in consultation with the Manning CMP Reference Group (May 2020), which called on the CMP to *"Manage the catchment to protect the native fauna – helmeted turtle, platypus in upper catchment, shorebirds and Little Terns in lower catchment."*

The Manning Catchment is rich in biodiversity due to its location at the transition between sub-tropical and temperate climatic zones and the region's vast altitudinal range from coast to mountains. [28] Biological diversity provides a range of ecosystem services and forms the cornerstone of ecological resilience; the ability for an ecosystem to adequately recover from natural or human-induced shocks.

Rivers, riparian zones and estuaries form a transition zone between aquatic and terrestrial ecosystems and contain a diverse range of ecological communities. This makes these areas exceptionally biodiverse. Healthy rivers are amongst the most diverse ecosystems on earth.[29] Rivers and their margins offer opportunities for connectivity conservation in

[27] (MidCoast Council MCC, 2019)
[28] MCMC (1996)
[29] (Rivers and Biodiversity, 2020)

fragmented landscapes. Their aquatic corridors connect areas of habitat, providing ecological linkages for migration and dispersal of wildlife.

Riparian zones, the interface between land and water, are particularly biodiverse. Some animals like the platypus are riparian specialists while others such as bass and the Manning River helmeted turtle depend on inputs from the riparian zone for food and shelter. The shady, cool and moist habitat of riparian zones and availability of water provides crucial refuge for terrestrial wildlife (e.g. koala) to minimise stress during drought and heatwaves. This function will become more important as the climate changes. Riparian zones also provide migration pathways to cooler altitudes.

Estuaries where fresh and saltwater meet are the "nurseries of the sea." Their sheltered waters provide vital nesting, breeding and feeding habitats for many species of fish, shellfish, aquatic plants and birds. Most commercially valuable fish species depend on estuaries at some point during their development.[30]

The entire Manning River and its tributaries have been designated as Key Fish Habitat by Fisheries NSW, recognising its importance to the sustainability of recreational and commercial fishing industries, the maintenance of fish populations generally and the survival and recovery of threatened aquatic species.[31]

Freshwater refuge pools play a critical role in supporting local and regional biodiversity. Deep freshwater pools and springs are home to an array of fauna forming biodiversity hotspots. Endemic threatened aquatic species depending on these refuges in the Manning include the Manning River helmeted turtle, Davies' tree frog, spiny crayfish, platypus, mussels, fish and a diverse assemblage of macroinvertebrates. Biota retreat to, persist in and expand from refuge pools under changing environmental conditions[32].

MidCoast Council's draft Biodiversity Framework (under development) provides a full listing of biodiversity assets and management strategies in the Manning region. The focus for the CMP is on aquatic and riparian fauna, and particularly listed threatened species, within the planning area. These include:

- The endangered (NSW) Manning River helmeted turtle is widely regarded as Australia's most beautiful turtle. Its entire known range is confined to the Manning catchment (see Map 1).


Photo courtesy Gary Stephenson

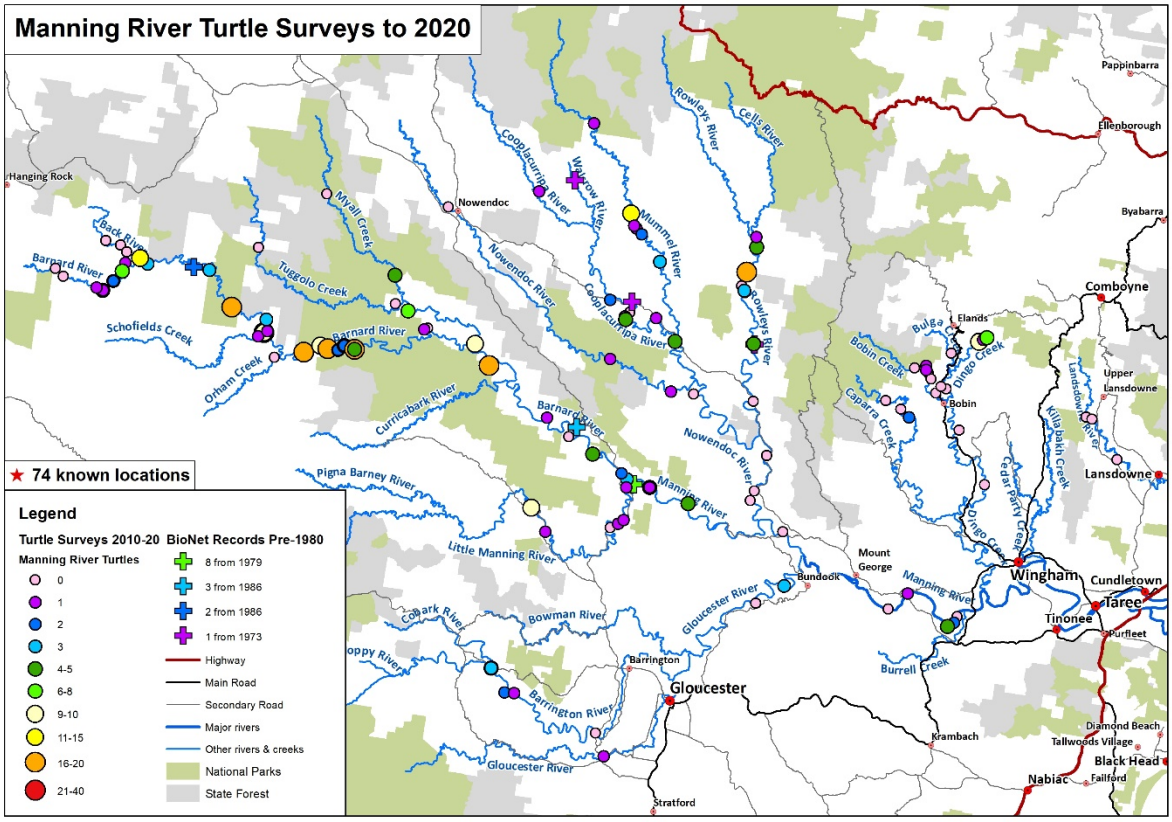
- The iconic platypus, one of only two monotremes on the planet, which is reported to be nearing threatened-species

[30] (NSW Government, Why estuaries are important, 2020)
[31] NSW Department of Primary Industries (2020)
[32] (Keppel et al, 2011)

status.[33] Regional declines of this species have been reported, particularly in the last decade (Dr. Keith Bishop, pers. comm.).

- Four nationally listed migratory shorebird species use the Manning estuary including the Critically Endangered (Commonwealth) eastern curlew, the largest migratory shorebird in the world.
- The endangered little tern: The Manning estuary is its most important breeding site in NSW.
- Threatened aquatic and aquatic-dependent fauna species including the freshwater spiny crayfish, several endangered frog species (stuttering frog, giant barred frog, Davies tree frog) and the southern myotis bat, which forages over streams and pools catching insects and small fish and the golden-tipped bat, which often roosts in abandoned bird nests in rainforest gullies in 1st and 2nd order streams.
- The maternity camp of vulnerable grey-headed flying fox in a patch of Sub-tropical Lowland Rainforest (EEC) at Wingham Brush. Flying foxes are keystone pollinators of over 50 native trees and are critical to the survival of eucalypt forests and riparian vegetation.
- At least twenty-five species of fish in the freshwaters of the Manning River have a range of values including recreational angling (Australian bass, yellow-finned bream and dusky flathead), conservation (east coast catfish) and commercial and ecological value (e.g. sea mullet and freshwater mullet)[34]. Migratory fish play a critical role in keeping our rivers, wetlands and oceans healthy by supporting a complex food web. Populations are declining globally[35].

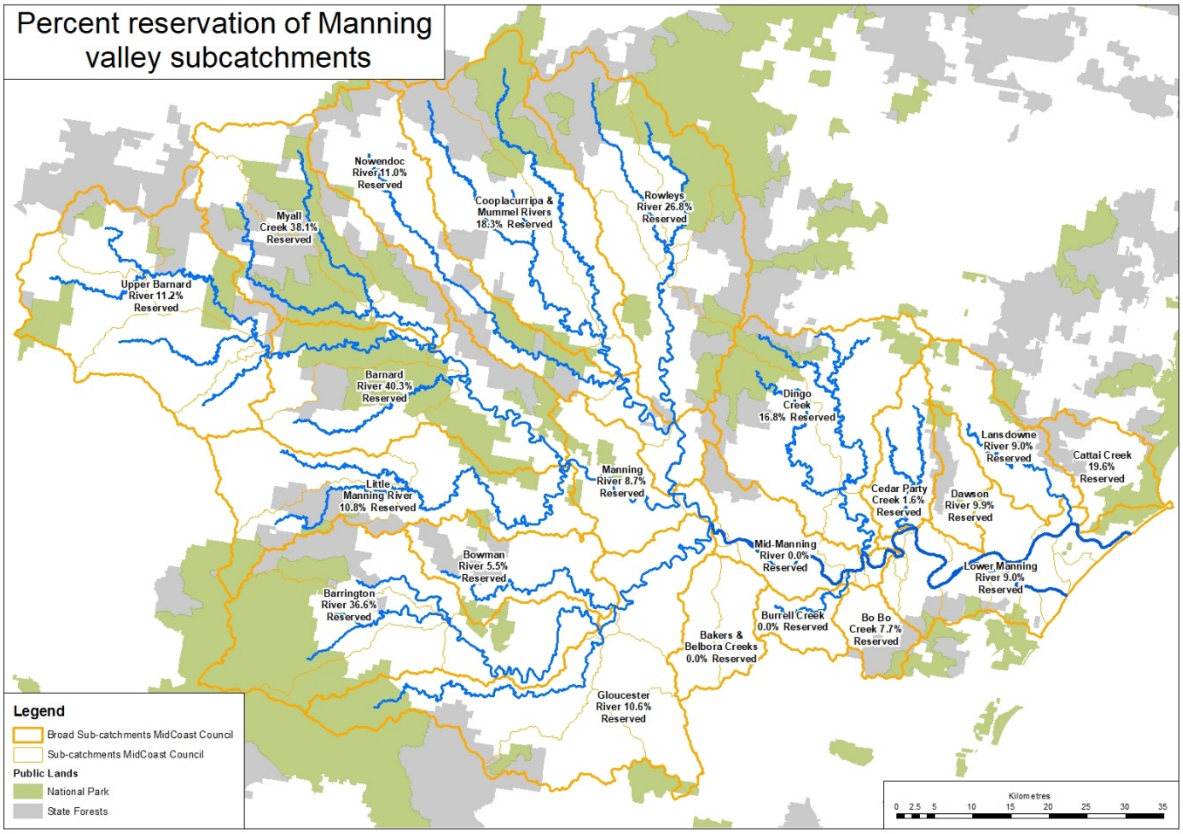
[33] (University of New South Wales, 2020)
[34] (Bishop, 2016)
[35] (World Fish Migration Foundation, 2020)



Map 1: Known Manning River helmeted turtle records to 2020. The Barnard, Mummel, Rowleys Rivers and Dingo Creek as well as the Manning are crucial turtle habitat.

Around 18.5% of the Manning River estuary and catchment are protected in the National Park estate. With the exception of Crowdy Bay N.P on the coast, National Parks in the Manning Catchment generally protect the ridgelands and steeper slopes while the river valleys and floodplains are largely unprotected. Significant National Parks include the Barakee, Tapin Tops, Coorabakh, Cottan-Bimbang, Curracabundi, Nowendoc, Mummel Gulf and the World Heritage listed Barrington Tops. There are three Declared Wilderness Areas.

Subcatchments with the highest levels of protection are the middle Barnard River, Myall Creek, Barrington and Rowley's Rivers. Lower levels of protection through conservation reserves can be seen in the middle Manning River and Burrell, Bakers and Belbora Creeks which have no reservation. Cedar Party Creek and Bowman River also have very low percentages of reserved land. Map 2 shows the percentage of reservation for each of the subcatchments in the Manning valley.



Map 2: Formal reservation as national parks for the subcatchments of the Manning valley.

Significant biodiversity assets occur on private lands. A workshop held in Wingham in February 2020 was attended by 77 landholders from the Manning catchment with average land-holdings of 60 ha per person. In an evaluation survey, 43% of respondents listed biodiversity conservation as their highest priority, while a further 40% listed a mix of biodiversity and productivity.

Stressors

Healthy in-stream condition contributes to conservation of aquatic fauna such as the platypus and Manning River helmeted turtle, and the productivity of fisheries including commercial species. Water sources with high instream value in the Manning Catchment include sections of the Upper, Mid and Lower Manning; Upper and Lower Gloucester and Barrington; Upper Barnard, Bowman and Nowendoc Rivers.[36]

However, during the Rapid Site Assessment conducted in 2019, most of the 175 sites assessed in the freshwater catchments were rated as having poor to fair instream condition .[37] Instream condition scores in both fresh and estuarine subcatchments showed indicators of elevated nutrients from fertilised pastures and crops and stock defecation.[38]

At the national level, key threats to biodiversity in aquatic ecosystems and marine receiving waters include diffuse-source water pollution, degraded riparian habitats and climate change, including the impacts of changed frequency, magnitude and intensity of floods and droughts[39]. In NSW, land clearing is currently the main threat to the extent and condition of native vegetation and habitat for terrestrial fauna[40]. Clearing, degradation and fragmentation of vegetation due to land uses such as agriculture and urban development result in loss of diversity and degradation of natural terrestrial and aquatic environments (Commonwealth of Australia, 2017).

These threats are reflected in the Manning River estuary and catchment, where major stressors include:

- Land clearing, habitat degradation and fragmentation
- Water pollution from sediments and nutrients
- Changing climate including extreme weather events such as drought and widespread and intense wildfires
- Invasive plants (Senegal tea, long-leaf willow primrose, small and large-leaved privet, vine weeds) and pest animals (foxes, rabbits/hares, feral deer, feral pigs, carp / goldfish)
- Diseases of concern include *Phytophthora* (causing dieback of trees), *Chytrid* fungus (killing frogs) and myrtle rust (causing dieback of species of myrtaceous plants)
- Altered hydrological regimes (e.g. weirs and causeways blocking fish passage)

[3636] (Betterridge & Rabbidge, 2016)
[37] (Swanson, 2020)
[38] (Swanson, 2020)
[39] (Commonwealth of Australia, 2019)
[40] (Commonwealth of Australia, 2017)

- Land-uses such as forestry (private and public) and mining
- Manning River helmeted turtle: predation, habitat degradation and illegal collecting.

With the exception of diffuse-source water pollution, all of these pressures are listed as key threatening processes under state and commonwealth legislation.

Impacts

The impact of extreme weather events experienced in 2019-20 foreshadows what we can expect under climate change scenarios. The record-breaking drought saw water quality and quantity decline dramatically. Many of the rivers and creeks across the MidCoast Region ceased to flow, with large sections of rivers dry and only disconnected pools present, often with fish kills. Remaining pools in parts of the Manning Catchment had poor water quality, with low oxygen and high nutrient levels from stock impacts.

During this time, local communities and landholders expressed deep concern about the condition of aquatic habitat for species such as platypus, turtles, fish and crayfish, as well as terrestrial fauna that relied on otherwise permanent waterways as a drinking or food source. Ancient river oaks died. Platypus were predated by foxes. Bass stopped breeding and exotic fish species (goldfish, mosquito fish) spread upstream.[41] Grey-headed flying-foxes also stopped breeding and were found dead in backyards throughout the lower catchment.

The wildfires of late 2019 burnt 244,173ha, representing 30% of the catchment, with several subcatchments burning over 90%. Up to 335km of riparian vegetation was burnt, (estimated at 25%[42]), including fruit trees such as lilly pillies and native figs which are significant food sources for many threatened species, including rainforest pigeons and the Manning River helmeted turtle.

Habitat loss due to clearing and other human activities has depleted the natural values of the catchment, resulting in erosion, invasive weeds, species' declines and local extinctions. For example, the number of species and populations of individual species of estuary and freshwater fish appears to be declining in the Manning River[43].

Loss of biodiversity (species and trophic levels) is classified as a high risk to social, economic and cultural benefits of the NSW Marine Estate[44]. The pressures that have pushed biodiversity and natural ecological systems in the catchment into decline also undermine the delivery of important ecosystems services, which in turn impacts social and economic drivers in the MidCoast Region.

[41] (Driscoll, 2019)
[42] (Steed, July 2020)
[43] MCMC (1996)
[44] (Marine Estate Management Authority, 2018)

Linkages that may be made between biodiversity impacts and negative community and economic outcomes are associated with:

- Reduced farm productivity and depleted fish stocks
- Increased treatment costs for domestic water supplies
- Damage to tourism brand, reduced visitor rates and spending
- Loss of lifestyle, amenity, and cultural identity.

2.2 Stakeholders

Management agencies

Government agencies: MidCoast Council (MCC), NSW National Parks and Wildlife Service (NPWS), Department of Planning, Industry and Environment (DPIE) - various units including Save Our Species, Crown Lands), Fisheries NSW, Hunter Local Land Services (HLLS), Federal Government Threatened Species Unit, Water NSW.

Indigenous organisations: Purfleet-Taree Land Council, Taree Indigenous Development and Employment (TIDE).

Community environment groups: Gloucester Environment Group, MidCoast2Tops Landcare, Manning River Turtle Conservation Group, Ozfish, Manning-Great Lakes Birdwatchers, Port Macquarie Hastings Birdwatchers, Hunter Bird Observers, Koalas in Care, FAWNA, Birdlife Australia.

Research: UNSW, Griffith University, Western Sydney University

Other: Tourism Expert Working Group, Team Taree

2.3 Existing Management Approach

- The National Park estate is managed by the NSW National Parks and Wildlife Service for biodiversity conservation and other values.
- The Manning River helmeted turtle was listed as endangered by the NSW Government in 2017 and added to the *Data Deficient* stream of the Saving Our Species program. A survey program was conducted by the Biodiversity & Conservation Division of DPIE in 2018-19.
- MidCoast Council is developing a Biodiversity Framework, which will set out Council's strategies for biodiversity conservation and protection across the MidCoast Region including the Manning.

- The community-based Manning River Helmeted Turtle Conservation Group coordinates a range of arts-based awareness and fund-raising activities to promote conservation.
- Aussie Ark is breeding an insurance population of Manning River helmeted turtle.
- The Water Sharing Plan has environmental objectives: "high instream value water sources are, by default, protected by the Water Sharing Plan by not allowing any trades in." [45]
- A collaborative study to assess the impacts of the 2019 drought and wildfires on water quality, fish kills, platypus and Manning River helmeted turtles was undertaken by MidCoast Council, DPIE, Hunter Local Land Services and Aussie Ark with a particular focus on Bobin and Dingo creeks and the Manning and Barnard rivers.
- A draft Conservation Action Plan to conserve migratory shorebirds in the estuary has been produced by BirdLife Australia as part of a wider partnership project led by LLS, funded by the federal Threatened Species Commission.
- MCC supports the NSW Government's Save Our Species (SOS) program to protect threatened beach nesting birds (little terns, beach stone curlews and pied oyster catchers) during the breeding season, including four wheel drive management, exclusion fencing, signs, fox control, compliance and education.
- MCC have existing weed control programs for high priority aquatic and environmental weeds.
- Regional priorities for feral pest control are identified in the *Hunter Regional Strategic Pest Animal Management Plan 2018 – 2023* (NSW Local Land Services). IN the National Park estate, priorities are set by the NPWS *Regional Pest Management Strategies (Lower North Coast Region)*. The NPWS approach concentrates on protecting key natural assets, include fox, corvid and gull control to protect beach-nesting birds at the Manning River entrances.
- MCC feral animal programs target deer control with Department of Primary Industries (DPI) at Cattai Wetlands and fox and wild dogs control in coastal areas (Cattai, Crowdy, Farquhar). Hunter Local Land Services and NSW National Parks and Wildlife Service delivers regional fox, dog and feral pig control programs across priority landscapes including Barrington Tops and Tapin Tops).
- Hunter LLS feral species control programs at various locations in the Manning valley.

[45] (Betterridge & Rabbidge, 2016)

2.4 Knowledge Gaps

Despite its significant value there is a lack of data on biodiversity status in the Manning River, the estuary and the catchment. In general, biodiversity knowledge gaps will be prioritised and addressed through the NSW Government's Saving Our Species program and MidCoast Council's forthcoming Biodiversity Framework. Vegetation research and management is covered in the Vegetation Management Issue Paper and the Coastal Wetlands Issue Paper in the CMP Issue Analysis series. With regards to aquatic and riparian fauna key gaps include:

- Identification and mapping of biodiversity hotspots
- Fauna prioritisation, auditing, monitoring, indicators, stressors and thresholds; including platypus, Manning River helmeted turtle, macroinvertebrate assemblages, rare and / or at risk freshwater fish
- Identification and prioritisation of freshwater hydrological (drought) refugia
- Distribution and prioritisation of invasive species including riparian and aquatic weeds.
- Impact of fish ways and causeways on fish and other aquatic fauna during drought.
- Role of dingos as apex predators: interaction of foxes, turtles and dingos; role in feral herbivore control.
- Aboriginal knowledge to guide conservation. For example, Aunty Faye Ridgeway is an elder who has deep affinity with dingoes, which play an important role in controlling feral herbivores.

2.5 What's working, what's not?

What's working:

- Community interest, engagement and support: The level of community interest and engagement in wildlife conservation, such as the Manning River Turtle, is a real asset for any activities wanting to be undertaken in the riparian zone and instream.
- Interagency collaboration: There is good communication and collaboration between agencies. Council staff - have been good to work with, putting effort into biodiversity planning.
- Private land conservation: There has been improvement in the last few decades on private land conservation projects, uptake in *Land For Wildlife Program* and landowners taking agreements to the next levels (i.e. Voluntary Conservation Agreements). There are a lot of keen and open landholders.

- Biodiversity Conservation Trust (BCT): representatives are active in our area. BCT have a lot of agreements in development, but there are a lot of opportunities here as well.
- State and Federal funding: There has been funding for wildlife conservation at State level (SOS program) and threatened species funding at federal level (National Landcare Program and Bushfire tranches)
- Aboriginal Rangers working on Country have been available to do a range of activities.
- Manning River Helmeted Turtle working group demonstrate good collaboration building on the workshop held in Wingham in 2019.

What's not working:

- Deficit in knowledge and data: There is a lack of biodiversity data and a sporadic approach to data collection as funding allows. We don't know what we are losing.
- Aboriginal knowledge – Could do better at incorporating Aboriginal knowledge in programs (e.g. traditional fire management); supporting Aboriginal communities to increase traditional knowledge, building capacity for Aboriginal land management and engaging existing service providers (TIDE, LALCs).
- Invasive species are widespread, especially post drought and fires.
- Stock in waterways: Landholder engagement in getting stock out of riparian areas and waterways is difficult. There are challenges working with larger stations but some are open to changing practices.
- Rate of biodiversity loss: We don't know the rate of biodiversity loss with major recent events (drought and fire) on top of cumulative impacts from land-clearing and degradation, pest species. Are funding and regional actions such as monitoring, on-ground works and engagement commensurate to address the rate of decline?
- Ongoing degradation and loss of riparian vegetation is critical issue, especially post fire.
- Modified floodplain drainage and coastal wetland degradation is a concern for these systems and the wildlife that relies on them.
- Inadequate reserve system: Although around 18.5% of the Manning catchment is protected in reserves, the public reserve estate is biased to "residual" reservation (conservation of leftover lands not valuable for other "productive" purposes). We need to enhance the comprehensiveness of the reserve system, especially in floodplain, depositional, and fertile landscapes; integrating terrestrial and aquatic conservation.

- Native timber harvesting has negative impacts on biodiversity and waterways.
- Feral animal control: better assess the threat of pest species including pigs, foxes, deer given that feral species are a major threatening process.

Opportunities

- Incorporate Aboriginal traditional knowledge in programs.
  - Traditional fire management and fire recovery.
  - Include significant species for Aboriginal custodians as indicators in monitoring and education programs.
  - Develop an Aboriginal seasonal calendar for the river and estuary.
  - Establish Indigenous Protected Areas.
- Flagship and Indicator species: Develop a suite of flagship and indicator species (e.g. platypus, turtles, fish such as bass, shorebird, crayfish, freshwater mussel, dolphin) from key groups, that link to the CMP vision and represent a healthy ecosystem. Use these species in monitoring and community engagement programs (see above).
- Include monitoring results for bio-indicator species in an annual Report Card linked to Biodiversity Framework to produce a *Health of the Catchment snapshot.*
- Partner with Aussie Ark on breeding and community education programs for threatened species
- Build research partnerships with Universities.
- Environmental DNA is a rapidly evolving technique for detecting species and getting information on assemblages.
- MRHT Conservation Group: a lot of enquires from schools, this could be developed.
- Carbon storage: quantifying carbon in riparian zones could be important, used for carbon credit programs
- Use of innovative technology – for example use of drones with LIDAR for depth measurements. TIDE has qualified drone pilots.
- Manage rivers and riparian zones as wildlife corridors by building connectivity of fragmented ecosystems.
- Create multi-tenure riparian reserves on priority reaches: use public land as a starting point (Crown, RMS) along with conservation agreements on private land.
- Build resilience into ecosystems, including exploring creation of novel ecosystems (e.g. for shorebirds).
- Nature based tourism and wildlife experiences e.g. birding routes, hides, boardwalks, river walks.

- Conservation partnerships with NGOs e.g. Australian Wildlife Conservancy, Bush Heritage Trust to establish fenced or unfenced reserves, animal protection, reintroduction.
- Crowd funding, social media, donations for threatened species e.g. captive breeding of MRHT. Best run by community sector.
- Identify and protect high biodiversity value areas: map, prioritise and protect freshwater refugia.
- Natural disaster response: Develop effective natural disaster responses to mitigate and reduce impacts of major events, particularly those associated with climate change.

2.6 Management Options

Planning

- Identify, prioritise and provide evidence to support amendments to the LEP and DCP for the protection of wildlife habitats and corridors.
- Develop (species-specific?) Conservation Action Plans for aquatic fauna and riparian specialists in priority subcatchments.
- Develop a Natural Disaster Response Plan to mitigate and reduce impacts of major disasters, particularly those associated with climate change (e.g. drought, fire).
- Develop a catchment management prioritisation tool that identifies spatial priorities for management actions, synthesising the CMP, Manning River and Estuary Risk Assessment 2019,[46] refugia modelling 2020, and riparian vegetation mapping 2019.[47]
- Develop a Best Management Practice Framework to integrate biodiversity, catchment and productivity outcomes on public and private land.
- Include resident and migratory shorebirds in planning for coastal wetland retreat.

Advocacy

- Identify and advocate for additions to the conservation reserve system to integrate terrestrial and aquatic conservation and improve representativeness, especially in floodplain, depositional, and fertile landscapes.

[46] (Swanson R. , 2019)
[47] (Pietsch, Daley, Stout, & Brooks, 2019)

Capacity Building and Community Stewardship

- Adopt a set of significant flagship and indicator species with Aboriginal and community input to use for monitoring and community engagement programs.
- Develop an interagency, multi-media suite of communication, education and training material to promote awareness, appreciation, understanding and skills for best management practice in urban and rural settings.
- Build capacity for Aboriginal involvement in NRM by supporting content development, delivery and recruitment of Aboriginal participants for accredited Conservation and Land Management training and issuing field work contracts.
- Promote and facilitate private conservation agreements through Land for Wildlife and Biodiversity Conservation Trust.
- Establish an annual citizen science BioBlitz through the Australian Living Atlas.
- Develop nature-based tourism experiences e.g. birding routes, hides, boardwalks, river walks.

Regulatory Compliance

- Adopt, monitor and enforce a standard native vegetation buffer width of 1-metre into the public road verge for the erection and maintenance of fences to preserve roadside.

Science and research

- Complete a refugia modelling study to identify, map and prioritise freshwater refuge pools.
- Sponsor an e-DNA research project to characterise aquatic fauna abundance and diversity.

On-groundwork/private land conservation?

- Develop and implement Local Integrated Weed Control Plans to protect priority assets.
- Develop and implement a cross-tenure Feral Pest Control Plan to protect priority assets.
- Engage Aboriginal Rangers in an ongoing conservation and land management program, incorporating both accredited technical training (e.g. TAFE CLM) and traditional Aboriginal knowledge. (e.g. cultural burning).
- Develop and implement a targeted landholder outreach and incentive program guided by the prioritisation tool and Best Management Practice framework.

- Restore fish passage at barriers identified as Medium-High and High priority.
- Improve condition, extent, connectivity and conservation status of riparian vegetation for wildlife habitat on public and private land.
- Protect and restore refuge pools.
- Implement the Shorebird Conservation Action Plan.

2.7 Monitoring program

- Design a multi species monitoring program with a set of bio-indicators. The Murray-Darling has good examples.
- Select reference locations including some that are accessible for public for water quality testing and macroinvertebrate sampling. A sub-set of the 206 sites from the 2019 Rapid Riparian Assessment should be used as the starting point.
- Incorporate community citizen science projects into the monitoring program (e.g. platypus). Consider monthly programs (labour-intensive) or an annual BioBlitz through the Australian Living Atlas.
- Engage stakeholders in regular and event-based data collection and monitoring, e.g. Aboriginal Rangers, weed control field officers (MCC, TIDE), fishermen (Birrbay), oyster farmers.

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3. Climate Change

The increase in greenhouse gases within the atmosphere, largely caused by the activities of humans, is causing the earth to warm. As a result, mean sea levels are rising along with the water levels inside estuaries.

Ocean and estuarine water temperatures are also warming, which will have flow-on impacts to water chemistry and ecology. Rainfall patterns are changing and any altered hydrology across the Manning catchment will change the prevailing mix of fresh and salt water in the estuary. Similarly, changes to the hydrology of the catchment will affect the usefulness of land for agriculture and the tendency for rainfall to cause erosion.

Two broad groups of management actions can be considered to address climate change: Mitigation, or the reduction of greenhouse gases to reduce the amount of global warming, and Adaptation, which includes options to live with the results of warming.

In the context of a local CMP for the Manning River Catchment, the authorities responsible for management only have agency to implement effective adaptive management options. These options are difficult to formulate, as there is substantial uncertainty surrounding the amount by which the earth will continue to warm, how quickly this will happen and how much local conditions will vary from other areas.

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3.1 Situation Analysis

3.1.1 Climate Change Background

Key Points
• The Earth has warmed over the past century.
• Global warming has been enhanced by the burning of fossil fuels and generation of greenhouse gases such as carbon dioxide.
• The increase in atmospheric greenhouse gases warms the Earth by trapping more heat in the atmosphere.
• Scenarios are often used to consider what future climate change will look like. For this paper, scenarios RCP8.5 (high greenhouse gas emissions) and RCP4.5 (moderate greenhouse gas emissions) are of most interest.
• A Catchment Management Program is largely concerned with actions that will allow us to adapt effectively to the changing climate.

The Earth has, on average, warmed over the past century. The Intergovernmental Panel on Climate Change (IPCC) is a scientific body established by the United Nations in 1988 to provide objective information on this global warming and climate change. In its most recent set of reports (Assessment Report 5, or AR5), the IPCC (2013) noted that:

> *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of greenhouse gases have increased."*

The Earth has warmed and cooled over geological time scales in the past. Current warming would not be remarkable if it were not for the influence of human beings. AR5 states:

> *"Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming and understanding of the climate system"*

The basis of climate change theory is that human caused emissions of greenhouse gases, particularly over the past several decades, are affecting the dynamics of energy exchange between the Earth and space. When the energy budget of the earth is in balance, the amount of solar energy entering the atmosphere matches the energy radiating back out into space. The various processes which contribute to the overall energy budget are relatively complex, as illustrated in Figure 1.

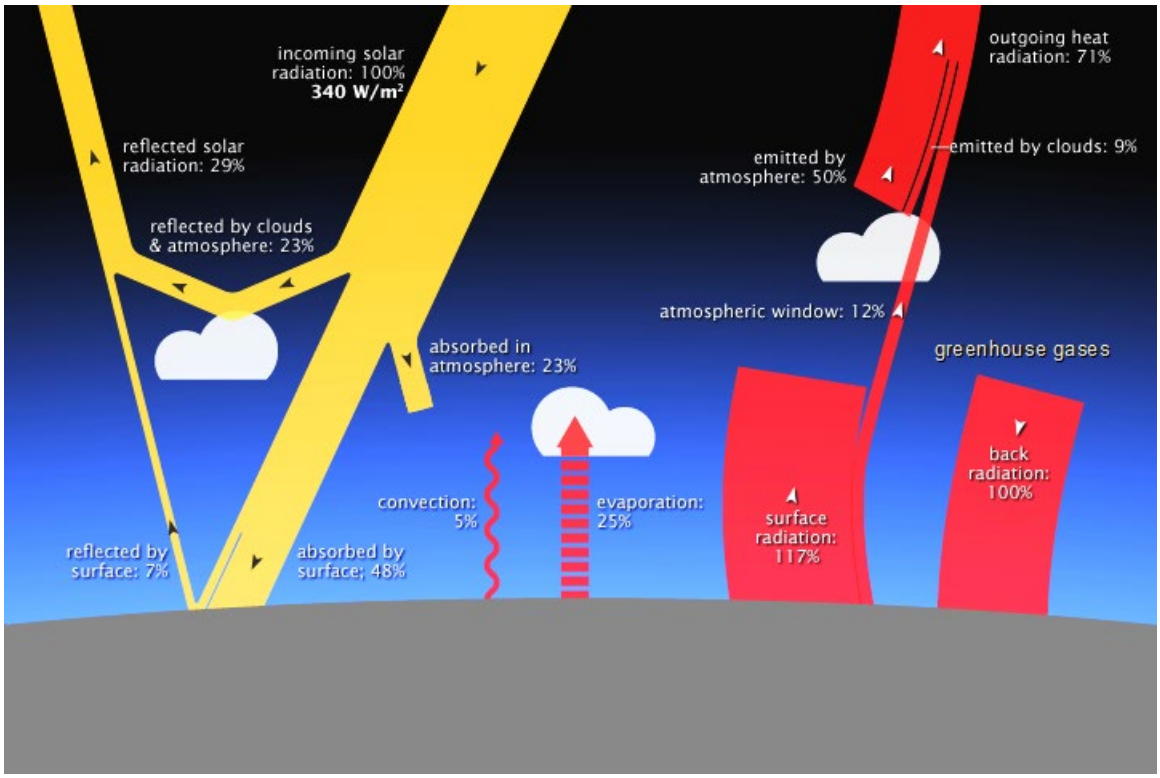

Figure 2 Sample Energy Budget and Its Components (source: Wikipedia, NASA)

Importantly, however, higher concentrations of greenhouse gases have caused an imbalance in the energy budget. The increase in greenhouse gas concentrations in the atmosphere makes it more capable of retaining heat. The effect is somewhat like adding blankets to a bed. More, thicker, or heavier blankets tend to make a bed warmer by reducing the rate at which heat can be lost and thus increasing the temperature underneath the blankets. Greenhouse gases have a similar effect on the Earth's atmosphere. Increasing concentrations of greenhouse gases reduce the efficiency with which energy is radiated back out into space from the atmosphere and therefore additional energy is "trapped", and, on average, the atmosphere, surface of the Earth and its oceans heat up over time.

Therefore, the underpinning cause of human induced climate change is global scale increases in the concentrations of greenhouse gases. Carbon dioxide is the most important greenhouse gas. Mauna Loa in Hawaii boasts the longest continuous CO_2 monitoring station. An up-to-date chart of carbon dioxide concentrations at Mauna Loa is shown in Figure 2.

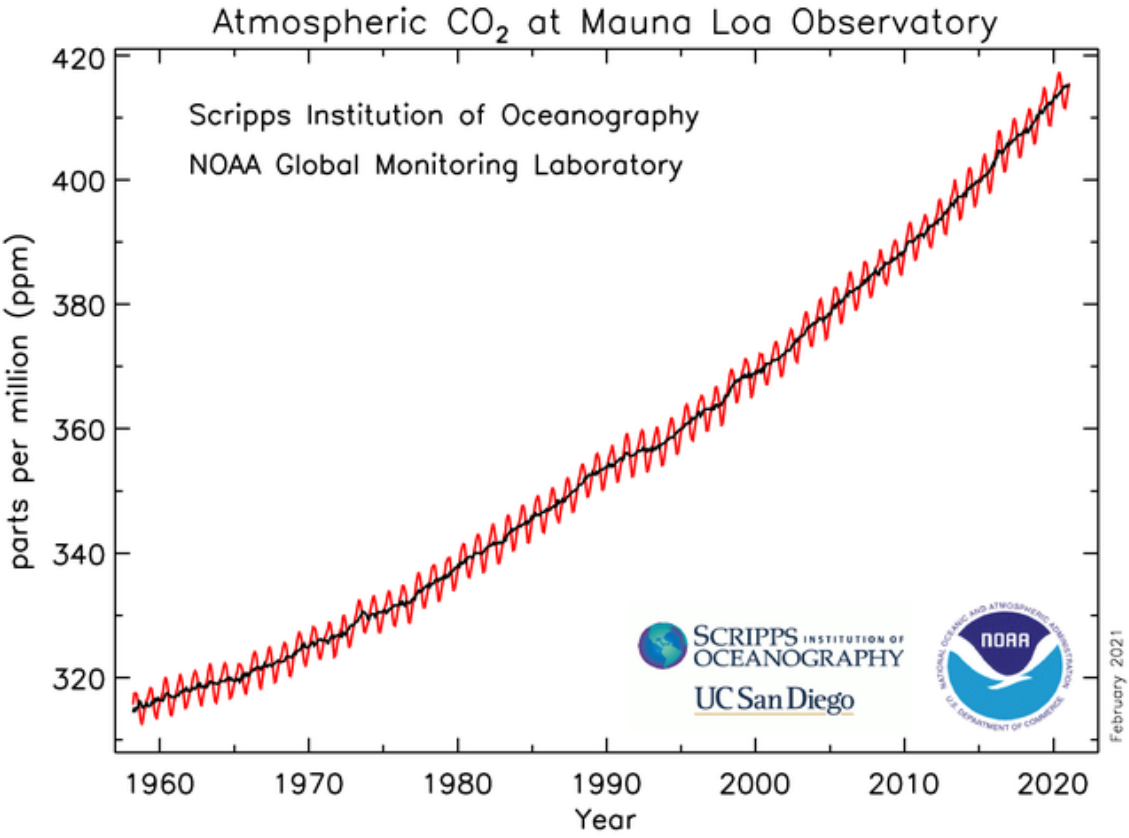

Figure 3 Historical changes in Carbon Dioxide Concentrations at Mauna Loa, Hawaii

Interestingly, Figure 2 does not yet reflect a slowing in the rate of carbon dioxide increase over time, even though there have been international agreements to address climate change for the past 30 years. The last few years have seen record quantities of carbon emissions and there seems little evidence that this slowed in 2020 during the height of the COVID19 pandemic.

Clearly, a wide range of uncertain future scenarios are possible, depending on the highly uncertain future behaviour of the global population and future economic growth. Even at a national level, emissions from Australia are unlikely to have a substantial impact on total global emissions in future. With this in mind, it is useful to recognise the two broad groups of management actions which can be considered to address climate change (Pittock, 2009):

- Mitigation, or the reduction of greenhouse gas emissions to reduce the amount of global warming. Local authorities possess limited capacity to effect measurable impact on global greenhouse gas emissions. Regardless, MidCoast Council has declared a Climate Emergency and has developed a *Climate Change Mitigation Plan* as part of MCC's Climate Change Strategy Phase 1 (2021).

- Adaptation, which includes options to live with the results of warming. The actions within the Manning River and Estuary CMP are limited to address adaptation. To plan for adaptation, it is necessary to have an idea of what the future under a climate change scenario might look like. This is fraught with substantial uncertainty, and the accepted way of exploring potential futures is to examine several plausible scenarios.

Four different scenarios of future greenhouse gas emissions were adopted in AR5, referred to as *Representative Concentration Pathways* or RCPs. Characteristics of these are summarised in Table 1.

Table 1 Representative Concentration Pathways (RCPs) used in IPCC's AR5.

RCP (Radiative Forcing at 2100 (W/m^2)	Equivalent Peak CO_2 Concentration	Description
8.5	>1370	Very high baseline scenario. Little effort to reduce emissions and warming not curbed by 2100
6.0	850	Medium Scenario. Stabilises soon after 2100.
4.5	650	Medium Scenario, Stabilises soon after 2100.
2.6	490	Very Low "Ambitious" scenario. Peaks early at 3.0 W/m^2 then fall due to active removal CO_2

While all of the RCPs were considered 'plausible' when they were first developed, it seems to have become customary in Australian practice, (e.g. Ball et al., 2019) to focus on RCPs 8.5 and 4.5 as upper and lower type scenarios as:

- RCP 2.6 is becoming increasingly unlikely given the current trajectory of CO_2 emissions and the ambitious need to actively remove carbon from the atmosphere.
- RCP 6.0 gives similar results to RCP 4.5 over medium to long term planning time frames.

Importantly, the RCPs do not have any given probability or likelihood associated with them. It is notable from Figure 2 that carbon emissions do not seem to be slowing yet and we seem to be headed along a similar or possibly more intensive trajectory than RCP8.5.

Over the past few decades, the approach of the IPCC has been to use these "emissions scenarios" or "representative concentration pathways" as inputs to a wide range of computer models of the global climate, known as "Generalised Circulation Models" or GCMs. These models use mathematical equations to represent the ways that energy, gases and water move through and between the ocean, atmosphere and land, and how these change as greenhouse gas concentrations in the atmosphere change. Dozens of different

models, run by various government and research organisations around the world, are considered by the IPCC including, for example, models from Australia's CSIRO and Bureau of Meteorology.

These models have improved markedly over time; however, they vary in their abilities depending on the mathematics and physics included in the model and performance in particular regions. For example, the models from CSIRO and BoM tend to perform better across Australia.

3.1.2 Threatening Processes

Sea-level Rise and Increased Tidal Inundation

Key Points
• As the Earth warms, sea levels will rise, on average, mainly due to expansion of water in the oceans as they warm, and the melting of ice from glaciers and polar ice caps.
• Following release of a major climate change report in 2013, the federally funded National Climate Change Adaptation Research Facility published local sea level rise projections relevant to the coast offshore of the Manning River. These projections included a range of factors that will affect the amount of sea level rise experienced offshore of NSW.
• Based on more recent work by the Intergovernmental Panel on Climate Change (IPCC) it is unlikely that, given a high future greenhouse gas emissions scenario (RCP8.5), mean sea level offshore of NSW will be higher than 1.25m above Australian Height Datum by 2100.

• Considering the available information, the following can be surmised:
  • 0.5m of local sea level rise could be considered a low limit for planning purposes by 2100 or, alternatively, a high upper limit of sea level rise by 2050.
  • 1.0m of local sea level rise probably represents a moderate value for planning purposes by 2100.
  • 1.5m of local sea level rise exceeds the 'likely' range of projections by 2100. It represents a very high, but still plausible, value for planning purposes by 2100.

Under a warming climate, sea levels are projected to rise primarily due to:

- Thermal expansion of water in the ocean as it warms.
- Melting of polar ice caps.
- Melting of glaciers.

These will contribute to a globally averaged rise in sea level. However, there are localised effects that need to be accounted for when projecting 'relative' sea level rise at any particular location around the coastlines of the world. These include:

- Uplift of adjacent land masses due to tectonic movements and adjustments including post-glacial rebound.
- Subsidence of adjacent land masses, for example due to the extraction of groundwater.
- Gravitational effects associated with movement of water mass from the poles to be more evenly spread around the oceans of the world.
- Changes to oceanographic features, such as strengthening of the East Australia Current.

Following AR5, the National Climate Change Adaptation Research Facility (NCCARF) published corresponding, localised relative sea level rise projections for application at a local government area scale[48], taking all these processes into account. These projections for the RCP 4.5 and RCP 8.5 scenarios are presented in Figure 3 and Figure 4 respectively. In this instance, the spread of GCM results used in AR5 is represented by a "likely" range. If an emissions scenario equivalent to the subject RCP is realised, AR5 states that there is a 1 in 6 chance that sea level rise will exceed the upper limit of the corresponding likely range and a 1 in 6 chance that is will be less than the lower limit.

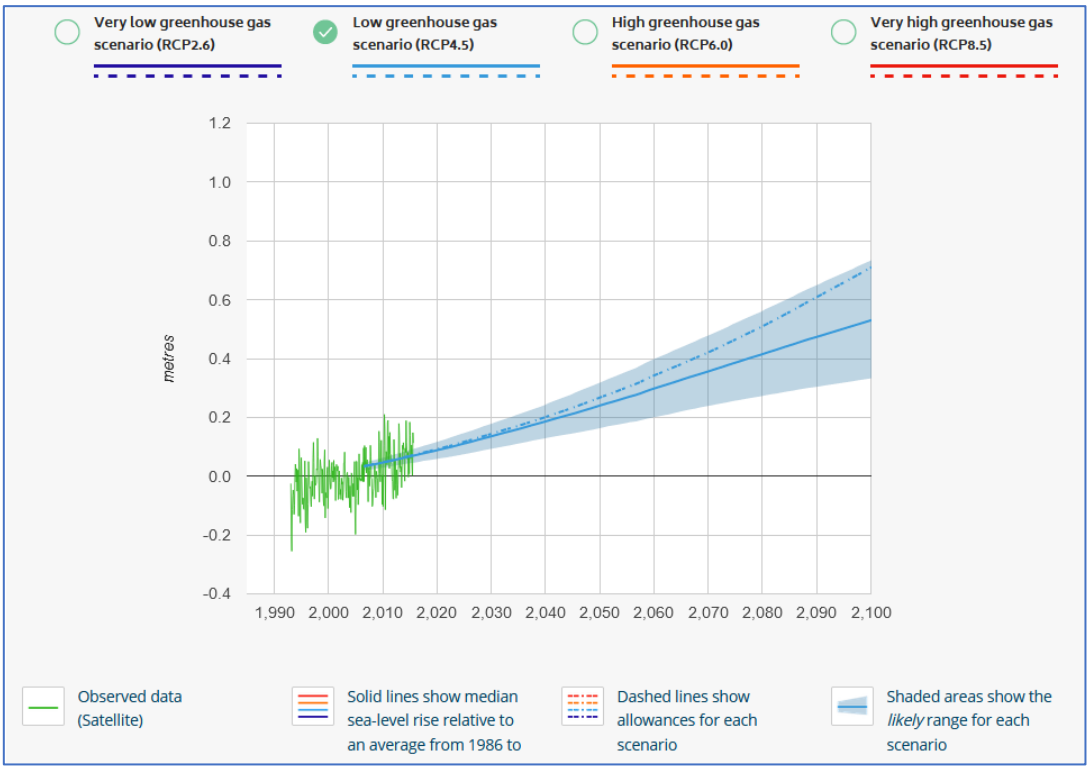

Figure 4 AR5 Consistent Sea Level Rise Projection for Manning Ocean Entrance, RCP4.5

[48] https://coastadapt.com.au/sea-level-rise-information-all-australian-coastal-councils#NSW_GREATER_TAREE_--MID-COAST--, accessed 4/03/2021.

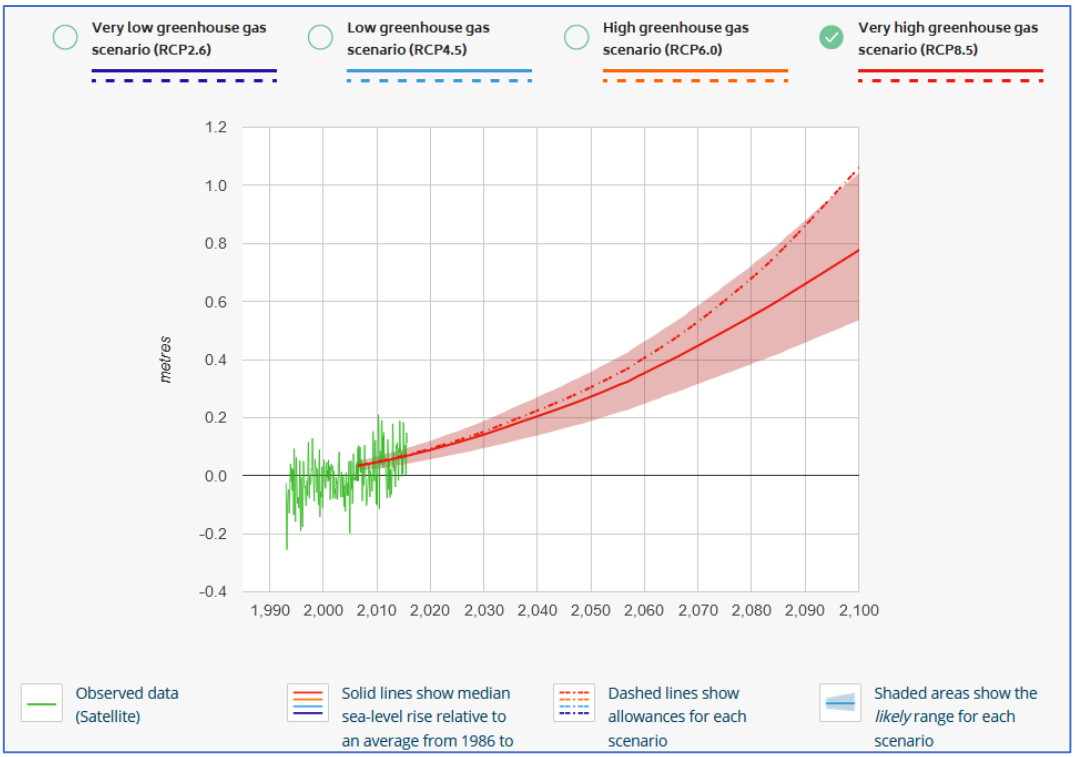

Figure 5 AR5 Consistent Sea Level Rise Projection for Manning Ocean Entrance, RCP8.5

The corresponding median and range for the two RCPs at 20-year intervals is presented in Table 2.

