Water Research Laboratory

Never Stand Still | Faculty of Engineering | School of Civil and Environmental Engineering

Collombatti-Clybucca Floodplain Remediation Feasibility Study

WRL Technical Report 2015/01
January 2017

By W C Glamore and D S Rayner

This project is supported by North Coast Local Land Services, through funding from the Australian Government

Water Research Laboratory
University of New South Wales
School of Civil and Environmental Engineering

Collombatti-Clybucca Floodplain Remediation Feasibility Study

WRL Technical Report 2015/01
January 2017

by
W C Glamore and D S Rayner

Project Details

Report Title	Collombatti-Clybucca Floodplain Remediation Feasibility Study
Report Author(s)	W C Glamore and D S Rayner
Report No.	2015/01
Report Status	Final
Date of Issue	January 2017
WRL Project No.	2014056
Project Manager	William Glamore
Client Name	North Coast Local Land Services
Client Address	PO Box 108, Kempsey, NSW, 2440
Client Contact	Max Osborne
Client Reference	NC-IS-14-15-2.5C

Document Status

Version	Reviewed By	Approved By	Date Issued
Preliminary Draft v1.0	W C Glamore		23/01/2015
Draft	W C Glamore	G P Smith	30/01/2015
Final	W C Glamore	G P Smith	30/01/2017

Water Research Laboratory
110 King Street, Manly Vale, NSW, 2093, Australia
Tel: +61 (2) 8071 9800 Fax: +61 (2) 9949 4188
ABN: 57 195 873 179
www.wrl.unsw.edu.au
Quality System certified to AS/NZS ISO 9001:2008

Expertise, research and training for industry and government since 1959

Expertise, research and training for industry and government since 1959

A major group within water@UNSW water research centre

Executive Summary

Construction of significant drainage infrastructure in the late 1960s and early 1970s, and the expansion of agricultural practices, has resulted in significant impacts to the wetlands of the Collombatti-Clybucca floodplain. The wetlands, once thriving with life, have been over drained by the construction of Andersons Inlet, Seven Oaks Drain and other infrastructure. This drainage scheme permanently changed the hydrology of the floodplain. Over-drainage resulted in the oxidation of acid sulfate soils, and provided an efficient pathway for the drainage of floodwaters as well as 'black water', acidic groundwater and associated by-products.

General impacts of the drainage works include:

- Clearing of vegetation
- Loss of native flora and fauna
- Loss of fish passage/habitat
- Poor water quality
- Oxidation of acid sulfate soils
- Consolidation of soils
- Low dissolve oxygen discharge
- Erosion and loss of sediment

Although the impacts of over drainage were identified by the mid-1970s, it was not until the late 1990s and early 2000s that remediation efforts began. These previous investigations identified the magnitude of the area affected and implemented strategies on the backswamp areas of Doughboy Swamp and Mayes Swamp to reduce surface scalding. However, despite these efforts poor water quality characterised by low pH, low dissolved oxygen (DO) and high metal concentrations continues to be discharged from the floodplain. Subsequently, the wetlands of the Collombatti-Clybucca floodplain have been identified as the highest environmental priority for the Macleay River Valley (Geolink, 2010, 2012). Broad-acre remediation of the site is unlikely unless the current land use practices are changed.

Currently, poor water quality from the floodplain impacts over 50 km of the lower Macleay River estuary during discharge events. During normal conditions, with a drain water level at mean sea level (0 m AHD), the drainage network holds approximately 500 ML of deoxygenated acidic water (pH ~ 3) that has high concentrations of aluminium and iron. This equates to approximately 220 Olympic swimming pools of vinegar (pH ~ 3) being discharged into the river at the first flush of a rainfall event.

To date, large-scale remediation of the site has been hindered by the complexity of multiple landholders on the floodplain. Recent land acquisitions by NSW Roads and Maritime Services, as part of offset requirements for the Oxley Highway to Kempsey Pacific Highway Project, have resulted in a single landholder owning a large portion of the worst acid affected areas of the floodplain (Figure ES.1). These acquisitions present a once in a lifetime opportunity to permanently remediate one of the most significant coastal backswamps in NSW.

Remediation of the site via a tidal strategy would result in significant conservation benefits to the local Collombatti-Clybucca area, and the wider Macleay River estuary. Outcomes of the strategy would include:

- Creation of approximately 1,540 ha of intertidal Endangered Ecological Community (EEC) habitat and 630 ha of freshwater habitat;
- Restoration of approximately 16 km of acidic waterways;
- Restoration of approximately 16 km of in-channel fish habitat;
- Approximately 1,540 ha to tidal flats, open water, tidal vegetation communities for primary production and migratory bird habitat;
- Enable habitat connectivity between wetlands in the wider Macleay River Valley;
- Reduce acidic discharges by buffering acid at the source;
- Provide significant carbon storage;
- Create migratory bird habitat which fulfils Australia's bilateral agreements; and
- Provide a long-term sustainable management of the site.

The tidal remediation strategy proposed provides the opportunity for large-scale remediation of the site. The re-introduction of tidal flushing will neutralise acid at the source and create significant EEC habitat. Detailed investigations are required to determine the full extent of tidal inundation, potential habitat distributions, and on-ground works required to mitigate impacts to adjacent landholders. Preliminary GIS 'bucket' modelling indicates that on-ground works in the order of $1,000,000 to $2,000,000 would be required.

Implementing the sustainable tidal remediation strategy involves further land acquisition of adjacent low-lying backswamp areas (Figure ES.1). Current RMS properties extend for the majority of the lowest-lying areas of the floodplain, Doughboy Swamp and Mayes Swamp. However, adjacent areas of the swamps remain as private holdings. Implementation of a tidal strategy without further acquisitions would require significant on-ground works to mitigate risks to adjacent properties. Additional acquisitions would enable the site to be operated as a single 'hydrological unit' and limit on-ground work requirements.

Although remediation has been previously attempted at a 'paddock scale', the site remains acidified and continues to discharge poor quality water into the Macleay River estuary. This report outlines the significant impact that drainage of the Collombatti-Clybucca floodplain has had on the local wetlands and wider Macleay River estuary and presents a strategy to remediate the site. The remediation option focuses on changing current land use practices to achieve large-scale remediation and habitat generation. The remediation strategy presents an opportunity to restore one the most significant coastal backswamps in NSW to the vibrant wetland it once was.

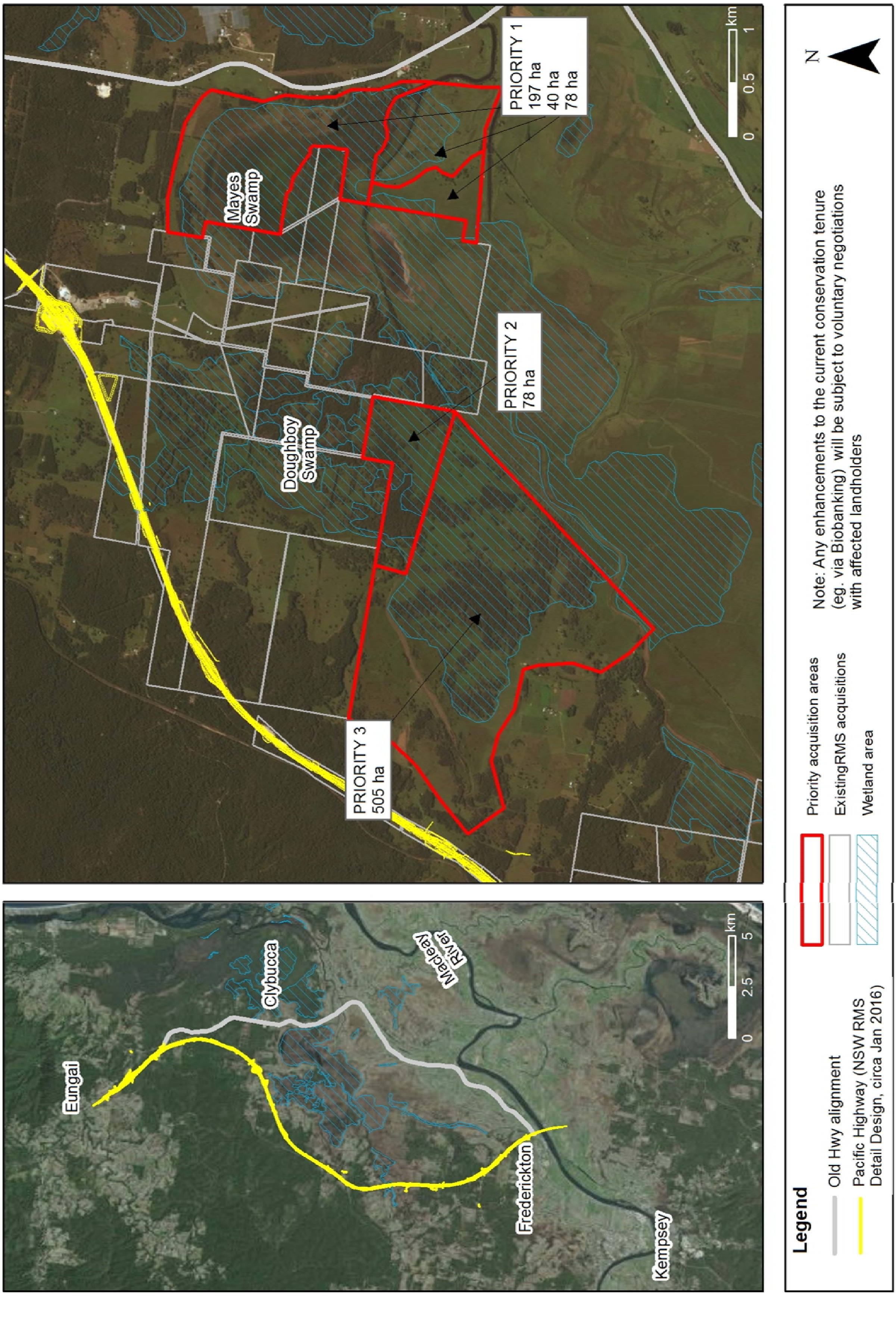


Figure ES.1: Overview of NSW RMS acquisitions across the Collombatti-Clybucca wetlands and identified priority acquisition areas

Contents

List of Tables

List of Figures

1. Introduction

The Collombatti-Clybucca wetland complex is located on the north floodplain of the Macleay River estuary, approximately 15 km from Kempsey on the NSW mid-north coast (Figure 1.1). The Collombatti-Clybucca floodplain has a catchment of approximately 26,000 hectares, which drains through the Seven Oaks Drain, Clybucca Creek and Andersons Inlet to the Macleay Arm, a north bank tributary of the Macleay River estuary. The wetland complex was historically one of the largest coastal freshwater backswamp areas in NSW featuring two key wetland areas of Doughboy Swamp and Mayes Swamp (Figure 1.2).

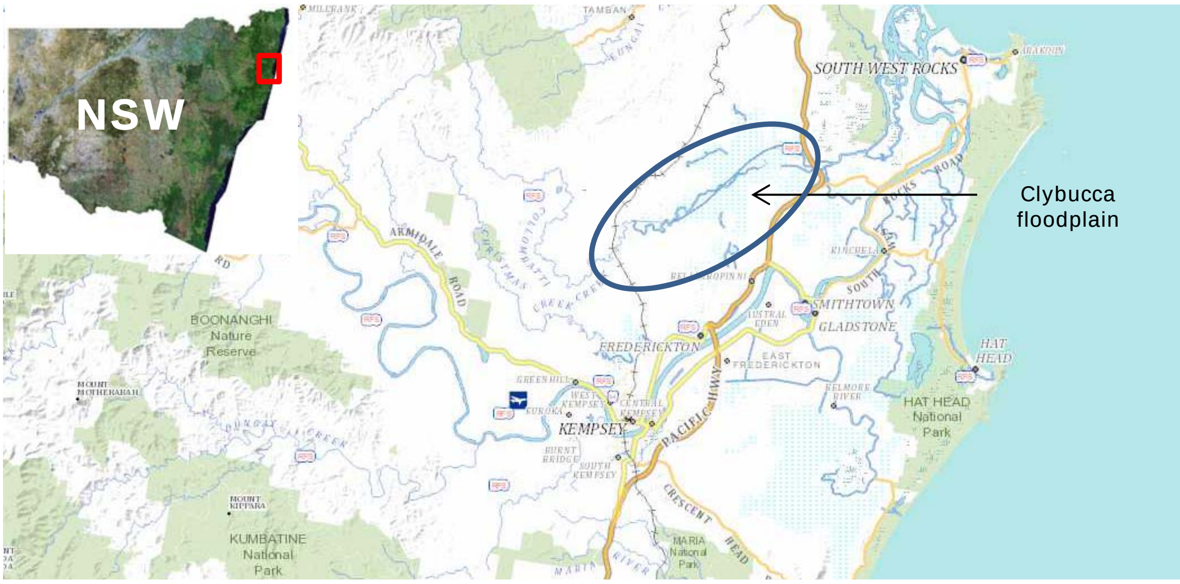


Figure 1.1: Collombatti-Clybucca floodplain location

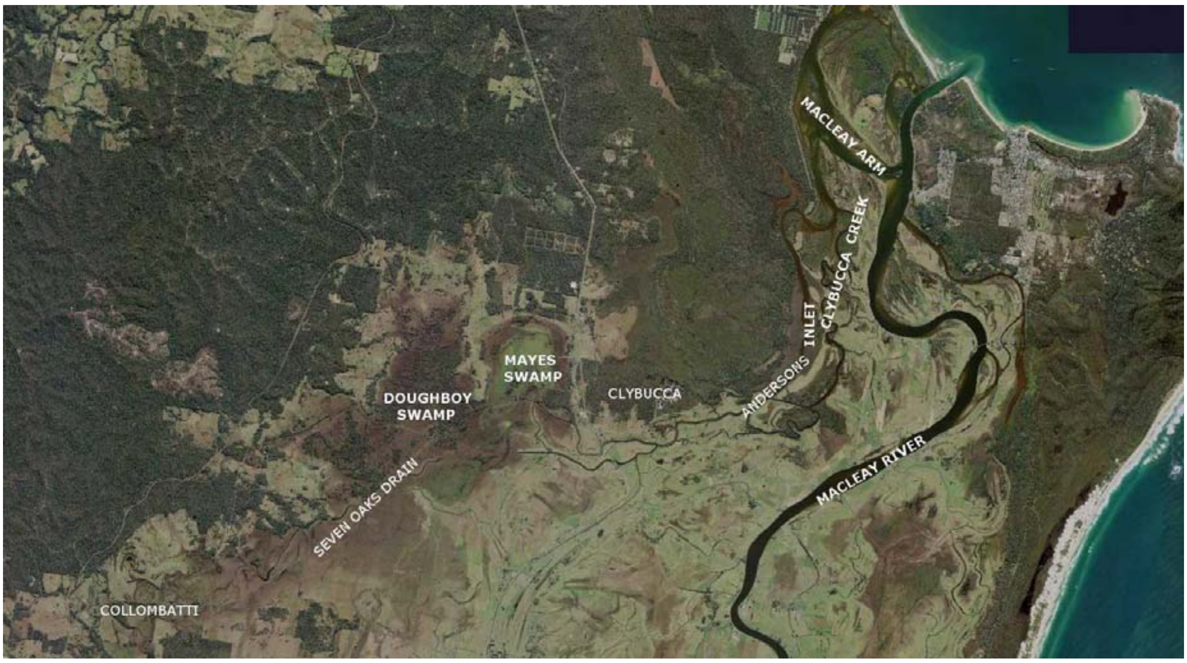


Figure 1.2: Key features of the Collombatti-Clybucca floodplain

The Collombatti-Clybucca floodplain is underlain with extensive acid sulfate soils (ASS) covering approximately 2,800 hectares of the lowest lying backswamp land (KSC, 2004). The ASS are typically within 1.0 m of the surface (KSC, 2004). Since being extensively drained and floodgated for agriculture in the 1960s, discharges from the Collombatti-Clybucca floodplain have impacted the local Clybucca region and the wider Macleay River estuary (Telfer, 2005). Over drainage of the ASS affected backswamps has resulted in increased generation and export of acid and associated by-products including iron and aluminium. Indeed, reduced aquatic productivity, including extensive fish kills, have been reported in Clybucca Creek for many years. Further, the Menarcobrinni floodgates, located within the Seven Oaks drain, impede tidal ingress, resulting in reduced fish passage, and creating a large reservoir of acidic water that is discharged every ebb tide.

