Coastal Management Program for the Tweed River Estuary

Literature Review

Working Draft

October 2016

Prepared on behalf of Tweed Shire Council by Hydrosphere Consulting.

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PROJECT 16-051 – TWEED RIVER ESTUARY CMP – LITERATURE REVIEW

REV	DESCRIPTION	AUTHOR	REVIEW	APPROVAL	DATE
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CONTENTS

TABLES

FIGURES

1. INTRODUCTION

This document provides a consolidated report on the available information which will inform and support the Coastal Management Program (CMP) for the Tweed River Estuary. The review includes:

- An overview of the study to which the CMP will apply including key features and characteristics;
- A review of the existing management context and organisations and agencies responsible for management and regulation of various aspects of the Estuary;
- A summary of the relevant information from the 1991 (Lower Estuary) and 1996 (Upper Estuary) Estuary Management Plans and Estuary Processes Studies;
- A summary of other relevant information including recent studies, plans of management or policy documents and its relevance to the CMP development;
- A discussion of the management issues, supporting data and historical context; and
- Identification of any gaps in the current knowledge relevant to estuary management.

This information is presented within the categories of community uses, coastal ecosystem health and coastal hazards. Management issues drawn from this review will inform the subsequent stages of the CMP.

1.1 The Study Area

The Tweed River Estuary is located between Tweed Heads and Murwillumbah on the NSW north coast within the Tweed Shire Council local government area (LGA). It is the northern-most river in NSW. The Tweed River Estuary runs approximately 35 km from the Bray Park Weir to its confluence with the ocean at Tweed Heads (Figure 1).

Figure 1: The Lower Tweed River Estuary showing Terranora Inlet, Ukerebagh Island and the ocean entrance at Tweed Heads (TSC, 2003).

In the upper catchment upstream of Murwillumbah, the Tweed and Oxley Rivers drain the steep ranges encircling Mt Wollumbin, and meet at Byangum, just above the Bray Park Weir. The Bray Park Weir forms the upward limit of tidal influence and the extraction point for the Tweed Shire potable water supply. Below

Murwillumbah the Estuary meanders across an extensive floodplain that is dominated by sugar cane, and is joined by its northern tributary, the Rous River, at Tumbulgum.

Other major tributaries of the Tweed River system are the Cobaki and Terranora systems, which join the estuary in Tweed Heads. The Cobaki and Terranora systems do not form part of the study area, having been assessed through preparation of the *Cobaki and Terranora Broadwater Coastal Zone Management Plan* in 2013.

The boundary of the Tweed River Estuary CMP study area follows the topographical catchment for the Tweed River Estuary as shown in Figure 2, bounded by Bray Park Weir at the upstream extent.

This management plan focuses on issues with direct impact on the Tweed River Estuary. Areas of the broader topographical catchment upstream of Bray Park Weir are only considered where activities or processes occurring in the catchment have been shown to affect the coastal hazards, ecosystem health, cultural heritage and/or community use of the Estuary.

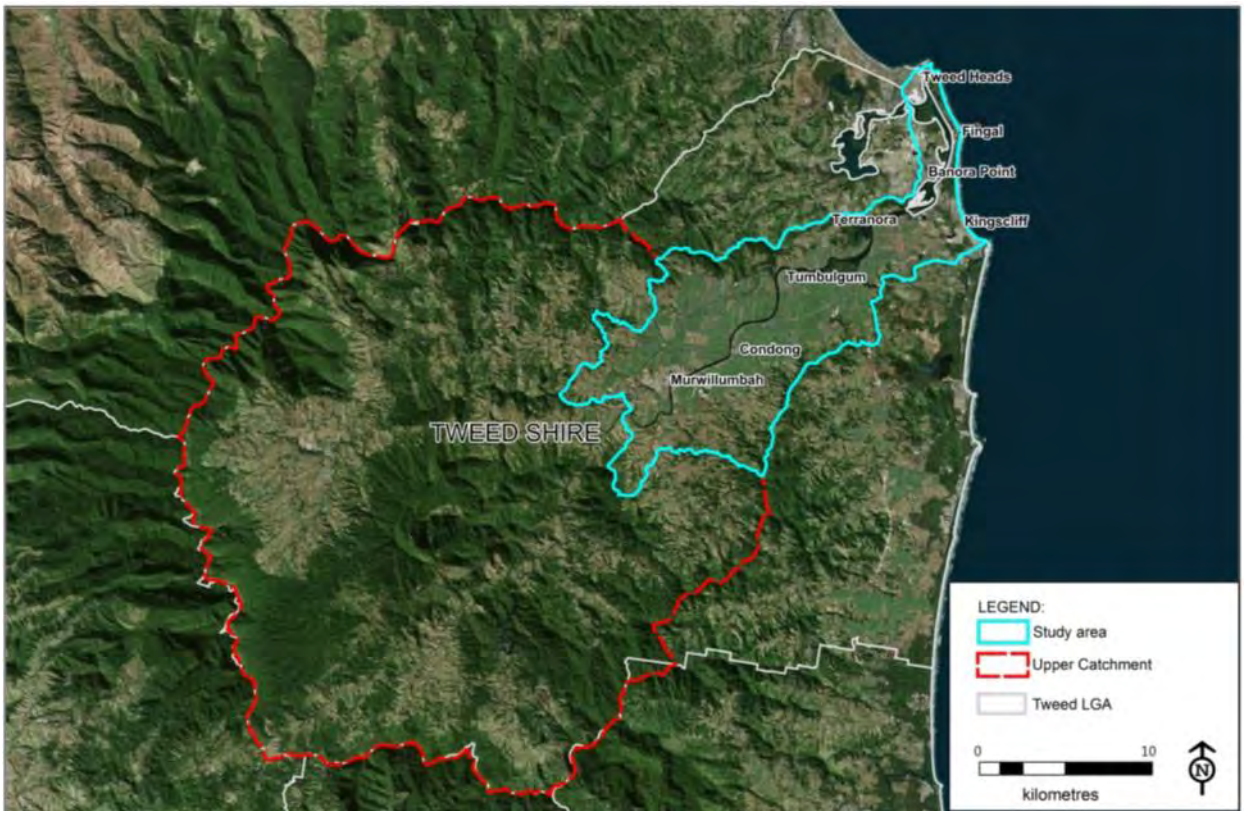

Figure 2: Tweed River Estuary study area and upper catchment upstream of Bray Park Weir

Previous study of water quality in the Tweed River Estuary (ABER, 2012) divided the waterway into five functional zones based on morphology, sediment type, hydrodynamics, salinity regime and water residence times. The broad functional zones described below and shown in Figure 3 will be used throughout the CMP to divide the study area:

- Lower Estuary – from the ocean entrance to Shallow Bay, upstream of Fingal Head;
- Transition – from Shallow Bay up to and including the Tweed Broadwater;
- Middle Estuary – from the Tweed Broadwater to the village of Condong;
- Upper Estuary – from Condong to Bray Park Weir; and
- Rous River – the tidal extent of the Rous River from the confluence with the Tweed River at Tumbulgum to Numinbah Road bridge at Boat Harbour.

ABER (2012) note that the boundaries of each zone can vary considerably with seasonal changes in freshwater inflows, with the greatest variability experienced in the 'transitional zone'.

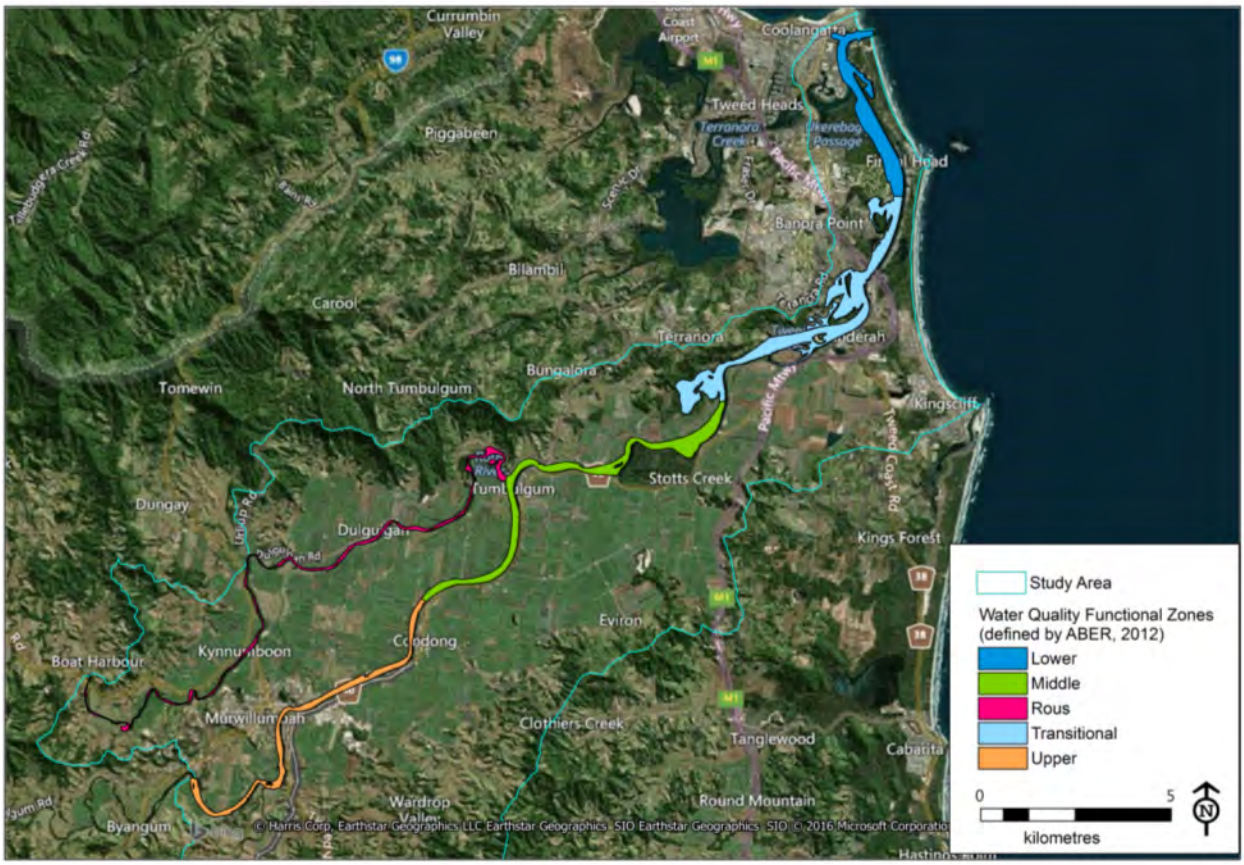

Figure 3: Tweed River functional zones (defined by ABER, 2012)

The Tweed River Estuary retains a significant cultural connection for the local Aboriginal people whose descendants have lived in the Tweed for thousands of years, deriving their physical and spiritual needs from the forests, rivers, lakes and streams of the Tweed valley (TSC 2016b).

European settlement began in the early 1800's when cedar getters first arrived by boat. The river was integral to the European settlers of the Tweed Valley and was the main transport medium for supplies and equipment from the cities and for cut timber and harvested crops to be sent back to the cities for sale.

The Estuary is a popular recreational area of great importance to the local community. Community uses of the Tweed River Estuary including a description of public access, recreational uses, amenity and cultural heritage are discussed in Section 4. Typical Tweed River recreational and commercial boating use is shown in Figure 4.

The Tweed River Estuary has evolved into a diversity of habitats for a wide variety of flora and fauna. Important estuarine habitats include areas of seagrass, saltmarsh and mangroves. Terrestrial vegetation in the immediate vicinity of the Estuary and surrounding catchment also provides habitat for a range of species and includes protected vegetation communities. A number of threatened fauna species are known to utilise the Estuary including shorebirds, raptors and fish species.

The estuary health status is discussed in Section 5.

Figure 4: Tweed River estuary recreational activities (Clockwise from top left: Sandy beach, Terranora Inlet with Sailing boat and mangroves of Ukerebaugh Island in background; Jet skis at Fingal Head Boat Ramp; Kayak at Murwillumbah; Fishing at Tumbulgum; Gas BBQs and picnic facilities at Tumbulgum; Letita Spit Sandy Beach).

2. EXISTING MANAGEMENT

2.1 Management Context

The Tweed River Estuary catchment consists of a myriad of different land uses and a range of natural and modified landscapes. These include: farming land; extractive industries; waste disposal facilities; coastal wetlands; National Parks and Reserves; Crown land; Council reserves; recreational areas; and residential developments. The Estuary is managed and regulated by the following agencies and government authorities:

- Tweed Shire Council (TSC) is responsible for the management of public spaces, assets and facilities around the Tweed River Estuary. The Tweed Local Environmental Plan (LEP) 2014 and LEP 2012 guides planning decisions within the LGA. Council is also responsible for the operation of the Tweed Shire water supply and sewerage systems, stormwater, roads, floodgates and other public assets and has a key role in managing the environment consistent with the principles of ecologically sustainable development;
- The NSW Department of Industry - Lands (DPI Lands) is responsible for the sustainable management of the Crown Land estate which encompasses the dry land and the submerged land of the State's waterways 5.5 km out to sea and includes the ocean floor, most coastal estuaries, many large riverbeds and some coastal wetlands;
- The NSW Department of Primary Industries – Fishing and Aquaculture (Fisheries NSW) regulates recreational and commercial fishing, investigates fish kills, manages invasive species and native species, populations and communities listed as threatened under the *Fisheries Management Act 1994* (FM Act) (including mangroves, saltmarsh and seagrass which are listed as "threatened" and are protected on Public Water Land and the foreshore up to the Highest Astronomical Tide level.)*;*
- NSW Roads and Maritime Services (RMS) manages boating, navigation infrastructure, oil spill and vessel based pollution; and the Pacific Highway and associated infrastructure which crosses the lower estuary at Banora Point;
- The North Coast Local Land Services (LLS) (formerly Catchment Management Authority) plays a key role in the management of catchment activities and natural resources relevant to the Tweed River Estuary and surrounding lands.
- The Office of Environment and Heritage (OEH) works closely with local councils and communities to reduce threats from flooding and coastal storms and ensure that people in NSW are well informed about these risks and better equipped to adapt to climate change. OEH also works with local councils and communities to maintain or improve the health of estuaries;
- The NSW Environment Protection Authority (EPA) licenses and regulates the operation of industrial premises including: Wastewater Treatment Plants at Banora Point, Tumbulgum and Murwillumbah; the Condong Sugar Mill; commercial sand extraction in the upper estuary; Stotts Creek Resource Recovery Centre; Quarries at Environ Road, Harrys Road, Dulguigan, and Stotts Creek.
- National Parks and Wildlife Service (NPWS) manages the Ukerebagh Nature Reserve, Tweed Heads Historic Site, Stotts Island Nature Reserve, Mount Nullum Nature Reserve and Mooball National Park; and
- The NSW Office of Water is responsible for managing access to surface and groundwater in accordance with the *Water Sharing Plan Tweed River Area Unregulated and Alluvial Water Sources.*

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

- The Tweed River Committee (TRC) established by TSC, consisting of Council, government agency and community representatives. The TRC's role is to advise TSC on River Management including catchment-wide activities that support biodiversity conservation, sustainable agriculture, riparian

restoration works, fundraising, environmental education and promotion, and inclusion of sustainability and climate change adaptation and mitigation.

- The Tweed Byron Local Aboriginal Land Council (LALC) manages Aboriginal heritage interests in the Tweed and owns a large part of the Fingal Peninsula in the lower estuary;
- The Tweed Aboriginal Advisory Committee is the peak advisor to Council on Aboriginal matters. The primary objective of the AAC is to provide advice to Council in order to encourage and facilitate the development of the Tweed Aboriginal and Torres Strait Islander Community in the Tweed Shire.
- The Tweed Cane Growers Association is made up of members of the cane industry in the Tweed Valley.
- The Gold Coast Airport, part of which is located within the Tweed River Catchment is managed by the private company Gold Coast Airport Pty Ltd. It is situated on Commonwealth land and governed primarily by Federal legislation.
- Tweed Landcare is a community based organisation which has been active in weed management and revegetation activities on private land within the catchment;

Tweed Shire Council, government agencies, statutory bodies and community groups are implementing management programs in parallel with the preparation of this CMP. Many of these initiatives are related to the management of the Tweed River estuary, foreshore areas and catchment. As there are many organisations responsible for land use management in the study area, effective coordination will be required to address management issues. This CMP will complement and inform existing and proposed plans of management.

2.2 Lower Tweed Estuary River Management Plan (1991)

The Lower Tweed Estuary River Management Plan was prepared by Public Works in 1991. The study area of the Plan extends from the ocean entrance to Barneys Point Bridge and included the Cobaki and Terranora Broadwaters. The overall goal for management of the Lower Tweed estuary in the 1991 EMP was:

"…*to sustain and enhance a healthy estuarine system"*

Management objectives were also developed to address the primary areas of concern:

- Fishery - to preserve and enhance the river as a fish nursery and habitat area and thereby sustain and hopefully enhance current levels of productivity.
- Ecology - to enhance the extent and value of habitat areas.
- Visual Amenity - to preserve or improve the visual amenity of the river and its immediate surrounds.
- Recreation - to encourage recreation in suitable areas including planning for future needs
- Navigation - to maintain navigation channels.
- Heritage - to ensure development proposals are cognisant of areas of archaeological significance.
- Discharges - to minimise the adverse water quality impact of all point source and diffuse pollution loads.
- Implementation - to maximise public involvement and establish an effective means of implementation and monitoring.

The outcomes of the River Management Plan were based on a series of technical studies in the disciplines of: ecology; influent impact; hydrodynamics; recreation; archaeology; and visual assessment.

A variety of options (structural and non-structural measures) were compiled from the technical studies to address the above management objectives. The lower estuary was divided into eighteen areas which include

the waterway and adjacent foreshore land. In each of these areas specific consideration has been given to shoaling problems, visual amenity, habitat value, recreational potential and the impacts of urban runoff.

2.3 Upper Tweed Estuary Management Plan (1996)

The Upper Tweed Estuary Management Plan was prepared in 1996. The study area of the Plan extends from Barneys Point Bridge to Bray Park Weir at Murwillumbah and includes the tidal extent of the Rous River. The objective for the Upper Tweed estuary EMP was:

"…*to provide an integrated programme of works and measures which will:*

- *Identify, enhance and protect significant habitat areas*;
- *Protect heritage areas;*
- *Provide integrated waterway and foreshore recreational facilities;*
- *Increase foreshore facilities for walking, fishing and picnicking;*
- *Encourage boating activities;*
- *Provide opportunities for ecology oriented recreations e.g. canoe trails and wetland boardwalks as well as the development of environmental awareness/education facilities;*
- *Address river bank erosion in key areas*
- *Improve water quality in the areas upstream of Stotts Is., particularly in the Rous River*
- *Minimise acid soil impacts; and*
- *Conserve the magnificent scenic qualities of the river."*

A variety of options (structural and non-structural measures) were developed as part of the EMP to address the above management objectives. Management tasks were then proposed to address the primary management issues of pollution, siltation, recreation and ecology.

2.4 Previous review of Tweed River Estuary Management Plans

Previous review of the Tweed River EMPs occurred in 1997 (Lower River EMP only) and 2001 (both EMPs). The 1997 review provided a summary of actions undertaken by the Tweed River Committee in the Lower River 5 years after completion of the plan. It documents further actions required by the committee and included re-prioritisation of actions based on current conditions.

The 2001 review addressed income and expenditure over the ten years and made suggestions about how future expenditure might best be directed. The review found that approximately $3 million had been expended on implementation over the ten years from 1991 to 2001 (CARE Engineering, 2001). A further $1.25 million was available for the 2001/2002 year and subsequent years. The NSW Treasury had contributed the majority of funds for the works with Council contribution estimated as just $320,000 in administration expenditure. At the time of the review, the majority of works had been directed to the area below Barney's Point Bridge and this was attributed largely to the five year head start for the lower estuary EMP.

Problems to implementation of the plan were identified with regard to Tony's Island, Fingal Wetlands and Cobaki Wetlands and Ukerebagh Passage. In these locations it was reported that little result had been achieved despite considerable effort and the review recommended no further significant project expenditure in these areas without written agreement from relevant parties to ensure outcomes could be realised.

The review also provided broad recommendations and direction for future expenditure and future funding sources for estuary management. These included directing more effort to the upper estuary actions.

2.5 Status of Tweed River Estuary Management Actions

In addition to the EMPs produced in 1991 and 1996, a range of other initiatives are directly relevant to the management of the Tweed River estuary including management plans and strategies addressing boating and navigation, bank erosion, foreshore structures, stormwater, water quality, vegetation etc..

To assist in the development of this CMP, an assessment of the status of actions from both the 1991 and 1996 EMPs and other related initiatives was undertaken. Actions that were noted as complete or no longer required in these reviews have not been included in the audit. Similarly, actions relating to management of the Cobaki and Terranora Broadwater have also been excluded, as they are outside of the study area for the CMP, having been dealt with in the Cobaki Terranora Broadwater CZMP (2010).

This audit of actions will assist in determining what management issues have been prioritised in the past, what requires further management and any lessons learned from previous implementation actions. Where residual issues are still apparent, further action that may be required is provided. Appendix 1 provides the results of the audit.

Related initiatives audited were:

- Sustainable Land Management of Coastal Floodplains-Tweed River (2001)
- Reducing the Impact of Road Crossings on Aquatic Habitat - Tweed Shire (2005)
- Bring Back the Fish – DPI Fisheries (2006-2009)
- Tweed Estuary River Bank Management Plan (2006)
- Tweed River Bank Erosion Management Plan (2014)
- Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (2006)
- Cobaki and Terranora Broadwater Catchment Management Plan (2010)
- Tweed Estuary Boating Plan (2006)
- Regional Boating Plan Tweed – Clarence Valley Region (2015)
- Tweed River Estuary Recreational Boating Facilities Study (2008)
- Tweed River Murwillumbah Reach Bank Enhancement Master Plan (2008)
- Tweed Valley Floodplain Risk Management Study (2014)
- Tweed Coast Regional Crown Reserve Plan of Management (2005)
- Tweed Urban Stormwater Quality Management Plan (2016)
- Review of Water Quality in the Tweed Estuary (2007-2011)
- A Spatially Intensive Approach to Water Quality Monitoring in the Rous River Catchment (1997)
- Tweed Vegetation Management Strategy (2004)
- Tweed Sustainable Agriculture Strategy (2016)

3. STUDY AREA CHARACTERISTICS

3.1 Physical characteristics

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

Table 1: Key characteristics of the Tweed River estuary

Characteristic	Data	Notes
Study area	195 km^2	Refer Figure 2
Upper catchment area	767 km^2	Refer Figure 2
Estuary area	22.7 km^2	Includes areas mapped as open water, mangrove and saltmarsh areas.
Estuary volume	56,954 ML	Based on areas at 0.6 m AHD (Roper *et al.,* 2011)
Average depth	2.6 m	Estimated by dividing the total volume at 0.6 m AHD by the total surface area of the estuary including mangrove areas but excluding saltmarsh (Roper *et al.*, 2011)

3.2 Climate

The Tweed region experiences a mild subtropical coastal climate with moderate maximum and mild minimum temperatures and high intensity rainfall. The majority of rain falls in the summer and autumn months (Figure 5). Although similar, climate statistics vary across the estuary. Average annual rainfall in the upper estuary is 1605 mm recorded at Bray Park since 1972 whereas average annual rainfall in the lower estuary is 1525mm recorded at Coolangatta. Mean maximum and minimum daily temperatures in the upper estuary vary from 9°C to 21°C in July to 20°C to 30°C in January. Temperatures in the lower estuary vary from 10°C to 21°C in July to 21°C to 28°C in January (BOM, 2016).

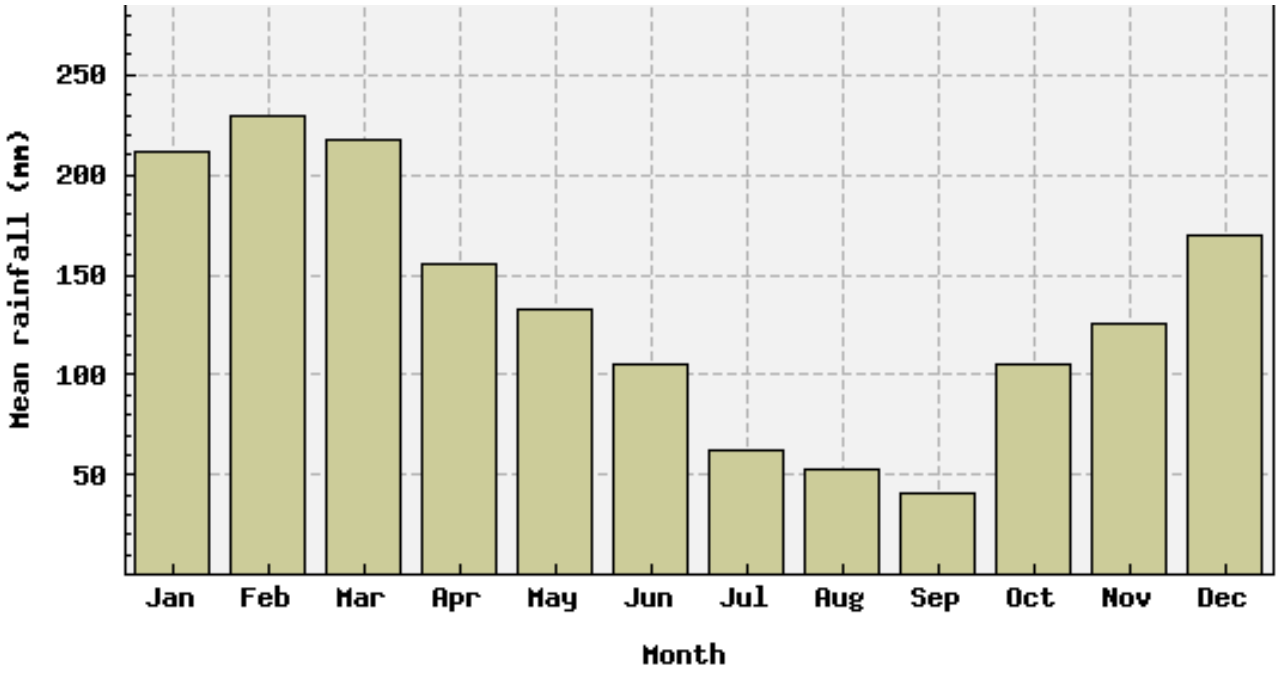

Figure 5: Mean monthly rainfall recorded at Bray Park from 1972 to 2016 (BOM, 2016)

3.2.1 Climate Change

Natural variations in temperature and rainfall in NSW are influenced by the naturally variable climate systems. Although there is natural variability in the climate, there is consensus among climate scientists that

the rate and magnitude of climate change is outside the expected range of this natural variability. Climate change is an important consideration for strategic planning, particularly in coastal areas where the combined effects of sea level rise and increased storminess are considered key threats.

Sea level rise is anticipated to result in management issues including increased inundation of low lying lands, infrastructure and development and implications for drainage and flooding in urban areas. The issue of potential increased storminess is less well understood. It is generally anticipated that rainfall events will become more intense, even if average rainfall reduces, in response to climate change. This may result in effects such as more floods as well as greater capacity for erosion and runoff and pollution of waterways within the catchment.

Climate change is inevitable and planning benchmarks already exist in terms of future sea level rise as discussed in Section 6.2. Locally, there will be impacts from climate change that are unavoidable such as sea level rise and changes to rainfall patterns and therefore long-term management planning needs to consider the likely changes to the Tweed River estuary and the factors constraining adaptation to such change.

3.3 Estuarine Hydrodynamics

Hydrodynamic processes operating in the Tweed River can be separated into two aspects, fluvial aspects and tidal aspects. Processes within the Tweed River estuary were assessed in WBM, 1992 and are summarised in the following sections.

3.3.1 Tidal

The entire estuary study area is influenced by the tide. In the main arm of the Tweed River estuary the tide propagates as far upstream as the Bray Park Weir, upstream of Murwillumbah, a distance of approximately 35km and into the Rous River up to Boat Harbour Bridge. Tidal processes progressively attenuate with distance upstream although the most rapid attenuation occurs within the first 2-4 km from the river mouth. At Murwillumbah the tidal range is generally 60% of that at the entrance. Peak tide velocities also decrease in an upstream direction with the highest velocities occurring at the mouth with peak velocities occurring at Murwillumbah approximately 10% of those at the mouth. Near the entrance, ebb tide flows are approximately 13.49 ($10^6 m^3$) with a tidal range of 1.55 m and flood flows are approximately 6.91 ($10^6 m^3$) with a tidal range of 1.02 m (NOW, 2012).

Tidal circulation processes are dominant in the estuary. During periods of dry weather, the salinity of the upper estuary can be approximately half that of seawater (35 ppt) however, during wet weather (usually occurring across the warmer months) the saline water is effectively pushed down stream. Under these conditions saline water seldom occurs as far upstream as Murwillumbah.

3.3.2 Fluvial

The Rous and Oxley Rivers, the major sub-catchments drain the northern portion of the upper Tweed River catchment (Figure 6). The Oxley River enters the Tweed River just upstream of the study are and Rous River catchment, comprising of the north west section of the study area joins the Tweed River at Tumbulgum. A number of other small creeks and Clarrie Hall Dam make up the remainder of the upper catchment of the Tweed River. Several small creeks within the study area, flow from the south, north across the floodplain into the Tweed River estuary. Terranora Inlet/Creek flows into the lower Tweed River estuary at Tweed Heads. Table 2 provides a summary of the gauged flows of the major tributaries.

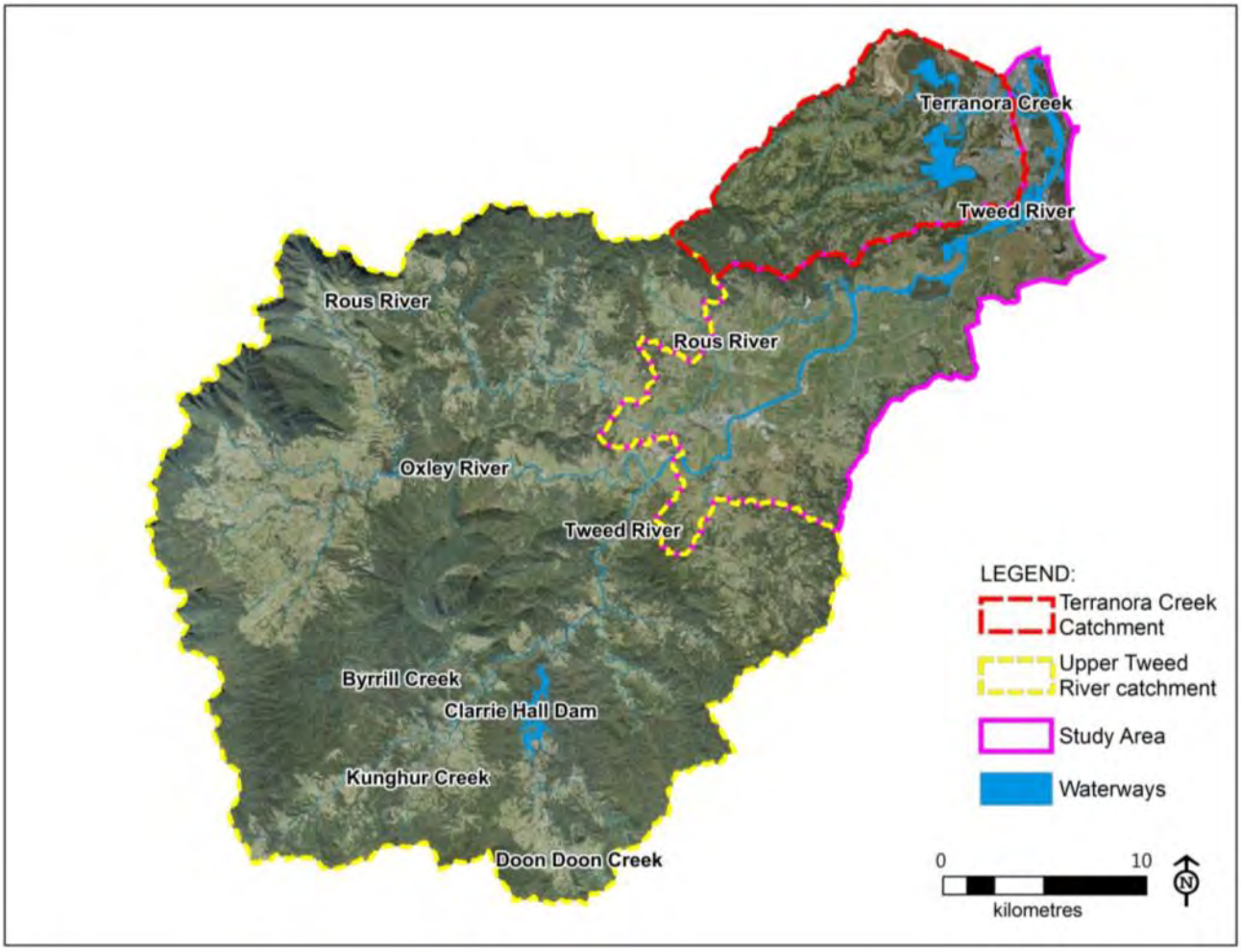

Figure 6: Tweed River catchment, major waterways

Table 2: Fluvial flows (NOW, 2015)

Waterway	Max and Min Mean Monthly Flow (ML)	Mean Annual Flow (ML)
Tweed River (Uki)	26,585 (Feb) to 1920 (Sept)	147,213
Oxley River (Eungella)	27,194 (Feb) to 2264 (Sept)	154,525
Rous River (Boat Harbour)	16,335 (Mar) to 1311 (Sept)	93,885
Cobaki Creek (Cobaki)	1,073 (Apr) to 155 (Sept)	6,483

The major infrastructure that impacts on flows in the Tweed River system are Clarrie Hall Dam (16,000 ML) and the Bray Park Weir (approx. 520 ML). Extraction primarily for town water supply occurs from the Bray Park Weir pool which is supplied by both the Tweed and Oxley Rivers. Releases are made from Clarrie Hall Dam to top up the Bray Park Weir pool (NSW Office of Water, 2010).

Flooding is a common occurrence on the Tweed River floodplain. Floods have been associated with rainfall events located in different parts of the catchment. Flood levels are higher in the upper estuary and at their lowest in the lower estuary and the entrance.

The Tweed River Floodplain has been extensively modified through draining and levelling, construction of floodgates, levees and roads, and the removal of most native vegetation. Council owns and manages drainage across the floodplain with considerable floodplain infrastructure including: 376 km of drainage; 10.4 km of levee banks; and 400 flood gates (TSC, 2015) (Figure 7).

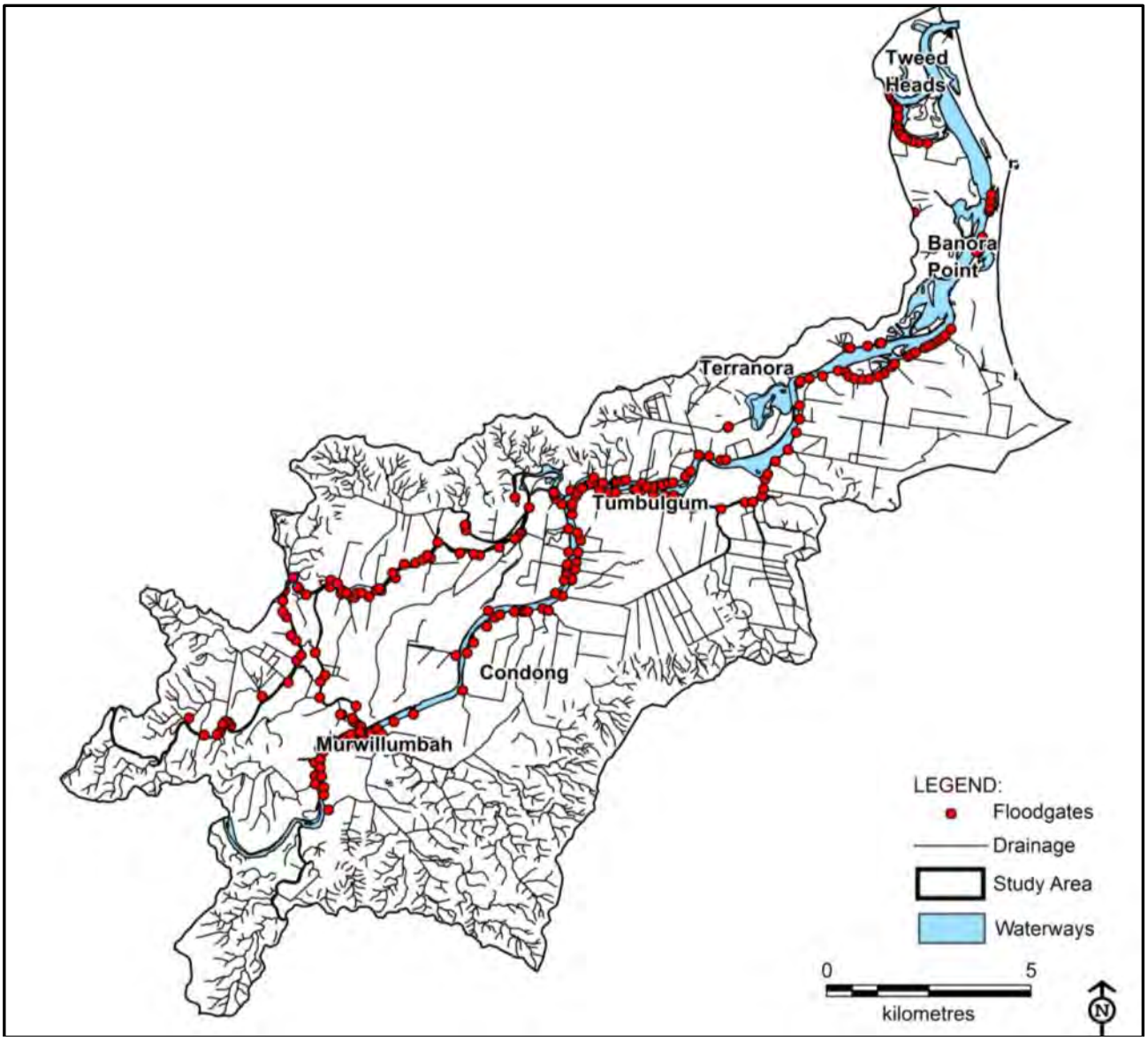

Figure 7: Floodplain infrastructure (Source: TSC Mapping)

3.4 Geomorphology

The Tweed River is a mature wave dominated barrier estuary with an open trained entrance (Roy *et al.*, 2001). Alluvium (2012) assessed the geomorphic condition of northern NSW rivers, including the Tweed River, using the RiverStyles assessment. In this assessment, the majority of the waterways within the study area are classed as '*tidal*' with many of the larger drains and creeks across the floodplain classed as '*channelized fill'*, all within a '*laterally unconfined valley setting'*. The majority of the assessed waterways within the study area for this project were considered to be in 'poor' condition with small stretches of 'moderate' and 'good' condition in the upper reaches of Dulguigan Creek and Dunbible Creek. The recovery potential/priority of all waterways was also assessed. The majority of waterways within the study area for this project were considered to have a low recovery potential except a small length of upper Dulguigan Creek which was considered to have conservation potential and small stretches of upper Dunbible and Dinseys Creek which had a 'moderate' recovery potential.