Table 2 Future Median and Range of Projected Sea Level Rise (m) at the Ocean Entrances to the Manning River, RCP4.5 and RCP8.5. Median of model results is shown, "Likely" range is in brackets.

	Representative Concentration Pathway	
Year	**RCP4.5**	**RCP8.5**
	(Moderate Emissions Scenario)	**(High Emissions Scenario)**
2030	0.14 (0.10-0.18)	0.14 (0.10-0.19)
2050	0.24 (0.17-0.32)	0.28 (0.19-0.36)
2070	0.36 (0.24-0.48)	0.45 (0.32-0.59)
2090	0.48 (0.31-0.65)	0.67 (0.46-0.89)

Subsequent to AR5, the IPCC has released a special report on the Ocean and Cryosphere in a Changing Climate (IPCC, 2019). Due to an improved understanding of ice sheet dynamics, including more reliable measurements of historical rates of ice melt and new models of ice sheet dynamics, **global** mean sea level rise for RCP4.5 and RCP8.5 were recalculated as shown in Table 3.

Table 3 Future Median and Range of Projected Global Mean Sea Level Rise (m), RCP4.5 and RCP8.5, from IPCC 2019. Median of model results is shown, "Likely" range is in brackets.

Year	Representative Concentration Pathway	
	RCP4.5 **(Moderate Emissions Scenario)**	**RCP8.5** **(High Emissions Scenario)**
2040	0.18 (0.13-0.23)	0.20(0.15-0.26)
2055	0.26 (0.19-0.34)	0.32 (0.23-0.40)
2090	0.39 (0.34-0.64)	0.71 (0.51-0.92)
2100	0.55 (0.39-0.72)	0.84 (0.61-1.10)

Importantly, Table 3 represents the global average. Local projections such as those in Table 2 have been adjusted to a **local** relative sea level. It is beyond the scope of the present issues paper to update the SROCC projections to estimate a locally applicable projections based on recent research. However, based on information in Wainwright et al. (2014) which calculated this adjustment based on information available when AR5 was released, it is likely that the upper end of the 'likely' range of sea level rise along the NSW coast in 2100, assuming RCP8.5, would be in the vicinity of +1.25m.

While there is substantial difference between projections over the long term, projections are similar over shorter timeframes (e.g., to 2040). While the CMP will aim to avoid actions that inhibit effective adaptation in the long term, the time frame over which the CMP adaptation actions are focussed is the next 20 years or so.

By 2040, it seems very unlikely that mean sea level will have risen by more than 35cm (compared to what it was in the mid-1990s[49]). Considering other minor adjustments, it seems very unlikely that mean sea level will exceed 0.4m above AHD, offshore of NSW, by 2040.

Three different scenarios of the impact of sea level rise inside the estuaries have been considered below by the NSW Government (OEH, 2018) and concurrently published by Hanslow et al. (2018), these corresponded to a rise in sea level offshore of the Manning River by 0.5, 1.0 and 1.5m. It is useful to link these levels to the results of the more recent IPCC report as follows:

- 0.5m of local sea level rise is close to the median value that could be expected under RCP4.5 in 2090. This probably represents a lower limit for planning purposes by 2100 or alternatively, a very high upper estimate of sea level rise for 2050.
- 1.0m of local sea level rise is close to the median value that could be expected under RCP8.5 in 2100. This probably represents a moderate value for planning purposes by 2100.

[49] Projections presented in AR5, and consequently in Tables 2 and 3 are all referenced to the average mean sea level between 1986 and 2005. Accordingly, this is the mean sea level rise that would have occurred since around the mid 1990's.

- 1.5m of local sea level rise exceeds the upper 'likely' limit that could be expected under RCP8.5 in 2100 by 25cm. It represents a very high, but plausible value for planning purposes by 2100.

The analysis presented by the NSW Government moved beyond the simplistic flat surface or "bathtub" estuarine inundation assumption which has been widely applied[50]. Hanslow et al. (2018) instead considered the existing HHWSS tidal plane for the Manning Estuary and then added 0.5, 1.0 and 1.5m of sea level rise. The resulting, sea level rise affected, tidal planes were then extrapolated across the floodplain to intersect the digital elevation model. The extents provide an estimate of the area that would be inundated several times per year (i.e., by a "King Tide") once the corresponding amount of sea level rise is realised. The results of the analysis are discussed further under **Potential Impacts of Concern.**

In addition to the work completed by the NSW Government, pure tidal inundation simulations, adopting a boundary representing King tides (HHWSS) and allowances for sea-level rise (+0.28m, reported as '2050'; and +0.98m, reported as '2100'), were also completed as part of the Manning River Flood Study (BMT WBM, 2016). While that flood study used different analysis techniques, results for the simulation of a 0.98m sea level rise are very similar to those reported by NSW Government (OEH, 2018) for 1.0m of sea-level rise. There are some discrepancies which could be investigated, but there is generally close correlation between the inundated extents.[51]

Increases in Extreme Rainfall

Key Points
• As the atmosphere warms, it can hold more moisture. This means that short duration rainstorms (~1 day or less) are becoming more intense. The behaviour for longer storms is less clear.
• Planning to manage the risks associated with extreme flooding is undertaken in NSW under the state government's Floodplain Risk Management Process, and studies have recently been prepared. The Catchment Management Program has only a minor role in managing the risks from extreme flooding
• Current Australian guidance recommends that the increase in short duration rainfall intensity can be neglected when planning over a 20-year time frame.
• Using current Australian guidance, an increase of between 10% and 20% in rainfall intensities was calculated as being appropriate for a facility or structure with a 60-year design life.
• The recent Manning River Flood Study completed for MCC in 2016 included sensitivity testing for scenarios with increases of 10% and 30% in rainfall intensity.

[50] For example, www.coastal risk.com.au. The bat-tub method can give very inaccurate results inside estuaries.
[51] A comparison can be made between figures T1 through T5 of the 2016 flood study and Figure 2 of Hanslow et al. 2018.

The most recent update to Australian Rainfall and Runoff (Ball et al., 2019; hereafter ARR) includes guidance on allowing for an increase in rainfall intensities as the climate warms.

There are several factors which impact on extreme rainfall intensities. At a very basic level, the amount of moisture which the atmosphere can hold increases as temperature increases. ARR recommends an increase in rainfall intensity of 5% per ^{o}C increase in temperature, although more recent research is indicating a value of around 7% per ^{o}C would be more appropriate.

ARR argues that, if the planning horizon being considered is relatively short (<20 years), then climate change will have negligible impact on design rainfall intensities. For longer periods, and the guidance provided by ARR involves outlines a process which involves several strategies for assessment including:

- Considers the purpose and nature of the asset or activity.
- Considers the consequences of failure.
- Considers whether climate change enhanced flooding will impair performance.
- Testing against more extreme events than would normally be used.

If this step demonstrates a level of concerning vulnerability, ARR recommends examining the outputs of a range of GCMs as made available through the *Climate Futures* online web service [52].

As part of the research completed for this paper, the process outlined by ARR was and, for a 60-year time frame (say, end of life of a facility or structure at 2080). To account for climate change in this instance, the design rainfall would need to be increased by 11.6% if RCP4.5 were assumed, and 19.2% if RCP8.5 were assumed. These calculated values are broadly consistent with published guidance specific to NSW[53].

ARR recommends that, as a minimum RCP 4.5 should be adopted but, if additional expense can be justified on "socioeconomic and environmental grounds", that RCP 8.5 should be used.

A flood study of the Manning River has been prepared (BMT WBM, 2016). As that study preceded the advice provided in ARR, a coarser approach, consistent with NSW Government guidance available at the time, was taken to the impact of climate change on rainfall intensities, with increases of 10% and 30% applied to the design values.

[52] https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/introduction-climate-futures/, accessed 3/03/2021.
[53] https://www.environment.nsw.gov.au/research-and-publications/publications-search/floodplain-risk-management-guide, accessed 4/03/2021.

Increased Drying of Catchments

Key Points
• The Manning catchment is expected to dry as the climate warms.
• This drying will not be felt uniformly, and it is expected to be at least 20 years before the change in dryness is definitive.
• The effects of Drying will likely be expected as an average increase in the intensity of droughts over time.

Overall, the Australian continent is expected to become drier as the global climate warms. This may seem counterintuitive considering the expected increase in extreme rainfall intensities, but there are multiple interacting factors which are expected to cause this. For example, under higher temperatures the base of the clouds tends to be higher, and the likelihood of rain is reduced. Higher clouds are particularly prevalent during dry periods and dry periods are generally expected to become longer across the Australian continent as it warms.

However, the patterns are not uniform. For example, changes in atmospheric circulations are expected to result in a general poleward shift of the locations of mid-latitude rain generating weather patterns. At a more local scale, changed weather patterns will interact with topography to determine the magnitude and direction of change ultimately experienced.

An increased tendency for the catchment to be dry may, at least partly, counteract the tendency for more intense rainfall to cause larger floods. A dry catchment at the onset of rainfall will tend to have drier soil profiles that can absorb more water, resulting in greater "initial losses" and less runoff at the start of a potential flood event. However, during extended drought conditions, land degradation including the loss of vegetation the trampling and compaction of soil by stock and the erosion of upper layers of soil, can also encourage water to runoff exposed surfaces more rapidly. The balance of these effects will vary over space and time.

The NSW and ACT Regional Climate Modelling (NARCliM) project is a climate modelling project which takes the outputs from global climate models and uses these models to drive more detailed regional climate models covering NSW and the ACT. This process is referred to as "downscaling" and, in the NARCliM data provided below, has provided outputs on a 10km Grid across the Manning Catchment. The NARCliM modelling effort has been recently updated to version 1.5 (in 2020), improving upon version 1.0 (2014) by using results from more modern GCMs. For NARCliM 1.5, three GCMs which have proven to perform well over south east Australia were used:

1. CSIRO BOM ACCESS 1.3
2. CSIRO BOM ACCESS 1.0
3. CanESM2 from the Canadian Centre for Climate Modelling and Analysis

The regional model used was the *Weather Research and Forecasting Model* (WRF), which was applied in two configurations which only varied in terms of the way that the effects of cumulus clouds are parameterised (the two configurations are referred to aRCM1 and RCM2). Therefore, a total of 6 combined GCM/RCM configurations are available from NARCliM 1.5.

Results were acquired for Seasonal Total Soil Moisture Content to reflect the degree of drying of the catchment as snapshots from the years 2020, 2040 and 2070. All four seasonal values for the 6 model configurations (total of 24 values) were averaged to give a representative annual soil moisture value. The results are summarised for RCP4.5 and RCP8.5 in Figure 5 and Figure 6 respectively.

The changes are relatively slight when compared to the spatial variability of soil moisture across the catchment. Importantly, these are "snapshots" of single years, and the results, which indicate that 2040 will likely be wetter than 2020, but that 2070 will be drier than 2020 need to be considered carefully.

The apparently wetter climate in 2040 reflects the fact that there is natural variability in the climate (i.e., some years are wetter than others even in the absence of climate change). Noting that these single year assessments are snapshots, a more robust assessment could be completed by averaging model results over longer periods (e.g., 20 years). Such analysis would effectively smooth out the ongoing climate variability.

What the results do indicate, however, is that overall catchment dryness is unlikely to change dramatically from the natural underlying variability that has been experienced historically. This points to a similar conclusion as that made by ARR for extreme rainfalls – that climate change will have a limited impact on design rainfalls over the next 20 years.

Perhaps more instructively, a comparison of soil wetness for RCP4.5 and RCP8.5 at both 2040 and 2070 is presented in Figure 7. That figure shows that the warmer climate represented by RCP8.5 demonstrates a more coherent pattern of catchment drying when compared to RCP4.5. There is still spatial variability across the catchment, reflecting the complexity of how overall global warming will impact on local weather patterns. It is clear however, that a warmer climate is expected to result in a drier catchment overall as we progress further into the future.

Increased Water Temperature

With increasing global temperatures, it follows that the water inside estuaries and rivers will also warm. Furthermore, it follows that areas closest to the ocean entrance will be more influenced by temperatures in the adjacent ocean temperatures and upper reaches more influenced by adjacent land and air temperatures. The area where the two mix in the estuary are likely to reflect a combination of both.

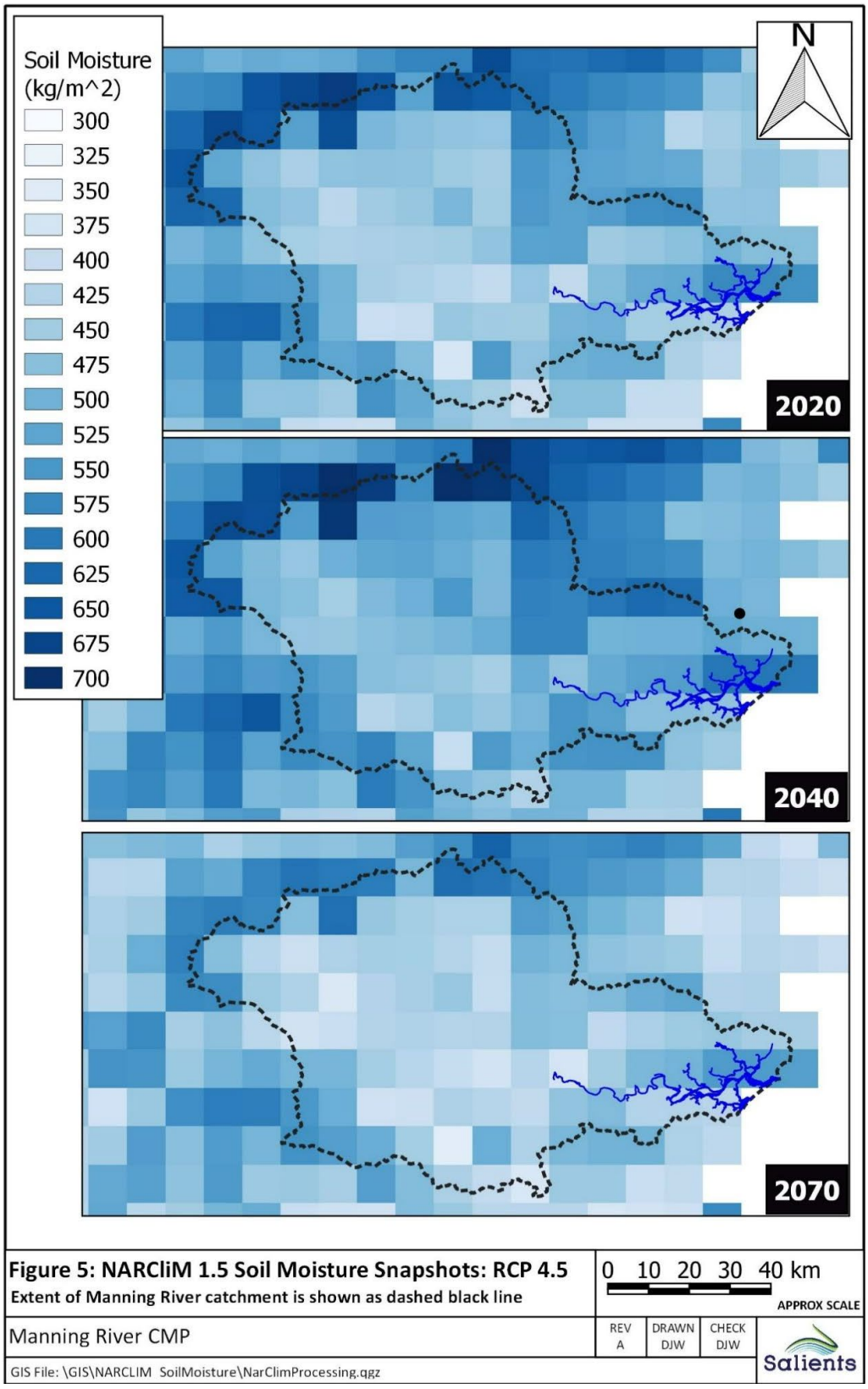

Figure 6 Gridded Indicative Soil Moisture Content derived from NARCliM 1.5 Simulations: RCP 4.5

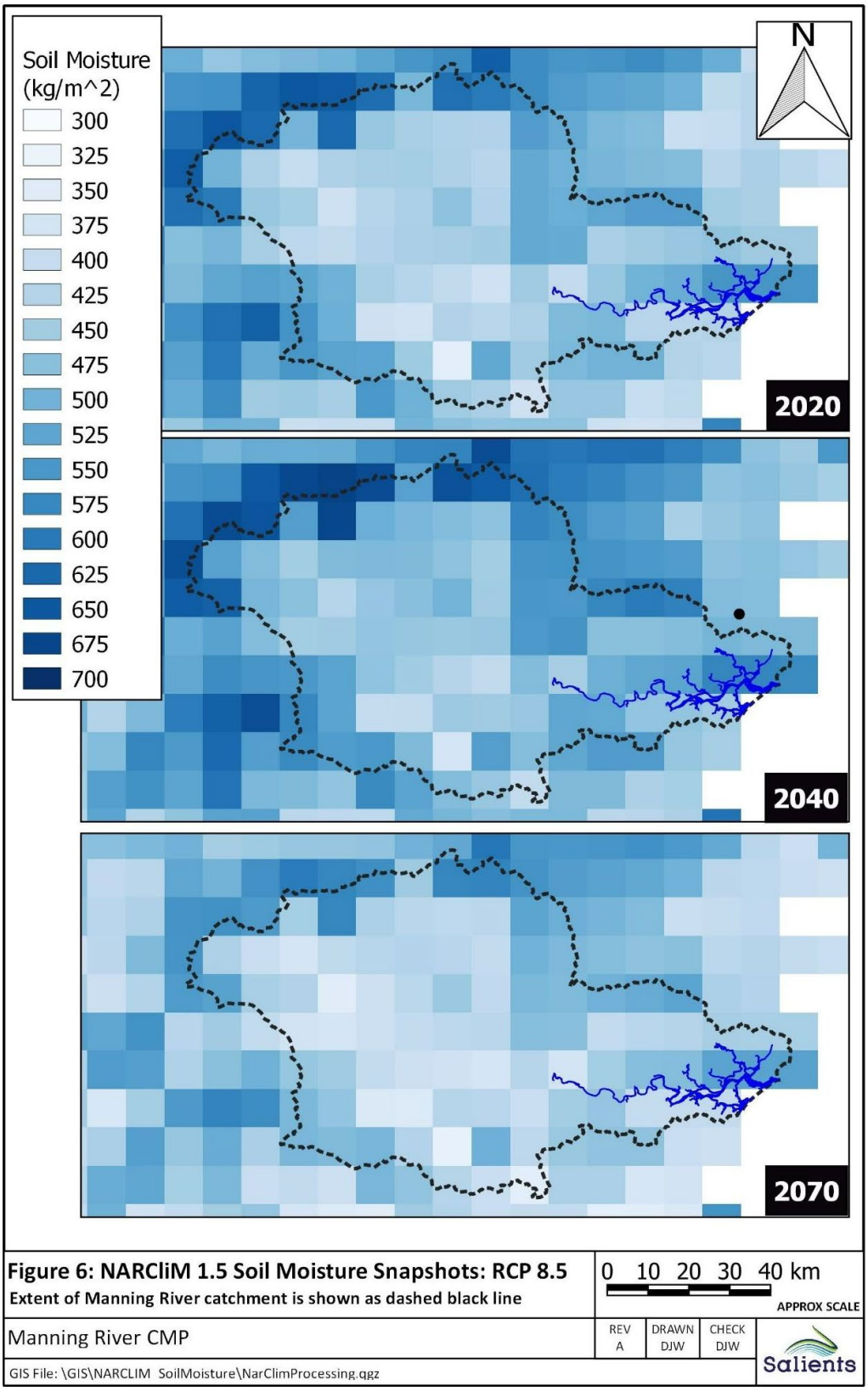

Figure 7 Gridded Indicative Soil Moisture Content derived from NARCliM 1.5 Simulations RCP 8.5

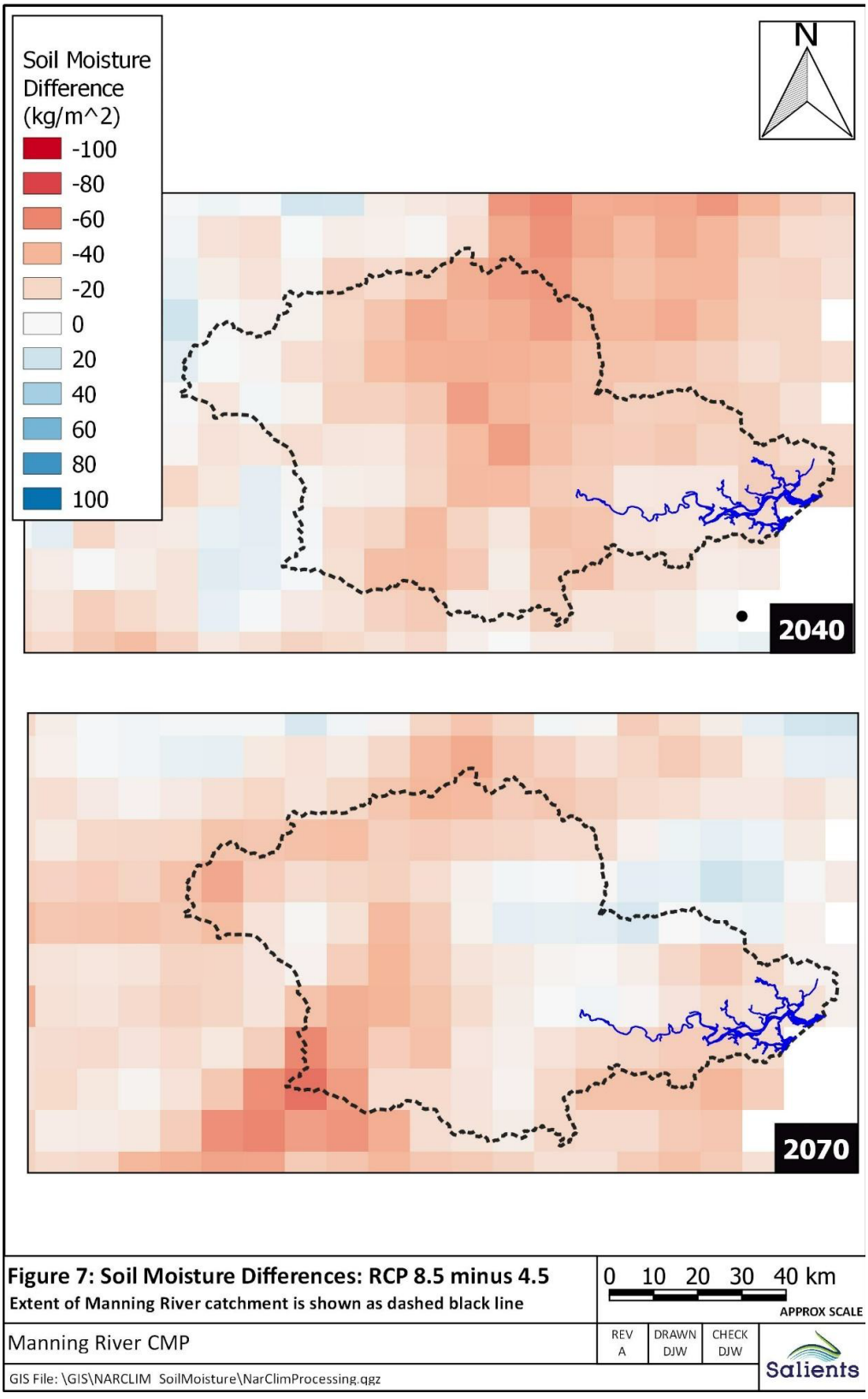

Figure 8 Gridded Difference in Indicative Soil Moisture Content between RCP4.5 and RCP 8.5 (obtained by subtracting RCP4.5 soil moisture from RCP 8.5 soil moisture)

The factors which will affect temperature at any given location and time are complex, relating to the degree of shading, depth, overriding climate (e.g., drought), recent weather, state of the entrance and flushing efficiency with the ocean. These factors combine to make it very difficult to predict exactly how much temperature will increase. However, two broad preliminary assumptions seem reasonable:

- Water temperature in the Manning River and will tend to increase if air and ocean temperatures increase.
- The temperature increase magnitude will be of similar magnitude to the increase in ocean and air temperature increase.

Of particular concern is that the extreme temperature conditions experienced from time to time, which could, for example cause death of species which use the estuary, will also increase. Accordingly, temperature related mortality events could be expected to increase in frequency over time.

3.1.3 Potential Impacts of Concern

Extents and Influence of Increases to Tidal Inundation

Key Points
• Impacts on tidal inundation from sea level rise impacts are not expected to be widespread for the next couple of decades.
• Different areas around the Estuary have been mapped for 0.5, 1.0 and 1.5m amounts of sea level rise in the ocean and the related inundation extents are described.
• If the entrance to the Manning River is trained, or dredged more extensively, the more open entrance will most likely increase the amount of tidal inundation.

Overall exposure of assets within the Manning catchment to Tidal Inundation was investigated in OEH (2018). The key results reported for the Manning River from that study are replicated in Table 4.

	Estimated Assets Affected during a King Tide for Various amounts of Sea-Level Rise				
Year	**0.0**	**+0.5m**	**+1.0**	**+1.5**	**Total in Catchment**
Properties (No)	168	504	854	1357	15128
Road Length[54] (km)	0.21	38.00	104.16	178.29	1009.61

[54] Affected roads are dominated by "Tracks" and "Local Roads" for Sea level rise of 0.5m, but with additional sea level rise, Arterial and Primary roads are more affected. Table C.23 of Hanslow et al. shows the breakdown.

Power Line (km)	1.44	45.30	111.57	186.65	1242.54

Table 4 Sea Level Rise Tidal Inundation Exposure Assessment for Manning Estuary

In addition to the increased heights of tides, the extent to which tides penetrate the estuary may increase as well. Some further investigation of the tidal extent of the Manning Estuary at "Abbotts Falls" is needed to determine whether the rapids in the river around this area could be overcome by higher tide levels driven by sea level rise in the ocean.

Abbot falls area could be overcome by tides in future. It is possible that areas which were consistently freshwater upstream of this location start to become tidal during some conditions. The importance of potential impacts on freshwater ecology is worth considering at this location.

We have examined the impact of sea level rise on pure tidal inundation utilising spatial data provided to us by the NSW government. This data comprises the extents of inundation under sea level rise amounts of 0.5, 1.0 and 1.5m. We cannot yet predict when these sea level rise values will be reached with any great accuracy. However, to facilitate interpretation of the following sections, we again note that:

- 0.5m of local sea level rise is close to the median value that could be expected under RCP4.5 in 2090. This probably represents a lower limit for planning purposes by 2100 or alternatively, a very high upper estimate of sea level rise for 2050.
- 1.0m of local sea level rise is close to the median value that could be expected under RCP8.5 in 2100. This probably represents a moderate value for planning purposes by 2100.
- 1.5m of local sea level rise exceeds the upper 'likely' limit that could be expected under RCP8.5 in 2100 by 25cm. It represents a very high, but plausible value for planning purposes by 2100.

Based on available information, it is extremely unlikely that 0.5m of sea level rise will occur in the next 20 years. Accordingly, the inundation extents described here, particularly those for 1.0 and 1.5m of sea level rise need to be interpreted in the context of a 'future' condition.

To facilitate a discussion on the areas and extent of impact, we have split the area surrounding the estuary into sub-areas for analysis and discussed. These areas are shown in Figure 8. The areas are discussed in turn. Much of the land that will be initially inundated by sea level rise is contained within coastal wetlands although agricultural land fringing these areas and the River will be increasingly affected.

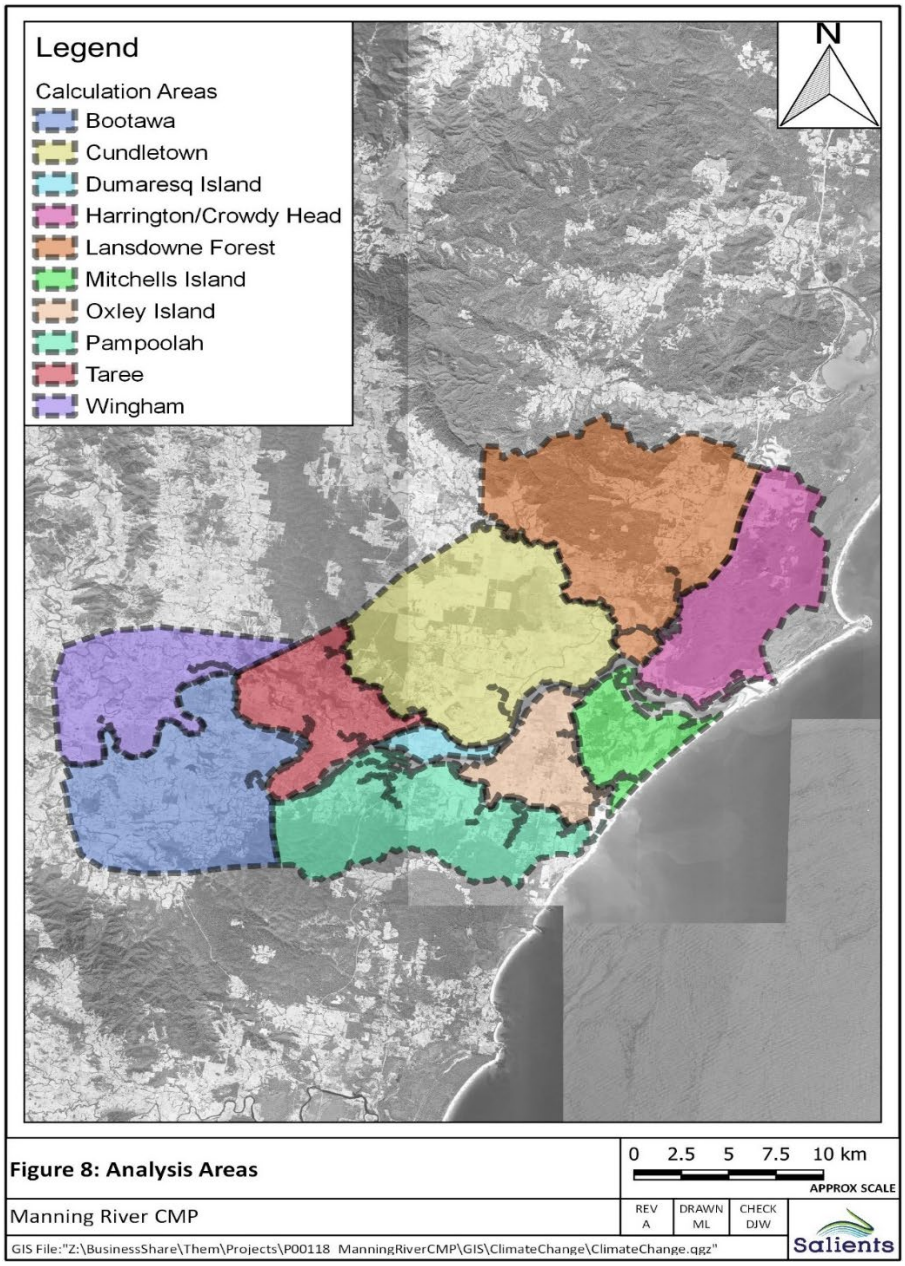

Figure 9 Analysis Areas

Harrington/Crowdy Head

Part of the mapped Harrington/Crowdy Head area is located outside of the area covered by the Manning CMP and the analysis for those areas should be considered in the forthcoming Manning Point / Old Bar CMP.

For current 'King Tide' conditions, there is a small amount of inundation along Cattai Creek (marked as "1" in Figure 9) covering a total area of 96ha. The inundated areas are all within areas mapped as coastal wetland under the *State Environmental Planning Policy (Coastal Management) 2018* (CMSEPP). This area is zoned for environmental conservation area under the Greater Taree LEP (2010).

With 0.5m of sea level rise, inundation by king tides increases markedly, covering nearly 1000ha. Inundation now fringes the entire length of Cattai Creek. There is also a significant amount of land impacted to the south of Coralville, marked as "2" in Figure 9. This land is also CMSEPP coastal wetland and zoned for environmental conservation in the LEP land zoning. Areas to the west of Coralville, marked "3" in Figure 9, are also impacted by inundation although this area is zoned rural - for primary production. Some areas around Harrington itself are also threatened, mostly comprising coastal wetland, although there is some threat to general residential (zone R1) and primary production (zone RU1) areas.

A sea level rise of 1.0m will cause tides to inundate areas further along Cattai Creek. A total of 1764ha is threatened in this instance. Again, most of this area is zoned as CM SEPP Coastal Wetland. Additional coastal wetland areas located in and around Harrington ("4" on Figure 9) are also inundated including, as for the 0.5m sea level rise case, areas zoned for general residential, primary production and recreation.

A sea level rise of 1.5m will see a total of around 2400ha inundated by a king tide, comprising more extensive inundation occurring in the areas described above.

Lansdowne Forest

This area generally extends between Cattai Creek and the Lansdowne River. Within this area, around 400ha of land is indicated as being presently inundated by King Tides. This occurs along the western side of Cattai Creek, to the east of Coopernook, in the area marked 5 in Figure 9. Most of the inundated area is within CMSEPP coastal wetland, and is environmental conservation area, although some inundation threatens areas outside of the mapped coastal wetlands, in land zoned for primary production.

For a sea level rise of 0.5m, there is a significant increase of inundated areas, with some 1750ha of land threatened. These threatened areas include:

- Over half of Mamboo Island, which is zoned for primary production.
- The area to the east of Coopernook and Moorland, along Cattai Creek, as marked "5" and "6" in Figure 9. These areas are zoned for primary production and environmental conservation.
- An area to the west of Coopernook, between Coopernook and the Lansdowne River, marked as "7" in Figure 9. This is a primary production zone.

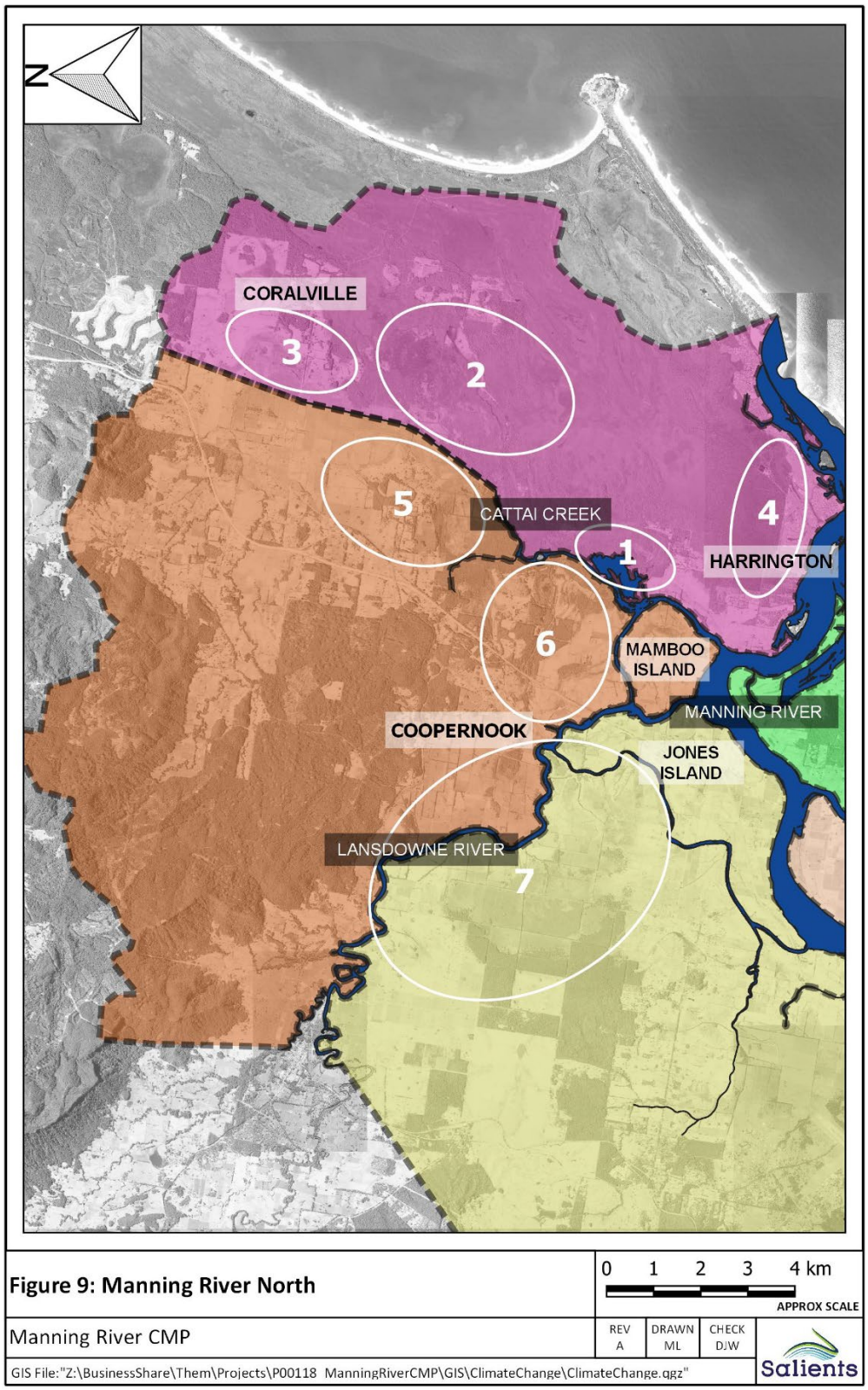

Figure 10 Manning River North

With a sea level rise of 1.0m, the areas threatened by inundation are located within the same areas as described above, but with more extensive inundation and a total threatened area of around 2500ha. Nearly all Mamboo Island is inundated by king tides with this amount of sea level rise.

With 1.5m of sea level rise, an estimated 2700ha of land would be inundated by King Tides. The threatened areas are the same as described above, with more extensive inundation. Mamboo Island would be completely inundated in this scenario.

Cundletown

Around 130ha of the Cundletown area is presently inundated by king tides. There is a small, primary production zoned area inundated to the north of Jones Island. A small area to the west of Cundletown, along the Dawson River, is also threatened. This area is within the CM SEPP coastal wetland area and is zoned for environmental conservation.

For a sea level rise condition of 0.5m, there is a very significant increase in inundation, with a total of around 3050ha of land threatened. The threatened areas are:

- Around half of Jones Island.
- An extensive area surrounding the creek to the east of Cundletown, marked as 8 in
- Figure 10.
- An extensive area zoned for mainly for primary production, but also containing environmental living and national parks to the north of Jones Island, along the Lansdowne River (marked as 7 in Figure 9).
- An area to the west of Cundletown, along the Dawson River. This area comprises coastal wetland.

For 1.0m of sea level rise, there is, again, a reasonably large increase in threatened area, with a total area increasing to more than 4500ha. The inundated areas are described for 0.5m of sea level rise, but with more extensive inundation. The areas marked 7 and 8, respectively in Figure 9 and Figure 10, are threatened with inundation. Inundation occurs up to the eastern side of Taree Airport, and almost all of Jones Island is expected to be inundated.

With 1.5 m of sea level rise, the estimated area inundated by King Tides totals 5257ha. The threatened areas are the same as those described previously, but slightly more extensive, with most of Ghinni Ghinni threatened, and the area south of Ghinni Ghinni between the Pacific Highway and the Manning River almost completely inundated. Both the eastern and western sides of Taree Airport are inundated.

Mitchells Island

Mitchells Island contains some small areas mapped as CM SEPP Coastal Wetlands, with other areas zoned for primary production, large lot residential, and small areas of national parks and nature reserves within the Island.

For the current sea level conditions of 0.0m, around 70ha is threatened by inundation during a King Tide. This area is predominately within mapped coastal wetland areas.

With a sea level rise of 0.5m, the inundated area increases to around 350ha of inundated land. This is also predominately within the mapped coastal wetland area, with some inundation extending beyond into areas zoned for primary production.

With 1.0m of sea level rise, there is a significant increase in predicted inundation (~930ha). This includes is a large proportion of the southern side of the island. That area is mainly zoned for primary production and is marked as “9” in Figure 10.

For 1.5m of sea level rise, a significant area on the south side of the island is threatened with tidal inundation. Furthermore, land around the shoreline of the entire island is threatened with inundation. Most of the threatened land is zoned for primary production.

Oxley Island

This area includes all of Oxley Island and Cabbage Tree Islands. There is a very small amount of CM SEPP Coastal Wetland area around the edges of the island. This area is mostly zoned primary production, with a small amount of environmental conservation land.

With current sea level, an area of some 130ha is threatened with tidal inundation. This occurs around the outsides of the mapped coastal wetlands, as well as towards the middle of the southern side of the island, shown as “10” in Figure 10. The area around location 10 is zoned for primary production.

With 0.5m of sea level rise, around 700ha would be inundated by tides. The same area is threatened with inundation as described for the current sea levels, but inundation is more extensive. In addition, a significant area to the north of the island (marked “11” in Figure 10) is threatened with tidal inundation. That area is zoned for primary production.

Given sea level rise of 1.0m, the threatened areas are the same as described above, but more extensive, covering a total area of around 1250ha. The western side of the island is starting to be inundated by tides in this scenario.

With a 1.5m of sea level rise, a total of more than 1720ha of land is threatened with inundation. This covers more than half of the island.

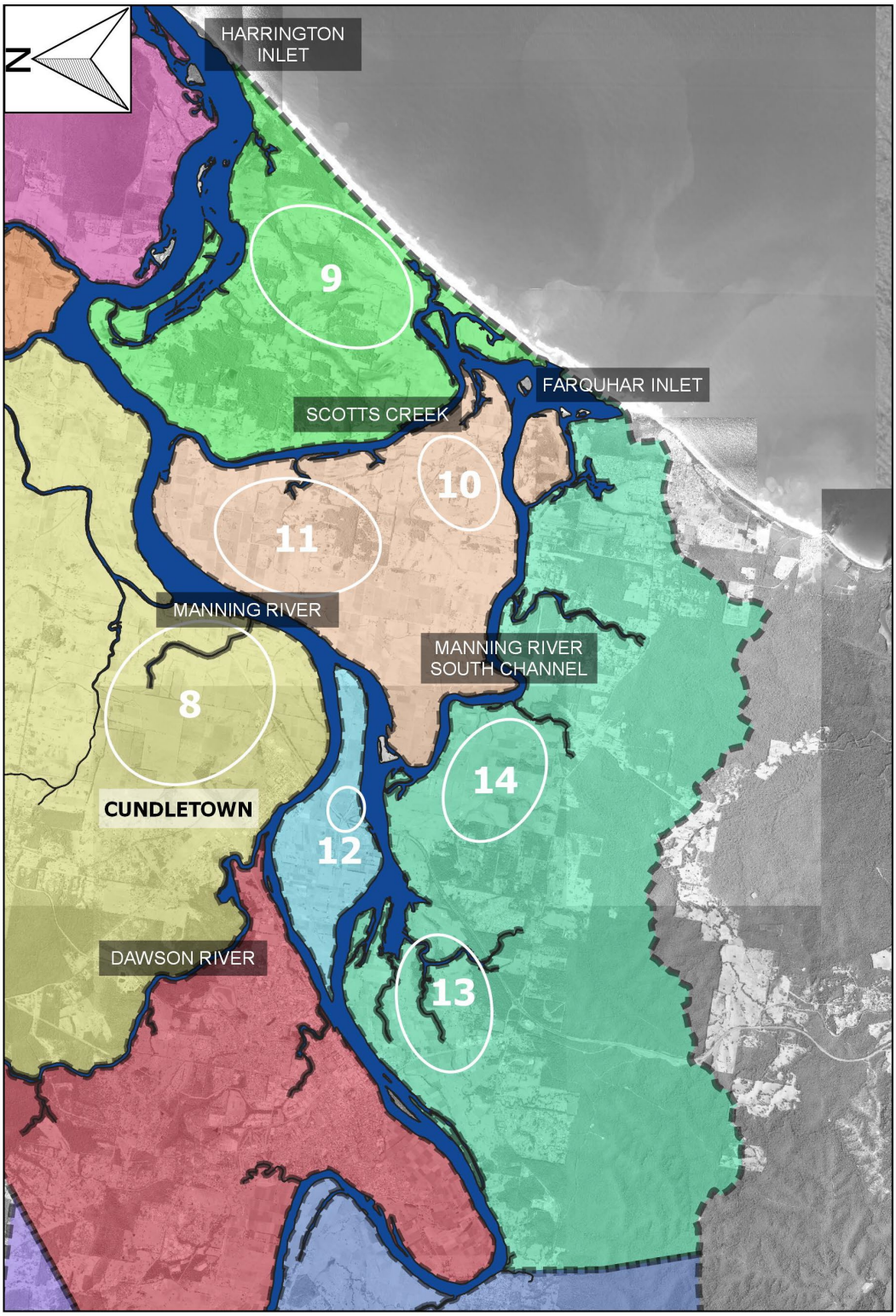

Figure 10: Manning River South	0 1 2 3 4 km APPROX SCALE			
Manning River CMP	REV A	DRAWN ML	CHECK DJW	Salients
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Dumaresq Island

A very small amount of coastal wetland is mapped around the outside of this island. Almost all the island is zoned for primary production.

For the current sea levels, there is a small (~25ha) area would be inundated by tides. The threatened area includes land along the Manning River on the southern side of the island and a small area marked as "12" in Figure 10.

With 0.5m of sea level rise, there is a slight increase in inundated land (to ~40ha). This occurs as an expansion to the inundated areas described above.

With 1.0m of sea level rise, there is a significant increase in inundated land, to a total of 220ha. A significant proportion of the island would be threatened with inundation in this scenario, with the threatened land mostly located on the southern side of the island.

With 1.5m of sea level rise, around half of the island is threatened with inundation, with the inundated area exceeding 300ha.

Pampoolah

This area covers land to the south of the southern arm of the Manning River, Stretching between Old Bar and Taree. It contains some mapped coastal wetlands. Areas threatened by inundation are mostly zoned for primary production.

With the current sea level conditions, around 40ha of land is threatened with tidal inundation. This is a very small amount of inundation, mostly within the coastal wetlands, around the creeks that come off the Manning River.

With 0.5m of sea level rise, the inundation is more extensive, with around 230ha of land threatened. The threatened areas are as described above, most prominently at location "13" in Figure 10.

With a sea level rise of 1.0m, inundation increases significantly to around 680ha. A reasonably large area, marked as "14" in Figure 10, is inundated in this scenario.

With a sea level rise of 1.5m, around 970ha are inundated, representing an expansion of the areas described above.

Taree

There is a reasonably large area of CM SEPP Coastal Wetland along the Dawson River, close to its confluence with the Manning River. This area is marked as "15" in Figure 11 and is zoned for environmental conservation.

For current conditions, around 40ha is inundated by king tides, mainly within the coastal wetlands.

With 0.5m of sea level rise, around 120ha would be inundated by tides. The subject land still mainly lies within the mapped coastal wetlands (zoned for environmental conservation) although some of the area is zoned for primary production.

With sea level rise of 1.0m, the increase of inundated land is moderate, (to ~160ha). A small amount of inundation is predicted in the town of Taree, around the creeks which join the Manning River,

marked as 16 and 17 in Figure 11. With the exception of Browns Creek, inundation is limited to land zoned for environmental protection and recreation (typically open space). There is a parcel of rural land at the downstream end of Dawson's River with is inundated. Around Browns Creek, the fringes of some areas zoned for industrial and business uses are also inundated.

At a sea level rise of 1.5m there is, again, a moderate increase in the inundated area to around 200ha. The threatened areas are zoned for recreation, light industrial and primary production. It follows that the town of Taree, excepting areas around creeks and wetlands, is estimated to only begin being This could change significantly if the efficiency of the entrance changes markedly and high tides are able to propagate into the estuary more easily threatened as sea levels rise above 1.0m AHD.

The patterns of additional tidal inundation that result from sea level rise indicate that existing catchment flood planning controls are more important than those that may arise from inundation due to tides. Residential areas are unlikely to be significantly affected by pure tidal inundation, even with up to 1.5m of sea level rise.

Wingham

Upstream of Taree, the River becomes notably channelised and the bifurcations which characterise the floodplain and wetlands downstream of Taree disappear. The river is more deeply incised into the landscape and therefore additional tidal inundation from sea level rise is a lesser concern.

Presently, there is a very minimal amount of inundation (~3ha), mainly occurring along Cedar Party Creek and the Manning River.

With 0.5m of sea level rise, inundation is still minor, with a total threatened area of 8ha. With 1.0m of sea level rise, the inundated areas expand to 14ha and with 1.5m of sea level rise it expands to 17ha. The area where additional tidal inundation occurs is marked as 18 in Figure 11 and is zoned for environmental conservation area.

As for Taree, the township of Wingham is unlikely to be significantly affected by pure tidal inundation, even with up to 1.5m of sea level rise.