Numerous studies undertaken over several decades (Walker, 1961, 1963 1972; Naylor *et al*, 1995; Webb McKeown, 1997; Tulau and Naylor, 1999; Cheeseman *et al*., 2004; KSC, 2004; Andrews *et al*., 2005; Chartres *et al*., 2005; McLennan *et al*., 2005; Telfer, 2005; Bush *et al*., 2006; Birch, 2010; GeoLINK, 2010; GeoLINK, 2012) have identified extensive acid sulfate soils in the Collombatti-Clybucca floodplain and significant water quality impacts on the wider estuarine health and productivity. Hurrell *et al*. (2009) noted that the most critical habitats for maintaining estuarine ecological health in the Macleay estuary occur within the Macleay Arm, which receives discharges from the floodplain.

Surface and groundwater discharges from the Collombatti-Clybucca system are characterised as:

- Highly acidic (pH ~ 3.0);
- Low dissolved oxygen (hypoxic); and
- High concentrations of metals (iron and aluminium).

In 2002, the Collombatti-Clybucca floodplain was selected by the NSW Government as one of seven (7) acid 'Hotspots' requiring immediate remediation. For many years, a large acid scald (approximately 400 hectares) in Mayes Swamp remained void of vegetation. Recent efforts have shown that improvements can be obtained via on-ground mitigation works. However, no solution to the large-scale discharge of acid from the Collombatti-Clybucca floodplain has been achieved. Limitations to successful broad-acre restoration have included multiple landholdings and the lack of natural acid buffering. The drainage system currently has no acid buffering, with each rainfall event flowing through the drainage network and across the floodplain, becoming acidified, and then being discharged into the Macleay River estuary.

The quality of water discharged from backswamp wetland areas has been identified as a high priority issue to the Macleay River estuary in the Macleay River Estuary Management Study (Geolink, 2010). The Collombatti-Clybucca drainage scheme has been identified as the highest priority wetland area in the Macleay catchment with the Macleay River Estuary Coastal Zone Management Plan (CZMP) (Strategy 7). Improvements and remediation of the Collombatti-Clybucca drainage scheme (and associated structures) and wetlands encompasses the aims of all high priority strategies outlined in the CZMP.

Restoration strategies range from enhanced freshwater ponding to full tidal restoration to promote acid neutralisation. Proven experience (Rayner and Glamore, 2011; Glamore *et al*., 2012; Glamore *et al*., 2014) at other similar sites has shown that effective remediation of these extremely acidic backswamps can be achieved through a change in land management. Undertaking remediation across entire hydrological units (i.e. continuous swamp/wetland areas) has been shown to provide the most practical and cost effective outcomes, and significant conservation benefit. The most effective solution includes the reversion of the lowest lying, most acid affected land from subsistence agriculture to Endangered Ecological Community (EEC).

2. Current Situation

Until now, remediation of the Collombatti-Clybucca floodplain has been impeded by a large number of private landholders and existing land practices. This has limited on-ground remediation works and associated environmental improvements over complete hydrological units. Given the limited success of smaller scale remediation attempts, the current view is that the only significant way to reduce water quality impacts, increase estuarine productivity and restore EECs will require a catchment wide solution. This chapter outlines the current situation regarding recent land acquisitions and general requirements to progress a remediation strategy.

The NSW Roads and Maritime Services (RMS) recently purchased a number of properties within the Collombatti-Clybucca floodplain as biodiversity offsets associated with the Oxley Highway to Kempsey (OH2K) Pacific Highway Upgrade project (Figure 2.1). For the first time since initial settlement of the Collombatti-Clybucca area, a single landholder owns the majority of the worst affected acid land. The RMS properties extend from higher ground, to low-lying backswamp floodplain areas. These properties were purchased to utilize the higher elevation land as biodiversity offsets with the low-lying wetland area (approximately 2,300 ha) not included within the offset requirements.

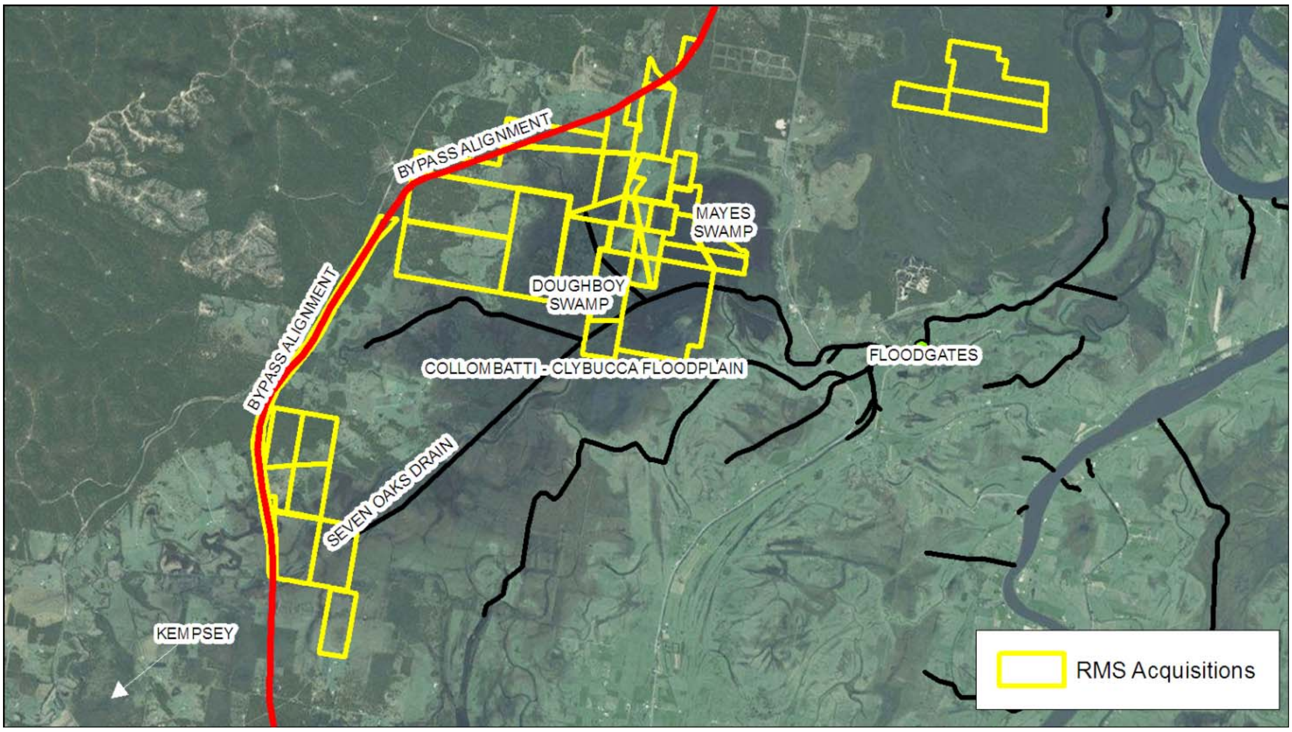


Figure 2.1: RMS land acquisitions

The recent purchase of properties by NSW RMS provides a once-in-a-lifetime opportunity to rehabilitate the degraded landscape. Remediation of the low-lying acidic areas of Mayes and Doughboy Swamps from poor agricultural land to a dynamic wetland would provide:

- The creation of higher order communities/EEC and subsequent improvements in terrestrial and aquatic biodiversity;
- Significant improvements in water quality within the adjacent waterways and broader Macleay River estuary with improved acidity and dissolved oxygen, reduced iron and aluminium loads and reduced turbidity;
- Reduced sediment loads being discharged into the Macleay River estuary;
- A high level of positive change to the existing degraded environment;
- Significant increase in aquatic biodiversity and estuarine primary productivity; and
- Improved health and productivity of the Macleay River estuary.

The purchase of additional adjacent floodplain properties would enable all directly connected wetland areas to be remediated, hence providing a sustainable management strategy (Figure 2.2). These additional acquisitions enable the lowest lying, worst acid affected land to be remediated and managed as a single, continuous hydrological unit in the most cost-effective method.

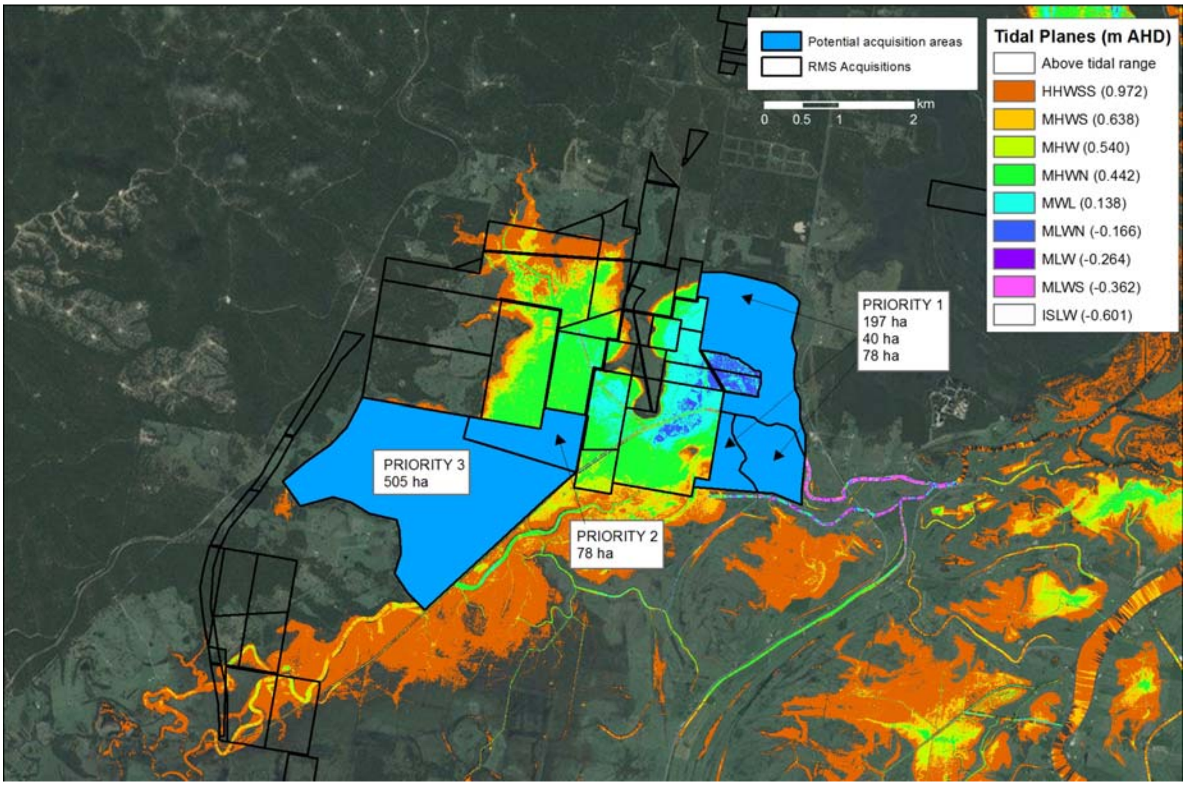


Figure 2.2: RMS properties recommended acquisition areas

For the wetland areas of the RMS properties to be utilised as an offset, it is essential that the environmental costs and benefits are clearly documented and tracked. The proposal to use the RMS wetland areas as a non 'like-for-like' offset, known as a 'Supplementary Measure', requires that the wetland offset proposal provide a net conservation benefit. The NSW Environment Protection Authority (EPA) has provided recommendations for furthering the wetland offset proposal and note that the approach to deliver a net conservation benefit is consistent with the NSW Biodiversity Offset Policy for Major Projects and is similar to trading into an offset community that "*is under the same or greater level of threat*". The EPA notes that consideration of the wetland proposal will only be given in place of like-for-like offsets after *"all reasonable steps have been taken to secure the number and types of species and ecosystem credits impacted at the development site".*

The EPA recommends that the framework for further considering the proposed biodiversity offset package includes:

1. Clear acknowledgment of the agreed policy framework and principles against which the proposal must be assessed.
2. Transparent accounting of the current offset package, including the extent to which to 'like-for-like' principle has been satisfied and any residual offset which is proposed to be offset via the wetland proposal.
3. Clear demonstration of the conservation benefits associated with the wetland proposal, which should clearly explain the net benefits of moving away from a 'like-for-like' principle.
4. Demonstrating that a co-ordinated management approach, involving the Clybucca Working Group, in the implementation of management strategies to address the acid sulfate soil issues and thereby improve the water quality and ecological values of the wetlands, can be delivered.
5. Demonstrating the ability to manage the catchment in part versus the entire catchment (e.g. saltwater impacts on private landowners) and effective land managements in perpetuity are achieved.
6. Conservation assessments of all proposed land parcels including vegetation type, condition and fauna habitat values are completed.

Points 1 and 2 above are items directly addressed by NSW RMS. This report addresses points 3, 4 and 5 above:

- Point 3 is addressed in Section 7 (Conservation Benefits of Remediation) of this report.
- Point 4 is addressed in Section 8 (Ongoing Management) of this report.
- Point 5 is addressed in Section 9 (Remediation Options) in conjunction with Section 8 (Ongoing Management).

Point 6 will be addressed upon agreement of the offset strategy.

Other sections of this report are included to provide the necessary background and technical support for the supplementary measure offset proposal. Correspondence from NSW EPA regarding the wetlands offset proposal for the Oxley Highway to Kempsey Pacific Highway Upgrade is attached in Appendix A.

Additional relevant correspondence between WRL, NSW EPA, and NSW OEH relating to the justification and benefits of remediation of the Clybucca wetlands is attached in Appendices D, E and F.

3. Site Background

The Collombatti-Clybucca floodplain has undergone significant transformation from a natural coastal wetland complex, to a drained agricultural floodplain. The impacts of drainage were observed in the years following construction of major drainage infrastructure, however it was not until the 1990s that investigation into remediation began. Despite ongoing remediation efforts through the early 2000s, the site remains extensively drained with highly acidic poor water quality being discharged from the site into the wider Macleay River estuary. The remediation strategy presented in this report provides a methodology to restore the once thriving wetland ecosystem.

This section outlines the modern drainage history and environmental impacts of drainage at the Collombatti-Clybucca floodplain and Seven Oaks drainage areas. Understanding the history of the site is critical to developing a conceptual understanding of acid sulfate soil generation and onsite remediation strategy.

3.1 Site Overview

The Collombatti-Clybucca floodplain consists of extensive low-lying backswamp wetland areas centred around Collombatti Creek and Seven Oaks Drain (Figure 3.1). The area is drained by the Seven Oaks Drain and grades to the northeast with elevations ranging from approximately – 0.3 m AHD in Mayes Swamp to 1.0 m to 2.0 m AHD at the western extent of the floodplain. The elevations across Mayes and Doughboy Swamps are some of the lowest in the Macleay River floodplain with land below mean sea level (Figure 3.2). A pictorial overview of the floodplain is presented in Figure 3.3.