3.4.1 River Sediments

Tweed River estuary sediment types are discussed in WBM (1992) and are outlined below.

The estuarine bed surface sediments can be classified into the following broad groups:

- River sands – Generally dark coloured, sub-angular and containing more than 10% lithic grains. These sands are poorly to moderately well sorted. Shell is generally absent.
- Marine sands – Clean, buff-coloured and significantly iron stained grains predominantly of silica with shell fragment s common.
- Reworked marine sands – These represent reworked Pleistocene inner barrier sands which were buried and indurated during the later stages of the post-glacial transgression. They are moderately dark due to humic coatings and contain up to 5% lithic grains and sub-rounded and moderately to well sorted.

Tidal and fluvial processes both affect the nature and behaviour of the estuarine sediments. Tidal flows have the capability to move and rework sediments particularly in the lower estuary where tidal influence is greatest. Tidal processes in the lower estuary generally result in an upstream movement of sand. However, there is little tide related movement of sediments upstream of about Stotts Island. The deeper less tidally active sections upstream of here tend to accumulate fine silty sediments and organic debris.

Floods in the river bring a fluvial sediment supply from the upper catchment as both bedload (sand and gravel) and fine suspended material. These floods occur infrequently but can transport large quantities of material downstream into the estuary in a short period of time. Flow velocities influence the deposition distribution of this material. Flood velocities are highest at Bray Park Weir where they decrease significantly to Murwillumbah before they gradually decrease (due to the influence of the floodplain) to around Barneys Point before increasing again to the mouth due to the return of floodwaters from the floodplain and tidal action. Subsequently, there is a deposition of coarser sediments in the zone where velocities and sediment transport capacity decreases in the far upper estuary (Bray Park – Murwillumbah), finer sediments then settle throughout the lower velocity mid reaches of the estuary across the floodplain. The presence of fines in bed sediments downstream of about Barneys Point generally decreases again due to increases in flood and tidal velocities and influence of marine sands. This general pattern within the mid-lower estuary is also reflected in sediment sampling results from other studies (Hydrosphere Consulting, 2015; Hydrosphere Consulting, 2016). These studies found that sediments within the lower estuary (Fingal) were dominated by coarse marine sands, sediments around Barneys Point were still dominated by sands but were finer than those lower in the estuary. Sediments around Stotts Island contained sands but had a high fines (silt and clay) content. Additionally, results from Hydrosphere Consulting (2015) and Hydrosphere Consulting (2016) indicated that the sulfidic content of bed sediments increase in an upstream direction. Sediment in the lower estuary (dominated by clean marine sands) was low in sulfides, material from around Barneys Point was still relatively low in sulfides but was higher than the lower estuary and sediment from Stotts Island was very high in sulfides (including volatile monosulfides).

Although there is a general trend in sediment types within the estuary with a zone of mixing of fluvial and marine sands around Chinderah there is no defined boundary as the zone extents shift depending on occurrence floods and other processes. In general, sediments downstream of about Chinderah are dominated by marine sands and are influenced greatest by tidal processes. Upstream of Chinderah, sediments are increasingly dominated by finer material (until the far upper estuary) and influenced most by fluvial processes.

3.5 Land Uses

3.5.1 Current Land Use

Current land uses are summarised in Table 3 and the spatial distribution of land uses is shown in Figure 8. Agricultural landuse occupies the majority of the study area (63%) and is made up of mainly sugarcane on the floodplain. Grazing pasture is concentrated on slightly elevated areas adjacent to the floodplain particularly in the upper half of the study area. Conservation/bushland is the second most dominant land use encompassing 23% of the study area and is concentrated in the upper/elevated extents of the study area on the northern and southern escarpments of the Tweed River valley. Urban land covers 9.6% of the study area

and is made up of the urban centres of Tweed Heads, Banora Point and Murwillumbah. Cleared land (not including urban areas) comprises 0.7% of the study area. Waterbodies and drainage (including floodplain drains) occupy 4% of the study area.

Table 3: Summary of mapped land uses within study area (Source: TSC Mapping)

Land Use	Area (ha)	% Study Area
Agriculture/cropping	8,634	44.2
Agriculture/improved pasture	108	0.6
Cleared land	142	0.7
Commercial and Industrial	88	0.5
Conservation/Bushland	4,406	22.6
Grazing/Pasture Unimproved	3,559	18.2
Sand/beach	51	0.3
Transport & communication	1,016	5.2
Urban recreational	245	1.3
Urban Residential	508	2.6
Water bodies and drainage	775	4.0

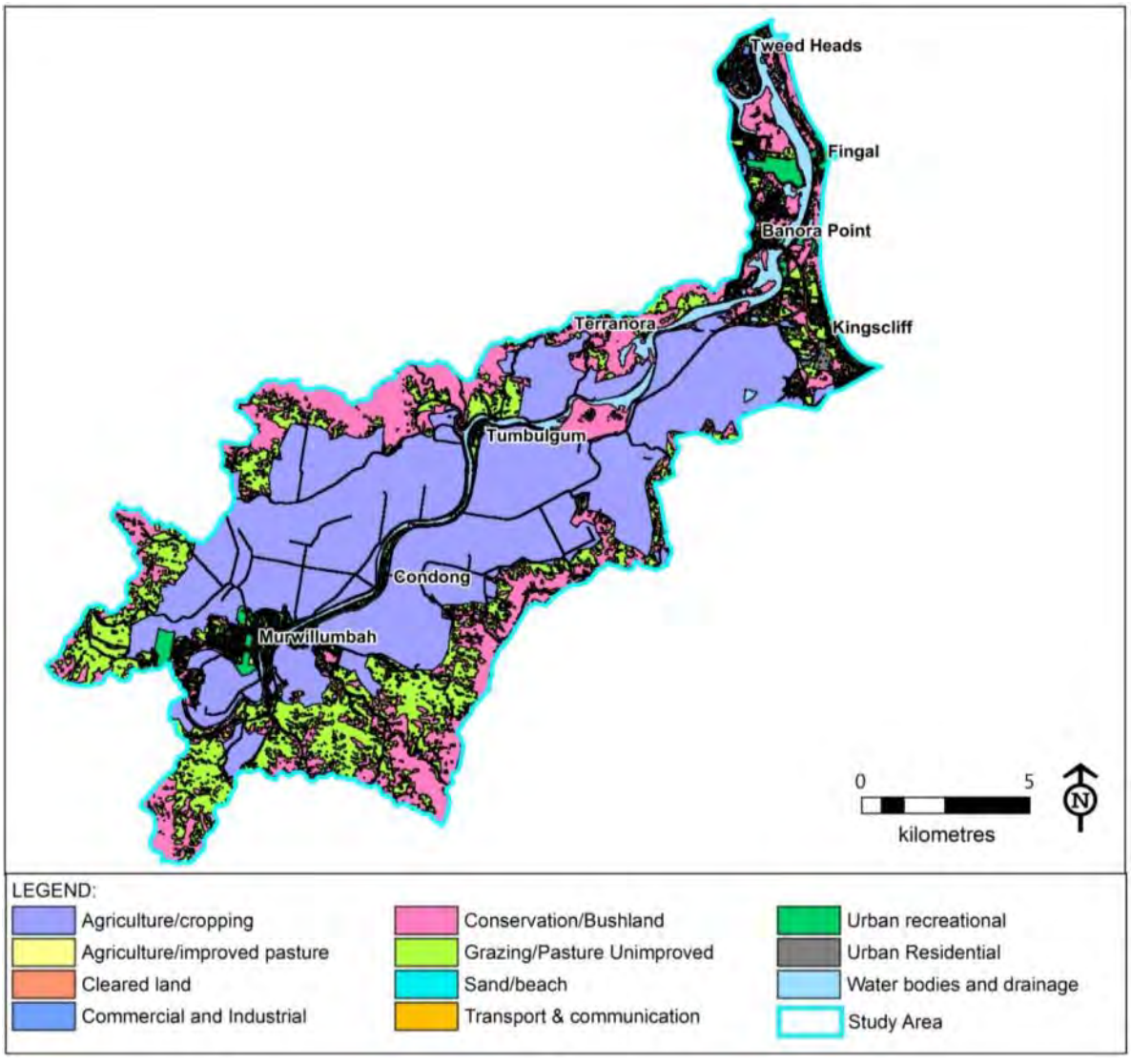

Figure 8: Land uses within study area

3.5.2 Land Use Zoning

Local Environmental Plans (LEP) are the primary tool for managing the development and utilisation of land within an LGA in line with the process set out in the *Environmental Planning and Assessment Act 1979* (EP&A Act). A LEP is a legal instrument that imposes standards to control development. LEPs are also used to reserve land for open space, schools, transport or other public purposes as well as to control advertising and protect trees and vegetation and generally comprises a written document and accompanying maps.

Table 4 provides a summary of Tweed LEP 2014 land zoning within the study area and Figure 9 provides an illustration of these zones. The land zones are not necessarily a reflection of actual current land use but provide an indication of what land uses are permitted in a given area/zone.

Table 4: Summary of Tweed LEP 2014 zoning within study area

Zone	Area (ha)	% study area
Business Development	53.38	0.27
Commercial Core	59.00	0.30
Deferred Matter	1,787.04	9.07
Environmental Conservation	8.62	0.04
General Industrial	216.53	1.10
General Residential	121.99	0.62
Infrastructure	370.07	1.88
Large Lot Residential	489.16	2.48
Local Centre	3.02	0.02
Low Density Residential	775.70	3.94
Medium Density Residential	178.88	0.91
Mixed Use	62.65	0.32
National Parks and Nature Reserves	391.61	1.99
Natural Waterways	236.06	1.20
Neighbourhood Centre	2.08	0.01
Primary Production	8,097.78	41.09
Private Recreation	206.31	1.05
Public Recreation	242.16	1.23
Recreational Waterways	624.70	3.17
Rural Landscape	5,220.31	26.49
Special Activities	2.15	0.01
Tweed City Centre LEP 2012	196.70	1.00
Village	114.76	0.58
Working Waterfront	0.89	0.00
Working Waterways	246.35	1.25

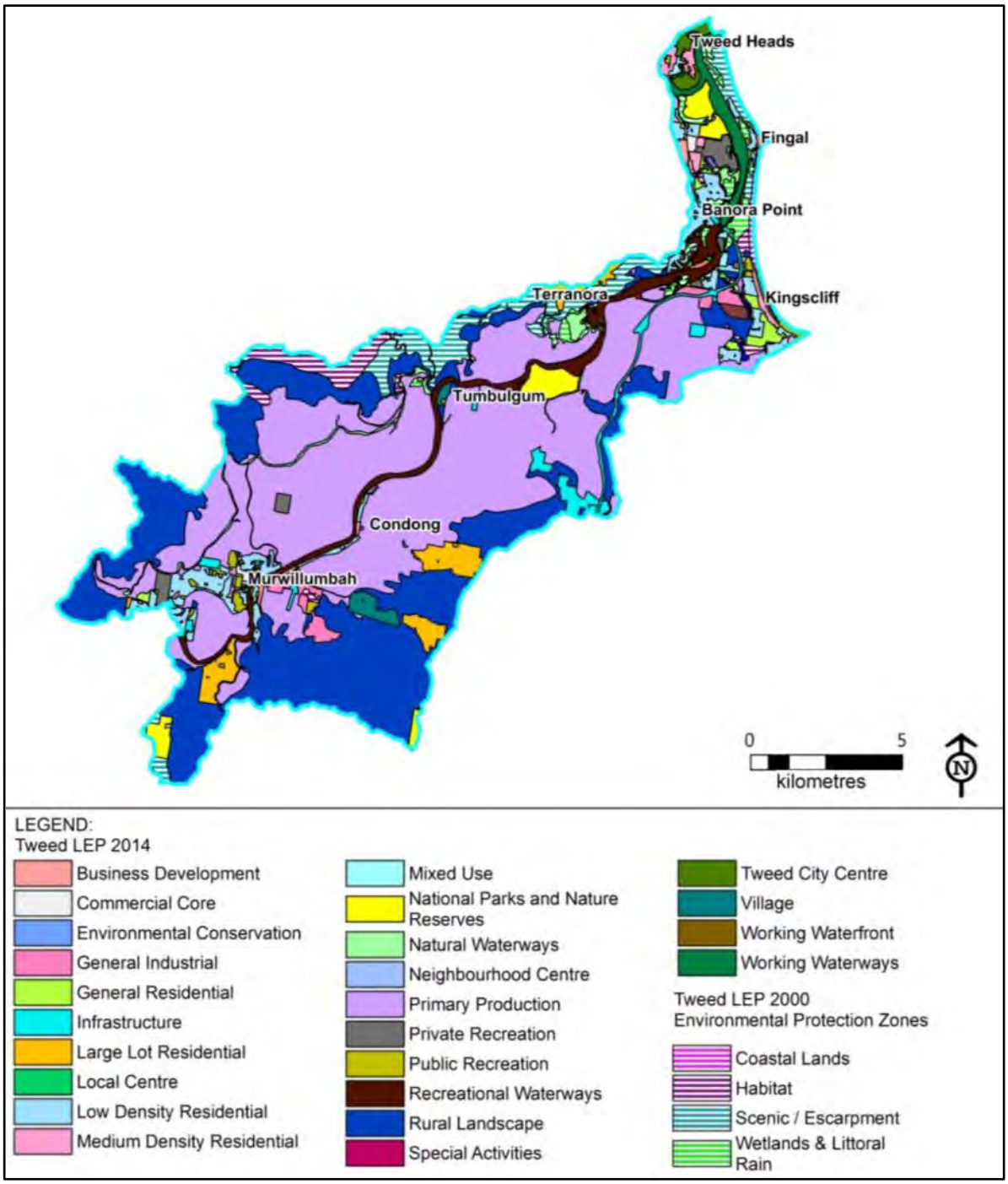

Figure 9: Tweed LEP 2014 land zone mapping

3.5.3 Urban Development

Major urban areas within the study area include parts of Tweed Heads, Banora Point and Kingscliff in the lower estuary catchment and Murwillumbah in the upper estuary catchment. Smaller urban/residential areas also exist throughout the study area including Tumbulgum, Condong, Terranora and Fingal.

The *Tweed Shire Urban Land Release Strategy (2009)* identifies and outlines potential urban release and proposed future urban release areas throughout the Tweed Shire. A number of these areas lie within the study area including areas identified at Kielvale (370 ha), West Murwillumbah (86 ha) and West Kingscliff (62 ha). These potential future urban release areas equate to approximately 2.5% of the study area.

While future land development within the study area is relatively limited, the surrounding regions (particularly South East Queensland) are significant urban expansion and population growth areas which are expected to increase visitor numbers to the Tweed River estuary in the future.

3.5.4 Agriculture

The Tweed River catchment supports a broad range of agricultural industries. Sugarcane occupies the largest land area in the catchment of any agricultural industry, comprising the majority of the Tweed River floodplain. The volcanic soils of the Cudgen plateau to the south (a portion of which lie within the Tweed River estuary catchment) supports intensive horticulture. In the upper catchment (upstream of study area), extensive areas are grazed with smaller areas of bananas grown on some of the elevated steeper slopes. Other industries occurring throughout the remainder of the catchment include small fruit and vegetable growing enterprises, dairy, poultry, tea, coffee, tea tree and native bush foods (TSC, 2016).

Tweed Shire's main agricultural industries, based upon their monetary value, are: Sugar (29%), Vegetable and Nurseries (27%), Beef (17%), Bananas (15%), and Dairy (6%) (Urban Enterprises & EnPlan, 2013). Sugar, horticulture and bananas are the most valuable agricultural industries within the Tweed Shire. In 2010 -2011 these crops made up more than half of the Shire's agricultural production in gross value (Urban Enterprises & EnPlan, 2013). Tweed Shire produced almost 27 % of the sugar produced in NSW during 2010-11, on almost 8,000 ha and over 30% of the state's bananas on 600 ha (Urban Enterprises & EnPlan, 2013). However, in recent years the area of bananas planted has diminished due to competition from growers in north Queensland and the spread of disease (Urban Enterprises & EnPlan, 2013).

Approximately 63% of the study area is mapped as agricultural land (Figure 8) with 42% classed as State or Regionally Significant Farmland (Figure 10). State Significant Farmland is defined by DIPNR (2005) as very high quality and unique agricultural soils/lands. Regionally Significant Farmland is defined as other lands that were also important to agriculture but which were more extensive and less productive generally per unit area (DIPNR, 2005). This farmland was mapped as a part of the Farmland Protection Project which aimed to protect important farmland from urban and rural residential development and informed the Far North Coast Regional Strategy (Department of Planning, 2006). Urban and rural residential development will be limited on land identified by the project so that areas with the most potential for production are not lost to urban uses (DIPNR, 2005).

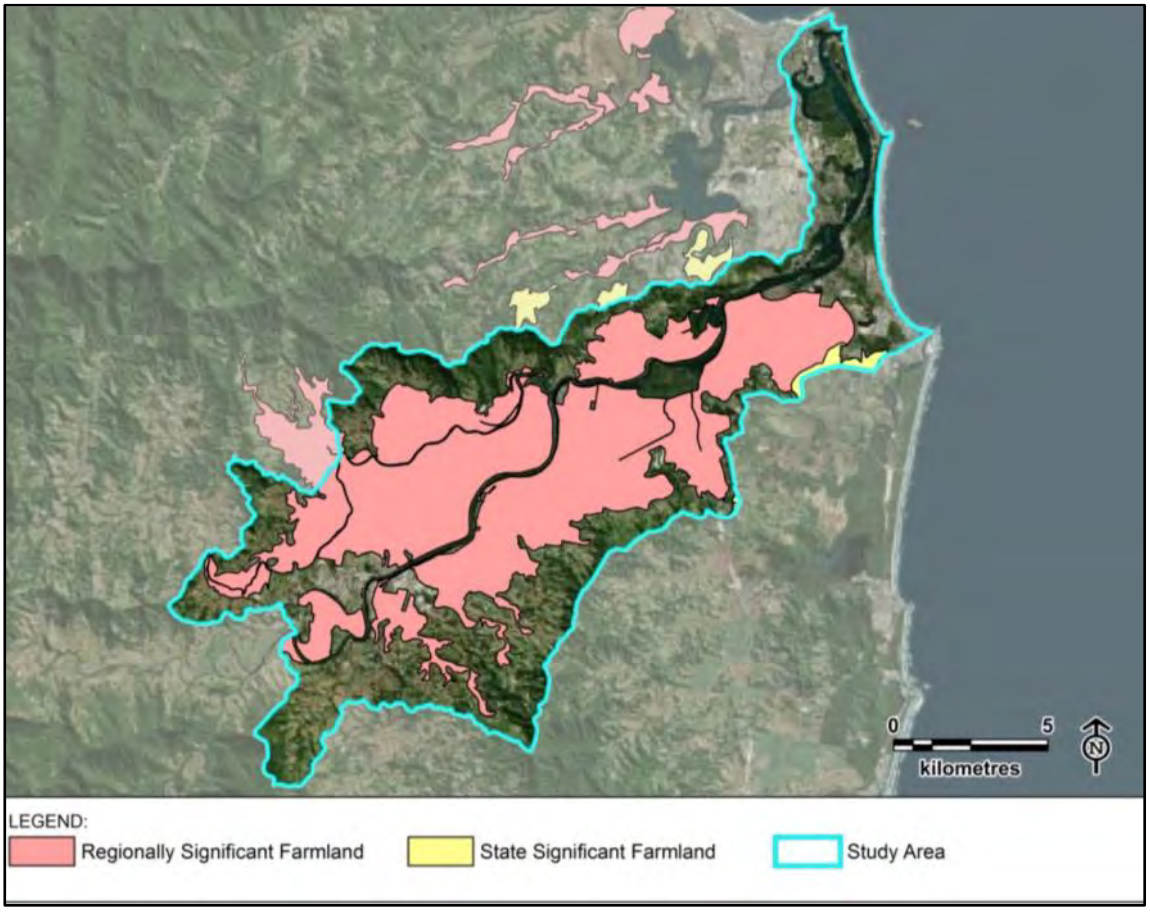

Figure 10: State or regionally significant farm land within the study area

3.5.5 Conservation

The study area encompasses a number of environmental conservation areas including Tweed heads Historic Site and Ukerebagh Nature Reserve, Stotts Island Nature Reserve in the mid-estuary and Mooball National Park and Mount Nullum Nature Reserve in the southern upper catchment of the estuary.

Ukerebagh Nature Reserve is approximately 125 ha in area encompassing Ukerebagh Island and a parcel of land to the south. Tweed Heads Historic Site is approximately 8 ha in area and directly adjoins Ukerebagh Nature Reserve to the west. Both reserves are managed by NSW National Parks and Wildlife Service (NPWS). The sites are of special cultural significance to the local indigenous people (See Section 4.5.1) and are of historic significance to the wider general community. The site is also of ecological importance with the presence of a number of coastal lowland vegetation communities the majority of which is mangroves and coastal saltmarsh (NPWS, 2010).

Stotts Island Nature Reserve encompasses approximately 160 ha of Stotts Island, a river island located in the mid-estuary of the Tweed River. The site is managed by NPWS under a plan of management. The island is the largest remnant of subtropical floodplain rainforest remaining in New South Wales (NPWS, 2001a). Lowland rainforest on floodplain is listed as an endangered ecological community under the *Threatened Species Conservation Act 1995* (TSC Act). Areas of wetland also occur within the reserve. The reserve contains important habitat for a number of species of threatened fauna. The Reserve provides the largest single area of remaining habitat and largest known population of Mitchell's rainforest snail which is declared as Endangered under the *TSC Act* and Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (NPWS,2001b). To honour the significance of the site, the reserve is declared as 'critical habitat' for Mitchell's rainforest snail under the TSC Act 1995.

Mooball National Park covers an area of 1,130 ha (33 ha located within study area) in the southern upper catchment of the Tweed River estuary. The park supports one of the largest lowland moist forest vegetation remnants between the predominantly cleared Tweed and Brunswick Valleys and is inhabited by a large number of threatened flora and fauna species. Mount Nullum Nature Reserve is located in the southern extent of the study area on the Tweed Caldera escarpment with approximately 77 ha of the reserve within the study area. The reserve protects habitat for a number of threatened species and forms part of a regional wildlife corridor for species migrating south-east to north-west through the Burringbar Range (OEH, 2014).

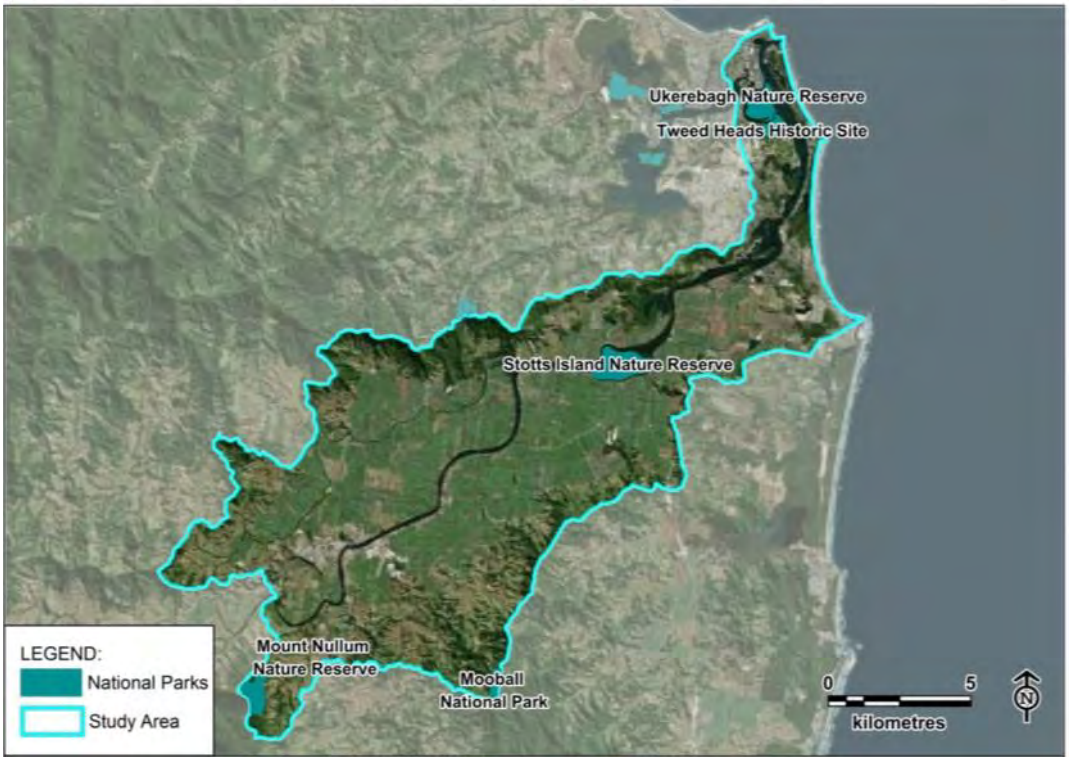

Figure 11: Conservation areas located within study area

3.5.6 Extractive Industries

The Tweed Shire supports a range of extractive industries. Within the study area a number of extractive industry sites occur including several quarries that supply stone for road making and construction purposes and dredging of estuarine sands (Figure 12).

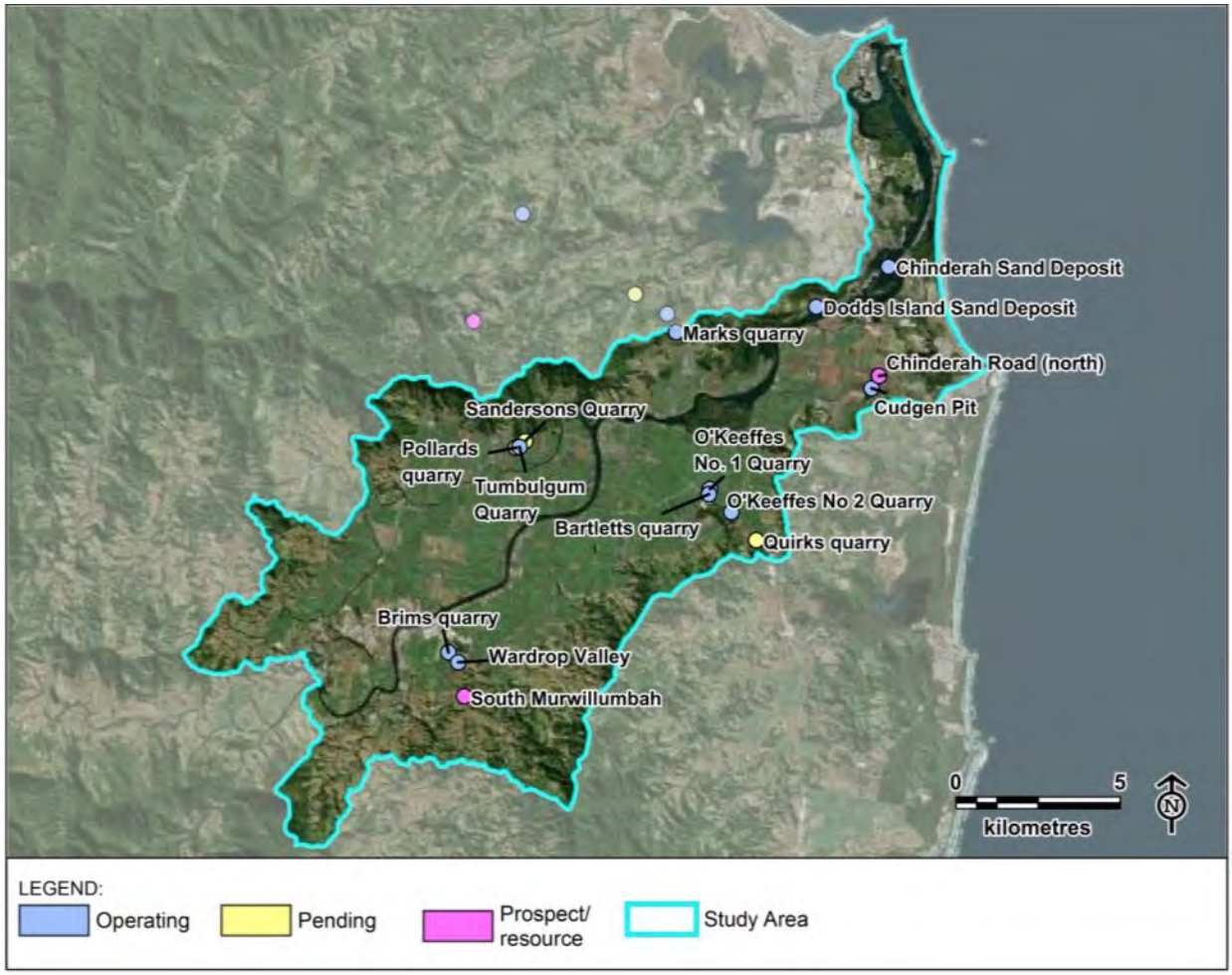

Figure 12: Extractive resources within study area

Estuarine sand extraction

Parts of the Tweed River estuary are actively dredged for the extraction of sand. A sand extraction licence is currently held by a commercial operator for a section of the upper Tweed River estuary including the Chinderah and Dodds Island sand deposits (Figure 13). The original licence covers the Tweed River bed between Barneys Point Bridge and Dodds Island (Figure 13) and permits the extraction of a total of 3,000,000 m³ of material over a period of 20 years. The material is removed by dredge before being pumped via pipeline to an onshore facility at Chinderah (opposite Chinderah Island) for processing. The original licence for the dredging commenced in 1994 and was to be by 2014. However, at the end of the licenced period, the total extraction amount had not been reached and following an application by the licensee, consent for the dredging was extended to 2024.

Dredge areas A-E and Part of F (closest to Barney's Point Bridge) were dredged in the early 1990's for fill for the construction of the Pacific highway and has not been dredged since 1995 (Ocean Park Consulting, 2013). There is no intention to dredge this area again under the current licence. The only areas not yet dredged downstream of Chinderah Island are within boxes F (part), G and H. Area G has been largely left alone because there are submarine cables which cross the Tweed River here with the operator indicating that this area will likely be dredged last (Ocean Park Consulting, 2013). TSC (2014) note that these areas are environmentally constrained by the location of seagrass beds. Areas L and K were dredged in the mid to late 2000's and in 2013 the dredge was located within the upstream extent of area M and working upstream

(Ocean Park Consulting, 2013).

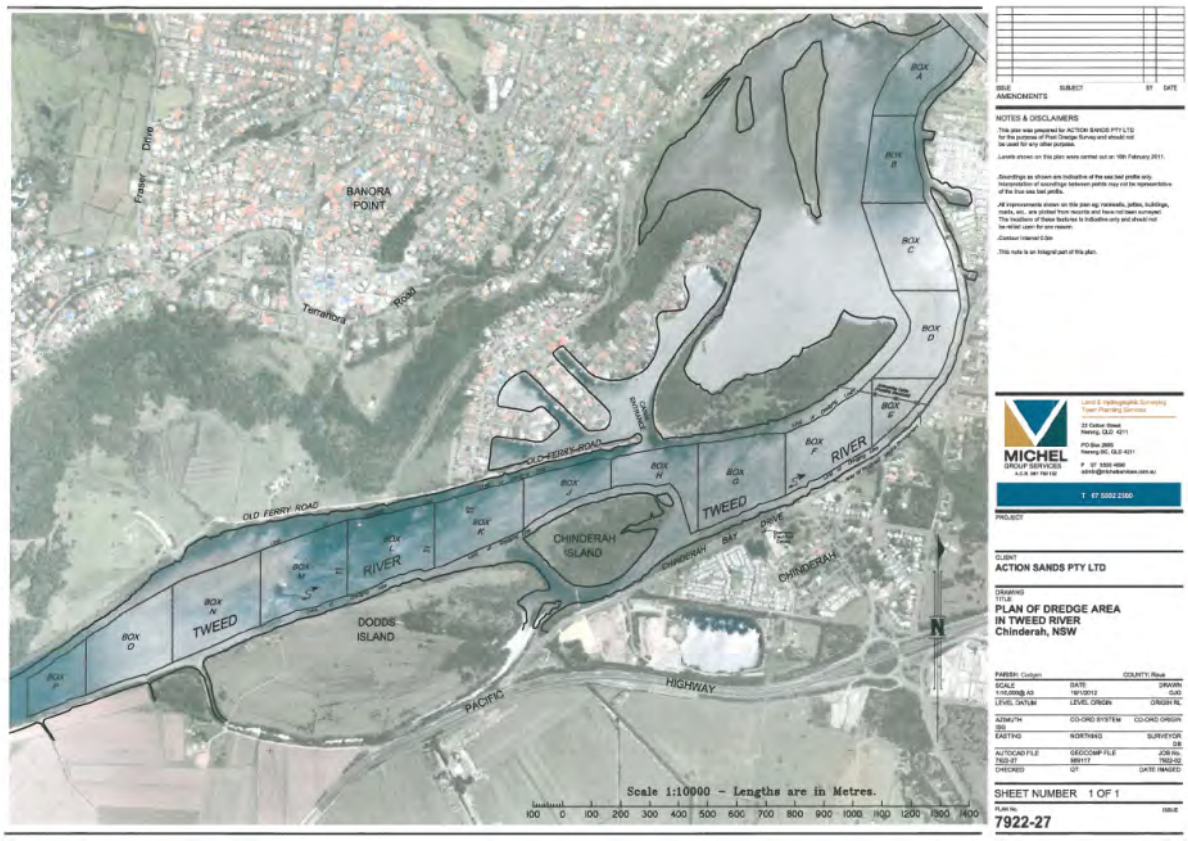

Figure 13: Estuarine sand dredge area (Ocean Park Consulting, 2013)

3.5.7 Solid Waste Management

Tweed Shire Council utilises a number of waste processing facilities which are located within the study area including Chinderah Material Recovery Facility (MRF) and Stotts Creek Resource Recovery Centre (SCRRC).

Chinderah MRF is a privately operated facility located in Chinderah that processes co-mingled dry recyclable material predominantly sourced from Council's waste collection. The SCRRC is located at Eviron adjacent to Leddays Creek. The centre processes a large range of waste materials and includes the following processes and infrastructure:

- Landfill facility which has a putrescible waste landfill cell, and an inert waste landfill;
- Organics processing;
- Green waste processing;
- Concrete/rubble processing;
- Transfer station for dry recyclables;
- Bulking facility for putrescible waste;
- Buy back centre;
- Landfill gas capture and electricity generation;
- Drop off facilities for the following materials from domestic and commercial sources:
    - General mixed waste;
    - Green waste;

- Building and demolition material;
- Recyclables (glass bottles, plastic bottles, plastic containers, steel and aluminium cans, clean paper and cardboard, e-waste, CFL / fluorescent light globes, car / boat batteries, empty gas bottles, oil (up to 20 L);
- Metal (car bodies, caravans, straight metal e.g. roofing iron / fencing wire, white goods);
- Hazardous and contaminated waste, including asbestos and dip sites;
- Deceased animals;
- Tyres (small quantities only); and
- Drums (as part of the DrumMUSTER program).