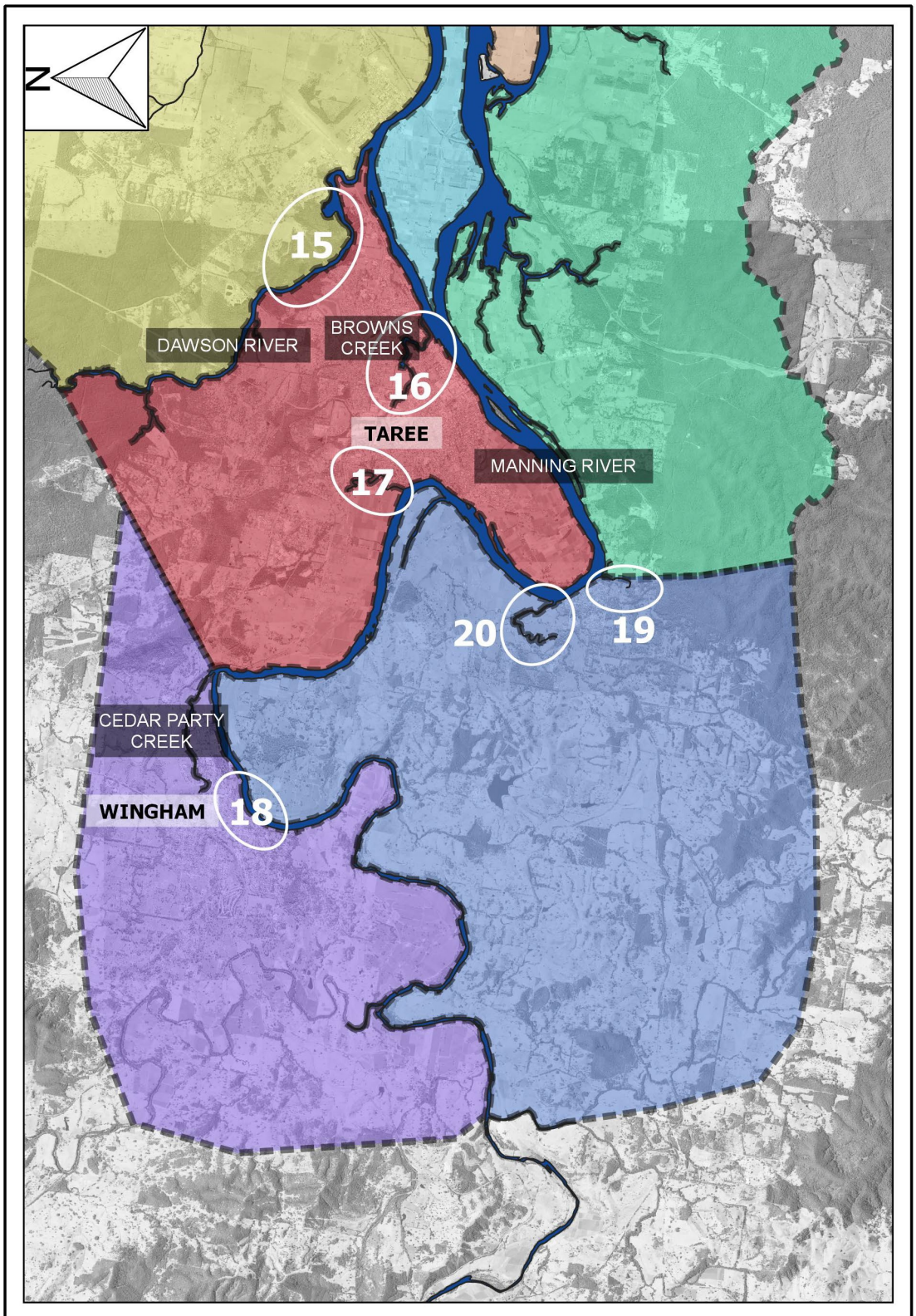

Figure 11: Manning River West

0 1 2 3 4 km
APPROX SCALE

Manning River CMP

REV	DRAWN	CHECK
A	ML	DJW

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Salients

Bootawa

The Bootawa area is located south of the Manning River and Wingham, upstream and to the west of Taree. With current sea levels around 14ha of land is inundated by tides along the edges of the River.

With a sea level rise of 0.5m, there is a very slight increase in inundated land to around 25ha, again along the edges of the river. This is occurring in the same areas as described for the current 0.0m condition. Similarly, for 1.0m of sea level rise, around 40ha of land is inundated by tides. With 1.0m of rise, the area marked as "19" in Figure 11 and zoned for primary production is inundated by tides.

With a sea level rise of 1.5m, the inundated area increases to an estimated 56ha. Notable, an area surrounding Peg Leg Creek near Tinonee, "20" in Figure 11 and zoned for Primary Production becomes threatened.

Increases to Erosion and Sedimentation

Sediment in the Estuary and River has a few sources:

- The Ocean, from which marine sediments are carried into the entrance by tides and storm surge events.
- The catchment which, through ongoing erosion of the landscape, delivers sediment to the river and upper reaches of creeks and wetlands.
- Riverbanks, which can erode, supplying sediment to the waterway.

The limits of ongoing deposition from the ocean are defined by an active marine delta which is downstream of the geographical area covered by this CMP. With sea level rise, however, this area is expected to become activated, extending further upstream as more sediment is carried in from the ocean to build up bed elevation inside the entrance. If sea levels stabilise, this situation will again reach a dynamic equilibrium.

It is difficult to estimate whether the marine delta elevations will keep pace or lag sea level rise, and this will have an influence on whether, and for how long tidal ranges inside the entrance will become larger because of sea level rise. If the entrance becomes deeper because sediment from the coast is not supplied quickly enough to maintain the depths, then the forces which attenuate the tide in the immediate area of the entrance will become less effective, and the tide range inside the entrance will become larger. A similar process is seen if an entrance is made more efficient by training.

From the catchment side, overall drying of the catchment, combined with more intense extreme rainfall events may well speed erosion of sediments from catchment surfaces and deposition of these sediments into the River. More frequent flood events of larger intensity may also tend to force more rapid geomorphological change in the river, including a larger load of sediment to infill the upper reaches of the river and more intensive erosion, supplying even more sediment from the riverbanks. The processes which transport sediment are related to water velocities in a highly non-linear way. As a rough example, an increase of stream velocity by around 10% could increase sediment transport loads by 50%.

In addition, the drying catchment and increased potential for more frequent and intense bushfires may also act to strip the land of vegetation, leaving bare earth and ash that is more easily washed into rivers. The experience of the recent 2019/2020 bushfires in NSW and subsequent study into the effects should provide some insight into what potential impacts could be in future. It is recommended that the outcomes of research being undertaken as part of the *South east catchment and waterways bushfire recovery plan* be monitored to inform future management of the catchment.

Changes to Water Chemistry

Water quality changes are going to arise in a complex manner in response to climate change. As outlined above there will most likely be an increased sediment load to the estuary and increases in turbidity could be anticipated.

Furthermore, it has been noted that temperatures will increase, and this is likely to have several secondary physical impacts:

- Increased temperatures of the ocean enable it to dissolve carbon dioxide more easily from the atmosphere. This makes oceanic (and by extension, estuarine) water more acidic.
- Increased tidal penetration, arising from sea level rise and the inability of entrance bed elevations to keep pace (as described above) will make the middle to upper reaches of the estuary more saline. As described above, it is also possible that the saline influence will extend upstream of the existing tidal limit of the River, affecting reaches that have been, to date, freshwater.
- Increased temperatures can encourage the release of nutrients previously trapped by sediments into the water column, encouraging algal blooms in areas characterised by still water and the ability to settle out organic matter.
- During periods of low catchment runoff and around the middle estuary (between Ghinni Ghinni & Tinonee) vertical stratification has been measured. This is caused by warmer, less dense catchment inflows flowing over denser, colder saline water (Webb, McKeown & Associates Pty. Ltd., 1997). This feature is referred to as a 'saline wedge'. With increasing dryness, the location and strength of this wedge is likely to move upstream and may strengthen. The resulting stratified water can inhibit overall mixing and deoxygenate water near the bed of the waterbody causing impacts such as fish kills.
- An increase in the mean tide level, assuming the tide range remains similar, will also result in higher low tide levels. Within the lower reaches of the estuary, which are impacted by acid drainage, the subject lands may become more permanently inundated, reducing the frequency with which acid generating drainage events occur.

The interactions between these processes are incredibly complex and it is beyond the state of the art to generate reliable quantitative predictions of how the whole water quality environment within an estuary will evolve under a given temperature increase and sea level rise scenario. Robust

monitoring of the changing situation is one of the key tools available to enable agile future adaptation and informed decision making. As noted by Glamore et al. (2016), *"The long-term monitoring of climate variables and key estuarine processes is critical"* and *"Comprehensive monitoring programs can be used to develop estuary-wide adaptation strategies"*.

A recent paper (Scanes et al., 2020a) looking at estuaries in NSW over a recent 12 year period argued that estuaries are warming at a rate higher than temperature increases predicted by "global models". While a 12-year period is very short for projecting absolute trends considering underlying climate variability, the reported relative trends relating temperature to salinity and pH are likely to be reasonably robust. With an increase in temperature, Scanes et al (2020) found that:

- pH will reduce (i.e., estuaries become more acidic).
- Riverine estuaries (such as the Manning) tend to become (slightly) more saline due to the decreased freshwater inputs (less rainfall) from the catchment.

Habitat loss or change

Estuarine species depend on various habitats for services such as food provisioning or nursery areas (Heck Jr et al., 2003; Raoult et al., 2018). Increasing temperature, sea level rise and ocean acidification will likely alter the distribution and diversity of estuarine habitats into the future, leading to flow-on impacts on the fishes, invertebrates and shorebirds that depend on them. Sea level rise is a driver of habitat loss for seagrasses (del Barrio et al., 2014), saltmarshes (Crosby et al., 2016), and mangroves (Lovelock et al., 2015), and is the most immediate climate-driven threat to these habitats. Tidal range determines the distribution for all three of these habitats, therefore any change in sea level will affect all three (Balke et al., 2016). Tidal ranges affect these habitats indirectly through a mix of factors including coastal squeeze (Pontee, 2013) and decreased light availability (del Barrio et al., 2014). In NSW, sea level rise is expected to decrease marsh extent by nearly 25% (225 to 168km^2) at the end of the century (Akumu et al., 2011), and will also likely result in seagrass losses in deeper parts of NSW estuaries (Davis et al., 2016). There may be rapid sedimentation in estuarine entrances leading to impacts on estuarine habitats that cannot adapt to these higher accretion rates.

Other factors such as extreme weather events that are predicted to increase in severity as a result of climate change can cause widespread die-offs on seagrass meadows (Cardoso et al., 2008) and mangroves (Duke et al., 2017). A progressive change in temperature is expected to introduce more tropical species of consumers that may shift trophic dynamics of grazers and impact habitat through consumptive effects (Heck Jr et al., 2015), discussed further in the following section.

All three most common estuarine habitats (seagrass, saltmarsh, mangroves) are expected to have a reduced areal extent because of climate change, however, the pressures are expected to be greatest on saltmarsh habitats (Valiela et al., 2018). Mangroves are increasingly found in saltmarsh habitats as a result of sea level rise (Saintilan et al., 2014; Whitt et al., 2020), and saltmarshes are typically 'boxed in' as a result of built environment so they cannot retreat with sea level rise (Leo et al., 2019). This pattern has occurred globally and around Australia (Saintilan et al., 2014).

Changes to fish and invertebrate communities

The combined changes in salinity, temperature, ocean acidification and sea level rise are expected to have complex impacts on fish communities that live within estuaries for at least part of their lives

(Gillanders et al., 2011). NSW estuaries' close proximity to the Eastern Australian Current may mean that the rate of increase in these parameters may be more rapid than in other parts of the world (Scanes et al., 2020b) and that any impacts typically expected on fish communities are compounded. However, the impact of climate change will likely be greater at the more temperate south-eastern end of Australia that will see a greater change in conditions rather than the northern border of NSW that naturally sees some degree of tropicalization (Gillanders et al., 2011).

The spatial extent or geographic use of fishes are likely to change due to higher temperatures and larger freshwater flows. For example, estuarine species commonly found in NSW waters typically move further towards the ocean during freshwater pulses (Williams et al., 2017). The increase in strength of the East Australian Current is likely to progressively tropicalize the fish communities that are otherwise temperate (e Costa et al., 2014) including on the NSW coast (Vergés et al., 2014). However, range extension of tropical species can only occur in estuaries that have similar features as the seeding habitat, which may result in only seasonal influxes of tropical fish larvae rather than permanent settlement (Malcolm and Scott, 2017).

The physiology of fishes that cannot be displaced easily is likely to be impacted by climate change. Most fishes are complete ectotherms and therefore their metabolism is directly linked to the ambient temperature. If fishes are not able to move to more southern estuaries, they likely have more limited aerobic scope (Clark et al., 2013; Pörtner and Knust, 2007). Ocean acidification will likely impact the chemosensory systems of fishes and affect predator avoidance and predation (Pistevos et al., 2015) though the evidence for the impacts of acidification is conflicting (Clark et al., 2020; Munday et al., 2020), suggesting it may not be a significant factor in fish management until at least the end of the century.

Invertebrates may be more susceptible to changes in ocean chemistry than fishes, especially those that build calcium carbonate skeletons. For example, fertilization success is lower in near-future ocean acidification conditions for sea urchins (Havenhand et al., 2008) though this pattern (as in fishes) may be very species and location-specific (Havenhand and Schlegel, 2009). The acidification of oceanic waters is of some concern and the oyster industry is undertaking research to examine potential impacts on the formation of oyster shells. Because of these contrasting effects, benthic invertebrate communities that are important food sources for many estuarine species may be altered significantly with changing climate (Hale et al., 2011). The flow-on effects that these changes could have on higher trophic levels such as fishes are hard to predict since many of the climate change impacts are interacting and are largely unknown. Since oyster reefs are key habitats in NSW estuaries, climate change impacts could reduce the extent of extant habitats or reduce the effectiveness of oyster reef rehabilitation projects.

In NSW, the predicted changes will be manifest in significant estuarine and nearshore habitat change, changes in trophic (food chain) relationships and a shift in the recruitment patterns of aquatic plants and animals, including commercially and recreationally harvested fish and invertebrates. While shifts in the range and distribution of harvested species, the composition and interactions within aquatic communities and the structure and dynamics of communities are predicted to occur, the magnitude and direction of changes is currently not known. Limited understanding in this area represents a risk which may be significant.

3.2 Stakeholders

Climate change will have broad impacts on many facets of estuary and catchment management. There are many stakeholders which will have interest, although for some risks issues may not arise for several decades.

Stakeholders include MCC; LLS; DPI-Fisheries; Commercial fishery and aquaculture businesses; DPIE-EES; Floodplain land holders; NPWS; Tourism (e.g., recreational fishing, ecotourism, boating); TfNSW (navigation and waterway access); Crown Lands; Local Aboriginal Land Councils, the Aboriginal community (e.g., impact on heritage sites); research institutions; DPIE-Planning; Federal government departments including the current Department of Agriculture, Water and the Environment.

3.3 Existing Management Approach

3.3.1 Greater Taree Climate Change Risk Assessment and Adaptation Plan - 2010

This report (Kinrade and Arold, 2010) was commissioned by the Hunter and Central Coast Regional Environmental Management Strategy (HCCREMS). It identified the following "High" and "Medium" scale risks of relevance to the scope of the CMP, and these have been considered, alongside the recommendations of the Plan for their management.

Permanent saturation of low-lying residential areas *due to sea level rise and a rising water table:* From the detailed spatial assessment within the situational assessment, this does not seem to be a significant concern for the tidal reaches of the Manning.

Increase flooding of low lying roads and other transport corridors *due to sea level rise***:** As examined by OEH (2018), there are notable lengths of road that would be inundated by tides with sea level rise of as little as 0.5m, but these are largely skewed towards local roads and "tracks". Generally these roads are probably already impacted by floods which occur more frequently that once every five years or so (BMT WBM, 2016)[55]. However, tidal inundation will have a different nature (occurring reasonably regularly, under king tides, several times per year for periods of a couple of hours under 'sunny day' conditions) as opposed to extreme catchment flood inundation which inundates for longer periods but is less frequent. Similarly, high tides combined with storm surge under a sea level rise scenario will have a greater impact as sea levels increase.

Increased pollution and silting of waterways *due to storms and flooding*: Resulting from increased runoff during extreme events, particularly in urban areas and in relation to runoff from roads and the overwhelming of wastewater systems. To address this, the Plan noted that council was requiring WSUD in developments, controlling location of development in proximity to waterways, controlling septic system siting and design. Legislation controlling pollution includes the *Water Management Act, 2000* and the POEO Act, 1997 and other related environmental planning legislation. The Plan noted that the planning and management frameworks seemed sound, but that climate change was

[55] Consider Maps A1 through A5, against Maps T1 through T5 of that report.

sometimes neglected. Furthermore, a water quality monitoring strategy was recommended to be implemented at a regional level. A management strategy for septic systems was also recommended.

Several of the risk / recommendations arising from the Plan have been addressed, particularly those relating to better flood information and the incorporation of sea level rise and climate change effects into flood estimates as presented above. This has been largely driven by guidance at the state and federal level. Other actions will be carried forward into the Manning CMP.

3.3.2 MidCoast Council Climate Change Strategy: Phase 1- 2020 (Draft)

The report (MidCoast Council, 2020) includes discussion of the overriding policy and strategy, and a framework for emissions mitigation targets. As noted above, however, mitigation is not the focus of the CMP. The report contains a Resilience and Adaptation Plan with the following relevant "High" ranked risks and associated relevant management actions. The original risk assessment upon which the strategy is based was completed for MidCoast Council by Statewide Mutual (2020).

R001 Changes in annual rainfall may change ecosystems including the loss of tree, plant and animal species: The strategy proposed that short-term actions include studies and plans such as preparing a greening strategy, adopting a Biodiversity Framework and development of Catchment Management Plans (i.e., this CMP). A medium-term action was the creation of corridors, refugia and pathways.

R003 Changes in annual rainfall may change environmental flows and negatively impact on water-dependent ecosystems: Herein, current controls including projects with DPI-Fisheries and the cease-to-pump controls for drought conditions were to be continued in the short term.

R004 Changes in the average rainfall level may increase the competitiveness of weed and pest species, resulting in the outcompeting and loss of species and a higher demand to manage the impact: Existing controls and participation in a regional weed committee were put forward as actions and this could be carried forward into the Manning CMP.

F007 & F008 Increased FFDI days will increase water pollution due to sediment and fire debris entering waterways. It was argued that riparian revegetation programs and ongoing work with private landholders could assist. The CMP is a suitable avenue for pursuing related actions.

SLR003 Increasing sea level causing loss/damage to adjoining infrastructure and assets, straining Council's ability to provide services. The Plan suggested that critical assets should be identified as part of an asset management plan and that future construction should meet appropriate flood level requirements (presumably incorporating sea level rise).

SLR001 Sea level causing loss/changes to key ecosystems such as wetlands, salt marsh and littoral rainforest. The plan included mapping coastal wetland and littoral rainforest (now completed) the implementation of a Coastal Management Program (this CMP) and identifying areas for retreat of wetlands and rainforest. We note that retreat options for littoral rainforest may be limited. The assessment of retreat is currently subject to research by the state government and Universities.

SLR004 Increasing sea level causing changes to public and private land due to erosion, re-alignment of shores due to flooding and the salinisation of land. The plan included, in addition to existing planning controls, the development of a Policy providing clear direction as to how sea level

rise should be considered during development assessment and the possible need to plan for relocation in the long term.

SLR005 Increasing sea level negatively impacting water quality due to salinisation and the inundation of coastal freshwaters. The Plan suggested that research into this matter could be undertaken.

SLR009 Increasing sea level increases failure of OSSM within low lying areas with resultant pollution impacts. The plan recommended finalisation and implementation of the assessment framework for onsite wastewater and to consider capping development within areas that are likely to be affected in future or strategic planning to reticulate presently unsewered areas. This action will be carried forward into the Manning CMP.

RI003 An increase in extreme rainfall events may cause increased rates of erosion resulting in surface and stormwater pollution. Actions here are of relevance to the CMP including development of a riverbank management plan, catchment controls, addressing sediment and erosion controls and signing an MOU with LLS (already completed).

RI005 An increase in extreme rainfall events may impact water quality via surface and stormwater pollution and sewer overflows. Relevant controls included replication of those for RI003 and the development of a Catchment Program (this CMP).

RI016 An increase in extreme rainfall events may result in pathogens entering waterways and closing aquaculture area. The actions identified largely comprised compliance actions such as more reactive response to complaints and Prevention and Clean-up Notices.

T006 Increased Average Temperature may increase algal blooms and other water quality problems. Actions included an Algal Management Plan, and future development of WSUD guidelines, the monitoring of water quality the inclusion of WSUD in capital works and management of the riparian zone. Furthermore, community education and an update to urban stormwater management plans was recommended.

While the Climate Change Strategy is on exhibition at the time of writing (February - Early March 2020) intends to integrate the strategy across its organisation and operations and will consider climate change impacts upon the management of Council's Assets. Council is proposing to develop a sustainability framework which will be delivered through the Integrated Planning and Reporting Framework applied by Council. An interdepartmental sustainability team within council is to be established alongside a new staff position to drive organisational change in sustainability initiatives.

3.3.3 Manning River Floodplain Risk Management Study and Plan (Draft)

Road raising management actions, to address the effects of frequent inundation, were assessed as part of this floodplain risk management study (BMT WBM, 2019). The assessed locations were:

- Pacific Highway.
- Harrington Road.
- Manning Point Road.
- Croki Road / Barton St.

In all cases, the draft study indicated very low cost-benefit ratios (0.05 or less) for these road raising initiatives. However, those ratios did not include a range of intangible flood damages. An additional "Rapid Analysis" was completed by BMT WBM. This indicated that the raising of Harrington Road was one of the better performing options in a qualitative sense. The other three road raising options did not score as well. Road raising options did not perform as well as "Planning and Development Controls", "Flood Planning Levels", "Update to Local Flood Plan" or "Ongoing Community Education and Awareness".

Importantly, the extreme flood related reasons for road modifications considered by BMT WBM vary from those which may result from sea level rise. Within coastal floodplains, a rise in mean sea level in the ocean will be reflected by a rise in the groundwater elevation. Once that groundwater level reaches into the sub-base of road pavements, rapid deterioration may onset, with the road surface condition degrading as a result. One way of addressing this is to reconstruct the pavement and to stabilise it in a way which makes it resilient to higher groundwater levels.

Eventually, roads will need to be raised, to remain suitably functional. Based on experience, an often-applied rule of thumb is that this would happen once they begin to be inundated by King Tides (i.e., several times per year). However, waiting this long to raise roads that are critical for evacuation during an extreme flood would be inappropriate.

An optimal balance needs to be found to determine when and where different roads might need to be managed. Raising and/or reconstruction to address the impact of severe flooding and/or rising sea levels should be coordinated to avoid potential maladaptation. For example, it may make sense to rebuild and stabilise the entire pavement depth at the same time a road is raised. During a workshop held on 10 March 2021, it was highlighted that improvements to roads across the floodplain could take advantage of the opportunity to improve cross drainage such that tidal inundation of the floodplain is enhanced or encouraged (as appropriate).

3.3.4 Integration of Sea Level Rise into Asset Management

Based on discussions during a workshop held on 10 March 2021, the study team understand the following:

- At present, the potential impact of sea level rise on MCC asset maintenance and management is not yet considered organisation wide.
- As part of ongoing migration across to the MC1 Enterprise System being rolled out by the Council, it is envisaged that sea level rise will start to be considered across MCC's operations.

3.3.5 Lower Manning Drainage Remediation Action Plan (2016)

The Remediation Action Plan (RAP, Glamore et al., 2016) assessed that three of the floodplain subcatchments to the Lower Manning represented 80% of the overall acid sulfate soil risk. Separate action plans were derived for these three sites, but it was acknowledging that detailed consultation and engineering design were required to ensure effective implementation of the recommendations. The three highest priority sites were:

- Moto: Comprising the area north west of Moto, and to the west of the Lansdowne River and Ghinni Ghinni Creek, approximately 3,500 ha with most of that below 1.0m AHD.
- Ghinni Ghinni: comprising the floodplain north and west of Ghinni Ghinni, North of the Manning River and east of Cundletown, approximately 2500 ha with a significant portion below 1.0m AHD. The floodplain is split into northern and southern parts by Dickensons Creek.
- Big Swamp: Comprising the area around Pipeclay Canal, which flows into the northern reaches of Cattai Creek – A tributary which runs into the Manning River to the west of Harrington. The floodplain covers some 4400 ha, with significant areas < 1.0m AHD adjacent to Pipeclay Canal. This site has been subject to ongoing efforts for the purchase and rehabilitation of degraded farmland in recent years.

These floodplains are further divided into sub-drainage areas which are also prioritised and cost estimates for rehabilitation are provided.

The RAP is presently being updated by the University of New South Wales on behalf of the Department of Primary Industries. The revision will incorporate more information on blackwater events and the impacts of sea level rise alongside more detailed action plans and budgets for high priority areas. The revised document is to be released by mid-2021.

3.4 Knowledge Gaps

Climate change by its nature is uncertain and knowledge gaps will remain as the future unfolds. However, key issues have been identified for attention as follows:

- Representative regional climate change parameters based on the latest NARCliM modelling (v 1.5, completed 2020).
- Lack of carry through of climate change projections into water sharing plans and cease to pump rules.
- Current salinity distribution patterns throughout estuary and what amount of sea level rise would result in tidal influence upstream of the current tidal limit.
- Current and future impacts of climate change on hydrology.
- A conceptual understanding of the scale of risks arising from climate change and those that pre-exist due to historical changes in the catchment to enable efficient targeting of funds.
- A conceptual understanding of the scale of risks relating to changes in the upper catchment when compared to the apparently severe issue of acid drainage in the vicinity of the estuary to enable efficient targeting of funds.
- Characterisation of the different processes and relative importance of tidal (with sea level rise) and flood inundation processes to enable better planning, for example, in the maintenance of roads.

- An understanding of the expected change of species behaviour due to climate change.
- Effect of acidification on shellfish.
- Likely impact of temperature change on the distribution of seagrasses.
- Distribution and vulnerability of floodplain rainforests to increased erosion due to sea level rise.
- While tide range inside at least the lower reaches of the River will almost certainly increase, resulting in more frequent inundation of low-lying areas, the scenario has not yet been modelled in significant detail. Quantification of the way in which any postulated entrance training works will have on tidal inundation and the distribution of salinity throughout the estuary and particularly its interaction with sea level rise.
- Extent of overtopping and inundation exposure of levees, including sea level rise.
- A lack of management options for a sea level rise scenario – at what point do existing management approaches begin to fail / overwhelm capacity to implement.
- Uncertainty regarding the interaction of sea-level rise and flood impacts over time. No tidal inundation (coastal vulnerability) information is available.
- What areas will ultimately change from pasture to coastal wetlands as use for grazing becomes infeasible under a sea level rise scenario.
- How far will existing coastal wetlands expand (or contract) considering adaptation pathways across the landscape. A comprehensive study and prioritisation, including landward retreat analyses, are required.
- Interaction between the two entrances under a sea level rise scenario.
- Quantification of the expected increased export of sediment and nutrients from the catchment under a drying climate with more intense infrequent events.

3.5 What's working, what's not?

3.5.1 What's working.

- Ongoing Actions on coastal floodplain remediation, particularly the Cattai Wetland and Big Swamp restoration works.
- Strong, ongoing locally targeted research involvement in the estuary, including consideration of climate change impacts supported by both local and state governments.
- MCC is upgrading their Integrated Water Cycle Management Strategy to consider climate change (overall catchment drying).
- A formal, cross-Council water resilience team was established during the 2019 drought. The capacity gained here can be used to better plan for climate change, considering the expected increased frequency of drought.

- The main settlements within the geographical scope of the CMP (Taree and Wingham) are mostly elevated enough to avoid severe impacts of sea-level rise (e.g., "sunny day" inundation due to tides) over the coming century.
- Based on climate change projections, impacts are expected to remain largely within the bounds of historical variability over the next couple of decades. This means that assets and ecological systems with some inbuilt resilience will tend to remain robust. Accordingly, there is still time to conduct more research and to plan for effective adaptation.
- Over the medium term (say to 2040) different projections are very similar, meaning that we are reasonably certain of appropriate values to plan for.
- Useful national level guidance is now provided for extreme rainfall impacts via the 2019 release of Australian Rainfall and Runoff.

3.5.2 What's not working?

- Efforts to reduce the rate at which greenhouse gases are being emitted do not seem to be having a noticeable effect. This means that, over the long term, we may be headed to 2.0 ^{o}C of warming or more, substantially more than the current aspirational goal of 1.5 ^{o}C. This means that adaptation will be required to manage the catchment, estuaries and wetlands.
- Translation of uncertain projections of climate change impacts into flexible and 'agile' adaptation management actions has not yet occurred. This should happen to enable timely adaptive actions, when required, in future.
- Apparent lack of coordination of activities between state scale (e.g., State Govt. through MEMA) and local scale research activities. A general need for better coordination of research and to ensure that targeted research meets the needs of future adaptation planning at the local scale.
- There is no accepted method for deriving "Coastal Vulnerability Area" extents for the "tidal inundation" coastal hazard under the *Coastal Management Act 2016*. There is significant overlap between tidal inundation flooding and the risks addressed by the floodplain risk management process in NSW. The potential for confusion and overlap between that process and coastal vulnerability areas is an issue.
- Need to integrate sea level rise planning into asset management programs.
- A recently released report into options for training the Manning River Entrance (Manning River Taskforce, 2020) does not refer to the impact that a larger tidal range inside a trained entrance will have in inundating wetland areas, particularly when combined with future sea level rise.
- Sea level rise will increasingly flood wetlands and saltmarsh.
- Where infrastructure and/or ecological systems have limited resilience, the increasing severity of extreme events will continue to have a deleterious effect.

- A lack of ongoing federal guidance relating to adaptation, following defunding of the National Climate Change Adaptation Research Facility in recent years.
- Ranges of uncertainty over long time frames (60 years or more) become very wide and projections begin to diverge markedly. This makes planning for these longer time frames difficult.
- It is difficult for planning to keep up with the changing understanding as new research is completed. It is difficult to plan and approve development in affected areas when guidance needs to be regularly updated.

3.6 Risk Assessment

During a workshop on climate change issues held on 10 March 2021, a list of risks associated with climate change that could be managed within the scope of the CMP. Based on an initial list provided by the Salients study team, the risks were refined. Subsequently an assessment was completed to identify those risks for which management options could be identified. The risk assessment was completed by the Salients study team and the full tabulated risk assessment process is presented in Attachment 1 and is based on a pro-forma spreadsheet provided to the study team by MCC. A summary is presented in Table 5.

Considering the degree of future uncertainty and the future period over which the CMP could be applied, a 20-year time frame has typically been adopted for assessing most risks. In assessing likelihood, a general rule of thumb was that, over a 20-year time frame, postulated changes to extreme event behaviour were given a likelihood score of 2 (unlikely), but more chronic changes (sea levels rising, temperatures increasing) were given a likelihood score of 3. The scale of change associated with that likelihood is based on the situation analyses presented in Section 1.1. Consequences have been assessed based on the study team's understanding of the physical constraints and processes which act within the estuary and the catchment. Only High and "Extreme" risks have been presented in Table 5.

Table 5 Outcomes of Climate Change Risk Assessment for CMP – High and Extreme Risks

Risk (over 20 yr Timeframe)	Impact (Social, Environmental, Economic)	Risk Level
CC2: Due to sea level rise, coastal groundwater levels rise causing low lying roads to fail	Economic	**High**
CC3: Ongoing sea level rise will encourage coastal wetlands to migrate upslope and onto adjacent often private land, eventually resulting in wetlands being "squeezed"	Environmental	**High**

Risk (over 20 yr Timeframe)	Impact (Social, Environmental, Economic)	Risk Level
CC6: Possibility that salt dynamics change and that a salt wedge combined with greater tidal penetration begin to effect potable water offtake upstream of current tidal limit. Quite unlikely over 20 yr timeframe, but impacts would be severe (e.g., trucking water into several towns)	Economic	**High**
CC13: Impact of higher tide levels and interaction with adjacent groundwater drainage on Acid floodplains is poorly understood. Impact of acid drainage events could be very bad for the environment.	Environment	**High**
CC16 – The potential for unknown weeds or existing weeds from other regions to get a foothold in the Manning Catchment could potentially have a devastating impact on parts of the catchment and productivity of agriculture.	Environmental/Economic	**High**
CC21 – Changes to Environmental Flows due to a drying climate may significantly alter runoff from acid drainage areas	Environmental	**High**
CC22 – Potential loss of subtidal habitats due to changes in environmental water quality (pH, salinity, temp, flows) with flow on effects to the productivity of fisheries.	Environmental, Economic.	**High**
Risk (50-100 yr Timeframe)	**Impact (Social, Environmental, Economic)**	**Risk Level**
CC19 – Over the long term, failure of the present generation to appropriately understand and plan for the impacts of climate change could have unknown, widespread and damaging impacts to future generations. Work is progressing to properly understand and manage the risks, but this must continue.	Social, Environmental and Economic	**High**
CC20 – Over Long term, significant or complete loss of saltmarsh/wetland habitat due to sea level rise would represent a local ecologically disaster and a failure of one of the cornerstone objectives of the CM Act.	Environmental and Economic	**Extreme**

Table 5 demonstrates that there is still time to plan, but failure to plan effectively could easily place an unfair burden on future generations.

3.7 Management Options

A range of Management Options relating to climate change were provided to the Salients study team at commencement of the project. These management options were assessed by the study team considering the summaries provided in this Issues paper and the completed risk assessment. That assessment is presented in Attachment 2. The resulting short list of management options to be carried forwards for assessment and are presented in Table 6. Comparing Table 7 and Table 6, Risk CC16 which deals with pests and weeds is not addressed. This action is instead covered by Action 7.02 which is to be carried forwards to the CMP.

Table 6 Short Listed Management Options for CMP Stage 3 Assessment

Description	Related Risk
Undertake event-based tidal gauging study at multiple locations examining flows, salinity and updated bathymetry to develop a reliable catchment and hydrodynamic baseline model for all future research and planning.	CC6, CC21, CC22
Establish a platform for integrated monitoring and data sharing.	CC19, CC22
Undertake Hydrological modelling of catchment to identify opportunities to influence water storage, water cycling, drought resilience, buffering, restoring the landscape.	CC21
Work collaboratively with landholders and other stakeholders to develop an adaptation plan to mitigate the risk of climate change impacts on the floodplain, including management of Acid Sulfate Soil and blackwater events.	CC13, CC21
Complete the MCC Climate Change Adaptation Framework to manage climate risks on Council infrastructure assets such as roads, stormwater systems, and river access facilities.	CC2
Ensure Council floodgate maintenance and replacement is included in MCC's asset maintenance system.	CC2, CC21
Complete modelling to identify retreat buffer zones to retain coastal wetland ecosystem services and littoral rainforest under sea-level rise scenarios.	CC3, CC20

3.8 References

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Attachment 1: CMP Climate Change Risk Assessment.

Risk #	Threat	Description	Causes/Stressors	Economic	Social	Environmental	Values impacted	Inherent Consequence Rating (1-5)	Inherent Likelihood Rating (1-5)	Risk Value	INHERENT RISK RATING	Existing key controls	Control effectiveness	Residual Consequence Rating (1-5)	Residual Likelihood Rating (1-5)	Risk Value1	RESIDUAL RISK RATING
#	What is the threatening Process	What are the consequences of the risk occurring?	How could the risk to occur?	*Risks that have a financial impact*	*Risks that impact the safety and wellbeing of staff and the community*	*Risks that impact the natural environment*		Rate the highest risk consequence - before controls are in place: 1 = Insignificant 2 = Minor 3 = Moderate 4 = Major 5 = Catastrophic	Rate the risk likelihood - before controls are in place: 1 = Rare 2 = Unlikely 3 = Possible 4 = Likely 5 = Almost Certain	Will be automatically calculated	**Extreme High Medium Low**	List processes, systems, plans, etc. currently in place to reduce the risk. Type one control per row (insert rows as required)	1. Using the attached Risk Assessment Criteria, select from the drop down list how effective the existing controls are (on a whole) at reducing the risk. 2. Re-rate the risk in the next columns with consideration of control effectiveness	Re-rate the highest risk consequence - after controls are in place: 1 = Insignificant 2 = Minor 3 = Moderate 4 = Major 5 = Catastrophic	Re-rate the risk likelihood - after controls are in place: 1 = Rare 2 = Unlikely 3 = Possible 4 = Likely 5 = Almost Certain	Will be automatically calculated	**Do not type in this field. The risk rating will automatically calculate**
CC1	Higher Mean Sea Levels (20 yr Timeframe)	Impedes effective drainage at stormwater outlets	Warming climate due to greenhouse gases			TRUE	**Environment**	2	3	6	Medium	N/A					
					TRUE		**Social**	2	3	6	Medium						
				TRUE			**Economic**	1	3	3	Low						
CC2	Higher Mean Sea Levels (20 yr Timeframe)	Failure of roads (moisture in sub-base as coastal groundwater levels rise + More frequent overtopping inundation	Warming climate due to greenhouse gases			TRUE	**Environment**	1	3	3	Low	Work is being undertaken to raise some roads in response to Floodplain Risk Management Plan, However, nature of damage from sea level rise is different than extreme flooding. Some roads may be being missed.					
					TRUE		**Social**	3	3	9	Medium						
				TRUE			**Economic**	4	3	12	High		Partly Effective	4	3	12	High
CC3	Higher Mean Sea Levels (20 yr Timeframe)	Migration of coastal wetlands & conflicts with land use. Also, impacts on low lying rainforest	Warming climate due to greenhouse gases			TRUE	**Environment**	4	3	12	High	Land Acquisition relating to rehabilitation for Acid Sulfate Soils presently being carried out, but not specifically targeting all low land adjacent to wetlands. May become a substantially bigger problem quite quickly.	Partly Effective	4	3	12	High
					TRUE		**Social**	3	3	9	Medium						
				TRUE			**Economic**	3	3	9	Medium						
CC4	More Intense Extreme Rainfall (20 yr Timeframe)	Capacity of stormwater drainage infrastructure exceeded	Warming climate due to greenhouse gases			TRUE	**Environment**	2	2	4	Low						
					TRUE		**Social**	3	2	6	Medium	N/A					
				TRUE			**Economic**	3	2	6	Medium						
CC5	More Intense Extreme Rainfall (20 yr timeframe)	Sewer pumping stations fail	Warming climate due to greenhouse gases			TRUE	**Environment**	3	2	6	Medium						
					TRUE		**Social**	2	2	4	Low	N/A					
				TRUE			**Economic**	2	2	4	Low						
CC6	A more pronounced salt wedge during extended droughts including higher sea levels (20 yr timeframe)	Starts to affect viability of potable water extraction locations	Warming climate due to greenhouse gases			TRUE	**Environment**	3	2	6	Medium						
					TRUE		**Social**	1	2	2	Low	None. Only limited monitoring of salinity in the Manning River					
				TRUE			**Economic**	5	2	10	High		Ineffective	5	2	10	High
CC7	Changing rainfall: Prolonged drought followed by rainy period	Shifting soils cause sewerage infrastructure to break (incl. impact on aquaculture closures)	Warming climate due to greenhouse gases			TRUE	**Environment**	3	2	6	Medium						
					TRUE		**Social**	3	2	6	Medium	N/A					
				TRUE			**Economic**	3	2	6	Medium						
CC8	Increased temperature (both air and water) + reduced inflows from catchment	Impact on species and ecosystems	Warming climate due to greenhouse gases			TRUE	**Environment**	3	3	9	Medium						
					TRUE		**Social**	2	3	6	Medium	N/A					
				TRUE			**Economic**	1	3	3	Low						
CC9	Increased extreme event intensity (20 yr Timeframe)	Increases in diffuse source runoff = more erosion and sedimentation	Warming climate due to greenhouse gases			TRUE	**Environment**	3	2	6	Medium						
					TRUE		**Social**	2	2	4	Low	N/A					
				TRUE			**Economic**	2	2	4	Low						
CC10	Storm surge occurring on top of sea level rise	Breaching of levees and inundation of farm land	Warming climate due to greenhouse gases			TRUE	**Environment**	1	2	2	Low						
					TRUE		**Social**	3	2	6	Medium	N/A					
				TRUE			**Economic**	3	2	6	Medium						
CC11	Increasing elevation of low tides	Reduced Drainage capacity of farmland	Warming climate due to greenhouse gases			TRUE	**Environment**	1	3	3	Low						
					TRUE		**Social**	2	3	6	Medium	N/A					
				TRUE			**Economic**	3	3	9	Medium						
CC12	Increased fire frequency including peat fires (~ Crowdy Bay)	Potential increase in sediment runoff of products of fire (e.g. Ash).	Warming climate due to greenhouse gases			TRUE	**Environment**	2	3	6	Medium						
					TRUE		**Social**	3	3	9	Medium	N/A					
				TRUE			**Economic**	3	3	9	Medium						
CC13	Changes to groundwater dynamics as a result of sea level rise (20 yr time frame)	Unknown impacts on acid generation	Warming climate due to greenhouse gases			TRUE	**Environment**	4	3	12	High	Poorly understood issue, needs research to properly ascertain potential impacts and to target actions, probably sooner rather than later.	Ineffective	4	3	12	High
					TRUE		**Social**	3	3	9	Medium						
				TRUE			**Economic**	3	3	9	Medium						
CC14	Drying Climate (20 yr Timeframe)	Dry catchment more susceptible to erosion and potential change in vegetation coverage, ecosystems	Warming climate due to greenhouse gases			TRUE	**Environment**	4	2	8	Medium						
					TRUE		**Social**	2	2	4	Low	N/A					
				TRUE			**Economic**	2	2	4	Low						
CC15	Drying Climate (20 yr Timeframe)	Change to environmental flows negatively impacting water-dependent ecosystems.	Warming climate due to greenhouse gases			TRUE	**Environment**	4	2	8	Medium						
					TRUE		**Social**	1	2	2	Low	N/A					
				TRUE			**Economic**	1	2	2	Low						
CC16	Changing Climate (20 yr Timeframe)	Increases capability of pest and weed species to outcompete desirable species	Warming climate due to greenhouse gases			TRUE	**Environment**	4	3	12	High	There are regional agreements which extend beyond the catchment boundaries which may need to be strengthened to get better protection.	Partially Effective	4	3	12	High
					TRUE		**Social**	3	3	9	Medium						
				TRUE			**Economic**	4	3	12	High		Partially Effective	4	3	12	High
CC17	Increasing Sea Level (20yr Timeframe)	More frequent failure of OSSM with resultant impacts	Warming climate due to greenhouse gases			TRUE	**Environment**	3	3	9	Medium						
					TRUE		**Social**	2	3	6	Medium	N/A					
				TRUE			**Economic**	3	3	9	Medium						
CC18	Increasing Temperature of water (20 yr Timeframe)	Greater potential for algal blooms and other water quality problems.	Warming climate due to greenhouse gases			TRUE	**Environment**	3	2	6	Medium						
					TRUE		**Social**	2	2	4	Low	N/A					
				TRUE			**Economic**	4	2	8	Medium						
CC19	Failure to account for long term impacts of climate change (50-100 years)	Potential maladaptation and restriction of future flexibility in addressing risks.	Warming climate due to greenhouse gases			TRUE	**Environment**	5	3	15	High		Future Effectiveness Uncertain	5	3	15	High
					TRUE		**Social**	5	3	15	High	Overarching and important long term	Future Effectiveness Uncertain	5	3	15	High
				TRUE			**Economic**	5	3	15	High		Future Effectiveness Uncertain	5	3	15	High
CC20	Increased sea level	Loss of saltmarsh/wetland habitat	Warming climate due to greenhouse gases			TRUE	**Environment**	5	4	20	Extreme	Limited current controls for Loss of habitat that supports ecosystem productivity. Saltmarsh is disproportionately important for the food web. Loss of surport for recerational and commercial fisheries	Ineffective	5	4	20	Extreme
					TRUE		**Social**	2	4	8	Medium						
				TRUE			**Economic**	4	4	16	High		Ineffective	4	4	16	High
CC21	Drying Climate (20 yr Timeframe)	Change to environmental flows negatively impacting water-dependent ecosystems.	Warming climate due to greenhouse gases			TRUE	**Environment**	4	3	12	High	Links between run-off and pH/aluminium/acid sulfate soils understood. Effects due to altered environmental flows not known	Uncertain	4	3	12	High
					TRUE		**Social**	1	3	3	Low						
				TRUE			**Economic**	3	3	9	Medium						
CC22	Changing Climate (20 yr Timeframe)	Loss of subtidal habitats due to changes in environmental parameters (pH, salinity, temp, [illegible])	Warming climate due to greenhouse gases			TRUE	**Environment**	4	3	12	High	No data exists on how seagrasses or oyster reefs will respond to a changing climate	Partially Effective	4	3	12	High
					TRUE		**Social**	3	3	9	Medium						
				TRUE			**Economic**	4	3	12	High		Partially Effective	4	3	12	High

Attachment 2: Climate Change Management Options: Preliminary Filtering

Session Number	Action No.	Description	Notes	Risk ID
3.2	1.21	Undertake event-based tidal gauging study at multiple locations examining flows, salinity and updated bathymetry to develop a reliable catchment and hydrodynamic baseline model for all future research and planning..	To be included as a priority in research program. A tidal gauging exercise was undertaken on 3rd November 1998, however limited information is readily available from Manly Hydraulics Laboratory and the report (MHL 1988) will need to be chased to confirm the full extent of investigations. However, the data collection exercise seems to have been limited to November 1998. A corresponding hydrosurvey was completed by the Department of Land and Water Conservation in 1999. It is likely that any salinity data collected was limited and a longer time series of data will need to be captured, including variations with depth to pick up saline and temperature stratification appropriately and to better understand salt wedge dynamics. A new tidal gauging exercise is recommended, at the same time as new hydrosurvey with multiple recorders deployed to measure conductivity, temperature and depth over a much longer deployment. The intention here is to establish the dynamics of salt wedge dynamics such that and appropriate three dimensional numerical hydrodynamic model can be developed for the River system. It is important to have a model which can investigate how these dynamics may change over time with higher sea levels, training walls and/or changed entrance conditions. It is possible that salt may begin to affect the offtake upstream of the present tidal limit. As part of this field exercise, the features which presently present a limit to tides should also be investigated and surveyed.	CC6, CC21, CC22
3.2	1.22	Establish a platform for integrated monitoring and data sharing.	It is important that data be freely available such that results from research and ongoing monitoring activities are readily available for the purpose of transparency and to facility honest and well informed decision making. A web enabled interface containing all public domain scientific data of interest to managing the estuary should be made available. This may include model simulation results files, field data collection, ongoing records from permanently installed instruments. Over time, historical data should be digitised and made available through the same platform. Open standards should be used and access should not be restricted to the data provided on this platform. The proposed platform will prove invaluable to the research needed to inform future management of the catchment and estuary under a sea level rise scenario.	CC19, CC22
3.2	1.23	Undertake Hydrological modelling of catchment to identify opportunities to influence water storage, water cycling, drought resilience, buffering, restoring the landscape.	Alternative Mechanism: It seems likely that this would be much better managed by the Water Resilience Team within Council through their integrated water cycle management plan. Understanding impacts on estuarine ecology from changes to inflows may benefit from this modelling.	CC21
3.2	2.01	Work collaboratively with landholders and other stakeholders to develop an adaptation plan to mitigate the risk of climate change impacts on the floodplain, including management of Acid Sulfate Soil and blackwater events.	Amalgamated into Actions 1.05 (Setting the example) and 1.08B (assisting with best practice management). There are also overlaps with 1.01. Those other actions deal with ASS and blackwater issues that are already present. However, more research and forward planning as part of the research program will help to inform future actions made necessary by ongoing sea level rise	CC13, CC21
3.2	2.02	Complete the MCC Climate Change Adaptation Framework to manage climate risks on Council infrastructure assets such as roads, stormwater systems, and river access facilities.	At the time of writing, the Climate Change Adaptation Strategy was on exhibition. The critical first action in the strategy relating to infrastructure and sea level rise is to identify critically impacted assets as part of the Asset Management Plan. This action should be carried forwards by the CMP. A study should: -Using sea level rise inundation layers (and potentially additional inundation modelling at lower levels of sea level rise, using the existing flood model) presently available to Council identify assets threatened at imminent, medium term and long term time frames. - A database showing critical elevations, existing asset condition should be developed to inform the Asset Management Plan. -Develop appropriate standards for the upgrade or replacement of assets, including preliminary cost estimates for assets needing work over the next 10 years. -Integrate forward financing of the replacement or upgrading of the assets to standard within Council's Asset Management Plan. These actions should cover roads, stormwater and river access systems and should consider whether assets would need to be replaced due to extreme flood risk regardless.	CC2
3.2	2.03	Address SLR threats to stormwater infrastructure through adaptation planning by asset managers.	Amalgamated with 2.02	
3.2	2.04	Identify Sea Level Rise thresholds at which existing coastal inundation emergency strategies will cease to be effective. Develop adaptation and mitigation strategies.	Amalgamated with 2.05	
3.2	2.05	Engage with the State Emergency Service to build capacity for long-term emergency plans responsive to climate change impacts.	Yes, this seems an appropriate action. Note, however, that this action does not address any of the "High" risks identified relating to climate change. However, it should probably be carried out as a matter of course because it is a "no regrets" type of action. Generally, emergency management considers extreme events and (if disaster planning is robust) is inherently able to manage conditions which are out of the ordinary. Long term planning is typically lower on the hierarchy of the concerns of the SES than immediate emergency events and their recovery. However, there is some value in prompting a discussion about future emergency planning. Most commonly, the actions of the SES are managed via Flood Plans prepared in parallel, and informed by, the floodplain risk management process in NSW. Similarly, open coast erosion will be informed by an emergency management sub plan which would be prepared as part of an Open Coast CMP which deals with the coastal vulnerability area. The existing Greater Taree City Flood Emergency Sub Plan (which also deals with coastal erosion) says: *The NSW SES Greater Taree City Local Controller will ensure that:* *a. NSW SES participates in local floodplain and coastal risk management committee activities when those committees are formed, in accordance with the protocols outlined in the NSW SES Controllers Guide.* *b. The NSW SES Mid North Coast Region Headquarters is informed of involvement in floodplain and coastal risk management activities.* It is recommended that the SES Local Controller be asked to a meeting of the Coastal / Estuary Management Committee to seek their advice on what is required regarding disaster planning and sea level rise.	
3.2	2.06	Build community awareness, understanding and preparedness for climate change impacts on flooding and inundation, fire, drought, and water availability consistent with Adapt NSW guidelines.	Alternative Mechanism: The Climate Change strategy has a number of climate change related education activities and these should be rolled into that initiative, potentially seeking funding through the Community Resilience Innovation Program. However, the CMP should support this process - for example, it would be useful to have the SES involved in this effort & for Action 2.05 to have been implemented alongside the actions in the CC Strategy.	
3.2	2.07	Ensure Council floodgate maintenance and replacement is included in MCC's asset maintenance system.	Action should be: 'Review the recommendations of the Remediation Action Plan regarding the upgrade and replacement of floodgates within the Lower Manning Floodplain and ensure that these are incorporated into MCC's asset maintenance plan.	CC2, CC21
3.2	2.08	Complete modelling to identify retreat buffer zones to retain coastal wetland ecosystem services and littoral rainforest under sea-level rise scenarios.	Action should be: Cultivate awareness of, and ensure that forward planning of activities to protect and allow for the migration of coastal wetlands and littoral rainforests is cognisant of, ongoing research such as that being carried out by the University of New South Wales, DPI-Fisheries and DPIE-EES.	CC3, CC20

4. Coastal Wetlands Loss and Degradation

Coastal wetlands are amongst the most productive ecosystems in the world. They form one of the four coastal management areas under NSW's *Coastal Management Act* 2016 and are protected under the *State Environmental Planning Policy (Coastal Management) 2018*[56], which aims to protect coastal wetlands in the environmental and economic interests of NSW. This issue analysis paper provides an overview of coastal wetlands in the estuary, key stressors, impacts and management options. Related issue papers for the CMP include Floodplain Drainage Management (which addresses Acid Sulfate Soils in more detail), and Wildlife Conservation (including shorebirds).