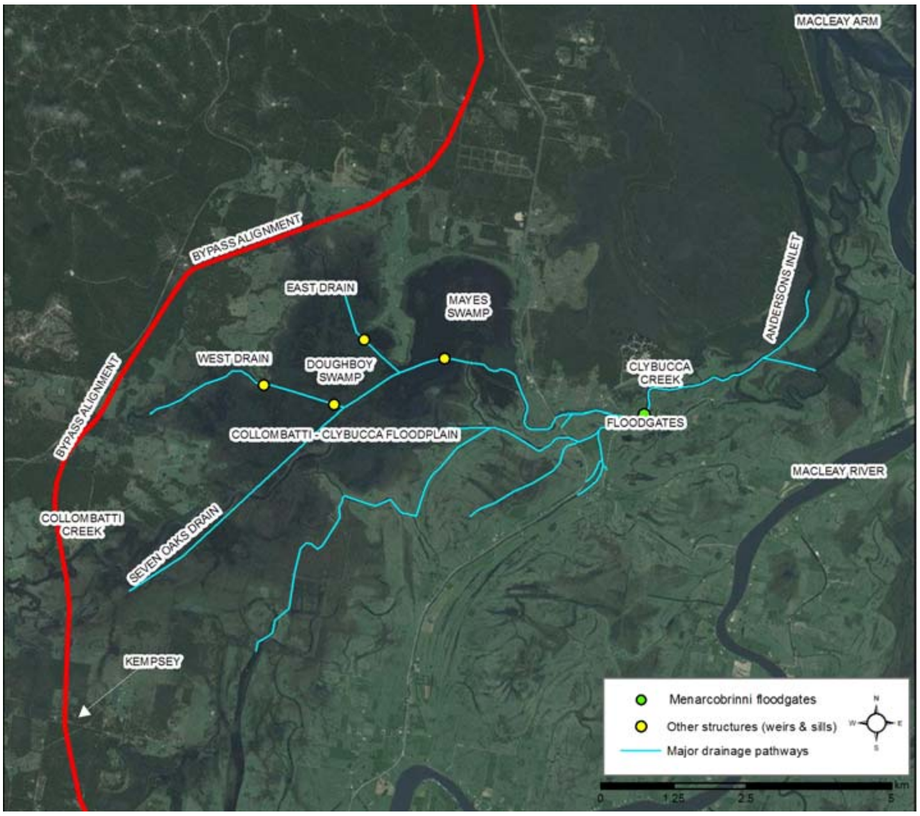


Figure 3.1: Collombatti-Clybucca floodplain overview

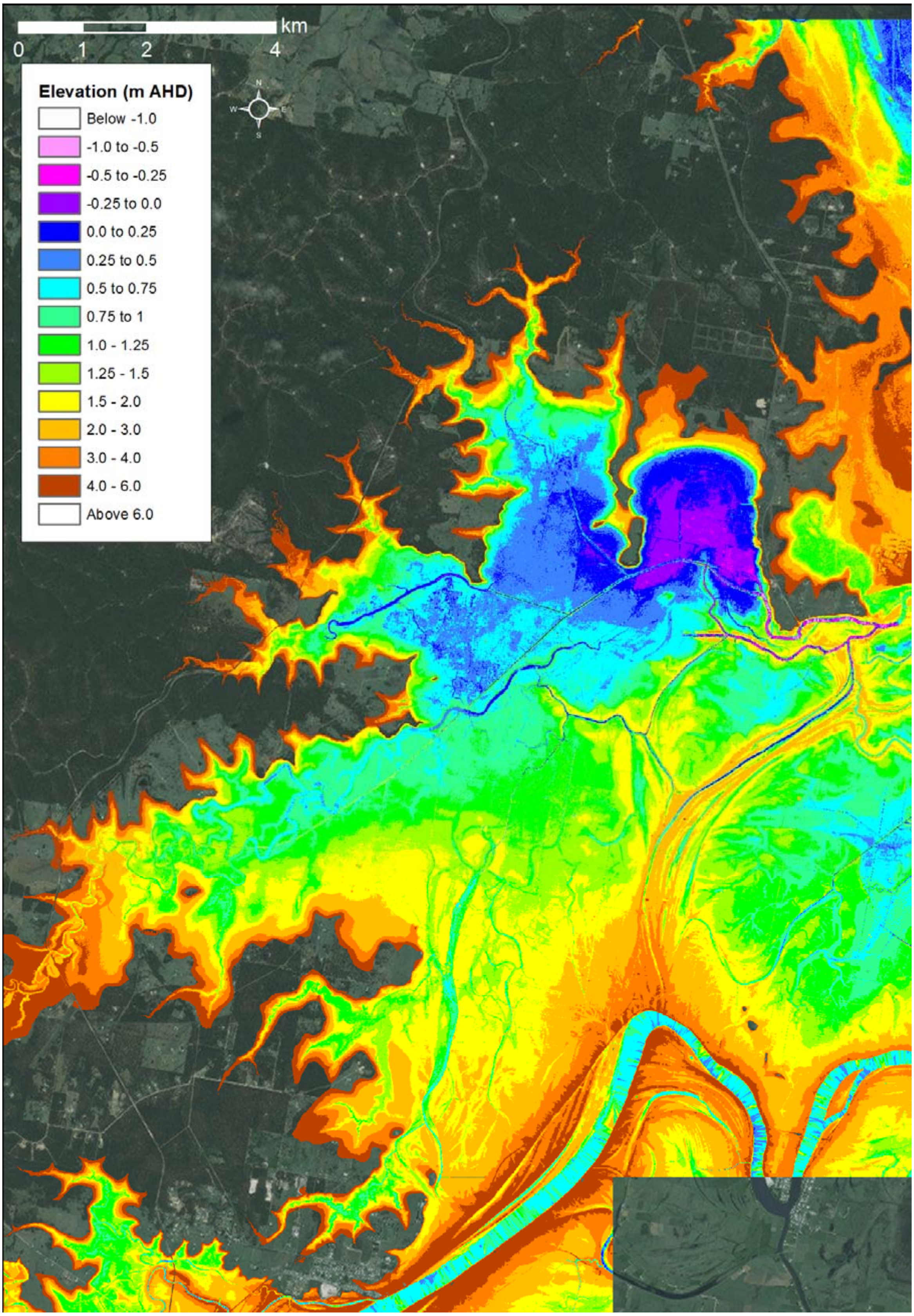


Figure 3.2: Topography of the Collombatti-Clybucca floodplain (note that 0 m AHD is Mean Sea Level)

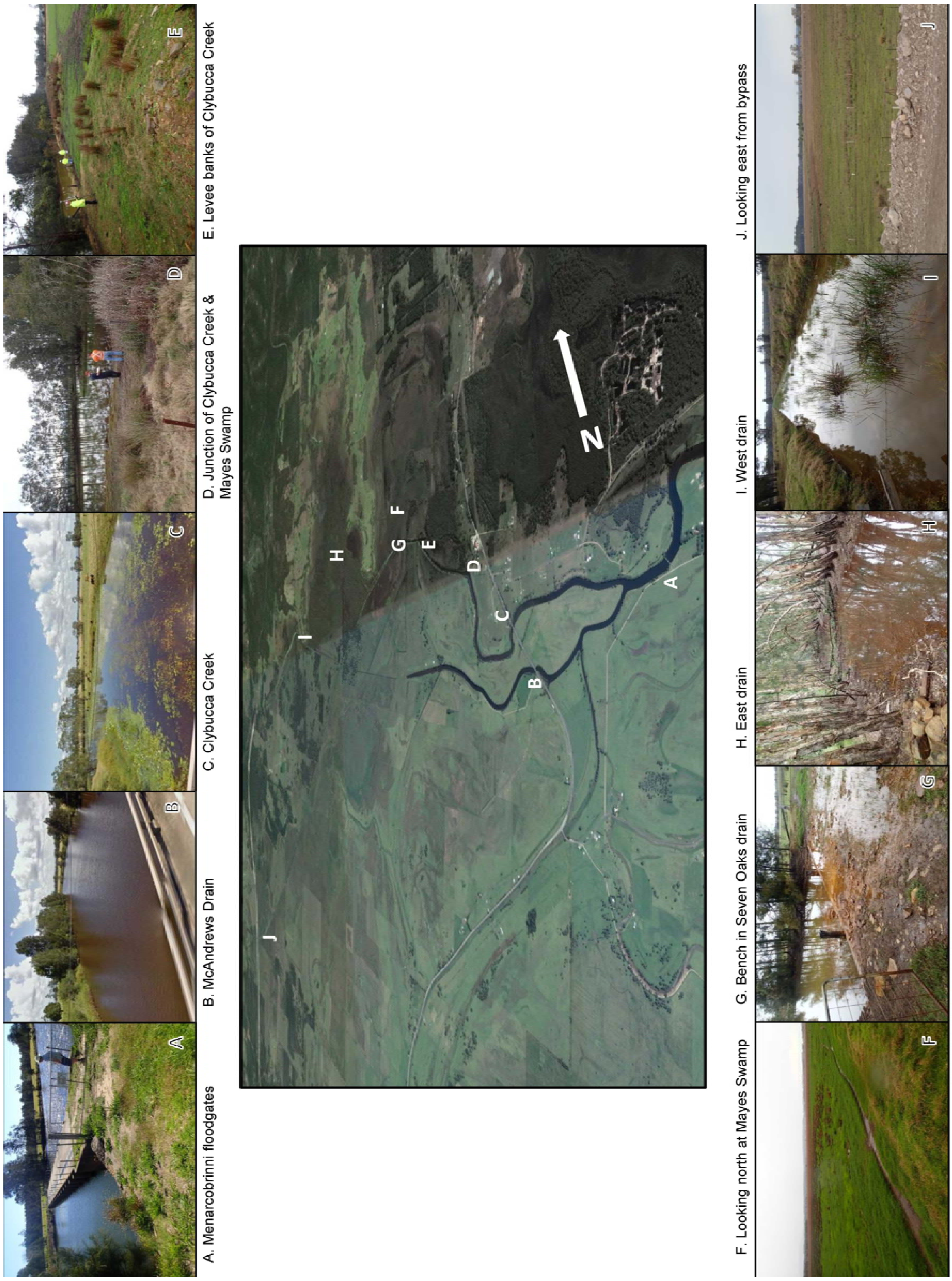


Figure 3.3: Overview of current floodplain (note that the shadow on the aerial image is due to different aerial imagery data sets being joined)

3.2 Drainage History

The Clybucca Swamp was once the largest contiguous open freshwater backswamp on the north coast (Tulau, 2011). Prior to being extensively drained, the wetland complex '*flourished with life*' and was identified as a valuable habitat for waterfowl (PWD, 1978). A range of important habitat was identified, including seasonal fresh swamps, fresh meadows, Sheoak swamps and reed swamps. Downstream of the Menarcobrinni floodgates in Clybucca Creek and Andersons Inlet extensive mangrove and saltmarsh habitats have been noted (PWD, 1978; Telfer, 2005; Hurrell *et al*., 2009). Observations by early settlers describe the Clybucca wetlands as '*extensive swamps and lagoons of many thousand acres in extent, whose verdant sea, of high waving reeds and sedge, stretches away to the base of the distant forest ranges. Large flocks of aquatic birds of wonderful variety, all busily engaged, and fish leaping out of the water in every direction*' (WetlandCare Australia, 2010).

Historically, the wetter swamplands were utilised by early settlers as grazing areas during dry periods. Efforts to improve the productivity of the Clybucca Swamp began as early as the 1880s, with a main drainage channel constructed by 1884, with headworks implemented at Clybucca Creek by 1895 (Tulau, 2011). The headworks primarily consisted of a concrete dam designed to inhibit saltwater intrusion. At the turn of the 20th century, the Public Works Department (PWD) undertook extensive surveys of coastal floodplains and outlined drainage plans for the Macleay River. Significant funding to undertake drainage activities followed the passage of the *Water and Drainage Act 1902* (Tulau, 2011).

Following World War 1, the clearing and draining of coastal backswamps along the NSW coast intensified. Opportunities for returned servicemen were provided in the form of affordable, arable land. In the Macleay River floodplain, construction of drainage infrastructure was a contentious issue, with some landholders experiencing adverse impacts from drainage works and questioning the effectiveness and efficiency of the drainage schemes. Following the formation of the Seven Oaks Drainage Union in August 1924, some landholders noted that "*the land… will depreciate in value by drainage*" (Tulau, 2011).

Further flood mitigation infrastructure and drainage works were undertaken along the NSW coast following World War 2. In the Macleay River Valley, the large floods of 1949 and 1950 resulted in construction of the Macleay Flood Mitigation Scheme (KCS, 2004). Major works included expanding the connection between Clybucca Creek to Andersons Inlet by excavating into layers of coffee rock (Figure 3.4), constructing the Seven Oaks scheme and upgrading the Clybucca headworks to the current Menarcobrinni floodgates (Figure 3.5). By the late 1970s, there were 69 kilometres of constructed drains in the Collombatti-Clybucca area (Tulau, 2011).

Construction of Andersons Inlet is of particular importance to the backswamp wetland areas of the Collombatti-Clybucca wetland. The construction works significantly improved the efficiency that floodwaters could drain from the floodplain during wet times. However, Andersons Inlet also provided improved efficiency for tidal waters to extend into the Collombatti-Clybucca area. This improved efficiency resulted in the construction of the Menarcobrinni floodgates to prohibit tidal flushing of the low-lying backswamp areas.

Figure 3.4: Clybucca Creek to Andersons Inlet cutting, 1966 (Kempsey Shire Council via Tulau, 2011)

Figure 3.5: Clybucca Creek headworks (Menarcobrinni floodgates)

The timeline of drainage and flood mitigation works on the Collombatti/Clybucca floodplain is provided in KSC (2003) and Tulau (2011) as follows:

- 1884: Construction of main drain through Clybucca Swamp
- 1895: First headworks at Clybucca Creek
- 1898: Drainage schemes designed for northern and southern floodplains of Macleay River
- 1901: Macleay River swamps drainage survey and plans developed
- 1902-04: Lower Macleay River Drainage Scheme prepared
- 1924: Formation of the Seven Oaks Drainage Union
- 1955: Macleay River Flood Mitigation Scheme commences
- 1959: Seven Oaks investigations
- 1966-70: Clybucca drain improvement and headworks upgrade

1966: Stage 1 Clybucca drain improvement with excavation between Clybucca Creek and Andersons Inlet
1968-69: Stage 1 Clybucca drain improvement involved widening and deepening of 7 km of Clybucca Creek
1968: Stage 1 of Seven Oaks drainage scheme implemented
1969: Stages 2, 3 of Seven Oaks drainage scheme implemented
1973: Seven Oaks drainage scheme completed
1975-1979: Improvement of East and West drains (i.e. deepening and widening)
1993-2002: Remediation efforts on Doughboy Swamp and Mayes Swamp including the trial of modified floodgates and the construction of weirs and earthen sills in East Drain, West Drain and Seven Oaks Drain.

The present day drainage infrastructure of the Collombatti/Clybucca floodplains includes five (5) key structures and over 25 km of flood mitigation drains (Table 3.1, Figure 3.6).

Table 3.1: Key floodplain drainage

Infrastructure	Type	Specifications
Seven Oaks Drain	Channel	16,000 m x 15 m at bank (approx.) 11 m bed width at -1.2m AHD from Clybucca Creek to West Drain 6 m to 9 m bed width at – 1.0 m AHD to 0.0 m AHD upstream of West Drain
East Drain	Channel	2,300 m x 7 m at bank (approx.) 3.5 m bed width at -1.0 m to 0.0 m AHD Invert = – 0.7m AHD (approx.) Additional private drains = 9 km Additional natural channels = 6 km
West Drain	Channel	1,300 m x 7 m at bank (approx.) 3.5 m bed width at -1.0 m to 0.0 m AHD Invert = – 0.7 m AHD (approx.)
McAndrews Drain	Channel	3,660 m x 40 m at bank (approx.) 35 m bed width at -1.2 m AHD Invert = – 1.2 m AHD
Menarcobrinni headworks (Clybucca Creek floodgates)	Floodgate	21 floodgate chambers 1.8 m wide x 2.1 m high Invert = – 2.1 m AHD Crest = 1.5 m AHD
Yerbury's Sill	Weir	Crest = – 0.3 m AHD
East Drain weir	Weir	Crest = – 0.15 m AHD
West Drain weir 1	Weir	Crest = 0.1 m AHD
West Drain weir 2	Weir	Crest = 0.2 m AHD

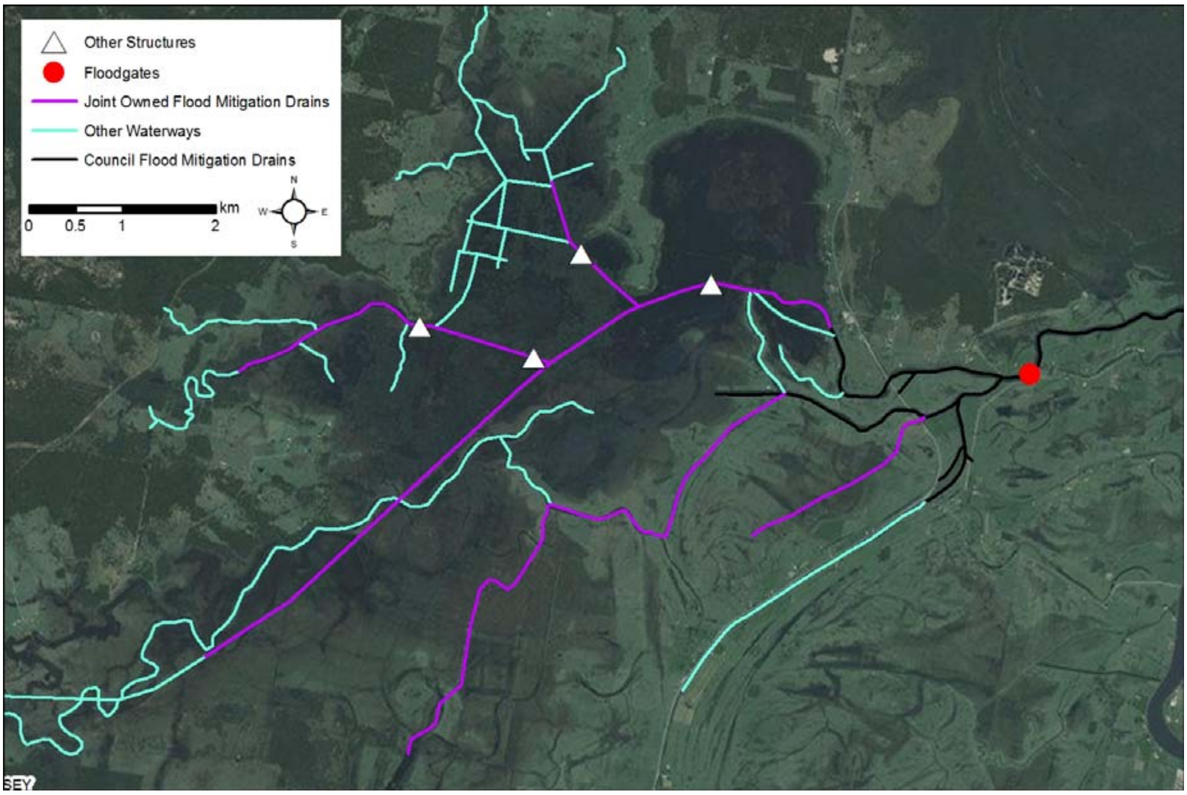


Figure 3.6: Existing drainage and infrastructure

3.3 Impacts of Drainage

The construction of the drainage works on the Collombatti-Clybucca floodplain and subsequent expansion of agricultural practices resulted in a number of impacts including:

- Clearing of vegetation
- Loss of native flora and fauna
- Loss of fish passage/habitat
- Poor water quality
- Oxidation of acid sulfate soils
- Consolidation of soils
- Low dissolve oxygen concentrations
- Erosion and loss of sediment

The potential damage of draining wetlands in the Macleay River valley was vocalised as early as 1968 by Allen Strom, Secretary of the National Parks Association (NPA), who warned the Macleay River County Council (MRCC) engineering staff that *"any further drainage of the Macleay wetlands could be disastrous"* (Tulau, 2011). However, it was not until the summer of 1970-71 that serious concerns about poor water quality arose (Tulau, 2011). By late 1972, the water draining from Clybucca and the nearby Yarrahapinni area began affecting water quality at South West Rocks. Similarly, residents at Stuarts Point claimed that polluted waters were threatening their tourist, fishing and oyster industries (Tulau, 2011).