The SCRCC is regulated by an EPL (No. 6108).

3.5.8 Wastewater Management

All residential areas within the study area are serviced by Council centralised sewerage infrastructure (Figure 14). Several wastewater treatment plants service these areas and are located at Banora Point (outside study area), Tumbulgum and Murwillumbah. All plants are operated according to Environmental Protection Licences (EPLs), issued under the *Protection of the Environment Operations Act 1997* (POEO Act) and administered by the NSW Environmental Protection Agency (EPA). EPLs require routine monitoring of discharges to the environment and reporting of any breaches to licence conditions. All licenses and data are published on the EPA Public Register.

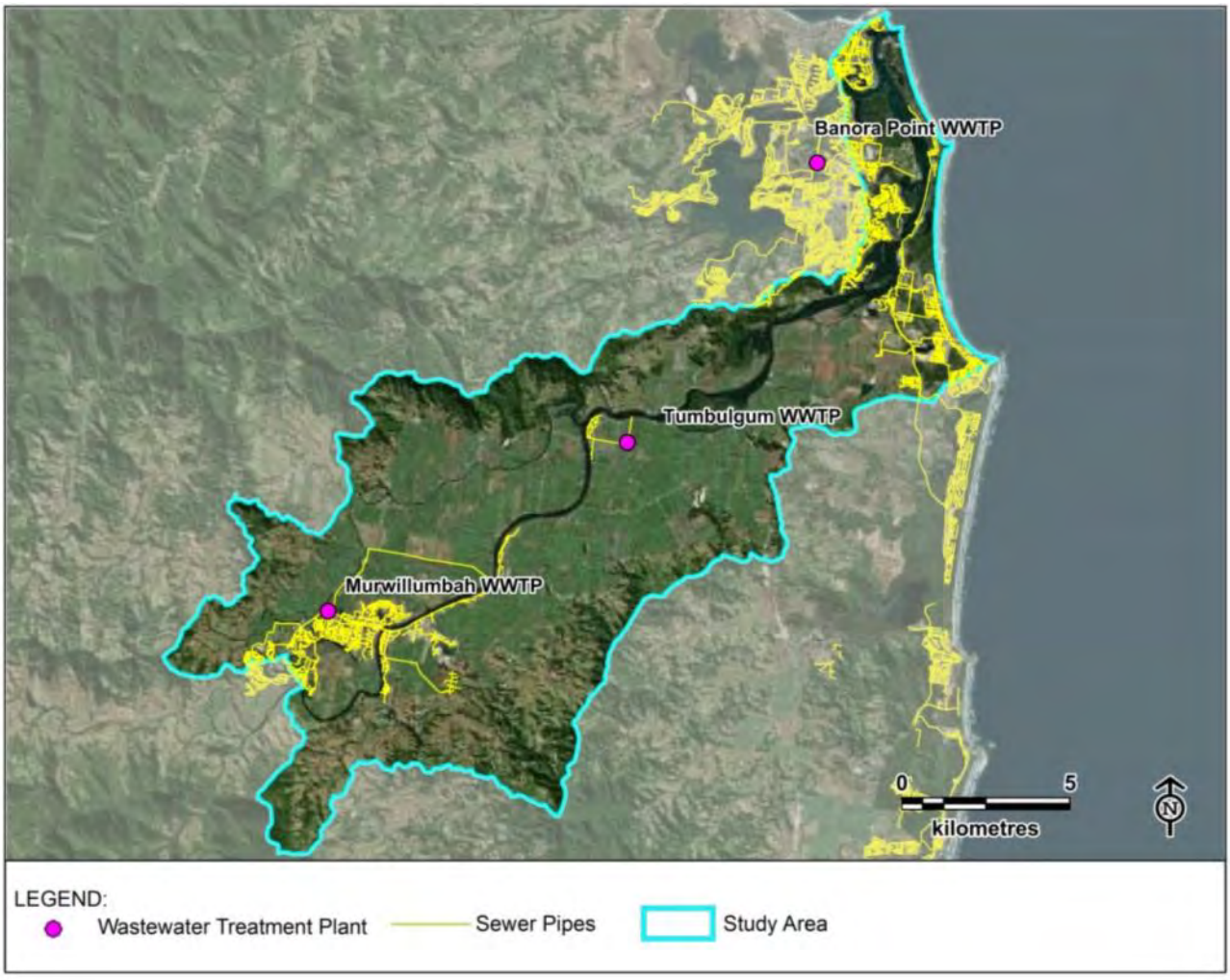

Figure 14: Sewerage systems within study area

Banora Point WWTP

The Banora Point WWTP discharges into Terranora Creek just upstream of Boyds Bay bridge (study area boundary) so although not in the study area, still has the potential affect the lower Tweed River estuary. The plant recently underwent a major upgrade to service anticipated future population growth and improve quality of discharge. The upgrade design included processes to significantly reduce nutrient levels in the final effluent discharged from the plant including: inlet screens; a flow balance and anaerobic tank; aeration system; clarifier; disk filter; UV disinfection system; odour treatment facility; control building.

Recycled water from the plant has historically been used for irrigation of the Tweed Heads/Coolangatta Golf Course however there are plans to extend this use to the playing fields at Council's regional sporting complex, Arkinstall Park, and the Tweed Heads South Memorial Gardens Cemetery. These projects will help reduce demand on the district's potable water supplies and cut the amount of effluent discharged to Terranora Creek.

Tumbulgum WWTP

Tumbulgum WWTP services the small village of Tumbulgum located adjacent to the upper Tweed River estuary. The system is a vacuum sewer system due to the flat nature of the area. The treatment at the plant is via an activated sludge process with the addition of Alum for phosphate reduction and ultra violet radiation is used for disinfection before treated water is discharged to the Tweed River.

Murwillumbah WWTP

The Murwillumbah WWTP services Murwillumbah and the surrounding area and is located on the northern side of Murwillumbah, adjacent to the Rous River. The plant operates a tertiary treated system involving an activates sludge process and tertiary treatment comprising an in-line filter, 2 membrane tanks (3ML/day), balance tank, UV system and permeate pumps, blowers and storage tanks. Condong Sugar Mill reuses about 30% of the treated water with the remaining treated effluent discharged to the Rous River directly adjacent to the plant.

Figure 15: Murwillumbah WWTP (Source: TSC, 2016)

4. COMMUNITY USES

TSC recognises the importance of community uses of the coastal zone. In this CMP, public access refers to the ability of the general public to gain appropriate access to public lands surrounding the Tweed River estuary as well as the waterway itself.

The following sections provide an assessment of current community uses and values of the Tweed River including discussion of any associated issues and environmental impacts:

- Scenic amenity;
- The current access arrangements to foreshores and the river itself;
- The current recreational uses and activities within the study area;
- Commercial activities with relevance to the estuary including commercial fishing and tourism operations; and
- The cultural and heritage significance of the area.

4.1 Scenic Amenity

In 1823 John Oxley became the first European to see the Tweed Valley where, after exploring seven miles upstream of the Tweed River, he entered into his journal:

'A deep rich valley clothed with magnificent trees, the beautiful uniformity of which was only interrupted by the turns and windings of the river, which here and there appeared like small lakes. The background was Mt. Warning. The view was altogether beautiful beyond description. The scenery here exceeded anything I have previously seen in Australia.'

Scenic amenity of the Tweed River estuary is valued highly by the local community and visitors. The Tweed River estuary is a beautiful place enjoyed by locals and tourists alike. Specific characteristics identified in the community survey include: (to be added)

Figure 16:The Tweed River at Murwillumbah (TSC, 2016)

4.2 Recreational Use

4.2.1 Recreational Boating

The Tweed River estuary is used by a large number of recreational boat users including (NSW Maritime, 2005; Transport for NSW, 2014):

- Cruising or pleasure boating for sightseeing, fishing, picnicking and similar activities is popular in all reaches of the river.
- The opportunity for water skiing and related activities attracts both locals and tourists to the river. This type of activity is concentrated in the reach of the river adjacent to the Fingal Head Boat Harbour, Chinderah to The Piggery and Tumbulgum to the Commercial Road Boat Ramp upstream from the Murwillumbah Bridge.
- Personal Water Craft (PWC – i.e. jet-ski), are particularly popular throughout the estuary and being of shallow draught, have traditionally only been restricted in areas of the river designated as 4 knot zones. The “wave-zone” area adjacent to the Jack Evans Boat Harbour is a popular PWC area due to the surf-like conditions created by the convex shape and wave current interaction effects on the entrance bar.
- There are two rowing clubs on the Tweed River estuary. The Tweed Heads Rowing Club is located adjacent to the Boyd’s Bay Bridge, with rowing predominately being enjoyed on Terranora Creek. The Murwillumbah Rowing Club is situated on the Condong to Murwillumbah reach of the river.
- Other activities such as canoeing, sailing and kayaking are also popular.

NSW Maritime (2005) undertook a study of vessel activity within the Tweed River estuary and found that cruising was the most popular vessel activity, followed by fishing, skiing, personal watercraft and wakeboarding. The most frequented area was between Tumbulgum and Condong with cruising, skiing, wakeboarding and personal water craft the most popular activities. Fishing was most popular between Barneys Point Bridge and the Tweed Broadwater.

Within the Tweed-Clarence Region (of which the Tweed River estuary lies) open runabouts dominate, accounting for 70% of all registered vessels with punts and cabin runabouts comprising 20% of all vessels (Transport for NSW, 2014). PWCs, yachts, motor cruisers and inflatables have a modest presence on the region’s waterways. Some powered catamarans, sailing catamarans, fishing vessels and houseboats are also registered in the region but these represent a relatively small proportion of the region’s total registered vessels (Transport for NSW, 2014). A majority (90%) of all vessels are between 2 and 6 m in length and the average vessel length for the region is 4.6 m (Transport for NSW, 2014). Vessels less than 6 m in length are defined as trailerable. This has a strong influence on the boating access and storage requirements in the region with a strong demand on boat ramps and trailer parking particularly during peak periods (Transport for NSW, 2014).

A large number of recreational boating users on the Tweed are Queensland boaters. A study undertaken by NSW Maritime (2005) indicated that approximately 64% of boaters using the Tweed River were registered in Queensland. It was indicated at that time that a large proportion of Queenslanders that boat on the Tweed reside south of Tugun on the Gold Coast.

PBP (2008) calculated a peak daily demand estimate for the estuary based on population growth predictions and number of boat registrations. Predicted peak demand estimates for the estuary were calculated using percentage boat usage (Figure 17). PBP (2008) noted that lack of boating facilities has been shown to limit boating activity on the estuary. Actual boat usage rates had fallen well short of previous boating activity estimates, for example the number of boats recorded in the 2004 survey (on a busy long weekend) was similar to the number estimated in 1997 as the 1997 peak demand. Consequently, it was concluded that predicted future potential peak daily demands could only be realised if additional facilities were implemented to accommodate such a demand.

PBP (2008) highlighted that with the ongoing provision of facilities on the Tweed River estuary the corresponding increase in boat usage on the river will put pressure on the environmental values of the estuary. To determine whether the increasing demand could be accommodated by the estuary in terms of required space and environmental objectives, they estimated the recreational boat environmental carrying capacity of the estuary. The environmental carrying capacity was calculated considering a number of factors and assumptions including:

- The river was segregated into management sections and the carrying capacity for each section was calculated.
- For each section the total useable river area was estimated. These estimations included reductions for environmentally sensitive areas, congested marina/mooring areas, and no skiing areas.
- Minimum boating densities of 5 ha/vessel for towing vessels and 1.2 ha for other vessels (as used in the *Lower Tweed Boating Study (PBP, 1997)*.
- Considering the minimum boating densities and the observed vessel type ratios the total number of allowable vessels in each management section was estimated by satisfying the following equation; available area ÷ boating densities = environmental carrying capacity for each section.

The total environmental carrying capacity for the Tweed River estuary was estimated as being approximately 650 vessels (PBP, 2008). The environmental carrying capacity relative to the predicted peak daily demand is illustrated in Figure 17. PBP (2008) noted that in some regions of the estuary (particularly upper reaches) the environmental carrying capacity is likely to have already being exceeded locally during peak demand periods. They attributed this to the concentration of high demand activities around a particular boating facility in a region favoured for this type of high demand use.

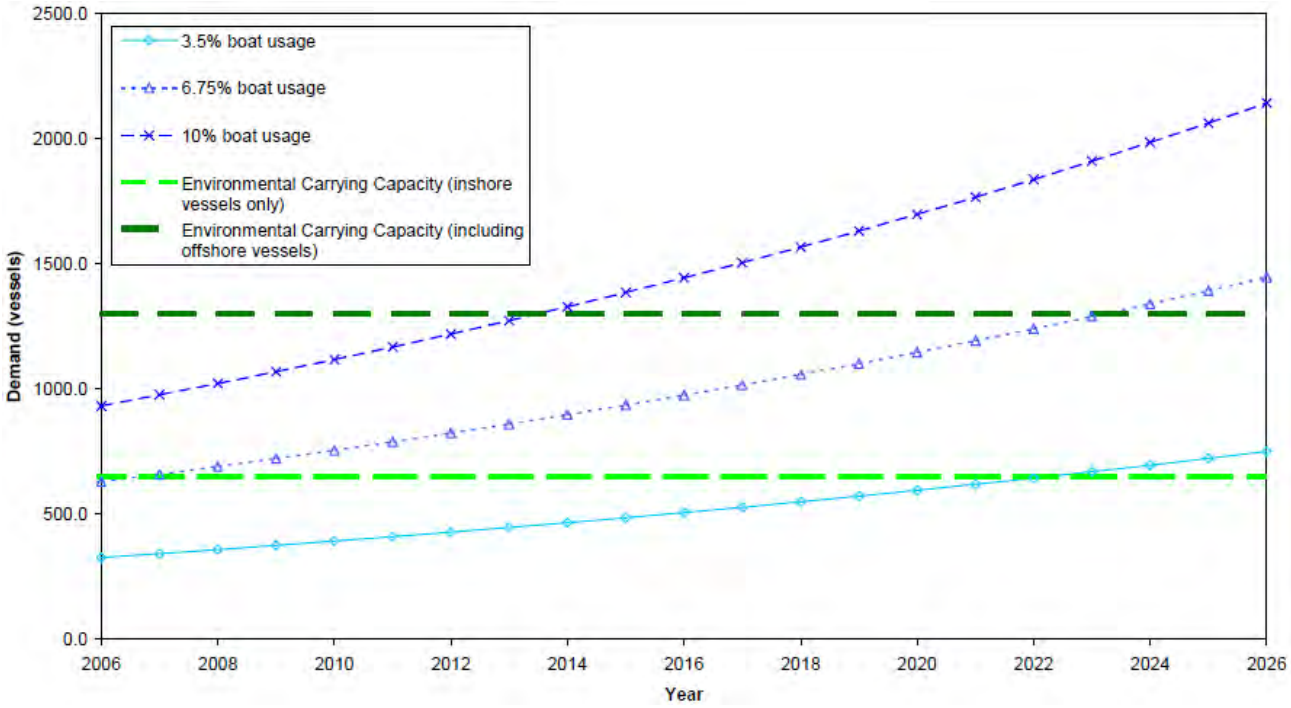

Figure 17: Predicted Peak Daily Demand and environmental carrying capacity for boating within the Tweed River estuary. Boat usage corresponds to percentage of registered boats using the estuary.

The Tweed to Clarence Regional Boating Plan (Transport for NSW, 2014) focusses on identifying boating safety, access and infrastructure actions needed to improve the boating experience in NSW. $2.78 million over three years has been allocated to support delivery of priority regional projects. Those identified within he Tweed River estuary are:

- Condong Boat ramp improvements and toilet facilities, Clarrie Purnell Park;

- Canoe launch facility in Tweed River at Byangum;
- Relocate and upgrade pontoon at Budd Park, Murwillumbah;
- Car park and river bank stability improvements at Murwillumbah boat ramp (Commercial Road);
- Replace pontoon and provide disabled access at Fingal boat harbour (Lighthouse Parade);
- Parking upgrade at Terranora Creek boat ramp, Tweed Heads (Kennedy Drive);
- Boat ramp improvements at Oxley Park, Chinderah; and
- Replace timber jetty with pontoon at Tumbulgum.

The Plan also discusses the issue of boating activity and riverbank erosion that was identified as a particularly contentious issue through their consultation with stakeholders and the general public. The Boating Plan does not address this issue and Transport for NSW is developing a state-wide policy framework to ensure a consistent approach to boating and riverbank management in areas that are subject to boating and erosion. The Boating Plan states that the "*policy will be implemented through pilot local management plans to be developed for the Tweed, Clarence and Upper Williams Rivers and will focus on delivering pragmatic solutions to improve these issues*". To date, the Clarence River Erosion Management Plan has been finalised and a pilot program is underway in the Clarence River and will run until September 2017. There has been no further work in the Tweed to date.

4.2.2 Recreational Fishing

Recreational fishing is growing in popularity and increasing with population growth in the Tweed and nearby SE Qld. It is a highly valued activity by the local community and important from an economic perspective, with significant flow-on benefits, such as providing employment opportunities in the tackle, boating, tourism, fishing charter and associated industries.

A number of fishing clubs are based in the area and utilise the estuary for fishing outings and competitions including:

- Tweed Heads Amateur Fishing Club;
- Twin Towns Fishing Club;
- Riverview Fishing Club;
- Brothers Fishing Club and;
- Seagulls Fishing Club.

The Tweed River estuary is also utilised for indigenous fishing activities and practices and is discussed in Section 4.5.1.

Recreational fishers target a range of species throughout the Tweed River estuary including bream, flathead, mulloway, whiting, bass, mangrove jack, trevally and mud crabs. Fishers utilise a range of habitats throughout the estuary including shallow sand flats, deep holes, rock walls/ledges, seagrass meadows, woody debris, depending on the species being targeted.

Fisheries NSW has conducted NSW/ACT recreational fishing surveys in 2000/01 and again in 2013/14 to provide 'big picture' information on the sector including participation rates, catch and effort data, boat ownership levels and social information. The Tweed/Richmond area was grouped into the North Coast Fishing Zone stretching from Tweed Heads to Coffs Harbour. This data revealed a number of characteristics of the local recreational fishing sector as follows (illustrated in Figure 18):

- the majority (68%) of all fisher days were shore-based (68%);

- total effort was concentrated in estuarine waters (58%), followed by inshore coastal waters (32%), freshwater rivers (6%), offshore waters (3%) and freshwater lakes/dams (1%); and
- Bream was the most common species caught (33%), followed by dusky flathead (15%), sand whiting (12%), swallowtail dart (11%), snapper (10%), red rock cod and tailor (at 6% each), with a range of other species at < 4% each.

While the catch of individual fishers was not large (about 2 fish per event), the recreational sector as a whole has the potential to impact aquatic resources. The recreational catch of several common estuarine species is larger than the commercial catch. Total recreational harvest weights were estimated for 10 key recreational species and compared with commercial fisheries data in 2013/14. Recreational catches exceeded commercial landings for 5 of the 10 species - namely: 71% of the total harvest of dusky flathead; 67% for sand flathead; 63% for both mulloway and tailor; and 52% for yellowtail kingfish (Table 5). However, when including all species, the commercial catch is substantially greater than the recreational catch.

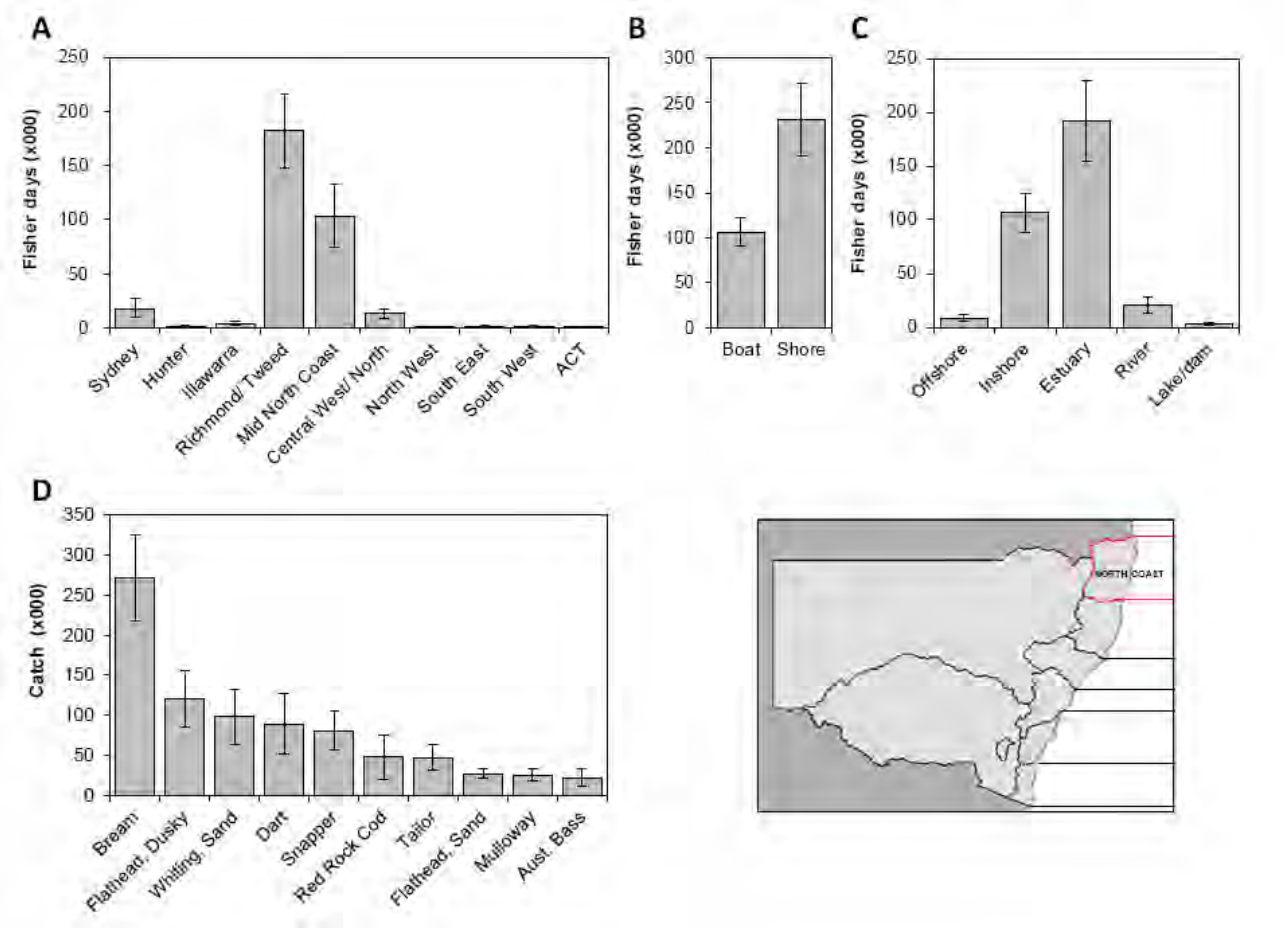

Figure 18: Characteristics of the North Coast recreational fishery based on 2013/14 fishing activity by NSW/ACT residents aged five years and older: A) fishing effort (fisher days) by residential stratum; B) fisher days by platform; C) fisher days by water body type; and D) total catch (numbers) for the key species. Error bars represent one standard error (Source: West *et al*., 2015).

Table 5: Harvest of key species in NSW waters by NSW/ACT residents - indicative estimates of the total weight (tonnes), compared with estimates for the commercial fisheries sector during 2013/14 (Source: West *et al.*, 2015).

	Total (tonnes)			%
Species/group	Recreational	Commercial	Total	recreational
Bream	330	343	672	49.1
Flathead, Dusky	288	115	404	71.4
Flathead, Sand	210	101	311	67.5
Mulloway	103	59	162	63.5
Salmon, Australian	182	1,112	1,294	14.1
Silver Trevally	27	168	195	13.9
Snapper	148	220	368	40.2
Tailor	107	62	169	63.5
Whiting, Sand	69	79	148	46.5
Yellowtail Kingfish	120	109	229	52.5

Fisheries NSW is responsible for the control and regulation of recreational fishing in NSW. The current recreational fishing rules and restrictions applicable to the Tweed River estuary are published in the *Tweed Recreational Fishing Guide* (Fisheries NSW, 2016). DPI fisheries officers routinely patrol waterways, boat ramps and foreshores to advise anglers about responsible fishing practices and to ensure compliance with NSW fishing regulations.

Many fish are subject to daily bag limits, which restrict the number of fish legally able to be caught and retained in one day. In addition, some fishing areas are subject to seasonal closures, which are imposed by State fishing authorities to protect certain fish species during their breeding period.

Fisheries NSW have introduced a requirement for all fishers to purchase fishing licences for both freshwater and saltwater fishing. Income received through the licensing system is used by the NSW government to undertake important research aimed at ensuring a healthy and sustainable fish population in NSW recreational fishing areas and improve fishing facilities and access.

Recreational fishing havens (areas where commercial fishing is excluded) are provided for recreational fishers at several locations throughout the lower estuary (Figure 19). These locations include downstream from Boyd's Bay Bridge and from south of Rocky Point east to Fingal Road. All enclosed waters on the Fingal Peninsula including Wommin Lake and Wommin Lagoon, and six canal estates beyond that area are also part of the fishing haven (i.e. Seagulls Canal, Tweed West Canals, Blue Water Canals, Crystal Waters Canal, Endless Summer Canal Estate, Oxley Cove). Recreational fishing havens aim to provide better angling opportunities for recreational fishers.

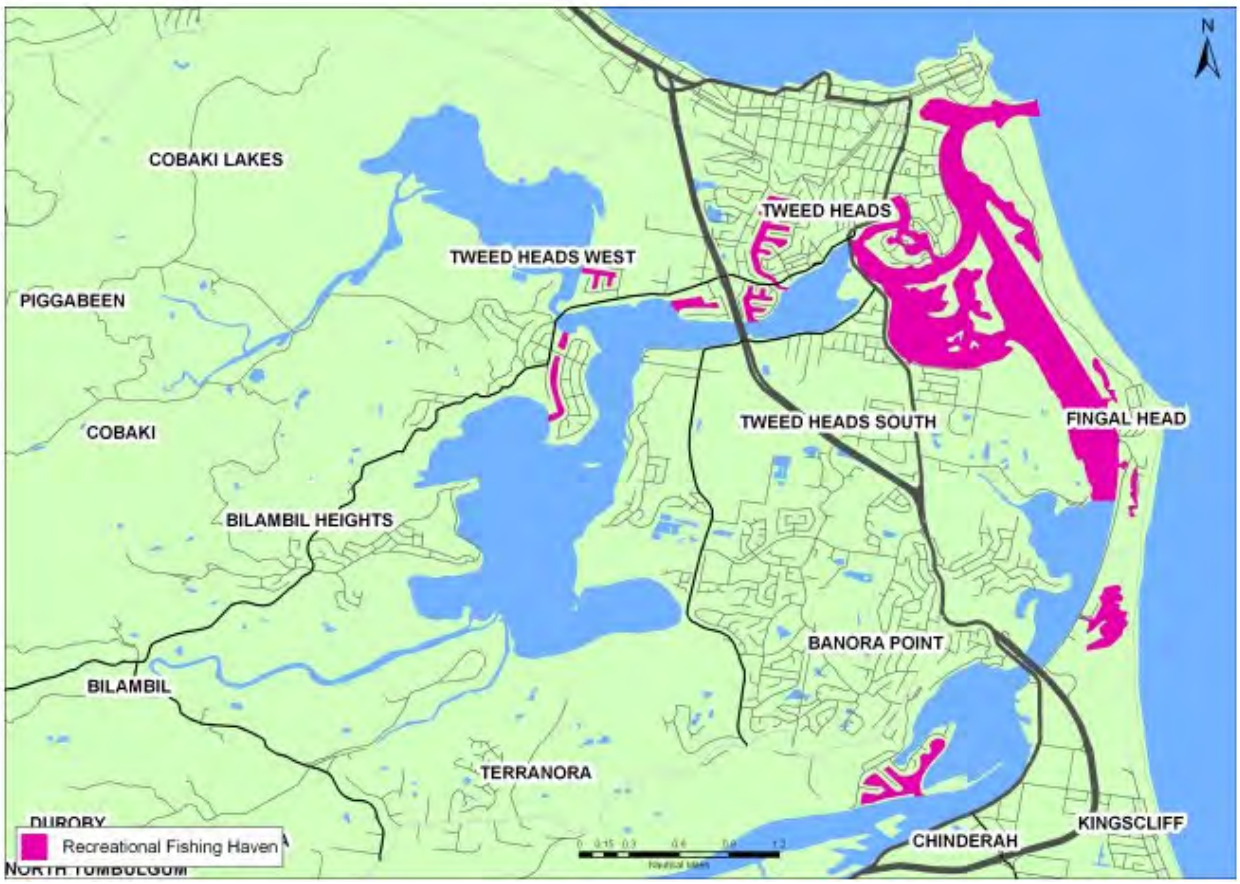

Figure 19: Recreational fishing havens within the lower Tweed River estuary. (Source: NSW DPI, undated)

4.3 Access

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

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

4.3.1 Access to river foreshores

Recreational reserves along foreshore areas of the estuary within the study area include:

- Duranbah Beach and Surrounds;
- Chris Cunningham Park and Coral Street Park (adjacent to Jack Evan Boat Harbour);
- Ebenezer Park (Terranora Inlet);
- Keith Curran Reserve (Terranora Inlet);
- Tweed Apex Park (Terranora Inlet);
- Old Boat Harbour (Fingal) ;
- New Boat Harbour (Fingal);

- Faith Bandler-Mussing Park (Tumbulgum);
- Bluey Hill Park (Tumbulgum);
- Clarrie Purnell Park (Condong);
- Nicholl Park (Murwillumbah);
- Budd Park (Murwillumbah).

A number of other areas along the estuary foreshore are zoned as public recreation under the Tweed LEP 2014 and may provide access to the estuary (Figure 20).

Figure 20: Estuary foreshore areas zoned as Public Recreation under the Tweed LEP 2014.

There are also constructed access points along the foreshore at a number of locations throughout the estuary including:

- Boardwalk at Ukerebagh Island
- Boardwalk at Keith Curran Reserve;
- Boardwalk and timber constructed access point in Jack Evans Boat Harbour including disabled access; and
- Various wharves and jetties outlined in Table 7.

Footpaths and shared pathways have been constructed around the foreshore along the lower tweed between Jack Evan Boat Harbour and Ebenezer Park, Fingal Peninsula foreshore south from the Fingal boat ramp and along the north and south training walls of the river.

Other informal access tracks have also been established along the foreshore, particularly on Letitia Spit.

Sandy foreshores within estuaries provide for a range of recreational activities including swimming, fishing, bait collecting, picnicking and other beach activities and subsequently are generally very popular areas amongst the public. Public access to these areas is important to the overall attractiveness of an estuary for recreational activities and use. There are a number sandy/silty intertidal and supra-tidal beaches and foreshores throughout the estuary that are land accessible for recreational use, however, are restricted to the lower estuary (Table 6). Council currently maintains the sandy beaches within Jack Evans Boat Harbour by undertaking regular sand distribution and beach grooming works (GHD, 2016). Council commissioned a study (GHD, 2016) into future management options for maintain the Jack Evans Boat Harbour foreshore. To provide an all-tide sandy recreational beach, support seagrass growth in the area and reduce the frequency of current sand management works the report recommended the nourishment of the beach and construction of a sill to retain renourished material.

Table 6: Directly accessible sandy estuarine foreshores located within study area.

Sandy Beach Name	Location	Accessible from	Facilities
Letitia Spit	River mouth	Letitia Spit Rd	Car Park,
Small beach similar to Letitia spit beach on north side of river	River mouth	Coral St., foreshore pathway	Car park
Jack Evans Boat Harbour		Wharf St., Chris Cunningham Park, Coral Street Park, boardwalk/footpath, ramp and steps into water	Car park, park, playground, amenities
Terranora Inlet beach	Just u/s of confluence of Terranora Inlet with Main River	Keith Compton Drive, Ebeneezer Park, Keith Curran Reserve, footpath	Car park, park, playground,
Old Boat Harbour (Fingal Head)	Fingal Head	Fingal Road	Car park, park, playground, footpath

4.3.2 Boating access

Tweed Shire Council owns various boat ramps, jetties, pontoons and wharves providing access to the Tweed River estuary (Table 7).

Table 7: Boating facilities within study area owned by TSC (TSC, 2016)

Facility Name	Facility Type	Location
Fingal Head Boat Ramp	Boat Ramp and Pontoon	Fingal Boat Ramp, Main Road Fingal
Condong Boat Ramp	Boat Ramp and Pontoon	Clarrie Purnell Park - McLeod Street, Condong.
Commercial Road Boat Ramp	Boat Ramp	Commercial Road, Murwillumbah.
Tumbulgum Boat Ramp	Boat Ramp and Jetty	Faith Mussing Bandler Park - Riverside Drive, Tumbulgum.

Facility Name	Facility Type	Location
Chinderah Boat Ramp	Boat Ramp	Oxley Park - Chinderah Bay, Drive Chinderah.
Dry Dock Road Boat Ramp and Jetty	Boat Ramp, Timber Wharf and Pontoon	Dry Dock Rd, Tweed Heads South.
Foysters Jetty	Timber Wharf and Pontoon and Sewage Pump Out Facility	Faux Park - Intersection Minjungbal Drive, Dry Dock Rd, Tweed Heads South.
Anchorage Wharf	Timber Wharf	Keith Curren Park - Keith Compton Drive, Anchorage Islands Tweed Heads.
Skinner Lowes Wharf	Timber Wharf and Pontoon	Nicholl Park - Tumbulgum Road, Murwillumbah.
Tumbulgum Pontoon	Pontoon	Faith Mussing Bandler Park - Riverside Drive, Tumbulgum.
Budd Park Pontoon	Pontoon	Budd Park - Alma Street, Murwillumbah.
Tweed Marina	22 Berth Marina, 2 berths available for short term public use. Includes sewage pump out.	Southern Boatharbour - River Terrace, Tweed Heads.
Old Barneys Point Bridge	Fishing Jetty	North end of Chinderah Bay Drive, Barneys Point, Chinderah.

4.3.3 Dredging

Dredging has occurred within the Tweed River estuary since European settlement. The majority of the river from the ocean entrance to Murwillumbah and including the Rous River has been dredged at some time in the last 130 years. Dredging was conducted for number of purposes including: navigational and river access purposes; extraction of natural resources such as sand and gravel for filling low-lying land and for construction materials; removal of islands; ferry approaches, and flood mitigation.

PWD (1991) provided a history of dredging in the Tweed River:

- From the turn of the century, until the 1950's, the Public Works Department was engaged in maintenance dredging to keep navigable routes open for commerce, and in particular, for cane barges.
- Since 1941 only fishing vessels, cane barges and tourist craft, used the river as far upstream as Murwillumbah. Cane barge activity principally ceased in the 1950's and the Public Works dredge fleet was ultimately disbanded in the early seventies.
- In the second half of the twentieth century, dredging was increasingly used as a means of acquiring fill for developing low lying lands. Between 1962 and 1991, approximately 2 million cubic metres of fill was been dredged from the lower river. Extensive dredging took place in the lower reaches between 1966 and 1976. Approximately 1.6 million cubic metres of sand were removed from the river. Through an agreement between the NSW and QLD governments, about half the dredged volume was placed on lower Gold Coast beaches via an overland pipeline.
- A small number of sand extraction operations were authorised by the Department of Lands between 1975 and 1991. These leases were located throughout the current study area, and primarily entailed the winning of fill materials for adjoining or nearby land fill.

Figure 21: Historical photo showing river boats at Murwillumbah in 1927

Since 1991, DPI Lands has undertaken regular maintenance navigational dredging within the estuary. In response to siltation of navigation channels, various locations throughout the lower estuary were recently dredged, including, the downstream section of the navigation channel in Terranora Inlet adjacent to Ebenezer Park, various sections of the navigation channel in the lower Tweed River adjacent to Fingal Head and downstream of Barneys Point (Figure 22). Sand from the dredging activities has been used to nourish Kingscliff and Fingal Beaches, which have been subject to severe coastal erosion in recent times. Further navigation channel maintenance dredging is proposed for a number of locations throughout the lower estuary in 2017.

Since 2001, the Tweed River entrance has been actively managed by the Tweed River Entrance Sand Bypassing Project (TRESBP) to maintain a safe, navigable entrance to the Tweed River and restore and maintain the coastal sand drift to the beaches on the southern Gold Coast of Queensland. Section 6.1 provides details of entrance management arrangements.

A sand extraction licence is currently held by a commercial operator for a section of the upper Tweed River estuary including the Chinderah and Dodds Island sand deposits. The current licence permits the extraction of a total of 3,000,000 m³ from 1994 to 2024 (refer Section 3.5.6 Extractive Industries for further details and mapping).