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4.1 Situation Analysis

Coastal wetlands in the Manning Estuary

The Manning Estuary has significant areas of coastal wetlands including:

- Large areas of mangrove forest and brackish wetlands in areas like Cattai and Big Swamp;
- Open freshwater lagoons and wet heaths in Crowdy Bay National Park;
- Forested wetlands characterised by swamp mahogany, broadleaved paperbark and swamp oak[57];
- Estuarine and near-shore marine systems made up of coastal mangroves, salt marshes and sea-grass beds which rely on the submarine discharge of groundwater[58];
- Crowdy Lagoon, which is classified as a high priority Groundwater Dependent Ecosystem (GDE)[59].

[56] (NSW Government, 2018)
[57] (MidCoast Council, 2020)
[58] (Geosciences Australia, undated)
[59] (NSW Government - Office of Water, 2009)

Mapping and description of coastal wetlands in the Manning was undertaken by consultants in 2019[60]. The data will form the basis for management planning and a proposal to amend the Coastal Management SEPP, as identified in the CMP Scoping Study[61].

The fine scale imagery and 3D mapping in the study allowed for the identification of wetlands across the landscape based on landscape position, signature and structure. Three broad condition states were allocated based on field validation and API:

- Poor/Very Poor – high level of disturbance including weeds, small patch sizes or under scrubbing;
- Fair – moderate level of disturbance including weeds, historical clearing/regeneration and land use;
- Good/Excellent – limited disturbance, vegetation in good condition.

The study mapped thirteen wetland types totalling 8,906 hectares across three vegetation formations and six vegetation classes. Wetlands were generally mapped in good/excellent condition (69%), whilst wetlands in fair condition accounted for 19% of the total area mapped and poor/very poor condition equated to 12%. The majority (86%) of all wetland types mapped are protected under State or Commonwealth legislation.

The majority of the remnant vegetation on Manning floodplain wetlands was mapped as Swamp Oak, with fringing Grey Mangrove and Saltmarsh remnants. Large areas of saltmarsh were mapped in close proximity to Swamp Oak remnants, however many of these patches are likely to be Swamp Oak derived, and therefore of much lower condition as they have been structurally modified.

While coastal wetlands in the Manning have been variously disturbed and modified, wetlands of considerable conservation significance still occur[62]. These include:

- Big Swamp and Cattai Wetlands
- Coopernook wetlands
- Dawson wetlands
- Crowdy Lagoon and Harrington Lagoon
- Large wetlands at Kundle Kundle and Manning Point
- Seagrass meadows.

[60] (Eco Logical Australia Pty Ltd, 2019)
[61] (MidCoast Council, 2020)
[62] (Eco Logical Australia Pty Ltd, 2019)

Some of the key wetlands are on public land including Council lands (e.g. Cattai Wetlands), National Park and Crown Land. Of the coastal wetlands on private land, some are protected by private conservation instruments, while others are unprotected and threatened by unsympathetic land use and management.

Despite examples of degraded and modified wetlands subject to stock damage and drainage modification, the majority of wetlands in the study area were of good condition and require little in the way of active management other than the prevention of threatening processes[63].

Seagrass distribution in the Manning Estuary has been monitored since 2015 (DPIE) and is known to naturally expand and contract. In 2018/19, seagrass distributions increased in the lower estuary near Harrington but had disappeared from one location in the mid-estuary at Taree[64]. The increase in seagrass distribution in the lower estuary was likely to be caused by lower turbidity during the 2019 drought allowing more light penetration into the water column and stimulating growth. The cause for the decline in seagrass in the mid-estuary is not known but may be linked to changes in salinity and temperature as a result of reduced freshwater flows during the drought[65].

Mangroves provide a range of benefits for water quality, ecosystem health and fish.

[63] (Eco Logical Australia Pty Ltd, 2019)
[64] (MidCoast Council, Waterways Report Card, 2019)
[65] (MidCoast Council, Waterways Report Card, 2019)

Coastal Wetland Values

Coastal wetlands are amongst the most significant vegetation formations on the NSW coast. They perform critical ecosystem services and have high economic, social and cultural values.[66] Environmental functions that coastal wetlands perform include:

- mitigating storm damage and flood impacts;
- recharging groundwater;
- storing carbon;
- helping to stabilise climatic conditions;
- purifying water quality (including denitrification);
- retaining and exporting nutrients and sediments;
- providing highly biodiverse foraging, roosting and breeding habitats for flora and fauna including migratory shorebirds;
- seagrass beds provide food, shelter and oxygen for organisms in the estuary, and reduce turbidity by stabilising the riverbed and trapping suspended sediments[67].

Coastal wetlands also provide significant economic, social and cultural benefits by:

- providing foraging and nursery habitat for many fish, crustaceans and molluscs, including species of commercial and recreational value;[68]
- providing opportunities for tourism and recreational activities such as swimming, boating, fishing, camping and birdwatching;
- having Aboriginal cultural significance, historical significance and importance for science and education[69].

Coastal wetlands have high economic value for their ecosystem services[70][71]. Despite making up only 15 per cent of wetlands globally, coastal wetlands make the most significant financial contribution of all wetland types[72]. The Coastal Management Act recognises coastal saltmarsh, mangroves and seagrass as the highest priority coastal wetland types. Studies by DPI Fisheries (for NSW) and Raoult and Gaston (Wallis lake) confirm that

[66] (OzCoasts, 2020)
[67] (DPIE, 2020)
[68] (OzCoasts, 2020)
[69] (DPIE, 2020)
[70] (Kirkpatric, 2011)
[71] (Janes et al , 2020)
[72] (Davidson, van Dam, Finlayson, & McInnes, 2019)

saltmarsh and seagrass are the most significant contributors to the productivity of commercial fisheries.

A Cost-Benefit Analysis for acquisition and remediation of agricultural property in Big Swamp comparing economic value of agricultural use with environmental showed a net benefit of 7:1 (over $7 of benefits realised for every $1 spent)[73].

Mangroves, saltmarshes and seagrasses help mitigate climate change by sequestering carbon. "Blue carbon" is the carbon stored in mangroves, salt tidal marshes, and seagrass meadows (ordered highest to lowest in carbon stocks per hectare)[74]. Blue carbon is an increasing area of policy and research, with methodologies being developed to quantify carbon credits for coastal wetland restoration.

The value of coastal wetlands was reflected in a community values survey conducted for the Manning River Estuary and Catchment Management Program (CMP)[75]. Aquatic ecosystems were ranked as the most important of nine values, followed by visual amenity and cultural and spiritual value. Respondents valued aquatic life associated with coastal wetlands such as fish, crabs and especially migratory shorebirds. Favourite places included Cattai Creek and its wetlands, Croki due its *"mangroves, as a great place to relax and swim,"* and Farquhar Inlet due to its *"feeling of wildness, fishing and beauty".*

Stressors

Coastal wetlands are under significant threat from development, modified hydrology and the impacts of climate change. The 2019 study of coastal wetlands in the Manning Estuary assessed tenure, condition and threats[76]. It found that a wide range of disturbances have affected the spatial distribution, structure, composition and function of coastal wetlands in the Manning Estuary. Key stressors causing wetland loss, disturbance and degradation include:

- agricultural and urban land use and associated floodplain draining and filling
- modified hydrology
- degradation by pollutants such as acid drainage
- clearing and fragmentation of vegetation
- stock access
- climate change (particularly sea level rise) and drought
- weed and pest invasion
- increased nutrients and sediment loads
- inappropriate fire regimes

[73] (Harrison, Glamore, & Costanza, 2019)
[74] (IUCN, 2014)
[75] (MidCoast Council, 2020)
[76] (Eco Logical Australia Pty Ltd, 2019)

- general ignorance of wetlands values[77].

At the state level, the top three threats listed for saltmarsh and mangroves under the Marine Estate Management Strategy (MEMS) are urban stormwater discharge, entrance modifications and agricultural diffuse-source run-off. The top ten stressors are shown in Table 1[78]. Stressors are described in more detail below.

ENVIRONMENTAL	Clean waters	Estuarine		
	Estuarine & ocean waters	Saltmarsh	Mangrove	Seagrass
ACTIVITY/THREAT				
1. Urban stormwater discharge	e	e	e	e
2. Estuary entrance modifications	e	e	e	e
3. Agricultural diffuse-source runoff	e	e	e	e
4. Clearing riparian & adjacent habitat including wetland drainage	e	e		
5. Climate change (over the next 20 yrs)		e		
6. Modified freshwater flows	e	e		e
7. Foreshore development		e	e	
8. Recreation & tourism boating & boating infrastructure	e			e
9. Navigation & entrance management & modification, including harbour maintenance	e			e
10. Sewage effluent & septic runoff	e			e

[77] (Eco Logical Australia Pty Ltd, 2019)
[78] (NSW Government, NSW Marine Estate Management Strategy 2018-2028, 2018)

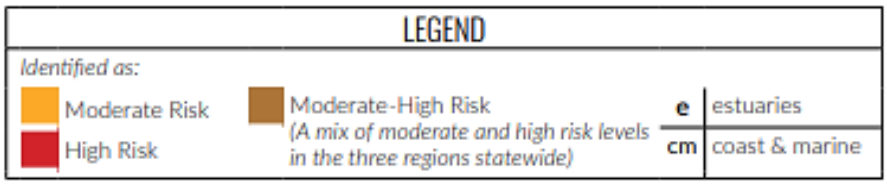

Table 1: Statewide priority threats to environmental assets, MEMS strategy 2018-20[79].

[79] (NSW Government, NSW Marine Estate Management Strategy 2018-2028, 2018)

Clearing, modified hydrology and agriculture impacts

Coastal wetlands on the Manning River Floodplain have been extensively cleared and drained for farming. In many cases the major drains have been colonised by Swamp Oak which has created a linear patchwork of this community across the floodplain[80].

A Rapid Site Assessment of the estuary conducted in 2019[81] assessed the condition of estuarine riparian and instream habitats, including the extent and distribution of native trees/shrubs, groundcover including native sedges/grasses, mangroves and saltmarsh and water quality and litter. Riparian Condition scored poorly at estuarine sites, with the majority rated *Poor* or *Fair*, primarily due to the sparse distribution of riparian vegetation.

Stock impact on the riparian zone was found to be a widespread threat to estuary health and the impact of land-clearing and agricultural run-off is influencing health in estuarine catchments. Cattle grazing was the dominant land use at sites surveyed in the estuarine catchment (42%) and stock frequently have access to riverbanks and wetlands, leading to soil degradation, erosion, reduced vegetation and poor water quality.

While occurring throughout the estuary, the extent and connectivity of mangroves stands has been reduced to narrow, patchy bands, rarely exceeding 10m wide. This provides limited protection of bank structure and shorelines from erosional forces such as high flows and boat wash. Distribution of saltmarsh identified through the Rapid Site Assessments was very low.

Modified hydrology through drainage, levees and floodgates, and the prevalence of Acid Sulfate Soils also present significant threats to the ecosystem health and productivity of coastal wetlands in the Manning floodplain. *The Lower Manning River Drainage Remediation Action Plan* indicated that the highest priority subcatchments to address acid sulfate soils are located on the northern side of the estuary and include Moto, Ghinni Ghinni and Big Swamp[82] (see CMP Issue papers on *Entrance Modification and Modified Flow; Floodplain Drainage Management*).

Weeds

Weed abundance within mapped wetlands was relatively low[83]. Environmental weeds such as Lantana, Bitou Bush, Tree Pear, Coastal Morning Glory and Cassia were becoming established in some wetlands, particularly on the floodplain. Several Swamp Oak and Mangrove Forests were observed to be dominated by an understorey of *Juncus acutus* (Sharp Rush) which should be prioritised for treatment. Crowdy Bay National Park is relatively weed free, apart from disturbed edges and along roadsides[84].

[80] (Eco Logical Australia Pty Ltd, 2019)
[81] (Swanson, 2020)
[82] (Glamore, W.C. and Ruprecht, J. E., 2016)
[83] (Eco Logical Australia Pty Ltd, 2019)
[84] (Eco Logical Australia Pty Ltd, 2019)

Pests

Sambar deer, fox, hares and *gambusia* fish are present in Cattai Wetlands. Deer impact through trampling, damage trees and grazing. Foxes prey on native species, particularly impacting threatened and migratory shorebirds in wetlands near north and south entrances.

Four wheel driving and other recreation

Activities such as four wheel driving can negatively affect salt marsh in a range of ways, including habitat (physical) disturbance, compaction and reduction in plant diversity[85]. It can also disturb wildlife, particularly threatened beach-nesting and migratory shorebirds.

Entrance modification and dredging

Impacts of entrance modifications is addressed within the CMP issues paper on *Entrance Modifications and Modified Hydrology*. Seagrasses at the river entrance at Harrington may be declining due to dredging.

Litter and urban stormwater run-off

No rubbish was recorded at over half of the estuarine sites during the 2019 rapid assessments. Grease/oil was observed at two creeks in the Lansdowne[86].

Climate Change

Climate change, particularly sea level rise, presents a major threat to coastal wetlands in Australia and globally. In NSW, MEMS[87] identified sea level rise as a significant threat to coastal wetlands and the threatened species that rely on these habitats.

With significant areas in low-lying floodplain areas, the effect of climate change in terms of sea level rise is likely to be the major impact on coastal wetlands in the Manning estuary within the coming decades.

Salt marsh is particularly at risk from climate change, which is reflected in its Endangered Ecological Community status under State and Commonwealth legislation. As well as increased storms, rising sea level will increase flooding and inundation resulting in loss of saltmarsh and other intertidal habitat including foraging areas for shorebirds.

Saltmarsh may be replaced by mangroves, with strong correlations found between sea level rise and rates of mangrove encroachment in NSW and Victoria[88]. There is a strong inverse relationship between saltmarsh diversity and temperature in Australia. Temperature

[85] (Schofeild, 2016)
[86] (Swanson, 2020)
[87] (NSW Government, NSW Marine Estate Management Strategy 2018-2028, 2018)
[88] (Wilton, 2002) (Rogers et al , 2006)

increases associated with climate change may reduce saltmarsh diversity by inhibiting germination of several species[89].

As the rate of sea-level rise is expected to accelerate over the coming century, planning for ecosystem protection in the future, including appropriate zoning, needs to start now. While areas of saltmarsh may establish elsewhere if space is left for migration, extreme drought may reduce wetland productivity and carbon sequestration potential[90].

Other potential stressors associated with climate change include changed sedimentation rates, changed fire regimes, changes to groundwater flow and biological productivity[91].

Impacts

Impacts of removal and degradation of coastal wetlands include:

- Increasing runoff, sediment, nutrient and acid loads to coastal waterways within the estuary causes declining water quality.
- Loss of critical habitat and biodiversity [92] including important shorebird feeding and roosting areas and fish habitat.
- Loss of ecosystem services including carbon sequestration and mitigation of flood and storm-surge.
- Algal blooms and stresses on benthic macroinvertebrate communities, plant beds and riparian vegetation.
- Sedimentation smothers sea grass and causes mangrove encroachment into saltmarsh habitat.
- Loss of economic values including fish productivity, recreation and tourism.

4.2 Stakeholders

Management agencies

MidCoast Council, HLLS, DPIE – Environment, Energy and Science, DPIE – Crown Lands, DPI Fisheries, NSW Government, NPWS. Other including WRL

Whose affected?

Private landholders, MCC, Crown Lands, Recreational and Commercial Fishers, Community.

[89] (Santilan & Rogers)
[90]
[91] (Santilan & Rogers)
[92] (OzCoasts, 2020)

4.3 Existing Management Approach

Legislation and Policy Framework

The majority of NSW coastal wetlands are listed as Endangered Ecological Communities under state biodiversity conservation legislation[93]. Saltmarsh is a federally listed ecological community under the EPBC Act [94].

Coastal wetlands along with littoral rainforest form one of the four coastal management areas under NSW's *Coastal Management (CM) Act* 2016. Objectives for management under the Act are:

(a) to protect coastal wetlands and littoral rainforests in their natural state, including their biological diversity and ecosystem integrity;

(b) to promote the rehabilitation and restoration of degraded coastal wetlands and littoral rainforests;

(c) to improve the resilience of coastal wetlands and littoral rainforests to the impacts of climate change, including opportunities for migration;

(d) to support the social and cultural values of coastal wetlands and littoral rainforests;

(e) to promote the objectives of State policies and programs for wetlands or littoral rainforest management.

Previously protected by the State policy SEPP 14, coastal wetlands are now integrated into the *State Environmental Planning Policy (Coastal Management) 2018* [95]. The aim of this policy is to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of NSW.

Under the revised SEPP, a coastal wetland is defined as "*land which displays the hydrological and floristic characteristics of coastal wetlands or littoral rainforests and land adjoining those features.*" These include the broad community types of mangroves, sedgelands, saltmarsh, melaleuca forests, casuarina forests, brackish and freshwater swamps, and wet meadows[96] (see Figure 1).

Spatial maps and development controls are provided within the Coastal Management SEPP. Most activities within a coastal wetland or littoral rainforest require development consent. Clause 10(1) of the *Coastal Management SEPP* lists the types of activities that require development consent. The SEPP requires an Environmental Impact Statement for

[93] (NSW Government, Biodiversity Conservation Act 2016 No 63, Part 2, p177, 2016)
[94] (Commonwealth of Australia, 1999)
[95] (NSW Government, 2018)
[96] (NSW Government, 2018)

restoration works that involve clearing, draining, filling or leveeing within a mapped wetland.

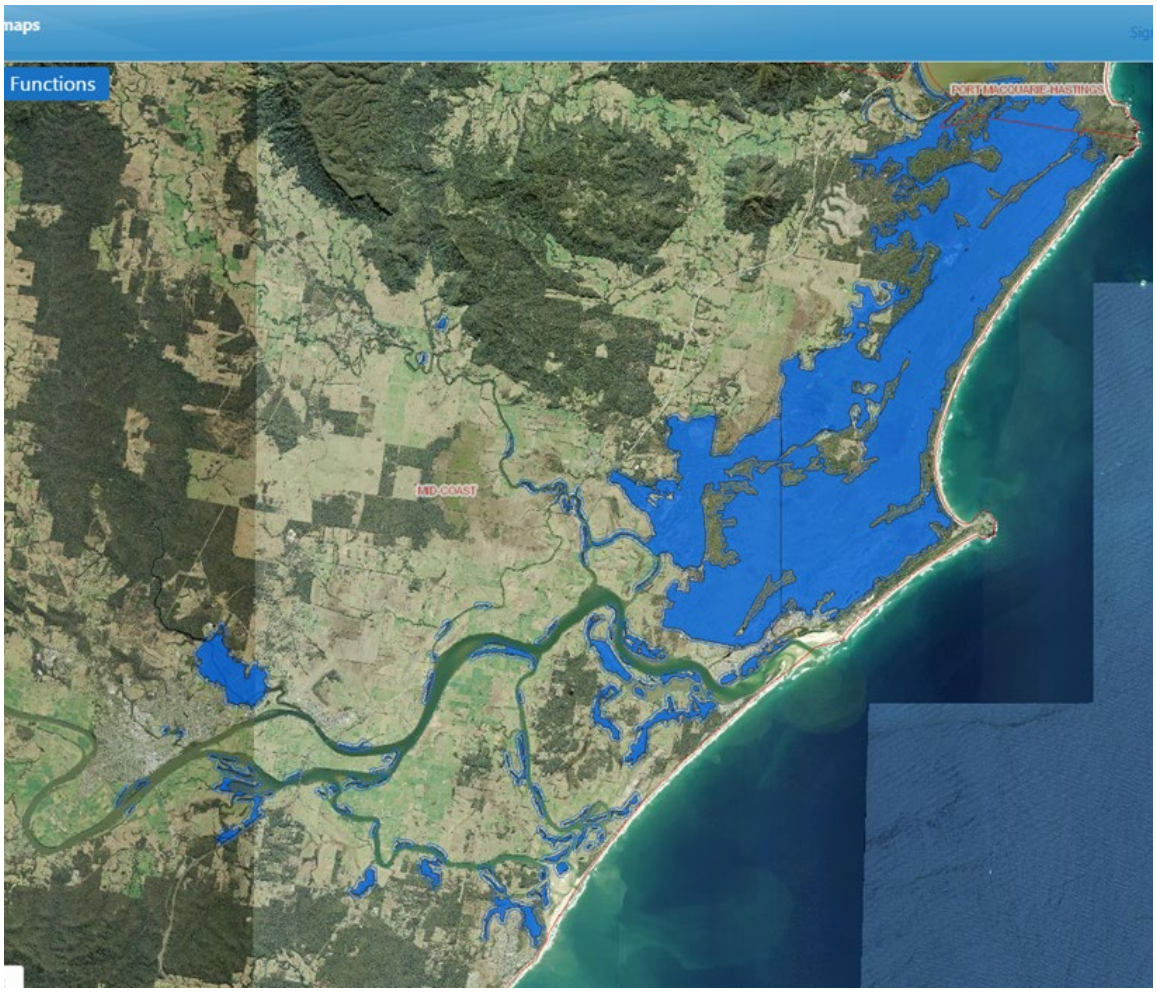

Figure 1: SEPP mapping (coastal wetlands) shown in blue for the Manning Estuary as at 2019[97].

Management of coastal wetlands is guided in NSW by the NSW *Wetlands Policy*[98] and federally for Subtropical and Temperate Coastal Saltmarsh in conservation advice that includes condition thresholds, priority research and conservation actions[99]. The principles with which wetlands should be managed and conserved under the Wetland Policy are listed in Appendix 1. Many other additional resources are available (see *Saltwater wetlands rehabilitation manual*[100], *Saltmarsh Ecology*[101]).

[97] (NSW Government, The State Environmental Planning Policy (Coastal Management) 2018, 2018)
[98] Dept of Environment, Climate Change and Water NSW, 2010, s2.3.2
[99] (Department of Agriculture, Water and Environment , 2013)
[100] (Department of Environment and Climate Change, 2008)
[101] (Laegdsgaard, Kelleway, Williams, & Harty, 2009)

Management activities in the Manning estuary

- The Lower Manning Floodplain Drainage Remediation Plan (RAP)[102] is being implemented as funds allow.
- MCC has acquired and remediated coastal wetlands including Big Swamp and Cattai wetlands, with positive cost benefit ratios of these projects showing significant community benefits[103]. In 2003, Greater Taree Council (now MidCoast Council) purchased and commenced remediation of Cattai Wetlands, covering 486 ha of the Big Swamp floodplain. Since then, an additional 927 ha of ASS affected land has been acquired at Big Swamp, making a total of 1425 ha with remediation ongoing.
- MCC and Hunter Local Land Services work on public and private land to undertake coastal wetland protection and remediation such as stock exclusion fencing, improvements to drainage and floodgates, and bank protection, funded through the MCC Environment Levy, MEMS and habitat fish action grants.
- Some control of priority introduced species (e.g. Rusa deer Cattai/Big Swamp).
- Gross pollutant traps to reduce urban stormwater impacts in Taree and Harrington were audited in 2019 and a rectification and maintenance program commenced 2020.
- Litter clean up days are coordinated by Friends of Brown's Creek and OzFish.

Research projects

- State based modelling of salt marsh and mangroves extent under three SLR scenarios, localised modelling case study 2020/21 (DPIE EES)
- Research undertaken by the Environment, Energy and Science group of the Department of Planning, Industry and Environment (DPIE) will help understand the predicted distribution of mangrove and saltmarsh under three sea level rise scenarios (0.5m, 1.0 and 1.5m) at state-level. The Manning estuary is included as a local case study.
- MCC risk assessment for septic runoff (2019).
- HLLS-funded study by WRL on boat wash impacts to coastal wetlands of Pelican Bay.

[102]

[103] (Harrison, Glamore, & Costanza, 2019)

4.4 Knowledge Gaps

- Comprehensive climate change risk assessment and prioritisation. Model the anticipated effects and develop strategies to avoid, mitigate or offset the predicted negative impacts.
- Valuation of environmental services versus agricultural production, when to transition, best mix of land-uses as seal-level rises.
- Replicate fisheries value research from Wallis Lake. Use similar methodology (stable isotopes) for trophic food. Demonstrate link to habitat and fisheries. Work in Hunter showed saltmarsh near estuary mouth most important. May be disproportionate wetland types most important, e.g. sea grass in Manning.
- Given the likely negative impacts of climate change and sea level rise, a landward retreat analysis should be undertaken. Use modelling to identify areas of land suitable for retreat ("retreat zones" on a landscape scale) and those that should be prioritised for protection.
- Social science research: Need to understand landholder willingness more broadly, what are key motivators (e.g. financial) or barriers to land-use change.
- Prioritise wetlands for conservation based on their size, perimeter to area ratio, condition and threats (pressures), extent within the catchment and more broadly in NSW, as well as listing status.
- Risk from blackwater events
- Research into the groundwater dependence of wetlands in general, including those within Crowdy Bay National Park. Risk to wetlands and GDEs from current and/or increased groundwater demand.
- Impacts of modified freshwater flows and declining water quality on system functions and aquatic communities. Does current Water Sharing Plan sufficiently protect/ benefit coastal wetlands?
- Population growth forecasts and potential impacts
- Habitat valuation for commercial and recreational fisheries, aquaculture and shorebirds.
- Research into dieback in Broad-leaved Paperbark (including mapping) to ensure this functional, structurally important and dominant species is not lost from these wetlands.

4.5 What's working, what's not?

What's working:

- Strong scientific evidence-base for coastal wetlands and floodplain management in partnership with Water Research Lab (WRL).
- Collaborative approach between agencies, research institutes, landholders and industry representatives is working well.
- The Remediation Action Plan been a good tool to prioritise work on the floodplain.[104]
- Council acquisition and remediation of coastal wetlands for environmental services, recreation and community benefit, e.g. Cattai, Big Swamp, Dawson Wetlands.
- LLS engagement and remediation projects to protect mangroves and saltmarsh in areas such as Pelican Bay are a good approach, especially when they include multiple properties and methods.
- Social science research to understand farmer drivers and barriers in Pelican Bay has been insightful and laid foundation for LLS work (Bullock 2019).
- Collaboration with Aboriginal groups for joint management in Crowdy Bay NP. NPWS placed emphasis on cultural heritage and engaging with Aboriginal community.
- Case studies on restoration are good education tools describing what has been done to provide best practice management information for landholders.
- Council environmental education discovery program of webinars, wetland walks helps inform wider community on environmental values, ecosystem services and sustainable management.

What's not working:

- Habitat degradation, land clearing, and wetland drainage are common throughout the system.
- Failure of state agencies to model best management practice on public lands in the riparian zone and coastal wetlands (e.g. Crown Lands and Transport for NSW). Crown lands need a systematic review of land management, grazing permits. Jones Island TfNSW land is similar. The ideal is for state agencies to model best management practice to other landholders. Might be regulatory tools that can be used.

[104] (Glamore, W.C. and Ruprecht, J. E., 2016)

- Failure to enforce compliance with fisheries regulation to prohibit grazing of foreshore areas. Need a systematic compliance program for this, including on Crown land, where there are cases of swamp oaks being illegally cleared for views.
- Difficulty liaising with NPWS on coastal management issues due to resource constraints, especially during fire season.
- Poor community understanding and awareness of what wetlands are and the ecosystem services they provide. Saltmarsh is seen as "most expendable" of wetlands.
- Detrimental activities on private land have a public cost for remediation (for example diffuse source pollution of water quality). Lack of regulation and accountability.
- Council roads and culverts blocking tidal flow in coastal wetlands (e.g. Pelican Bay).
- Invasive weeds especially prickly pear abundant on foreshore areas between Taree and Harrington. Increased in last decade. Bio controls in place but significant infestations remain. large infestations of *Juncus acutus* uncontrolled on private properties. Lower Hunter control trials – best treatment is glyphosate foliar spraying.

4.6 Opportunities

- Blue carbon: Potential investment and offset opportunities for coastal wetlands and fringing vegetation. Will carbon credits and offsets be a driver or a distraction? Worth pursuing. NPWS has a blue carbon project underway.
- Partnering opportunities on blue carbon with The Nature Conservancy.
- Continue using best available science to prioritise coastal wetlands for acquisition and/or remediation.
- Seagrass restoration in the estuary (LLS project with fishermen transplanting zostera underway 2020)
- BCT Voluntary Conservation Agreements in the estuary in perpetuity.
- Climate change and sea level rise present opportunities to transition inundated agricultural land to intertidal wetlands with ecosystem service benefits. Use Bradley Henderson's PhD (underway) to develop a landscape scale plan with mix of land uses for longer term. Do pilot demonstration projects for different elevations, water levels. When and where do we transition land with SLR?
- Incorporate Aboriginal traditional knowledge and Aboriginal Rangers for coastal wetland monitoring and management.

- Establish a floodplain management group following on from CMP Reference and Technical Working Groups to implement CMP and coordinate ongoing management and planning.

4.7 Management Options

Planning

- Use Council's strategic planning framework to implement planning controls to protect wetlands (Rural Strategy, SEPP, LEP, and DCPs).
- Provide evidence and propose amendments to the Coastal Management SEPP to support acquisition, rezoning and remediation of coastal wetlands to improve ecosystem services.
- Develop a whole-community long-term, landscape-scale plan for the floodplain under future sea-level rise scenarios. Build agreement and map an appropriate mix of land-uses that will be sustainable in the longer term.
- Develop agreed interagency principles and priorities for coastal wetland management.
- Prioritise wetlands for conservation based on their size, perimeter to area ratio, condition and threats (pressures), extent within the catchment and more broadly in NSW, as well as listing status.

Advocacy

- Advocate for investment in coastal wetland acquisition and/or remediation by the NSW Government.

Capacity Building

- Develop a coordinated education and awareness program including case studies and field events to promote wetland values, best management practice and sustainable use.

Regulatory Compliance

- Establish a systematic compliance program to address illegal clearing on public and private land and compliance with conditions on Crown Land grazing permits.

Science and research

- Complete modelling and identify retreat buffer zones to retain coastal wetland ecosystem services under sea-level rise scenarios.
- Undertake a coastal wetlands valuation study for commercial and recreational fisheries, aquaculture and shorebirds.

On-ground

- Acquire and remediate coastal wetlands prioritised for community benefit, including retreat zones to mitigate impact of sea level rise.[105]
- Manage threats to coastal wetlands in the National Park estate and adjacent lands, in collaboration with Aboriginal Traditional Owners.
- Manage coastal wetlands on public land for ecosystem services and/or as demonstration sites for agricultural best management practice (Crown lands, TfNSW). Review agricultural permits before renewing.
- Remediate and restore intertidal hydrology on priority public and private land, (in partnership with TIDE, commercial fishermen, OzFish, Landcare, LLS, oyster industry).
- Implement an integrated weed and pest management program in partnership between land management agencies and private landholders.
- Incorporate Aboriginal traditional knowledge and Aboriginal Rangers for coastal wetland monitoring and management.

Governance

- Establish a floodplain management group following on from CMP Reference and Technical Working Groups to implement CMP and coordinate ongoing management and planning.

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[105] (Glamore, W.C. and Ruprecht, J. E., 2016)

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Appendix 1: The NSW Wetland Policy principles for management and conservation[106]

- Wetlands are valued as significant parts of NSW landscapes – their conservation and management are most appropriately considered at the catchment scale.
- Water regimes needed to maintain or restore the ecological resilience of wetlands should be provided through water management planning, water recovery and water purchase, recognising that a balance between environmental and human requirements must be reached.
- Floodplains should be managed to maintain the natural distribution of water to and from wetlands, and to allow for the movement of aquatic biota.
- Wetlands of international, national and regional significance should be identified and given priority for conservation and investment.
- Land management practices should maintain or improve wetland habitats, ecosystem services and cultural values.
- Wetlands should be recognised as places with important cultural values, in particular that wetlands are an important part of Country for Aboriginal people.
- Degraded wetlands and their habitats should be rehabilitated and their ecological processes improved as far as is practicable.
- The potential impacts of climate change should be considered in planning for wetland conservation and management.
- Research into wetland ecology should be encouraged to better support water and land-use planning and management.
- Natural wetlands should not be destroyed or degraded. If social or economic imperatives in the public interest result in a wetland being degraded or destroyed, the establishment and protection of a wetland offset that supports similar biodiversity and ecological functions will be needed.
- Cooperation and incentives among land managers, government authorities, catchment management authorities, non-government organisations and the general community are essential for effective wetland management.
- Regular reporting of wetland extent and condition is vital to assess management performance and understand wetland dynamics.

[106] (Dept of Environment, Climate Change and Water NSW, 2010)

5. Community Stewardship

The purpose of this issue paper is to identify some principles, methodologies and communication tools for environmental education, agricultural outreach and community engagement.

In consultation with the stakeholder discussion group, we will identify target groups and match them with the behaviours sought, key messages, engagement methods and communication tools to be used in the Manning River Estuary and Catchment Management Program (CMP).

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5.1 Situation Analysis

5.1.1 The need for engagement

Engagement and stewardship are key themes for the Manning River Estuary and Catchment Management Plan (CMP). The need to improve community stewardship was identified as a high priority in consultation with the CMP Community Reference Group (May 2020). Comments received during the consultation process included:

> *"It's the responsibility of everyone to respect and understand our iconic river system...to appreciate it, utilise it, and do their bit to keep it clean."*

> ***"****This is a people issue. A lot of people don't get the impact of day-to-day decisions. Promote public education on the issues. Publicise issues affecting the river. Engage with landholders in the catchment. Improve decision-making."*

In a series of discussion groups held for the CMP issue analysis, education and engagement were proposed as management options for almost every issue.

The call to improve community stewardship is reflected in the draft vision and objectives for the CMP:

> Vision: "The Manning River, its tributaries and the estuary give life to our community connecting the mountains to the sea. *Together* we manage the catchment holistically and respond to a changing climate - safeguarding environmental, social, cultural and economic values."

Objective 4: Engage and educate our community to understand, appreciate, respect and protect natural processes and socio-economic values of the river, the estuary and the whole catchment.

Public participation is enshrined in the Coastal Management Act 2016, which has an object to:

> *"Support public participation in coastal management and planning and greater public awareness, education and understanding of coastal processes and management actions."*

Community engagement to promote stewardship is also a strong feature of the NSW Marine Estate Management Strategy (MEMS).[107] Identified threats to social, cultural and economic benefits statewide include:

- Lack of community awareness of the marine estate and associated benefits and threats
- Lack of, or ineffective community engagement in governance
- Antisocial behaviour and unsafe practices

Management action 8.1 in the MEMS calls for increasing stakeholder and community awareness of the marine estate and promoting safe and ecologically sustainable use by:

- Building on existing school and community education programs to encourage environmental stewardship, enhance self-compliance and promote the physical and mental health benefits associated with nature;
- Developing and promoting best practice guidance and codes of practice to reduce resource use conflicts;
- Developing online information resources and digital technologies.[108]

5.1.2 Guidance from consultation and local social science research

In 2019, MidCoast Council (MCC) engaged Nick Bullock Consulting to investigate the motivations and challenges for beef and dairy farmers implementing measures to improve the ecology of the Manning River Basin (MRB); and to report on its findings, with recommendations to support those farmers to change. The full report can be found on the MCC *Our Manning River* web page. Findings and recommendations are provided in Appendix 1.[109]

[107] (NSW Marine Estate Management Authority, 2018)
[108] (NSW Marine Estate Management Authority, 2018)
[109] (Bullock, 2019)

The report calls for programs that change the paradigm, so that farmers willingly "buy-in" to a catchment management program to achieve the long-term goal of improved water quality.

A program which builds upon existing catchment management efforts, promotes an integrated suite of practices, demonstrates a relative advantage for farm management and benefits waterways will be most beneficial to farmers and could readily be linked to their values and aspirations.

Providing incentives, training and extension advice to develop new concepts and skills; supporting peer-to-peer learning; and negotiating win-win management actions will advance the goals of farmers while influencing culture and practices to improve management of the Manning River Basin.

This builds on a comprehensive analysis of practice change undertaken for Great Lakes Council's Water Quality Improvement Plan 2009.[110]

5.1.3 The Manning River Estuary and Catchment CMP Engagement Strategy 2018

The engagement strategy developed for the CMP planning process contains a wealth of principles and methods that can fruitfully be applied to ongoing engagement in implementation of the program.[111]

The CMP Engagement Strategy notes that social capital (people, networks, relationships) and natural capital (ecosystems, environment, nature) are intrinsically linked, as diagrammatically shown in Figure 1. Changes in ecosystems can impact trust, involvement, and cohesion within communities by altering human-environment relationships. For example, the economic and public health costs associated with damage to ecosystem services can be substantial. Conversely, strong social bonds at the community level can enhance ecosystem services and the success of environmental management programs (Barnes-Mauthe, et al., 2015; Nichols, 2014).

[110] (Great Lakes Council, 2009)
[111] (MidCoast Council, 2018)

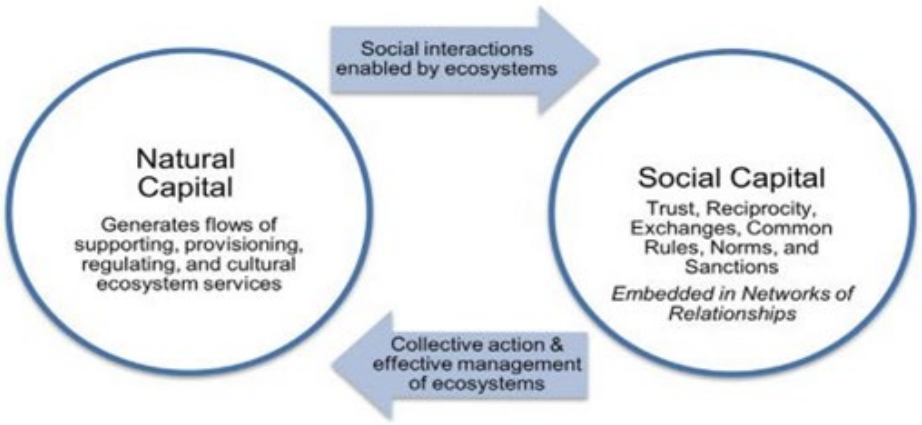

Figure 13: Relationship between Natural and Social Capital.

When people are well connected and their knowledge is sought, incorporated and built upon during planning and implementation, they are more likely to sustain stewardship and protection of natural resources over the long-term (Pretty & Smith, 2004).

The Engagement components of the Manning CMP will help develop the relationship between social and natural capital in order to foster sustainable catchment and estuary management.

5.1.4 Diffusion of Innovation

Diffusion of innovations is a theory that seeks to explain how, why, and at what rate new ideas and technology spread. It was conceptualised by Everett Rogers, who drew on multiple disciplines including communication studies to propose that innovation is shared and adopted over time among participants in a social system by a process of diffusion.[112]

Rogers proposes that four main elements influence the spread of a new idea: the innovation itself, communication channels, time, and a social system. This process relies heavily on human capital. The innovation must be widely adopted in order to self-sustain. Within the rate of adoption, there is a point at which an innovation reaches critical mass.

The categories of adopters are innovators, early adopters, early majority, late majority, and laggards. Diffusion manifests itself in different ways and is highly subject to the type of adopters and innovation-decision process. The criterion for the adopter categorization is innovativeness, defined as the degree to which an individual adopts a new idea.

[112] (Rogers, 2003)

The goal for engagement officers is to identify where on the bell curve (Figure 2) their community sits on an issue, then focus engagement and education interventions on those who have yet to adopt the practice.

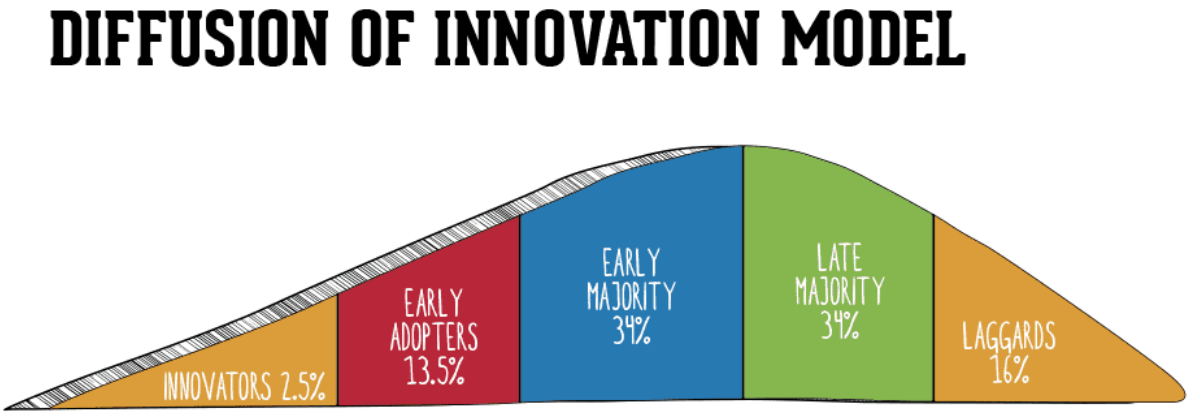

Figure 2: Diffusion of Innovation bell curve[113]

5.1.5 Methods

There are numerous methods and frameworks for community engagement. Some of these that are most familiar with the MidCoast Council (MCC) project team are shown below.

Action Learning involves establishing a small group to work on real, complex problems. Taking action, reflecting and learning as individuals and a group. The group uses a process of asking open questions (appreciative inquiry or strategic questioning) to clarify the exact nature of the problem and identifying possible solutions. Action is taken, evaluated and reviewed or scaled up. Action Learning solves problems and develops leaders simultaneously by encouraging participants to think critically and creatively, and to work collaboratively.[114]

Changeology is an approach to designing programs to generate behaviour change developed by Les Robinson, whose training workshops are widely attended by both MCC and HLLS engagement officers. It is based on five principles:

- Create familiarity - through hands-on experiences linked to existing knowledge and experience.
- Be visible – make the correct behaviours highly visible close to the point where they are made.

[113] (Rogers, 2003)
[114] (Revans, 1998)

- Redesign for ease – reduce the number of steps or decisions, matching best practice with existing activities.
- Establish best practice as the norm – provide evidence others are doing it.
- Passionate champions – connect and support people who will model and promote the practice change.[115]

ADKAR is an acronym which stands for Awareness, Desire, Knowledge, Ability, Reinforcement.[116] It is a change management model for business, government and community and is used by MCC across a range of programs. The ADKAR models defines five basic building blocks for social change. ADKAR programs commence with an assessment of where target groups are situated with regards to the five building blocks, them implement change activities targeted at each of the five elements. Change activities include communications, coaching, training. Factors influencing the success of each element are shown in Table 1 below.

Element	Factors influencing success
Awareness Of the need for change	• A person (or group's) perception of the current state or problem • Credibility of the sender of awareness messages • Misinformation, rumours, contestability of the reasons for change
Desire To support and participate in the change	• The nature of the change, how much it will impact on the person (or group) • Their personal situation and motivations
Knowledge Of how to change	• The current knowledge base of the individual or target group • Their capability to gain additional knowledge • Resources available for training and education • Access to or existence of the required knowledge
Ability To implement required skills and behaviours	• Psychological blocks, physical abilities, intellectual capacity • Tie available to master new skills • Availability of resources

[115] (Robinson, 2019)
[116] (Hiatt, 2006)

Reinforcement To sustain the change	• Meaningful and specific reinforcement for the person or target group impacted by the change • Association between reinforcement and demonstrated results aligned to program targets • Absence of negative consequences • Accountability system to monitor and report on change

Table 1: ADKAR Factors for success[117]

Asset Based Community Development (ABCD) is an approach to sustainable community-driven development. Institutions such as government and not-for-profits are stretched thin in their ability to solve community problems. In this approach, instead of focussing on deficiencies, facilitators work within their community to identify strengths and mobilise them to solve the identified problem. Agencies lead by providing facilitation, support and resources while stepping back to create opportunities for grass roots, community- led initiatives.[118]

Asset Based Community Development facilitators work with community groups to identify assets in five categories: Individuals, Associations, Institutions, Facilities and Connections. A good example of this is the suggestion by farmer Peter Bignell from the CMP Community Reference group that the project team could use meetings at Rural Fire Sheds to engage local communities:

> *"The CMP team could join meetings at the fire sheds to discuss fixing estuary issues. People get together at the fire sheds to discuss issues, plus the annual Xmas parties. Up to 200-300 people come…People yarn a lot about land management. There's a fire shed up every creek and every gully. People will know the land and what the issues are in their patch."*

The same farmer noted the way a younger generation of farmers are leading change to more sustainable better practices.

> *"I'm really enjoying seeing young people coming through and changing our practices. Views have changed through a lifetime living on the land: 3rd and 4th generation producers are modernising our thinking. The old timers are dropping away and the young ones are combining a lot of agricultural science and coming onto properties with a better array of farming methods…Its farmers talking to farmers. Authorities are the last resort."*

Building relationships between actors is the key to success in ABCD programs. Principles of are shown in Table 2 below. There are many tools available to help facilitate ABCD. Graeme

[117] (Hiatt, 2006)
[118] (McKnight, 2013)

Stuart from the University of Newcastle's Family Action Centre is a local leader in the field and his blog is a good place to start.

EVERYONE HAS GIFTS
With rare exception; people can contribute and want to contribute. Everyone in a community has something to offer.
PEOPLE CARE AND ARE MOTIVATED TO ACT
Facilitators work with individuals and groups to uncover what they care about and their motivations to act in ways that will address the issue.
RELATIONSHIPS BUILD A COMMUNITY
An intentional effort to nurture relationships and build effective networks is the core of ABCD.
CITIZENS AT THE CENTRE
Community participants are engaged as leaders and actors, not just as recipients of a program: "Join us, we need you."

Table 2: Asset Based Community development

Agricultural Extension

Agricultural Extension assists farmers to learn about and adopt improved technology from reliable sources.[119] While traditionally the focus was on enhancing production efficiency, the same approach can be used to promote "triple bottom line" sustainable practices that improve social, economic and environmental outcomes. The general objectives of extension are to:

- Assist farmers to discover and analyse their problems and identify their felt needs.
- Develop leadership among farmers and help them organise groups and solve their problems.
- Disseminate research information of economic and practical importance in a way farmers can understand and use it.
- Assist farmers to mobilise and utilise the resources they have and to identify what they need from outside.
- Collect and transmit feedback information for solving management problems.[120]

[119] (Famuyiwa, Olaniyi, & Adesoji, 2016)
[120] (Famuyiwa, Olaniyi, & Adesoji, 2016)

Farm field days are used to build relationships and disseminate information in a practical way

Bennett's Hierarchy is a long-standing tool to evaluate and improve agricultural extension programs.[121] The hierarchy is used to design monitoring and evaluation. The further up the hierarchy you can gather data, the more directly you can demonstrate practice change and results.

1. Inputs: What resources were used to run the extension program?
2. Activities: What activities have been provided e.g. workshops, field days, or resources produced.
3. Participation: How many people attended workshops/field days or saw our work on social media?
4. Reactions: What do people self-report as their response? What did they learn? What will they use?
5. Knowledge, Attitude, Skills and Aspirations (KASA): What changes did the program achieve in KASA? These are the precursors to practice change at the next level.

[121] (Rockwell & Bennett, 2004)

6. Practice change: What new practices, technologies, or skills were adopted and became "business as usual."
7. End results: What are the big picture outcomes: the social, economic, environmental or cultural change driven by the practice change.