The Collombatti-Clybucca floodplain has a long history of water quality issues. The extensive drainage works of the Macleay Flood Mitigation Scheme in the late 1960s reduced pasture inundation following flooding, however the deeply incised drainage works oxidised significant areas of acid sulfate soil affected floodplain and provided a direct flowpath for surface and ground water to be discharged into the Macleay River estuary (Enginuity Design, 2003). The drainage works also increased the frequency and rate of discharge for low DO water, known as 'black water', as well as acid and associated oxidised by-products from backswamp areas into the estuary (Enginuity Design, 2003).

The wider economic impact of backswamp drainage was noticed in the early 1970s. Although fish kills have historically occurred in the rivers of North Coast NSW following large floods, fish kills and poor water quality began impacting commercial and recreational fishers, and local oyster farmers with increasing regularity (Tulau, 2011). The fish kills were usually associated with black water events, whereby very low anoxic waters are discharged from the floodplain following prolonged periods on inundation (as a result of decaying organic matter which consumes dissolved oxygen in surface waters). Between 1977 and 2009, NSW Department of Primary Industries recorded 42 reports of fish kills on the estuarine waters of the Macleay River estuary (Birch, 2010) (Figure 3.7). A large fish kill in 2001 closed fishing in the estuary for three (3) months, with fish stocks taking 5 months to show signs of recovery (Kennelly and McVea, 2002).

Oysters, fish die in rivers

POLLUTION BLAMED FOR MASSIVE KILL

Oyster farmers on the lower Macleay have lost stock valued at thousands of dollars and many of the river's fish breeding grounds have been seriously affected in the past couple of days by the discharge of floodwaters into creeks and streams.

In the latest incidence of water pollution, oyster growers in the Clybucca Creek area are putting their losses in excess of $60,000. They blame them on flood mitigation works carried out in Clybucca Creek, Yarrahappinni and Andersons Inlet eight to 10 years ago.

The discharge from Lower Macleay swamps is also blamed for the huge fish kill which appears to have wiped out breeding grounds in Belmore River, Kinchela Creek, Spencers Creek and the Stuarts Point arm of the Macleay River.

Thousands upon thousands of dead fish, killed apparently by lack of oxygen, are floating in creeks and streams, creating a health hazard as they begin to decay.

The Kempsey Shire Council, told of the situation yesterday, had no answers to it when contacted mid-afternoon.

The health surveyor (Mr. J. H. Bow... the situation w... assessed and ... was done the p... getting rid of the carcasses would then be tackled.

The district inspector for State Fisheries (Mr. J. Beattie) yesterday alerted his head office. Water samples were collected and sent to Sydney for analysis.

Mr. Beattie does not know what killed the fish. He believes lack of oxygen to be the cause and this supports information given to the "Argus" yesterday.

A reporter said thousands of fish had been seen on Saturday swimming with their heads above water close to the banks and obviously sick.

By Sunday, most were dead. River mullet, small perch and eels up to two metres in length were victims of the "kill."

The reporter said the Belmore River in particular seemed to have little flow, particularly around the headworks where dead fish were scarcely moving. At that ... test under flood conditions last week.

Mr. Beattie said his inspection of the lower Macleay River system yesterday had revealed huge numbers of dead fish in the river between Jerseyville and Smithtown and as far up the Belmore River as the Seale Road bridge.

Fishermen who have lived on the Macleay all their lives claim most of the troubles began in 1967 when certain drainage schemes were constructed by the flood mitigation committee.

Since then, they say, flood and stormwater drainage from the Clybucca and Yarrahappinni catchments has been forced down the old bed of the river.

There have been repeated claims that flood mitigation works in Clybucca Creek have changed tidal patterns.

Andersons Inlet, opened to make a new bed for the Clybucca Creek, is being blamed for losses by many oystermen.

Mr. Bill Barber, manager of Mr. Oyster Company, said yesterday he had already lost 33 per cent of his maturing oysters in Anderson's Inlet. He had moved 500 trays of oysters to his farm at Renwick's Island.

Mr. Barber put the value of each tray at $30. He still had to move 27,000 sticks of oysters valued at between $1.20 and $1.50 a stick.

Of these, he expected to lose between 60 and 70 per cent.

Other oyster farmers forced to move their stock were Messrs Rex Nunn and James Byrnes, and George Cameron and Ron Biddell.

About 1,000 trays of oysters are believed to have been moved from the Golden Hole - Andersons Inlet area.

Oysters are only able to survive for about three days in the polluted water.

Oyster farmers with stock below the "barrel" are not so seriously affected by the flood discharge.

Mr. Barber said black water from the Kinchela area was killing fish in Spencers Creek, something he had never seen in his 48 years on the Macleay.

He believed the pollution problem was as bad as last year's and reiterated that floodwater was being "ponded" by the flow from Broadwater and the head of Clybucca Creek.

He said that until the flood channel was cut through Andersons, the problem now existing was unheard of. It had also been aggravated by the construction of headworks and levees on the Broadwater.

Dead fish at the Belmore River headworks.

Figure 3.7: Article from the Macleay Argus, 15 March 1977, p.1 (via Tulau, 2011)

By the mid-1970s, the reduction in fisheries and oyster yields was significant and there were public calls to open the Yarrahappinni floodgates and Clybucca Creek headworks (Tulau, 2011). Department of Fisheries biologist Desmond Dunstan noted that the estuary previously supported 33 full-time commercial fisherman and had diminished to two fulltime fisherman by 1976 (Tulau, 2011). The oyster industry in Anderson's Inlet and Clybucca Creek also suffered a similar fate. In March 1976, oyster mortalities were 50% and in March 1977 reached 80% (Tulau, 2011). The reduction in fisheries and aquaculture production was attributed to a combination of habitat loss through the floodgating and draining of backswamp areas such as Clybucca and Yarrahapinni, and the resulting poor water quality being discharged (Tulau, 2011).

During this period the landscape was also observed to dramatically change and by 1976 large areas of the Clybucca floodplain were scalded and featured toxic levels of aluminium salts on the surface (Tulau, 2011). What was noted by local landholders to be *"once a swamp area capable* *of carrying 30 to 35 head of cattle throughout the year, had been dried out and now carried nothing"* (Macleay Argus via Tulau, 2011). The subsequent degradation and large scale acid scalding of Mayes and Doughboy Swamps resulted in ongoing agricultural difficulties and the loss of the wetland ecosystem.

The lower Macleay River estuary continues to be impacted by discharges from floodgated backswamps. In March 2001 a large fish kill event following flooding closed recreational and commercial fishing on the lower estuary for three months (Walsh *et al.,* 2004). Walsh *et al.* (2004) estimated that a 1.5 km stretch of river near South West Rocks contained approximately 180,000 individual fish of various species. At the time of the fish kill, DO was measured to be below 1 mg/L and pH below recommended levels.

3.4 Recent Remediation Investigations

3.4.1 1990s

Investigations into acid sulfate soils and potential remediation options began in 1993 on the southern part of the drain in Mayes Swamp. Fifteen demonstration sites were established to modify drainage lines with a view of raising the water table in affected ASS areas (Tulau and Naylor, 1999). This project involved the creation of small levees, or bunds, to retain surface waters. Earthen sills were also constructed in some drains, aimed at increasing the groundwater table and reducing over-draining. A major earthen sill was constructed in the Seven Oaks drain at the southern extent of Mayes Swamp to an elevation of – 0.2 m AHD. Management options were also investigated including:

- Wet pasture management and grazing;
- Enhancing wetland habitat values; and
- Reducing the potential for acid discharge into the estuary.

Smith (1997) noted that establishment of pasture on previous acid scalds was successful following the 1993 remediation trials, however the pH of the ponded water at the demonstration sites was recorded to be pH 3.5, with acidic discharges continuing. Tulau and Naylor (1999) noted that up to 0.5 m of standing water occurred regularly in many of the demonstration sites.

In 1999, funding was received by the Seven Oaks Drainage Union to modify the existing floodgate structures at Menarcobrinni to allow for tidal flushing and fish passage (Smith, 1999). Two (2) of the 21 floodgates were modified to incorporate sluice gates, however management of the gates proved difficult. Saline inundation of low lying areas of the floodplain raised significant concern with potential impacts to vegetation and agricultural productivity (KSC, 2004). The modified gates were closed after a short trial period.

3.4.2 Hot Spot Program

In 2000, the NSW Government provided funding for a state wide ASS strategy known as the ASS Hot Spot Remediation Program. The aim of the program was to reduce the frequency, intensity and duration of acid discharge events from identified acid sulfate soil sites. Stage 1 of the program included developing remediation measures for seven (7) of the 26 identified Hot Spots. The seven Stage 1 sites were:

- Collombatti-Clybucca floodplain, Macleay catchment;
- Broughton Creek, Shoalhaven catchment;
- Lower Lansdowne, Manning catchment;
- Partridge Creek, Hastings catchment;

- Upper Maria, Hastings catchment;
- Everlasting Swamp, Clarence catchment; and
- Cudgen Lake, Tweed catchment.

Significant acid sulfate soils investigation at Collombatti-Clybucca were undertaken between 2002 – 2004. Investigations focused on acid scalds located in Mayes and Doughboy Swamps, and the main drainage channels of Seven Oaks Drain, East Drain and West Drain. Outcomes from the remediation works undertaken at Collombatti-Clybucca for the Hot Spot program included:

- Investigating acid sulfate soil composition and resulting groundwater quality;
- Rehabilitating major surface scalds on Mayes and Doughboy Swamps (on the previous Latham and Yerbury properties);
- Constructing weir structures in East and West drains to maintain an elevated groundwater table;
- Analysis of water quality, hydraulic conductivity, surface acid salts, groundwater gradients; and
- Construction of exclusion fencing to enhance wetland areas and prevent overgrazing.

Monitoring undertaken at the Menarcobrinni floodgates between 1998 to 2004 continued to measure extended periods of low pH and low DO discharges (Enginuity Design, 2003), indicating that the remediation efforts achieved improvements in local agriculture and pasture condition but poor water quality continued to be discharged from the Collombatti-Clybucca floodplain. These findings are in-line with detailed research undertaken by Blunden (2000) which highlighted that once acidified, raising the ground water table has limited influence on reducing acidity or metal concentrations in drain waters.

3.4.3 Other Improvements

Recent floodplain remediation by WetlandCare Australia (2010) has promoted the conservation of wetland values on the floodplain through promotion of stock control, control of introduced fauna and control of weeds. WetlandCare Australia (2010) also outlined management plans for seven (7) key holdings which cover large areas of the Clybucca wetland complex. The plans focus on fencing around waterways and wetland areas in conjunction with weed and pest control and recommend maintenance of weir/earthen sill structures throughout the Seven Oaks drainage area.

The concept management plan outlined by WetlandCare Australia (2010) recommends that floodgate redesign be investigated; including decommissioning of the main Menarcobrinni floodgates and construction of a series of floodgates and fish-friendly weirs at targeted upstream locations. Similar comments were made by Tulau (2001) who noted that the impacts of such a scheme on agricultural productivity requires further investigation. WetlandCare Australia (2010) also recommended that land acquisition of low-lying wetland areas be investigated.

3.5 Summary

The Collombatti-Clybucca floodplain has undergone extensive drainage during the 20th century which transformed the area from a large coastal wetland complex, to a drained agricultural floodplain. The drainage works permanently altered the hydrology of the catchment, significantly increasing the drainage efficiency and connection to the wider estuary. The impacts to the floodplain and downstream waters have been significant but are likely reversible.

General impacts of the drainage works and agricultural expansion include:

- Clearing of vegetation
- Loss of native flora and fauna
- Loss of fish passage/habitat
- Poor water quality
- Oxidation of acid sulfate soils
- Consolidation of soils
- Low dissolve oxygen discharge
- Erosion and loss of sediment

Despite recent efforts to remediate the site, poor water quality characterised by low pH, low DO and high metal concentrations continues to be discharged from the floodplain. Broad-scale remediation of the site is unlikely unless the current land use practices are changed. Remediation of the site has the potential to restore the backswamp areas to the coastal wetlands which thrived prior to drainage.

4. Summary of Existing Data

The Collombatti-Clybucca area has a history of discharging poor quality water. However, it was not until the site was listed as one of seven target sites as part of the Hot Spots program that detailed acid sulfate soils investigations were undertaken at Doughboy Swamp and Mayes Swamp (KSC, 2004; Bush *et al*., 2006). Since these activities undertaken as a part of the Hot Spot program, further research has been undertaken on the eastern area of the floodplain (Cheeseman *et al*., 2004; Andrews *et al*., 2005; Chartres *et al*., 2005; McLennan *et al*., 2005). Large-scale investigations of acid sulfate soil distribution across the floodplain and delineation of acid contribution from different drains and paddocks have not been undertaken.

A range of data sets relevant to assessing remediation at Collombatti-Clybucca floodplain are outlined in this section.

4.1 Water Quality Monitoring

In general, monitoring of water quality across the floodplain has been sparse and discontinuous. However, the available water quality data provides a useful reference for comparison. The longest water quality dataset is from 1998 to 2005, collected upstream and downstream of the Menarcobrinni floodgates as part of the Hot Spot program (KSC, 2004; Bush *et al*., 2006). A range of parameters were monitored including:

- Water level;
- pH;
- Electrical conductivity (EC);
- Temperature;
- Dissolved oxygen (DO); and
- Oxidation reduction potential (ORP).

This monitoring program confirmed the poor quality of discharges from the Collombatti-Clybucca floodplain (KSC, 2004; Bush *et al*., 2006). The annual records from this monitoring have been included in Appendix B.

Spot measurements of surface water quality and groundwater quality were taken between 2002-2004, at the southern extent of Mayes Swamp, East Drain, West Drain and Seven Oaks drain (KSC, 2004).

Currently, water quality is monitored weekly at the Menarcobrinni floodgates by Kempsey Shire Council. A range of parameters are monitored including:

- Temperature;
- pH;
- Oxidation reduction potential (ORP);
- Electrical conductivity (EC);
- Dissolved oxygen (DO); and
- Salinity.

Although regular spot monitoring provides an indication of water quality during average conditions, water quality during events is not captured.

4.2 Topography

Detailed topography of the Collombatti-Clybucca floodplain is available from a LiDAR dataset collected between October 2009 and March 2010. Lidar provides vertical accuracy of ± 0.3 m on a 1 m grid resolution. LiDAR does not penetrate open water or dense vegetation, providing a false positive reading at such features. Comparison of LiDAR to high resolution aerial photography allows for potential areas with inaccurate measurements to be identified. The topography of the floodplain is presented in Figure 3.2.

Detailed surveying of key floodplain features was undertaken by East Coast GPS Surveys Pty Ltd for Council in December 2002, which measured levels of natural surface points, creek inverts, drain inverts, piezometers and benchmarks on the floodplain. Original, as constructed, drawings of floodplain drainage works are available from the NSW Department of Public Works (PWD, 1978).