Figure 22 provides an overview of the historical and most recent dredging operations in the Tweed River estuary compiled from the available data.

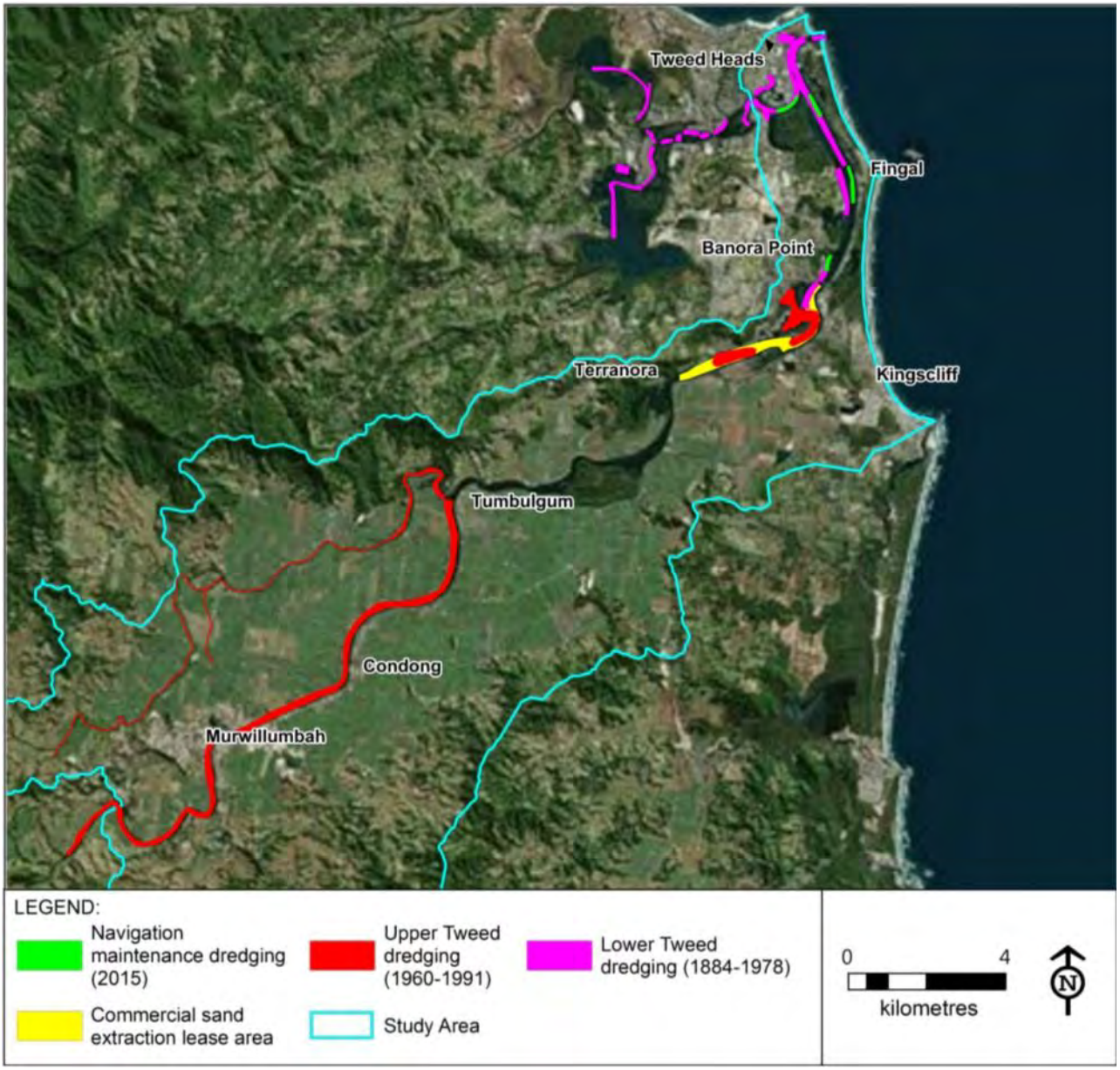

Figure 22: Recorded areas dredged within the estuary.

The available historical data indicates that considerable areas of the Tweed River estuary have been dredged in the past and dredging is ongoing in some areas, although on a lesser scale. WBM (1992) concluded that overall, historical dredging has substantially reduced the ecological value of the Tweed River through removal of fish and shorebird habitat including sand islands and seagrass areas, altering benthic community composition, excavation of deep holes with poor quality bottom waters, disposal of dredge spoil in wetland areas, and exacerbation of bank erosion. Today, the environmental impacts of dredging activities must be assessment and managed under environmental legislation before projects are approved. However, the extent of impact from the combined present day dredging activities is not currently known.

4.4 Commercial Activities

4.4.1 Commercial Fishing

The Tweed River estuary is utilised for commercial fishing by a number of licensed commercial fisherpersons, providing fish for the community to enjoy. The industry is primarily made up of small family businesses that rely on high levels of local knowledge and skills learnt over many generations (Fisheries NSW, 2016).

The NSW coastal fisheries resource is divided into 10 management zones. The Tweed River estuary lies within the Upper North Coast Region 1 which encompasses various estuaries and coastal areas from the Evans River north to the Tweed River. A number of fishery types operate within this zone including Ocean Hauling, Ocean Trap and Line, Ocean Trawling, Estuary General and Estuary Prawn Trawl fisheries. Several Ocean Trawling vessels operate from the Tweed Marina which is located off Terranora Creek downstream of Boyds Bay Bridge. Within the estuary itself an Estuary General Fishery is operated which targets fish species such as sea mullet, flathead, luderick and bream (Tuckey, *et al.*, 2008).

The primary methods of fishing are mesh and haul netting which is most often undertaken on gently sloping sand/mudflats. Hauler nets are typically up to 750 m in length and are hauled in an arch around schools of milling fish. Hauling is limited by the morphology of the river and its ability to accommodate both the periodic schooling of viable quantities of fish and the effective operation of the hauler (Tuckey, *et al.*, 2008). Prawn haul nets are also a key part of the fishery and can again only be used in locations with appropriate geomorphic configuration (Tuckey, *et al.*, 2008).

Figure 23: Commercial Fishing boats at Tweed Heads Marina

The NSW DPI has the responsibility to manage fish stocks on behalf of the community. Since the 1990's there have substantial changes to fishing regulation and management in Australia including a large emphasis of science-based management. Australia is now recognised as having some of the best managed fisheries in the world (CSIRO, 2016). There are a number of regulations and controls in place to assist in the long term sustainability of the fishery and ensure fishing activities are environmentally sustainable. An Environmental Impact Statement (EIS) has been prepared for each of the commercial fisheries in NSW. The EIS looks at the environmental impacts of the fishing activities on the targeted and bycatch species, important fish habitats, the broader ecosystem, and economic and social issues. It also considers the impact on the resource from other fishing activities and other non-fishing activities. Based on this assessment, fisheries management plans have been developed for each of the commercial fisheries to ensure that harvesting is sustainable.

Measures include a limit on the number of commercial fishers authorised to operate in the fishery, temporal and spatial closures, gear restrictions (i.e. mesh sizes and net lengths) and minimum size limits (Fisheries

NSW, 2016). In the Tweed River, commercial fishing is excluded from the recreational fishing havens located within the lower estuary (Figure 19) and restricted to operation during weekdays only (Mon-Fri), leaving weekends open to recreational fishing only. Fisheries officers are employed by NSW DPI to patrol waterways to ensure commercial and recreational fishers are licenced and are following the rules. The NSW DPI undertakes ongoing scientific research and monitoring programs to ensure sustainable management of the resource.

Harrison (2010) conducted a study on the socio-economic value of the commercial fishing industry in Northern NSW. From 1998 to 2008, commercial fishing effort in the Estuary General Fisheries has declined significantly in Northern NSW. This decline is mirrored in the number of fishing businesses reporting to DPI Fisheries and is thus accounted for by the reduction in participating fishers. The Estuary General Fishery catch weights have also shown a reduction directly relative to the decrease in fishing effort. Both effort and catch levels in the Estuary Prawn Trawl Fisheries has remained fairly consistent.

NSW Fisheries undertook a major assessment of fish stocks in NSW in 2013-2014. Most of the key species have been classified as 'Fully Fished', indicating that harvesting is sustainable, but that there should be no significant expansion of commercial or recreational catches (DECCW, 2009). For NSW-managed species, grey morwong and mulloway continue to be assessed as 'Overfished'. Stock rebuilding programs are underway for mulloway. Five species (redfish, silver trevally, snapper, yellowtail kingfish and eastern king prawn) are considered 'Growth Overfished', where harvest is being restrained by excessive fishing mortality and/or their size at capture being too small. Growth overfishing may be sustainable; however it can lead to recruitment overfishing and the status of these species is monitored closely.

The State Environmental Planning Policy 62 – Sustainable Aquaculture and the *NSW Oyster Industry Sustainable Aquaculture Strategy* (NSW DPI, 2014) identify and provide protection for priority oyster aquaculture areas. No priority oyster aquaculture areas are located within the study area however a number located within Terranora Inlet upstream of Boyds Bay Bridge.

4.4.2 Tourism Operators

There are a number of tourism operators that undertake business directly within the estuary including:

- Tweed River Boat Hire – operating from Terranora Creek;
- Big Trevs WaterSports – Operating in Jack Evans Boat Harbour;
- Tweed Endeavour Cruises – daily river cruises from the lower estuary to Tumbulgum;
- Catch a crab – fishing charters and yabby pumping expeditions in lower estuary;
- Brad Smith Fishing Charters – utilise various areas throughout the Tweed River estuary for fishing charters;
- Gypsy Calm Water Cruises – boat hire and cruises within estuary;
- Endless Summer Hire – jet ski, stand-up paddleboard and kayak hire on the Tweed River estuary; and
- A number of offshore fishing charters operate from the Tweed Marina.

4.5 Cultural and Heritage Environment

TSC recognises that cultural heritage is an important coastal management value due to the long association of Aboriginal communities with the Tweed River over many tens of thousands of years. More recently, European settlement has also made extensive use of the River, resulting in a multi-layered pattern of cultural usage of coastal sites and resources.

The Tweed River estuary has spiritual and cultural significance for local communities. Both European and Aboriginal heritage sites and items exist in and around the estuary and their recognition and protection are important to the local community.

4.5.1 Aboriginal Cultural Heritage

The Tweed Shire is part of the historic Bundjalung Nation which stretched from Grafton in the south to Beaudesert in the north (TSC, 2016b). Aboriginal people have lived in the Tweed for thousands of years, deriving their physical and spiritual needs from the forests, rivers, lakes and streams of the Tweed valley (TSC 2016b). The Tweed's Bundjalung descendants have a special connection with the Tweed River and floodplain which provided a rich source of marine and freshwater food, natural resources, significant cultural places and spiritual meaning. With regard to Aboriginal culture and heritage the Tweed Byron Local Aboriginal Land Council (TBLALC, 2012) explains that "*Like all Aboriginal peoples' our definition of culture is not limited to particular places or physical evidence of Aboriginal existence on the land; it includes whole of landscape values and both tangible and intangibles that tell a story about the land & waters, environment, people, family, history, law, community and spirituality."*

Several archaeological studies had been completed in the study area either as part of research, work for NPWS or for development assessments. Most focused on assessing and recording cultural sites such as bora rings, shell middens, fish traps, scarred trees, quarry sites, open artefact, shell scatters and single artefact finds (PWD, 1991). Cane (1989) conducted a study of the Fingal Peninsula which confirmed the strong cultural, spiritual and mythological connection in this area with several areas of significance identified. PWD (1991) also carried out archaeological survey of the Lower Tweed River in 1991 in consultation with the TBLALC.

A search for Aboriginal Places declared by the Minister for the Environment under the *National Parks and Wildlife Act 1974* (NPW Act) identified Ukerebagh Island in Tweed Heads as a listed Aboriginal Place. It is described as a former Aboriginal settlement and reserve. In 1980 the area was gazetted as the Ukerebagh Island Nature Reserve. Today the Island falls within the Ukerebagh Nature Reserve, and is used for conservation purposes to protect its natural and cultural values.

The recent Bundjalung Mapping Project resulted in the creation of a computer-based record keeping system through which communities can record and thus own their cultural knowledge. The Project was a joint venture between Southern Cross University, the Bundjalung Nation Aboriginal Cultural Heritage and Natural Resource Management Committee, Northern Rivers Catchment Management Authority, and the then NSW Department of Environment and Conservation, National Parks and Wildlife Division. The system automatically transfers information to the NSW Government's Aboriginal Heritage Information Management System (AHIMS) database (excluding confidential information) to ensure traditional objects and places are considered in planning and development and protected into the future. The knowledge recorded in Tweed Heads via the Project proved a key resource in allowing the Tweed community to put their case in the design and construction process of the Pacific Highway (SCU, 2016). There are a number of significant sites located within the study area.

The TBLALC is the peak body representing Aboriginal peoples in the Tweed Byron region. Established under the *Aboriginal Land Rights Act 1983* (NSW) (ALR Act), TBLALC is an independent, self-funded non-government organisation that has an elected governing Board.

Tweed Council's Aboriginal Advisory Committee (AAC) is the peak advisor to Council on Aboriginal matters. The primary objective of the AAC is to provide advice to Council in order to encourage and facilitate the development of the Tweed Aboriginal and Torres Strait Islander Community in the Tweed Shire (TSC, 2016).

Maintenance and management of Aboriginal heritage interests within the Tweed Shire is, in the first instance, overseen by the TBLALC and is supported by the *National Parks and Wildlife Act, 1974* and the *NSW Heritage Act, 1977,* which provide legal protection for Aboriginal sites and relics in NSW, including sites yet

to be recorded. The Office of Environment and Heritage (OEH) have a legislated responsibility to record Aboriginal sites and places and this is undertaken through the NPWS database known as the AHIMS.

TSC is currently preparing a Shire-wide Aboriginal Cultural Heritage Management Plan. This plan aims to identify and assess known and potential Aboriginal Cultural Heritage and provide a framework for the management of Aboriginal Cultural Heritage. The plan is being prepared in consultation with the Aboriginal community and within the protocols of the signed Memorandum of Understanding (MOU).

Council adopted an Aboriginal Cultural Heritage Management Plan (Fox, 2006) for Terranora/Cobaki in November 2006 which was developed as part of the Cobaki Terranora Broadwaters CZMP (Australian Wetlands, 2010). The Plan identified a number of conservation and management issues raised by Aboriginal Stakeholders, and developed management strategies, many of which are likely to be relevant to management of the Tweed River estuary.

4.5.2 Indigenous Cultural Fishing

In 2010, the NSW government amended the FM Act to recognise Indigenous cultural fisheries as one of the three fishing sectors in Australia along with the commercial and recreational sectors. In comparison to the commercial and recreational sectors, little was known about Indigenous cultural fisheries and research was required to provide input into fisheries management decision-making processes about the management of cultural fisheries.

In 2011, Southern Cross University was commissioned by the Fisheries Research Development Corporation (FRDC) to research Aboriginal fisheries in NSW, determining catch, cultural significance of species and traditional fishing knowledge needs. The study by Schnierer (2011) focused on the Tweed River catchment in partnership with the Minjungbal traditional owners. The project report was influential in strengthening wider recognition of the role of Indigenous cultural fishing within State and Commonwealth fisheries policies (SCU, 2016). This report found that cultural fishing in the Tweed region occurs on a regular basis, is predominantly shore-based and focussed around the estuary and adjacent coastal waters. The main gear types used are rods and handlines with nets, traps and spears used to catch some species. The top 10 culturally most important species, based on a ranking given by participants, comprised a mix of finfish and invertebrates. pipis (*Plebidonax deltoides*) and mud crabs (*Scylla serrata*) were the top two, followed by sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*), sand whiting (*Sillago ciliata*), dusky flathead (*Platycephalus fuscus*), beach worms (*F. Onuphidae*), Sydney rock oysters (*Saccostrea glomerata*) and the bait yabby (*Callianassa australiensis*) (Schnierer, 2011). Most of the cultural catch is consumed either by the fisher, their family and extended family or the community as a whole. Some of the catch is also used for bait. To a lesser extent, but still importantly, some of the catch is bartered or traded for other goods and services within the community and some is sold (Schnierer, 2011).

Key issues identified by Schnierer (2011), through consultation with the Tweed Shire community were:

- The development of culturally suitable bag limits for key species;
- the use of large nets to catch culturally iconic species, such as sea mullet, in larger numbers and on a more regular basis;
- restrictions on the consumption of certain bivalves such as pipis and oysters;
- translocation or reseeding of species like the Sydney cockle (*Anadara trapezia*) from one estuary to another;
- the selling of species taken in a cultural catch; and
- enforcing compliance through community rangers or more culturally sensitive fisheries officers.

Following on from Schnierer (2011), further study by Schnierer and Egan (2015) funded by the FRDC sought to build on what had been achieved and develop a local Tweed Aboriginal Cultural Fisheries Management Plan. Support for the project was obtained from the NSW Aboriginal Fishing Advisory Council (AFAC), the

Fisheries NSW, the NSW Aboriginal Land Council (NSWALC) and the Indigenous Reference Group to the Fisheries Research and Development Corporation (IRG) and the Tweed Aboriginal community. The draft plan contains information on historical and contemporary Aboriginal cultural fishing in the Tweed region as well as suggested management arrangements relating to cultural bag and size limits, Aboriginal fishing gear, waters that can be fished, and identification of who can fish under the Tweed Plan. Currently, negotiations with Fisheries NSW and the Aboriginal Fishing Advisory Council are underway to agree on a way forward for implementation of the Plan.

4.5.3 European History

The 1991 EMP provides a comprehensive account of early European history of the Tweed River:

The oldest record of European observation of the Tweed area is found in the 1770 log of Captain James Cook who made reference to Mt Warning and Point Danger. In 1823 the John Oxley expedition sighted the mouth of the Tweed River making mention of the hazards encountered in navigating the entrance. Cedar getters are said to have first arrived in the Tweed Valley in 1844 and the removal of timber continued at a rapid rate for several decades with animal husbandry commencing in the early 1850's. By the 1860's shipyards and commerce were well established.

In the early days the coastal shipping trade was important to Tweed Heads and valley residents. Their supplies of groceries, clothing and hardware came to them from city stores via the ocean. Cut timber and harvested crops then retraced the waterway, *en route* to the Sydney markets. The dangerous conditions of the Tweed River entrance caused many problems for trade and transport. Training wall construction was commenced in 1891 and further work carried out between 1899 and 1904.

Figure 24: Historical image of a River Boat in the Upper Tweed River

In 1880 the Colonial Sugar Refining Company opened the Condong Sugar Mill. Dairying developed in the 1880's and the first butter factory opened at Murwillumbah in 1887. From the earliest days of sugar cane farming and dairying, the river was used as a transport medium. The usage continued into the first half of the twentieth century.

Figure 25: River Boats at Tweed Heads early this century (photo courtesy of the Lower Tweed River Historical Society, cited in PWD, 1991).

4.5.4 Heritage Register Search

The Tweed Local Environmental Plan 2014 identifies heritage items of relevance to the Tweed River estuary (Table 8 and Figure 26). A search of the NSW Stage Heritage Register revealed no items of significance in the study area.

Table 8: Tweed Local Environmental Plan 2014 heritage items

Heritage Item or Area	Statement of Significance (OEH, 2016)
Osprey Nests recorded by NPWS along the river foreshore	Osprey nests as mapped from time to time by NPWS and notified to Council. The nests represent a major collaborative initiative to preserve a highly threatened species. The birds are protected by both the National Parks & Wildlife Service and Threatened Species Act.
Tumbulgum Conservation Area	This village has an important association with Tweed history since the days of the cedar getters in the 1850's. The conservation area was the first major population and business area of the Tweed, prior to the development of Murwillumbah.
Condong Conservation Mill Area	On site are a factory and associated buildings, machinery, a wide range of C.S.R. staff houses, a shop and storage sheds, railway tracks and spur line to Murwillumbah, wharves, sunken punts, river pylons, navigation markers, recreation facilities and landscape features. This precinct is unique on the Tweed and is of state significance in that it has been the site of the continuous production of sugar and associated activities and infrastructure since 1888 and contains a remarkable and largely intact historical record of its 125 years of use.
Ferry Approach at Tumbulgum	The ferry approaches at Tumbulgum and North Tumbulgum are symbolic of the time in the Tweed Valley history when transport prior to 1930 was by means of water. The Tumbulgum Ferry was the last serving ferry on the Tweed River, ceasing operations in 1987.
Wharf Pylon Remains at Murwillumbah	These two piles are all that remains of the Government Wharf, Murwillumbah, that provided facility for all forms of river craft and small coastal schooners and steamers in the late 1800's and first half of the 1900's.
Water Pumping Station at Bray Park Weir	The Boatharbour Water Pumping Station was the first water supply for the Municipality of Murwillumbah, and was initiated after the disastrous fire in the centre of town in 1907.

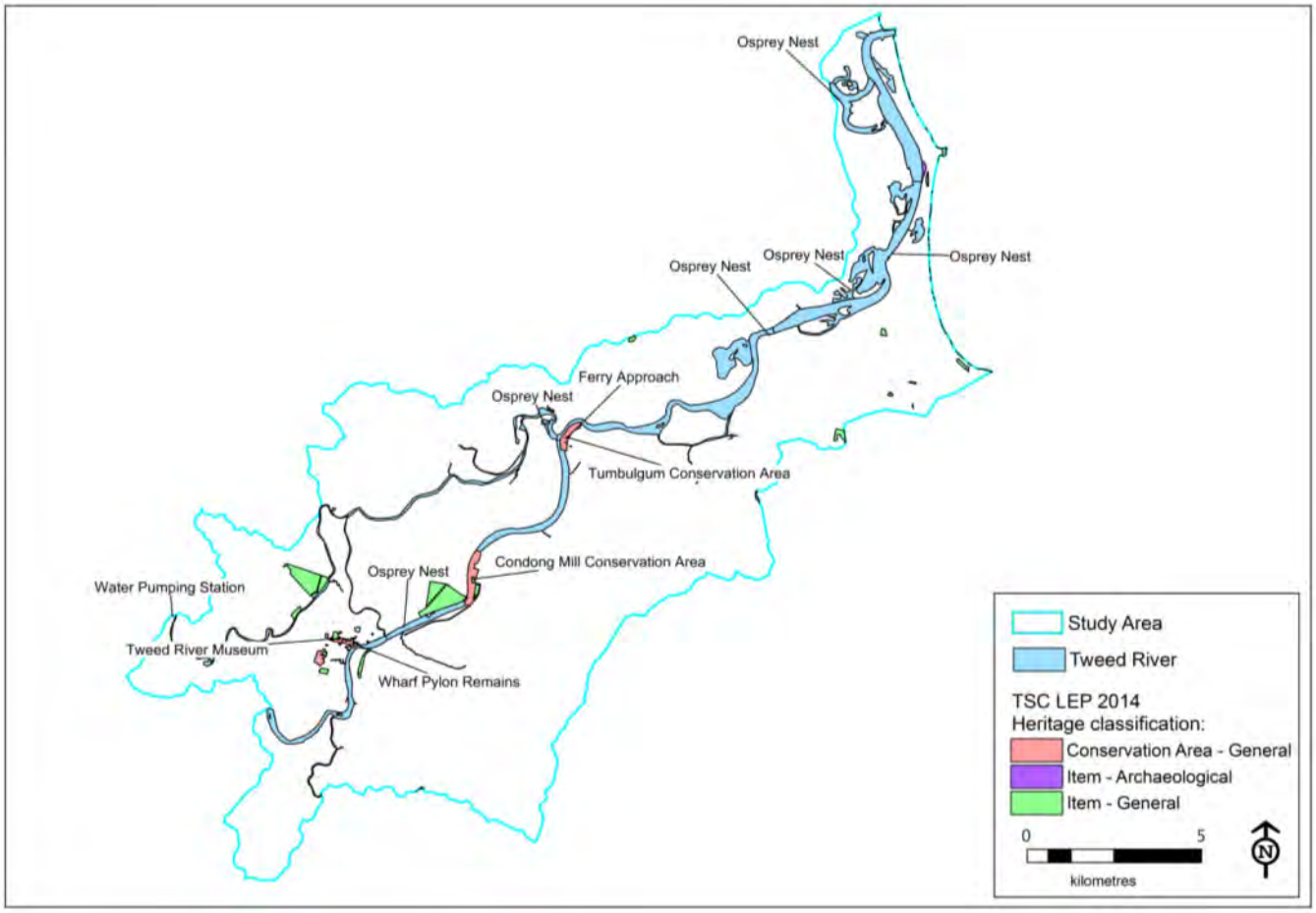

Figure 26: Tweed LEP 2014 Heritage Items of relevance to the estuary

Figure 27: Condong Sugar Mill

5. ECOSYSTEM HEALTH

This section provides an overview of what is currently known about the ecological health of the Tweed River based on previous studies. The *Estuary Processes Study* (PWD, 1991) provided a comprehensive assessment of ecosystem health based on a review of background and historical information as well as ecological surveys, technical investigations and mapping. Since then, a number of studies have been conducted by a range of stakeholders examining various aspects of the estuarine ecosystem. The following section provides a summary of the key findings of previous studies that are considered to be relevant to the current state of the Tweed River estuary.

An understanding of coastal ecosystem health and the vulnerability of the system to pressures is required to provide a sound basis for designing management actions and understanding the effects of management practices.

5.1 Estuary-Scale Ecosystem Health Assessment

The NSW Monitoring Evaluation and Reporting (MER) Strategy is a state-wide program providing information on natural resource condition and trends within catchments and includes assessment of estuary health. Findings are reported in the State of Catchments reports. The MER Strategy assessed the Tweed River in 2007/08 and 2008/09. The 2010 State of Catchment Report (DECCW, 2010b) reported the overall condition as “Very Good” for the Tweed River. This was essentially an average of all scores which ranged from “Very Good” ratings for seagrass and saltmarsh, “Good” rating for Chlorophyll a and “Fair” rating for Fish assemblages.

The University of Queensland Marine Botany Unit conducted an ecosystem health assessment of the Tweed River estuary in 2000 and 2001. The seasonal surveys involved measuring a suite of factors including water and sediment quality; algal blooms; phytoplankton counts; seagrass depths; and estuarine and riparian vegetation mapping. They also conducted nutrient tracing studies to identify major sources. Community consultation materials were produced as part of the work to communicate findings including a report card and conceptual models (Figure 28). The 2001 Report Card assigned an overall grade of B- to the Tweed estuary with the following summary points of ecosystem health status:

- Some healthy seagrass;
- Cleared streambank habitat;
- Localised wastewater impacts;
- Agricultural runoff impacts;
- Consistently high phytoplankton; and
- Well flushed river mouth.

The Rous River received a D-; Upper estuary received a C; The Mid estuary received a D; and the Lower estuary performed the best scoring an A-.

Figure 28: Conceptual model of Tweed River estuary Catchment (University of Queensland, 2003)

5.2 Water Quality

A formal water quality review will be undertaken as part of detailed studies to this CMP. A list of the water quality information available for the Tweed River estuary is provided in Table 9 including details of the data collected, timeframes, modelling undertaken and key conclusions drawn from reporting of results.

Table 9: Water quality information available for the Tweed River estuary

Data type	Reporting	Key Conclusions
TSC water quality monitoring program 2007-2012	*Review of water quality in the Tweed Estuary 2007 – 2011* (ABER, 2012). The review assessed water quality data over this time period, presented results and provided management recommendations	• Seasonal processes are a primary influence on water quality. Tweed River estuary ecosystem has evolved with episodic pulses of high nutrients and organic matter to the system during floods, followed by opportunistic increases in primary phytoplankton) and secondary (benthic invertebrates, detritivores, fish, birds) productivity during the months following the flood event. • During flood flows low-lying catchments on the floodplain discharge water with low pH (acid) and low oxygen. • During the dry season inputs of nitrate from STP effluent and the ocean are the primary drivers of new productivity in the estuary at this time. • The Tweed estuary has elevated concentrations of TN especially in the middle estuary which receives inputs of nutrient-rich wastewater. Concentrations are highest during high flows when diffuse catchment sources dominate. • The Tweed River estuary experiences moderately severe phytoplankton blooms in the middle and upper estuary and Rous estuary. Modelling shows that blooms are controlled by

Data type	Reporting	Key Conclusions
		wastewater inputs of bio-available nitrogen and water residence times. • The Tweed River estuary is prone to moderate hypoxia along the middle to upper estuary reaches during low to median flow conditions. Hypoxia is due to high sediment oxygen demand caused by organic matter enrichment from phytoplankton blooms. • During high flow, oxygen-poor flood waters draining from low lying swamps and cane land cause hypoxia to extend to the lower estuary transition zone. • The Tweed estuary experiences greatly elevated TSS concentrations (poor water clarity) during floods and high flow conditions reflecting the erosion of sediments from the catchment. Much of this material is deposited in the estuary as flows subside. • Recommended management actions included: reducing nutrient export through STP management; reduce acid and oxygen poor water by reducing ponding on cane land, introducing wet pasture management and reinstating back swamp flood reserves.
TSC water quality review and improvement program	*Tweed River and Catchment Interim Water Quality Management Plan* (WBM Oceanics, 2000) collated and reviewed existing data and proposed management and further investigations.	Key water quality problems for the Tweed River are: • Lower estuary – High bacterial levels; acid sulfate soils • Mid estuary - Elevated nutrient and algal levels; potential for Cyanobacterial (Blue green algae) blooms; acid sulfate soils • Upper estuary - Elevated nutrient and algal levels
Lower Tweed River estuary water quality data 1997-98	*Water Quality in the Lower Tweed Estuary System* (KEC Science, 1998) provided a detailed analysis of water quality data collected over a 12-month period.	• Primary contact guidelines were met • Nutrient levels approached or exceeded guidelines but algal growth was not excessive. • Suspended solids exceeded guidelines and catchment erosion was identified as the primary source. • Stormwater had a significant impact accounting for 70-90% of the variation in water quality.
Water quality Monitoring in Rous River 1997	*A Spatially Intensive Approach to Water Quality Monitoring in the Rous River Catchment* (Eyre and Pepperell (1997)	• Three point sources the Murwillumbah STP, a dairy shed and horse stables had the largest impact on water quality in the Rous River catchment. • The poorest water quality due to non-point source inputs was associated with cane land, which had elevated nutrient concentrations and elevated temperatures, stimulating algal growth, resulting in high turbidity. • High oxidised N was associated with bananas which was attributed to use of N-fertilisers. • Elevated faecal coliforms concentrations across the catchment were attributed to direct cattle access to waterways.
EPA Investigations	*The Northern Rivers – A Water Quality Assessment* (EPA, 1996)	• In the estuarine sections, eighty percent of the sites were ranked Poor or Very Poor. The main reason for failure was suspended solids concentrations (56%), with some other failures caused by low pH, high nutrient concentrations, low dissolved oxygen and high faecal coliform levels.

5.3 Estuarine Vegetation

Estuarine vegetation refers to seagrass, mangrove and saltmarsh plant communities within the Tweed River estuary study area. Seagrass occurs in the intertidal or sub-tidal (marine) zone and is generally covered with water except during very low tides, mangroves occur in the intertidal zone between low and high tide and saltmarsh communities occur mostly behind mangroves in the upper limits of the intertidal zone and are only inundated briefly on high tides (Figure 29). In an estuary, riparian vegetation is vegetation above the high tide level and generally does not include estuarine vegetation.

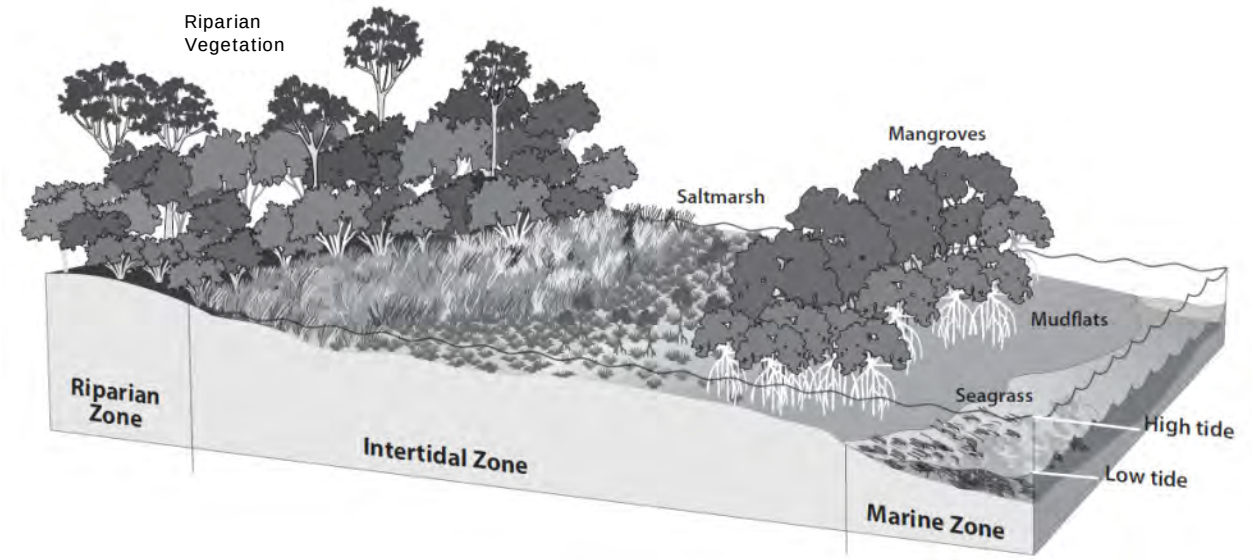

Figure 29: Zonation of estuarine vegetation

Source: OEH (2014d)

Estuarine vegetation performs a number of important ecosystem functions. Saltmarsh, mangrove and seagrass habitats are essential nursery areas for many species of commercially and recreationally important fish and crustaceans and the food they eat, contributing large amounts of organic material to the ecosystem (Hannan & Williams, 1998). Depending on their type and location, estuarine vegetation reduces the effects of erosion due to waves or currents and helps trap sediments. Saltmarsh and mangroves also act as a buffer from urban areas and a filtration system for sediment and nutrients entering the waterway from the terrestrial environment (Russel, 2005).

Natural events such as floods, storms and sea level changes have impacted on seagrass, mangrove and saltmarsh in the Tweed River estuary. Human actions such as construction of infrastructure (e.g. roads, walkways, buildings etc.), actions to exacerbate bank erosion, poor water quality and direct disturbance from vehicles, watercraft and humans can also influence the distribution, abundance and condition of estuarine vegetation.

5.3.1 Seagrass

Seagrass forms a critical part of estuarine and marine ecosystems playing a major role in fishery production and sediment accumulation and stabilisation (Short *et al.*, 2007). Highly productive seagrass ecosystems have a relatively complex physical structure, providing a combination of food and shelter that enables high biomass and productivity of commercially important fish species (Beck *et al.*, 2001).

In the past, a number of seagrass species have been recorded in the Tweed River estuary including *Zostera capricorni, Halophila ovalis* and *Halophila ovata* (PWD 1990; PWD 1991). Areas of *Halophila* were recorded by PWD (1991) in Wommin Lagoon, Wommin Lake, Kerosene Inlet, Ukerebagh passage and Terranora Inlet. Generally the dominant species was *Z. capricorni* with the exception being Wommin Lake where

extensive areas of *H. ovalis* were recorded and the absence of *Z. capricorni*. PWD (1991) noted that areas where *Z. capricorni* and *H. ovalis* occurred as a mixed community were subject to greater tidal and wave action than areas where only *H. ovalis* occurred. *H. ovalis* has also been recorded more recently in Kerosene Inlet by Australian Wetlands (2010).

Historic Seagrass Distribution

Seagrass growth and distribution is influenced by a multitude of factors. As evident across the Northern Rivers region, one of the major factors effecting seagrass growth is weather events which exhibit a range of growth limiting mechanisms. Wet season events bring increased turbidity (reduction in light), scouring through strong currents and sedimentation (smothering of seagrass beds). These high rainfall events generally occur in the summer months reducing seagrass growth and distribution. In winter, cold water temperatures are common which can lead to a reduction in productivity causing winter die back of seagrass. Anthropogenic impacts such as dredging, land reclamation, built structures and smaller scale impacts such as trampling also influence seagrass growth at various scales based on the nature of impact.

Changes in seagrass distribution across the lower estuary (downstream of Barneys Point, including Terranora Inlet) were determined by PWD (1991) using aerial photographs from 1930, 1947, 1976 and 1991. A significant decline in seagrass area was recorded across those years, particularly between 1947 and 1976 (Table 10). PWD (1991) attributed the large loss of seagrass to a combination of extensive dredging, extensive catchment development and the impact from the significant 1974 floods. Seagrass appeared to partially recover with an increase in area between 1976 and 1991.

Table 10: Changes in seagrass cover within the lower estuary 1930-1991 (PWD, 1991)

Year	Seagrass Cover (ha)	% Change from previous year mapped
1930	200	-
1947	160	-20
1976	40	-75
1991	67	+67

More recently, Hossain (2005) assessed changes in seagrass distribution within the lower Tweed River estuary including Terranora Inlet. Mapping of seagrass areas from aerial photography indicated that seagrass areas within the study area increased by 8% between 1997 and 2001. Within Ukerebagh Channel in particular, seagrass extent increased by 27% between 1997 and 2001.