Environmental Interpretation is an environmental education process involving first-hand experience with a resource such as a river or wetland. It uses communication tools such as guided tours and interpretive signage to foster emotional and intellectual connections between the interests of the audience and the values of the resource. Technical language is translated into terms and ideas that people with no prior knowledge can understand. Information conveys relationships and meanings centred around a theme. The goal is to build understanding, a desire to conserve the resource, and commitment to a set of sustainable behaviours required for asset protection.[122] Principles of environmental interpretation are provided in Appendix 3.

5.1.6 Tools

Education tools need to be carefully selected and designed to meet the needs of the target audience. This is best done in consultation with the audience themselves. Tools include:

Farm Field Days	Forums and seminars
Best practice frameworks	Webinars
Sustainable farming or Landcare groups	Community action days e.g. clean-ups
Networks	Guided tours
Workshops	Interpretive signage
Presentations	Brochures and fact sheets
Public meetings	On-line content

[122] (Freeman, 1957)

Social media posts

Training manuals

One-on-one field visits and advisory services

Stories

Videos

Media release

Advertising campaigns

Competitions

Flagship species

Exhibitions

Postcards, bumper stickers, posters

Competitions

Citizen science activities

Outdoor classrooms

Drain stencilling

Gutter talks/kitchen table talks

5.2 Stakeholders

Delivery agencies

MidCoast Council; Hunter Local Land Services; Midcoast-to-Tops Landcare; National Parks and Wildlife Service; local schools; community groups (e.g. Manning River Turtle Conservation Group, OzFish, birding clubs); Manning Regional Art gallery; Libraries

5.3 Existing Management Approach

MidCoast Council, Hunter Local Land Services and Midcoast-to-Tops Landcare work individually and in partnership on a range of landholder and community engagement programs to promote catchment management. Memorandums of Understanding are in place between HLLS and MCC, HLLS and Landcare, with a draft MOU underway for Landcare and MCC.

5.4 What's working, what's not?

5.4.1 What's working

- Partnerships between organisations (Council, Landcare, Hunter Local Land Services) are really important. The MOU's are building clarity and shared understanding.
- There's a lot of capacity between the three main agencies, with paid Landcare coordinators, Council catchment officers, environmental project officers and Land Services Officers.
- Still important to have an incentives and engagement program but it's not the only way to promote change.
- LLS projects on productive agricultural land, especially larger properties.

- Field days and events, e.g. living museum, tree planting. Anything hands on works very well.
- Regenerative agriculture movement and *Young Farmers Connect* – has momentum with landholders networking and sharing resources. It's a very grass-roots movement, almost anti- government, ahead of formal science. People are trying new things, seeing what works on their property. Part of a movement to heal country, connecting to like-minded people with an inspiring vision and similar ideologies. Landowners see direct on-ground benefits e.g. improvements in soil fertility, wildlife. Only a small percentage of group are commercial farms (Yeo's, Tim and Kirrily Hill) but not in the Manning. Full range of people in group – some without properties yet. Innovative.
- Farmers learning from farmers: What's our role without taking away from the grass-roots approach?
- Urban space – Browns Creek model could work on a larger scale – catchment scale or larger. Small groups in general. Supporting groups and helping to establish networks - community development approach.
- Cross agency referrals are working well – knowing who to talk to and refer landholders to for information on certain issues.

5.4.2 What's not working:

- Gap between science and community - Some science programs aren't translated for community understanding and uptake.
- Covid19 situation – makes field days and events very difficult. However, there are opportunities for remote learning. Doesn't completely take the place of hands on events.
- Engagement and recruitment - Younger generations not coming through in Landcare groups and audiences. Covid has helped somewhat. There has been increased attendance at webinars or workshops of younger people but need to see if and how this translates to new influx of volunteers and interested Landcare. This is priority.
- Regenerative and young farmers – fragmented information, interpretation of science and knowledge is lacking and needed. Need evidence based, but innovation ahead of science. Every case is different.
- Challenge – huge wide range of properties and people you're trying to connect with.

5.5 Opportunities

- Where is our effort best spent? What is Council, LLS and Landcare's role? Need to map that out to get the best from our resources.
- Co-design a cohesive program with all the stakeholders working on different elements - as a way of directing great work and being consistent across our catchments

- Science communication - Need to break down scientific literature to make it relevant and accessible to local area.
- Capacity building – Council and/or LLS paying for maintenance. Follow up and ongoing support to landholders. Process of working out what's fair and equitable – at the moment we have criteria for that.
- Citizen Science: A lot of other models around – e.g. Rivercare
- Remote learning in Covid-19 situation: Zoom events allows a range of people in locations to attend with a large LGA. Zoom meetings helps broaden audience and get different speakers. Zoom webinars allow flexibility and cost savings.
- Recruitment and engagement –engaging new people, engaging people who attend webinars and workshops into the Landcare movement.
- Build capacity of young farmers – young at heart, willing to try new things, new techniques. Use information such as "Call of the Reed Warbler", experts in that space, podcasts, blogs, running zoom events. Informal networks that come together as a group opportunistically e.g. Farmers markets.
- Support Sustainable Farmers Groups with farmers learning from farmers.
- Field days and demonstrations - opportunities to touch, see and do.
- Use on farm-impacts to a flagship species e.g. Manning River Helmeted turtle as the hook for engagement.
- Community based social marketing – need to define what behaviour change is.
- Link stewardship with recreation - e.g. new OzFish groups or kayaking/canoe groups.
- Environmental certification – e.g. "turtle friendly" milk or beef that are productive as well as look after the river. Connect with Councils Economic development program.
- Farmers talking to farmers – oyster farmers talking to beef and dairy farms, food trails, farm to fridge.
- Use innovation and Best Management Practice to boost productivity, catchment management and biodiversity.
- Boost communication and marketing presence.
- Support groups that align with what we're trying to do. E.g. Team Taree, advocacy groups.
- New Landcare models that appeal to younger people. Landcare adventures are becoming more and more popular.

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6. Entrance modifications & modified hydrology

This Issue Analysis paper considers entrance modifications in the north and south channel of the Manning River estuary, as well as modifications to hydrology in the floodplain and catchment such as causeways and weirs.

With regards to entrance modifications, note that the planning area for the Manning River Estuary Catchment Management Program commences 2km up-river of AHD and is a whole-of-catchment plan primarily concerned with the impact of water on land. MidCoast Council is preparing a Coastal Management Program for Old Bar-Manning Point which addresses coastal processes and will more fully consider the issue of entrance modifications. There will be integration and consistency between the two programs.

This paper takes a risk management approach as prescribed by the Coastal Management Act 2016 and the Coastal management manual. Drainage channels in the floodplain are considered in more detail in the CMP Issue Analysis on Floodplain Drainage management.

6.1 Situation Analysis

Activities

The Manning River estuary functions is primarily a result of river energy and is a wave-dominated delta. The estuary is classed as an open mature wave dominated barrier estuary[123]. Estuarine hydrodynamics are influenced by catchment freshwater flow modification (addressed through the CMP Issue Analysis paper on modified flow), modified catchment hydrology, floodplain hydrological changes, dredging, entrance opening and impacts of climate change. The Manning estuary, particularly in the lower reaches, has important social/recreation, economic and ecological values, all of which can be affected by hydrological and entrance modification.

Floodplain hydrology has been changed by infilling, numerous freshwater and tidal flow-modifying structures predominantly for drainage, such as levees and floodgates. This drainage has resulted in exposure of Acid Sulfate Soils, which is covered in more detail in the CMP Issue Analysis on floodplain drainage management).

At the river entrances, a single breakwater/training wall at the northern entrance at Harrington has created a permanent ocean entrance while Farquhar Inlet at the southern

[123] Manning River Estuary Management Strategy (2009).

entrance, has been intermittently opened and closed naturally by littoral sand deposition at many periods through recorded history. It has been mechanically opened to the ocean since the 1950s, and more recently when flood trigger levels are reached[124]. Numerous reports, studies and plans, as well as risk assessments have been completed addressing the issue of entrance modification in the Manning and at State level[125], and of flood risk in the estuary[126].

There have been community and industry concerns regarding the water quality at Farquhar Inlet due to long flushing times when the inlet is closed. Concerns include:

- potential water quality impacts on the oyster industry (for harvesting, inability to direct harvest);
- flooding, with community discussion focussing on the potential for a second permanent entrance to reduce the perceived flood risk.
- social and economic issues such as the impact of entrance closure on navigation and recreation in the lower estuary; and
- the influence of the entrance conditions on tourism and aesthetic values.[127]

Community interest and advocacy on these issues typically respond to perceptions about the condition of each of the entrances[128].

Within the wider Manning catchment, water sources are unregulated (i.e. no major weirs, dams), however flows are modified by water extraction for various purposes including agriculture and drinking water supply (addressed within the CMP Issue Paper on modified flow issue), as well as infrastructure such as dry and wet causeways, which can act as barriers for aquatic species, particularly fish. Former Greater Taree and Gloucester LGAs currently have the greatest number of recorded obstructions to fish passage within the Hunter/Central Rivers region[129]. While currently non-operational, a weir within Glenrock Station on the Barnard River was constructed for the proposed Barnard River Scheme, an inter-basin water transfer system, designed to enable the transfer of water from the Barnard River and the upper catchment of the Manning River into the Hunter River to meet shortfalls from the Hunter River system[130].

Pressures and Impacts

Entrance modification

[124] (Parsons, 2010)
[125] (Webb, McKeown & Associates Pty Ltd , 1997), (Laboratory, 2018) (Patterson Britton & Partners, 2009)
[126] (BMT WBM Pty Ltd , 2019)
[127] (Parsons, 2010)
[128] (Parsons, 2010)p2.
[129] (NSW Department of Primary Industries, 2006)
[130] (Connell Wagner Pty Ltd, 2007)

- Under the Coastal Management Act 2016, coastal lake or watercourse entrance instability, while seen as a natural process is listed as a threat to access, recreational activities, dune vegetation, shorebird nesting sites, infrastructure near the shoreline and inland estuary flooding.
- Predicted changes to seasonal temperatures and hydrologic variables as a result of climate change are likely to impact on rivers of the Manning catchment, which may exacerbate these pressures and impacts.
- The *NSW Marine Estate Management Strategy 2018 – 2020*[131] states that estuarine entrance modification, harbour maintenance, drainage, and other works are the highest threats to species, populations and communities that are listed as protected or threatened under the *Fisheries Management Act* 1994 (FMA) and the *Biodiversity Conservation Act* 2016 (BCA).
- The Marine Estate Management Authority completed an evidence-based Threat and Risk Assessment for the NSW marine estate (Statewide TARA).[132] TARA ratings are as follows:
    - Estuary entrance modifications were rated as the second priority threat to the environment at state level (TARA Table 3-4);
    - Estuary entrance modification was rated as the top priority threat to the environment for the Northern region planning area, including the Manning, (Table 3-5 & Table 5-2);
    - Modified hydrology / hydraulics and flow regime is a priority threat to the Social, Cultural and Economic Benefits Statewide (Table 4-1);
    - Modified hydrology / hydraulics and flow regime were ranked as a priority threat to the Social, Cultural and Economic Befits for the Northern region (Table 4-3);
    - Physical disturbance to habitats was ranked as shared priority threat across assets and benefits Statewide (Table 5-1) and for the Northern Region (Table 5-2).
- In 2016 a NSW Department of Industry - Crown Lands feasibility study for a southern breakwater along the Harrington entrance considered the practicality, constructability, cost and financial aspects as well as environmental implications, surmising it would:
    - generate significant changes to existing coastal processes, some of which may not be well anticipated or understood;

[131] NSW Marine Estate Management Authority, July 2018
[132] NSW Marine Estate Threat and Risk Assessment Report, BMT WBM, August 2017

  - involve very high capital construction costs; and
  - require ongoing dredging.

- The Draft - Manning River Floodplain Risk Management Study and Plan prepared for MidCoast Council discusses a trained entrance for Farquhar (southern arm of the Manning River) as potentially improving estuary flushing, water quality and channel navigation. The study also notes that:
  - breakwaters constructed at entrances can significantly alter coastal and estuary processes affecting sand and sediment transport along the coast;
  - have substantial detrimental environmental impacts; and
  - high capital cost.
- For the first pass risk assessment in Council's Coastal Scoping Study (2020) estuary entrance modifications were listed as a top threat to environmental assets[133]. Environmental impacts of changing entrance conditions include loss of breeding grounds for migratory birds and significant alteration of aquatic flora and fauna assemblages at the inlet.
- A continually open entrance could increase the potential for scour of riverbanks.[134]
- Entrance modification has been shown to create large tidal range changes and unstable scouring that last for decades, with prognoses of centuries for them to reach new hydraulically stable regimes[135].
- Major works and capital investment would be required at Harrington and Farquhar Inlet to improve estuary flushing times and entrance navigability. These works would require further justification on environmental grounds, and are likely to require a commitment for ongoing maintenance (*for example dredging of the entrances*) in order for them to be viable[136].
- Depending on the required dimensions, it is expected that the total cost of a trained entrance at Farquhar Inlet may be in the order of $50-100M. A cost-benefit analysis is expected to indicate that a training wall constructed at Farquhar Inlet is not economically viable, particularly when considering the ongoing maintenance costs[137].
- Modified entrances (i.e. training/break walls) are still influenced by tides waves, currents, sediment movement and freshwater flooding. Interactions of these could cause entrances to silt up; direct coastal processes into adjoining water bodies;

[133] (MidCoast Council, 2020)
[134] (Parsons, 2010) p 13
[135] (Nielsen & Gordon, 2008)
[136] (Parsons, 2010) p 4.
[137] (BMT WBM Pty Ltd , 2019)

undermine associated structures and exacerbate down drift beach erosion. Threats from these pressures include boating, flows within coastal water bodies and inland estuary flooding.

- Multiple investigations of the entrances have highlighted issues of concern such as heavy shoaling and treacherous entrance conditions at the permanent entrance at Harrington.
- It is noted that a Parliamentary Taskforce is currently investigating the engineering and economic feasibility of a second break water at the Harrington entrance of the Manning River.

Modified hydrology

- Modified hydrology in the catchment through causeways and in the estuary with levees and floodgates has the potential to change flows and flushing times. In the estuary in particular, this can have consequences for sedimentation and reduced water quality.
- Modified hydrology within the catchment can result in reduction of freshwater inflows to the estuaries and may increase upstream saline intrusion; cause hyper-salinity; reduce nutrient and organic inputs required for primary production; change biological structure and function; and alter the physical features of the estuary mouth.
- The number and extent of structural barriers, largely causeways, within the Manning Catchment and Estuary impede and compromise fish movement, which can cause local extinctions or greatly reduce fish abundance and diversity138, as well as restrict migration, including to new habitats.
- Changes to hydrology through infilling of wetlands, drainage, channels, floodgates and levees in the floodplain have resulted in a range of impacts such as loss, fragmentation and reduction of EECs and freshwater wetlands and exposure of extensive Acid Sulfate Soils deposits, leading to poor water quality. This acid drainage can form a behavioural barrier that impedes fish movement through deterring migration or inhibiting swimming ability139.
- Poor water quality from acid drainage impacts oyster industry, amenity, local tourism and recreation within the estuary.
- Climate change predictions of inconsistent and extreme weather patterns can exacerbate these pressures and impacts.

[138] (Thorncrat & Harris, 2000)
[139] (Thorncrat & Harris, 2000)

- Obstructed/reduced freshwater flow into estuaries affects salinity levels, aquatic plant distributions, migration and spawning of aquatic animals, frequency of estuary mouth openings and fish communities.

6.2 Stakeholders

Management agencies

DPIE, MCC, NSW Government, Crown Lands, Maritime Infrastructure Development Organisation (MIDO), Parliamentary Taskforce – Southern Break water Harrington

Whose affected?

Oyster Farmers, recreation users, tourism industries, landowners

6.3 Existing Management Approach

- An estuary process study was developed for the Manning Estuary in 1997.
- Estuarine hydrodynamics modelling 'Manning River Estuary Management Study- Numerical Modelling Investigation' was completed in 2001.
- Flood models were developed as part of the 'Manning River Flood Study' (1991) 'Manning River Floodplain Management Study' (2019).[140] Details of the behaviour of flooding, such as flood level information were also obtained for Farquhar Inlet from these reports.
- Management of the Manning river estuary and its entrances is guided by a number of management plans including the Manning River Estuary Management Plan (EMP) 2009[141] and the Draft Farquhar Inlet and Old Bar Entrance Opening Management Plan (EOMP)[142]. The implementation of dredging activities is one aspect in these management plans that council is responsible for.
- The Farquhar Inlet opening strategy[143] describes options to manage the entrance to maintain appropriate water quality for community and economic values. Also provides recommendations for the future management of the entrance.

[140] (BMT WBM Pty Ltd , 2019)
[141] (Patterson Britton & Partners, 2009)
[142] (Parsons, 2010)
[143] (Parsons, 2010)

- Manning floodplain assessment and management guided by the Lower Manning River Drainage Remediation Action Plan (RAP).[144]
- Current dredging program for boating navigation at Harrington and Farquhar Inlet.
- Tidal gauges are installed in the Estuary.
- Water quality data has been collected by the Oyster Farmers Association and NSW Food Authority since 2003, Report Card Monitoring has been undertaken by DPIE for MCC since 2017.
- NSW Fisheries have mapped and prioritised fish barriers and commenced restoration of fish passage.
- Member for Myall Lakes, Mr Stephen Bromhead MP has established a Taskforce of experts to review options for providing a permanent entrance to the Manning River. The focus of the Taskforce is to provide further advice to the Government on the potential costs, benefits and technical feasibility of the various options for Harrington and Old Bar. A range of options are being considered, informed by a feasibility study undertaken by Manly Hydraulics Laboratory. That report identified a number of potential options including construction of a new breakwater, routine dredging, stabilisation of the Manning Point sand spit and creating an artificial spit using large sandbags.[145]

6.4 Knowledge Gaps

- Impacts of build-up of sediment, changing bathymetry, dredging.
- Trigger levels for entrance opening – do they allow sufficient flushing of sediment?
- Clarity and updated data for flushing times of estuary in closed and open scenarios.
- Entrance dynamics, including the interaction between the two entrances.
- Significant species and ecological impacts from permanent entrance openings from change in saline dynamics, inundation etc.
- Further additional long-term data collection including entrance conditions and inflow gauging.
- Cost benefit analysis of permanent entrance openings.
- Impacts on estuarine ecosystem health from trained entrance at Harrington

[144] (Glamore, Ruprecht, & and Rayner, 2016)
[145] (Stephen Bromhead MP, 2020)

Gaps/controls/recommendations from the Coastal Scoping Study relating to estuary entrance modifications:

- Review of previous literature/plans etc. on trained estuaries
- Trained inlet impacts on the wider estuarine environment
- Tidal prism regimes under climate change/coastal hazards scenarios
- Review of the physical structure and integrity of the existing engineered break walls
- Continue water quality monitoring of each estuary (report cards), seagrass monitoring program/mapping
- Entrance modifications are currently being considered by a NSW Ministerial Manning River Task Force will create very different hydrodynamic conditions for the estuary, including changes to the hydraulic efficiency of entrance, the tidal prism and how it interacts with freshwater inputs, coastal wetlands etc. This is of concern as the Manning estuary has a lot of low-lying lands in the lower floodplain. These changes need to be modelled and accounted for in management planning and actions. For example, if Moto and other coastal wetland systems are opened to tidal flow – what influence will entrance changes have? Will the entrance need more or less dredging?

6.5 What's working, what's not?

What's working:

- Harrington dredging program
- Shorebird assemblages at Farquhar are representative of pre-disturbance condition, and can be used as a reference site.
- There is limited call for access to the ocean from the river. Recreational boating is river-based. One business wants oceanic access to date. A study of harbours by Crown Lands identified Wallis Lake– Forster Tuncurry as the oceanic harbour in this district. Alternate port entrances are located in Port Stephens and Port Macquarie.

What's not working:

- Competing interests and lack of consensus on who and what are we are serving environmental values, community needs or economic development.
- Fragmented relationships between government agencies.
- Need to acknowledge risk of further entrance modifications in the CMP.
- Aboriginal cultural heritage understanding relating to flood notch maintenance is not adequately addressed through the Aboriginal Heritage Impact Permit (AHIP) register.

- Community perception doesn't match conditions on the ground. The Water Quality Report Card demonstrated good water quality at Farquhar but community still express belief that the ICOLL is "dead." Communications and public relations messages are not getting across. This is a statewide problem with ongoing community pressure to actively manage entrances.
- The entrance isn't working in its current form for boating access. Maritime access between the ocean and river has not been a significant issue historically. Crossing bar is difficult.
- The rock training wall (gantry wall) at Harrington is not designed to cope with existing environmental forces of oceanic swells. Wave action is dislodging rocks, pushing rocks over the top of the trained wall and causing deeper long-term damage that will need to be addressed at some point. Northern entrance migration puts extra pressure on training wall. Needs asset management/maintenance.
- Need more state-level support to tackle local issues through the Marine Estate Management Strategy (MEMS).

6.6 Opportunities

- Aboriginal management plan for Farquhar.
- More cohesive relationships between government agencies. DPIE now has a representative on the Manning River Taskforce.
- Develop a CMP specifically for the north entrance if additional modifications are recommended through the Ministerial Manning River Taskforce.
- State-level guidance for entrance modification is under preparation through the MEMS.
- If a new trained breakwall is installed and dredging is required, the sand spoil could be used for beach nourishment to address erosion (e.g. Old Bar, Manning Point).

6.7 Management Options

Planning

- Review the Farquhar Entrance Opening Strategy including flood height and water quality triggers, Aboriginal heritage management and a Standard Operating Procedure for entrance opening (in the Old Bar-Manning Point CMP).
- Develop a holistic approach to entrance management with agreed vision, targets, and plans, in collaboration with the community, business interests and agencies to.

Advocacy

- Advocate for transparency and integration between the Manning River taskforce, the Coastal Management Act and the Coastal Management Program.

Capacity Building

- Develop communication tools using best available science and case studies from other areas to build community understanding of entrance issues and an informed base for participation in decision-making.

Regulatory Compliance

Science and research

- Undertake a cost benefit analysis of permanent entrance opening options.
- Develop hydrodynamic and morphodynamic models to test impacts of different entrance modification options and use for decision making.
- Develop a platform for integrated monitoring data sharing between agencies and academic institutions. (Peter Scanes MEMS program for data sharing.
- Undertake a coordinated, event-based tidal gauging study at multiple locations (as per the 1998 MHL study) examining bathymetry, flows, salinity and updated bathymetry across the estuary.

On-ground

- Restore fish passage by removing or re-modelling identified priority barriers.
- Re-introduce tidal flushing to areas of floodplain.
- Design and implement asset maintenance program to ensure the Harrington breakwater gantry wall is stable.

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7. Erosion and Sedimentation

This paper considers sources, impacts and management actions for erosion and sediment in the Manning. Related CMP Issue Papers include Agricultural Impacts, Vegetation Management and Urban Stormwater. Sources considered here include dirt roads, driveways, earthworks, construction, forestry, infrastructure and boat wash.

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7.1 Situational Analysis

7.1.1 Activities and stressors

Erosion is the largest contributor to turbidity and nutrient pollution in water bodies. A high proportion of the mid and upper Manning catchment is comprised of steep slopes with shallow soil, many of which are used for farming.[146] A spatial risk assessment conducted for the Manning River Estuary Catchment Management Plan (CMP) highlighted that diffuse catchment runoff from agriculture is the driving force behind nutrients and sediments within the estuary.[147] Many tributaries in the catchment have narrow, fragmented or missing protective riparian vegetation.[148] Land-clearing and removal of woody debris leaves the floodplains, stream bed and banks more vulnerable to erosion.[149]

These issues are addressed in the CMP Issue Papers on Agricultural Impacts and Vegetation Management. Other activities that contribute to erosion and sedimentation are considered below. These include:

Unsealed roads, stock crossings and dirt driveways throughout the catchment have a localised impact on sediment loads (Map 1).

Forestry operations including dirt roads and timber harvest contribute sediment to waterways in the Manning.[150] Forestry is found in many upper subcatchments including the Barrington, Barnard, Myall Creek, Nowendoc, Dingo Creek and Lansdowne River (Map 2).

Infrastructure such as roads, weirs, bridges and stormwater drains create impermeable surfaces and barriers that redirect water through single points or culverts, leading to

[146] (Midcoast Water, 2011)
[147] (MidCoast Council, 2020)
[148] (Midcoast Water, 2011)
[149] (Midcoast Water, 2011)
[150] (Midcoast Water, 2011)

channelling of water. This increases the volume and velocity of surface water during rain events and the potential for erosion.

Construction sites disturb soil and create dust and debris. Construction includes Council road, bridge and drainage works and private rural infrastructure such as homes and dams.

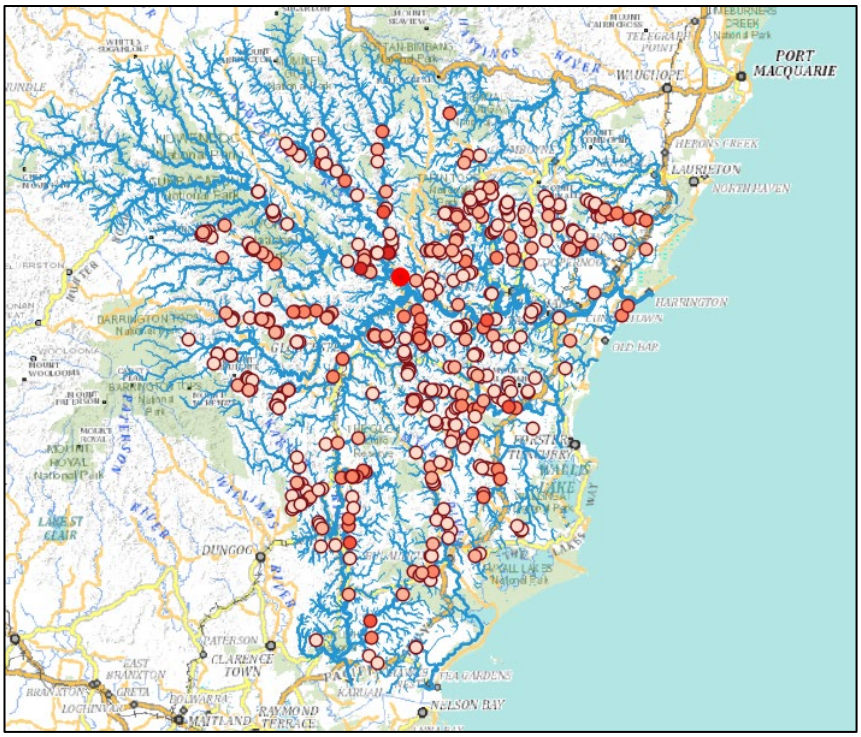
Riverbank erosion from boat wash is recognised as a significant issue for the future health and stability of our river systems by Transport for NSW and the community.[151] The Manning CMP Reference Group noted that flood, tide and wind waves are of more concern in the Manning main channels. However, there is community concern that boat wash erosion is causing significant bank erosion in the Lansdowne River which is acknowledged by the Department of Primary Industries.

The bushfires of late 2019 burnt 244,173ha, representing 30% of the catchment, with several subcatchments burning over 90%. Up to 335km of riparian vegetation was burnt. The potential for soil erosion after a bushfire can be severe due to the destruction of ground cover and the litter layer.

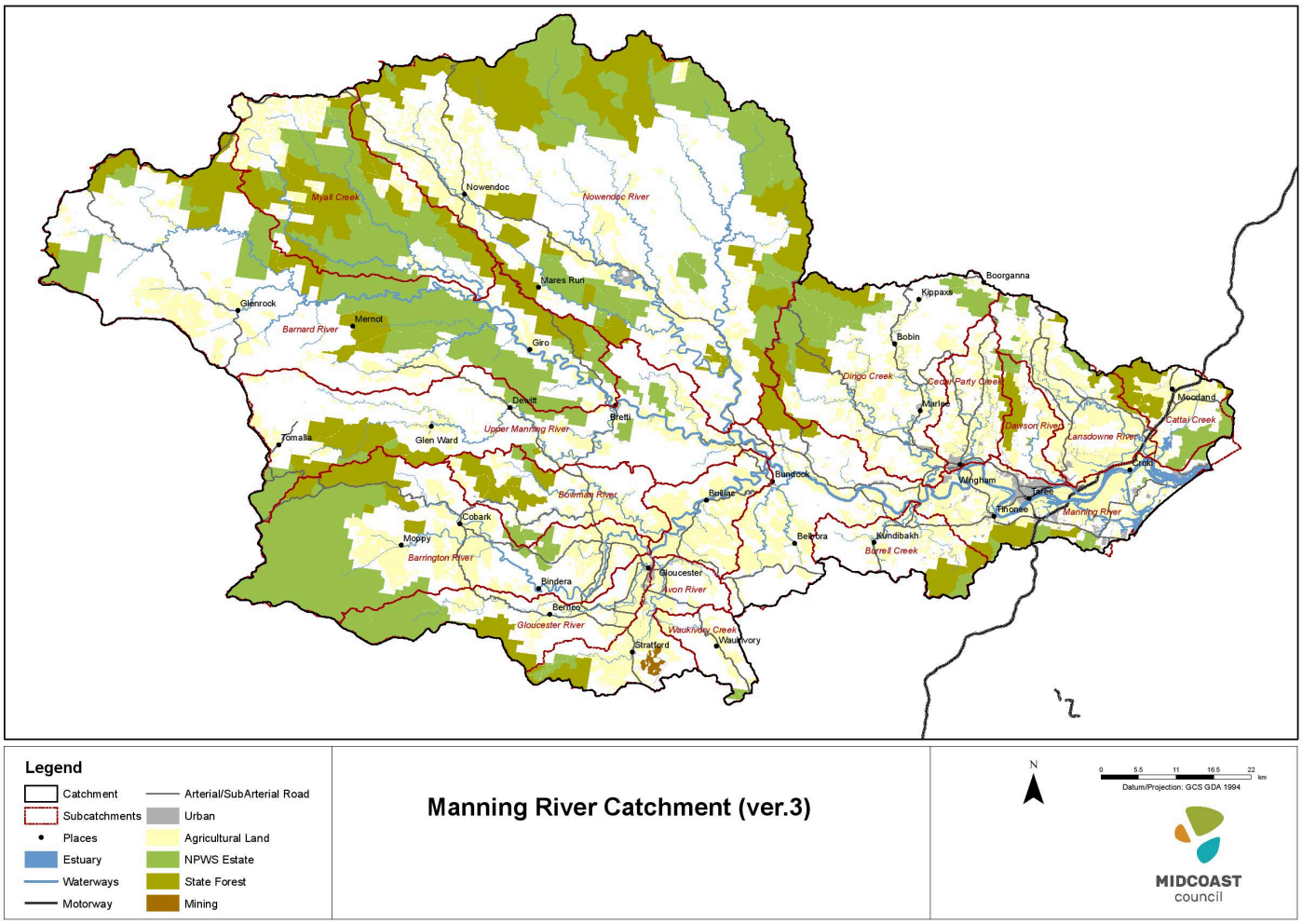
The relative contribution of these sources varies across the catchment and is unknown. The Great Lakes Water Quality Improvement Plan (GLC, 2009) identifies agricultural runoff, dirt roads and urban stormwater as very significant sources of pollution in the Wallis Lake catchment immediately to the south of the Manning. The high energy nature of the Manning Catchment has led to the view that floodplain stripping and bank erosion are the primary contributors.[152]

Preliminary data from the Barnard indicates that forestry operations are not as significant a source as expected. Unsealed road crossings can be observed increasing turbidity significantly locally during wet weather; however how this translates downstream and in the estuary is not known.[153] Modelling for the Wallamba and Crawford Rivers in the Great Lakes Water Quality Improvement Program found that remediation of unpaved roads would reduce sediment export from roads within the subcatchments but would have little impact on total loads and estuary sedimentation.[154]

[151] (Transport for NSW, 2020)
[152] (Raine & Gardiner, 1992)
[153] (Midcoast Water, 2011)
[154] (Great Lakes Council, 2009)



Map 1: There are about 800 unsealed roads crossing creeks across the whole MidCoast LGA.



Map 2: State Forest shown in khaki green is most prevalent in the upper catchments.

The Adapt NSW climate change data provides an overview of modelling results for the North Coast Region. While there is significant and complex variability, key trends forecast include increased intensity of rainfall and runoff events by 2050. This will increase the potential for pulse events with significant inputs of sediments to the estuary. More intense storms could lead to enlargement of streams through bed and bank erosion, thus releasing significant volumes of sediment downstream.[155]

A proposal to install a second training wall at Harrington will impact on tidal flows and storm surges, exacerbating bank erosion and sedimentation.

7.1.2 Impacts

The estuary has an average flushing time of 31.6 days, compared with a State-wide median estuary flushing time of 9 days (Roper *et al.* 2011). Due to the long residence time of fresh water, the estuary is sensitive to the accumulation of sediments. These inputs can severely degrade the ecological health of both the catchment and the estuary and cause a decline in social and economic values, such as swimming, oyster farming and the quality of raw water potable water supply and stock water.

Turbidity is a measure of the ability of light to penetrate the water. Suspended sediment, plankton, and detritus can contribute to turbidity. In the Manning the main cause of high turbidity is silt and clay.[156] It is usual for creeks to become slightly turbid following heavy rainfall, however, when high turbidity is recorded it indicates diffuse source sediment pollution from the sources listed in the previous section.[157] Spatial dispersion, volumes and the impact of sediment plumes on receiving waters vary according to conditions.

Estuary monitoring undertaken by MCC's Waterway and Catchment Report Card program and OEH's Estuary Monitoring Program has shown that the estuary experiences both high turbidity and algal levels in response to catchment runoff. This is highlighted in the 2014 and 2018 Report Card results:

"High turbidity levels were evident following periods of rainfall in the catchment, particularly in the middle and upper sections of the estuary. Likewise, chlorophyll-a concentrations were consistently high in the estuary, indicating that the system is currently acting as a massive nutrient sink" (Greater Taree City Council, 2014, p. 5.)

High concentrations of suspended sediments in rivers can:

- cause turbidity and reduce stream clarity
- inhibit respiration and feeding of stream biota
- diminish light needed for photosynthesis, reducing condition and extent of aquatic plants including seagrass at the base of the food chain
- cause eutrophication of rivers and wetlands

[155] (NSW Government, 2009)
[156] (Midcoast Water, 2011)
[157] (OEH, 2019)

- make water unsuitable for irrigation and cattle
- increased the cost of potable water treatment and infrastructure maintenance
- smother the stream bed, macroinvertebrate habitat and seagrass
- increase land flooding.[158]

Sedimentation is also an important contributor to the nutrient cycle, adding nitrogen and phosphorous associated with organic matter and fine clays.[159] Excess nutrients are associated with phytoplankton and algae blooms, including toxic blue-green algae.[160]

7.2 Stakeholders

MidCoast Council, Hunter Local Land Services, Transport for NSW, Department of Primary Industries - Fisheries (DPI-F), DPI - Forestry, Environmental Protection Authority, recreational boating associations.

7.3 Existing Management Approach

The Protection of the Environment and Operations Act 1997 is the primary legislation regulating the management of sediment from construction sites. It is an offence to pollute water under Section 120 of the PEO Act.

Erosion and Sediment Control Plans (ESCP) or Soil and Water Management Plans (SWMP) are used to manage erosion and sediment on construction sites and subdivision. These plans are submitted to council at the Development Application (DA) stage. It is the size of works that dictates which of the two kinds of plans will be used. Both plans are principal management tools used during works.

MidCoast Council's construction operations have a range of measures in place to ensure erosion and sediment are managed during roadworks and other infrastructure projects. The aim of all road drainage is to prevent the concentration of flow at any one point. Multiple drainage structures spread the flow and reduce the likelihood of concentrated flows and erosion. A Works Permit is issued for minor projects and a Review of Environmental Factors is prepared for projects subject to Part 5 of the Environmental Planning and Assessment Act 1979. The specific responsibilities of the Operations Works Engineers, Designers, Co-ordinators, Team Leaders and Team Members in relation to erosion and sediment control are documented and included in Position Descriptions and Individual Work and Development Plans. There are work procedures for erosion and sediment control on road construction, reconstruction and maintenance works. A field guide for outdoor staff

[158] (NSW Government, 2009)
[159] (NSW Government, 2009)
[160] (NSW Government, 2009)

including standard drawings and photographs of best practice erosion and sediment control was updated in 2019 by the Soil Conservation Service, and all staff involved in construction received training.

Forestry plantations and native forests on public and private land are managed by the NSW Government for economic (wood and forest products), social (jobs and recreation) and environmental benefits (carbon, biodiversity and soil and water conservation), and cultural heritage values. The Environmental Protection Authority is responsible for the regulation of native forestry operations on private and public land in NSW. Following the 2019-20 fires, DPI – Forestry recommended risk controls to reduce sediment loads from fire-affected plantations and appointed an audit team. Controls included improving road and track drainage to ensure that increased overland flow onto roads and tracks is dispersed without undue concentration of flow or increased velocity; regular inspection and stabilisation of mitre drains to prevent scouring, and a recommendation that to the sensitivity of the flow lines, plantations in the riparian zone should be deferred until a reasonable groundcover has re-established within the stream.[161]

Bank erosion caused by boat wash was identified as an issue during consultation for the NSW Boating Strategies by Maritime NSW (now Transport for NSW - Maritime). As a result, the department planned to develop a statewide strategy and use pilot projects in the Tweed, Clarence and Williams Rivers to assess:

- the condition of riverbanks and potential solutions for managing the effects of erosion.
- possible infrastructure investment options for the rivers.
- if relocation of some water activities is possible or desirable.
- potential changes to regulation in order to better manage boating and erosion.[162]

Currently (2020) development of a statewide boat wash erosion strategy has not proceeded, and the focus is on developing a trialling innovative approaches to bank stabilisation, with trials underway in Nambucca and Tweed.

A submission by Transport for NSW to the Manning River Estuary CMP Reference Group consultation stated that with regards to source control, *"NSW Maritime promotes all forms of waterway activity in line with community expectations but does not generally support the characterisation or zoning of the waterways that segregate different forms of boating activities."*

[161] (DPI - Forestry, 2020)
[162] (Transport for NSW, 2020)

Hunter Local Land services engaged the Water Research Laboratory to evaluate bank erosion in Pelican Bay and prioritise reaches for remediation.

Remediation of erosion and sediment from dirt roads and riverbank erosion commenced in 2019, in a project funded through the MEMS and delivered by MidCoast Council. A section of the Lansdowne River at North Moto was stabilised with rock revetment

7.4 Knowledge Gaps

- Characterisation of sediment contributions from the full range of sources
- Extent that runoff of sediment into waterways from unsealed roads contributes to sedimentation in waterways, subcatchments, river and ultimately the estuary.
- Extent and impact of boat wash erosion on environmental, social and economic values. Prioritisation for remediation.
    - Consider high impact boat wash e.g. wake boats (intensive, only in certain locations) vs boat wash from daily/regular use (e.g. Lansdowne).
    - Contacts: Macquarie University, Kirsty Fryors; WRL; Brendon Kelleher re desktop and drone studies; Stephen Holtznagel (DPIE) re estuary hydro and bank surveys; Emma Wilkes from DPI for prioritisation tool and best practice remediation.
    - Identify high-use sites, boat movements and trends e.g. traffic counters at boat ramps during peak times.
    - Shape of river and depth needs to be part of identifying high-risk sites re boat wash erosion.
    - Use markers in the river to estimate wake height.

7.5 What's working, what's not?

What's working

- Council sediment and erosion control project in 2020 with road maintenance team embedding best practice into an Environmental Management System
- Current MEMS-funded project to addressing source pollution from roads – e.g. sealing creek approaches, causeways etc. Could improve the prioritisation process.
- Sealing of intensive stock crossings in Great Lakes area.

What's not working?

- Clearing of roadside vegetation for road maintenance and weed control on verges is causing erosion and sedimentation.
- Forestry operations –anecdotal. Clear felling has downstream impacts.
- Boat wash erosion is an issue in the estuary catchment.
    - Wake boarding impacts at Pampoola. Good location for skiing/wakeboarding due to infrastructure, as well as conditions.
    - Bank protection isn't often funded by TfNSW-maritime.
    - Boat wash erosion issues on the Lansdowne, with large areas of undercutting of riparian vegetation on private and public land (e.g. TfNSW site).
    - Weak REF process for new or upgraded boat ramps.
- Gloucester River – legacy issues causing bank erosion.
- Legacy issues with erosion and sediment from private properties including driveways, dam batters etc. Difficult to prosecute.

7.6 Opportunities

- Several project through Marine Estate Management Strategy (MEMS) that we could bring to the Manning:
    - Upgrading Blue Book with a focus on urban construction.
    - Initiative 2 of MEMS is a riverbank management strategy. Manning is listed as medium priority. Offering matching funds could help push us up the priority level.
    - A tool to prioritise banks for stabilisation is available.
    - Initiative 1a of MEMS is a water quality working group to document and identify who is responsible for what (contact Neil Gemmell).
- Rural strategy: Marine use and access audit, waterways zone review, DCP for sediment and erosion control.
- Use a recreation management plan and strategic development of public infrastructure to encourage people to go where we want them, and not go where we don't, e.g. cCarparks, boat ramps, toilets.
- Target works to reduce turbidity at potable water offtakes.

- Research partnerships to assess impacts/benefits of sediment control projects.

7.7 Management Options

Planning

- Require developments within potable water subcatchments and groundwater aquifers identified in the LEP to be integrated developments.

Advocacy

- Advocate for Transport for NSW – Maritime to support and co-fund research and mitigation of boat wash erosion.

Capacity Building

- Promote understanding and commitment to erosion and sediment control through the construction industry, forestry, landholders and recreational boat users.
- Promote reporting of illegal vegetation clearing in the riparian zone.

Regulatory Compliance

- Reduce erosion and sediment runoff from construction sites through development controls, regulation and enforcement.
- Improve compliance activities to prevent illegal clearing of mangroves and riparian vegetation.

Science and research

- Characterise of sediment contributions and impacts on community values from the full range of sources.
- Assess the location, extent and impact of boat wash erosion on environmental, social and economic values. Prioritise for remediation.

On-ground

- Control erosion of unpaved roads and creek crossings in priority areas by sealing or diverting run-off into biofilters.
- Establish an EMS and capacity building program for Council operations to improve erosion and sediment control.
- Stabilise priority riverbanks using best practice methodologies.

7.8 References

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8. Flood, Coastal Inundation, Tidal Inundation

8.1 Situational Analysis

Under the Coastal Management Act 2016, the Coastal Zone comprises the following coastal management areas mapped in the Coastal Management State Environmental Planning Policy (SEPP):

(a) the coastal wetlands and littoral rainforests area,

(b) the coastal vulnerability area,

(c) the coastal environment area,

(d) the coastal use area.

A coastal management program may be made in relation to the whole, or any part, of the area included within the coastal zone.

MidCoast Council is currently preparing two programs under the Coastal Management Act. The scope of the Manning River Estuary and Catchment Management Program (Manning CMP) will cover issues and management actions for all Coastal Management Areas mapped in the Coastal Management SEPP 2018 in the Manning estuary, commencing 2 km inland from the average low tide water mark (Attachment 1). The Area of Interest (AOI) extends to cover the Manning river, its tributaries and the catchment (Attachment 2).

Concurrent to the development of the Manning River Estuary CMP, a CMP is being prepared for the 'coastal erosion hotspot' of Old Bar - Manning Point. The Old Bar -Manning Point Coastal Management Program (OBMP CMP) covers from the average low tide water mark to approximately 2 km inland.

There are several objects of the Coastal Management Act 2016 relating to flood, coastal inundation and tidal inundation within the planning area for the Manning CMP. These include:

(e) to facilitate ecologically sustainable development in the coastal zone and promote sustainable land use planning decision-making

(f) to mitigate current and future risks from coastal hazards, taking into account the effects of climate change

(g) to recognise that the local and regional scale effects of coastal processes, and the inherently ambulatory and dynamic nature of the shoreline, may result in the loss of coastal land to the sea (including estuaries and other arms of the sea), and to manage coastal use and development accordingly

(i) to encourage and promote plans and strategies to improve the resilience of coastal assets to the impacts of an uncertain climate future including impacts of extreme storm events

Under the State Environmental Planning Policy, the Coastal Vulnerability Areas are defined as land subject to current and future coastal hazards.

There are seven types of coastal hazard defined by the Act. Within the Area of Interest for the manning CMP, the potential hazards could include:

- coastal inundation
- tidal inundation
- erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters

The primary aim of the CMP is to document practical actions to be carried out by council and other stakeholders to address risks from coastal hazards and risks to the health of the estuary. Most of the council actions will be implemented through council's Delivery Program and Operational Plan, environmental planning instruments and plans of management for community land or Crown land under council control. CMPs under the Coastal Management Act are not intended to take precedence over other council plans, but rather provide information to support the more effective consideration of coastal hazards and estuary health in other statutory and operational plans.

In the case of flood, coastal inundation and tidal inundation, the primary planning document is the Manning River Floodplain Risk Management Study and Plan

8.1.1 Flood

MidCoast Council engaged BMT WBM (2019) to prepare the Manning River Floodplain Risk Management Study and Plan. The study area encompasses the low-lying floodplain area downstream of Wingham. The principal source of flooding considered within the study is mainstream flooding of the Manning River. The impact of climate change in the form of increased rainfall intensities and sea level rise has also been considered.

There is a long and relatively frequent history of flooding within the lower Manning River catchment. The three largest floods on record occurred in 1866 (peak flood level: 5.15 m AHD), 1929 (peak flood level: 5.6 m) and 1978 (peak level: 5.45 m). In more recent years, large flood events have occurred in 1990 and 2011, with a smaller event in 2013.

The Manning River Floodplain Risk Mgmt. Study and Plan (BMT WBM 2019) defines the flood behaviour of the catchment. Through the establishment of appropriate numerical models, the study covers flood flows, velocities, levels and extents for a range of flood event magnitudes under existing and future catchment and floodplain conditions. It assesses risk to infrastructure including residential and commercial property.

The Manning River Floodplain Risk Management Study and Plan considers climate change scenarios as follows:

- Predicted increased rainfall intensity: modelled 10% and 30% increased rainfall
- Sea Level Rise (SLR): +0.28 m by 2050; and +0.98 m by 2100.
- Great Lakes CZMP: SLR scenarios include: 2050 = +0.4 m; and 2100= +0.9 m

The Floodplain Risk Management Study (FRMS) has derived an appropriate plan of measures and strategies to manage present and future flood risk in accordance with the NSW Government Floodplain Development Manual. These include flood modification measures, property modification measures, risk modification measures and emergency measures (e.g. evacuation, sandbagging etc.).

The FRMS has also identified a Flood Planning Area for the Manning River floodplain. Development of land within the Flood Planning Area is restricted and controlled by Council due to the hazard of flooding. In defining the Flood Planning Area in the MidCoast LGA, Council has considered a future flood scenario that has accounted for climate change in the form of increased rainfall and sea level rise in a combined riverine flooding and high tail water scenario to the 1% Annual Exceedance Probability (AEP, 1 in 100-year event) plus a freeboard of 500mm.

The Plan will be benchmarked against the mandatory requirements of the Coastal Management Act and noted in the Manning CMP as the appropriate management approach for flooding.

8.1.2 Coastal Inundation

Coastal inundation is the flooding of coastal management areas by ocean waters. According to the NSW Coastal Management Program Manual Part B Stage 2 (2018):

> *"Coastal inundation occurs when a combination of marine and atmospheric processes raises ocean water levels above normal elevations and inundates low-lying areas or overtops dunes, structures and barriers. It is often associated with storms resulting in elevated still water levels (storm surge), wave setup, wave run-up and over-wash flows. In the longer term, the extent of coastal inundation will be influenced by water levels that are elevated by other processes such as climate change and sea level rise."*

Coastal inundation on the NSW coast is most often associated with east-coast lows (Heimhuber et al 2019). It is typically a short-term event with waters receding to normal conditions. Coastal inundation from storm surge in the Manning River Estuary is caused by a confluence of low barometric pressure, strong onshore winds, high tides, and trapped coastal waves.

Coastal inundation generally affects the open coast and low-lying areas near the entrance, such as Harrington. For the Manning CMP AOI, threats associated with coastal inundation

include rising groundwater, impacts on coastal wetlands and vegetation, inland estuary flooding and damage to riverbanks and infrastructure.

The Manning River Floodplain Management Study (BMT WBM 2016) considers flood events driven by both catchment and oceanic processes, with the potential impact of climate change on flood behaviour within the catchment. As mentioned above, it covers flooding under climate change scenarios:

- Increased rainfall: 10% increase to design rainfall at 2050; and a 30% increase to design rainfall at 2100.
- Sea level rise increases of 0.28 m by 2050 and 0.98 m by 2100.

Storm surge is factored into tail-water levels. In general, coastal inundation causes more frequent nuisance flooding while riverine flooding is less frequent but causes more damage. Impacts include reduced efficiency of stormwater infrastructure and increased groundwater levels.

Modelling in the MRFMS (2016) shows that in storm events, the impact of water across land from high rainfall and riverine flooding will always be higher than the impact of coastal inundation. The flood mitigation, planning and emergency response measures set out in the MRFMS and Plan (2019) should therefore provide an effective management approach to coastal inundation.

This picture is complicated by Heimhuber et al (2019), who state that while “east coast lows have the potential to simultaneously trigger storm surges and catchment flooding, there are few recorded instances of large catchment flooding coinciding with extreme sea levels along the NSW coast.” The authors advise this may be because the NSW coastal database contains only 20 years of continuous water level data, which is not adequate to capture a statistically significant number of major floods. In the Manning River Estuary, there is historic anecdotal evidence that coastal inundation has led or combined with riverine flooding in some locations.