4.3 Acid Sulfate Soils and Groundwater

The Collombatti-Clybucca floodplain is identified as a high risk acid sulfate soil area (Figure 4.1) (Enginuity Design, 2003). Investigations undertaken as part of the Hot Spot program indicated that the actual acid sulfate soil layer is at approximately 0.1 m AHD (Enginuity Design, 2003). This elevation has resulted in some areas of the floodplain having acid surface scalds. Large acid scalds remediated during 2002 to 2004 were located directly adjacent to major drainage channels, indicating that excessive draining of the groundwater at these low elevation areas resulted in acid surface scalding (KSC, 2004, Bush *et al.,* 2006).

Groundwater boreholes installed adjacent to the acid scald locations, and adjacent to West Drain and East Drain measured consistent groundwater acidity of pH 3. Assessment of the piezometric water levels indicated that groundwater surrounding the major drainage channels was predominantly controlled by drain water levels. KSC (2004) also states that some drains act as ‘bath tubs’ below an elevation of – 0.2 m AHD where there is no conductivity between drain waters and groundwater and the drains are not controlling groundwater levels. KSC (2004) suggest that accumulation of monosulfidic black oozes (MBO) in drains and plugging of the drain walls by cattle is restricting groundwater discharge into some drains.

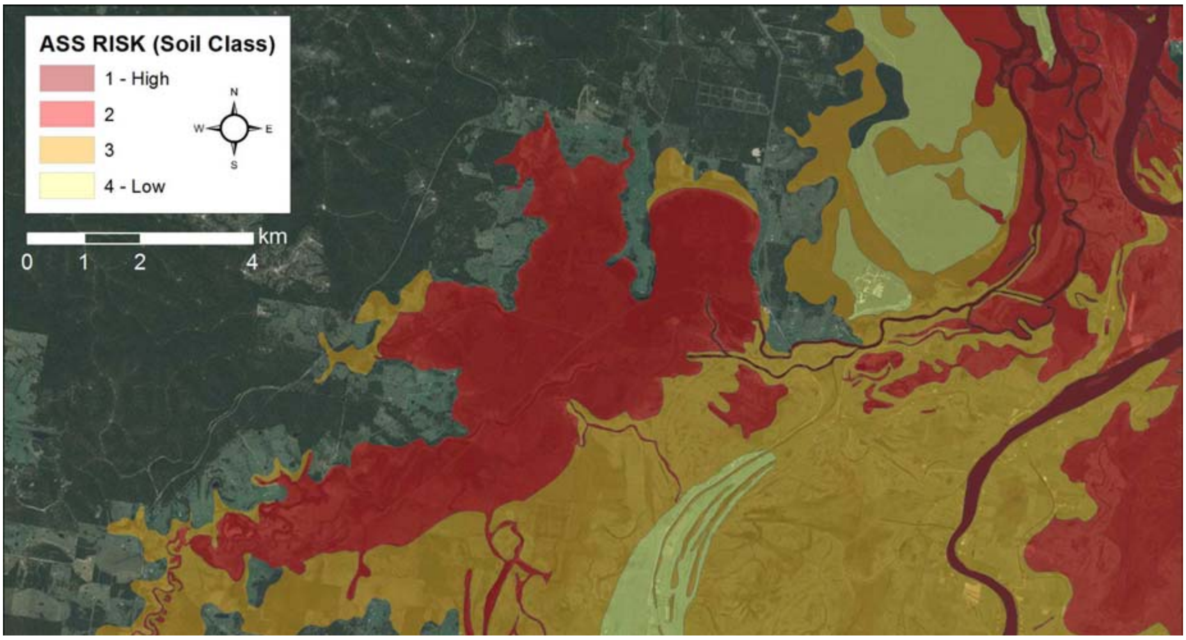


Figure 4.1: Acid sulfate soil planning risk maps (NSW Department of Planning and Infrastructure, 2014)

4.4 Hydraulic Conductivity

Saturated hydraulic conductivity (K_{sat}) measurements were undertaken by KSC (2004) using the open pit method adapted by Johnston *et al.* (2003). This method involves the excavation of a shallow pit, extraction of standing groundwater and measurement of the rate of infilling. This technique provides a rapid, semi-quantitative assessment of the insitu bulk hydraulic conductivity and an estimate of the transport rates of acid from the soil profile to adjacent surface waters.

Measurements were undertaken on the Latham scald, adjacent to East drain at the southern extent of Doughboy Swamp, and the Yerbury scald, located at the southern extent of Mayes Swamp (Figure 4.2). The test pits identified a hydraulic conductivity of 13 m/day at Mayes Swamp and 22 m/day at Latham's scald. These results indicate the soils have a high hydraulic conductivity, equivalent to a fine, clean sand (KSC, 2004).

Figure 4.2: Location of hydraulic conductivity test pits (in KSC, 2004)

4.5 Vegetation

Enginuity Design (2003) provided a summary of flora and fauna distribution in the wetland complex. Vegetation mapping for the Collombatti-Clybucca backswamps in the Macleay Wetlands Management Plan (North Coast Environment Centre, 1999) show five (5) predominant plant communities populate the area:

- Sedgelands are the dominant vegetation community;
- Swamp sclerophyll forest (*Casuarina glauca, Melaluca quinquenervia, Glochidion ferdinandi*) are abundant;
- Grassland communities are relatively abundant;
- Forest Melaleuca communities occur in small pockets; and
- Forest Casuarina communities occur in small pockets.

Recent vegetation mapping of the acquired RMS properties (Ainsworth, Latham, Yerbury and Blair) has been undertaken by Niche Ecological (2014) and is attached in Appendix C. The predominant communities observed on the low-lying backswamp areas are:

- Coastal freshwater meadows and forblands of lagoons and wetlands (NR150);
- Swamp Oak swamp forest of the coastal lowlands (NR255); and
- Paperbark Swamp forest (NR217).

Higher elevation areas of the properties are vegetated by the following communities:

- Shatterwood – Giant Stinging Tree – Yellow Tulipwood dry rainforest (NR229);
- Blackbutt – Tallowwood dry grassy open forest (NR119);
- Blackbutt – Pink Bloodwood shrubby open forest (NR117);
- Paperbark Swamp forest (NR217);

- Cabbage Gum open forest or woodland (NR145); and
- Tea-tree shrubland of drainage areas (NR269).

4.6 Discharge

No discharge data is available for the Collombatti-Clybucca floodplain. Flow monitoring equipment was installed as part of the Hot Spots program designed to coincide with water quality monitoring upstream of Menarcobrinni floodgates (KSC, 2004; Bush *et al*., 2006). Data from the flow monitoring instrument was deemed inaccurate due to instrument malfunction and contamination by drain oozes (KSC, 2004; Bush *et al*., 2006).

Discharge is currently measured in the main Macleay River estuary at Turners Flat by NSW Office of Water (NoW).

4.7 Water Levels

There is currently no water level monitoring undertaken in the Collombatti-Clybucca floodplain. Greenspan collected water level data upstream of the Menarcobrinni floodgates as part of the Hot Spot program from 1998 to 2004 (KSC, 2004; Bush *et al*., 2006).

Previous monitoring of tidal water levels has been undertaken in Andersons Inlet, including at the Menarcobrinni floodgates as part of the 2003 Macleay River Estuary Data Collection Program (MHL, 2004) (Table 4.1). Mean tidal levels at the Menarcobrinni floodgates are generally elevated when compared to ocean levels, indicated by a mean tide level (M.T.L) of 0.138 m AHD. The peak tidal water level is 0.972m AHD, which is below the headworks crest elevation of 1.5 m AHD. Note that the tidal data collected by MHL (2004) was measured for a two (2) month period only and does not include flooding influences. Present day tidal planes are likely to vary from the 2003 data due to changes in estuarine geomorphology, climate, sea level rise affects and impacts from restoring Yarrahapinni wetlands.

Water levels are currently monitored at various locations throughout the wider Macleay River estuary (Table 4.2).

Table 4.1: Tidal plane analysis at Menarcobrinni floodgates compared to ocean levels (m AHD) (MHL, 2004)

Tidal Plane*	Ocean Site (m AHD)	Menarcobrinni Floodgates (m AHD)
H.H.W.S.S	1.124	0.972
M.H.W.S	0.736	0.638
M.H.W	0.594	0.540
M.H.W.N	0.453	0.442
M.T.L	0.074	0.138
M.L.W.N	-0.304	-0.166
M.L.W	-0.446	-0.264
M.L.W.S	-0.587	-0.362
I.S.L.W	-0.864	-0.601

*Expanded tidal plane acronyms are as follows:

H.H.W.S.S – High high water spring solstice
M.H.W.S – Mean high water springs
M.H.W – Mean high water
M.H.W.N – Mean high water neaps
M.T.L – Mean tide level
M.L.W.N – Mean low water neaps
M.L.W – Mean low water
M.L.W.S –Mean low water springs
I.S.L.W – Indian spring low water

Table 4.2: Current data collection in the Macleay River estuary

Location	Provider	Data Collected	Station Record
Macleay River at South West Rocks	MHL	Level	Apr 1989 - ongoing
Andersons Inlet at Middle Island	MHL	Level	Feb 1996 - ongoing
Andersons Inlet at Double Island	MHL	Level	Feb 1996- ongoing
Macleay River at Smithtown	MHL	Level	Feb 1986 - ongoing
Macleay River at Kempsey	MHL	Level	Feb 1983 - ongoing
Macleay River at Euroka Upstream	MHL	Level	Jul 1990 - ongoing
Collombatti Creek	MHL	Level and Rainfall	ongoing
Macleay River at Moparrabah	MHL	Level and Rainfall	ongoing
Macleay River at Turners Flat	NoW	Level and discharge	Oct 1945 - ongoing

4.8 Climate

The Collombatti-Clybucca floodplain has a temperate to subtropical climate (Hurrell *et al.*, 2009). On average, the area is dominated by evaporation with average annual total evaporation exceeding the average annual total rainfall (Table 4.3). Rainfall patterns are generally seasonal, with wetter summer months and dryer months from July through to October.

Table 4.3: Kempsey climate statistics (BoM station 059017)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean max (^{O}C)	29.2	28.8	27.8	25.5	22.6	20.0	19.7	21.3	24.0	25.6	27.1	28.5	25.0
Mean min (^{O}C)	17.7	17.9	16.6	13.3	9.7	7.1	5.7	6.3	9.0	11.8	14.4	16.5	12.2
Mean rain (mm)	134.1	158.1	151.4	115.3	91.6	99.4	65.2	62.6	55.4	78.0	95.4	110.0	1217
Mean rain days	11.1	11.6	12.8	10.1	8.8	7.7	6.7	6.5	6.7	8.7	9.8	10.8	111.3
Evaporation (mm/day)	5.2	4.6	3.7	3.0	2.3	2.1	2.1	3.0	4.0	4.7	5.0	5.2	1369

4.9 Climate Change

Predicted climate change over the coming century will result in changes to the existing hydrology and hydrodynamics of the Lower Macleay River estuary. Changes in evaporation and rainfall across the Macleay River catchment, both increases and decreases, are likely to influence catchment hydrology, flooding and land management. Predicted changes in temperature, precipitation and evaporation for the North Coast region were forecast by the NSW Government (DECCW, 2010) (Table 4.4).

Table 4.4: Summary of predicted temperature and rainfall changes in the North Coast NSW Region to 2050 (DECCW, 2010)

Season	Minimum Temperatures	Maximum Temperatures	Precipitation	Evaporation
Spring	2.0–3.0°C warmer	1.5–2.0°C warmer	No change	10–20% increase
Summer	2.0–3.0°C warmer	1.0–1.5°C warmer	5–20% increase	10–20% increase
Autumn	2.0–3.0°C warmer	1.5–2.0°C warmer	5–10% increase	10–20% increase
Winter	2.0–3.0°C warmer	2.0–3.0°C warmer	5–10% decrease	5–20% increase

A detailed assessment of the above changes on biota, saline dynamics, catchment hydrology and flooding was not assessed in detail as a part of this study. The NSW Government summarised the overall impacts of climate change on the North Coast region (DECCW, 2010):

- *By 2050, the climate is virtually certain to be hotter, with rainfall increasing in summer and decreasing in winter. However, changes in weather patterns that cannot be resolved by the climate models mean that rainfall in coastal regions is difficult to simulate.*
- *Run-off and stream flow are likely to increase in summer and autumn and decrease in spring and winter.*
- *Sea level is virtually certain to keep rising.*
- *Soil erosion is likely to increase on steeper slopes in the upper catchments, potentially causing sedimentation on the floodplains. Gully erosion is likely to ease.*
- *Sea level rise is virtually certain to pose a major risk to property and infrastructure. Developments closest to the shore and on sand spits are most at risk. Increases in brief, heavy rainfalls are expected to increase the likelihood of flooding along urban streams. Towns on coastal plains and near estuaries are likely to suffer additional risk of flooding.*
- *Sea level rise is virtually certain to have a substantial impact on estuarine and foreshore ecosystems. Sea level rise, increased temperatures and changes in hydrology and fire regimes are likely to have a substantial impact on terrestrial and freshwater ecosystems. Vulnerable ecosystems include saline wetlands, low-lying coastal ecosystems and fragmented forests and woodlands in the hinterland.*

Tidal dynamics in the estuary are variable with changes in tidal amplitude throughout the river. Amplification or dampening of tidal amplitudes due to sea level rise is beyond the scope of this investigation, however an overall increase in water levels is expected. This trend will result in higher high tide level, and elevated low tide levels.

The overall impact to floodplain hydrology due to sea level rise includes:

- Increased frequency of tidal/saline inundation;
- Elevated groundwater levels;
- Increased soil salinity in exposed low-lying areas adjacent to the open estuary due to elevated groundwater levels;
- Reduced drainage due to elevated low tides levels;
- Extended inundation of backswamp areas following flooding; and,
- Reduced severity of acid discharge events.

4.10 Heritage and Indigenous Sites

The Macleay River Valley has significant Aboriginal cultural and heritage values including some of the most significant middens in NSW. Kempsey Shire Council plans identify the location of a midden at the downstream end of East Drain (KSC, 2004). KSC (2004) states that ongoing consultation with the Local Aboriginal Land Council is required to confirm the status of the midden and identify any other significant sites within the Collombatti-Clybucca floodplain.

No heritage sites are nominated within the Collombatti-Clybucca floodplain in the Kempsey LEP 2013. Consultation with the local Heritage Society is recommended prior to finalising the remediation strategy.

4.11 Data Gaps

Data critical to any future stages of the remediation of the Collombatti-Clybucca floodplain include:

- Updated survey of drain cross-section;
- Confirmation of flow control structures (location, size, condition);
- Timeseries of water levels at key locations in the Seven Oaks drainage area; and
- Concurrent monitoring of discharge and water quality through Menarcobrinni floodgates.

The collection of these datasets would enable a detailed numerical model of the site to be constructed and calibrated. A calibrated numerical model would provide a basis for assessing remediation options, confirm any required on-ground structures, assess risk to adjacent landholders and the environment, and predict resulting habitat and vegetation communities.

5. Data Collection

Based on the data collation and review, a data collection program was undertaken. Key site specific information that was collected includes:

- Water levels at five (5) locations;
- Salinity downstream of Menarcobrinni floodgates
- Structure survey;
- UAV topographic survey; and
- Drain cross-section survey.

5.1 Water Levels

Long-term water level and electrical conductivity (EC) monitoring was undertaken over an 18 month period between May 2014 and July 2016. Water level was monitored at five (5) locations, and salinity at one (1) location (Figure 5.1). Due to the corrosive environment (i.e. salt and acid) instrument failure occurred at two (2) monitoring locations for a portion of the monitoring period. Time series of water levels are presented in Figure 5.2; note that daily rainfall at Kempsey (BoM station 059007) is also presented for reference.

Electrical conductivity at Location 1 is presented in Figure 5.3.