In a comparable study Pacific Wetlands (2012) examined changes in estuarine vegetation, including seagrass, within Terranora Inlet and a small area of the lower Tweed River estuary between 2000 and 2012. Results from this study found that seagrass areas within a fluvial channel environment in the Tweed River and the tidal channel of Lower Terranora Inlet increased by 61% and 14%, respectively between years 2000 and 2012. They found that overall, seagrass increased by 20% across the entire study area. This increase in seagrass extent across the lower estuary was attributed to stable conditions in the estuary, following several years of reduced rainfall and storminess.

Results from a number of studies indicate that seagrass distribution within the lower Tweed River estuary appears to have fluctuated over time but has seen a general increasing trend since the late 1970's. WBM (1992) determined changes in distribution of seagrass in the upper estuary (Barneys Point to Stotts Island) using 1954 and 1989 aerial photography. The only seagrass recorded from the 1989 photo was a large meadow (8-9 ha) in Chinderah Bay. This report noted that the only obvious change in seagrass distribution between 1954 and 1989 was a loss of approximately 3 to 4 ha of patchy seagrass at the entrance of the Tweed Broadwater.

Historic Seagrass health

There are a number of indicators often used for the assessment of seagrass health including seagrass blade length, density and epiphytic algae density.

Australian Wetlands (2010) assessed seagrass health within Kerosene Inlet in 2009 and found that the average height was 20.3cm, with a substantial coverage of epiphytes at 31.5%, however the overall extent of seagrass cover was relatively high at 98%. Several potential reasons for the high epiphytic algae growth were raised including a combination of high nutrient input from the Tweed River and poor tidal flushing of the inlet and potentially low numbers of macro/micro invertebrate grazers that actively feed on the epiphytic growth attached to seagrasses.

Australian Wetlands (2014) assessed seagrass health further up the Tweed River estuary at Oxley Cove Peninsula and Dodds Island channel. *Z. capricorni* was the only seagrass species observed. Results from the study indicated that the sites supported well established seagrass beds with densities ranging from 29-70% cover recorded within quadrats. Epiphytic algae cover was relatively high with densities recorded ranging from 78-90%. Australian Wetlands Consulting (2014) suggested that the high levels of epiphytic algae cover is most likely directly related to elevated nutrient levels within the estuary.

5.3.2 Mangroves

Mangrove communities can comprise several species that inhabit the intertidal shores of sheltered sub-tropical and tropical waterways. Mangroves are adapted to saltwater, anoxic and sulfidic environments exhibiting several adaptations which allow them to thrive in such environments. They provide many ecosystem services to the estuarine system including:

- Trapping sediments both reducing turbidity and buffering the shoreline against erosion;
- Providing habitat for both terrestrial and aquatic species;
- Providing nursery areas for juvenile aquatic species;
- Providing food and habitat for terrestrial birds and important roosting sites for migrating shorebirds; and
- Filtering surface runoff of nutrients and pollutants.

Five species of mangrove were recorded within the Tweed River estuary including (PWD, 1991; WBM, 1992b): Grey Mangrove (*Avicennia marina*); River Mangrove (*Aegiceras corniculatum*); Orange Mangrove (*Bruguiera gymnorhiza*); Milky Mangrove (*Excoecaria agallocha*); And Red Mangrove (*Rhizophora stylosa*).The Tweed River is the only estuary in NSW where all five species have been recorded. *A. marina* and *A corniculatum* are the most numerous widespread species distributed along the entire length of the estuary (WBM, 1992b).

TSC (undated) notes, in addition to the above, two additional species of mangroves present within the Tweed River estuary including the mangrove fern (*Acrostichum speciosum*) and the yellow mangrove (*Ceriops tagal*).

Historic Mangrove Distribution

Mangrove distribution can be influenced locally by a range of factors including: clearing for development; trampling of pneumatophores and seedlings; restriction of extent due to hard structures such as retaining walls and roads; major storms; pollution, in particular heavy metals and petrochemicals, causing dieback; and changes in sediment dynamics (i.e. a newly formed sand/mud bank maybe colonised by mangroves).

Russell (2005) analysed estuarine habitat mapping data from estuaries across the northern rivers including the Tweed River estuary. Estuarine vegetation (mangroves, seagrass, saltmarsh) was mapped using aerial photographs from the 1940's to 2000. The aim of the project was to determine, using aerial photo interpretation, the extent of changes over time in seagrass, mangrove and saltmarsh habitats in the estuaries

within the Northern Rivers. This study made a number of observations/findings with regards to mangrove distribution within the Tweed River estuary (including Terranora Inlet and the broadwaters) including:

- Mangrove areas in the Tweed River increased by 75.6% between the 1940's and 2000.
- Approximately 34% of the mangrove area occurring in 2000 had been stable mangrove habitat since 1947. Significant areas of stable mangroves include Ukerebagh, Wommin, Big and Tonys Islands and in the Cobaki Broadwater.
- Losses of mangroves generally occurred from Greenbank Island, the Tweed and Terranora Broadwaters and around Boyds Bay, however these were matched or exceeded by increases in areas of mangroves in other areas.
- Upstream and upslope migration of mangroves was noted as occurring within the broadwaters, around Stotts Island and Tumbulgum. The expansion of mangrove communities was attributed to increased sedimentation due to catchment landuse and increased tidal amplitude within the estuary due to construction of training walls and various dredging campaigns.

As a part of the TRESBP an estuarine vegetation monitoring program was undertaken (Pacific Wetlands, 2012). The study mapped estuarine vegetation within the lower Tweed River estuary including mangroves over a number of years. The lower estuary was divided into four geomorphic settings: the Cobaki Broadwater; Fluvial Channel; Terranora Broadwater; and Terranora Tidal Channel (Figure 30). Estuarine vegetation was mapped across years 2000, 2002, 2003, 2005, 2007, 2010 and 2012. The mangrove area recorded in each year across the sites is presented in Table 11. The largest increase in mangrove area, 25.1%, occurred within the Fluvial Channel site with an average of 11.7% across all sites which is equivalent to an average increase of 0.97% per year. This increase was attributed to estuarine sedimentation and elevated water levels and is common in most estuaries within the region (Pacific Wetlands, 2012).

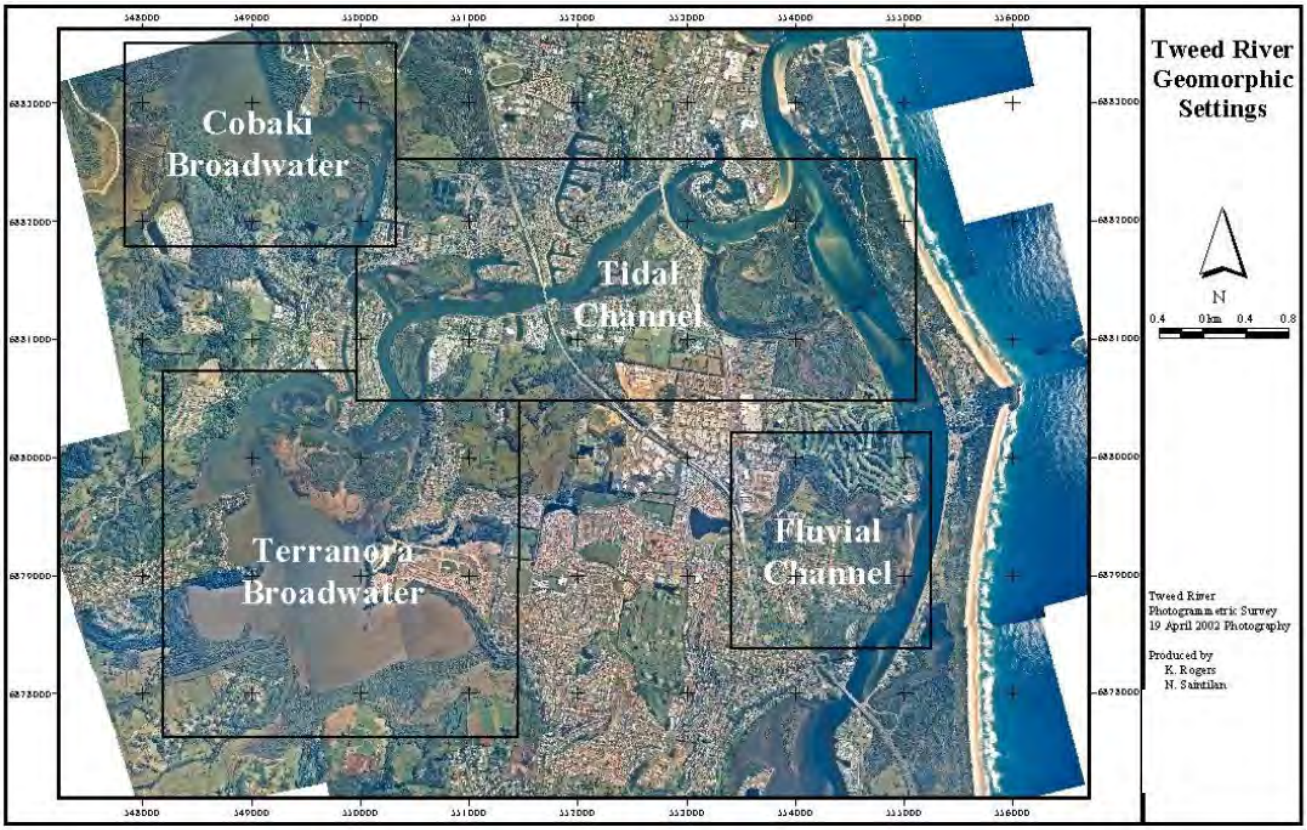

Figure 30: Sites used in Pacific Wetlands (2012) estuarine vegetation monitoring mapping

Table 11: Mangrove area mapped within the Lower Tweed River estuary in Pacific Wetlands 2012

Date	Mangrove Area (ha)	
	Fluvial Channel	Tidal Channel
May 2000	20.62	110.26
April 2002	22.78	111.16
June 2003	23.05	144.02
March 2005	23.82	110.67
June 2007	24.23	159.39
April 2010	24.81	113.92
April 2012	25.78	114.70

The results from the Pacific Wetlands (2012) study reflect the same general trend of increasing mangrove area as an earlier study conducted in the Tweed River by Saintilan (1998). However, Saintilan (1998) recorded even larger increases is mangrove area of 80% (Fluvial Channel) and 73% (Tidal Channel) between 1930 and 1994 (Table 12). It was noted that the majority of the increase had been due to the seaward extension of the seaward edges of mangrove forests although landward incursions, including into wetland/saltmarsh areas were evident at several locations. In addition, Wilton (2002) found from analysing aerial photographs of Ukerebagh Island dating from 1948 to 1998, a trend of mangrove encroachment on saltmarsh between 1961 and 1998, with saltmarsh declining by 20% and mangrove increasing extent by 20% over the same period.

Table 12: Mangrove area mapped within the Lower Tweed River estuary in Saintilan (1998)

Date	Mangrove Area (ha)	
	Fluvial Channel	Tidal Channel
1930	51.19	44.33
1948	62.93	69.48
1962	68.86	82.17
1971	67.41	81.41
1985	87.71	79.80
1994	92.03	77.65

Rogers *et al.* (2014) undertook a specialised study within the Tweed River where they considered the response of mangrove and saltmarsh in the Tweed River estuary (also at Ukerebagh Island) to changes in environmental variables over a 12 year period (2000-2012) by comparing rates of surface elevation change and vegetation distribution dynamics to hydrological and climatic variables, specifically water level and rainfall. This period of analysis captured inter-annual variability in sea level and rainfall associated with different phases of the El Nino Southern Oscillation (ENSO). The study reported a number of findings including:

- The seaward mangrove boundary remained relatively stable over this period; however the north-western salt marsh area of Ukerebagh Island diminished in extent due to both mangrove expansion and conversion to mudflat by the loss of salt marsh vegetation. Salt marsh area decreased by approximately 2 ha by displacement with mangrove (1 ha) and mudflats (1 ha).
- Mangrove elevation increased at a rate of 1.40 mm/year.

- Mangrove elevation trends at Ukerebagh Island are largely controlled by position within the tidal prism, which was defined by inundation depth, time and distance from the primary channel delivering tidal flows. Other external climatic variables, such as rainfall, acted as drivers of mangrove elevation variability.
- Rates of surface elevation increase were found to lag behind rates of water level change within the Tweed River, which may facilitate further expansion of mangrove into salt marsh.

Mangrove expansion into salt marsh is a trend that is receiving wider global recognition with expansion of mangrove into salt marsh increasingly observed (Saintilan *et al.*, 2014).

5.3.3 Saltmarsh

Coastal saltmarsh is an inter-tidal community of plants such as sedges, rushes, reeds, grasses, succulent herbs and low shrubs that can tolerate high soil salinity and occasional inundation with saltwater (DPI, 2013). Saltmarsh communities inhabit sheltered, soft substrate foreshores of coastal lakes and estuaries. They often occur behind mangroves in the upper limits of the inter-tidal zone and are only inundated briefly on high tides often to the extent of the highest astronomical tide (DECC, 2007b). Distribution of coastal saltmarsh is influenced by the combination of elevation, salinity and frequency of inundation (DPI, 2013).

Saltmarsh communities are comprised of low growing hyper-saline adapted plant species and are often zoned within the community according to tide levels and frequency of inundation and subsequently salinity levels. Dominant species that are indicative of a saltmarsh community in NSW include Samphire (*Sarcocornia quinqueflora*) at the lower more frequently inundated levels, Saltwater Couch (*Sporobolus virginicus*) dominating the mid-level saltmarsh and Sea Rush (*Juncus kraussii*) which is usually dominating the drier plant communities at higher elevations (DPI, 2013). However, with over 200 plant species known to occur in Coastal Saltmarsh environments there are a number of possible combinations of plant species.

Saltmarsh communities provide important ecosystem services, including:

- Providing food and habitat for not only aquatic animals (when inundated at high tide) but also for terrestrial animals such as shorebirds when exposed at low tide;
- Providing basic inputs of carbon to estuaries in the form of dead leaves and branches which becomes part of the food chain when broken down and dispersed by tidal currents. Material can be taken in by filter feeders such as mussels and oysters and surface feeders such as crabs and mullet (Valiela *et al.*, 1978);
- Filtering surface runoff water of nutrients and sediments before it enters coastal waters; and
- Providing vegetative cover along estuary banks which traps sediment and helps minimise erosion.

Saltmarsh distribution and condition can be influenced locally by a range of factors including:

- Clearing for development;
- Physical disturbance (e.g. trampling, vehicle access etc.);
- Reclamation and drainage activities;
- Stormwater runoff;
- Weed invasion;
- Encroachment by other vegetation such as mangroves; and
- The combination of sea level rise and barriers to upslope migration restricting suitable habitat areas for saltmarsh (refer Section 5.3.4).

Within NSW, saltmarsh area is contracting, with losses of between 12% and 97% (NSW DPI, undated (b)). Coastal Saltmarsh is currently recognised as being at very high risk of extinction in NSW and is classified as an Endangered Ecological Community (EEC) under the TSC Act.

Historical Saltmarsh distribution

Numerous studies have been undertaken on the distribution of saltmarsh in the Tweed River estuary and are summarised below. Saltmarsh distribution within the Tweed River estuary has fluctuated overtime. The general historical trend appears to be an increase of saltmarsh area from the 1930-40's to 1970- early 80's, a decrease to the early 1990's then increasing again to year 2000 (Saintilan, 1998; Russell, 2005). Saltmarsh areas then decreased again between 2000 and 2012 (Pacific Wetlands, 2012; Rogers *et al.* 2014).

PWD (1991) recorded 21 ha of saltmarsh occurred within the Tweed River with Ukerebagh Island, Cobaki Creek and Sponsors lagoon supporting the largest areas with numerous other smaller areas throughout the estuary.

Saintilan (1998) mapped saltmarsh distribution in the lower Tweed River estuary from aerial photographs dating from 1930 to 1994. Saintilan (1998) found that generally saltmarsh increased in the lower Tweed River estuary from the period 1930-1971. However, saltmarsh extent decreased across the period 1971-1994, with 1994 distribution similar to that of 1930, primarily as a result of:

- Reclamation for urban development;
- Dune instability leading to smothering of saltmarsh (Ukerebagh Island, kerosene Inlet, Greenbank Island) and;
- Mangrove transgression into saltmarsh areas.

Wilton (2002) mapped the distribution of saltmarsh at Ukerebagh Island using aerial photography from 1948 to 1998. Results from the study generally reflected the patterns seen throughout the estuary except for the decrease between 1983 and 1998.

Table 13: Changes in saltmarsh distribution at Ukerebagh Island between 1948-1998 (Wilton, 2002)

Year	Change in saltmarsh area
1948-1961	+4%
1961-1971	-10%
1971-1983	+6%
1983-1998	-16%
Total	-17%

Russell (2005) mapped saltmarsh distribution throughout the Tweed River estuary using aerial photography from the 1940's to year 2000. Findings from the study with relation to saltmarsh include:

- The net area of saltmarsh communities remained relatively stable between 1940 and 1980, dropping dramatically in the 1990s and then significantly increasing in the 2000 data (Figure 31);
- Only 6.4 ha of the 2000 area of saltmarsh (76.3 ha) or 8.3% is stable habitat from 1947, suggesting the need for buffers around these habitats to enable accommodation of the communities of stochastic and gradual changes occurring within estuaries.

As mentioned in Section 5.3.2, Pacific Wetlands (2012) undertook mapping of estuarine vegetation in the lower Tweed River estuary which included mapping of saltmarsh distribution. Areas recorded within the Fluvial Channel and Tidal Channel sites during the mapping exercise are presented in Table 14. Across the entire lower Tweed River estuary saltmarsh area decreased by 25.93%, in particular 38.89% within the

Fluvial Channel site and 18.06% within the Tidal Channel site, which was considered to be consistent with historic trends.

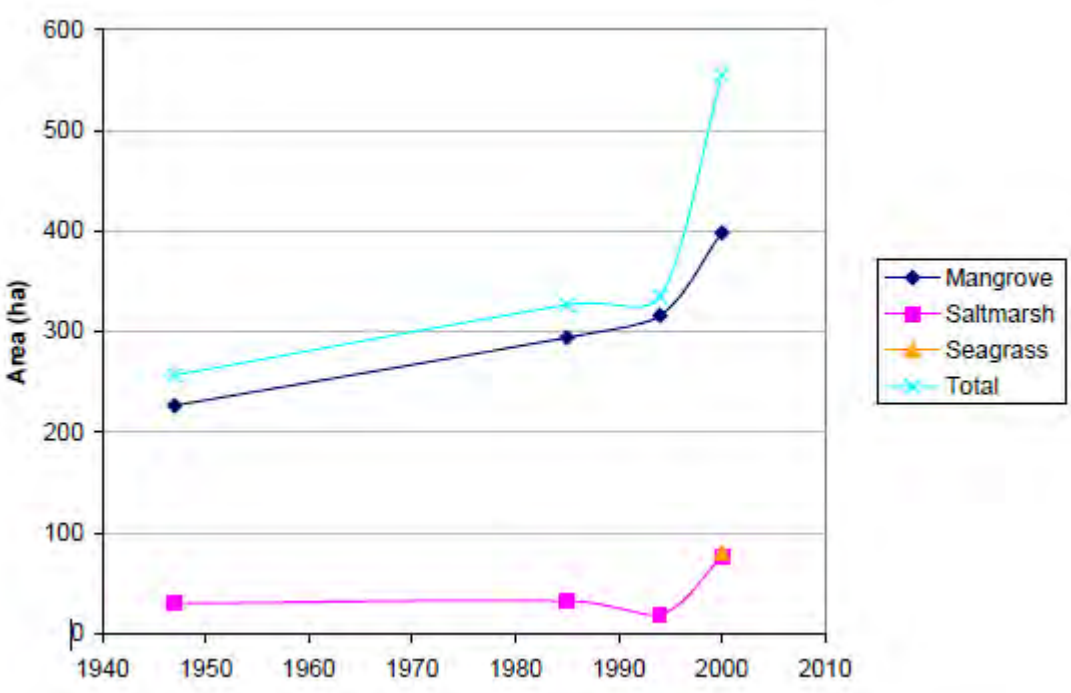

Figure 31: Changes in estuarine vegetation within the Tweed River estuary (including Terranora Inlet) between the 1940's and year 2000 (Russell, 2005)

Table 14: Saltmarsh area mapped within the Lower Tweed River estuary in Pacific Wetlands 2012

Date	Saltmarsh Area (ha)	
	Fluvial Channel	Tidal Channel
May 2000	1.80	17.04
April 2002	1.76	16.90
June 2003	1.76	16.90
March 2005	1.66	16.62
June 2007	1.66	16.61
April 2010	1.54	15.14
April 2012	1.10	13.87

Rogers *et al.* (2014) used aerial photography to map and determine changes in saltmarsh distribution around Ukerebagh Island from years 2000-2012. Results from this study were similar to Saintilan (1998) indicating that mangroves were expanding into saltmarsh habitat resulting in the loss of salt marsh vegetation and the development of un-vegetated mudflats between mangrove and salt marsh on Ukerebagh Island.

5.3.4 Impacts on Estuarine Vegetation due to Sea level rise

Sea level rise (refer Section 6.2) is expected to increase the average water depth and extend tidal propagation in the Tweed River estuary with associated changes in salinity regime. It is anticipated that sea level rise will result in the landward recession of fringing estuarine wetland systems. The location of estuarine habitats such as mangrove stands and saltmarsh are controlled principally by tidal range and salinity influence and will gradually respond to changes in increases in average water levels and salinity.

There is a risk that natural upslope migration of these wetlands will be curtailed by anthropogenic constraints such as roads, rock walls, retaining walls and urban development on the landward side (DECC, 2009). This impact has been named “Coastal Squeeze” by the Department of Climate Change (now OEH, DECC, 2009) (refer Figure 32 below). Under these conditions the landward side of these important habitats will be fixed but the lower margin will gradually be pared away, leading to a loss of habitat area.

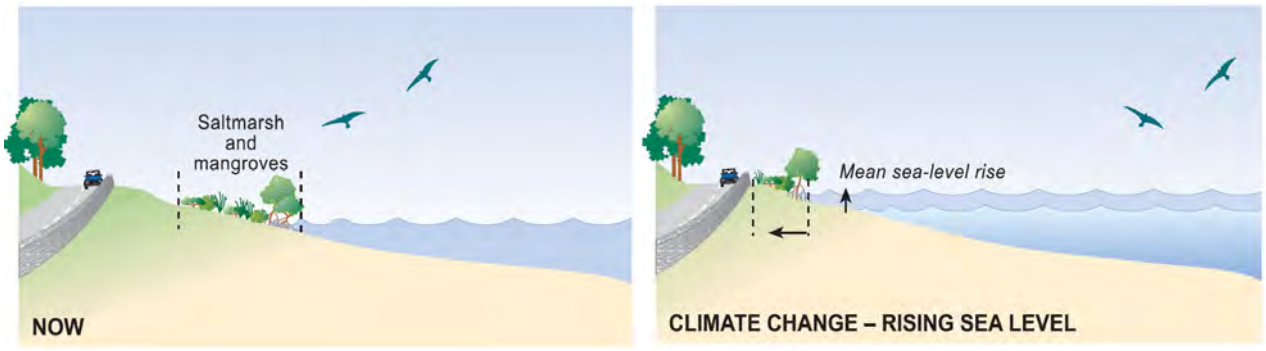

Figure 32: ‘Coastal squeeze’ under sea level rise: impact of development. (Source: DECC, 2009)

5.4 Riparian vegetation

Riparian zone functions include fisheries habitat, terrestrial habitat, fauna corridors, bank stability and maintenance of soil structural integrity, land use buffering, water quality filtering, lowering water temperature and reducing aquatic weeds as well as providing scenic amenity. Riparian zones can also offer resilience to climate change by creating a buffer for development and providing space for migration of vegetation communities with changes in water level.

With regard to the Tweed and Brunswick catchments Lampert *et al.* (1999) found the tidal reaches to have been significantly impacted through loss of riparian vegetation. Immediately upstream of the tidal reach, the ‘meandering fine grained’ Riverstyle of both the Tweed and Richmond were found to exhibit bank erosion and poor bed structure (Lampert *et al.*, 1999).

Figure 34 indicates that the vast majority of riparian vegetation within the study area is highly modified/disturbed, particularly in the mid-upper estuary. Small remnants of native riparian exist on Stotts Island, around the Tweed Broadwater, Ukerebagh Island and Letitia Spit. WBM (1992b) notes that little of the original native vegetation remains along the estuary. Timber cutting and sugar cane cultivation in the mid and late 1800’s, respectively, led to the alteration and clearing of the majority of native vegetation around the estuary (WBM (1992b). Results from the TSC (2014) *Tweed River Bank Erosion Management Plan 2014* also reflect the lack of riparian vegetation along the estuary. As a part of the plan, a total bank length of 15,863 m comprising an area of 181,099 m² was identified as potentially suitable for revegetation. A number of priority sites in the upper estuary were identified for riparian revegetation and bioengineering to restore riparian vegetation and manage erosion Figure 33.

Further assessment of riparian vegetation along the entire length of the estuary is required to establish the current extent and condition of riparian vegetation and identify prioritise suitable riparian vegetation management sites.

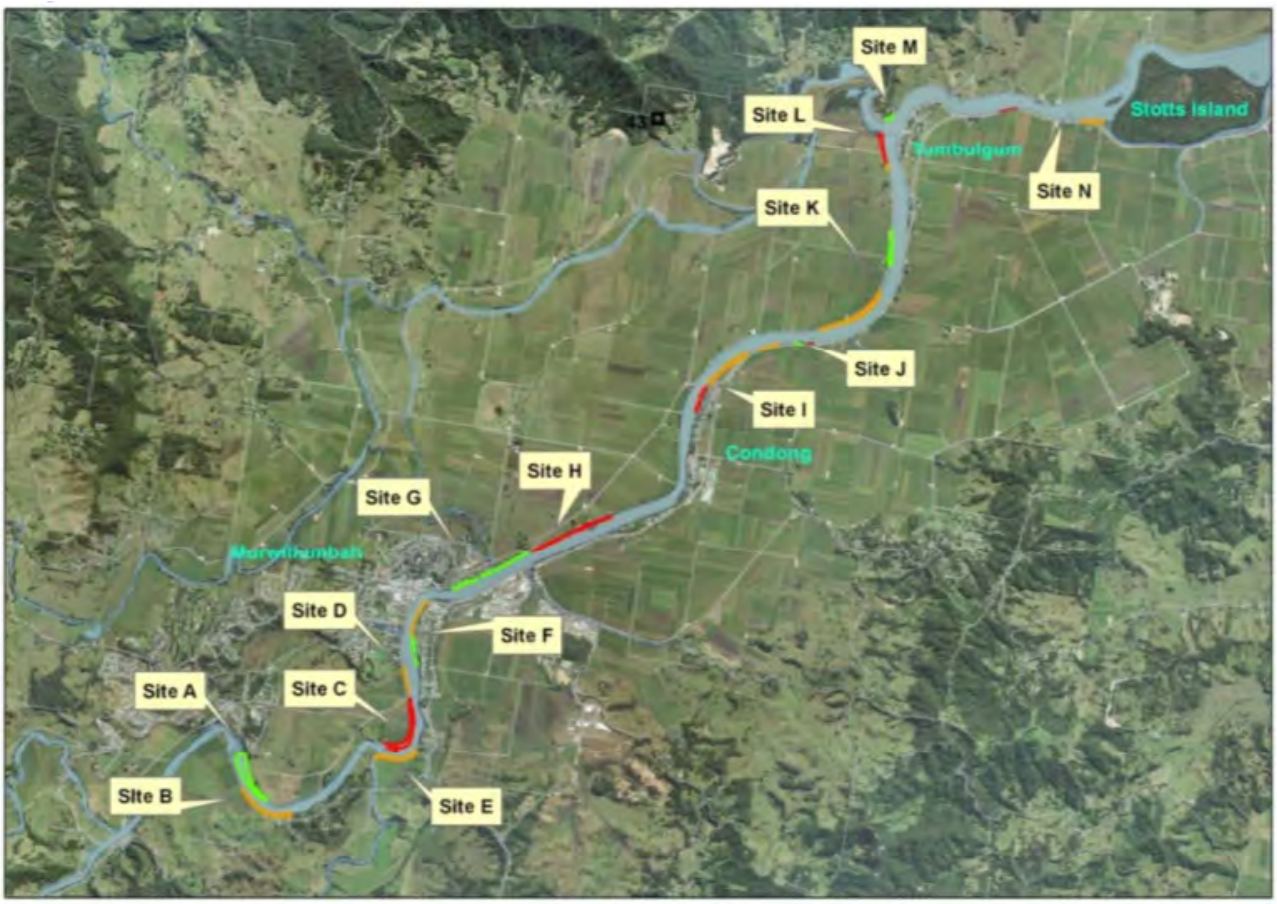

Figure 33: Riparian revegetation and bioengineering sites identified in TSC (2014b)

Tweed River estuary Riparian Restoration Project (ALA, 2016)

The project involves revegetation of riparian vegetation at Tygalgah, on the north side of the upper Tweed River estuary. The site is one of the largest potential revegetation areas on the Tweed River estuary, and will involve establishing a protective buffer adjacent to existing mangroves by planting 4,550 tubestock plants. Grant funds will be used to prepare site, purchase and install plants and undertake maintenance over the project period. On-going maintenance will be undertaken by Council's Waterways Program. The project will achieve restoration of lowland rainforest, an endangered ecological community, and will enhance fish and aquatic habitat by restoring highly degraded riparian vegetation.

Green Banks Project

To address a range of environmental issues associated with floodplain drains including ASS management, bank slumping, weeds and sediment runoff Council's Sustainable Agriculture Program has undertaken the Green Banks project since 2006 to establish locally native floodplain vegetation along drain banks. The project involved collaboration between, Council, other agencies, landholders, nurseries and private bush regenerators. Including areas outside the study area, over 28 km of drain banks have been planted with >70,000 groundcover plants, >3500 trees and involving over 30 landholders (TSC, undated).

5.5 Terrestrial Vegetation

The *Tweed Vegetation Management Strategy* (Kingston *et al.*, 2004) provides a coordinated approach to the management of vegetation in the Tweed Shire and is summarised in Appendix 1:

Terrestrial vegetation refers to all non-aquatic and non-estuarine plant species occurring within the Tweed River estuary study area (refer Figure 29). This includes riparian vegetation which is located adjacent to the

Bay, above the high tide level. Healthy terrestrial vegetation communities in the catchment are important for maintaining general biodiversity, aesthetic value and improving runoff water quality to the estuary.

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

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

Vegetation mapping of the Tweed Shire was undertaken in 2009 and major vegetation types within the study are mapped in Figure 34. In general, the distribution of vegetation throughout the study area is patchy and fragmented. The most dominant vegetation type (covering approximately 78%) throughout the study area is highly modified/disturbed major vegetation type which is evident throughout the entire study area, particularly across the floodplain. The Melaleuca and swamp she-oak forests, riparian and rainforest communities on and around Stotts Island in the mid estuary floodplain are an exception. This area of vegetation is protected within the Stotts Island Nature Reserve and is discussed in Section 3.5.5. There is also a small area of these communities situated within the lower Rous River catchment. The less disturbed, steeper, higher elevation areas of the upper study area are dominated by Sclerophyll open forests.

A number of vegetation types surround the Tweed Broadwater at Terranora including estuarine vegetation, sclerophyll open forests and rainforest and riparian communities. In the lower estuary a significant area of native vegetation is locate on and around Ukerebagh Island including estuarine vegetation, Melaleuca and Swamp She-oak forests and Sclerophyll Forests/woodlands. Considerable areas of Melaleuca and Swamp She-oak Forest lie to the west and north-west of Kingscliff.

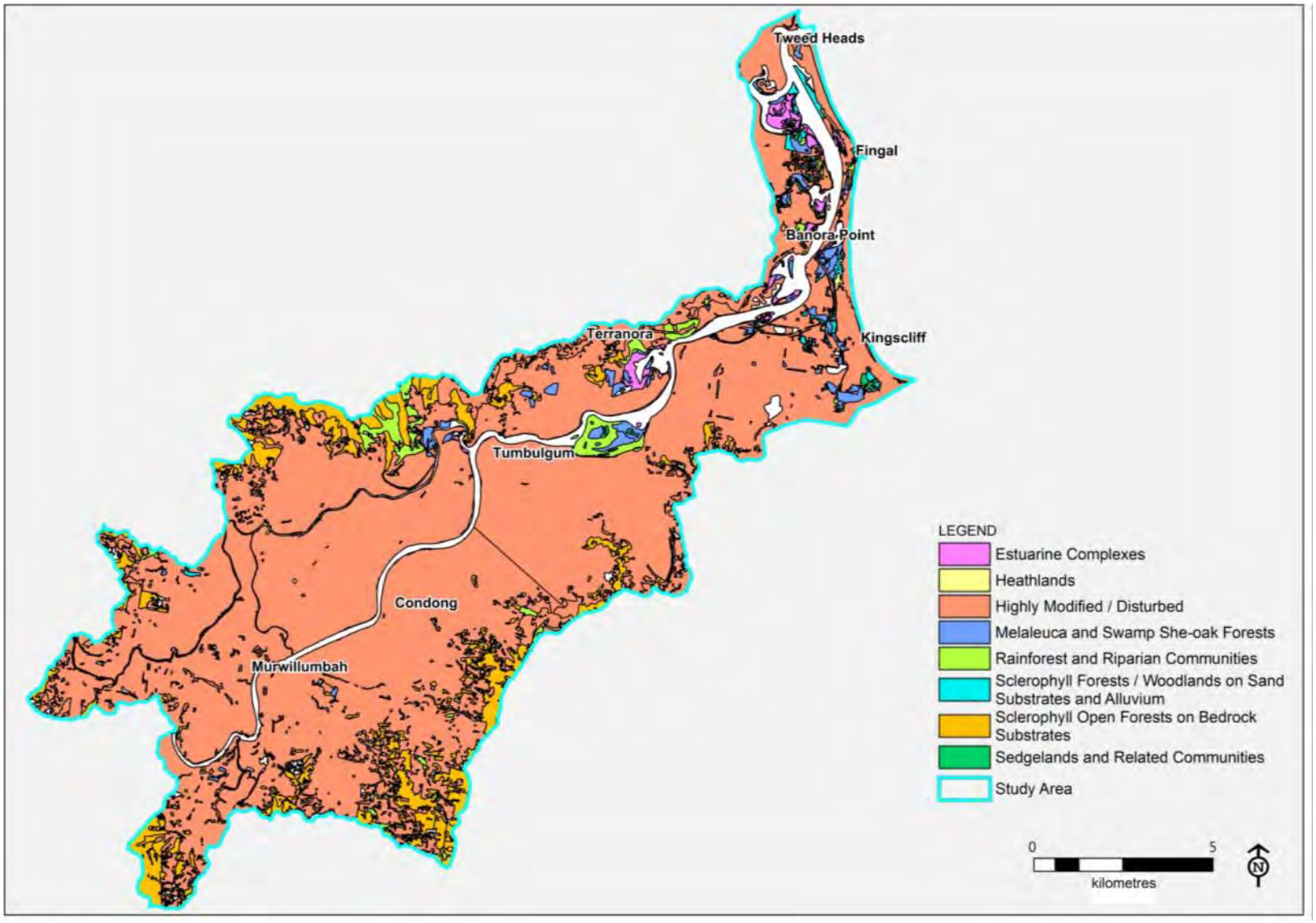

Figure 34: Major vegetation communities throughout the study area Source: TSC Mapping

5.5.1 Weeds

A large number of Declared Noxious and Serious Environmental Weeds have been recorded within the Tweed Shire including the study area (Ecograph, 2004).

Upper catchment riparian weed mapping

Ecosure (2009) undertook an aerial survey and extent mapping of riparian vine weeds in the Upper Tweed River Catchment, upstream of Bray Park Weir. The target species of the survey were Cats Claw Creeper (*Macfadyena unguis-cati*) and Madeira Vine (*Anredera cordifolia*). Approximately 521 ha and 172 isolated infestations of the target weeds were identified and mapped within riparian zones. The strategic removal of the weeds starting from the most upstream location was recommended. As both target weeds predominantly grow in the riparian zone and seed and tuber dispersal is predominantly via the waterways, this approach will reduce the likelihood of the weeds reinfesting work areas by the transportation of seeds from upstream populations. Although this survey was undertaken outside the study area, the presence of these species in the upper catchment and nature of their dispersal mechanisms indicates a potential presence in the riparian zones of the estuary.