The current priority is to understand impacts of coastal inundation on Acid Sulfate Soil and coastal wetlands, to inform MCC’s strategy to acquire and restore ASS. A study is underway by DPIE to evaluate the impact of climate change including coastal inundation on the distribution of mangroves and saltmarsh under three sea level rise scenarios (0.5m, 1.0 and 1.5m on the open coast, noting that the amount of SLR will be different at different locations inside the estuary). This assessment was undertaken on a State (NSW) basis in 2019. Several NSW estuaries are being assessed in more detail through local case studies, one of these includes the Manning Estuary. The research project is being undertaken by Science Division, Environment, Energy and Science, Department of Planning, Industry and Environment (DPIE) and will be a valuable input to the CMP Stage 3.

Heimhuber et al (2019) provide guidance on estimating the ocean boundary for flood risk assessment in estuaries, including coastal inundation.

8.1.3 Tidal Inundation

The Coastal Management Program Manual Part B Stage 2 (2018) defines Tidal Inundation or nuisance flooding as *"the inundation of land by tidal action under average meteorological conditions*." It causes short term nuisance flooding in low-lying coastal areas.

Tidal inundation is mapped in the Manning River Floodplain Management Study (MRFMS 2016), using the High High-Water Spring tidal signature provided in the Flood Risk Management Guide (DECCW 205) for locations south of Crowdy Head as the ocean water level boundary.

The MRFMS 2016 covers tidal inundation due to sea-level rise in base-flow conditions, for HHWS(SS), HHWS(SS)+2050 SLR and HHWS(SS)+2100SLR. HHWS(SS) means High High-Water Springs (Solstice Spring) which is essentially HAT (Highest Astronomical Tide i.e. no storm surge or anomaly included).

In the NSW Estuary Tidal Inundation Exposure Study (NSW Department of Planning, Infrastructure and Environment DPIE 2018) assessed the exposure of current development to tidal inundation associated with a range of potential, future sea level rise (SLR) scenarios. Types of infrastructure assessed include properties, roads and powerlines.

The study focused on exposure to tidal inundation at the High High-Water Solstice Springs (HHWSS) level and/or berm height in mostly closed coastal lakes and lagoons. The HHWSS tidal plane is consistent with levels for higher (king) tides. SLR scenarios of 0.5 m, 1.0 m and 1.5 m are assessed. The use of a 0.5 m water level offset also allows a first order estimation of effects of less frequent inundation at around the 100-year annual return level associated with storm surge and other non-tidal processes (excluding wave setup, run-up and riverine flooding effects).

Results show that the Manning River has been classified as a Mature Barrier Estuary. These estuaries are characterised by relatively narrow and shallow entrance channels of relatively constant width and constant depth, consisting predominantly of sandy bed sediments. The shallow nature of the channels promotes tidal resonance which is counter-balanced by energy losses across entrance shoals and frictional dissipation at the sandy bed. Consequently, the tidal range along the estuary nearly always displays initial attenuation, followed by mild amplification before complete damping at fluvial gravel and sand bars around the head of the estuary (NSW Government 1992). Thus three kilometres upstream from the estuary mouth, the tidal range is only 50% of the ocean value because of the dissipative effects of the entrance bar.

The Manning river was placed in the North Coast region of this study. For the entire North Coast region:

- 6,816 properties are exposed to tidal inundation (HHWSS) with 0.5 m of SLR

- 15,593 properties are exposed to tidal inundation with 1 m of SLR, and
- 22,808 with 1.5 m properties are exposed to tidal inundation with 1 m of SLR.

The 10 most exposed estuary systems in the North Coast region are shown in Figure 1 (DPIE 2018). The Manning is included in these systems.

8.1.4 Climate Change

In New South Wales, climate change has already caused an increase in mean sea level of over 10 cm, changes in the seasonality of rainfall, increases in the average land temperature of around 0.8°C and in the average sea surface temperature of 1.5°C (Heimhuber et al 2019).

The Adapt NSW climate change data provides an overview of modelling results for the North Coast Region. While there is significant and complex variability, key trends include:

- Increased extent of dry periods by 2050, resulting in major periods of low flow potentially impacting the estuary;
- Increased intensity of rainfall and runoff events by 2050. This will increase the potential for pulse events with significant inputs of sediments to the estuary;
- Warming climate
- Inundation within the floodplain across the acid sulphate soils.

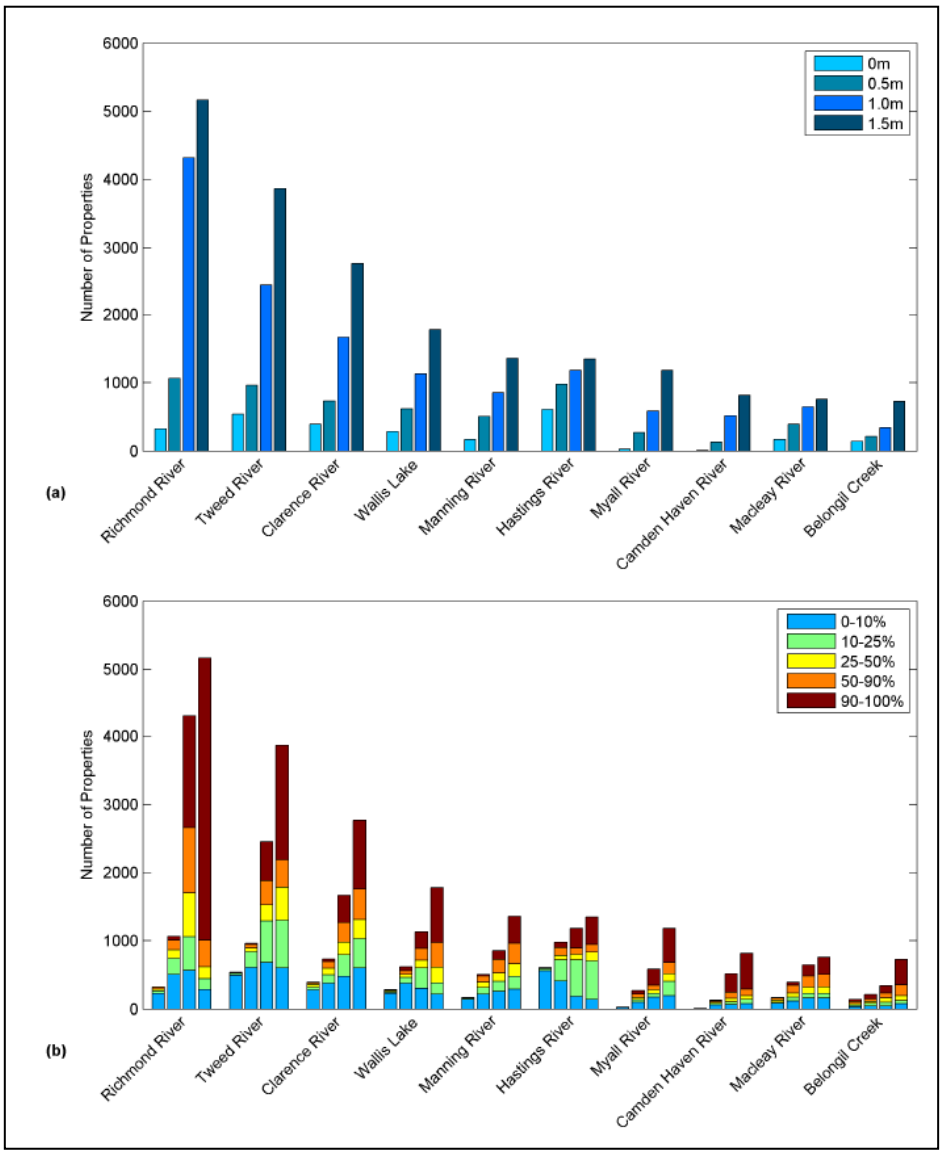


Figure 1: Total numbers of properties exposed to inundation (HHWSS) for the 10 most exposed estuaries in the North Coast region.

Pressures associated with climate change are predicted to introduce or exacerbate a number of issues in the Manning River Estuary and its catchment. Some of the existing management issues and approaches to be included in the CMP are outlined below.

Coastal inundation and Flood: Increased rainfall intensities and sea level rise scenarios are projected to impact on ocean boundary conditions. These potential changes will translate into increased coastal and flood inundation, such that future planning and floodplain management in the catchment will need to take due consideration of this increased flood risk (see below).

Sea Level Rise: Sea Level Rise is attenuated as one moves landward through the estuary. For the Area of Interest covered by the Manning River Estuary CMP, the most immediate risk of Sea Level Rise to be addressed through the CMP will be impacts on coastal wetlands (see below). There is a large proportion of the Manning River floodplain where emergency management is the only reasonable management option for inundation caused by flooding and coastal inundation. However, the enduring aspect of Sea Level Rise induced by climate change will mean that at some point in the future, emergency management arrangements will be increasingly less effective as a management approach. Further study and assessment will be required to identify this threshold and associated secondary impacts that will require mitigation. This will be addressed in Stage 5 (implementation) of the Manning River Estuary CMP.

Coastal wetlands: are highly vulnerable to climate change impacts particularly sea level rise. Management options to protect, restore and improve resilience of coastal wetlands, including migration pathways, will be considered in the CMP.

8.2 Stakeholders

Management agencies

MidCoast Council; NSW State Emergency Service; Adapt NSW; Department of Planning, Industry and Environment.

Who's affected?

Landowners on the floodplain and coast.

8.3 Existing Management Approach

Riverine flooding, tidal inundation and coastal inundation are managed through the Manning River Floodplain Risk Management Study and Plan (2019).

The Manning River Floodplain Management Study and Plan (BMT 2019) notes that flood gates are fitted in several locations in the lower Manning estuary to limit inundation from both riverine flooding and tidal inundation. The gates provide immunity from more regular events and impede saltwater flow into stormwater infrastructure. Some of these gates contribute to a significant reduction in flood risk; for example, the large western piped culvert under Manning Point Road at Manning Point is fitted with gates which provide immunity up to the 20% AEP event. Another example is the historic flood gate on Croakers Creek, Oxley Island which provides protection from daily tidal inundation and from minor, more frequent riverine flooding events to a significant portion of Oxley Island.

With the increasing risk of climate change related sea level rise and more frequent tidal inundation events, flood gates will take on even greater importance. The FRPMSP (BMT

2019) notes that the constant exposure of floodgates to a marine environment means they have a finite life, which will be considered in the Management Options.

Additional floodgates are located on private land, which are managed by the Drainage Unions to keep saltwater from pasture. Some floodgates are owned and operated by Council.

Farquhar is opened to mitigate flooding in accordance with the Farquhar Entrance Opening Strategy 2010. The current trigger level for opening is 1.6m AHD. The entrance opening strategy needs to talk to flood risk management plan; also plan for sand nourishment; and the opening training plan.

Emergency planning and response is covered by the MRFMS and Plan (2019), State Emergency Services Emergency Plan for the Manning River and Estuary. Within the Old Bar Manning Point AOI there is an Emergency Action Plan prepared for Greater Taree Council under the Coastal Protection Act 1979 for coastal erosion emergencies.

Current thinking is that a new Emergency Response Sub Plan is not required.

Infrastructure management: MidCoast Council is developing a Climate Change Adaptation Framework to manage climate risks on Council infrastructure assets. The Framework process will be outlined in the Manning River Estuary CMP.

Acid Sulfate Soil discharge: The Lower Manning Drainage Remediation Plan (Glamore et al. 2016) examined the impact of sea level rise on the Manning River floodplain, using sea level rise projections for 2050 and 2100. The greatest issue identified is elevated low tides, which will reduce drainage from low-lying back swamps within areas identified as high ASS risk.

A Climate Change Risk Assessment was completed by Greater Taree City Council. It sets out a range of actions for climate change adaptation and mitigation.

Key references include:

- The NSW Estuary Tidal Inundation Exposure Study (NSW Department of Planning, Infrastructure and Environment DPIE 2018)."
- Climate change in estuaries: State of the science & guidelines for assessment (Water Research Lab, NSW Office of Environment and Heritage and Macquarie University).

8.4 Knowledge Gaps

The top priorities for further research identified by the discussion group workshop (2/9/2020) are:

- Impacts of more training walls on coastal and tidal inundation
- Need for bathymetry study in the estuary
- Research to support the Farquhar Entrance Opening Strategy.
- Assessment of floodgates.

The following knowledge gaps were identified:

- Assessment of floodgates is underway as an update to the RAP:
    - Where are the gates in the main channels?
    - Not the sub-gated behind the main gates.
    - What is the likelihood for inundation behind them now and in climate change conditions?
- Drainage unions – what is the scope for growing knowledge and capacity within these groups…?
- Overbank inundation – where does it occur?
- Landholder attitudes to inundation: how willing are they to engage in adaptation measures such as identifying retreat areas and removing stock from high risk areas.
- Impact of new training walls on flood behaviour and tidal range.
    - How would salinity dynamics change?
    - Hydrodynamics and bathymetry?
    - Saline intrusion upriver and possible impacts on Bootawa in the future?
- Farquhar opening: is the current level of 1.6 AHD most appropriate trigger? Can we go higher? What is the impact on shorebirds?
- Hydrodynamic functioning and updated bathymetry for Farquhar estuary and mouth. Possibly LIDAR for tidal area.
- Is the depth of the ICOLL an issue for ecosystem health?

- Currently good triggers in the flood plain management plan re riverine flooding. Need research to identify appropriate triggers for oceanic flooding (e.g. sea level rise, tidal, etc.). This issue will increase as sea level rises.
- Management responses under sea level rise scenarios - will these change, or just increase in frequency?
- Future impacts on creeks behind Harrington and Croki (and Manning point/Old Bar)
- Need more regular beach escarpment modelling between Farquhar and Manning point. Very thin berm here with a flood risk to Manning Point if breached.
- We know large freshwater floods impact estuary function, but we haven't quantified it. Is the estuary ecosystem health driven by floods, or prolonged dry periods?
- How significant is the influence of the catchment on water quality in the estuary?
- Interaction between sea-level rise and flood. Combining probabilistic hazard modelling study with flood study. E.g. erosion recession focus: Does this increase flood risk, or loss of Manning Point.? How do the two models interact? (E.g. Big flood + big swell + high tide events).
- Cost Benefit Analysis: what areas will change (e.g. convert to coastal wetlands). Will it be regular or event based? Impacts on land use/change.
- Changes to saltmarsh and mangroves. Particularly saltmarsh: where will it retreat to? Do grazing pastures create a barrier?

8.5 Management Options

Planning

- Complete the Climate Change Adaptation Framework to manage climate risks on Council infrastructure assets such as roads and stormwater systems.
- Prepare mapping to inform a future planning proposal for a Coastal Vulnerability Area to be added to the Coastal Management SEPP, LEP and DCP.
- Address SLR threats to stormwater infrastructure through the Integrated Water Cycle Management Plan
- Review emergency plan for manning Point to incorporate coastal impacts (OBMP CMP).
- Prepare a Review of Environmental Factors for the Dredging Plan (reference?) to consider the impacts of dredging on hydrodynamics, tidal prism impacts and shorebird habitat (sand shoals).

Capacity Building

- Engage with the State Emergency Service to build capacity for long-term emergency plans responsive to climate change impacts.
- Build community awareness, understanding and preparedness for climate change impacts on flooding and inundation.

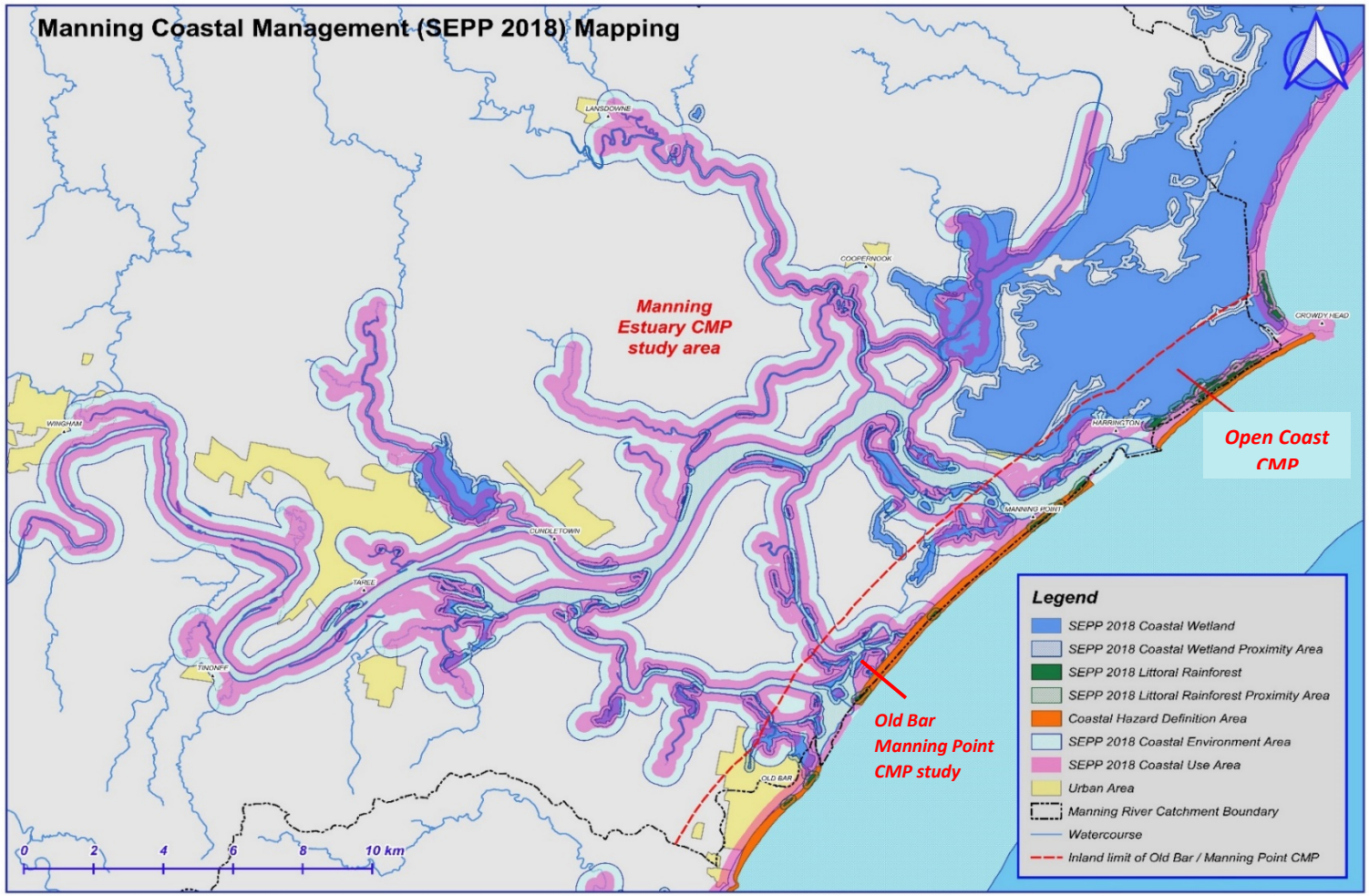
Science and research

- Identify Sea Level Rise thresholds at which existing coastal inundation emergency strategies will cease to be effective, associated secondary impacts, adaptation and mitigation strategies.

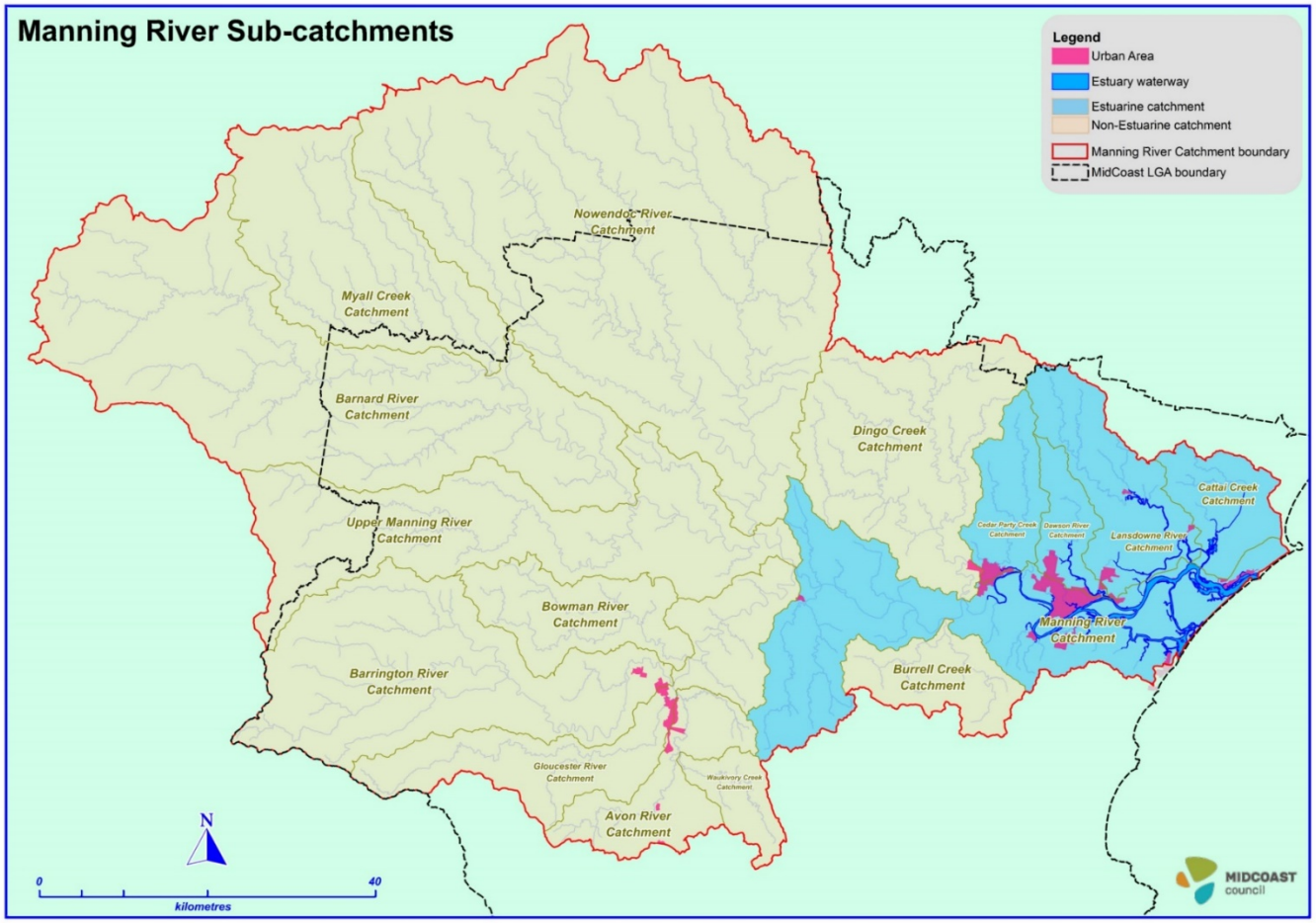
On-ground

- Implement the Climate Change Risk Assessment.
- Ensure floodgate maintenance and replacement is programmed through MCC's asset maintenance program.

Appendix 1: Coastal Management Areas and Planning Area for Manning ECMP



Appendix 2: Manning River Catchment



9. Floodplain Drainage, Acid Sulfate Soil and Blackwater

The Manning River floodplain covers approximately 450 km^2 with an extensive network of drainage canals, coastal wetlands, back swamps and 6 low-lying islands predominantly used for agriculture. This analysis covers issues relating to floodplain drainage and water quality including acid sulfate soil and blackwater events. Related issues addressed in separate papers include *agricultural impacts* and *coastal wetlands*.

Contributors: Louise Duff, Prue Tucker, Gerard Tuckerman, Bob McDonnell, Karen Bettink, Tanya Cross, Geoff LeMessurier, Will Glamore, Brad Henderson.

9.1 Situational Analysis

Acid Sulfate Soils

Acid sulfate soils (ASS) formed naturally on the Manning estuary floodplain from 3,000 to 6,000 years ago. When waterlogged under natural conditions the soils are harmless. However, when exposed to atmospheric oxygen the soils can create high concentrations of sulphuric acid (pH <4.5) and heavy metals (e.g. iron, aluminium).

The Manning estuary floodplain has 33,797 hectares of potential acid sulfate soils (PASS) and four areas identified as ASS Hot Spots.[163] Cattai Creek-Pipeclay Canal is classified as one of the worst ASS hotspots on the NSW east coast.[164]

Over the past two centuries an extensive network of drainage channels was installed on the Manning floodplain to mitigate inundation and flood, promote dry-land pasture and prevent saline intrusion (Figure 1). As a result, prolonged drying of the floodplain allowed oxygen to penetrate the ASS sediments, acidifying soils and groundwater.2

Following rainfall events extensive floodplain areas can be impacted by acidic runoff and high concentrations of heavy metals. The drains quickly transport the acid water into the Manning River estuary.

ASS pollution has significant adverse impacts on water quality, aquatic species and ecosystems, amenity, oyster production and commercial and recreational fishing.

[163] (NSW Government, 1999)
[164] (Glamore, Ruprecht, & and Rayner, Lower Manning River Drainage Remediation Action Plan, 2016)

High risk areas

The highest priority ASS areas for remediation are Moto, Ghinni Ghinni and Big Swamp (Figure 2). These three areas contribute 81% of the overall acid drainage risk. Ghinni Ghinni Creek, Dickenson's Creek, Lansdowne River and the northern arm of the Manning River downstream of Dumaresq Island are the highest acid impacted surface water areas in the estuary.

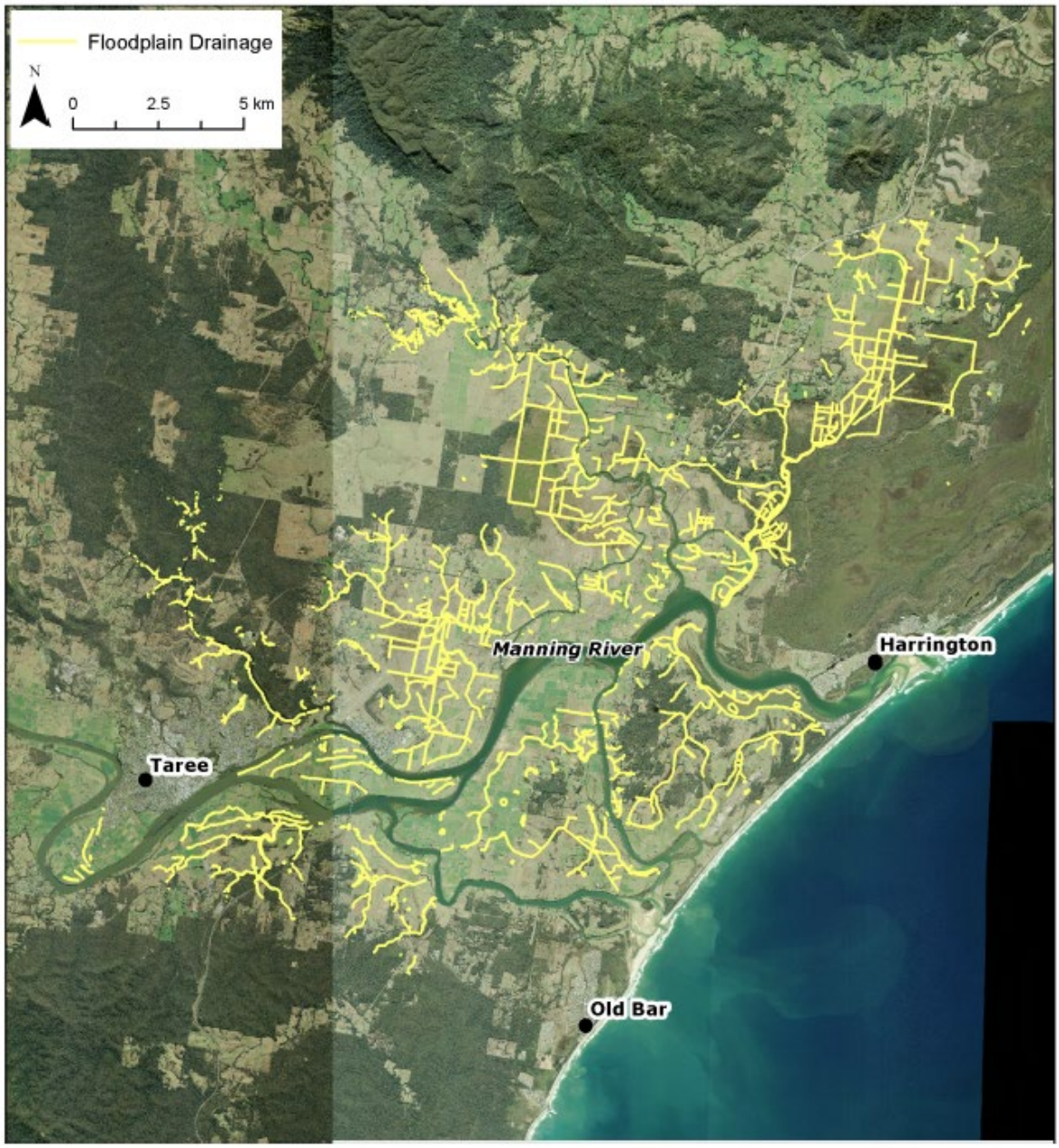


Figure 1: Drainage channels in the Manning River floodplain

Glamore and colleagues (2016) assessed the impact of rising sea levels on the Manning estuary floodplain as predicted for 2050 and 2100. Forecasted increases in high tides will

reduce drainage, cause overtopping of levees, impact on back swamp connectivity, and affect agricultural productivity in some regions. The Lower Manning River Drainage Remediation Plan notes that the greater issue for land management will be elevated low tides, which will reduce drainage from low-lying back swamps[165].

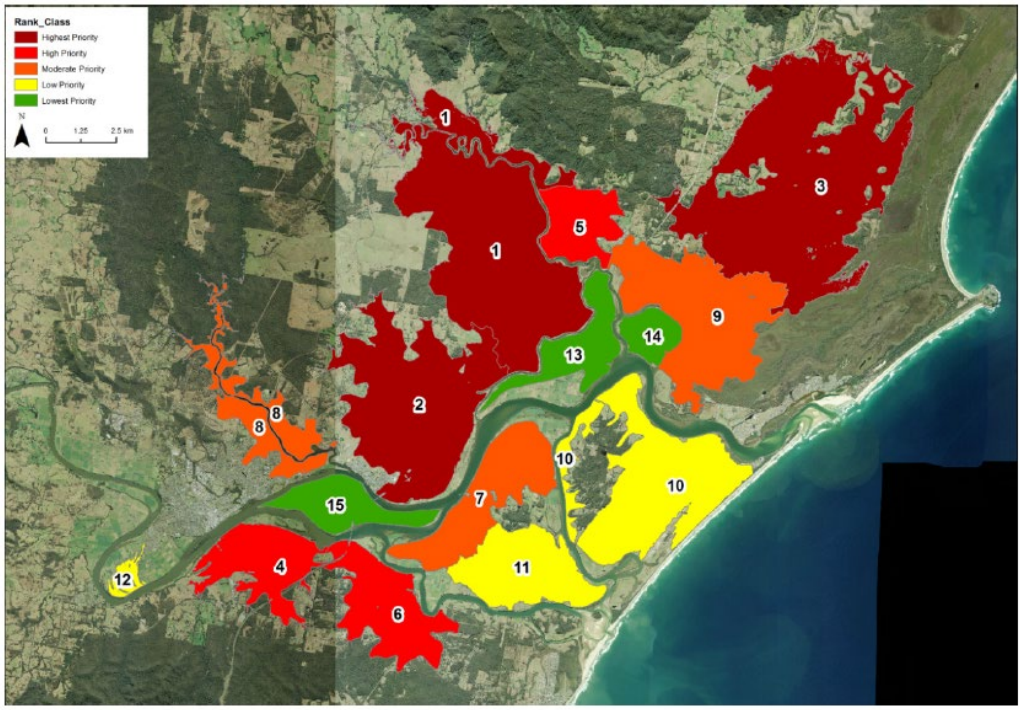


Figure 2: Final priority rankings of catchment-wide ASS assessment (Glamore et al 2016)

Blackwater

Blackwater forms on the Manning floodplain when severe rainfall events occur after prolonged dry periods, combined with warm temperatures and build-up of organic material. When this material is washed into waterways, bacterial decomposition can cause deoxygenation of floodwater. The black appearance of impacted water is caused by release of carbon compounds including tannins as the organic matter decays. Widespread blackwater events that degrade water quality and deplete oxygen can result in fish kills[166], along with a range of other ecological impacts.

Blackwater can be trapped on the floodplain when water recedes. The network of drainage channels in the Manning River floodplain are fitted with floodgates, which are opened to allow rapid drainage after floods, mitigating the impacts of blackwater on the floodplain. SLR will mean water will inundate more places, increasing potential for trapped, low DO water.

[165] (Glamore, Ruprecht, & and Rayner, Lower Manning River Drainage Remediation Action Plan, 2016)
[166] (Australian Government, Undated)

The frequency and impact of blackwater events in the Manning is not well researched. In general, the Manning estuary does not experience long retention times which lowers the blackwater risk (pers. comm. Glamore 13 Aug. 2020). Research underway by the Water Research Laboratory (WRL) will identify areas of high risk for blackwater risk.

9.2 Stakeholders

Management agencies

Drainage Unions; MidCoast Council; Hunter Local Land Services (LLS); Water Research Lab (WRL); Department of Primary Industries, Planning and Environment (DPIE), DPIE-Crown Lands; DPIE fisheries.

Who's affected?

Floodplain farmers; fishers and commercial oyster growers; recreational users of the estuary.

9.3 Existing Management Approach

The Manning River Estuary CMP Technical Working Group noted that current management is not commensurate with the scale of this issue within the Manning Floodplain.[167]

Drainage Unions

Drains on the Manning floodplain are managed by individual landholders in association with four Drainage Unions: Dumaresq Island, Oxley North, Oxley South and Moto. Administration of the Drainage Unions is set out in the NSW Drainage Act 1939 with the objective to mitigate flood for pasture management. Drainage channels are rated. Rates are collected by the Drainage Unions and distributed to landowners to maintain their drains. Drain Maintenance Guidelines are an appendix to the Greater Taree Development Control Plan.

During consultation with the CMP Reference Group (February 2020) it was noted that *"rules to maintain tidal exchange and an appropriate depth of water in the drains are generally under control, as long as people stick to the rules."*

ASS Remediation Plan

MidCoast Council commissioned the University of NSW's Water Research Laboratory to produce the *Lower Manning River Drainage Remediation Plan* in 2016.[168] This plan, and subsequent plans, recommend on-ground works to reduce or eliminate acid drainage from 15 subcatchments. This strategic approach ensures the ASS drainage sites with the greatest potential for adverse impact are prioritised and investment provides the best value-for-money and environmental outcomes.

[167] (MidCoast Council, 2020)
[168] (Glamore, Ruprecht, & and Rayner, Lower Manning River Drainage Remediation Action Plan, 2016)

Glamore et al. (2016) note that the results from their study, including the Action Plans, require detailed stakeholder consultation and training prior to implementation on-ground.

Agricultural extension

An Environmental Officer employed by MidCoast Council works with farmers to improve drain management for mitigation of ASS and blackwater. A program to replace floodgates with an invert set at the level of ASS to keep the soil as wet as possible is being implemented as funds allow on high priority subcatchments rated in the WRL Remediation Plan. This approach has the additional benefit of holding the water table much closer to the root zone of the pasture grass, improving drought resilience. More capacity is added to the outlet to remove surface water as quickly as possible during flood events, reducing pasture die-of and the risk of blackwater events.

Acquisition and remediation

In 2003, Greater Taree Council (now MidCoast Council) purchased and commenced remediation of Cattai Wetlands, covering 486 ha of the Big Swamp floodplain. Since then, an additional 927 ha of ASS affected land has been acquired at Big Swamp, with remediation ongoing.

Remediation activities have included filling over 14kms of paddock drains, removing floodgates and levees and creating tidal swales to reinstate the natural hydrology, introduce tidal flows and reduce acid discharge. A long-term monitoring program will evaluate project success and guide future remediation.

Partnerships are important to success at Big Swamp, with a range of government agencies, the Indigenous community and environmental groups and volunteers involved.

Marine Estate Project

There is a project underway under the Marine Estate Management Strategy to develop drainage management plans that will inform water regulation and guidance.

9.4 Knowledge Gaps

- The impact of acid on biodiversity and ecosystem health in the estuary is yet to be established and is acknowledged as a state-wide knowledge gap.
- Review of effectiveness of remediation efforts to date.
- Frequency and impact of blackwater events.
- Find out if there is a way to include ASS on the planning certificates.
- Impact of potential entrance works on the future floodplain management.

9.5 What's working, what's not?

What's working

- Councils approach to floodplain management: forward thinking, willingness to take risks, land acquisition, willingness to work with landholders, experienced and proactive team with good continuity and environmental levy to back up the approach.
- Good science for evidence-based decision making and management.
- Researchers are able to value-add to remediation programs. The Memorandum of Understanding (MOU) between LLS and MCC creates an opportunity to co- fund new research. Responsiveness of WRL providing feedback to Council so that we can respond to the community questions.
- Partnerships e.g. MOU with LLS, agency staff, researchers, NPWS. The task is too big for only one stakeholder.
- Advocacy from the community to support the projects. There is an expectation from the community to do this kind of work.
- Guiding principles in the Natural Systems Business Plan: evidence-based decision making, innovation, adaptive management, community engagement.
- Connecting and communicating with landholders rather than taking a bureaucratic approach. Building trust between Council environmental officers and the landholders is central to the success of the engagement.
- Council officer Bob McDonell is highly regarded because of his experience on-farm, practical knowledge, local knowledge and connections within the community.
- The community has confidence to do floodplain remediation projects.
- Cattai Wetland works well as a demonstration site to showcase successful remediation. It is appreciated and enjoyed by the community.
- Acquisition has worked well in the lower Manning estuary but needs to be complemented by other management actions.

What's not working

- There are a lot of farms still discharging into the estuary. Most recently acid plumes were observed in the north and south channel in July 2020.
- Polluters are not held responsible for acid discharge through regulation and compliance.
- Need to expand extension work across the floodplain to raise awareness and build trust with a wider range of farmers.
- Clogged drains: farmers are noting that there is water lying on the landscape for longer than expected.
- New landholders are unaware of ASS and don't understand their responsibilities and how to manage ASS. There is a lack of communication between neighbours, for example on the impact of filling drains on adjoining properties.
- Capacity of Drainage Unions to effectively manage drainage on ASS.
- More ASS monitoring and event-based monitoring. We need to measure the values that people care about.
- A reliable model is needed for the estuary to inform management that all scientists agree on as a point of 'truth'. This will save time, money, not starting from scratch each time a new research organisation commences work). Establish guidelines for model establishment to ensure consistency.
- SLR will result in saltmarsh flooding.

Acid plume reaching the Manning River, July 2020

9.6 Opportunities

- Pilot and showcase a range of new approaches to manage ASS across the landscape in partnership with farmers.
- Improve monitoring, data sharing and establish a reliable model for the estuary. Collect specific data to answer questions about the impacts of ASS; promote the results in a proactive community engagement program.
- Drainage unions have the power to rate farmers, they have meetings, landholders are members. How can we build the capacity of this group and involve them as advocates for ASS management best practice?
- Blue Carbon Trading Scheme and other options.
- Landscape-scale planning to adapt to climate change and Sea Level Rise (SLR).
- New approaches to acquisition and remediation: NPWS ownership, philanthropic acquisitions, private conservation organisations, Biodiversity Conservation Trust.

9.7 Management Options

Planning

- Revise the 2005 DCP guidelines for floodplain drainage best management practice. Use the guidelines as a tool for engaging with landholders and building capacity.
- Undertake landscape-scale planning to achieve social, economic, ecological outcomes to manage future sea level rise impacts on the floodplain.

Advocacy

Capacity Building

- Work with farmers and support whole-farm planning for climate change, Sea Level Rise (SLR) and ASS management. Disseminate research so farmers understand how the landscape will change. Take a long-term outreach approach to transition farms from productive land to environmental use or promote new farming approaches.
- Continue advocacy and education about the impacts of ASS, how it occurs, impacts and management within Council and other land management agencies.
    - Target groups include councillors, council staff involved in construction in those areas, compliance team. Undertake succession planning, knowledge management and capacity building to ensure appropriate skills are retained (LLS and MCC).

- Undertake education and advocacy in the wider community to support practice change and management actions.
- Build relationships and offer training and research sharing with the Drainage Unions. Explore opportunities to leverage DU rates, Environmental Levy and Coast and Estuary Grants for farm field trials.

Regulatory Compliance

- Use regulation and compliance to hold landholders to account for ASS discharge.

Science and research

- Improve monitoring and evaluation of ASS impacts and management.
  - Build a stronger relationship with fisheries to monitor ASS; add data loggers for pH at additional locations. Use drones after rainfall events to monitor the distribution of acid plumes and identify the location of the issues.
  - Improve data sharing and partnerships so that researchers can get the most out of the data being collected in the estuary (recognising multiple uses for the same data).
  - Consider building on the MCC Water Quality Report Card to report on the 'values' identified in the CMP and revise the data collected if needed.
  - ASS Model: Collaborate across agencies and research organisations to build a reliable model so that there is an agreed baseline used for all future research and planning.

On-ground

- Implement the existing Lower Manning River Drainage Remediation Plan including acquisition of high priority ASS land and remediation to reinstate coastal wetlands.
- Establish field trials at different elevations in partnership with farmers to use as demonstration projects: e.g. liming, re-flooding, wetland rehabilitation (with some grazing), farming on the ASS, wet pasture. In the mid to high country, replace many deep drains with fewer broad shallow drains using laser levels. Moto could be used as a case study.
- Establish environmental credit systems / stewardship payments for restoring areas of environmental value whilst also maintaining productive lands. Identify finance mechanisms for ASS remediation on private land. For example, trade-offs, credits, rate relief, Biodiversity Conservation Trust offsets, blue carbon credits.
- Identify and protect migration pathways for coastal wetlands.
- Review the DCP guidelines for drain management developed in 2005, seek feedback from WRL to update and improve the recommendations. Give consideration for the

most appropriate way to implement these recommendations (does this suit the DCP). Build awareness of the guidelines as a tool for engaging with landholders.

9.8 References

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10. Modified Flow

Ensuring that water is provided for environmental purposes is central to the National Water Initiative and NSW Water Sharing Plans. This paper considers the impacts of extraction, drought, climate change and increased peak run-off on flow rates and aquatic ecosystem health in the Manning catchment and the estuary.

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10.1 Situation Analysis

Asset values

The Manning River originates at 1570m above sea level in the Gondwana World Heritage Area of the Barrington Tops and flows 261 km to the Tasman Sea on the mid-north coast of NSW.[169] Its catchment covers an area of approximately 8,420km^2 with 16 major tributaries, of which 11 are freshwater and five are estuarine (Map 1).

The Manning River is one of Australia's few large river systems not to be dammed for water supply purposes anywhere along its 261km length and there are no significant on-stream storages on the river.[170]

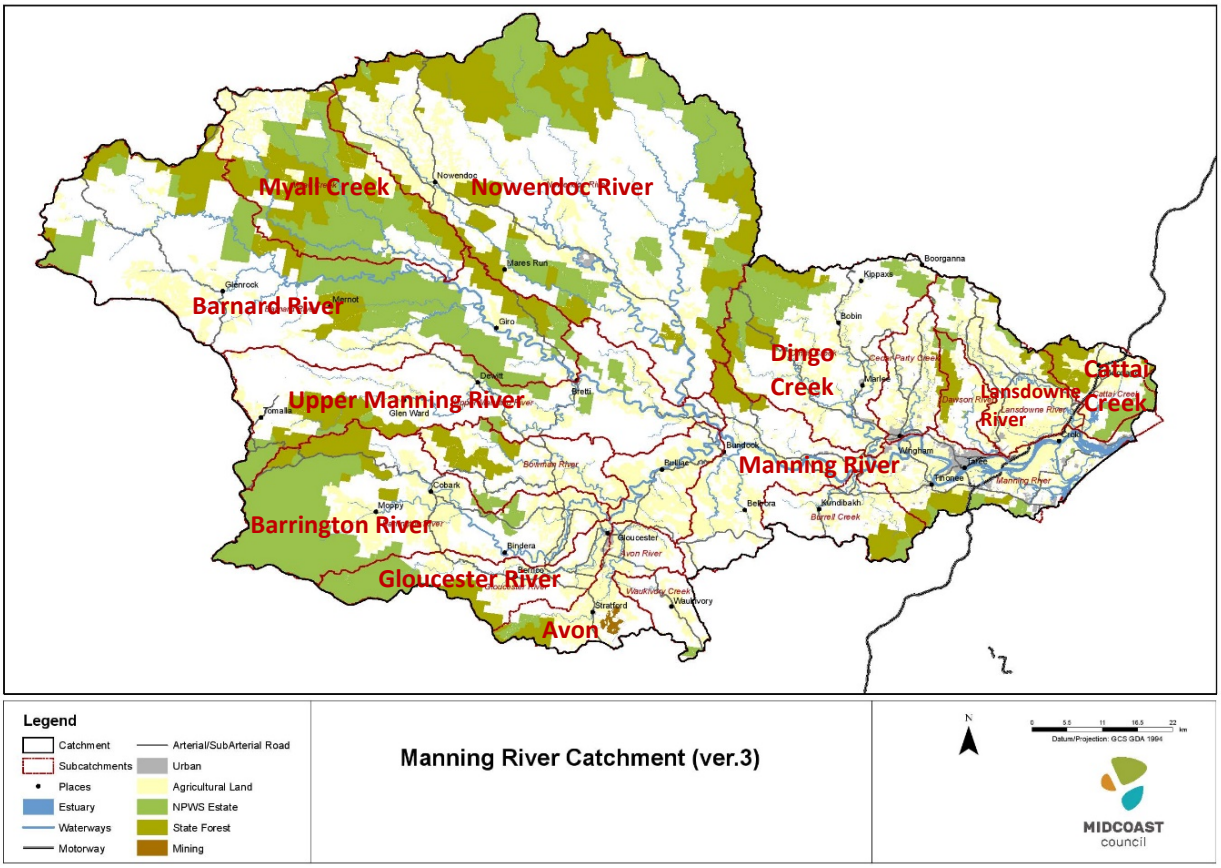
The Manning has a mean annual discharge of 1,854 GL/yr. During the Rapid Site Assessment of the Manning catchment at the height of the 2019 drought the major flow centres were posited to be the Barrington Tops, Gloucester Tops and the New England Tablelands as well as regional and local groundwater.[171]

The Water Services department of MidCoast Council has extensively monitored catchment hydrology, identifying:

- The Barrington-Gloucester Catchment supplies between 25 - 58% of the flow
- The Nowendoc Catchment supplies between 12 -33% of the flow
- The Barnard Catchment supplies 8 - 32% of the flow
- The Little Manning supplies less than 7% of the flow
- Dingo Creek contributes 1 to 10% of the flow.

[169] (Betterridge & Rabbidge, 2016)
[170] (Betterridge & Rabbidge, 2016)
[171] (Swanson, 2020)

In the Manning River, the source of water at high flows is variable and depends on the location of rainfall. During low flows the Barrington River is the major source of water to the Manning[172].



Map 1: Major subcatchments of the Manning River.

The upper Manning estuary has a moderately significant tidal pool in the main channel of the river directly downstream of Wingham. Despite being affected by daily tidal movements, the tidal pool is primarily fresh and sustains some commercial extraction[173].

Freshwater wetlands contribute to base flow of the river[174]. Some of these wetlands such as the alpine swamps in the Barrington Tops are high priority Groundwater Dependent Ecosystems[175].

Groundwater aquifers are found throughout the Manning catchment.[176] They make a significant contribution to baseflow in the river (Pers. Comm. Dr. Peter Serov, August 2019). Up-river alluvial aquifers and coastal sand aquifers have significant connectivity to surface

[172] (Midcoast Water, 2011)
[173] (Betterridge & Rabbidge, 2016)
[174] (Midcoast Water, 2011)
[175] (NSW Government - Office of Water, 2009)
[176] (Commonwealth of Australia, 2017-18)

water.[177] Understanding the connection between groundwater and surface water is important when regulating groundwater use, recognising that draw-down of the aquifer influences surface water flows.

Flow volume in the Manning River, its tributaries and the estuary make a critical contribution to the environmental, social and economic values of the region. The availability of water from the Manning catchment for potable town water supply, stock and domestic water, irrigation and industry underpins the viability of regional communities located throughout the catchment. Commercial fishing, including Aboriginal fishing, also depends on maintaining ecologically sustainable flow regimes.

Three of the water sources in the Manning catchment are classified as having a high economic dependence on commercial extraction in the NSW Water Sharing Plan, as shown in Table 2 below.[178]

Table 2: Manning Water Sources classified as high economic value

Water source	Description
Lower Manning	Relatively high value of extraction due to regional town water supply extractions.
Lower Barrington/Gloucester	Relatively high value of irrigation for improved pasture and lucerne.
Upper Gloucester	Relatively high value of irrigation for improved pasture and lucerne.