Figure 5.1: Water level and salinity monitoring locations

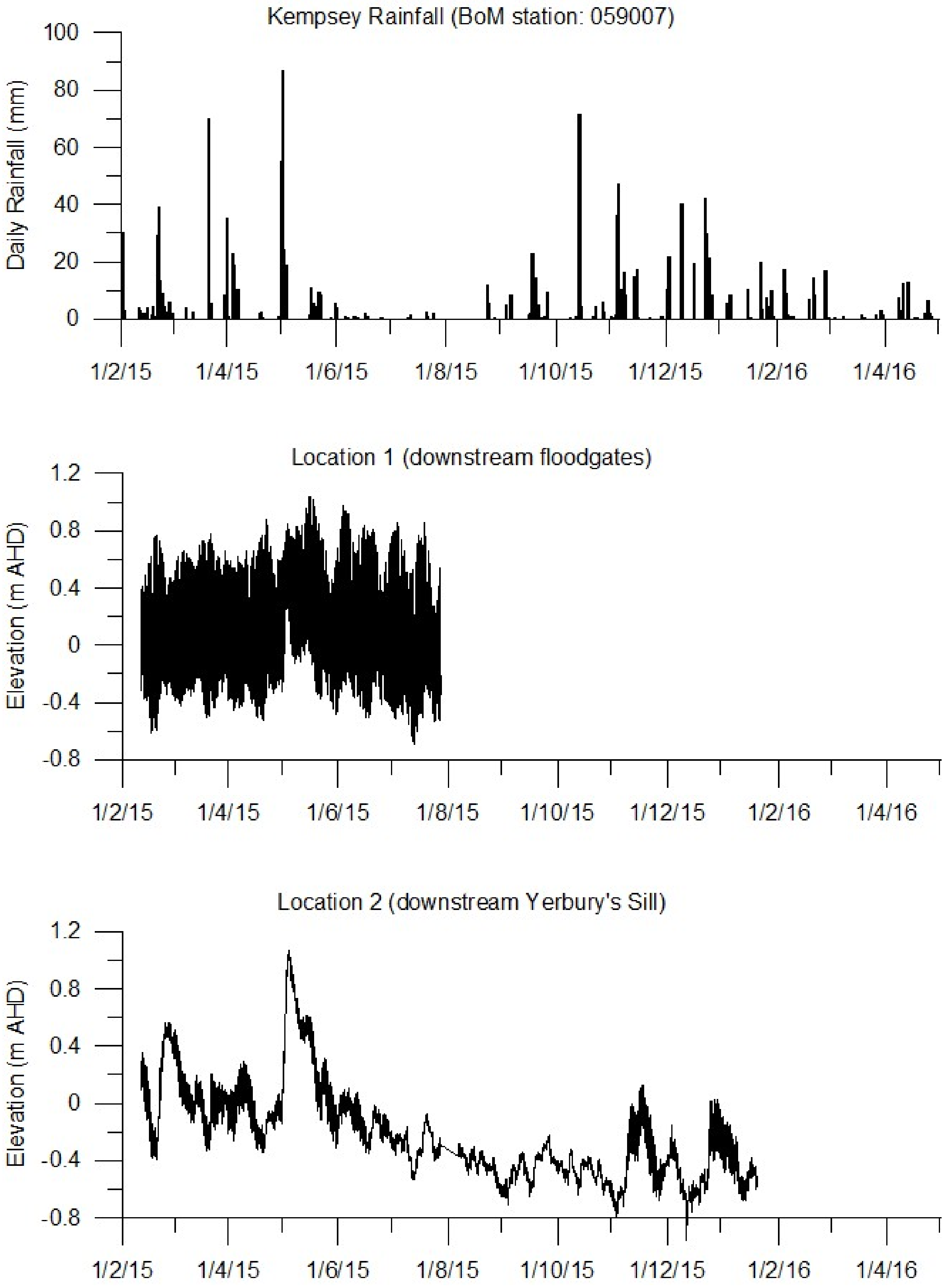


Figure 5.2a: Water level observations

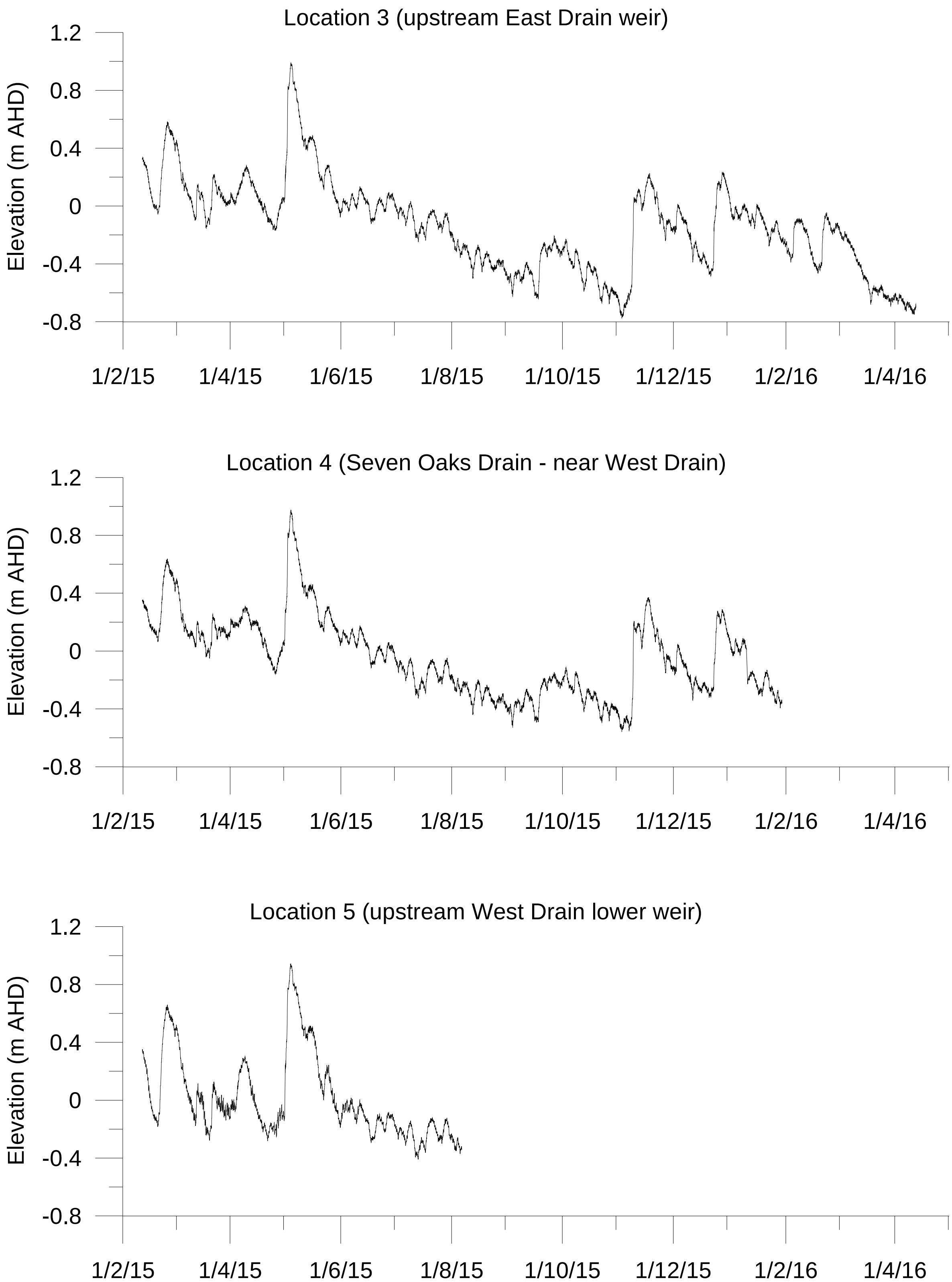


Figure 5.2b: Water level observations

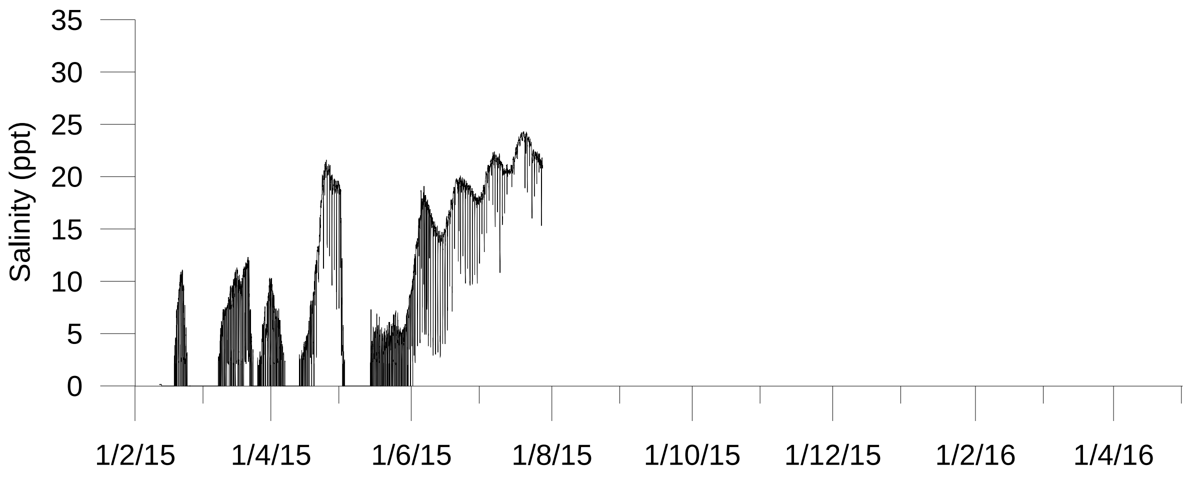


Figure 5.3: Salinity downstream of Menarcobrinni floodgates (Location 1)

5.2 Structures

The hydrology of the floodplain is determined by a number of key factors, including hydraulic control structures. A total of five (5) major structures were surveyed (Table 5.1). Numerous secondary structures (i.e. small diameter pipes) were also observed across the floodplain, primarily designed to facilitate drainage of individual paddocks. Secondary floodplain structures were not surveyed.

Table 5.1: Key hydraulic structures

Structure	Location	Easting (GDA94)	Northing (GDA94)	Details
Floodgates	Menarcobrinni	496428	6576620	Crest = 1.5 m AHD Invert = - 2.1 m AHD 1.8 m wide x 2.1 m high 21 culverts
Weir	Seven Oaks Drain (Yerbury's Sill)	493015	6577593	Crest = - 0.3 m AHD Width =
Weir	East/Union Drain	491627	6577901	Crest = - 0.2 m AHD Width = 9 m
Weir with low-flow culvert	West Drain	491123	6576796	Crest = 0.1 m AHD Width = 9 m Culvert invert = - 0.1 m AHD Culvert diam. = 450 mm
Weir	West Drain			Crest = 0.2 m AHD Width = 4 m

5.3 UAV Topographic Survey

High resolution aerial survey and imagery was captured over a three (3) day period between 27-29 July 2016. A total of 5,339 photos were captured using an RTK enabled eBee fixed wing UAV (unmanned aerial vehicle). Aerial imagery was processed to create a photogrammetry survey, which was verified using ground control points (GCPs) to ensure high accuracy. The survey results are presented in Figure 5.4.

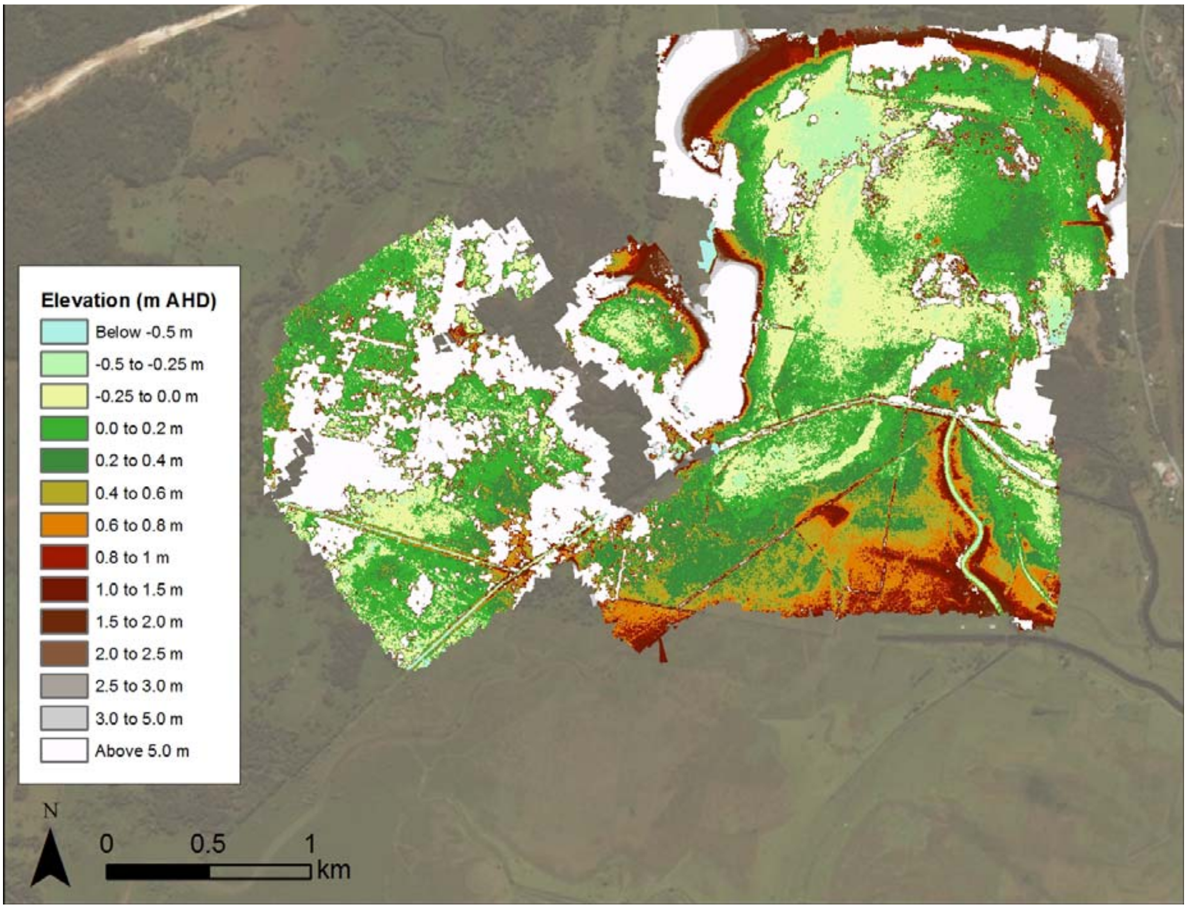


Figure 5.4: UAV topographic survey extent

5.4 Drain cross-sections

Drain cross-sections were measured at 24 key locations. Measurements were undertaken using a Trimble RTK GPS where depths were less than 1.5 m. A Ceescope echo sounder was used where depths exceeded 1.5 m. Measurement of drainage channel cross-section was not possible where extensive tree coverage prohibited GPS correction. Cross-section locations are presented in Figure 5.5. Cross section profiles are presented in Figure 5.6 to Figure 5.12.

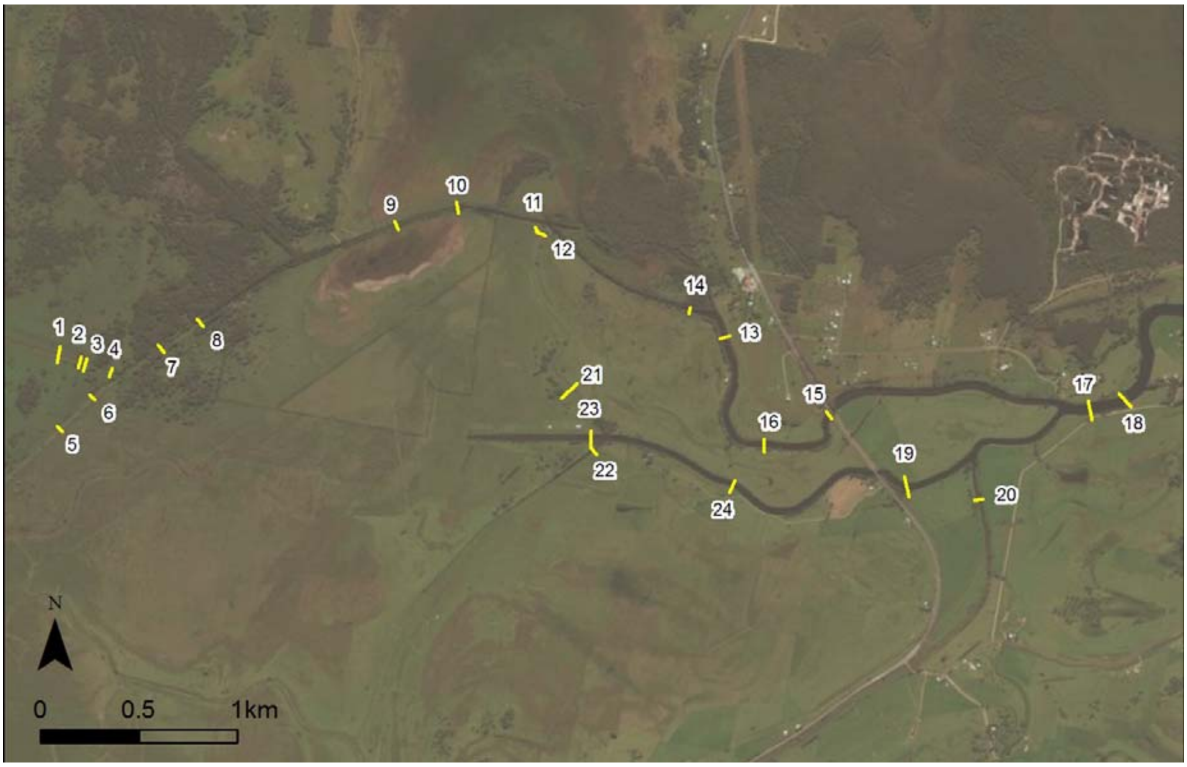
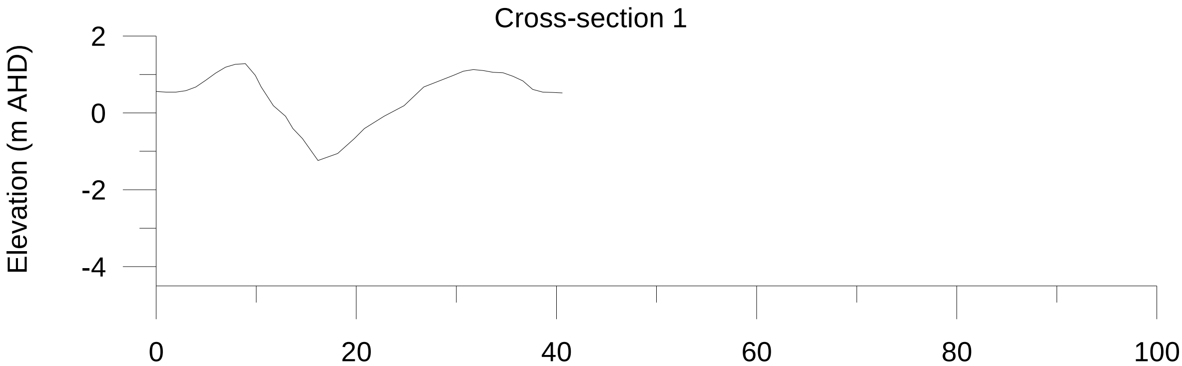