Bitou Bush control (TSC, 2016c)

The project has been undertaken in two stages. The first stage involved reducing the density and extent of Bitou Bush from the northern 10 km of the Tweed coastline. This project was funded by the NSW Environmental Trust and the Northern Rivers Catchment Management Authority and was supported by Tweed Shire Council. Within the study area if this project, areas targeted included the Fingal Head Peninsula, Ukerebagh Island Nature Reserve and areas north of the Tweed River. The second stage of the project involves an expansion of the NNCZ project area to include the entire Tweed coastline and hinterland. Whilst on-ground Bitou Bush control is being coordinated by the bush regeneration contractor Bushland Restoration Services, the project relies on considerable support and in-kind contribution from numerous project partners including Tweed Shire Council, Far North Coast Weeds, the Tweed Byron Local Aboriginal Land Council, Dune and Coast Care groups at Fingal Head, Kingscliff, Casuarina, Cabarita Beach, Hastings Point and Pottsville and the National Parks and Wildlife Service.

5.6 Aquatic Fauna

The Tweed River estuary supports a large range of estuarine and marine aquatic fauna including macroinvertebrates, fish, reptiles and marine mammals.

5.6.1 Fish

Fish species within the Tweed River estuary are a diverse mixture of tropical and temperate, marine and estuarine form (PWD, 1991). PWD (1990) concluded that the lower Tweed River estuary supported 149 species of fish. PWD (1991) undertook a several netting surveys over several seasons to characterise fish species present across sandy substrates within the lower Tweed River estuary. A total of 30 species were recorded during the survey with mullet, whiting, bream, herring and perchlets were the most dominant species recorded. A search of the Bionet Atlas of NSW Wildlife and Atlas of Living Australia revealed the records of 37 additional fish species. The number of species recorded from these sources is not comprehensive but provides an indication of the diversity of fish species recorded within the study area from the marine dominated lower estuary to the freshwater reaches of the estuary tributaries. It is this diversity of fish species that support commercial and recreational fisheries in the Tweed River estuary (See Sections 4.4.1and 4.2.2, respectively).

Fisheries NSW (2016) undertook an analysis of all available fish community data across NSW waterways, including the Tweed River. Using the data, the condition fish communities in waterways across the State

were classified as either Very Good, Good, Fair, Poor or Very Poor. The study considered the fish communities of all waterways within the study area to be in fair condition (Figure 35).

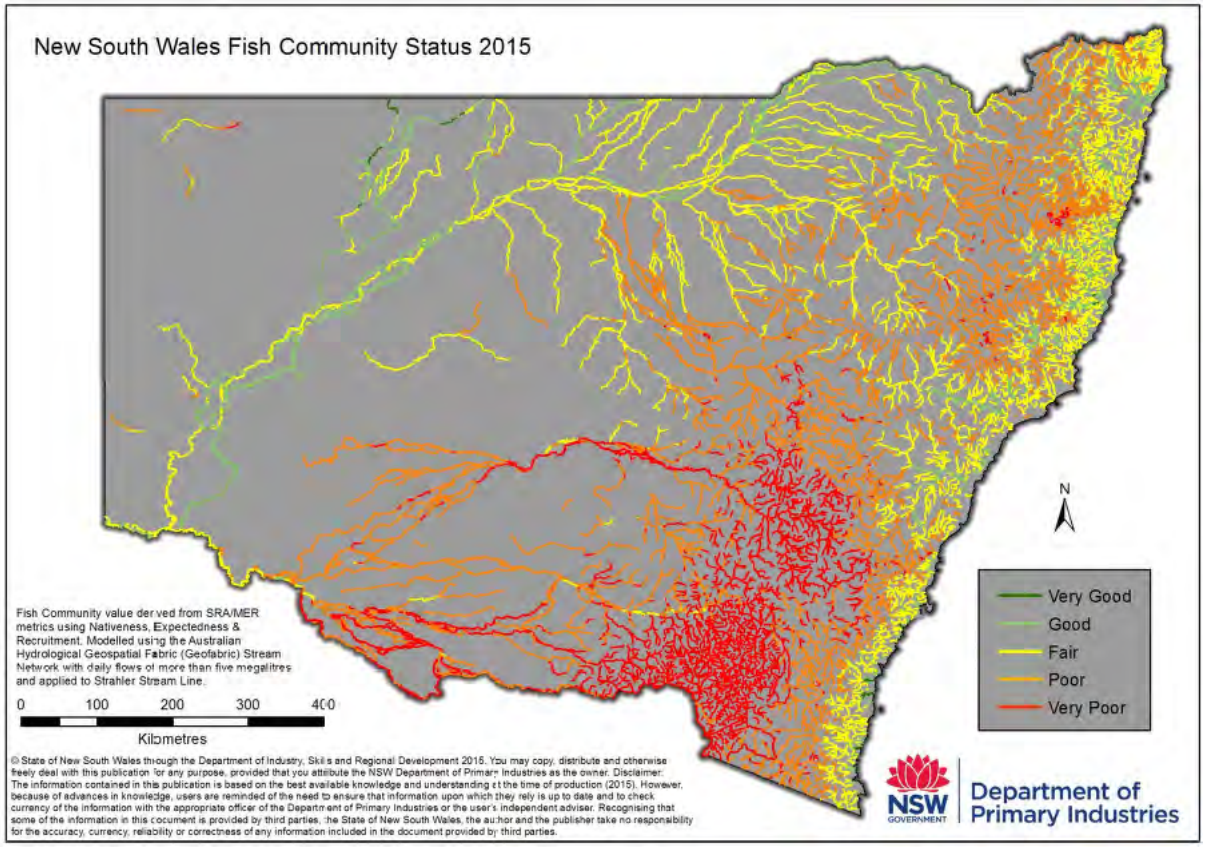

Figure 35: Status of fish communities within NSW. Source: Fisheries NSW (2016)

Estuarine Fish kills

Fish kills are sudden and unexpected mass mortality of wild fish. Estuarine fish kills are fish kills that occur within or within a part of an estuary. Within NSW, estuarine fish kills contribute to approximately 45% of all fish kills (NSW DPI, undated). Fish kills have been recorded in a number of Northern River estuaries, particularly the Richmond River, but also the Tweed River.

Generally, fish kills can occur at any time, however, data indicate that fish kills are more likely to occur in summer during the months of January and February (NSW DPI, undated). . Fish kills are generally associated with water quality changes, pollution, infection, associated directly with human activities or a combination of causes (NSW DPI, undated). NSW DPI, (undated) examined NSW fish kill data from between 1970-2010 and found that for approximately 38% of fish kills, no identifiable cause was recorded. Of those that had a suspected cause reported the main causes were low dissolved oxygen levels (e.g. caused by bushfires, flood events, decaying vegetation matter - 18%), pesticide/chemical pollution (8%), high or low temperatures (6%), algae and algal blooms (4%) and acidic runoff (4%) (Figure 36).

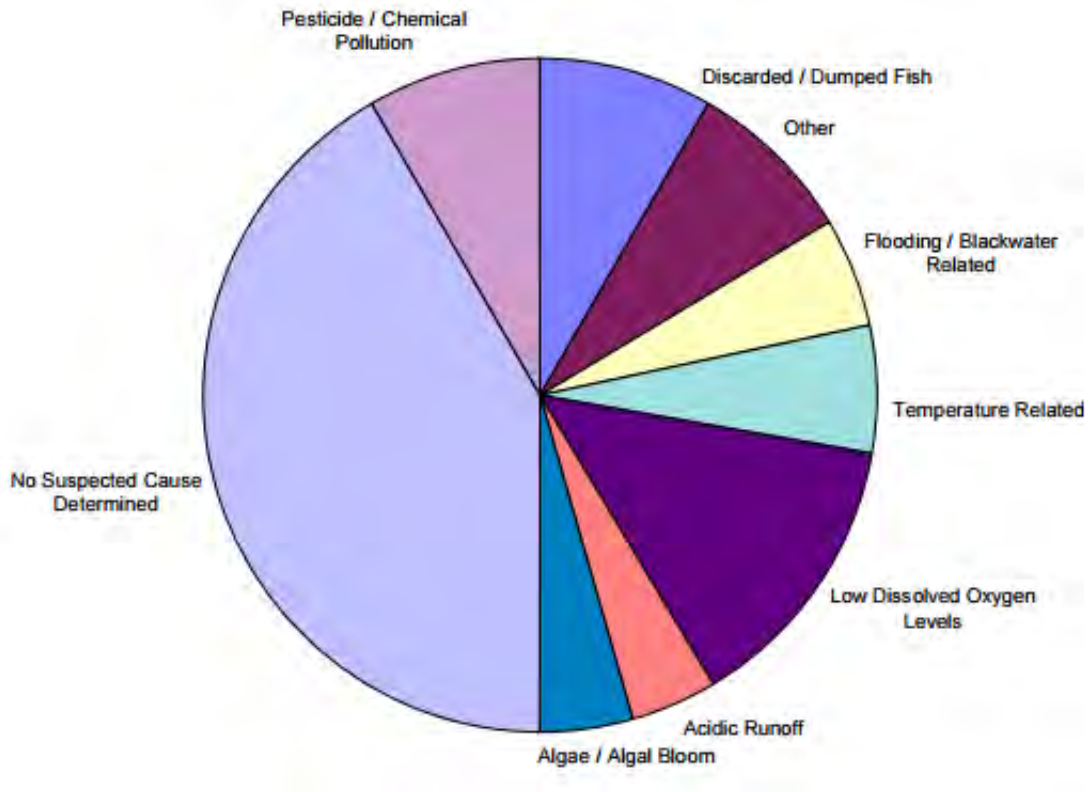

Figure 36: Causes of reported fish kills within NSW (1970-2010) (NSW DPI, undated(c))

PWD (1991b) reported that fish kills have were observed within the Tweed River estuary in preceding decades, with kills occurring in 1956, 1969, 1978 and most notoriously in 1987. Historically, pioneering families of the area report being told of fish kills in the river by local aborigines (PWD 1991b). Records from the Fisheries NSW Fish Kill database indicate that fish kills have not become any more common in recent decades with only two kills recorded within the Tweed River since the 1987 fish kill, one in 1994 and 2004. The 1994 kill occurred adjacent to Stotts Island and the 2004 event occurred in Jack Evans Boat Harbour.

5.6.2 Marine Mammals and Reptiles

The estuary provides habitat for a number of marine mammals and reptiles particularly within the lower estuary. A number of species of dolphins have been recorded within or are likely/known to have habitat within the estuary including the common Bottlenose Dolphin and the migratory Indo-Pacific Humpback Dolphin. Dolphins are likely to utilise a number of habitats throughout the estuary hunting a variety of prey. Humpback and Southern Right Whales migrate along NSW coastal waters. Although not considered a common occurrence in estuaries may briefly and intermittently enter the Tweed River estuary.

The inshore marine environment and estuaries for Northern NSW is known as feeding and foraging areas for marine turtles. The feeding requirements and foraging habitats vary between species with some species being predominately pelagic feeders in the open ocean (e.g. *D. coriacea*) and others utilising a wide range of habitats including seagrass beds, mangrove bays, mudflats, or hard bottomed habitats such as coral reefs. A number of marine turtle species have been recorded within or are likely or known to occur within the Tweed River estuary including Loggerhead Turtle (*Caretta caretta*) – Endangered under the EPBC Act;

- Leatherback Turtle (*Dermochelys coriacea*) - Endangered under the EPBC Act;
- Green Turtle (*Chelonia mydas*) - Vulnerable under the EPBC Act;
- Flatback Turtle (*Natator depressus*) - Vulnerable under the EPBC Act; and

- Hawksbill Turtle (*Eretmochelys imbricate*) - Vulnerable under the EPBC Act.

Typically, nesting occurs further north, along the coasts of Queensland, Northern Territory and Western Australia and in tropical international areas including Indonesia and throughout the Pacific. Occasional and sporadic nesting has been recorded on Northern NSW beaches, however The Tweed River estuary is unlikely to provide breeding habitat for any of the above species but is likely to provide foraging habitat, particularly for the Green Turtle.

5.6.3 Benthic infauna

Benthic infauna are small fauna species that live on or within the estuary floor. Soft bottom sediments throughout the estuary provide habitat for a large range of benthic infauna including crustaceans, polychaetes, bivalves and amphipods. Recreationally important benthic infauna species include the Yabby (*Callianassa australis*) and Soldier Crabs (*Mictris longicarpus*). Both species tend to colonise sandy intertidal flats and are food sources for a large number of estuarine animals including a number of fish and bird species. Subsequently, both species, particularly the Yabby, are prized by recreational fishermen as a source of bait. Intertidal sand/mud flats, particularly those that are close to population centres and easily accessible are often popular bait collecting grounds for these species.

Mud crabs (*Scylla serrata*) and Blue swimmers (*Portunus pelagicus*) are two crab species that are present within the Tweed River estuary. Both species inhabit a large range of habitats throughout the estuary and likely to be distributed from the lower estuary through to the upper estuary, particularly Mud crabs. Both species are targeted by recreational fishers, particularly throughout the warmer months. Mud crabs are also targeted by licenced commercial fishers.

Other benthic infauna such as polychaetes, bivalves and amphipods may be not be as directly important as recreational species, however, perform important ecological functions within the estuary such as nutrient cycling and providing a food resource or other fauna. Benthic infauna communities of the Tweed River estuary have been studied in the past. An early study by PWD (1990) indicated that:

- Most benthic species found in the lower Tweed River estuary are widespread and common in NSW estuaries;
- Seagrass beds contain the richest diversity and number of infauna species whilst sand bottom channels hold comparatively poor diversity and abundance;
- Floods cause a reduction in diversity and abundance of infauna primarily as a result of freshwater and substrate scour;
- Seagrass beds, shallow bays and backwaters provide refugia for benthic infauna during floods;
- Considerable fluctuations occur in the composition and abundance of benthic communities;
- Benthic communities of Kerosene Inlet, Sponsors Lagoon and Wommin Lagoon differ to that of the main estuary.

PWD 1991 also undertook a study of benthic infauna within the lower Tweed River estuary. Several results from this study were similar to that of PWD (1990) including species recorded were common in northern NSW and southern QLD estuaries and benthic communities of Kerosene Inlet, Sponsors Lagoon and Wommin Lagoon were more diverse and had a high abundance than the main estuary. They also found that benthic infauna abundance and diversity was higher in areas of shallow banks and bays away from main channels and abundance and diversity generally increased upstream (furthest upstream site was at Chinderah).

A study of benthic fauna in the upper Tweed River estuary was undertaken by WBM (1992) and the results were compared to that of the lower estuary. As was the lower estuary, the upper estuary was dominated by polychaetes and the relative abundance diversity of polychaetes was also similar to the lower estuary. The

relative abundance of bivalves and crustaceans was slightly higher in the upper estuary however diversity of these groups was higher in the lower estuary. Gastropods were less numerous in the upper estuary however the upper estuary had a higher diversity and abundance of other benthic fauna than the lower estuary which was attributed to the presence of freshwater fauna in the far upper estuary.

5.7 Birdlife

The Tweed River estuary is home to a wide range of bird species utilising the area for feeding, foraging, roosting and nesting.

5.7.1 Shorebirds

Shorebirds (often called waders) are birds that commonly feed by wading in shallow water or saturated substrate along the shores of lakes, rivers and the sea (Geering *et al.* 2007). Shorebirds are generally considered as either resident shorebirds (i.e.do not undertake large-scale migrations) or migratory shorebirds (i.e. undertake large migrations). Many migratory shorebirds that occur in Australia breed in the northern hemisphere during the southern winter before migrating to Australia for the summer to feed before migrating back north before the winter. Shorebirds migrating to and from Australia utilise what is termed the East-Asian Australasian Flyway.

Shorebirds utilise a range of habitats in estuaries and open beaches including intertidal sandflats and mudflats, supratidal sand banks, mangroves, intertidal and upper areas of sandy beaches and foreshores, and rocky foreshores. The Tweed River, Terranora Inlet and Fingal Beach all provide areas of suitable shorebird habitat. A search of the Bionet Wildlife Atlas (NSW OEH, 2016) revealed that 28 species of shorebirds have been recorded within the Tweed River estuary.

Several studies have examined shorebirds within the Tweed River estuary and are summarised below.

DECCW (2010a) undertook a study which collated and analysed shorebird data from across the Northern Rivers from Tweed Heads in the north to Tacking Point in the south. The study area was divided into three main habitats; estuaries, (including Tweed River estuary), ICOLL's and coastline sections and analysed shorebird records to priority rank the habitats. Average population estimates for shorebird species were calculated for each location within the study area with the three sites/locations with the highest average population for a species were deemed to be 'priority sites' for that species.

The Tweed River estuary is considered by DECCW (2010a) to be priority 3 habitat for threatened migratory species including Terek Sandpiper (Vulnerable – TSC Act, Marine, Migratory – EPBC Act) and priority 3 habitat for threatened resident shorebird species including Beach Stone Curlew (Critically Endangered- TSC Act) and nesting Australian Pied Oystercatcher (Endangered – TSC Act).

Rohweder (2007) summarises shorebird data from the Tweed River estuary from 1987-2003. The results show a significant decline in the total population of migratory shorebirds within this period, with declines recorded for Bar-tailed Godwit (*Limosa lapponica*), Curlew Sandpiper (*Calidris ferruginea*) and Pacific Golden Plover (*Pluvialis filva*). The specific reason for the decline in the population of migratory shorebirds is unclear and could be due to a combination of local and international factors. Local factors may include the loss of nocturnal habitat, the declining quality of high tide roosts or increased levels of human disturbance around roosts. High tide roosts within the study area are mapped in Figure 37. Rohweder (2007) suggested that action is required to restore or replace degraded roosts and reduce human disturbance at roost and feeding sites. Measures proposed included the construction of spring-tide roosts close to feeding grounds and away from areas of intense human activity, further restrictions on vehicular access to important sites, designating some site as no beaching areas for boats and increasing public awareness of the importance of roost and feeding sites.

Avifauna Research & Services (2006) mapped habitat utilised by threatened migratory shorebirds, specifically Sanderling, Great Knot, Greater Sand Plover, Lesser Sand Plover, Broad-billed Sandpiper, Black-tailed Godwit and Terek Sandpiper along the NSW north coast including the Tweed River Estuary. Locations were ranked (0-4) according to their importance for the previously mentioned shorebird species, 4 being the highest importance. The Tweed River estuary was given an overall ranking of 2 with species rankings as follows:

- Black-tailed Godwit - 0
- Great Knot - 2
- Greater Sand Plover - 1
- Lesser Sand Plover - 2
- Terek Sandpiper - 1
- Sanderling - 0
- Broad-billed Sandpiper - 0

The study identified important roost sites at Kerosene Inlet, Tony's Island and South Beach (Figure 37). They noted that Tony's Island may be under threat as a shorebird roost site due to the spread of mangroves across the island. South Beach was significantly modified during the installation of the pumping station as part of the sand nourishment project at Tweed Heads and noted that fewer shorebirds use the site since the modification of the beach.

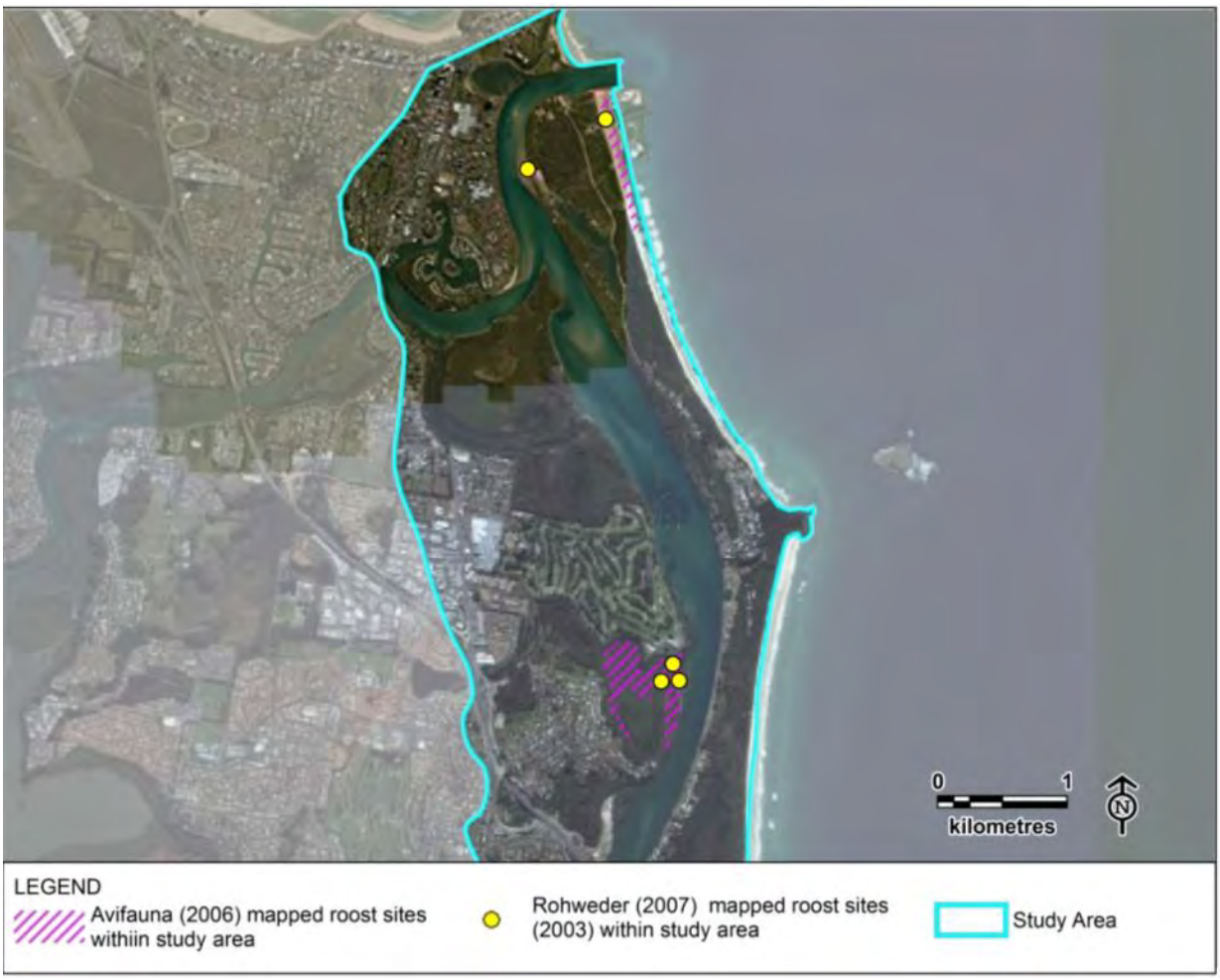

Figure 37: Shorebird roosting habitat as mapped in Rohweder (2007) and Avifauna (2006).

Evaluation of the status of important sites within the East Asian – Australian Flyway indicates that the Tweed River estuary and surrounds is not of national or international importance for any species of migratory shorebirds (Bamford *et al.* 2008). Despite this, the Tweed River estuary is important shorebird habitat from a state and local perspective (Rohweder, 2007).

5.7.2 Raptors

The Tweed River estuary supports a number of raptor species including White-bellied Sea Eagle (*Haliaeetus leucogaster*), Brahminy Kite (*Haliastur indus*) and Eastern Osprey (*Pandion cristatus*). Eastern Ospreys are of particular interest within the estuary with the species listed as Vulnerable under the TSC Act. Nests are mapped from time to time by NPWS and notified to Council (several can be seen in Figure 26). A total of 21 osprey nests have been constructed throughout the estuary and surrounding areas, with the majority being utilised by ospreys. The nests represent a major collaborative initiative to preserve a highly threatened species.

5.8 Acid Sulfate Soils

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

ASS runoff impacts on the estuarine environment include low pH, high concentrations of dissolved iron, aluminium and other metals (ABER, 2008). Exposure to ASS runoff can impair gill function and increase susceptibility to disease in fish. Major negative implications of ASS impacts include fish kills and major aquatic habitat changes, reduced plant growth (acid scalds), and corrosion of concrete, iron and steel structures.

Figure 38 provides mapping of ASS risk areas within the study area. ASS risk is based geologic and elevation information and is assessed on the probability of occurrence. As indicated in Figure 38 ASS has a high probability of occurring across almost the entire Tweed River estuary floodplain, equating to approximately 50% of the entire study area.

Table 15: ASS probability as mapped in Figure 38.

Probability of occurrence	ha	% study area
High	9,841	50
Low	1,271	7
NA	931	5
No known occurrence	113	1

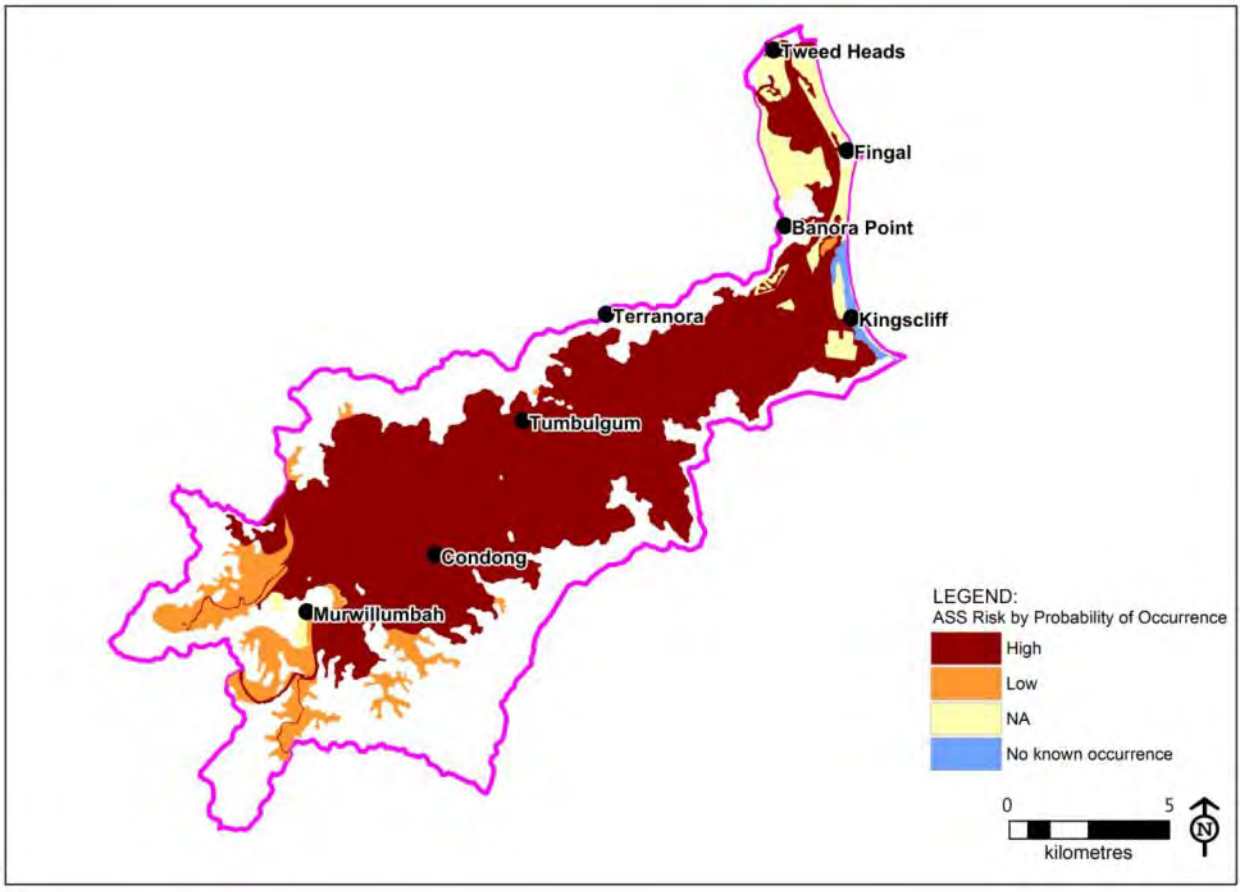

Figure 38: ASS risk by probability of occurrence (NSW Office of Environment and Heritage, 1998) Note: white areas are outside of the risk mapping area (not on the floodplain).

5.8.1 ASS Issues

ASS have been attributed to a large range of environmental, agricultural and infrastructure issues including:

- Acidification and deoxygenation of runoff;
- Acidification of groundwater;
- Mobilisation and release of heavy metals;
- Scalding of soils and damage to vegetation;
- Acidification of agricultural soils and reductions in production;
- Damage to built infrastructure such as corrosion of concrete and iron.

White *et al.* (2007) provides a summary of ASS issues as follows. When drained or exposed to air during prolonged dry periods, sulfides in the sediment are oxidised to sulfuric acid. Acid then leaches iron, aluminium, silica and other metals from soils making soil water toxic for plant and fish species. Detrimental environmental impacts of drainage and oxidation of acid sulfate soils include: decreased plant growth, plant deaths and changed plant ecology; corrosion of engineering infrastructures; massive fish kills and fish diseases; dramatic changes in stream ecology; blooms of harmful cyanobacteria; and emissions of sulfur dioxide. While fish kills can occur naturally in acid sulfate soil areas, constructed drainage of floodplains has exacerbated the problems. Acidic outflows can also threaten aquaculture and exported acidic materials can be sequestered in the sediments of shallow receiving waters where they are available for subsequent remobilisation.

A range of ASS related issues have been recorded within Tweed floodplain and the receiving estuary. One of the earliest recordings of an ASS issue in the Tweed was the occurrence of a large fish kill in the mid estuary during 1987. Dissolved aluminium completely clarified the normally turbid estuary and all gilled organisms were killed in massive numbers. Possibly more than a 1,000 tonnes of dissolved and colloidal aluminium was discharged in the event and the river remained almost sterile for a further 18 months (White *et al.*, 2007). Since then, there has not been another major fish kill event it the Tweed although two minor fish kills near Stotts Island and in Jack Evans Boat Harbour were recorded in 1994 and 2004 (refer to Section 5.6.1 for further details of fish kills).

Water quality issues associated with ASS have been well documented within the Tweed River estuary and are briefly summarised:

- PWD (1991b) reported that the occurrence of acidic runoff events was observed as far back as the 1930's.
- PWD (1991b) - Following the large fish kill event of 1987 a large amount of resources were devoted to the cause. Low pH drain waters were recorded across the flooplain with the greatest concentration of low pH drains occurring on the floodplain to the south of Stotts Island. Other areas with acidic drain waters were Kynnumboon, northern portion of Tygalgah, South Murwillumbah and Dulguigan. Localised areas within the river were affected by the acidic runoff including The Tweed River within the vicinity of Stotts Island and the Rous River at Dulguigan Creek. Pollards Quarry was also identified as a source of acid discharge.
- A number of research studies were undertaken through the 1990's within the McLeods Creek catchment recording acidic waters within the drains (Tulau, 1999).
- PWD (1991b) undertook further field investigations. Acidic drain waters were again recorded across the floodplain to the south of Stotts Island. They noted that estuarine water penetrating into the lower ends of the drains was buffering acidic water.
- WBM (1992) noted acidic waters within Rous River and recorded acidic and high aluminium discharges from McLeods Creek and resultant low pH water within Stotts Channel.
- MHL (1997) carried out water quality monitoring in a number of main cane drains in the Tumbulgum area in 1995-96 and recorded low pH within the McLeods Creek Catchment.
- WBM (2000) identified ASS as a key water quality problem of the lower and mid estuary.
- Macdonald *et al.* (2007) recorded large fluxes of acid along with Aluminium, Iron and Zinc from in drain water at two locations (McLeods Creek and Blacks Drain) on the Tweed River floodplain during a flood event.
- ABER (2012) undertook a review of Tweed estuary water quality from 2007-2011 and identified influxes of low pH ASS runoff as a cause of low pH within the estuary during high flow conditions. They noted that consistently lower pH measurements in the Rous estuary indicate a relatively greater influence of acid sulfate soil runoff in this tributary. Data also suggested that during at least one event, sulfate soil runoff may have had a primary influence on the estuary as a whole. ABER (2012) also attributed acid runoff liberated of iron hydroxides to an increase in the TN:TP ratio of the estuary, particularly during the wet season.

5.8.2 ASS Management

Development controls are placed over areas of the study area with potential for ASS through zoning within the Tweed LEP 2014 (Figure 39). Mapping in the LEP indicates areas where works require approval to minimise potential impacts from the disturbance of ASS. Areas are classed 1-5 with development consent required for the carrying out of works as follows:

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

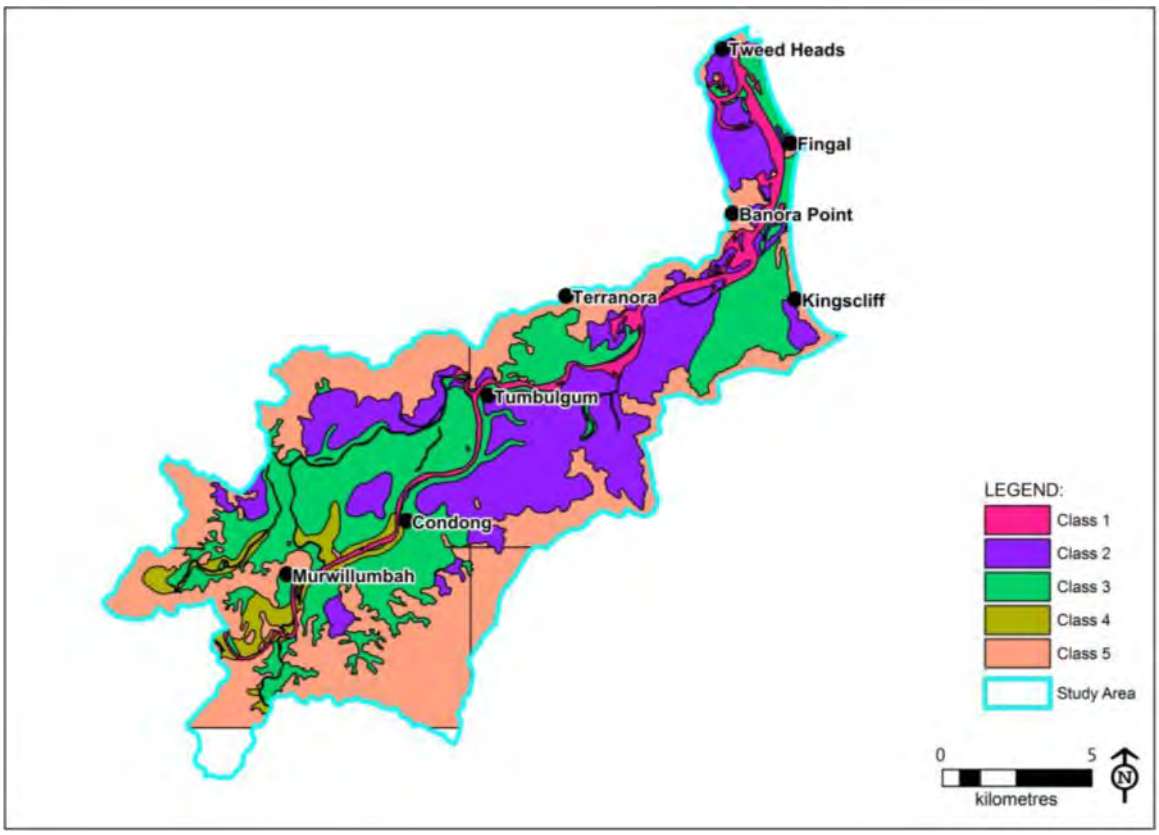

Figure 39: Tweed LEP 2014 ASS class map

Among other exemptions, development consent is not required for works being carried out on the above land if the works are carried out in line with a drainage management plan that is prepared in accordance with the NSW Sugar Industry Best Practice Guidelines for Acid Sulfate Soils (2005), and is endorsed by the Sugar Milling Co-operative as being appropriate for the land.

Several priority areas for management of acid sulfate soils on the Lower Tweed floodplain were identified and mapped by Tulau (1999). Priority Areas were areas where land management decisions in relation to ASS have contributed to, and can lead to further, severe soil acidification, poor water quality, reduction in agricultural productivity and capability, loss of estuarine habitat, and/or degraded vegetation and wildlife. This report identified areas within the Lower Tweed that were of immediate concern for remedial action. Priority areas identified within the Lower Tweed River catchment include the area surrounding McLeods Creek – Main Trust Canal and an area adjacent to the Rous River at Dulguigan (Figure 40).