Flow contributes to the social values of the river. Water is an intrinsic and inseparable element in the physical and spiritual existence of Aboriginal people. Aboriginal consultation for the Gloucester Sub-region Biosphere Assessment Program states that "water sustains and nourishes all living creatures, it carries the past and the future, it holds knowledge and secrets."[179] For both Aboriginal people and the wider community, activities such as swimming, recreational boating, canoeing and fishing are part of the cultural life of the Manning community and depend on the presence of sufficient water. Tourism and population growth based on the appeal of natural resources including the river and estuary are noted in the Regional Economic Development Strategy[180]. These values are reflected in community comments received during consultation events for the CMP:

> *"I love being able to swim in the river at a variety of locations with easy access for all."*
>
> *"The river is my happy place – water and boats."*

From an environmental perspective, the full range of flows are necessary to maintain a healthy river system. These include flood flows to scour channels, rework sediments, and

[177] (Betterridge & Rabbidge, 2016)
[178] (Betterridge & Rabbidge, 2016)
[179] (Constable & Love, 2015)
[180] (Cabinet, 2018)

inundate floodplains; medium flows to oxygenate water and allow fish passage; and low flows to maintain connectivity and assist the survival of aquatic and riparian flora and fauna.[181] This is recognised by the Manning community. In a CMP community survey in 2019, aquatic ecosystem health was identified as the top value and flow was identified as one of the top three most significant attributes. The CMP Issue Paper on Wildlife Conservation provides more information on the assemblage of aquatic flora and fauna dependent on maintenance of natural flow regimes.

The timing and volume of freshwater inflows is important to ecosystem health in the estuary, which in turn provides significant environmental, commercial, tourism and aesthetic values.[182] The Manning River estuary has medium sensitivity to freshwater inflows.[183] Salt and fresh water mixing in the estuary contribute to the high levels of habitat diversity and biological productivity. Freshwater inflows from the upper catchment are a major determinant of estuarine conditions, influencing salinity gradients; estuarine circulation patterns; water quality; flushing; productivity and the distribution and abundance of many species of plants and animals including commercial fish species. Freshwater inflows also influence the dynamics of estuary entrances and the characteristics of tidal flushing.[184]

Stressors

Key stressors on flow rates in the Manning include extraction, drought, climate change, sedimentation and infilling of deep pools, and increased peak run-off due to land-clearing and urban development.

The total volume of surface water extracted via licenses in the Manning catchment is relatively low, authorised at 78,100 megalitres (ML) from an annual average flow of 2,530,000 ML.[185] An entitlement of 17,256 ML/year is allocated to MidCoast Council for potable town water extracted at Barrington and Bootawa. Typical extraction is now around 6,000 to 8,000 ML/year (pers. comm. 2020 David Bowland, MCC Water Services).

MidCoast Council's Water Services team uses an Integrated Water Cycle approach to manage potable water supply to the community via two schemes. The Manning Water Supply Scheme makes up 90% of water supply in the MidCoast LGA. Water is pumped from the Manning River near Wingham to Bootawa Dam if turbidity permits, then treated at Bootawa Treatment Plant before being distributed to approximately 30,000 households and businesses. The Gloucester Water Supply Scheme draws from Barrington River upstream of

[181] (Betterridge & Rabbidge, 2016)
[182] (Betterridge & Rabbidge, 2016)
[183] (Betterridge & Rabbidge, 2016)
[184] (NSW Government, undated)
[185] (Betterridge & Rabbidge, 2016)

Gloucester and supplies 1,700 customers.[186] The largest users of the potable supply are caravan parks and Council playing fields.[187]

The majority of extraction licenses in the catchment are used for irrigation for beef pasture and dairy farms.[188] Other irrigators include citrus and vegetable growers, turf farms, equine industries and hobby farms.[189] According to the Water Sharing Plan (2009),[190] most river systems in the Lower North Coast Region are at or close to the limit of sustainable water extraction and competition for water access between towns, farmers, industries and irrigators is increasing and putting pressure on the ecosystem health of rivers and aquifers.

In the Manning catchment however, irrigation is below the licensed capacity. Of the 180 irrigation licence holders along the rivers and creeks only a relatively small number (about 30) are irrigating regularly throughout the year.[191] According to a background paper published by the NSW Government, about 20% of irrigation licenses are active; the balance are 'sleeper' licenses.[192] During the 2019 drought, the CMP project team received reports from concerned landholders of illegal pumping for irrigation when cease-to-pump levels had been exceeded in the Dingo Creek sub catchment.

Basic landholder rights for stock and domestic use are also allowed. All properties with river/creek frontage have unregulated access for stock and domestic supplies and can store runoff in surface dams up to a volume of 10% of the rainfall falling on the property. Some landowners and industrial users (e.g. in the Barrington and Gloucester catchments) have licences for substantial on-farm collection and storage of runoff from rainfall. Large structures need to be licenced even if not used for irrigation.[193]

Extraction from the tidal pool has the potential to impact on estuary values and requires further study to ensure adequate protection measures are put in place through the Water Sharing Plan.[194]

Groundwater extraction via bores can impact on both river base flows and Groundwater Dependent Ecosystems (GDEs). An increase in demand of water from aquifers is likely as a result of increasing insecurity in surface water supply.[195] This could be significant during drought when the base flow through much of the system is made up of groundwater.

In addition to extraction, drought can be a significant stressor on flow, as was seen in 2017-19 when the Manning experienced the worst drought since instrumental records began in

[186] (Midcoast Water, 2011)
[187] (Midcoast Water, 2015)
[188] (Betterridge & Rabbidge, 2016)
[189] (MidCoast Council, 2020)
[190] (NSW Government - Office of Water, 2009)
[191] (MidCoast Council, 2020)
[192] (Betterridge & Rabbidge, 2016)
[193] (Gloucester Shire Council, 2015)
[194] (Betterridge & Rabbidge, 2016)
[195] (MidCoast Council, 2019)

1880. Manning River flow fell below 50 megalitres per day (ML/d) for 90 days, compared to the previous record of 26 consecutive days.

The Adapt NSW climate change data provides an overview of modelling results for the North Coast Region. Key trends include a warming climate and increased extent of dry periods by 2050, resulting in major periods of low flow. Natural flow regimes will also be impacted by more frequent severe weather events.

Concern about the impact of climate change on flow rates was raised by the Manning River Estuary CMP Reference Group: *"We are facing more dry periods and low flows, and more severe events. We need to be prepared for that."* The drought followed by flooding rains provided water managers and users with experience of the kind of low-flow and extreme weather events expected to increase under climate change scenarios and can be used to inform resilience planning.

At the other end of the scale, land-clearing for agriculture and increased impervious surfaces in urban areas increase run-off volume and velocity during high rainfall events.[196]Associated stressors include increased sediment and turbidity; nutrient loading; pollution from pathogens, litter and urban stormwater; acid leachate from exposed Acid Sulfate Soils, blackwater (deoxygenated water) from decomposition of organic matter washed into waterways. These stressors will be exacerbated by climate change.

Impacts

The drought of 2019 caused a range of impacts across environmental, social and economic dimensions. The Rapid Site Assessment of 206 sites throughout the Manning catchment in August 2019 revealed many reaches had no surface flow,[197] and much of the baseflow present in the river and its tributaries was sustained by groundwater (Dr. Peter Serov Pers. Comm. August 2019). Plants died in the riparian zone, including large River Oaks. Farming families experienced personal and financial stress, buying feed from as far afield as Victoria and struggling to de-stock as cattle prices plummeted.

In November 2019 unprecedented drought stress in the Manning catchment forced MidCoast Council to impose Severe Level 4 water restrictions on users for the first time in the history of the service.[198] By December 2019, the Manning River made national news when it stopped flowing at Killawarra, just upriver of the tidal limit near Wingham.[199] Flow ceased in many reaches of the river and its tributaries. From late December 2019 to late January 2020 the Barrington River stopped flowing and MidCoast Council trucked water to supply the community of Gloucester. Cease-To-Pump (CTP) rules came into force reducing agricultural productivity for irrigators. Low flows also had social impacts, reducing scenic amenity and recreational opportunities for locals and visitors.

[196] (NSW Government, undated)
[197] (Swanson, 2020)
[198] (MidCoast Council, 2019)
[199] (Canberra Times, 2019)

Many reaches of river were reduced to scattered pools providing crucial drought refuge for native fauna. Low flow obstructed species' passage (e.g. fish, turtles) and increased fauna exposure to predation (e.g. platypus). These impacts and management actions are covered more fully in the CMP Issue Paper for Wildlife Conservation.

Potential impacts caused by reduced freshwater inflows from water allocations and drought include upstream saline intrusion and hyper-salinity in upstream aquatic habitats, coastal wetlands, riparian zones and groundwater dependent ecosystems.[200] Other potential impacts on the estuary include reduced nutrient and organic inputs for primary production and alterations to the physical features of the estuary mouth.[201]

These impacts may:

- Reduce the abundance, distribution, breeding success and diversity of fish and prawns;
- Negatively impact on water quality and fish habitats and increase algal blooms.[202]

During the 2019 drought there was higher than usual salinity in closed ICOLLS and rivers and salt extended much further upstream (David Bowland, pers. Comm. Feb 2020). In the Manning catchment, saltwater intrusion into the upper estuary around Wingham resulted in plant deaths (e.g. water ribbon) and changes in biological structure and function.[203]

At the other end of the scale, land-clearing for agriculture and increased impervious surfaces in urban areas increase run-off volume and velocity during high rainfall events.[204] Associated stressors include increased sediment and turbidity; nutrient loading; pollution from pathogens, litter and urban stormwater; acid leachate from exposed Acid Sulfate Soils, blackwater (deoxygenated water) from decomposition of organic matter washed into waterways. These stressors will be exacerbated by climate change.

There are numerous impacts caused by peak flows from agricultural and urban land during high rainfall events. Sediments smother micro-habitats in the stream bed and impact on potable water extraction and treatment. Decomposition of excessive organic matter washed into waterways during flood can cause deoxygenation and fish kills. Pathogens from stock defecation can prevent direct harvest of oysters.

[200] (NSW Government, undated)
[201] (Betterridge & Rabbidge, 2016)
[202] (NSW Government, undated)
[203] (MidCoast Council, 2020)
[204] (NSW Government, undated)

10.2 Stakeholders

Management agencies

NSW Department of Planning, Industry, and Environment DPIE – Water Planning Group; NSW DPIE – Water and Science Group; Natural Resources Access Regulator (NRAR); MidCoast Council (MCC); Department of Primary Industries DPI – Water; **Manning Water Users Association; Barrington Irrigators Group.**

Whose affected?

Entire community; farmers and irrigators; large water users.

10.3 Existing Management Approach

In NSW the key legislation to manage flow and extraction is the NSW Water Management Act 2000 (WMA 2000). It is administered by WaterNSW (rural landholders, rural industries) and the Natural Resources Access Regulator (most users including water utilities).[205] Under the WMA 2000, Water Sharing Plans provide a legal basis for sharing water between the environment and consumptive water users.

The sharing of water must protect the water source and its dependent ecosystems and as well as basic landholder rights. Sharing water to licensed water users is effectively the next priority for water sharing. Among licensed water users, priority is given to water utilities and licensed stock and domestic use, ahead of commercial purposes such as irrigation and other industries.

The NSW Government's Water Sharing Plan (WSP) for the Lower North Coast Unregulated and Alluvial water sources (2009) regulates license allocations for town use, farms, irrigators and industry, and reserves environmental water for the overall health of the river and aquifer.[206] It covers the unregulated rivers and groundwater in the upriver alluvial aquifer and coastal sands. The WSP is currently under review (2020).

DPIE is responsible for managing and allocating groundwater resources as set out in the WSP. To ensure local impacts are monitored and managed, all applications for new bores and trades are individually assessed. If there are excessive groundwater level declines in an area, management controls may include restricting extraction by license holders.[207] Bores for basic landholder rights (stock and domestic use) are exempt.

In many areas, existing extractions from tidal pools have not been licensed in the same way as extractions from freshwater rivers and groundwater. There are no extraction licenses from the Manning tidal pool (Pers. Com. Claire Evans DPIE August 2020).

[205] (Natural Resources Access Regulator NRAR, 2020)
[206] (Betterridge & Rabbidge, 2016)
[207] (NSW Government, 2020)

The DPIE Water and Science Group undertakes monitoring and research to underpin the WSP, and are improving water quality guidelines.

Current WSP conditions have high ecological risks as a result of the paucity of ecological information used to determine an appropriate CTP threshold.[208]

DPI Water licences irrigators. Licences set out how much water can be taken; what size pumps and other equipment can be used; where pumps can be located and where water can be applied. During low flow periods, cease-to-pump (CTP) rules protect environmental flows, excluding licences held by local water utilities, licensed stock and domestic users, and licences used for food safety and essential dairy care.[209]

The Manning Water Users Association (WUA) is a voluntary group of irrigators from throughout the Manning catchment. The WUA meets frequently during drought to agree on reduced-pumping, CTP flow levels and re-commence points. Although these points are determined formally by DPI Water, the Manning WUA has a history of voluntarily imposing restrictions before these official restriction points are reached. MidCoast Council is not responsible for licensing or regulating irrigation but is involved in these discussions as a key stakeholder. CTP arrangements can be found on Council's website.[210] In the Manning River the CTP threshold is 98 ML/d at the Killawarra gauge.[211]

Hunter Local Land Services, MidCoast Council and Midcoast-to-Tops Landcare work with farmers to improve land management practices including measures to rehydrate the landscape and conserve water.

MidCoast Council's (formerly MidCoast Water's) Integrated Water Cycle Management Strategy sets out the direction for sustainable management of potable water for the next 30 years. It is being revised in 2020. The strategy covers water quality, treatment, resilience and conservation through a range of measures such as diversifying water sources, increasing utilisation of recycled water, catchment management and education.[212]

MidCoast Council implements water restrictions in response to declining river flow rates, available storage and weather outlook. The restrictions are set out on Council's website.

With regard to monitoring, Water NSW is conducting a gauging review across the state (2020) and investigating whether there is the need to increase gauge data collection. DPIE Water and Science Group is responsible for long term condition monitoring for the WSP and is developing a statewide MER framework (Pers. Comm. Claire Evans DPIE). MCC Water Services primarily uses flow and height gauges to manage extraction. Council pays annual fees to Water NSW to maintain the instruments and upgrade monitoring stations as

[208][208] (MidCoast Council, 2020)
[209] (Betterridge & Rabbidge, 2016)
[210] (MidCoast Council, 2020)
[211] (NSW Government - Office of Water, 2009)
[212] (Midcoast Water, 2011)

required. Data is available publicly. The NSW Food Authority conducts regular monitoring through the Shellfish management program.

MCC's natural Systems team contracts DPIE's Environment, Energy and Science Group to undertake annual water quality monitoring. Indicators assessed include Chlorophyll-a, turbidity and seagrass extent. There are five monitoring sites in the manning estuary and the results are available in an annual WQ report Card on Council's web site.

Data sharing is occurring to some extent. MCC's Water Services and Natural Systems data are publicly available on the Council web site. MCC Water Services has a Memorandum of Understanding with NSW health. DPIE Water and Science Group are preparing to request a data sharing MOU with NSW Councils.

10.4 Knowledge Gaps

- Current and future impact of climate change (altered flows) on hydrology.
- Understanding of the capacity of rivers in the Manning catchment to resist and recover from drought.
- Importance of different flow regimes to ecosystem health. Impact of extraction on ecosystem health during low flow events.
- Scientific evidence to demonstrate sufficient environmental water has been allocated.
- The tidal pool requires further study (although there are no extraction licenses currently).[213]
- The ecology of the groundwater-dependent ecosystems and karsts is not well understood.
- Better understanding of hydrodynamics and impacts of extraction on freshwater inflows to the estuary.
- Minimum flow requirements to maintain hydrologic refuge pools.
- Impacts of instream sediment load on flow and ecosystem health. It would be useful to assess instream depths and volumes of sediment accumulation over time.
- There are current gaps/patchy data in coastal catchments on water quality compared to inland systems. Inland systems tend to be monitored more for water quality, particularly for DO related to fish kills.

[213] (Betterridge & Rabbidge, 2016)

- The knowledge base upon which decisions are made could be improved (e.g. ecological impacts of allocation). Climate change predictions and estuary studies should be included in the revised Water Sharing Plan and CTP rules.[214]
- Socio-impact assessment of CTP options.
- Economic valuation of tourism and recreational use of the river and estuary.

10.5 What's working, what's not?

- MCC Water restriction program worked well with excellent communication and strong uptake and ownership in the community, including behaviour change and reporting of breaches.
- The merged Council encompassing Gloucester, Taree, Great Lakes and Midcoast Water enabled a more cohesive, whole-of-catchment drought response.
- Substitution of treated recycled water for dairy wash-down and dust suppression helped save potable water.
- MCC established a formal, cross-Council water resilience team to manage water security during the drought, with some representation from NSW agencies. The team continues to drive water management improvements. A debrief of performance and learning during the 2019 drought is underway.
- Compliance and enforcement of regulations could be improved. During the drought there was an increase in reports about illegal pumping to Council's Water Services and Natural Systems teams, some of which were passed on to NRAR for investigation.
- There are limited resources for monitoring generally. DPIE currently have patchy data on coastal catchments including the Manning and require more comprehensive water quality data to undertake robust risk assessments for WSPs. More monitoring gauges are required to monitor flow at key locations.[215]
- Does the Water Sharing Plan achieve the right balance between consumptive and environmental needs during drought and non-drought periods?
- Environmental flows should have at least the same degree of security as water access entitlements.[216]
- Drought management strategies currently in place involve user-driven pumping restrictions which may be ineffective.

[214] (MidCoast Council, 2019)
[215] (MidCoast Council, 2019)
[216] (MidCoast Council, 2019)

- The natural environment (e.g. montane wetlands) at the top of the catchment could be better managed to slow water movement, improve water quality and infiltration rates by addressing the effects of vegetation clearing, degradation from wild horses and cattle.
- Potential impact of sediment accretion on flow volumes: Flow has a key role in flushing sediment. Some sedimentation is a natural part of the system, but it is exacerbated through land-clearing.
- During the 2019 drought there was saline intrusion upstream. Extraction for irrigation was occurring at the extremity of the tidal flow, which could pose a threat to crop health. There's no gauging station for electro-conductivity there at present. Investigation and risk assessment of electro-conductivity levels and targets for irrigation is being conducted by the DPIE Water and Science group. Longer term data is required.

10.6 Opportunities

- Improve monitoring of extraction, reporting, accounting and compliance of water use through the WSP.
- The WSP could be improved by specifying the environmental flows for specific areas. Salinity triggers for CTP could be written into the WSP as a control, as already used in the Hunter and Richmond.
- Groundwater sources throughout the Manning Catchment should be protected through no net increase in allocation.[217]
- Improve collaboration, integration, data sharing and cost-sharing for water monitoring programs. DPIE's Environment, Energy and Science group are planning an open database focussed on coastal catchments.
- The State MER framework in development will look at standardised, transferable, cost-effective methods for water quality and bio-indicator monitoring. Explore opportunities for citizen science or grant-funded projects. Investigate new techniques such as remote sensing or event-based surveying, rather than intensive regular macroinvertebrate sampling.
- Use strategic planning (e.g. Rural Strategy, Local Environment Plan, Development Control Plans, Development Assessment) to protect flow. Strategies could include regulating lot size and reducing the number of lots with direct river frontage and harvestable rights for stock and domestic water; retaining or creating public reserves in riparian zones; regulating high intensity water use.

[217] (MidCoast Council, 2019)

- There are opportunities for land use change through zoning and ceasing certain land use activities.
- Improve management of Crown and RMS land with water frontage, much of which is agisted for grazing.
- Purchase and retire unused "sleeper" water access licences to reduce the impact of extraction, improve environmental flows and water security for farmers and irrigators.[218] As the biggest water user, MCC has an interest in purchasing licences. Cost Benefit Analysis is required. Prioritise purchase from subcatchments at risk of hydrologic stress/over extraction, e.g. Gloucester and Barrington. Purchase licences in a flood year to get best market price. This could be linked with support for improved on-farm water storage and off-stream watering.
- Provide education, training and support for irrigators to promote landscape rehydration, sustainable extraction, sustainable on-farm practices and onsite farm water storage.[219]
- Identify and protect drought refugia pools to conserve aquatic fauna and flora.
- Investigate high-flow conversions through appropriate on-farm and other storage to help alleviate the severe competition for water during extended dry periods, while acknowledging regular high flow flushing events contribute to ecological health.[220]
- Work with the dairy industry to improve drought resilience. Recycled water was supplied to dairy farms instead of potable water during drought. However, it is highly regulated and very costly due to the energy required for processing and treatment.

10.7 Management Options

Planning

- Complete review and implementation of Integrated Water Cycle Management Plan [do we need this in CMP?].
- Use development controls and land use zoning through the MCC Rural Strategy to improve drought resilience and mitigate impact of future development on extraction and water use.

Advocacy

- Advocate for improved research and monitoring to secure environmental flows through the water sharing plan.

[218] (MidCoast Council, 2019)
[219] (MidCoast Council, 2019)
[220] (MidCoast Council, 2019)

Capacity Building

- Promote uptake of best management practice to conserve water and improve drought resilience on farms.
- Develop best management practice for water conservation on Council open space and use as demonstration projects.
- Continue MCC programs with residents to promote water efficiency, e.g. water restrictions, ongoing education, pricing mechanisms.

Regulatory Compliance

- Liaise with NRAR to report illegal extraction.

Science and research

- Establish a Memorandum of Understanding between key stakeholders to improve integration, knowledge-sharing and water management. The MOU could cover water monitoring, data-sharing, project updates, share-the-science webinars etc.

On-ground and operations

- Establish a program to purchase and retire un-used water licenses.
- Upgrade MCC water infrastructure to reduce leakage and maximise water efficiency.
- Continue MCC programs to support implementation of the Smart Water Advice Audit for large water users, e.g. caravan parks, abattoir, dairy industry, hospital. Tools include pricing mechanisms, audits to identify leakage and savings, on-site water capture and storage, demonstration projects, use of recycled water.
- Identify, map and protect drought refuge pools and upland wetlands.

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11. Vegetation Management

11.1 Situation Analysis

It is widely accepted that riparian vegetation plays a central role in stabilising waterways, reducing channel boundary erosion, filtering diffuse-source run-off and providing habitat. Riparian vegetation helps maintain water quality by reducing the amount of pollutants entering the waterway and serves as a physical buffer, slowing down overland flow and mitigating the negative impacts of flooding.[221]

Vegetated riparian areas are also very important for biological connectivity. Intact and connected riparian vegetation is critical for building resilience to climate change impacts and has an important role in carbon sequestration (see also CMP Issue Analysis on wildlife conservation).

Managing riparian vegetation is a primary tool to effect catchment-scale improvements in the river environment, both in terms of its intrinsic values, and its impacts on social and economic values[222]. The importance of riparian vegetation in maintaining water quality and ecosystem health was noted throughout consultation for the CMP.

When asked to describe their vision for a healthy catchment, members of the CMP Reference Group said:

> *"A river in which intact and effective ecological processes are maintained, with the physical characteristics of a river in good condition, clothed in a healthy riparian strip."*
>
> *"The catchment is stable, well-vegetated and stock are well managed. There is a healthy riparian buffer to filter run-off."*
>
> *"The river and its riparian vegetation are a crucial refuge and corridor for wildlife connecting the mountains to the sea - especially important during drought and fire."*

CMP Reference group members highlighted the need to protect and improve the condition, extent and connectivity of riparian vegetation: *"the remaining native vegetation remnants are very important – we need to improve and maintain them."*

During a workshop of MCC internal stakeholders, the Water Services team noted that riparian vegetation has an important role protecting and improving raw potable water quality for ease of treatment.

[221] (Swanson, 2020)
[222] (Pietsch, Daley, Stout, & Brooks, 2019)

Terrestrial vegetation including ground cover also has an important role to play in soil organics, erosion control, providing shade for livestock away from watercourses, driving microclimates and the local water cycle, and hydrating the landscape.

However, extensive clearing and degradation of riparian and terrestrial vegetation has occurred throughout the Manning River catchment and estuary. Biodiversity and vegetation, streambank erosion and sedimentation were issues in early catchment management planning for the Manning[223]. Many tributaries in the catchment are observed to have narrow, fragmented or missing protective riparian vegetation. Floodplain stripping and bank erosion have been identified as the largest contributors to sediment in the river[224].

Activities impacting on riparian and terrestrial vegetation include:

- Clearing riparian vegetation for land uses including urban development, foreshore development, agriculture, roads and river access.
- Catchment-wide vegetation clearing, including public and private native and plantation forestry.
- Cattle and livestock over-grazing of pastures and access to the riparian zone for shade and water in both fresh and estuarine waterways degrades native vegetation.
- Weeds and feral pests degrade riparian and terrestrial vegetation.

Pressures

Decades of land clearing for agriculture, and extended periods of drought have left a landscape of bare steep hills with minimal groundcover. In a 2019 program of 206 rapid site assessments of the Manning River catchment and estuary, the estuary was classified as severely modified based on the changes to the catchment from substantial clearing of natural vegetation cover[225].

In freshwater catchments, the riparian zone was typically a narrow band (less than 10 metres wide) of River Oak (*Casuarina cunninghamiana*) trees, with exotic species dominating the shrub layer. The native green mat-rush (*Lomandra longifolia*) was present at many sites[226].

Riparian Condition scored poorly at estuarine sites, with the majority rated Poor or Fair, primarily due to the sparse distribution of riparian vegetation. Mangroves occur throughout the estuary and provide some protection of bank structure where they occur. Continuity of mangroves along the shoreline can be patchy and the band width rarely exceeded 10m. Even though present, mangroves at this density provide limited protection of shorelines

[223] (Manning Catchment Management Committee, 1996)
[224] (Raine & Gardener, 1992)
[225] (Swanson, 2020)
[226] (Swanson, 2020)

from erosional forces of high flows and boat wash. Casuarina (*glauca, littoralis*) were the dominant native trees while native grasses/sedges were only present in patches[227].

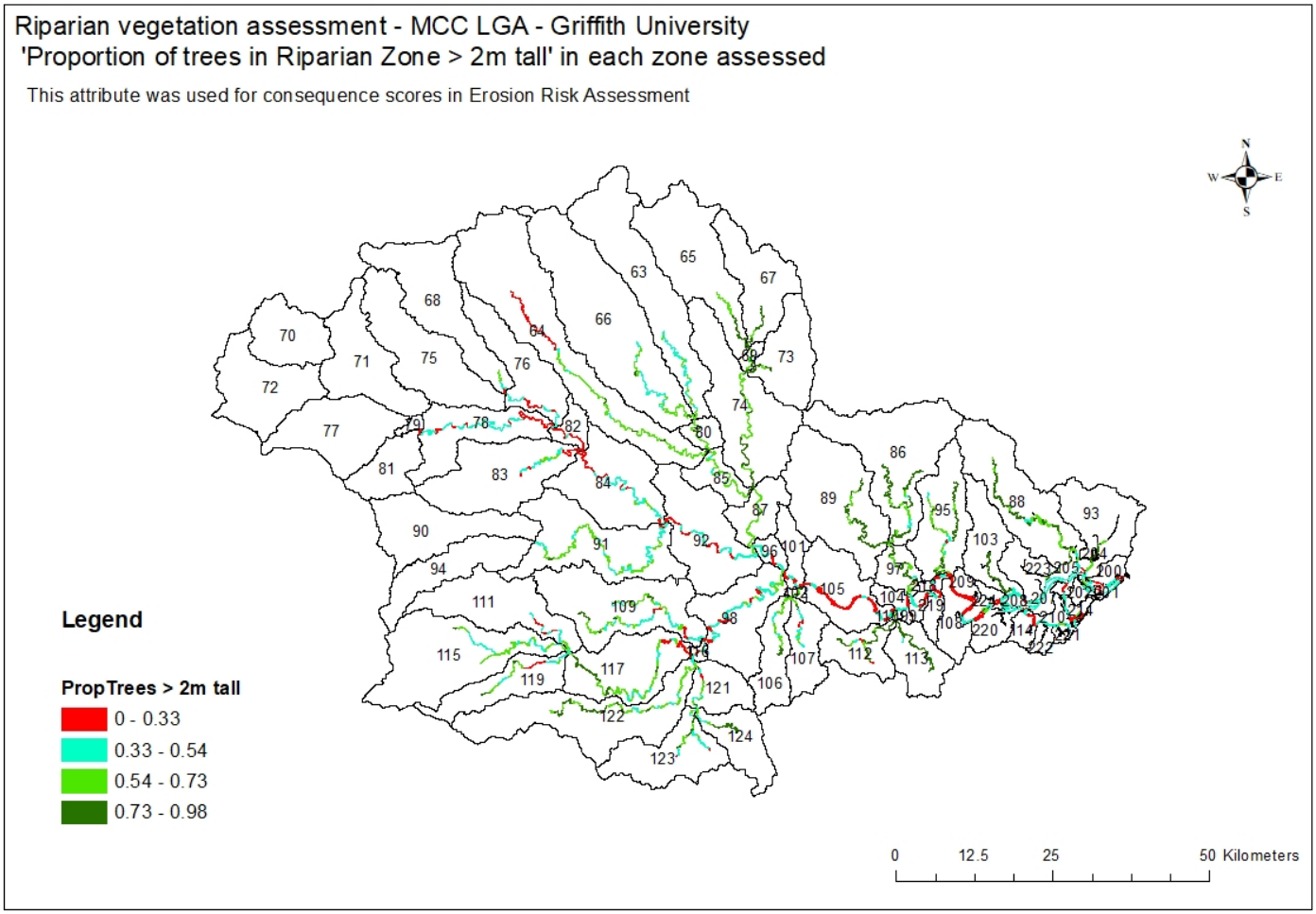
Hillslope erosion, erosion gullies and an absence of riparian vegetation were a common sight throughout the catchment during the rapid site assessment conducted in 2019.

The results of riparian vegetation mapping of the Manning River catchment by Griffith University (Pietsch 2019) are provided in Map 1, showing the proportion of trees (in each reach surveyed) over 2 m tall.

Erosion of hillslopes and streambanks is a widespread pressure in the catchment leading to loss of structure in the riparian zone and loss of vegetation. Hillslope erosion contributes large amounts of sediment to waterways in the catchment following rainfall. An intact riparian vegetation zone captures some of the sediment.

Based on the data produced by Pietsch, Swanson (2019) assessed the risk of hillslope erosion and streambank/streambed erosion (pressure, likelihood criteria) to riparian vegetation (asset, consequence criterion). Map 2 overleaf was used as a "consequence" layer in the risk assessment and shows the proportion of trees under and over 2m in each sub catchment of the system.

[227] (Swanson, 2020)



Map 1: Proportion of trees in the riparian zone over 2m tall[228]

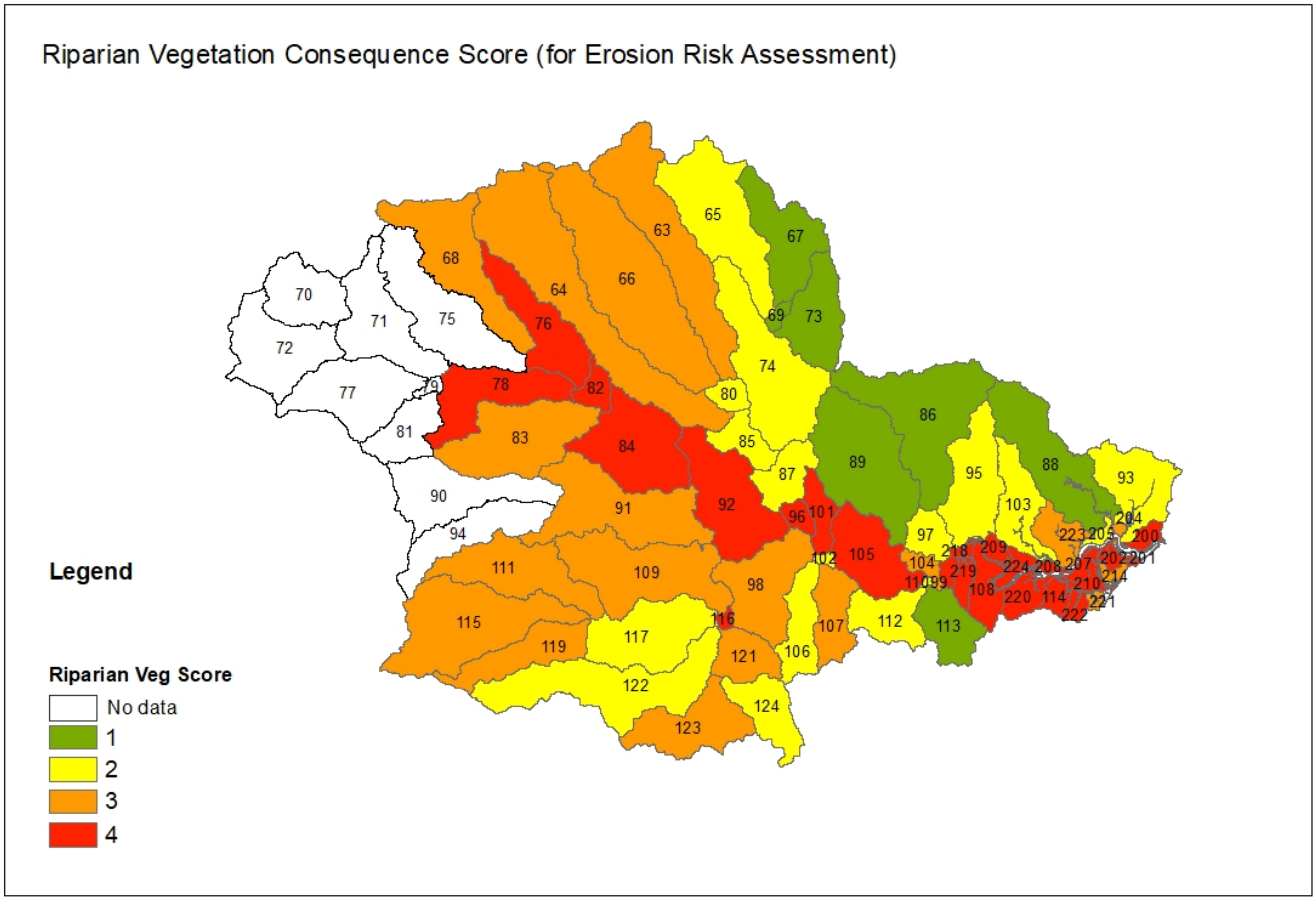
The risk analysis assessing the risk of hillslope and bank erosion impacting riparian vegetation and ultimately water quality in streams and the estuary shows subcatchments in the Manning River, Upper Manning River, Myall Creek and Barnard River pose the highest risk (Swanson 2020).

Other pressures include:

- Widespread erosion is evident throughout the catchment, including stream bed and bank erosion, sheet and gully erosion.[229]
- Lack or vegetation in or near community recreation zones, where eroding banks reduce visual amenity.

[228] (Pietsch, Daley, Stout, & Brooks, 2019)
[229] (Swanson, 2020)

- Increased impacts from diffuse runoff from agriculture contributing sediment, nutrients and other contaminants (see Issue Analysis paper on agriculture for details).
- Uncontrolled wildfire can damage riparian vegetation, bare the mineral soil and create an erosion risk and possibly water quality problems.
- During the rapid site assessment, stock impact on the riparian zone was found to be a widespread threat to stream/estuary health across the catchment.[230]
- The Barnard River sub catchment contributes excessive levels of turbidity during high rainfall events and is also a significant contributor of nutrients (particularly nitrogen and phosphorus) at all flows. This sub catchment is also shown to have least riparian veg cover.



Map 2: subcatchments with the least proportion of trees>2m in the riparian zone assessed (averaged for subcatchment) in red, and the highest proportion of trees in green

[230] (Swanson, 2020)

Impacts

The impact of land-clearing and agricultural run-off is influencing catchment health in both freshwater and estuarine catchments.

Loss of riparian vegetation in both the freshwater and estuarine catchments exposes shorelines to erosion from high rainfall events, wind waves, tides and boat wash.

The extensive areas of hillslopes and pastures with barely any ground cover and limited vegetation across the catchment coupled with poor riparian vegetation are mobilising large amounts of sediment into the system, smothering micro-niches for fauna, reducing instream condition and causing turbidity with consequent impacts on aquatic fauna and flora.

Stock in riparian and marine vegetation are degrading ecological condition, instream values and water quality by adding nutrients, sediment and pollutants including bacteria and pathogens. Grazing, and trampling of riparian zones erodes banks, adds/suspends sediment, non-point source of TSS, nutrients and pathogens (see CMP Issue Analysis – agriculture for more information).

Loss of habitat within the catchment has resulted in loss and declines of species diversity of plants, animals, invertebrates, Endangered Ecological Communities and degradation of natural environment.

Socio–economic impacts include higher drinking water treatment costs and periods of no availability to extract water, due to increased sediment and nutrients

11.2 Stakeholders

Management agencies

HLLS, MCC, DPIE, Crown Lands, Forestry Corp, NPWS, State Forests

Whose affected?

Private property owners in rural and urban areas, Council (Council owned land), Crown, general community (recreation and cultural purposes, cost-bearing)

11.3 Existing Management Approach

- Legislation governing the clearing of native vegetation changed in NSW in 2017. The Native Vegetation Act 2003 was repealed on 25 August 2017 and the clearing of native vegetation on rural land is legislated by the Local Land Services Act 2013 and the Biodiversity Conservation Act 2016. Clearing of native vegetation in urban areas and land zoned for environmental protection is legislated by the NSW Vegetation SEPP.

- The native vegetation legislation reforms resulted in the implementation of monitoring and reporting of both woody and non woody vegetation change on land regulated under the LLS Act.
- LLS provide approvals and information on native vegetation removal and management on rural zoned land (under Council's Local Environment Plan). Assessment and approval pathways for clearing native vegetation depend on the purpose, nature, location and extent of the clearing. Options for managing native vegetation on rural property is determined by land categories land, which include Exempt land (Category 1), Regulated land (Category 2) and Excluded land (Category 3).
- HLLS engaged a riparian vegetation mapping study 2019 by Griffith University
- HLLS, MCC and Manning Landcare facilitate incentive programs when funds allow. These help farmers install stock-exclusion fencing to protect riparian vegetation along with off-stream watering, pasture management and shade.
- Rapid riparian site assessment program as a Stage 2 CMP study assessed riparian vegetation condition at 206 sites.
- Bank erosion works with some replanting native species through MCC grants.
- Council program of bushland restoration on Council natural areas
- Council's ongoing role in development assessment and strategic planning
- Council is developing a Rural strategy, Greening Strategy and Biodiversity Framework

11.4 Knowledge Gaps

- Current extent of vegetation extent and condition outside of riparian areas, changes over time including high value areas of native vegetation regrowth over the past thirty years.
- Identification of riparian protection priority sites.
- Finer scale vegetation connectivity mapping.
- How to best restore vegetation and reduce impacts of climate change, with increased predicted drought (long periods of low or no flow) and warming climate. How to incorporate hydrological extremes into the management and restoration of ecosystems and landscapes.
- Develop vegetation prioritisation scheme as a recommendation of Pietsch et al. 2019 mapping study, where it was thought the opportunities for revegetation in completely open areas are limited. Recommended prognostication, based on forecasting the likely changes that will happen without further direct intervention and then focussing on those areas that will still not be sufficiently vegetated in 20 years.

11.5 What's working, what's not?

What's working

- Good prioritisation tools to guide strategic prioritisation of riparian vegetation management in the Manning were completed in 2019, including the CMP spatial risk assessment[231] and the Griffith riparian vegetation mapping study.[232]
- The NSW biodiversity reforms have benefitted private conservation instruments and associated funding.
- Vegetation cover has increased in recent decades following a legacy of extensive clearing in the early settlement period.
- There are good provisions for retaining vegetation in riparian zones and drainage lines as an outcome of land management reforms for the Local Land Services Act.
- Council's environmental special rate secured in perpetuity enables programs and actions for native vegetation including support for private land conservation, a nursery to propagate plants for landholders, and management of Council's bushland reserves.
- Council's environmental rate is leveraged to win additional investment.
- Council has good relationships with regulatory bodies (e.g. DPI-Fisheries) over native vegetation controls particularly compliance with marine vegetation (mangroves).
- MCC is currently investing in vegetation mapping.
- There are benefits to working across multiple properties and tenures on whole river reaches, for example previous river care plans in the Manning.
- Compliance has recently improved, with EES following up on many of the observed illegal clearing events. The extent of prosecution is not known.

What's not working

- There is a legacy of clearing on landscapes riparian and floodplain areas with higher fertility.
- Landowners are clearing land for capital gains in the future.
- Areas of bank erosion are correlated with an absence of riparian vegetation, posing a high risk during extreme weather events.
- Cumulative impacts of clearing are not being considered.
- Need to clarify jurisdiction over vegetation management in the foreshore area.
- There is a paucity of functional public river reserves (e.g. Crown Land) throughout the Manning. It is challenging that river frontages are fragmented in privately

[231] (Swanson R. , 2019)
[232] (Pietsch, Daley, Stout, & Brooks, 2019)

owned holdings, and good riparian management depends on views and management of each landholder.

- Weeds cross landholder boundaries. We need tailored solutions to work collectively. Previously Rivercare Plans could influence a group of landholders on a reach.
- Lack of funding for on-ground incentive programs.
- Throughout much of the catchment, cattle have access to riparian zones 100% of time. There isn't legislation/regulation to prevent cattle impacts adequately.
- Landholders are reluctant to protect and restore riparian vegetation. Farmers in the CMP Reference group noted the complexity and expense of stock exclusion from the riparian zone. Issues include the need for alternate water and shade, weed control and flood damage to fences.
- Private native forestry is a big issue in the Manning. There is a lack of ecological assessment and compliance.
- The 2019 drought resulted in extensive Casuarina and Eucalypt deaths and bare hills. Stock were kept on properties longer than they should have been and many areas were over-grazed.
- There is a need for better awareness on the benefits of maintaining vegetation in key areas, especially economic benefits. It is difficult to communicate this to landholders. Raise awareness of values of vegetation including mangroves, terrestrial and riparian vegetation and good pasture cover.
- Policy and legislation: Native vegetation legislation reforms which reduced clearing regulations while introducing funding and incentives for BCT private conservation agreements hasn't worked effectively. BCT is focussed on preserving land in hills/inland areas while there is clearing elsewhere.
- There are loopholes in planning policy and regulations that allow clearing (e.g. The Vegetation SEPP doesn't require consent under thresholds; there are loopholes in the LLS Act; there is no tree preservation policy in Gloucester and Taree).
- Vegetation legislation reforms of 2017 have opened more opportunities to clear vegetation, resulting in increased clearing of native vegetation.
- The Biodiversity Conservation Act provides for a biodiversity values map however few riparian zones are included. This doesn't adequately limit an ability to develop these lands through the development application process.
- Biodiversity and productivity: For good catchment management, we should work with landholders to explore models where biodiversity is in balance with production, rather than separately. However, BCT has a more narrow, single-issue focus on biodiversity.

- Compliance: Illegal clearing is a problem, including vandalism and riverbank clearing especially in the Manning estuary (Taree area). There is limited enforcement for compliance. The EPA issue warnings but rarely prosecute.
- Strategic planning and assessment: There is a lack of strategic planning and assessment to protect vegetation.
- Public reserves: There is an inadequate integrated freshwater / terrestrial conservation scheme across the Manning. The public reserve scheme in the catchment is mostly residual; that is geared towards "leftover" lands not suitable for other "productive" purposes.
- The net increase in vegetation in the Manning is mainly due to regrowth, which can be cleared without approval under current legislation if it is under 30-years old. It is susceptible to being cleared again as stock prices increase.

11.6 Opportunities

- Improve understanding of best management practice, using evidence-based science (e.g. HLLS study on Goulbourn River).
- New landholders education package.
- Support peer-to-peer learning.
- Demonstration sites for education and training.
- Educate landowners about the true cost of clearing for capital gains.
- Use iconic species to promote increase in vegetation cover e.g. koalas as a surrogate for vegetation particularly for riparian zones.
- Use property planning to manage vegetation within a productive landscape.
- Improve knowledge and skills for drought management.
- Target large properties for bigger gains. Focus on upper catchments and work down. Use MCC's property Glen Almond as a demonstration project.
- Protect regrowth: Identify and prioritise the regrowth areas (Griffith Uni could analyse vegetation that has appeared in last 30 years using Landsat data, to map and highlight regenerated vegetation, and areas of high value).
- Council is in the process of consolidating the Local Environmental Plan (LEP) and DCP, and preparing a Greening Strategy and Rural Strategy. Identify important vegetation and use zoning changes to protect them.
- Create riparian reserves on public land and expand through strategic acquisitions.
- Pietsch et al (2019) recommend that majority of effort should be directed to assisted natural regeneration and careful assessment and control of pressures, including weeds and cattle.
- Consider fast growing non-invasive clumping bamboo in paddock corners, to shade cattle away from riparian zone. North south rows planting gives good shade.
- Partnership projects to attract investment including NGOs.

- The Griffith study plus current vegetation mapping project by council, plus a connectivity study (similar to Karuah/Myall), plus koala mapping projects, would provide good direction on where to invest in the catchment with regard to protection of existing vegetation.

11.7 Management Options

Planning

- Implement development controls to protect terrestrial and riparian native vegetation in Councils DCP and LEP.
- Review and consider riparian native vegetation in Councils DCP and LEP
- Review and update subdivision controls to avoid fragmentation of riparian vegetation and reduce stock access and domestic extraction.

Advocacy

- Advocate for reform of the Biodiversity Act and Local Land Services Act to reduce opportunities for unregulated land-clearing. Add riparian zones to the Biodiversity Values map under the Act.

Capacity Building

- Identify and undertake a needs assessment of key target audiences for engagement to promote protection, natural regeneration and revegetation.
- Establish Best Management Practice framework for vegetation management in productive landscapes and towns.
- Develop co-branded, multi-media training and education materials promoting understanding and commitment to Best Management Practice for vegetation management in the region, to be shared across agencies.
- Deliver outreach and incentive programs to improve the condition, extent and connectivity of terrestrial and riparian vegetation in priority areas.
- Use public land to demonstrate best practice.

Regulatory Compliance

- Prioritise and enforce regulatory compliance to protect riparian vegetation.

Science

- Use existing research and mapping to identify and prioritise target areas for protection, natural regeneration and revegetation.

On-ground work

- Identify, prioritise, protect and restore the condition, extent and connectivity of riparian vegetation on public land.
- Monitor natural regeneration and partner with landholders to undertake targeted, assisted regeneration and revegetation to improve condition, extent and connectivity of riparian vegetation, stepping stones and shade trees on private land where required.

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12. Pathogens: Sewerage and Septic Systems

This Issue Analysis considers the risk and management of human pathogens from sewerage treatment infrastructure including on-site sewerage treatment (septic systems). The focus is on identifying source control opportunities appropriate to the Manning River Estuary and Catchment Management Program (CMP). Pathogen risk from stock is addressed in an Issue Analysis paper on agricultural impacts. Bacterial pollution from stormwater inputs is included in the Issue Analysis paper on Urban Stormwater.

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12.1 Situational Analysis

Activities

Approximately 50,000 people live in the Manning River estuary and the catchment, of which approximately 70% live in urban centres (Taree, Wingham, Gloucester) and small villages, while 30% live in more sparsely populated rural areas.

MidCoast Council operates eight Sewerage Treatment Plants (STPs) in the Manning catchment, at Gloucester, Wingham, Dawson wetlands (Brimbin), Harrington, Manning Point, Old Bar, Coopernook and Lansdowne.

The majority of the region is unsewered, relying on on-site sewage management (OSSM) systems including traditional septic systems and pump-to-sewer systems. MidCoast Council (MCC) has the responsibility to ensure that all onsite sewage management systems are approved, installed and managed so that they comply with the requirements under the Local Government Act 1993 and Local Government (General) Regulation 2005, and do not pose a risk to the environment or public health.

Failing systems or mismanagement of OSSMs present a pathogen risk to groundwater and receiving waters, with consequent health risks for the oyster industry, potable water and recreation.[233]

Consultation with the Manning CMP Reference Group identified pathogen pollution from STPs, sewerage overflow during storm events and un-sewered villages as concerning issues in the catchment, calling on the CMP to “safeguard capacity of the sewerage system now, and in a changing climate.” Research into pathogens was flagged as critically important by the CMP Technical Working Group.

[233] (Swanson, 2019)

The extent of potential impact and need for pathogen source-control was illustrated in nearby Wallis Lakes in 1997 when the oyster fishery was contaminated with Hepatitis-A virus. In all, 422 consumers contracted Hepatitis-A from the oysters and two people died.[234][235] Investigations found that the pathogens had entered the lake from diffuse sources during a high rainfall event.[236] Faecal contamination was attributed to entering the estuary from failing septic systems from a nearby unsewered village, caravan parks around the lake, pit toilets and potentially from Council's sewerage sullage operations, along with faecal contamination from urban stormwater.[237]

The incident initiated a ten-year catchment improvement program the Great Lakes region involving residents, business and the farming community. While monitoring and management controls set by the NSW Food Authority are in place to prevent contaminated oysters from reaching the market, the incident highlights the ongoing importance of pathogen source control in the estuary.

Stressors

Sewerage and STP run-off has been found to affect water quality in the Manning, particularly during high rainfall events.[238] However, it is important to note that the source of pathogens remains uncertain. During the discussion group held for this issue it was stated that, for the oyster industry, the highest faecal input comes from livestock impacts (on oysters) but human pathogens have the highest safety risk. Genetic research is underway to understand the incidence of human, stock and native animal sources in Pelican Bay through the Food Agility CRC's Oyster Transformation project. Field and GIS investigations can also identify the likely source.

Poor microbiological water quality is an issue in the lower estuary, where the Shellfish Quality Assurance data held by the Food Authority continues to show elevated faecal coliform and E.coli readings after 25mm of rain (Food Authority).[239] Although data is highly variable, high E. coli counts frequently occur at the downstream end of Barrington River at the offtake for Gloucester water supply. Cattle have access to the river upstream of the offtake, and poor on-site sewage management could also be contributing to the pathogen load.