Figure 5.5: Cross-section locations



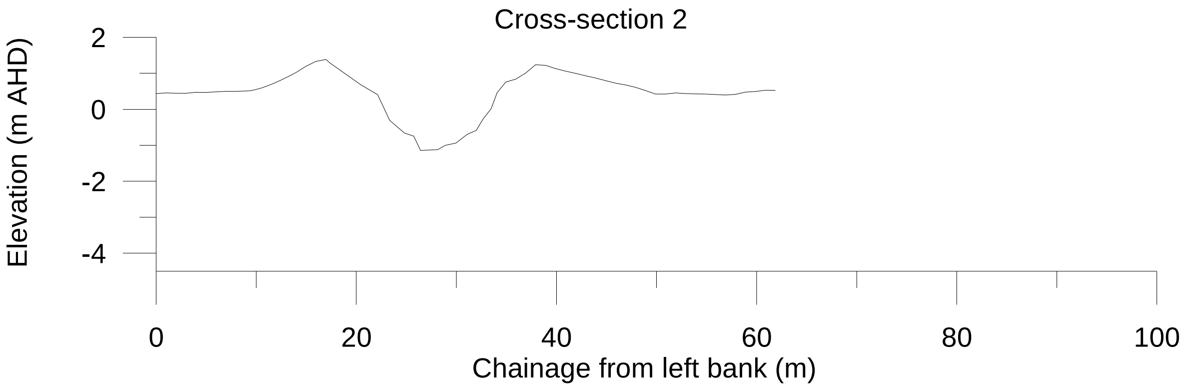


Figure 5.6: Cross-sections 1 and 2

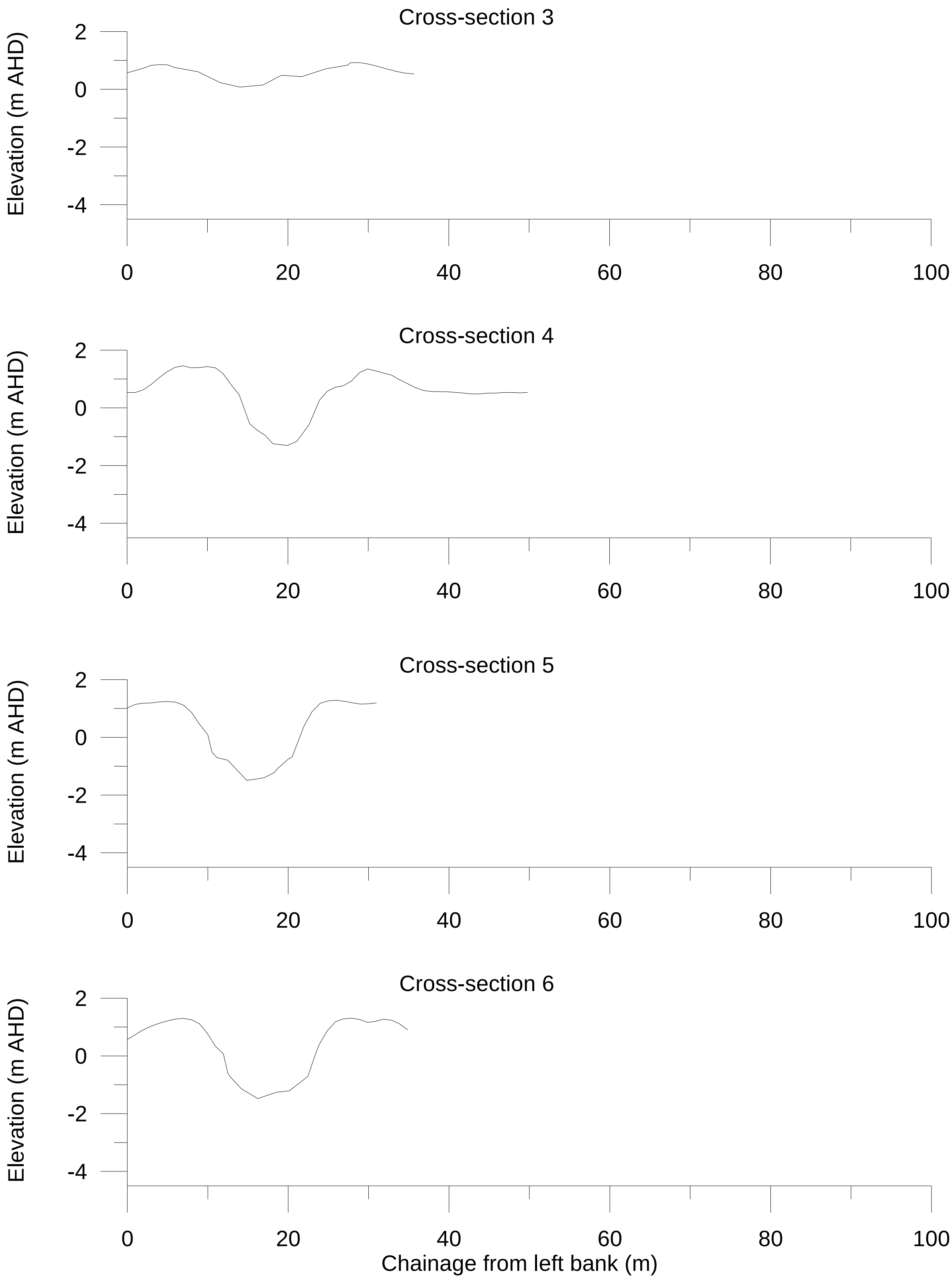


Figure 5.7: Cross-sections 3 to 6

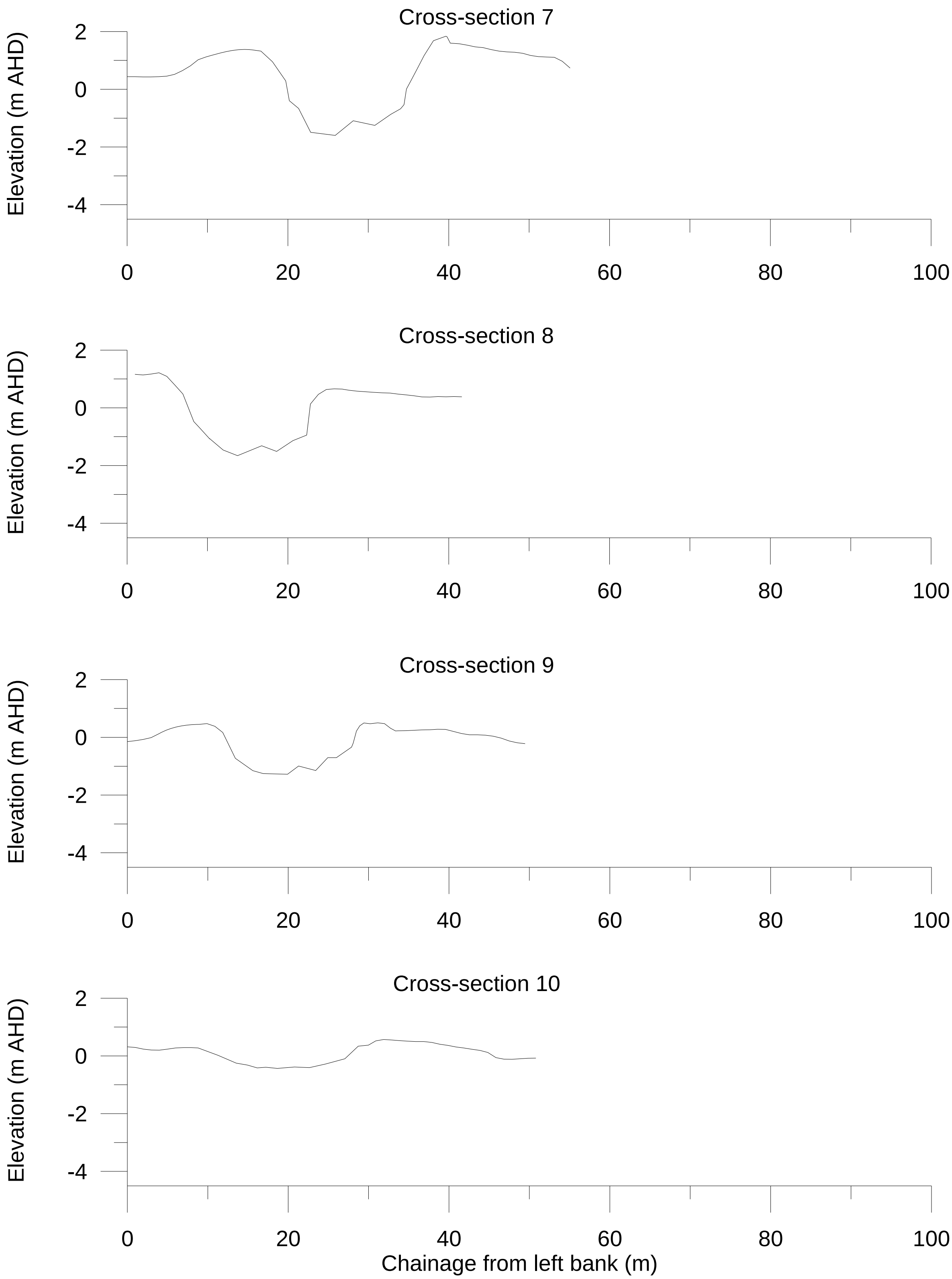


Figure 5.8: Cross-sections 7 to 10

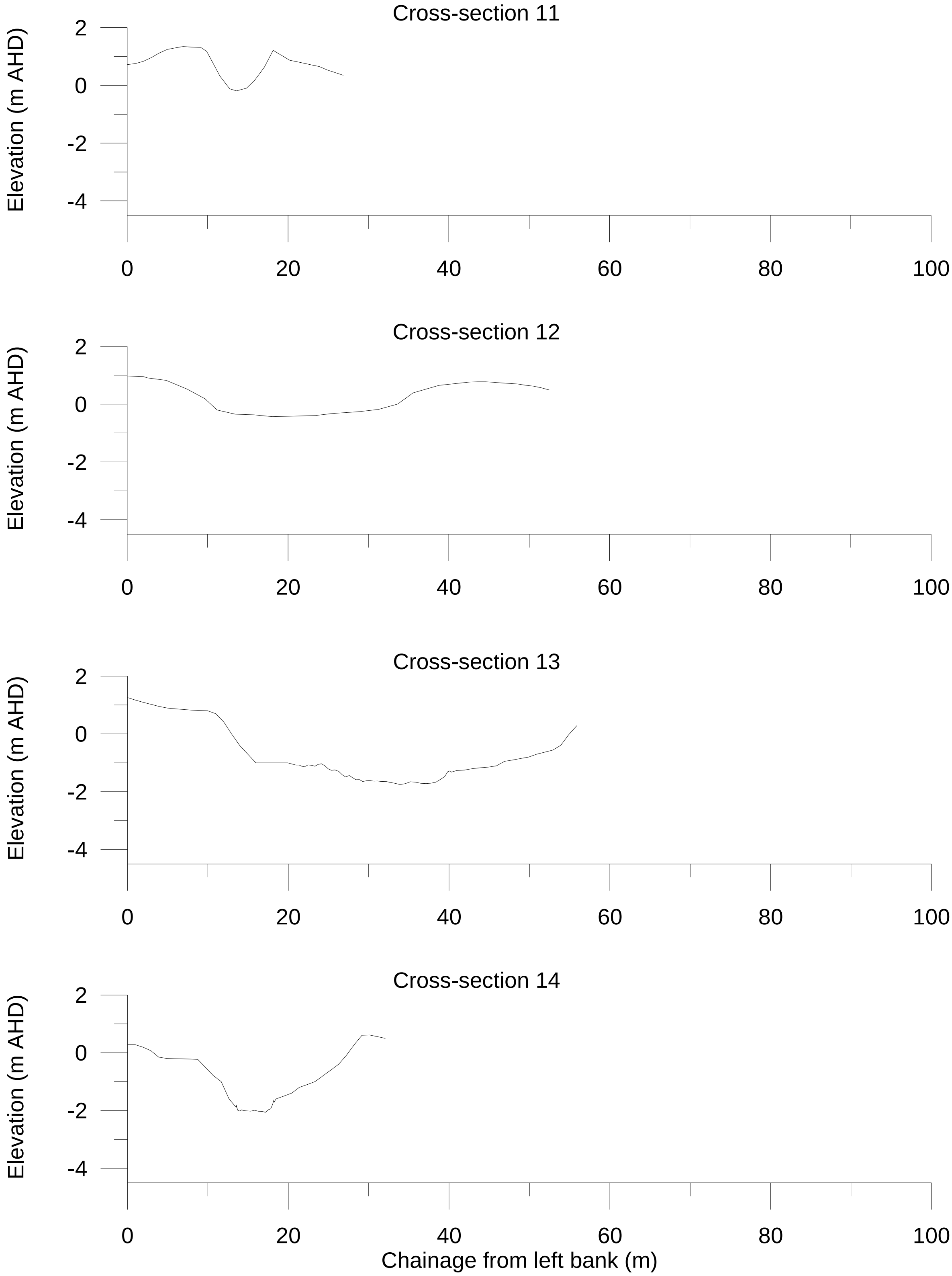


Figure 5.9: Cross-sections 11 to 14

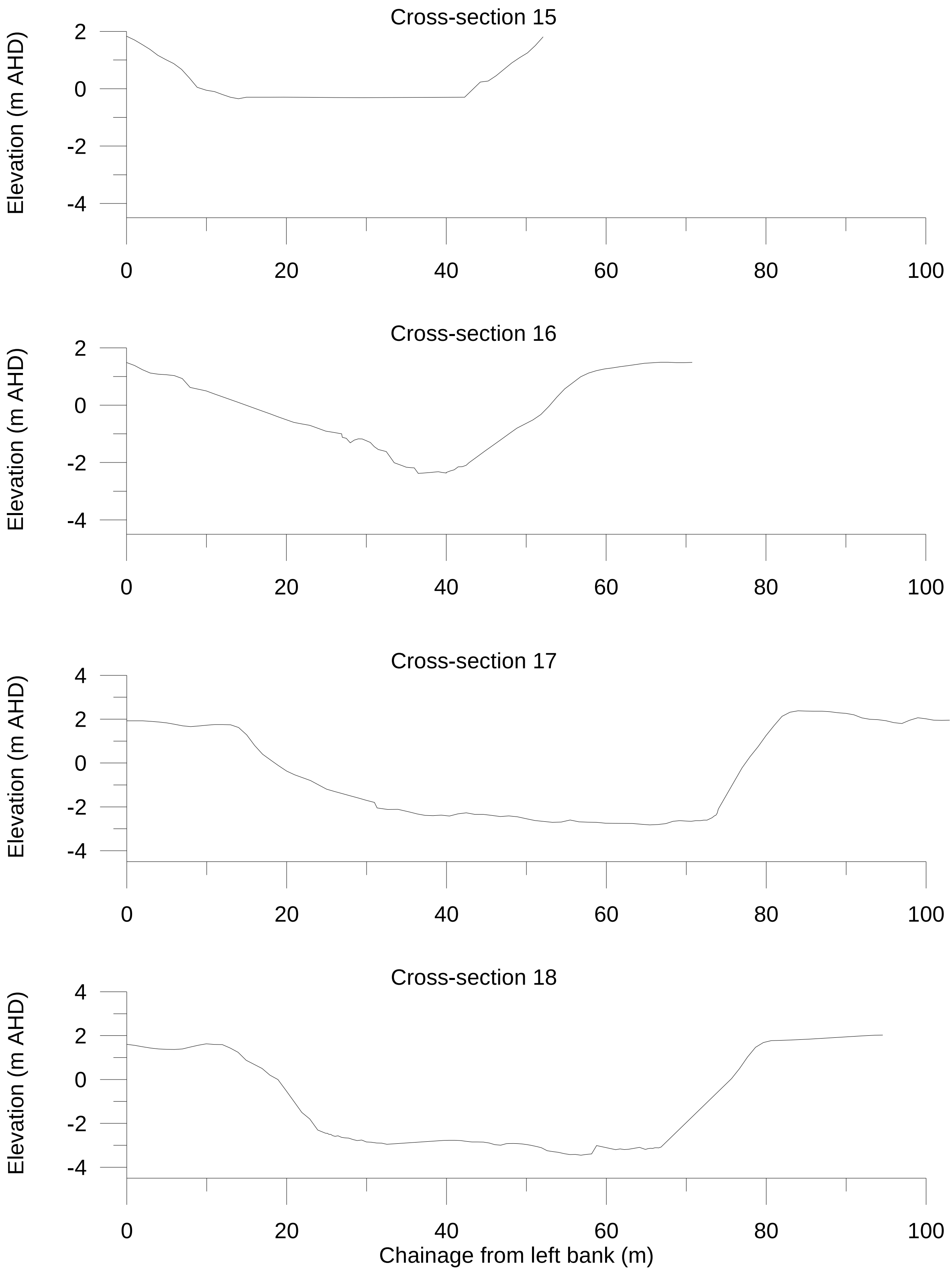


Figure 5.10: Cross-sections 15 to 18

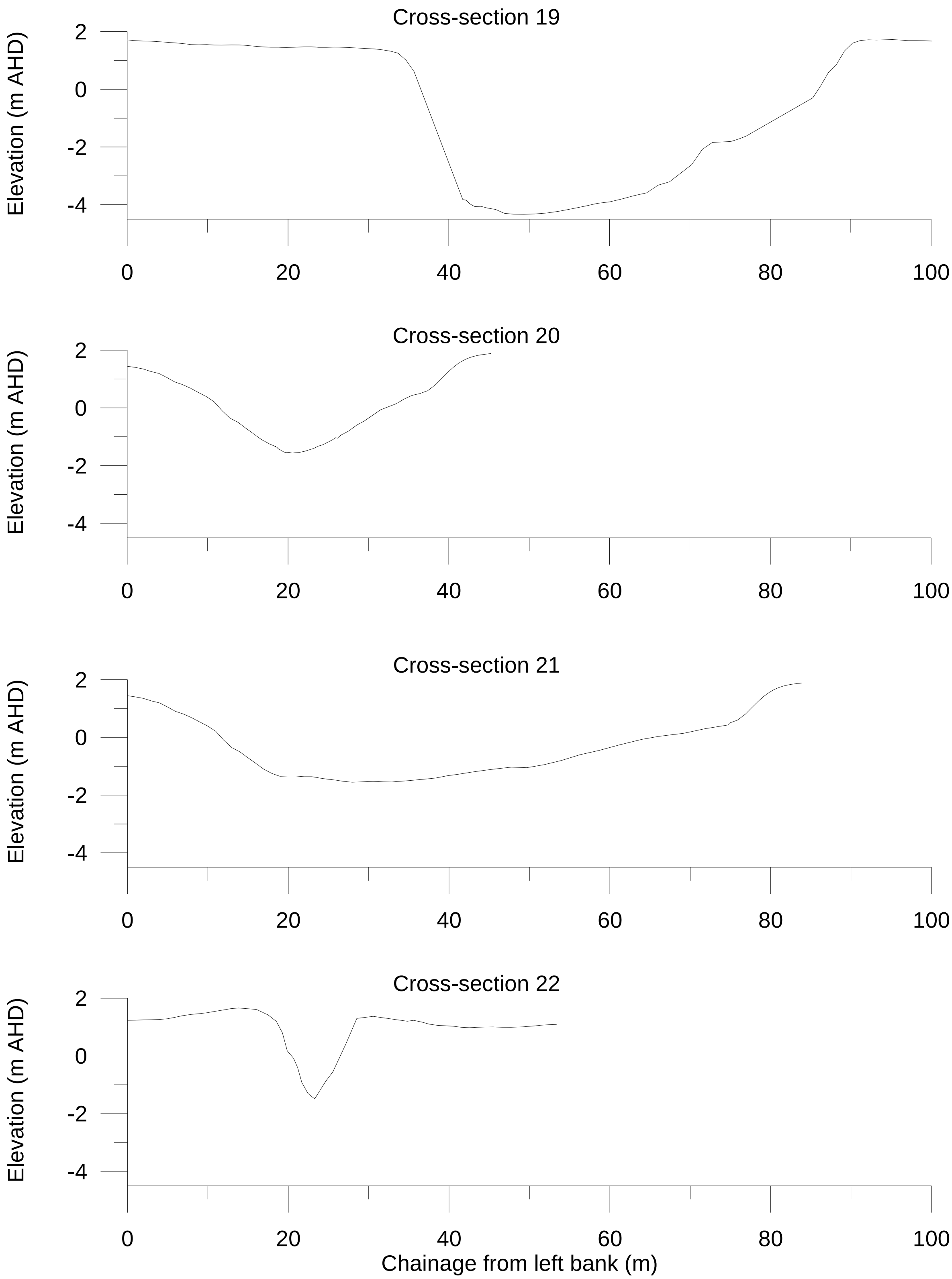


Figure 5.11: Cross-sections 19 to 22

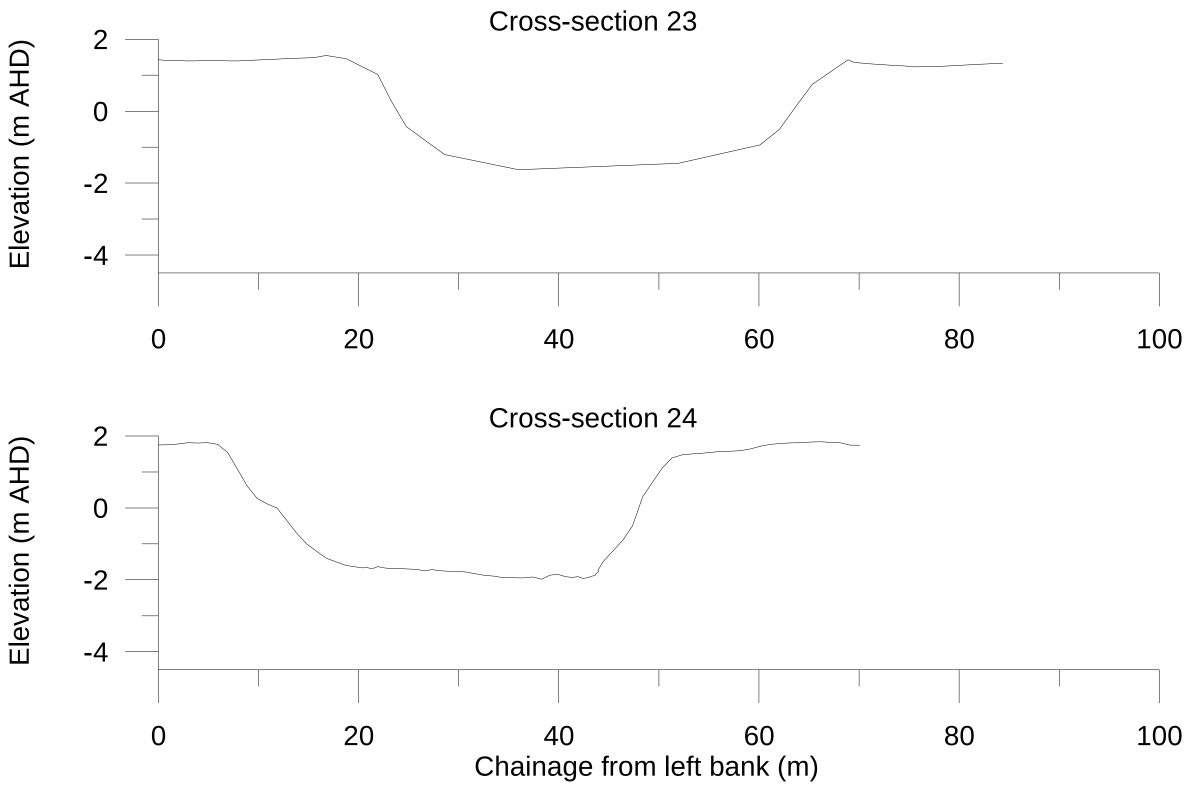


Figure 5.12: Cross-sections 23 and 24

6. Environmental Impacts of Existing Drainage Configuration

This section provides a conceptual model of the water quality processes influencing the Collombatti-Clybucca floodplain and lower Macleay River. Understanding acid generation and export from the Collombatti-Clybucca floodplain is crucial to determine appropriate and effective remediation strategies. Local floodplain drainage processes as well as wider estuarine dynamics are described.

6.1 Discussion of Acid Sulfate Soils

Acid sulfate soil (ASS) is the common name of soils and sediments containing iron sulfides, the most common being pyrite (DERM, 2009). Pyrite is predominantly located within 5 m of the surface and is found extensively on Australia's coastline (DERM, 2009). Pyrite in the Macleay River valley was formed by sedimentation of sands and muds during the last major sea level rise period approximately 6,500 years ago during the Holocene period. Deposition occurred in low-lying coastal zones characterised by low energy environments, such as estuaries and coastal lakes similar to the Collombatti-Clybucca backswamps.

When pyrite is exposed to air, the iron sulfides react with oxygen to form sulfuric acid and numerous iron compounds. ASS that remains in an anaerobic state are termed Potential Acid Sulfate Soils (PASS), with oxidised soils deemed Actual Acid Sulfate Soils (AASS). The problem is exacerbated when the acidity breaks down fine clay particles, causing the release of soluble aluminium (Al^{3+}) and Iron (Fe^{3+}). Potential ASS are commonly oxidised to form Actual ASS through the clearing of coastal land for agriculture, including extensive drainage resulting in a subsequently lower groundwater table as per the Collombatti-Clybucca floodplain, introducing gaseous oxygen from the atmosphere to the soil matrix.

Acid flux is the mass of acid discharged from a system and can be characterised by Equation 6.1. As such, a system that produces a large volume of higher pH (but still acidic) water may result in more acid discharges than a system that discharges a small volume of low pH water.

$$\text{Acid Flux} = \text{Volume of discharge (Q)} \times \text{Acidity } [\text{pH}, Al^{3+}, Fe^{3+}] \qquad (6.1)$$

Acid can be exported by three common mechanisms:

1. Advection (or physical movement) due to a difference in groundwater and surface water levels (i.e. low drain levels and high groundwater levels);
2. Diffusion (or chemical transport) from high acidity groundwater to lower acidity surface water; and
3. Mobilisation of monosulfidic black oozes (MBOs).

Advection of acidic groundwater occurs due to the construction of deep (> 0.5 m) drainage systems on coastal floodplains (Johnston *et al.*, 2003). The discharge of acidic and deoxygenated runoff is exacerbated by the installation of one-way tidal floodgates on drainage channels (Glamore, 2003), installed to prevent floodwaters and tidal brackish water from inundating low-lying areas of the floodplain. Floodgates act to maintain low drain water levels, creating a strong water level gradient between the drain and surrounding groundwater, resulting in the efficient transport of acidic and deoxygenated ASS leachate from groundwater to the drainage channel.

Advective transport is likely to occur in the areas adjacent to the major drains which form the Seven Oaks drainage scheme. The water level in these drains is controlled by the Menarcobrinni floodgates, and a number of weir/earthen sill structures. Acid generated from this process is usually exported 5 to 14 days following a flood event, once downstream water levels have re-established. Acid generated from this process is often highly acidic. The volume of acid water generated is a function of the area of land drained and the hydraulic conductivity of the soil.