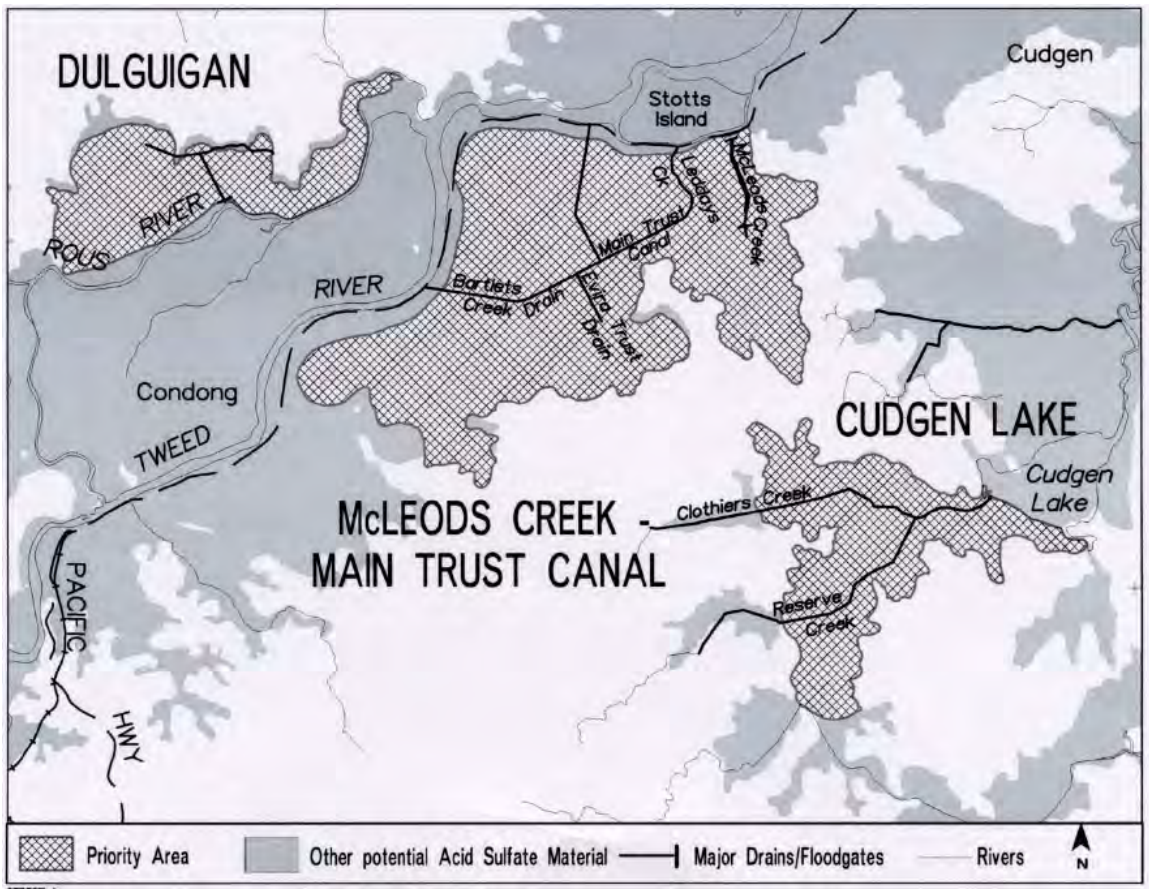

Figure 40:ASS priority areas as mapped in Tulau (1999). (Source: Tulau, 1999)

Rehabilitation strategies for the priority areas included:

- McLeods Creek
    - Laser leveling, planting in mounds, redesigning the drainage system and liming drainage banks.
    - Length of field drains will be halved from 16 km to 8 km.
    - Drain waters are kept low at –400 mm (above the PASS) with pumps to increase the potential storage for rain waters.
- Dulguigan
    - A pilot project has been implemented which involves the installation of manually-operated winches and the opening of three floodgates on Dulguigan Creek (with one also on Condong Creek). On Dulguigan Creek
    - 20 km of creeks and drains have been returned to a degree of tidal influence.
    - Generally, the gates are opened in dry conditions and closed when water levels are higher due to high fluvial flows or high tides. However, a protocol needs to be developed regarding practices and rights and responsibilities of the parties involved.

ASS and Sugarcane Farming

ASS occur beneath approximately 50% of sugar cane farming areas within the northern rivers (Beattie, 2001). Over 62% (7,300 ha)of the Tweed River floodplain (potential ASS) is used for sugarcane production and consequently sugar cane farming is often implicated as the cause of ASS issues in the Tweed River estuary (White *et al.*, 2007). A significant amount of research on ASS has been undertaken within the

Tweed River floodplain, primarily within the McLeods Creek catchment. White *et al*. (2007) highlights that due to collaborative on-ground research in the Tweed, farmers on the Tweed have generally taken up ASS management practices early in their development. One example was the abandonment of plans to increase drainage and instead focus on control and rapid removal of surface water through laser levelling of fields.

Quirk (2016) provides a summary of land management practices adopted by sugarcane farmers on the Tweed (in particular, McLeods Creek) and is summarised below:

- Cane farmers in the Tweed became aware of ASS as an issue in 1987 following a large fish kill and poor water quality event and consequent criticism from the wider community. This criticism extended into the early 1990's.
- In 1991 an ASS research site was established in the McLeods Creek catchment in order to better understand ASS.
- Over the next ten years the McLeod's Creek research site became one of the most studied ASS sites in the world with 10 PhD studies and numerous masters and honours studies all being undertaken at the site.
- The studies identified many of the active processes occurring within the ASS landscape and assisted quantification of acid loads, discharge mechanisms, and drainage system contributions to acid in the water column. Remedial liming rates and impact mitigation activities were also identified. With the help of the scientists and their students, land management techniques were developed to reduce acid discharges.
- It was found that the discharge of acid came from a wedge shaped section of the soil profile 60 cm deep and 5 m from the drain bank. The filling of 50%of the drains reduced the problem by half.
- The drain banks of the remaining drainage ditches were heavily limed at the rate of 10 tons/ha. This raised the drainage pH from 3.5 to 5.5 and is now accepted best practice on the flood plain (Melville *et al*. 1996).
- An automated dewatering system was designed and installed at the study site. This was set to start pumping when the water in the drains reached minus 0.50cm AHD and shut down when the water level reached minus 60cm AHD.
- The cane was planted on natural ground level and the soil mounded over the cane. This gave about 20 cm more drainage head than using the conventional system of planting below the ground. This system gives a much larger storage for the flood water. It gives the site storage for a 50 mm rain event before any damage occurs to the crop.
- Fields have been laser levelled to drain towards the pumps at a grade of 0.05%. The lower ends of the fields are used as storage for the run-off water.

The NSW Sugar Industry Best Practice Guidelines for Acid Sulfate Soils

There is significant history in the process towards the NSW sugar industry self regulation and coastal floodplain ASS management and is basically summarised below from Beattie (2001) and White *et al*. (2007):

- In 1994, the NSW Sugar Industry developed the first drain construction and management guidelines which was distributed to growers across the northern rivers region.
- By 1996, it was considered that the sugar industry had 'taken ownership' of the ASS issue, recognising that the release if acid was natural but assumed stewardship in the role of ASS management. The field phase of ASS research was roled out where soil on almost all cane farms in NSW was analysed.
- By 2001 a Best Practice Guidelines for Acid Sulfate Soils was prepared, which is described below.

The latest best practice guidelines are NSW Sugar Industry Best Practice Guidelines for Acid Sulfate Soils which was published in 2005. The industry's objective is to ensure that activities of its members do not contribute to or exacerbate acid sulfate runoff. The BPG were developed by the NSW Sugar Milling Co-operative in conjunction with the Acid Sulfate Soil Management Advisory Committee. The guidelines outline recognised farming techniques capable of delivering environmentally and economically sustainable sugar cane production. The intended purpose of this document is to provide guidelines, based on the best available information, for canefarmers with these soils in order that they:

- minimise the export of acidity from their farms;
- minimise any downstream environmental impacts caused by acid export; and
- maximise production from their land
- comply with the relevant legislative provisions and statutory plans including Local Environment Plans

The guidelines identify what farming activities have the potential to cause ASS issues and outlines best practice (at the time) methodologies to minimise and mitigate ASS issues on cane farms, particularly around drain management. Under the guidelines all cane farms are required to have a drainage management plan, which must be lodged with and endorsed by the NSW Sugar Milling Co-operative Limited. The plans should provide information on depth, location and nature of acid sulfate soils. They should also provide information on the location and dimensions of existing, new or redesigned drains that will provide efficient drainage without creating an acid hazard and indicate liming rates for spoil and drain water.

Under the guidelines, through best practice, the NSW sugar industry provides a commitment to minimising the production and outflow of acid from the acid sulfate soils which occur beneath much of our cane land to protect and improve the soil and water quality on farms and to protect surrounding ecosystems for current and future generations. The industry's objective is to ensure that activities of its members do not contribute to or exacerbate acid sulfate runoff. All members of the NSW Sugar Milling Co-operative Ltd are signatories to a Memorandum of Agreement that individually confirms this commitment. The Co-operative will refuse to accept or pay for cane from land where the Co-operative concludes that the landholder continues to refuse to comply with best practice. Farmers are required to keep records of all ASS management undertaken on their farms including land forming (laser grading), earthworks including drain construction and maintenance and any applications of lime to their farms. An annual review of drainage management plans is required with results forwarded to relevant Councils. To ensure the transparency of the self regulation system a selection of farms across the cane farming area are selected for an annual compliance audit.

Figure 41: Left: Lomandra and Callistemon planting along Blacks Creek cane drain; Right: Float-style fish gate on floodgate near Murwillumbah.

6. COASTAL HAZARDS

The coastal zone is exposed to many hazards of differing severity that may threaten coastal ecosystems, built assets, human activities and coastal amenity. While the hazards are part of the natural coastal processes, they can affect the human uses of the coastal zone, and responses need to be planned and managed. An understanding of coastal hazards and their potential effects on development, safety and amenity is essential if the coastal zone is to be effectively managed.

The following coastal hazards are relevant to the Tweed River estuary:

- Entrance Instability;
- Sea Level Rise;
- Flooding and Tidal inundation; and
- Bank Erosion.

Relevant background information under for these topics has been summarised below.

6.1 Entrance Instability and Tweed Sand Bypassing

In terms of numbers, the Tweed River entrance is predominantly used by trailer-borne recreational craft. Commercial usage of the entrance is mainly by the small professional fishing fleet and a number of commercial dive operators and charter operators.

Historically, the Tweed River entrance was regarded as particularly dangerous to negotiate and was responsible for many shipwrecks and loss of life. In the 1890s, rock walls were constructed north and south of the river entrance to improve river navigation. In the 1960s, the walls were extended seawards - by almost 400 metres. But sand accumulated south of the river entrance walls and eventually moved into the river entrance. During the 1950's, 60's and 70's dozens of severe storms hit the Gold Coast, stripping the beaches of sand and threatening property. There was little natural replenishment of sand, as the northward sand drift was intercepted by the river wall extensions.

Since 2001, the Tweed River entrance has been actively managed by the New South Wales and Queensland State Governments to establish and maintain a safe, navigable entrance to the Tweed River and restore and maintain the coastal sand drift to the beaches on the southern Gold Coast of Queensland. The Tweed Sand Bypassing project is a sand transport system that collects sand from the southern side of the Tweed River entrance at Letitia Spit, and pumps it under the river to outlets on the northern side. From there the sand is transported by waves and currents to nourish the southern Gold Coast beaches (Figure 42 and Figure 43). The project periodically dredges sand that accumulates at the Tweed River entrance which is also transported to southern Gold Coast beaches. The last entrance dredging campaign occurred in 2016. A total of 41,938 m³ was dredged from the Entrance and placed in the Duranbah inner and outer nearshore placement areas. The system is designed to transport the natural quantities of sand that move northwards along the coast (NSW DPI, 2016).

The project is monitored closely by the NSW and Qld Governments including:

- Bathymetric Survey of the entrance seabed depth (bathymetry) every three months to ensure safe navigable depths (Figure 44 shows the May 2016 survey);
- Bathymetric survey of the estuary up to Barneys Point Bridge every two years (next survey planned for November 2016)
- Monitoring the quantity of sand dredged and pumped to different locations;

- Estimation of the amount of sand moving north towards the Tweed River Entrance by natural processes;
- Quarterly beach profile surveys north and south of the river mouth;
- Continuous monitoring of wave conditions.

Figure 42: Schematic plan of the Tweed River Entrance Sand Bypassing Project (NSW DPI, 2016)

Figure 43: Tweed River Entrance showing the sand collection jetty south of the river mouth (DPI Lands, 2016)

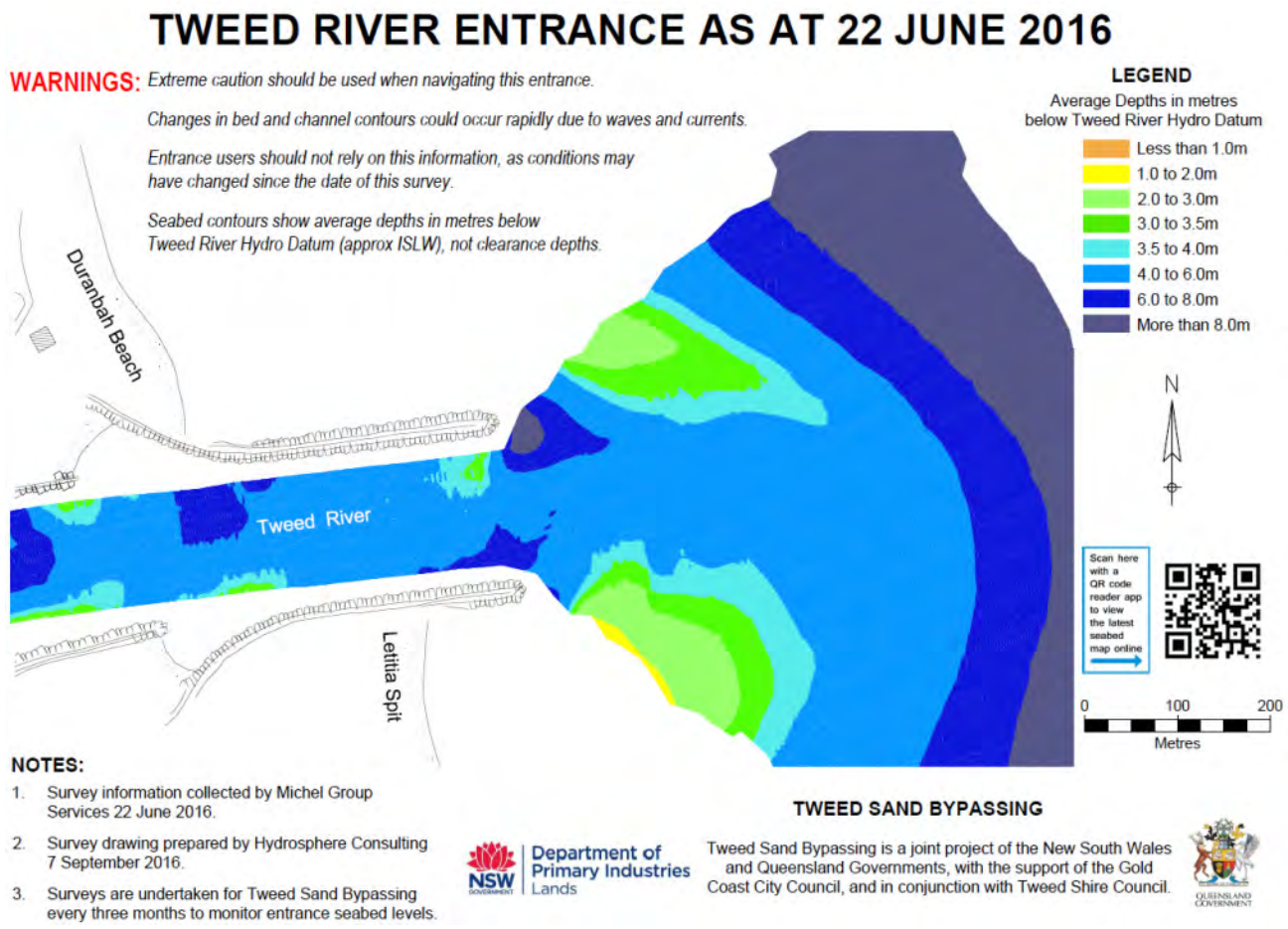

Figure 44: Survey of Tweed River Entrance June 2016 (DPI Lands, 2016)

6.2 Sea Level Rise

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

In the absence of detailed localised studies, many NSW councils, including Tweed Shire Council continue to use the 2050 (+0.4 m) and 2100 (+0.9 m) projections provided in the rescinded *NSW Sea Level Policy Statement*, as the most appropriate basis for coastal planning and risk assessment.

Sea level rise has implications for shoreline recession, inundation risk, estuarine ecosystem health as well as public access and amenity as discussed throughout this document.

6.3 Flooding and Tidal Inundation

Estuarine flooding, particularly in the lower reaches is heavily dominated by oceanic conditions. Inundation can occur due to extreme tides, swell and/or meteorological conditions and may or may not be accompanied by catchment flood discharges.

The components defining the current tidal inundation risk for the Tweed River estuary area are combinations of:

- Astronomical high tides;
- Storm surge (the combination of increased water levels due to low atmospheric pressure plus a provision for wind setup); and
- Wave setup (the 'piling up' effect of large waves increasing water levels on the coastline).

In addition to the present day inundation risks, it is also necessary to consider the effects of sea level rise on future inundation risks (for future ocean levels corresponding to 2050 and 2100 as well as present day risks).

The Tweed Valley study area has a long history of flooding and will continue to flood in the future. There have been a number of major floods in the Tweed catchment in living memory, including the largest flood on record in 1954. During this flood, much of the floodplain was inundated with high velocity floodwater that caused significant damage to houses at South Murwillumbah and agricultural land on the floodplain. The Tweed Valley is generally quite wide, flat and steep sided with few structures that significantly control the hydraulics of the floodplain. Low natural and man-made banks and levees are present along much of the Rous and Tweed Rivers, but are generally exceeded in small flood events. In the lower Tweed, the embankment and drainage structures of the Pacific Highway and the constriction at Barneys Point influence flood behaviour in large events. In extreme events, flood levels in the lower Tweed area are controlled by the constriction at the river mouth / entrance and the dunes between Kingscliff and Fingal Head. There is anecdotal information to suggest that floodwaters break through the coastal dune at Fingal in large events, such as the 1954 flood (BMT WBM, 2014).

The Tweed Valley Flood Study Update (BMT WBM, 2009) and subsequent Risk Management Study (BMT WBM, 2014) investigated flood risk within the Tweed Valley floodplain downstream of Byangum, also referred to as the extend of 'flood-prone land'. The studies focused on a combination of ocean and Tweed River (catchment) flooding.

The study found a high level of existing flood risk with an estimated 41,500 people currently residing in flood-prone land and an estimate average annual damage due to current flood risk at $22.5 million (BMT WBM, 2014). Appendix 2 provides mapping of the 100 Year ARI Flood Extent for the Tweed Valley for the current and future climate scenarios.

Past efforts to reduce the flood risk have resulted in levees in Murwillumbah and Tweed Heads South, as well as a voluntary house purchase and house raising program. The Risk Management Study concluded that despite the considerable existing flood risk, and risk posed by climate change, future development can occur with well design flood controls and appropriate assessment of the impact of development. The study provides a number of recommended floodplain management measures including structural changes, warning and evacuation planning, education campaigns, climate change planning, changes to development controls and further investigations.

Figure 45: Left: 1974 Flood at Tumbulgum Right: Flood marker at Tumbulgum foreshore in 2016

6.4 Bank Erosion

Bank erosion is presently occurring throughout the tidal reaches of the Tweed River estuary, which result from both natural processes and human-induced factors. At several sites along the estuary, current riverbank erosion threatens private land, public property and natural resources. Such erosion has been identified by Council as a major environmental and social concern.

Council has undertaken a number of previous bank erosion studies to assess and prioritise erosion areas, identify causes of erosion and prepare management plans to address problem areas. WBM Oceanics undertook preliminary riverbank assessment in 1992. PBP (1995) expanded on this preliminary assessment as part of the Upper Tweed River EMP (PWD, 1996). PBP (1995) carried out a riverbank assessment which included identifying areas of bank erosion and accretion through air photo interpretation, historical hydro-survey comparisons, riverbank inspections, and underwater diving inspections.

In 1998, Council and the Tweed River Committee commissioned PBP to carry out a Bank Management Study and prepare a formal Management Plan to address the issues of existing and on-going bank erosion and morphological changes of the Tweed River estuary, including the Rous River up to Kynnumboon, Terranora Inlet, Terranora Creek, and the entrance to the Cobaki Broadwater. The 1998 bank management study and plan provides a comprehensive assessment of the condition of banks along the estuary; prioritisation of sites based on severity of erosion, erosion rate, and risks associated with continued erosion; the causes of bank erosion and bank failure including human activities compounding erosion issues; and an analysis of various management options to address bank erosion. PBP (1998) concluded that the most widespread erosion problem in the Tweed River estuary was wave induced erosion in the inter-tidal zone. Key findings are shown in Table 16.

Table 16: Summary of key findings of PBP (1998)

Issues	Key findings
Causes of bank erosion	• surface scour of bank material; • toe scour and subsequent over-steepening and collapse through bank failure; • loss of internal strength through excessive pore pressure; and • wave induced erosion at the waterline.
Causes of bank failure	• altered flow patterns; • tidal currents; • river velocities; • boat and wind waves; and • saturated bank soils.
Human activities compounding bank erosion and bank failure	• vegetation clearing of the catchment and riparian areas; • rural and urban development; • boat generated waves; • farming practices; • dredging; and • flow training works.
Bank erosion solutions best suited for the Tweed River estuary	• phragmites planting behind a rock toe; • phragmites planting behind a wave wall; • gravel or cobble fillet behind a rock toe; • gravel or cobble fillet on a shallow low tide berm; • regrade riverbank and re-vegetate surface; • cutting of overhanging trees and roots; • creation of sandy beaches; • full bank rock revetment; • reconstruct revetment with existing material; and • top-up revetment with additional armour

In 2012 Council commission SMEC Australia to undertake an assessment of the impact of vessel wake on bank erosion on the Tweed River. They found that both naturally generated wind waves and waves resulting from vessel wake have the potential to result in erosion and the influence of the two factors varied at different locations in the river. It was identified that because of the repetitive nature of towing activities (i.e. undertaking numerous laps along the same stretch of the river) and the size of the wake waves which they generate when travelling at operational speeds, they are the most likely vessel activities to cause significant bank erosion. It was found that the influence of wind generated and vessel wake vary through the Tweed River depending on the exposure of the river to the dominant wind directions and the frequency that towing activities occur in the area. They reported that between Chinderah and Bray Park the river was more susceptible to bank erosion as a result of vessel wake, as this area generally experiences limited wind generated waves. Downstream of Chinderah, vessel wake was not expected to significantly increase river bank erosion in these areas given current practices (SMEC, 2012). SMEC (2012) also completed a cost-benefit-analysis of potential management options: maintain the current practise; implement a “No-towing activities” policy; and to restrict towing to a specific reach of the river.

TSC completed the Tweed River Bank Erosion Management Plan in 2014. The objective of the plan was to provide a schedule of works to stabilise river bank erosion on public land (to be undertaken by Council), as well as updated design advice for works required on private land. River reaches with the most severe and continuous bank erosion are located between Murwillumbah and Stotts Island, primarily adjacent to the Tweed Valley Way and Tumbulgum Road. Within this river reach, erosion is predominantly impacting on road reserve, as opposed to private land or public open space (TSC, 2014). TSC (2014) estimated that there is 5,754 m of roadway within the priority reach that is at risk of being affected by bank slips within the next five to ten years. A summary of erosion risk is provided in Table 17.

Table 17: Summary of Erosion Risk for the Tweed River (Source: TSC, 2014)

Erosion risk	Severe/high risk	Vulnerable	Generally Stable
Length of bank: (Bray Park Weir to Stott's Island both banks combined = 35,855m)	9,207m	10,381m	16,267m

TSC (2014) provided a prioritised schedule of works for bank erosion management including revegetation; pre-emptive bioengineered stabilisation works; and structural protection. The total cost to stabilise severe erosion adjacent to roads was estimated to be as much as $9,000,000 over ten years, with maintenance costs adding to this figure. The report highlights the major challenge to Council in funding the stabilisation of river bank erosion and in dealing with erosion without seriously compromising the environmental and amenity values of the Tweed River.

Figure 46: Left: Recent rock revetment along Tweed Valley Way, Right: Bank erosion works incorporating habitat elements (tree logs and artificial reef-style structures)

7. GAP ANALYSIS

Based on the background information reviewed and compiled in this document, the following gap analysis was completed to document gaps in the current knowledge. Table 18 identifies key knowledge gaps, documents where gaps will be filled as part of detailed studies planned for this CMP, and highlights any remaining shortfalls. Where there are remaining gaps, the need for further investigation of these issues will be informed by Council and community feedback currently being gathered.

Table 18: Analysis of current knowledge gaps

Issue	Knowledge Gaps	Work planned as part of CMP Detailed Studies	Remaining knowledge gap
Recreational Use	There are a number of gaps in current knowledge regarding recreational use including environmental impacts, demand, conflict and community aspirations.	Recreational Use Strategy to be developed as part of CMP	none
Public Access	No current assessment of the adequacy of public access to the river.	Recreational Use Strategy will provide an assessment of public access.	none
Gold Coast Airport contamination	Very little information is available on the extent of contamination (due to fire fighting chemicals) and impact on the Tweed River estuary and community.	none	Council to follow up with Airport management /EPA to determine status as information becomes available.
Water Quality	The last review of water quality data for the estuary was completed in 2011.	Water Quality Assessment of data since 2011	none
Impact of Future Development	Limited information on the potential impacts of future catchment development on estuarine water quality	Assessing the extent and impact of potential catchment development	none
Current impact from ASS	There has not been a detailed survey of acid drainage impacting the estuary in recent years.	Audit of Floodplain drains	none
Floodplain connectivity	There are concerns in the community about the impact of the floodplain on the river (e.g. infrastructure, drainage, connectivity, land use and activities) although to date there has not been a comprehensive look at the potential changes to floodplain use.	Floodplain connectivity assessment with the aim of identifying realistic management alternatives for the floodplain.	none
Riparian Vegetation	There is no comprehensive assessment of riparian vegetation extent within the estuary	Mapping riparian extent Rapid assessment of selected sites in riparian zone	none
Seagrass condition and extent	Last comprehensive mapping of seagrass in the estuary was 10 years ago (2006).	Mapping of seagrass extent Monitoring of 6 seagrass sites to assess condition	none

Issue	Knowledge Gaps	Work planned as part of CMP Detailed Studies	Remaining knowledge gap
Impacts of climate change and SLR on ecosystems	There is little information on the impacts of SLR on estuarine vegetation.	An assessment of likely estuarine vegetation migration with SLR and identification of barriers to migration.	none
Weeds/pest species	There is limited information on weed encroachment and pest species and the relative importance of these issue for river management	none	Current weed/pest species status Determine the need for further investigation of these issues based on Council and community feedback.
Shorebird data	The last shorebird surveys for the Tweed estuary were completed over 10 years ago.	none	Current shorebird status
Goss pollutants/litter	There is limited information in the background literature regarding this issues and the relative importance of these issue for river management	none	Current status/severity of gross pollutant issue Determine the need for further investigation of these issues based on Council and community feedback.
Dredging	There is no current assessment of all dredging activities being undertaken within the estuary.	As part of Coastal Hazards and Risk Identification we will document current dredging activities to ensure that appropriate levels of dredging are recognised in the long-term management of the estuary.	none

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GLOSSARY AND ABBREVIATIONS

Acid sulfate soils (ASS)	Acid sulfate soils are the common name given to soils containing iron sulfides. In Australia, the acid sulfate soils of most concern are those which formed within the past 10,000 years, after the last major sea level rise. When the iron sulfides are exposed to air and produce sulfuric acid, they are known as actual acid sulfate soils. The soil itself can neutralise some of the sulfuric acid. The remaining acid moves through the soil, acidifying soil water, groundwater and, eventually, surface waters.
Anaerobic	Living without air
Aquatic	Living or growing in water, not on land.
Amenity	A desirable or useful feature or facility of a building or place
Bathymetry	Measurement of water depth in lakes, oceans and seas. In other words, bathymetry is the underwater equivalent to topography.
Causal factors	Contributing causes
Chlorophyll a	The green pigment in plants used to capture and use energy from sunlight to form organic matter (see photosynthesis). Concentrations of chlorophyll-a in the water column are used as an indicator for phytoplankton and benthic algae biomass. It provides a useful proxy indicator of the amount of nutrients incorporated into phytoplankton biomass, because phytoplankton have predictable nutrient-to-chlorophyll ratios
CZMP	Coastal Zone Management Plan
CMP	Coastal Management Program
DECCW	Former (NSW) Department of Environment, Climate Change and Water (now OEH)
Dissolved oxygen	Oxygen dissolved in the water (oxygen saturation). Often abbreviated to DO
DPI	(NSW) Department of Primary Industries
DPI Lands	NSW Department of Industry - Lands
Ecology	The interactions between organisms and their environment
Ecosystem	Refers to all the biological and physical parts of a biological unit (e.g. an estuary, forest, or planet) and their interconnections.
Estuarine	Part of the river channel with a mix of fresh water and salt (tidal) water
EMP	Estuary Management Plan
EPA	NSW Environmental Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environmental Protection Licence
Fisheries NSW	NSW Department of Primary Industries – Fishing and Aquaculture
FM Act	*Fisheries Management Act 1994*
Foreshore	That part of the shore that lies between the mean high tide mark and the mean low tide mark
Hydrodynamics	The motion of a fluid and interactions with its boundaries
Hydrographic	Refers to topographic/bathymetric features of a water body (depth and morphology)
Hydrology	The study of water and its properties, including precipitation onto land and returning to oceans
LEP	Local Environmental Plan
Macroinvertebrate	Animal lacking a backbone
MER	NSW Natural Resources Monitoring, Evaluation and Reporting Strategy
NPW Act	*National Parks and Wildlife Act 1974*
NPWS	National Parks and Wildlife Service

OEH	Office of Environment and Heritage
Physico-chemical	Physical properties dependent on and influencing chemical structure, properties and reactions
POM	Plan of Management
Raptor	Bird of prey
Riparian	Of, on or relating to the banks of a watercourse
Salinity	The level of salt dissolved in the water
Sedimentation	The deposition or accumulation of sediment
SEPP	State Environmental Planning Policy
SOE	State of Environment
SQIDs	Stormwater Quality Improvement Devices
Terrestrial	Living or growing on land (not aquatic)
Tidal prism	The difference between the mean high water volume and mean low water volume of an estuary
TSC Act	*Threatened Species Conservation Act 1995*
Turbid	Cloudy or dirty (not clear)
Turbidity	A measure of the amount of light-attenuating particles in a water body.
TRESBP	Tweed River Entrance Sand Bypassing Project

APPENDIX 1: CURRENT STATUS OF TWEED RIVER ESTUARY MANAGEMENT ACTIONS

Table 19: Current Status of Tweed River Estuary Management Actions

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
Upper Tweed Estuary Management Plan 1996 Note: supporting studies included detailed volumes on ecology, hydrodynamics and water quality, archaeology, recreation, riparian vegetation corridors and foreshore visual quality.	To provide an integrated program of works that will: • Identify, enhance and protect significant habitat, particularly tidal wetlands and riparian corridors • Protect heritage • Provide recreation facilities, • Encourage boating activities • Increase awareness • Address river bank erosion • Improve water quality, particularly in Rous • Minimise ASS impacts • Conserve scenic qualities of river	Summary of key actions: 1. Address LEP as required to ensure protection of valuable habitats, inc. Osprey nests and flying fox camps 2. Prioritise revegetation of riparian corridors 3. Support volunteer groups 4. Set up demonstration sites 5. Develop rehab guidelines 6. Support ASS research and mitigation 7. Disseminate knowledge of ASS management 8. Develop catchment based water quality plan 9. Monitor water quality 10. Set and review water quality objectives 11. Develop WQ education program 12. Develop natural resource education centre 13. Construct regional boat ramp at Condong 14. Upgrade facilities at Commercial Road 15. Upgrade Tumbulgum foreshore 16. Construct sandy beaches in river 17. Remove sandbars in Stott's Channel 18. Construct small craft launching facility in Bruce	Majority of actions complete. Exceptions include: 13, 16, 17, 18, 20, 21 13. Site not suitable due to bank erosion issues nearby. 16. Sandy beaches not pursued due to mostly private land tenure. Also ongoing works required to maintain sandy beaches in the upper estuary prohibitive. 17. The area was dredged historically but has not been for a while. Some calls from Cane farmers to do this to improve drainage. 18. Not pursued 20. Not completed to date but Council is currently looking at this option. 21. Not pursued	CMP to consider re-evaluation of sites for upgrade of foreshore at Tumbulgum. Council is currently looking at a potential Canoe trail in the Rous River. Potential for a launching facility at Pat Smith Park. CMP to consider option and work underway.