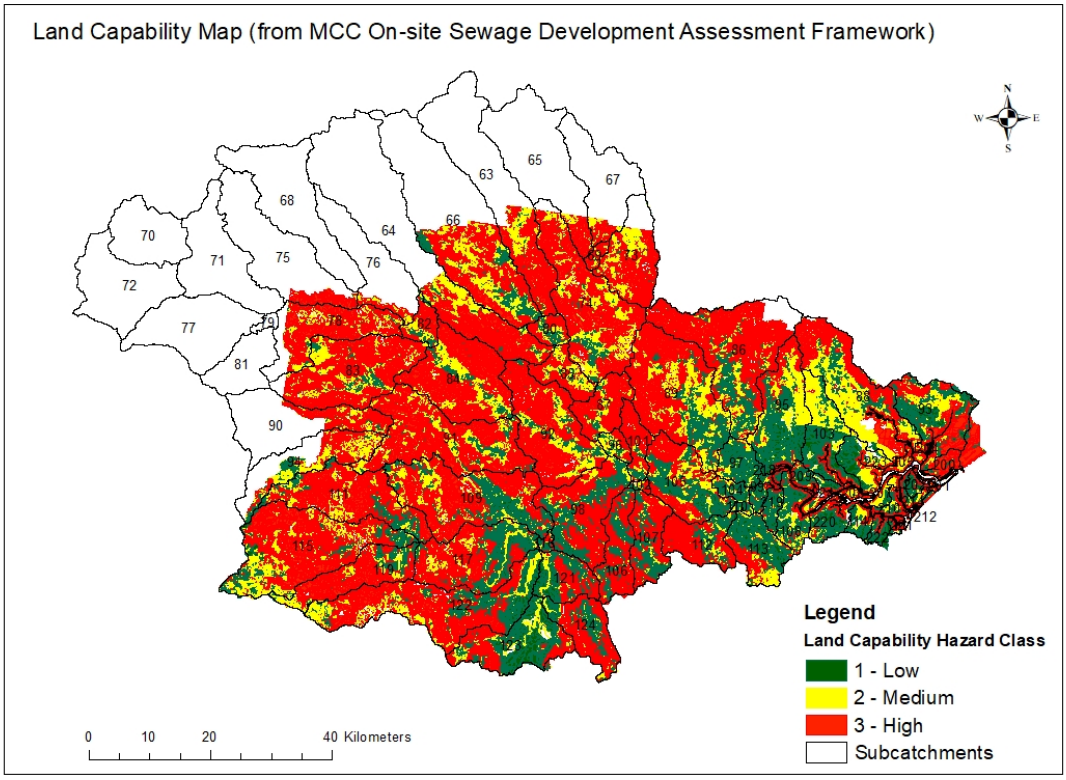
Additional risks to the wastewater treatment system as a result of climate change were discussed at an interdepartmental workshop for MidCoast Council personnel in October 2019. Increased severity and frequency of extreme weather events modelled for the Manning catchment will increase risks of pathogen pollution by increasing water and run-off volumes during high rainfall events. Manning Point and Old Bar STPs are vulnerable to sea

[234] (Kardamanidis, Zammit, & Corbett, 2009)
[235] (Great Lakes Shire Council, 2009)
[236] (Kardamanidis, Zammit, & Corbett, 2009)
[237] (Pengilley, 2003)
[238] (Williams, 1987)
[239] (Bullock,, 2018)

level rise (SLR) and extreme weather events. Marine water quality impacts and infrastructure risk for the ocean sewerage outfall at Janie's Corner were also discussed at this workshop.

Decentralised Water Consulting (DWC) has developed an On-site Sewage Management Development Assessment Framework (DAF) for MCC to guide Council's levels of investigation, acceptable solutions (deemed to satisfy) and minimum standards for the installation of onsite sewage management systems in unsewered areas (DWC 2018a). This document is currently in Draft and is currently being aligned with Councils planning instruments (DCP and LEP) to ensure consistency across the entire LGA. Once this process has been completed, the DAF will be placed on public exhibition and a report will be prepared for Council.

Map 1 below shows hazard classes for land capability to attenuate discharge from OSSM systems. Note that the low capability for sustainable OSSM equates to a higher risk for pathogen discharge, which is clustered along the Manning estuary, the lower tributaries and Gloucester River. The risk assessment considered many factors in assigning the Hazard Class such as soil, slope, climate as well as proximity to, and sensitivity of receiving environments.[240]



[240] (Decentralised Water Consulting (DWC), 2018)

Map 1: Land Capability Map showing Hazard Class assigned to unsewered lots in the MCC LGA. [241]

The NSW Food Authority has also mapped and ranked risk from OSSM systems as extreme, high, medium and low in its *potential pollution point surveys* that form the basis of food safety risk assessments for shellfish harvest areas. These assessments are call sanitary surveys and follow the principles outlined in the Australian Shellfish Quality Assurance Program.[242] Critical risk on-site sewage management systems for the oyster industry are located within 100 meters of the shoreline and adjacent to a shellfish harvest area. Spatial data on the current shellfish harvests is available on the NSW Fisheries Spatial Data Portal.[243]

Oyster industry: Pathogens (faecal coliforms and *E. coli*) from sewerage and septic systems are an issue for the local oyster industry, particularly at Pelican Bay, Scotts Creek and the South Channel. Historical water quality results for the lower estuary have not met the standard required for the NSW Food Authority to approve direct harvest of oysters from the area without depuration prior to sale.[244]

The oyster industry relies on water quality and oyster meat monitoring to ensure that food safety criteria set by the NSW Food Authority are maintained for harvesting. There is usually a correlation between rainfall and increased coliforms, typically due to increased runoff across urban areas and grazed pasture following rainfall events, with faecal matter carried by stormwater into the river system. However, instances of high rainfall and faecal coliforms above the threshold limit are not always correlated [245]. There can high rainfall with low faecal coliforms, and also high faecal coliforms with low rainfall. The second is more problematic as it is a difficult risk to manage. If this is being caused by failing OSMS or sewerage systems, it is a very high-risk public health situation. Using genetics to identify the relative contribution from a range of sources including human effluent, stock and native fauna is the subject of current research by the Food Agility Cooperative Research Centre's Oyster Transformation project. It is hoped this project will identify the primary source of faecal contamination in Pelican Bay, and help management agencies direct resources to address this issue.

Drinking water: Pathogens from human sources also pose a risk to raw water quality for potable water extracted from the Manning catchment at Barrington and Bootawa. MidCoast Council's water services team (formerly MidCoast Water) held drinking water risk workshops in May 2016 and July 2020, both of which identified bacteria, viruses, protozoa

[241] (Decentralised Water Consulting (DWC), 2018)
[242] (Anon ,2019) Australian Shellfish Quality Assurance Program Operations Manual; http://safefish.com.au/reports/manuals-and-guidelines/the-australian-shellfish-quality-assurance-program-manual)
[243] NSW Fisheries Spatial Data Portal - https://www.dpi.nsw.gov.au/fishing/spatial-data-portal
[244] (Bullock,, 2018)
[245] (Parsons, 2010)

as high to extreme risk for raw untreated water[246]. According to a preliminary NSW Health (2020) assessment of *Cryptosporidium* risk to drinking water supplies, Gloucester supply is ranked as medium risk, Manning is low.

MidCoast Council has developed a risk based *Drinking Water Management System*[247] under the provisions of the *Public Health Act* 2010 that follows the requirements of the *Australian Drinking Water Guidelines* (ADWG) 2011. It is a proactive, risk based approach to managing drinking water supplies. An annual monitoring plan specifies programs for drinking water quality monitoring in each of Water Services' water supply systems including catchments.

In the financial years 2018-19 and 2019-20, results for microbiological and physical water quality testing across the Manning and Gloucester water supply schemes post-treatment met ADWG for 100% of samples collected and tested.[248] While unmitigated risk is still very high, Water Treatment Plant and operational policies (e.g. selective extraction from the river) produce safe drinking water (L. Andersons pers. comm. Aug. 2020).

Recreation: Pathogens present a hazard for a range of other activities including passive and secondary recreation, with popular activities including swimming, boating and kayaking. There have been no recorded issues, however if there is a failure of sewerage systems that may impact creeks/river that have recreational use, MCC will erect signs (in discussion with NSW Health) advising people not to swim until water quality results return to acceptable levels. They also notify the NSW Food Authority and Environment Protection Authority as part of the license requirements (L. Andersons pers. comm. Aug. 2020).

Impacts

When compared to pathogens from stock defecation, human pathogens pose the greatest human health risk. Ingestion and skin contact through recreation, drinking contaminated water and eating contaminated seafood can lead to health impacts such as diarrhoea and gastroenteritis. Infection, disease and illness present a high social and economic cost to the community.

Oyster industry: Human pathogens affect the productivity of the local oyster industry and its ability to direct harvest, thus impacting the local and regional economy. In the Manning oyster fishery, rainfall exceeding 25mm in 24 hours is a trigger for closure of harvest areas due to the potential decrease in salinity and increase in faecal coliforms that can result from significant rainfall stormwater run-off.[249][250] Depuration requirements add time and cost to the harvest-to-market process. Hunter Local Land Services is working with the oyster industry with a goal to lift the trigger to 30-35mm by identifying and remediating pathogen sources. This would yield significant savings to oyster growers.

[246] (Bligh Tanner, 2016)
[247] (MidCoast Water Services, 2018)
[248] (MidCoast Council, 2019)
[249] (Bullock,, 2018)
[250] (Parsons, 2010)

Drinking Water: The potential for pathogens in drinking water to impact on human health is mitigated by a range of treatment methods at the Water Treatment Plants at Bootawa and Gloucester. If guidelines for *E. coli* bacteria or other water quality parameters measured as critical control points are not met during regular water quality monitoring, MidCoast Water Services may issue a boil water alert to affected customers in consultation with NSW health.

12.2 Stakeholders

Management agencies

NSW Food Authority, MCC Water Services, MCC Environmental Health and Natural Systems teams, Environment Protection Authority (EPA), Department of Primary Industries - Fisheries, Hunter Local Land services (HLLS).

Whose affected?

Oyster farmers, MCC Water services (rate payers, water buyers), passive and secondary recreation users, recreation and commercial fisheries. Tourism industry (e.g. kayaking Barrington and Gloucester).

12.3 Existing Management Approach

- MCC sewage treatment plants treat water to a tertiary level and operate under licences from the NSW Environment Protection Authority (EPA) which sets standards for the treated water returned to the environment from the plant. Over recent years many sewage treatment plants have been upgraded to provide a higher level of treatment and to be able to cope with growing populations – particularly in coastal areas. There has been increased beneficial reuse which reduces volumes of treated effluent discharged to river, along with discharge of tertiary-treated water into groundwater via exfiltration ponds that further polish the water.
- Over the past 20 years, MidCoast Water, now MCC Water Services, has expanded off-site sewerage services to smaller villages, particularly those in environmentally sensitive areas. In the Manning estuary catchment these include Lansdowne, Harrington, Manning Point, Coopernook and Old Bar. Lack of funding from NSW Government, low cost-benefit ratios and caps on growth mean some villages on the estuary such as Croki remain unsewered.
- MidCoast Council engaged consultants DWC to develop an On-site Sewage Management Development Assessment Framework for council to guide levels of investigation, acceptable solutions and minimum standards for sewage management in unsewered areas.[251] All unsewered allotments in the MidCoast area have been

[251] (Decentralised Water Consulting, 2018)

assigned an On-site Sewage Management Hazard Class that determines the level of detail required for supporting information submitted with development applications and applications to install or alter sewage management systems. The mapping produced can be used to inform those subcatchments which are a source of human pathogens to aquifers, groundwater and waterways, if waste systems fail or are not fit-for purpose.

- Council audited high risk on-site septics in early 2000's, and complying systems were issued an "approval to operate", some of which required an annual renewal. While there is currently no systematic audit program, Council is reviewing and preparing an On-site Sewage Management Strategy for the entire MidCoast Council region. This will ensure that Council has a robust inspection and monitoring program in place for existing OSSM operating within the catchment.
- Oyster farming: Water quality data for the lower Manning River estuary has been gathered by the Oyster Farmers Association (OFA) and the NSW Food Authority since 2003 (salinity and faecal coliforms) at key oyster growing areas on Scotts Creek, the South Channel and the Manning River. Stones collect monitoring data for the Shellfish Quality Assurance program. Records and analysis are the role of the NSW Food Authority.
- A study of the suitability of Pelican Bay as a direct harvest area was prepared in 2018 for HLLS,[252] and a real time data sensor was installed. HLLS has contracted further fieldwork to identify sources of poor water quality and possible remediation actions and locations in the Pelican Bay area. MidCoast Council carried out inspections of all pump-to-sewer on-site sewage management systems in 2019 to ensure the performance of these systems were not contributing to potential poor water quality results.

12.4 Knowledge Gaps

- Limited in-stream bacterial data available to determine the source and nature of faecal coliforms – human, livestock, urban stormwater, septics, cattle grazing, dairies
- Weekly *E. coli* data is available at all WTP intakes. Expanded water quality monitoring program for *E. coli* is recommended at recreational sites, offtake locations, aquaculture sites and at upstream locations. This sampling could also include genetic sampling to determine the source of faecal contamination (stock, human).
- The source of *E. coli* in Barrington River (stock and/or human waste) could be characterised through genetic analyses (via Seymour group, UNSW).

[252] (Bullock,, 2018)

- Discrepancies in Council records of sewered properties on Manning Point Road, and those which have on-site sewage systems with pump-out facilities, should be addressed.[253]

12.5 What's working, what's not?

What's working

- Improvements in water quality achieved in Coopernook, Manning Point.
- Dawson sewage treatment plant (which services Taree, Tinonee and surrounding areas has minimum impact on the oyster leases, largest impact comes from farms and OSSM.
- Amendments were made to the LG Act as a result of the oyster crisis in Wallis Lake included requirements for development approval and inspection of OSSMs.
- MCC is preparing a development assessment framework to ensure OSSM systems are designed to meet the constraints of the land.
- MCC is preparing an OSSM audit program. All systems within 500m of oyster leases have been mapped. Considering an inspection plan that focuses on the risk of the systems and their location to create a sustainable inspection program across the LGA. (OSSMs within 50m might be a more achievable and useful target – pers. comm. Anthony Zammit August 2020).
- MCC recently mapped and audited all of Pelican Bay pump to sewer OSSM systems (2019-2020).
- Water services are revising their Integrated Water Cycle Management Strategy (2020-21), this takes into account the management of climate change and potential impacts on overflows during dry weather. Strategies are being considered to manage the system via sensors and new technologies.
- With regard to offsite sewerage management, Manning catchment doesn't have problems with areas that are sewered, but if there are large events, spills need to be notified as soon as practicable to the industry to manage harvest (dry weather spills have a greater impact).
- Protocols are in place for sewage overflow and these are effective at communicating to the oyster industry, this is very critical for human health.
- A servicing strategy for sewer in smaller localities (e.g. Croki) is being developed by water services, undertaking a risk assessment to determine the priority sites across MCC.

[253] (Bullock,, 2018)

- Funding the servicing of these small schemes is challenging and the servicing strategy will establish the basis for funding applications to service high risk areas with small scale technologies.
- The oyster transformation project has been taking weekly water samples for the last two years to quantify the *E. coli* and identify the source. Real time temperature and salinity sensors are in the Manning, correlating rainfall to *E. Coli* results to guide the management strategy for oyster growing. Results are going to be ready by the end of September.
- Information flow is good in relation to this issue, good networks across agencies and industry, and good continuity of personnel.
- Wastewater re-use increased during the drought but has a high energy cost.

What's not working

- The inspection program for OSSMs under the former Greater Taree Council has not been completed, but areas in high risk oyster growing areas have been inspected.
- Pathogen risks would be reduced by increasing compliance audits. Inspection plans should prioritise high risk areas e.g. OSSMs close to oyster leases and drinking water catchments should be inspected every 3 years as a minimum.
- Improve risk management on septic pump-to-sewerage line e.g. Pelican Bay
- Limited resourcing for monitoring OSSM across MCC LGA. There are more than 12,500 OSSMs registered in MidCoast LGA, with 3.5 EFT Environmental Health Officers and 0.75 EFT Business Support Officers to manage the operation, maintenance and inspections of all OSSMs.
- Stock in riparian zone are impacting on oyster growers test results: there are some areas that have seen improvements due to land ownership change and some areas that haven't (see CMP Issue Paper on Agricultural Impacts)

12.6 Opportunities

- Use improved site specific pathogen data now available to identify and locate high risk sources.
- Use natural infrastructure to attenuate pathogens by excluding stock and restoring coastal wetlands and riparian vegetation, hydrology and tidal exchange.
- If there are too many OSSMs in the 500m buffer for regular auditing, reduce range to 100m for "high priority" classification.
- Seek support from industry for funding applications for sewering locations which are in close proximity to oyster leases.

- Use Oyster Transformation genetic study data to guide on-land investigations of sources of human pathogens which are of most concern to the oyster industry.
- Utilise new technologies in OSSM and small offsite community sewage management schemes to improve wastewater solutions in high priority small villages (Croki).
- Croki residents have approached water services and local member to seek sewering of the village, local member indicated that there may be some resources available.

12.7 Management Options

Planning

- Update the MCC LEP and DCPs to reflect the MCC On-site Sewage Development Assessment Framework.
- Identify and map high risk areas for pathogen contamination. Use monitoring data, results of Oyster Transformation study and field investigations to characterise the source and risk rating for pathogens in each area.
- Develop site-specific pathogen management plans for high priority areas.
- Ensure STP management is effective and capacity matches new residential demand.
- Review the Farquhar Inlet Entrance Opening Management Strategy as an action of the Old Bar Manning Point CMP.

Compliance

- Complete and commence implementation of the OSSM Audit and Compliance Plan to inform proactive MCC inspection program in high risk locations. Properties within 100m of oyster farms should be the focus for Council investigations, followed by popular sites for primary and secondary recreation.
- Develop a resourcing strategy that identifies staff requirements and additional safeguards that can be put in place to reduce the risk of OSSM failure.
- Integrate MCC compliance management of STPs and OSSMs in the DPOP as a high priority to protect estuary health.

On-ground operations

- Implement the Pelican Bay Subcatchment Improvement Program to improve water quality led by HLLS in partnership with MCC and BCT.
- Gloucester STP is currently in the design phase of a significant upgrade which will ultimately result in a decrease in nutrients and pathogens in treated effluent entering the river.

Capacity Building

- Coordinate a private conservation incentive program to restore coastal wetlands and improve tidal exchange in partnership with landowners.

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13. Urban Stormwater and Litter

This issue paper covers the risks to estuary health from stormwater runoff from urban areas. It considers the impacts of urban development both during the construction phase and the ongoing impacts that occur once the urban area is developed.

Contributors: Prue Tucker, Erin Masters

13.1 Situation Analysis

Activity

Urbanisation in the towns of Taree, Wingham, Harrington and Old Bar has resulted in the creation of large areas of impervious surfaces such as roads, rooves, driveways and carparks which decrease rainfall infiltration and increase stormwater overland flow velocities and runoff volumes into the estuary (Worley Parsons 2009).

The major tributaries of the Manning River estuary which lie within the MidCoast area include Dingo and Cedar Party Creeks (upper tributaries), Browns Creek, Cattai Creek, Dawson River and Lansdowne River (lower tributaries). Urban areas have been established along many of these tributaries (see Figure 1 below). A complex estuarine system occurs where the lower Manning River divides into a meandering network of channels and passages. The Manning River enters the ocean at Harrington with another intermittent entrance at Farquhar Inlet north of Old Bar.

Tides influence stormwater quality within the urban catchments of Old Bar, Harrington, Cundletown, Taree, and Black Head Lagoon. Intermittent opening of Racecourse Creek at Old Bar and Harrington Lagoon affects stormwater quality in these locations due to concentration of pollutants and sediment. Stormwater outlets flow direct to the Manning River estuary from Taree, Cundletown and Harrington urban catchments. These outlets are set at various levels and many are fitted with flood mitigation structures such as floodgates (GTCC 2000).

The townships along the Manning River are well established and, in many cases, contain aging stormwater infrastructure. There are also significant development areas proposed North of Taree on the Western side of Dawson River.

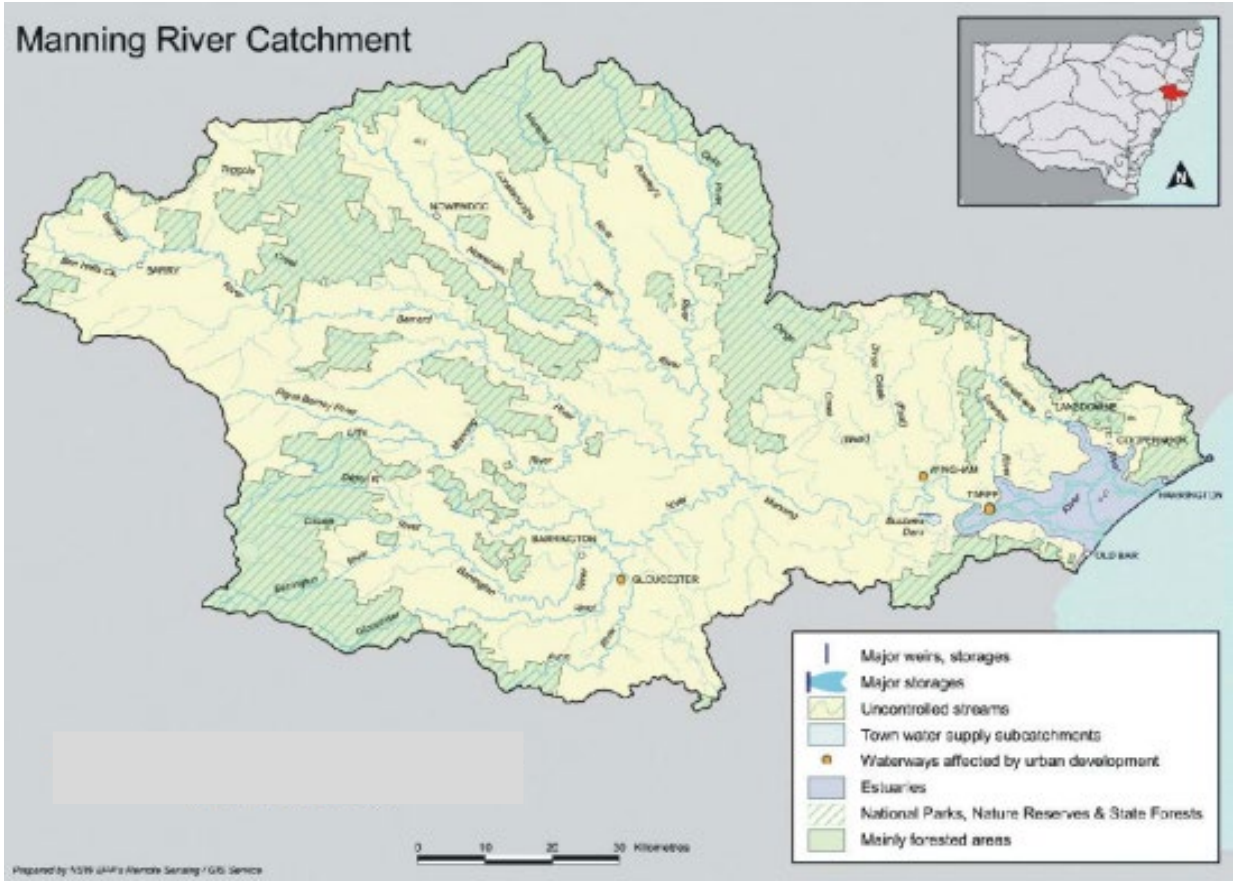

Figure 1: Waterways affected by urban development (NSW EPA 1999)

Stressors

Stormwater runoff can include a variety of different pollutants that have an effect on water quality. In the Manning region runoff from urban townships which have large areas of impervious surfaces, pollutants often include litter, bacteria, nutrients, sediment, organic matter, chemicals and pesticides (NSW Govt. 2009).

- Litter and micro plastics: A form of visual pollution, plastics can mimic natural food sources and injure/kill wildlife including birds, fish and dolphins. Litter also often contains toxins that can affect water quality and damage plants and animals.

  While litter and plastic waste is an issue throughout the Manning catchment this is particularly the case in areas like Taree (which is the largest township but also sees a transient population from outlying rural areas). Taree contains very large catchment areas (see Figure 2 below). Of particular concern for litter management T1, T4 and T5 are highly built-up and contain mixed land uses (residential, commercial and industrial). These catchments discharge into outlets that create a build-up of litter at each location (for example Browns Creek).

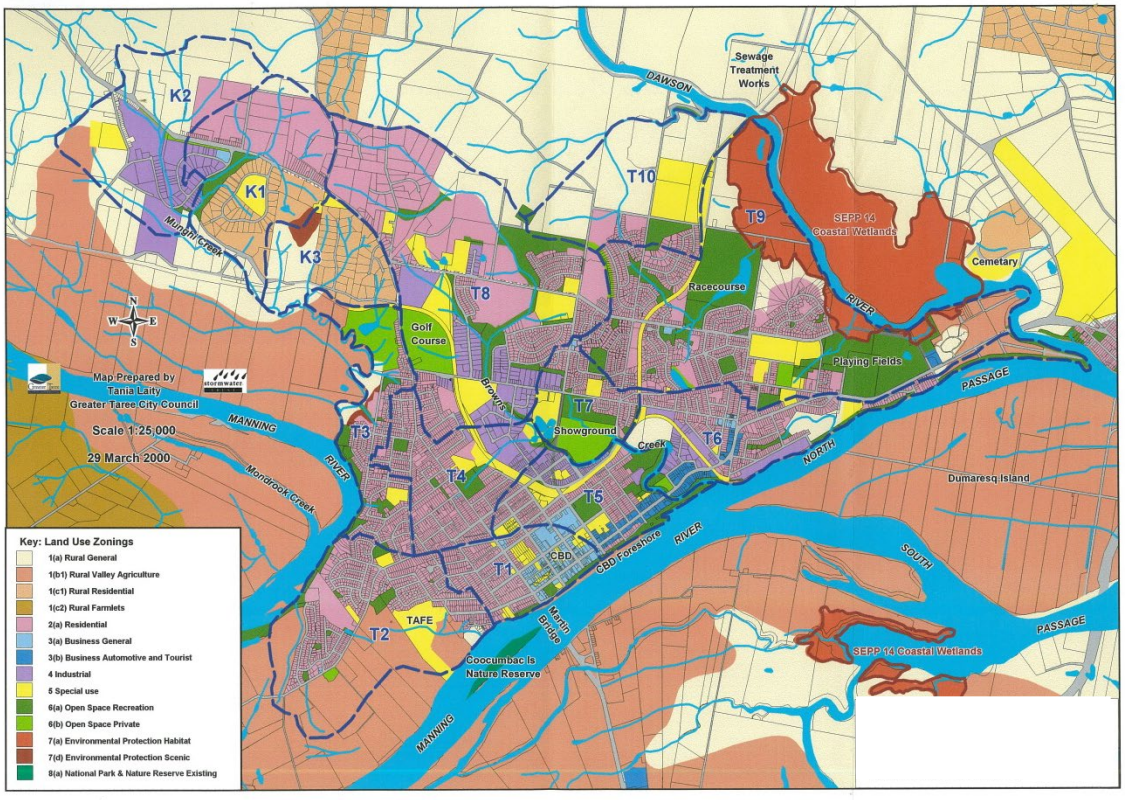

Figure 2: Taree Urban Stormwater Catchment Areas

- Nutrients and Sediment: Increased levels of sediments entering into the waterways from stormwater runoff reduce the amount of light available for seagrass to grow, compromising habitat as well as directly impacting on aquatic fauna.

  Sediment transport is particularly problematic during the construction phase of urban development during which time soils are exposed increasing the risk of sediment being transported to the waterways. Over the life of a development 80% of sediment lost occurs during the construction phase.

  Excess nutrients fuel algal blooms which also lead to habitat loss. While rainwater naturally contains nutrients, the development of urban areas throughout the Manning estuary means there is less vegetation, reduced evapotranspiration, less infiltration of rainfall to ground water, and greater volumes of runoff. The increased runoff volume contains the nutrients from rainfall, but also has the added inputs of sediments, fertilizer and petrochemicals that are collected in the stormwater as a result of human activity.

- Organic matter: As vegetation breaks down in the water it reduces oxygen levels in the water killing plants and animals. Urban areas in the Manning estuary can add to this issue through the disposal of grass clippings and other materials through the stormwater system. This has been particularly evident in larger residential areas such as Harrington where an increase in grass clippings resulted in a targeted campaign to reduce this activity in 2009.

- Chemicals, pesticides: Chemicals and pesticides transported by stormwater runoff can form a film over water and make it difficult for aquatic animals and plants to breathe. In the Manning estuary these kinds of chemicals have the potential to become problematic in two main areas - industrial zones in Wingham and Taree and to a lesser extent in residential areas.
- Hydrocarbons, heavy metals: Across all urban areas, runoff from roads sees hydrocarbons and heavy metals such as copper (from tyre wear and tear) transferred into the waterways.

Climate Change pressures will impact on the effectiveness of the stormwater system. The majority of urban areas in the Manning are located in the catchments of the estuary and as such will be affected by climate change, in particular sea level rise and extreme weather events. Increased sea levels will reduce the efficiency of stormwater assets such as Stormwater Quality Improvement Devices (SQIDs) including gross pollutant traps and biofiltration systems.

Increased storm activity will also reduce the ability of stormwater systems to function correctly, preventing runoff from escaping and potentially causing both stormwater quality and quantity issues.

Impacts

A preliminary spatial risk assessment for the Manning River Estuary produced for the Scoping Study in Stage One of the catchment management planning process found that pollutant loads from urban stormwater are relatively low compared to catchment loads from agricultural land (MCC 2020). Potential ecological impacts from urban stormwater include reduced diversity and abundance of macro-invertebrates and disruption to spawning cycles of some native fish species which are often triggered by seasonal floods (Worley Parsons 2009).

Increased levels of sediments entering into the waterways from stormwater runoff reduce the amount of light available for seagrass to grow. Parts of the Manning Estuary are home to seagrass beds, an important natural habitat for aquatic life. Seagrass monitoring is undertaken as part of the annual Waterways and Catchment Report Card program. The 2019 results showed a change in seagrass from moderate depth range in 2018 to no seagrass present in the Upper Manning Estuary. In the Mid Manning Estuary, the 2019 results continued with the poor depth range (MidCoast Council 2018, 2019). While this does not conclusively link urban development with seagrass health, it is important to note that a combination of activities may be exhibiting stress on the ecological health of the Manning estuary.

The impacts of stormwater on water quality differ in each of the main urban areas located within the Manning catchment and are dependent on land use and infrastructure in each area. In the Taree catchments identified hotspots (GTCC 2000) such as Browns Creek are affected by runoff from the town centre and large percentages of the residential area which

carries with it litter, hydrocarbons, sediments and nutrients reducing the water quality in the creek.

In the Wingham area large catchments with aging infrastructure have led to increased erosion at outlets causing sedimentation in the local waterways. Additionally, issues with hydrocarbons and litter entering the system have been reported in the past, particularly at the Wingham Wetlands site which is located next to the major shopping centre.

In the Harrington and Old Bar areas, urban expansion has been increasing the extent of impervious surfaces and stormwater runoff. Racecourse Creek is also an identified stormwater hotspot.

13.2 Stakeholders

Management agencies

Agencies: MidCoast Council (MCC), Hunter Local Land Service (HLLS), DPIE – Environment, Energy and Science, NSW Government.

Community: Friends of Browns Creek; businesses including organised groups like Team Taree, OzFish, Landcare, Dunecare

Who's affected?

Private landholders, MCC, Crown Lands, community members, fishing and oyster industry.

13.3 Existing Management Approach

Stormwater Quality Improvement Devices: In the 1990s and early 2000s a large number of Stormwater treatment devices were installed throughout the Manning area and include Gross Pollutant Traps (GPTs), side entry litter baskets in the gutter and biological systems such as wetlands. These stormwater treatment systems filter stormwater pollution before it has a chance to enter our waterways.

In the Manning area there are 24 gross pollutant units located in Taree, Wingham, Harrington, Black Head, Old Bar and Gloucester. An additional ~150 side entry litter baskets are located in Taree and Redhead and constructed wetlands are located in Wingham and Black Head.

MidCoast Council (MCC) is working to ensure that the current stormwater treatment systems are operating effectively to protect our waterways. A project is underway which aims to establish a cross-Council approach to maintaining stormwater quality improvement devices. The project will involve reviewing current maintenance arrangements, asset monitoring and renewal. In 2019, Council with assistance from consultants Optimal Stormwater completed an audit of the majority of GPTs in the MidCoast region including the devices found in the Manning. The audit assessed how well the GPTs were functioning and provided recommendations for repair and maintenance.

Following the audit, a comprehensive clean of each device is now being undertaken (June 2020) and rectification works are underway on several devices that have started to deteriorate with age. Works will continue in 2020/21 funded by Council's Stormwater Management Services Charge to ensure that all devices are operating at their full capacity.

Plastic Pollution Reduction Project (PPRP): The PPRP is a joint project between Hunter Local Land Services (LLS), MidCoast Council, Friends of Browns Creek, Tangaroa Blue, TIDE and JR Richards. The PPRP is a collaborative approach to education and engagement with the ultimate goal of reducing the sources of litter/marine debris entering waterways in the MidCoast Council LGA.

The project involves building the capacity of the community to help reduce litter and other stormwater contaminants at the source through education and engagement and has a focus on the Browns Creek catchment.

Browns Creek has been chosen as an example location for this project due to the active community group (Friends of Browns Creek) and the very visible need to remove litter from Browns Creek. As noted above, this is consistent with the fact that Browns Creek has a number of high litter-generating land uses within the catchment. The group have been undertaking clean-ups and beautification works along the foreshore since 2007 and this project has involved supporting and involving the group in developing a source reduction plan for the catchment. The project has also built their capacity to use the Tangaroa Blue methodology to monitor the types and quantities of litter being collected in within the Browns Creek Catchment. Further support is being provided in 2020 to progress actions in the source reduction plan through the appointment of a part time officer based at Taree Indigenous Development and Employment (TIDE), jointly funded by LLS and MCC.

Development Controls: Subdivisions within the Manning region are required to address stormwater management as part of their development application to ensure that any future development has no net increase on water quality (neutral or beneficial effect). The controls are called up by 'Part C Subdivision requirements, C3.5 Drainage' within the Greater Taree Development Control Plan 2010. Any development application for a subdivision is required to demonstrate how they meet these targets by developing a MUSIC Model (stormwater quality model) and Stormwater Strategy. These are developed in accordance with MidCoast Council's Guidelines for Water Sensitive Design Strategies (2019).

If development other than subdivisions occur within the Coastal Environment Area or Coastal Use Areas (Coastal Management Act SEPP mapping) the objectives of the Act are considered in the assessment process. MCC have identified any service stations, commercial and industrial developments, multi-use development, alterations on commercial and industrial and additions that are greater than 10% of the existing impervious area, tourism facilities, mines and quarries as having the potential to impact on stormwater quality and as such estuary health. The targets applied to these developments are derived from the Water Sensitive Design chapter (Chapter 11) of the Great Lakes Development Control Plan (2013). All of these developments (as with subdivisions) are required to demonstrate how they meet the identified targets using the Water Sensitive Design Strategy guidelines.

Once developed, the water quality treatment systems identified in the stormwater strategies are either dedicated to Council following 2-5 years of maintenance by the developer (where the

development is within a Torrens title subdivision); or they are maintained in perpetuity by the owner as a condition of development consent.

In addition to the ongoing water sensitive design controls, it is a requirement of development consent that any development (from large subdivisions though to single dwellings) meet the erosion and sediment control requirements in The Blue Book ("*Landcom. 2004. Managing Urban Stormwater: Soils and Construction. 4th Edition").* It is noted from compliance records that there are ongoing issues with implementation of Erosion and Sediment Controls across all development types.

13.4 Knowledge Gaps

13.5 What's working, what's not?

Stormwater Quality Improvement Devices

- Since their installation many of the Stormwater Quality Improvement Devices (SQIDs) haven't been well maintained. An audit of the Gross Pollutant Traps (GPTs) undertaken in 2019 suggested recommendations for rectification works on these devices and as of 2020 this work is now underway. The project also includes monitoring and data analysis which is being used to develop triggers and an ongoing monitoring and maintenance schedule. The project is an important one and is highlighting the ability of Council departments to form long term relationships to reach long term goals.
- Other SQIDs also require maintenance work including the constructed wetlands. Wingham Wetlands has been placed on the list for assessment and will likely need a major refurbishment over the next few years.
- While there is currently a number of side entry litter baskets located in several housing developments around the Manning Catchment it has been noted that these are not an effective control measure in residential areas. The litter baskets fill up quite quickly with heavy materials meaning that they cannot be manually cleaned and require a vacuum truck to maintain. These litter baskets will be audited during the next phase of the SQID improvement program.
- It is noted however that side entry litter baskets can have a role to play in industrial centres, main streets, commercial or shopping centres.
- In the Manning Region the focus on Stormwater Quality Improvement Devices has often been on hard options such as GPTs and proprietary devices rather than utilising natural infrastructure e.g. bio-swales, constructed wetlands for stormwater management – WSUD, especially in Taree, Wingham. Moving forward with new developments MidCoast Council require biological treatment of stormwater as indicated in the 'Guidelines for Water Sensitive Design Strategies' (October 2019).

Erosion and Sediment Control

- Erosion and Sediment Control is important for protection of the Manning and more work needs to be undertaken across Council's activities and private developments.
- Council needs to lead by example to reduce erosion and sediment runoff. For example, vegetating bare areas such as roadsides to prevent erosion; improving drainage to capture sediment and ensure training is held regularly in a multi-disciplinary way.
- Council's compliance team have issued compliance requests to internal construction teams, and the response has been positive.
- Between 2010 and 2012 Council undertook an erosion and sediment control program for Councils operations; this included an audit program and training, then follow-up audits. Improvements in erosion and sediment control were noted as a result of the program however, the standard of sediment and erosion control dropped off when audit program ended. In June 2019 the erosion and sediment control manual was updated and new training was held for all staff involved in road construction.
- On development sites, erosion and sediment controls can be lacking, this has been observed as being a particular issue on individual lots. When building a new home, the developer can use either Council or a private certifier and it is the certifier's responsibility to check erosion and sediment control as set out in the development application. If erosion and sediment controls are not appropriate it will be the responsibility of the relevant certifier address any issues.
- Where there is no development consent or private certifier the MidCoast Council compliance and engineering team may become involved in compliance. Engineers are the subject area experts and provide advice on what standard is required; the compliance team issues notices and then the engineers may attend to check it has been rectified to appropriate standard.

Planning Policies

- MidCoast Council have a number of different Local Environment Plans (LEPs) and Development Control Plans (DCPs) across the region. The relevant plans for the Manning Region do not currently contain a trigger to require water quality treatment for ‘other development’ (development other than subdivisions) within the Manning Catchment
- Currently there is not a process in place for long term follow-up of development consent conditions for GPT maintenance. This is will need to be included as part of the SQID improvement program in the future.

Community Involvement

- The work undertaken by the Plastic Pollution Reduction Project (PPRP) and Friends of Browns Creek over the past 10 years has been invaluable. Litter collected as part of this project has been uploaded to the Tangaroa Blue database and can be classified to inform source reduction planning in the future. The ongoing challenge for litter removal in the Browns Creek Catchment is the reduced levels of volunteerism that often occurs in long term community groups.

Stormwater Infrastructure

- Much of the stormwater infrastructure in the Manning is older and this can cause issues. Stormwater courses also have legacy issues, for example areas like Browns Creek, Racecourse Creek at Old Bar. Historically they were creek lines or pond systems and now have been turned into permanent watercourses that function predominately as stormwater drains with increased flows and velocity.
- Weeds around stormwater infrastructure are an issue as backyard escapees travel through the system to other areas.

13.6 Opportunities

Community Engagement

- Undertake targeted stakeholder engagement on source reduction. For example, working with businesses in hotspots such as Browns Creek, commercial areas such as those present in Wingham and with sporting organisations at recreation grounds.
- Offer resources and meaningful support to local community groups who are involved in working on public lands.
- Undertake Council lead or provide support for community lead clean up events such as Clean-up Australia Day.
- Reassess historical community education campaigns that could potentially be utilised again in the future. This could include programs such as drain stencilling, messaging during community events, gutter talks etc.
- Establish partnership between government agencies (MidCoast Council, LLS) independent organisations (Tangaroa Blue) and community groups (Friends of Browns Creek, Ozfish) to undertake on ground works and community engagement projects.
- Look at what community engagement projects are being run in other areas and how they could be undertaken in the MidCoast area. For example, Tangaroa Blue has a project in Victoria on nurdles called Operation Cleansweep https://www.tangaroablue.org/amdi-network/reefclean/opcleansweep/

- Utilise data collected during clean-ups/GPT audits to target source reduction programs at hotspot locations with highest loads as well as types of litter.

Stormwater Infrastructure

- Use WSUD and integrated urban stormwater management to improve design of new developments in the Manning Catchment.
- Look for opportunities to improve stormwater infrastructure utilising contemporary best practice. Investigate a range of new technologies that could be installed (e.g. Floating Bandelong traps/booms, CDS Units).
- When modification is being made to stormwater infrastructure for water quantity issues also look for opportunities to mitigate pollution and improve water quality. This could be targeted in high priority subcatchments or opportunistic as other works are already being undertaken.

Planning Policies

- Establish stormwater discharge baselines, set clear water quality objectives and monitor against it to track performance.
- Include water quality controls within the MidCoast Council LEP and DCP.

Compliance Programs

- Run proactive, targeted compliance programs these could be similar to those run in the past which included a targeted education program along with Council officers running a blitz of inspections and rectification notices. Breaches could include first breach warning, second breach fine, repeat offenders identified. Would need to bear in mind the roles and responsibilities Council vs. private certifiers on some developments.
- Benchmark and promote erosion and sediment control within Council teams to promote best practice.
- Utilise the POEO Act when appropriate.

Additional Opportunities

- When information from the container deposit scheme is release utilise this information for further education. There is currently anecdotal evidence that some litter types such as drink cans have reduced.
- Work with programs like the container deposit scheme to ensure that there is not additional litter issues coming from their sites.
- Key litter items survey run by DPIE is being used in Taree every three months - systematic survey. Results not released yet (Edwina DPIE has data).

- Assess opportunities presented by state run programs like the NSW plastics plan which include a data survey sheet can be used for monitoring and analysis.
- Undertake research on the effects of litter on waterways for example PET bottles on the river bed.
- Investigate opportunities to involve government agencies in undertaking clean-ups. For example, Georges River used to utilise community service teams a week to undertake litter collection in priority areas.

13.7 Management Options

Develop a litter and stormwater pollution source control program:

- Monitor for volume, type and location of litter, set targets and monitor progress
- Utilise this data for targeted education and engagement campaigns including the use of source control plans that promote responsible behaviour
- Provide support for existing community groups involved in litter removal and clean-up programs
- Apply lessons learnt at Browns Creek to develop clean-up programs in new areas
- Reassess historical community stormwater education and advocacy campaigns and implement a new program for the general community.

Develop an erosion and sediment control (ESC) improvement program:

- Build the capacity of designers, builders, engineering consultants and developers to improve the planning and construction of ESC.
- Undertake proactive, targeted compliance program across private and public land.
- Review Councils approach to ESC, identify and implement improvements, set benchmarks, establish audits.

Implement best practice stormwater infrastructure management:

- Take an integrated approach to the management of stormwater quantity and quality, seek opportunities to incorporate water quality treatment into infrastructure upgrades and new infrastructure.
- Review the Taree stormwater plan integrating water quality and quantity controls, implement actions.
- Implement the MCC wide approach to maintaining stormwater quality improvement devices, including maintenance arrangements, asset monitoring and renewal (including Wingham Wetland).

Establish water quality requirements in the planning framework:

- Include water quality controls in the MidCoast LEP and DCP clearly identifying targets and development types where water quality controls apply.

13.8 References

MidCoast Council MCC (2018). Scoping Study: Manning River Estuary Coastal Management Program.

MidCoast Council (2018). *Waterway and Catchment Report Card, Reporting on data October 2017 to March 2018*. MidCoast Council.

MidCoast Council (2019). *Waterway and Catchment Report Card, Reporting on data October 2018 to April 2019*. MidCoast Council.

NSW Government (2009). *NSW Diffuse Source Water Pollution Strategy*. NSW Government.

Worley Parsons (2009). *Manning River Estuary Management Study*. Greater Taree Council.

Alluvium Consulting, MidCoast Council (2019) Guidelines for Water Sensitive Design Strategies. MidCoast Council.

Landcom (2004). Managing Urban Stormwater: Soils and Construction. 4th Edition.

14. Appendix 1: Issue Analysis Process

ISSUE	Issue paper & Peer review complete	Discussion group meeting date	Discussion Group Participants	Final Issue paper complete (incl discussion group input)
Agriculture Impacts	8/07/2020	2pm-3:30pm Tuesday 11/8/20	Facilitator/Notes: Louise Duff/Prue Tucker Attendees: Albert Mullen, Geoff LeMessurier (HLLS), Brad Henderson (WRL). David Bowland, Drew Morris, Aaron Kelly (MCC) Lyn Booth (M2T Landcare), Kirsty Hughes(CMP Reference group).	14/08/2020
Floodplain Drainage Management	16/07/2020	10am-11:30am Thursday 13/8/20	Facilitator/Notes: Louise Duff/Prue Tucker Attendees: Gerard Tuckerman, Bob McDonell, Karen Bettink; Tanya Cross (MCC); Geoff LeMessurier (HLLS); Will Glamore, Brad Henderson (WRL)	14/08/2020
Modified Flow	7/08/2020	2-3:30pm Tuesday 18/8/20	Facilitator/Notes: Louise Duff/Karen Bettink Attendees: David Bowland (MCC water services); Mathew Bell (MCC Natural Systems); Claire Evans (DPIE Water and Science group).	21/08/2020
Sewerage and Septic	18/08/2020	10-11:30 am Wednesday 19/8/20	Facilitator/Notes: Louise Duff/Karen Bettink Attendees: Malcolm Hunter (MCC Enviro health), Prue Tucker (MCC Natural Systems); Adam Turville (MCC Water Services); Anthony Zammit (NSW Food Authority) Shauna Murray and Matt Tesorario (UTS); Ian Crisp (Manning River Oyster Farmers Association)	11/09/2020

Vegetation Loss	10/08/2020	10am-11:30am Thursday 20/8/20	Facilitator/Notes: Louise Duff/Karen Bettink Attendees: Mat Bell, Tanya Cross, Drew Morris (MCC Natural Systems), Geoff LeMessurier, Jesse Gollan (HLLS); Tim Pietsch (Griffith Uni); Chris Scott (MC2T Landcare)	10/09/2020
Urban Stormwater, litter and marine debris	8/07/2020	2 PM-3:30pm Thursday 20/8/20	Facilitator/Notes: Prue Tucker/Louise Duff Attendees: Erin Masters (MCC Natural Systems); Michael Millang (MCC Drainage Engineer); Becky Hunter (MCC Health and Environment).Tony Wales (Manning River ECMP Reference Group)	10/09/2020
Biodiversity Loss	28/07/2020	2-3:30pm Tuesday 25/8/20	Facilitator/Notes: Louise Duff/Karen Bettink Attendees: Anthony Marchment, Mat Bell (MCC); Chris Sheed (TIDE), Andrew Steed (Aussie Ark); Reegan Walker, Rye Gollan, Toby Whaleboat, (HLLS); John Harris (CMP Reference Group); Kerrie Guppie (Manning River Turtle Conservation Group)	15/09/2020
Coastal Wetlands Loss	20/08/2020	10am-11:30am Wednesday 26/8/20	Facilitator/Notes: Louise Duff/Karen Bettink Attendees: Prue Tucker (MCC); Brian Hughes, Geoff LeMessurier, Kirby Byrne (HLLS); Josh Chivers (NPWS); Tony Wales (CMP CRG).	23/09/2020
Entrance Modifications and Modified Hydrology	20/08/2020	10-11:30am Thursday 27/8/20	Facilitator/Notes: Louise Duff/Karen Bettink Attendees: Prue Tucker Andrew Staniland (MCC); Catherine Knight (Crown Lands); Neil Kelleher (DPIE); Will Glamore (WRL); Kevin Morton (Transport for NSW - MIDO).	23/09/2020
Community Stewardship		2-3:30pm Thursday 27/8/20	Facilitator/Note: Louise Duff/Karen Bettink Attendees: Erin Masters, Prue Tucker Drew Morris (MCC); Kirsty Hughes (Manning CMP CRG); Jessica Leck (MC2T Landcare); Kirby Byrne (HLLS)	

Erosion and Sediment		10-11:30 am Tuesday 1/9/20	Facilitator/Notes: Louise Duff/Drew Morris Attendees: David Bowland (MCC Water Services); Aaron Kelly (MCC Strategic Planning); Geoff Le Messurier, Kirby Byrne (HLLS); Scott Carter, Kylie Russell (DPI Fisheries)	23/09/2020
Flooding, Coastal Inundation Tidal Inundation		10am-11:30am Wednesday 2/9/20	Facilitator/Notes: Louise Duff/Drew Morris Attendees: Evan Vale (MCC Flood Engineer), Peter Hatton (MCC Emergency planning); Andrew Staniland (MCC Natural Systems); Will Glamore, Bradley Hancock (WRL), Neil Kelleher (DPIE); Reegan Walker (HLLS)	23/09/2020