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
		Chick Park 19. Dock facility at Budd Park to support rainforest centre 20. Canoe trail in Rous River 21. Upgrade park facilities, pat smith and weir, Bluey Hill, Bullamakanka etc. 22. Prioritise and design structures for bank stabilisation 23. Implement mozzie and midge control 24. Develop a dredge policy		
Lower Tweed Estuary River Management Plan 1997 Document includes technical reports on: ecology, influent, hydro-dynamics, recreation, archaeology and visual assessment.	Detailed objectives have been set for: • Fisheries • Ecology • Visual amenity • Recreation • Navigation • Heritage • Discharge • Public involvement *(Maintain a civic liaison committee to overview the impact of progress and development pressures on river well being.)* All objectives encompass a maintain and improve approach - delivering the plans aim of, "maintain a healthy river". Specific recommendations/actions have been set for 18 different areas within the river	There are approximately 70 actions listed in the plan under main objectives, and each 'specific area' has a number of short and long term actions recommended for it. A separate process will need to be under taken to document and assess the status of all actions.	Audit completed separately (see Table attached).	see Table attached
A Spatially Intensive Approach to Water Quality Monitoring in the Rous River	Investigate the relative magnitude of sources of sediment and nutrients on WQ in whole of catchment, including fresh reaches.	• Control N from point sources at Mbah STP, dairy and stables. • Control diffuse runoff from	• Mbah STP was upgraded in 2007 to tertiary treatment facility with reuse of wastewater at Condong Sugar Mill. • No action on diary to date (though	• CMP Water Quality review to assess any current evidence of Mbah WWTP and dairy

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
Catchment 1997		cane, banana and grazing land.	Council did investigate and attempt discussion with landholders). • Extensive work with Cane Industry to improve environmental outcomes. • Ongoing effort to engage riparian land owners and fence cattle out of creeks.	impacts. • Consider re-evaluating potential management actions at dairy • Continue work with Cane Industry to further riparian restoration work and commitment.
Sustainable Land Management of Coastal Floodplains-Tweed River 2001	• Achieve sustainable land management of coastal flood plains through improved flood gate management. • Document status of 250 flood gates in the Tweed • Actively manage / modify 47 high priority flood gates in Tweed	• Recommendations made to address multiple aspects of many floodgates. • Includes template floodgate management plans and agreements between TSC and drainage unions.	• All high priority ASS remediation floodgates modified (28). • 100's of hectares laser levelling and drain infilling • ASS scald remediation • Green banks, lomandra and trees approx 30 km.	Audit of floodplain drains as part of CMP studies to assess ASS impacts from major floodplain drains. Based on results of audit, consider further management in consultation with cane industry.
Reducing the Impact of Road Crossings on Aquatic Habitat - Tweed Shire 2005	• Locate and prioritise road crossings that form barriers to fish passage • Provide remediation recommendations for individual barriers	• Recommendations provided to remove 23 high priority structures	Largely driven by DPI Fisheries. 7 structures removed, ranging from a major project ($100k plus) on Oxley River to smaller projects on Rous, Durroby, Rowlands and some small tributaries. All sites mapped on TSC GIS layer. Projects are generally very expensive and best approached through incorporation into road upgrades or compensatory measures. All upper catchment sites	None in estuary. Fisheries program to put fish gates on floodgates completed (discussed below).
Bring Back the Fish – DPI Fisheries 2006-2009	• enhance aquatic ecosystems by restoring stream connectivity and rehabilitating key aquatic habitats	• Improve fish passage by modification of floodgates in the Tweed Floodplain	Cooperative project between DPI Fisheries, Drainage Union , Council and landholders. 22 auto-tidal fish gates installed on priority floodgates to allow some tidal exchange and fish passage. Fish gates still operational and seen as a success by all parties.	All priority floodgates have fishgates. Discuss as successful management approach.
Tweed Estuary River Bank Management Plan 2006	Provide an integrated program of works that will: • Identify current areas of bank erosion and prioritise them in order of severity and impact on the community	1. Recommendations made for stabilisation at all major identified erosion locations, with prioritisation of key sites of public land.	Works completed at most high priority locations. Information used to guide erosion stabilisation works on private land. Management plan reviewed in 2012 wake and bank stability study, new priorities to be set out in 2012 River Bank Management	Superseded by 2014 plan

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
	• Identify the main causes of bank erosion at those sites • Provide solutions to the main bank erosion problems identified on the river	2. Recommendation for monitoring program at erosion sites 3. Recommendation on public awareness raising	Plan	
Tweed River Bank Erosion Management Plan (2014)	Outline strategic approach to river bank erosion management - prioritising TSC investment and guiding works on private land.	• Revegetation 15,863m • Pre-emptive bioengineered stabilisation works 4,668m • Structural protection - up to 5,754m Plan provides a list of prioritised sites for each of the 3 categories of works	High priority works between stotts is and mbah underway, some completed. Done as funding is available through roads dept. • Need to ensure that impacts of works are mitigated. • Sites where revegetation should occur • Browns Lane Murwillumbah – rock lined with reef balls and large woody debris OEH funded trial. • Chinderah Many projects happening. Mbah boat ramps, geotextile bags at Condong.	CMP to review Erosion Plan and update if necessary Look at funding the program. CMP to include action to fund works. Emphasis on pre-emptive work required in places.
Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan 2006	• Enhance understanding of natural environment by integrating values of both Aboriginal and natural heritage • Enable a systematic approach of consulting Aboriginal people in assessment of heritage significance • Educate broader community on Aboriginal occupation of area • Assist TSC to meet corporate objectives and statutory requirements relating to Aboriginal heritage.	• Compile list of sites and places to be included in LEP • Implement DA process to ensure Aboriginal cultural study be undertaken for all relevant developments • Implement formal process for consultation with Aboriginal community through AAC • Ensure al agencies undertaking works have access to information relating to sites • Install signage to raise awareness of Aboriginal sites of importance in C&T broadwater • Review plan as required	• Procedural matters relating to consultation and studies dealt with through AAC and statutory processes • Signage project complete • Plan updated in draft form, however likely to be incorporated into Shire wide Aboriginal Cultural Heritage Management Plan.	Outside study area but good to use as background information for CMP

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
Tweed Estuary Boating Plan 2006	• 5 year plan to identify and protect the recreational and environmental values of the Tweed River Estuary, ensure that boating practices maximise user safety • Compliment Estuary Management plan	• Range of actions including introduction of minimal wash zones, 4 knot zones and other boating safety educational programs.	• Actions implemented by NSW Maritime	Superseded by Regional Boating Plan 2015
Regional Boating Plan Tweed – Clarence Valley Region (2015)	• The plan examines physical characteristics of the waterways, water users, safety issues, waterway access and vessel storage across the waterways and recommends improvement projects.	• Condong Boat ramp improvements and toilet facilities, Clarrie Purnell Park; • Canoe launch facility in Tweed River at Byangum; • Relocate and upgrade pontoon at Budd Park, Murwillumbah; • Car park and river bank stability improvements at Murwillumbah boat ramp (Commercial Road); • Replace pontoon and provide disabled access at Fingal boat harbour (Lighthouse Parade); • Parking upgrade at Terranora Creek boat ramp, Tweed Heads (Kennedy Drive) and; • Boat ramp improvements at Oxley Park, Chinderah.	• All projects underway or being planned by Council. Most will be complete in 2017.	Document work underway Discuss with Transport for NSW boating and bank erosion management work underway in NSW
Tweed River Estuary Recreational Boating Facilities Study 2008	• identification of current and future infrastructure requirements for recreational boating generated from within the region; • assessment of the potential to develop a marine precinct to foster the growth of marine services in accordance with recognised best practice principles; • identification of the order of costs in implementing individual strategic	• Upgrade and expand boat ramps, wharves jetties to cater to unfulfilled demand for recreational boating facilities.	• Ongoing maintenance and improvement of recreational boating facilities is undertaken by TSC Waterways program with funding from NSW Maritime Better Boating Program. • pontoon at Chinderah now complete **The plan has not been formally adopted or funded by TSC*	CMP Recreational Use Strategy to provide current assessment of boating access adequacy

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
	options; and • identification of staging for individual options. • assessment of river carrying capacity carrying capacity.			
Tweed River Murwillumbah Reach Bank Enhancement Master Plan 2008	• Guide management and rehabilitation of river banks in urban and residential areas of Murwillumbah • Increase profile of the river in the community, by increasing visibility, accessibility and amenity • Leverage on improvements above to gain environmental and river related social gains in other parts of the catchment	• The master plan makes recommendations based on improving connections between people and river, within three themes: • Visual connections • Green connections • Pedestrian connections	• Budd Park river bank stabilisation and amenity improvement project is the only initiative from the plan now completed. • Improve riparian veg from YHA to MBah boat ramp has been discussed and has had some interest from the community • Nothing else being pursued at present. **The plan has not been formally adopted or funded by TSC*	Consider riparian vegetation improvement from YHA to MBah boat ramp as a potential site for works.
Cobaki and Terranora Broadwater Catchment Management Plan 2010	• Improve water quality and ecosystem health • Improve rural stormwater discharge quality • Improve urban stormwater discharge quality • Restore riparian habitat • Protect and enhance shorebird habitat • Increase and enhance public access • Protect commercial and recreation fishing • Stabilise degraded creek banks • Increase awareness and protection of Aboriginal cultural heritage	There are a large number of actions within 11 different strategic areas. Priority works include rural riparian restoration, bird habitat enhancement and improving stormwater quality discharge from the western drainage scheme.	All priority actions have been commenced and are at varying stages of implementation. Many actions, for example riparian zone restoration, will be ongoing.	Outside the study area. CMP to refer to the Plan for relevant information as needed.
Tweed Urban Stormwater Quality Management Plan 2016	Confirm councils stormwater management objectives Provide ambient and stormwater quality	• Provides policy guidance for consideration in assessment of new developments, and in council accepting stormwater	• Adopted by TSC 2016 • Stormwater group not established to date	CMP to consider funding of upgrades to existing stormwater assets where auditing shows need for

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
	management objectives Provide specific guidance for monitoring and management of stormwater quality improvement devices	management assets for maintenance • Establish stormwater group)TSC internal) to meet regularly and coordinate approach • Build skills in assessment and management of built assets • Monitor performance of existing SQIDS • Develop budget estimates to deliver SQID maintenance programs	• Council is conducting condition assessment of existing assets. This work is ongoing.	improvements to improve river health.
Tweed Valley Floodplain Risk Management Study (2014)	Directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard, and does not create additional flooding problems in other areas.	• Studies and investigations including local drainage studies (Murwillumbah, Lower Tweed), levee investigations (Murwillumbah, Tweed Heads), evacuation planning study • Flood warning and evacuation planning and management; • Community engagement and education; and • Climate change planning, development controls and strategic planning recommendations.	• Actions are being implemented by Council and are ongoing	CMP to consider flood risk mapping and implications for the estuary in Coastal Hazards Assessment as part of detailed studies
Tweed Coast Regional Crown Reserve Plan of Management (2005)	Consolidates information about the reserve, its values, current and proposed future use and management issues. The vision for the plan is “Publicly accessible Crown Land with enhanced and sustainable environmental, social, cultural and economic values for the benefit of the community”.	22 mostly high level strategies. No implementation costs or timeframes given. Most sites outside the study area.	• Jack Evans Boat Harbour site improvement works completed by TSC	CMP to liaise with Lands to determine status of: • redevelopment & upgrade of Southern Boat Harbour, Boyds Bay Marina. • Site improvement plans at Old Fingal Boat Harbour
Review of Water Quality	Analysis of temporal and spatial trends in	• Reduce catchment fine	• Sustainable agriculture strategy	• Water Quality review as

Plan	Objective	Key actions relevant to management of the Tweed River	Current Status (October 2016)	Potential Considerations for CMP
in the Tweed Estuary 2007-2012	water quality, identifies likely controlling processes and discusses ecological implications and management actions	grained TSS exports during median and high flows • Reduce phytoplankton blooms during low to median flows through STP management • Reduce DIN in STP effluent • STP Discharge during median to high flow • Reuse during low flow • Reduce N and P in tandem to achieve effluent ratio of 16:1 • Reinstate backswamp flood reserves • Introduce wet pasture management • Reduce ponding in caneland	implementation ongoing including measures for soil conservation and erosion management • Laser levelling of caneland mostly complete for ponded sites. • WWTP upgrades undertaken at Banora Point and MBah.	part of CMP to assess current wq status. • CMP to evaluate effluent impacts from WWTPs • CMP to consider opportunities for potential floodplain connectivity/changes in landuse/ management.
Tweed Vegetation Management Strategy (2004)	Aims to provide a coordinated approach to the management of vegetation in the Tweed Shire.	1) the recovery existing bushland areas; 2) restoration of previously cleared areas; 3) Threatened species recovery, 4) management of threatening processes and 5) education, monitoring, planning and research.	The strategy informed zoning of LEP	High level doc. No actions relevant to CMP
Tweed Sustainable Agriculture Strategy 2016	Provides a strategic direction for sustainable agriculture in the shire	27 actions relating to sustainable land management, monitoring, education, promotion of best practice etc.	Ongoing implementation.	CMP to support relevant actions including potential for funding of actions where benefits for the estuary can be realised

Table 20: Status of Actions from 1991 Lower River EMP

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
<u>High Priority Actions-1 (as assessed by 1997 review)</u>		
Fish Habitat Action (i) Construct wetlands on Letitia Spit and retain these new areas as Aquatic Reserves.	• Regeneration of coastal wetlands on Fingal Peninsula • 1997 Review noted the aboriginal community were keen to ban commercial fishing in all enclosed waters of Fingal peninsula. The Recreational Fishing Haven now covers these areas meaning no commercial fishing is now	• Defer to TBLALC for status/management of issues.

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
	permitted in these areas. Netting is also prohibited in Wommin Lake and Wommin Lagoon. • Sponsors Lagoon saltmarsh revegetation works 10 yrs ago successful • Attempt to control vehicle access at Kerosene Inlet was not successful	
Fish Habitat Action (iv) Monitor seagrass and mangrove distributions in the Lower Estuary.	• Russell (2005) analysed estuarine habitat mapping data from estuaries across the northern rivers including the Tweed River estuary. Estuarine vegetation (mangroves, seagrass, saltmarsh) was mapped using aerial photographs from the 1940's to 2000. • Hossain (2005) assessed changes in seagrass distribution based on aerial photography within the lower Tweed River estuary including Terranora Inlet from 1997-2001. • DPI Fisheries conducted estuarine vegetation mapping in the Tweed River in 2006 as part of a state wide mapping project • Baseline ecological assessment at Kerosene Inlet (Australian Wetlands, 2010) including seagrass mapping and assessment. • Pacific Wetlands (2012) examined changes in estuarine vegetation (mangroves, seagrass and saltmarsh) within Terranora Inlet and small area of the lower Tweed River estuary between 2000 and 2012. • Australian Wetlands (2008) completed mapping and health assessment of seagrass at Chinderah Pontoon.	• Estuarine vegetation distribution to be considered by CMP including potential impacts due to sea level rise.
Ecological Action (xii) Oversight a monitoring program formulated to detect and report on ecosystem vitality.	• There have been a number of ecosystem health assessments throughout the Tweed River including: Ecosystem Health Monitoring Program Scoping Study and implementation in the Cobaki Terranora Broadwaters; ongoing water quality sampling and analysis; targeted (short-term) water quality investigations (e.g. Rous River assessment Eyre, 1997); shorebird monitoring; baseline ecological assessment at Kerosene Inlet (Australian Wetlands, 2010); Ecosystem health assessment (Uni of Qld, 2003)	• CMP Detailed studies include ecological assessment to be conducted as part of the CMP
Discharge Action (ii) Invite interested organisations to comment on water quality targets suggested.	• Consultation with relevant stakeholders undertaken and Tweed River water quality objectives adopted by TSC in 2000, see WBM (2000).	• Water Quality Assessment to consider Tweed WQ objectives
Discharge Action (iii) Continue water quality monitoring with a view to identifying any potentially damaging constituents as well as constituents for which opportunities for removal are available and practical.	• Routine water quality monitoring is undertaken in the Tweed Estuary. • Results are analysed and reported and management recommendations provided. Most recent report was ABER (2012). • Management actions e.g. catchment management, WWTP upgrades etc. are undertaken as part of Council operations and other stakeholder actions.	• Detailed studies as part of the CMP to include a Water Quality Assessment since 2007 and development of a Water Quality Improvement Plan
Discharge Action (v) Produce public education material to alert the public to the problems caused by providing nutrients to stormwater and the problems arising from the use of fertilisers,	• Stormwater Pollution Guide (NSW DEC, 2000) available on Council website. • Tweed Urban Stormwater Quality Management Plan (TSC, 2016).	• Opportunity for further public education as part of CMP

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
carwash soaps, animal excreta, grass clippings, paints, oils and chemicals.	• Council has an Environmental Education Program and a dedicated Environmental Education Officer and ongoing intiatives.	
Implementation Action (i) Disseminate results of river monitoring to the broader community.	• Results are analysed and reported and management recommendations provide. Most recent report was ABER (2012) available on Council website along with other water quality reporting. All licensed discharges under the *Protection of the Environment Act 1997* are required to publish pollution monitoring data from March 2012 onwards. TSC publishes all their data on the Council website.	• Detailed studies as part of the CMP to include a Water Quality Assessment since 2007 and development of a Water Quality Improvement Plan • Potential for annual report on water quality
Implementation Action (iii) Ensure all new stormwater systems connected to the river incorporate trash racks and siltation pits/ponds.	• Tweed Urban Stormwater Quality Management Plan (TSC, 2016) and Tweed Shire Council's Development Design Specification D7 – Stormwater Quality provide guidance on required stormwater treatment devices. The design of stormwater systems has evolved since the 1991 EMP and there are other options for stormwater management than just trash racks and siltation ponds. • TSC auditing of existing stormwater improvement devices is underway. • 2000 stormwater plan had huge list of actions and some delivered.	• CMP to discuss current stormwater management and identify issues/gaps. • CMP to consider funding of upgrades to existing stormwater assets where auditing shows need for improvements to improve river health.
Implementation Action (iv) Monitor water quality within specific areas against agreed area targets and report annually on departures.	• Routine water quality monitoring is undertaken in the Tweed Estuary. • Reporting is completed on longer time scales than annual.	• Detailed studies as part of the CMP to include a Water Quality Assessment. Reporting timeframes to be reviewed as part of assessment.
Implementation Action (v) Establish a centralised system for recording and analysing water quality within the Tweed River.	• Tweed Laboratory Centre conducts water quality sampling and recording on behalf of Council. Council maintains a central database of water quality results.	none
Implementation Action (xi) Conduct annual reviews of progress and achievements.	• Reviews have been completed on longer time scales than annual. • Review of the EMP were conducted in 1997 and 2001	• This audit provides a review of current status of EMP actions • CMP to set review timeframes
High Priority Action - 2 (as assessed by 1997 review)		
Fish Habitat Action (ii) Incorporate habitat diversity in the design of the Lower Estuary Dredge Program.	• DPI Lands currently conducts dredging of entrance and lower river as required for maintenance of navigation channels • All dredging campaigns are required to assess environmental impacts of proposal (including impacts on habitat) under EP&A Act and other relevant legislation (Fisheries Management Act, POEO Act etc.).	• The CMP will document all current dredging activities to ensure that appropriate levels of dredging are recognised in the long-term management of the estuary.
Fish Habitat Action (vi) Construct carefully designed waterway ventilation improvements to Wommin Lake & Wommin Lagoon.	• Pipes were upgraded to culverts in 2008 (Wommin Lagoon) and 2016 (Wommin Lake). Done mainly to shore up structure of road. Careful work	• TSC is aware of shoaling occurring at inlet to lake and there

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
	undertaken to make sure changes in hydraulics do not impact wetland zonation. Adaptive management with rock work to adjust water level and flow. • Wommin Lagoon saw some increases in seagrass after works.	is a need to monitor this with regard to potential impacts
Fish Habitat Action (vii) Produce maps showing changes in distribution of seagrass & mangroves at intervals of 3 years or thereabouts.	See Fish Habitat Action (iv)	• Estuarine vegetation distribution to be considered including potential impacts due to sea level rise
Fish Habitat Action (xiii) Regularly update influent auditing of wastes directed to the Tweed River. Monitor discharges of sewage effluent, industrial wastewater and stormwater to appraise the effect of such discharges on fish production.	• Discharges of sewage effluent and industrial wastewater are licensed by the NSW EPA and monitored according to licence requirements. • Stormwater discharges not monitored at every outlet • Tweed River Water Quality Monitoring Program assesses overall water quality • Effect on fish production not assessed	• Detailed studies as part of the CMP to include a Water Quality Assessment
Ecological Action (ii) Ascertain which types of river habitat are in need of extension in association with proposed future river dredging works.	• All dredging campaigns are required to assess environmental impacts of proposal (including impacts on habitat) under EP&A Act and other relevant legislation (Fisheries Management Act, POEO Act etc.). This may include provision for compensatory habitat if impacts occur.	• The CMP will document all current dredging activities to ensure that appropriate levels of dredging are recognised in the long-term management of the estuary.
Ecological Action (iii) Identify opportunities for general habitat improvements within the estuary and foreshore areas.	• A number of habitat improvement works have been undertaken. • Fish Unlimited was an on-ground project repairing mangrove and saltmarsh in Sponsors Lagoon, a collaboration between TSC, Fisheries, Wetland Care Australia and TBLALC	• Opportunity for further work as part of CMP
Ecological Action (iv) Identify measures to improve habitat security for the Little Tern, Osprey, Brahminy Kite and other endangered birds.	• Permanent Osprey nesting poles provided in the lower estuary. 21 artificial nest structures in Tweed Estuary. Was cooperatively managed by NPWS and Essential Energy and Council. Council is now taking over responsibility. • Tweed Osprey Monitoring Group – keeping records on this. • Most shorebird habitat conditions met. The key factor at risk is spring tide roost sites, especially considering SLR impacts. • TSC proposed to do clearing of Mangroves on Tonys Bar and Keroscene Inlet where they are taking over important roost areas. Application made to Fisheries was not supported.	• Action in CMP to manage Osprey Poles. • Action in CMP to review roost requirements Tonys Bar/Kerosene Inlet and consider re-application to clear mangroves.
Ecological Action (vii) Investigate options to provide/ extend formal security over important habitat areas whether through zoning, fencing or statutory controls.	• SEPP14 and SEPP26 mapped areas in lower estuary, Estuarine habitat (mangrove, seagrass, saltmarsh) protected under the Fisheries Management Act. National Parks and Nature Reserves in the study area include Ukerebagh Nature Reserve and Historical Site, Stotts Island Nature Reserve, Environmental Protection Zoning under Tweed LEP 2000 for much of the Fingal Peninsula including enclosed waters of the (Kerosene Inlet,	• CMP to assess level of protection of existing habitat areas and identify areas for improvement.

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
	Wommin Lake and Lagoon, Sponsors Lagoon); Ukerebagh Passage etc.	
Ecological Action (ix) Formulate a future works program that identifies site specific habitat creation and habitat enhancement possibilities.	• Riparian zone management undertaken where landholder willingness	• CMP to include habitat creation aims with actions such as bank erosion management, riparian reveg works etc.
Ecological Action (x) Produce information sheets highlighting the importance of foreshore and river habitats.	• Community consultation materials produced as part of the EMP. • Since then TSC and other agencies have produced a number of materials providing this information e.g. estuarine habitat brochures, fisheries resources etc.	• Opportunity for further education as part of CMP
Recreational Action (i) Produce a Waterway Recreation Strategy.	• Recreation Management Plan for the Upper Tweed Estuary (UNE, 1992) • Tweed River Estuary Recreational Boating Facilities Study (PBP, 2008) • Tweed Estuary Boating Plan (NSW Maritime, 2006) • Regional Boating Plan Tweed – Clarence Valley Region (Transport for NSW Maritime Management Centre, 2014) – this covers boating safety, access and infrastructure actions but does not address bank erosion issues or other types of recreational use.	• Recreational Use Strategy to be developed as part of this CMP • Check status of planning for boating.
Recreational Action (iv) Assess whether any existing important habitat is under threat from existing recreational activity.	• Bank erosion assessed • DPI Fisheries estuarine habitat assessments and mapping	• Seagrass assessment to be conducted as part of this CMP • Recreational Use Strategy to be developed as part of this CMP
Discharge Action (i) Prepare annual reviews providing details of all authorised discharges and any significant unauthorised discharges that reach the Tweed River.	• Discharges of sewage effluent and industrial wastewater are licensed by the NSW EPA and monitored according to licence requirements. • Stormwater discharges not monitored at every outlet • Tweed River Water Quality Monitoring Program assesses overall water quality	• Detailed studies as part of the CMP to include a Water Quality Assessment since 2007 and development of a Water Quality Improvement Plan
Discharge Action (iv) Examine all stormwater networks with a view to installing sediment trapping devices and, where nutrient infeed is known to be a problem, consider denitrification measures such as wetlands.	• Tweed Urban Stormwater Quality Management Plan (TSC, 2016) and Tweed Shire Council's Development Design Specification D7 – Stormwater Quality provide guidance on required stormwater treatment devices. • TSC auditing of existing stormwater improvement devices is underway.	• CMP to discuss current stormwater management and identify issues/gaps. • CMP to consider funding of upgrades to existing stormwater assets where auditing shows need for improvements to improve river health.
Discharge Action (vi) Encourage operators of licenced discharges to comply with licence conditions.	• Discharges of sewage effluent and industrial wastewater are licensed by the NSW EPA and monitored according to licence requirements. Upgrades of WWTPs have occurred to improve treatment performance and increase	• CMP to discuss existing compliance and enforcement, any outstanding issues and areas for

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
	capacity (see Section 3.2.8)	improvement.
Discharge Action (vii) Disseminate knowledge regarding development problems that can arise in areas of acid sulphate soils	• Over the last 20 years there has been a large effort in the field of Acid Sulphate Soil research and education. Tweed Council have worked collaborated with state agencies, key industries, landholders and the broader community to better manage ASS on the Tweed floodplain. All ASS are mapped and incorporated into planning and development processes.	• Further work to be conducted as part of the CMP: • Audit of floodplain drains and assessment of floodplain connectivity
Implementation Action (ii) Ensure all future discharges to the Tweed River are sited with reference to likely ecological and water quality impacts.	• Planning provisions incorporate requirements for environmental impact assessment for any new development/activities	• Managed by existing DA process
Implementation Action (vii) Produce publicity brochures detailing the need for community and individual co-operation in sustaining the vitality of the Tweed River.	• Various public education campaigns have been undertaken by Council and other agencies and are on-going • General community awareness of environmental issues has increases in the last 20 years	• Opportunity for further public education as part of this CMP and continuing
Implementation Action (viii) Produce project material for Tweed Shire Schools (and further afield) to promote understanding in the community as to the fragility of river ecosystems.	• Council has an Environmental Education Program covers topics relating to sustainability, waste, water and biodiversity. It links to the current NSW primary school curriculum and can also be adapted to High School. Council has a dedicated Environmental Education Officer.	• Opportunity to incorporate CMP findings into education program
Implementation Action (x) The Lead Agency, when identified, to develop a strategy to review the changing priority of river problems.	• Reviews completed in 1997 and 2001 involved assessment of changing priorities	• This CMP will prioritise actions for implementation
Maintenance and Improvement Action (i) Prepare and execute a program of high priority works.	• A detailed program of works, timing, costs and priority was not completed	• This CMP will document a detailed implementation program including priority, timing, responsibility, cost.
Maintenance and Improvement Action (ii) Prepare and oversight the execution of a longterm works program of river improvements	• As above	• As above
Maintenance and Improvement Action (iv) Liaise with river Committees and the community generally concerning proposed lower estuary improvement work.	• The Tweed River Committee meets regularly to discuss river management	• TRC overseeing this CMP
Maintenance and Improvement Action (v) Maintain full and open liaison with all community sectors interested or concerned with proposed river improvements.	• Council has consulted with the community, interested groups and key government agencies through the TRC and community consultation activities	• Community and stakeholder engagement undertaken throughout the CMP
Medium Priority Action - 3 (as assessed by 1997 review)		
Fish Habitat Action (iii) Monitor changes in water level throughout the Lower Estuary including Cobaki and Terranora	• Tide gauges installed throughout lower estuary • Water levels monitored closely by Tweed River Sand Bypass Project	• none

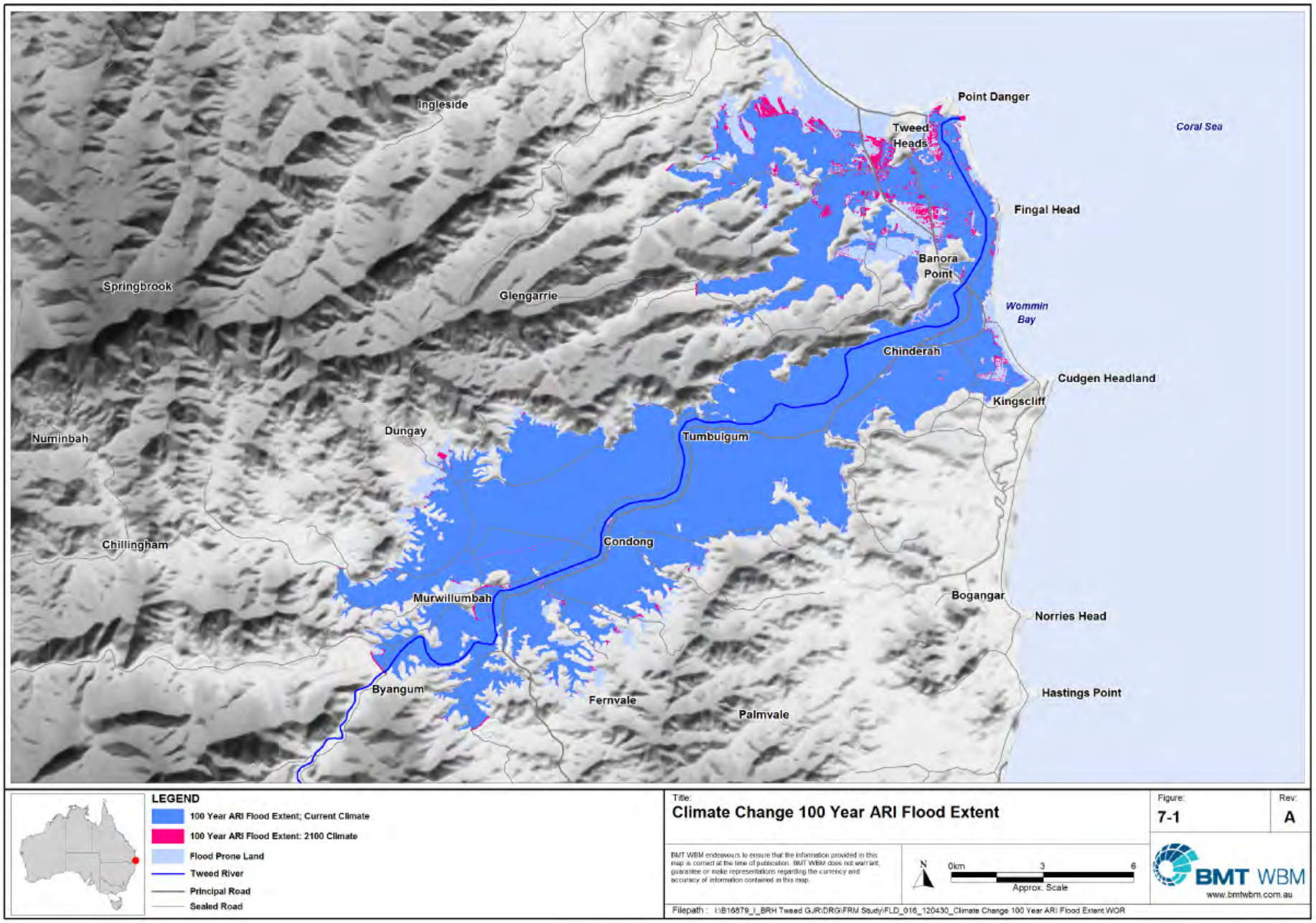
1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
Broadwaters.		
Fish Habitat Action (v) Examine the merit of closing Sponsors Lagoon to professional fishing.	• Now closed to commercial fishing and forms part of the recreation fishing haven	• none
Fish Habitat Action (xi) Monitor changes in average water levels within the estuary with emphasis given to linking detected changes with causes.	• Tide gauges installed throughout lower estuary • Water levels monitored closely by Tweed River Sand Bypass Project • Sea Level Rise is now accepted as occurring and TSC has adopted benchmarks for SLR.	• CMP to consider climate change impacts including SLR on estuarine vegetation communities.
Ecological Action (i) Conduct ecological assessments of the relative importance of any major near-river undeveloped lands not considered in studies to date	• All future development areas in the study area have been developed	• CMP will look at future development impacts
Ecological Action (vi) Compile a strategy for linking dependant habitats.	• NPWS Key Habitats and Corridor Mapping Project • Filling the Biodiversity Gaps Connecting Tweed Coast to Border Ranges (project partners are Tweed Shire Council, North Coast Local Land Services and the Office of Environment and Heritage).	• Managed by NPWS
Ecological Action (viii) Seek to ensure all development proposals are assessed with reference to the need for habitat preservation	• Development applications must comply with ecological requirements under the LEP and other relevant legislation e.g. Fisheries Management Act, EPA Act , EPBC Act etc.	• Managed by existing DA process
Visual Amenity Action (iii) Ensure visual impacts of riverside development proposals are fully assessed as development applications are formalised.	• Development applications must comply with visual amenity requirements	• Managed by existing DA process
Visual Amenity Action (v) Identify major sites of negative visual impact and where practical recommend options to improve the viewscape.	• Current work ongoing on landscape character by TSC.	• CMP to Support study and recommendations • Consider in bank stabilisation works.
Recreational Action (ii) Seek to encourage recreation in 'preferred zones' to minimise disruption to other river systems.	• No recreational ‘zones’ have been established to date on the river. • Would happen with review of boating plan. Suggest passive recreation zone around Stotts Island?	• CMP Recreational Strategy to consider potential for zones
Recreational Action (iii) Monitor implementation of the Waterway Recreation Strategy for compatibility with existing ecosystems.	• Waterway Recreation Strategy (1992) out of date	• Recreational Use Strategy to be developed as part of this CMP
Recreational Action (vii) Confirm the need for further land areas for waterfront recreation and establish a priority list for possible future acquisitions.	• Sandy beaches limited in lower estuary. Some calls for beach creation from the public.	• Recreational Use Strategy to consider areas for acquisition and use for foreshore recreation area.
Navigation Action (i) Prepare a works program to extend and improve navigable waterways in the Tweed Estuary identifying	• Crown Lands dredging underway. Kingscliff Beach and Fingal beach	• Crown Lands carrying out

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
needs, priorities and castings.	nourishment.	dredging
Navigation Action (ii) Prepare a map for public use describing the location of existing and proposed navigation waterways.	• Not completed	• Recreational Use Strategy to consider public use and access
Navigation Action (iii) Confer with existing River Committees to ensure changes in navigation needs are identified and accommodated where feasible in updates to the RMP.	• Not completed	• Recreational Use Strategy to consider public use and access
Heritage Action (ii) Take expert advice as to how to risk least damage to unrecorded sites during development works.	• Tweed Shire and NPWS AHIMS mapping of sites is required to be considered in any development proposal. Recent mapping effort have created a comprehensive database of sites.	• Managed by existing DA process
Implementation Action (vi) Examine the practicality of organising a network of voluntary water quality analysts to collect data on turbidity, pH, BOD and other quality indicators.	• Not completed • TSC Water Quality Monitoring is ongoing	• none
Implementation Action (xii) Organise a fully independent assessment of river condition on a three year basis. The assessment to examine achievements won and reference progress being made in other river systems where alternative management systems operate.	• Water quality assessment is ongoing. Other ecological assessment at specific sites is undertaken.	• Detailed studies as part of the CMP to include a Water Quality Assessment. Reporting timeframes to be reviewed as part of assessment.
Area 1: Jack Evans Boat Harbour • Continue to monitor water quality and sediments to detect the presence of contaminants. • Search for opportunities to control stormwater related problems.	• TSC's ongoing water quality monitoring program includes a site in Jack Evans Boat Harbour • Major foreshore improvement and recreational amenity works completed 2011 incorporating extensive stormwater control and treatment works to ensure removal of pollutants prior to river discharge.	Detailed studies as part of the CMP to include a Water Quality Assessment
Area 2 Kerosene Inlet Wetland Area • Partition endangered bird roost areas • Continue ecological monitoring program • Develop a traffic management plan. • Seek to rehabilitate natural vegetation systems in the areas surrounding Kerosene Inlet.	• TSC proposed to do clearing of Mangroves at Keroscene Inlet where they are taking over important roost areas. Application made to Fisheries was not supported. • Baseline ecological assessment at Kerosene Inlet (Australian Wetlands, 2010). Follow up survey done by TSC. • 4wds still a problem. Australian Wetlands (2010) mention unauthorised access by 4wd as a 'pressure' on the system, particularly at northern end. • Compensatory works for highway, increase flushing by lowering rock wall. Algae on seagrass.	Action in CMP to review roost requirements Tonys Bar/Kerosene Inlet and consider re-application to clear mangroves. TBLALC manages this area
Area 3 Sponsors Reach • Develop management plan to control vehicular traffic • Continue ecological monitoring program in Sponsors Lagoon. • Integrate immediate improvement proposals into a	• Vehicles managed successfully. Action Completed. • Management Plan developed • New boat ramp constructed at Fingal. • Parkland near old boat harbour including children's playground recently	Considered self-sustaining

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
larger term rolling program for water related recreation and habitat improvements.	completed.	
Area 4: Wommin Reach • Prepare designs for new aquatic/wetland centre areas between Wommin Lake and Wommin Lagoon. • Prepare designs for improved ventilation of Wommin Lake and Wommin Lagoon. • Integrate immediate improvement proposals into a longer term rolling program for water related recreation and habitat improvements. • Examine options for routing urban stormwater away from Wommin Lagoon or seek methods to remove nutrients from the stormwater. • Examine the need for a higher standard of protection over wetland/aquatic areas.	• Wetland centre not pursued • Stormwater not considered a current issue • Recent drain/culverts installed 2008/2016	• TSC is aware of shoaling occurring at inlet to lake and there is a need to monitor this with regard to potential impacts
Area 5: Tonys Island Reach • Finalise designs for shoal removal and mitigation of midge problem at Tonys Bar. • Create additional secure bird habitat on Tonys Bar for the Little Tern and other vulnerable birds. • Seek high level of protection for vulnerable bird habitats. • Monitor benefits arising from bird and fish habitat enhancement works.	• TSC proposed to do clearing of Mangroves at Tonys Island where they are taking over important roost areas. Application made to Fisheries was not supported.	• Action in CMP to review roost requirements Tonys Bar/Kerosene Inlet and consider re-application to clear mangroves.
Area 6: Rocky Point Reach • Closely monitor the impacts of any maintenance dredging and other enhancement works. • Seek a high level of protection for bird habitats	• Bird habitats not considered at risk in this section	• none
Area 7: Ukerebagh Passage – • To prevent access by feral and domestic dogs, reduce the trafficability of the existing causeway remnants at the eastern end of Ukerebagh Passage • Install trash racks on all stormwater discharges into Ukerebagh Passage. • Establish a program to monitor key ecological indicators and a program to quantify and describe	• Ukerebagh Island Plan of Management (NPWS, 1999) lists elimination of pest species as a priority. The Plan discusses that fencing to restrict feral animals is not practical but limiting access points and installing signage, and through public education which explains the reasons for excluding domestic animals is recommended. • TSC's ongoing water quality monitoring program includes a site in Ukerebagh Passage	• Discuss environmental values, issues as raised through consultation

1991 Lower River EMP Actions	Actions undertaken and current status (October 2016)	Potential Considerations for CMP
influent pollutants discharging into the waterway. • Examine the need for a plan of minor selective maintenance dredging to revitalise inlet channels shoaled by urban sedimentation and to maintain the passage of a protective buffer for the island.	• No dredging works in Ukerebagh Passage have been undertaken and are not supported by NPWS unless impacts of estuarine fauna and birds are adequately assessed and found to have minimal impact.	
Area 8: Terranora Inlet • Allocate a high ranking for ongoing maintenance of Terranora Inlet waterways within any proposed program of river improvement works. • Undertake regular monitoring of navigable depths in Terranora Inlet.	• Terranora Inlet has been dredged a number of times to maintain the navigational channel at suitable and safe depths. The most recent dredging campaign was undertaken by Crown Lands in 2015. • Hydrographic survey is undertaken routinely as part of OEH monitoring and for specific dredging campaigns.	• Discuss Crown Lands Dredging campaigns
Area 9: Boyds Bay • Identify all stormwater inflows to the area and design suitable treatment measures (e.g. GPT) • Determine a suitable site to establish a future sullage pump out facility. Changed to-educate and encourage use of sullage pump out facility and increase regulation • Maintain acceptable water quality in authorised discharges. • Investigate methods of improving the quality of stormwater discharges.	• Stormwater issues in Tweed marina. Stormwater drains • Sewage Pump out facility located at the Tweed Heads Marina, owned and maintained by TSC. • The entire Tweed Estuary is a no discharge zone for both treated and untreated sewage from vessels (NSW Maritime, 2010).	• Consider options in CMP for stormwater improvements. Cross-ref with Council staff undertaken audits of existing stormwater assets
Area 11: Entrance Reach • Recognise the necessity for a long-term commitment to navigability.	• Since 2001, the Tweed River entrance has been actively managed by the NSW and QLD governments to maintain a safe entrance.	• none

APPENDIX 2: CLIMATE CHANGE 100 YEAR ARI FLOOD EXTENT (BMT WBM, 2014)


Ingleside
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point
LEGEND
100 Year ARI Flood Extent; Current Climate
100 Year ARI Flood Extent: 2100 Climate
Flood Prone Land
Tweed River
Principal Road
Sealed Road
Title:
Climate Change 100 Year ARI Flood Extent
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