Diffusion of highly acidic groundwater to near neutral surface water can occur when the hydraulic conductivity is very low or the residence time of standing surface waters is significant. This process involves molecular diffusion of H^+ protons through pore water to the surface over a longer period of time (i.e. weeks to months) coupled with evaporation resulting in the accumulation of acid salts. This process could occur at areas of the Collombatti-Clybucca floodplain where limited drainage results in long residence time for floodwaters. This acidic reservoir can then be exported following the next rainfall event, with high volume, moderately acidic water being discharged from the site. This acid export process generally leads to more infrequent acid runoff events with lower acid export rates (Johnston *et al*., 2003). Acid production by this method can be detected by monitoring of the first flush of surface water runoff after an extended dry period (Telfer and Birch, 2009).

During dry periods the Collombatti-Clybucca drainage network contains a significant reservoir of acid. At a water level of 0 m AHD (mean sea level), the drainage network contains approximately 550 ML of acidic water. This is equivalent to 220 Olympic swimming pools of acid ready to be discharged into the estuary at the 'first flush' of a rainfall event. The acidity of drain waters during dry period has been measured to be approximately pH 3 (i.e. equivalent to vinegar).

6.2 General Environmental Impacts

The discharge of acidic plumes with low pH and high concentrations of soluble metals can have devastating impacts on the environment. Acid plumes can be compounded by discharge from multiple drainage areas combining in the open estuary to form a 'super-plume'. Coupled with detrimental environmental impacts are economic losses due to the impacts on aquatic (i.e. oyster, prawns, etc.) and terrestrial (i.e. reduced agricultural production) industries.

The NSW Department of Environment and Climate Change (DECC, 2008) (now NSW Office of Environment and Heritage (OEH)) identified numerous environmental impacts of acid discharge including:

- Habitat degradation;
- Fish kills;
- Outbreaks of fish disease;
- Reduced resources for aquatic food;
- Reduced ability of fish to migrate;
- Reduced recruitment of fish;
- Changes to communities of water plants;
- Weed invasion by acid-tolerant plants;
- Subsidence and structural corrosion of engineering structures; and
- Indirect degradation of water quality.

Aaso (2000) notes further chronic impacts, such as:

- Loss of spawning sites and recruitment failure in both estuarine and fresh-water species;
- Habitat degradation and fragmentation from acid plumes, thermochemical, stratification of waters and the smothering of benthos from iron oxyhydroxide flocculation;

- Altered population demographics within species;
- Simplified estuarine biodiversity with invasions of acid-tolerant exotics and loss of native species; and
- Reduction in dissolved nutrients and organic matter entering the estuarine food web.

6.3 Poor Water Quality Discharge Events at Clybucca

Long-term (1998 – 2005) water quality monitoring upstream of the Menarcobrinni floodgates by Greenspan measured water level, pH, electrical conductivity (EC), dissolved oxygen (DO), and oxidation reduction potential (ORP). Discharge was also measured upstream of the floodgates, however data from the instrument was considered inaccurate and un-usable (KSC, 2004; Bush *et al.*, 2006). Similarly, monitoring of water quality parameters was also intermittent due to instrument failure.

With data interpretation, it is possible to determine the mechanisms of poor water quality generation and discharge from the Collombatti-Clybucca floodplain. A rainfall event in 1999 showed that acidic discharge coincided with a first flush of acidic water from the floodplain (Figure 6.1). Acidity during this event ranged between pH 2 to pH 4. As water levels are above 0.5 m AHD prior to the flood event, it is likely that there was standing acidic water on the floodplain preceding the event. This indicates that discharge was comprised of long-term floodplain waters which had been acidified by diffusion. The immediate discharge of acid coinciding with the flood event indicates that diffusive acid generation occurs on the Collombatti-Clybucca floodplain. Note that this process can also occur due to evaporation, with acidic surface waters evaporating to leave acidic salt accumulation on the surface. Accumulated acid salts can then be mobilised during flood events.

The water levels preceding the rainfall event were elevated at approximately 1 m AHD during early July 1999. At this elevation, large areas of the Collombatti-Clybucca floodplain are inundated (refer to LIDAR topography in Figure 3.2). This large scale inundation of the floodplain is likely to have resulted in a black water event. However, a lack of dissolved oxygen (DO) data for the event in July 1999 does not allow for comparison to water levels and therefore discharge of black water. Indeed, DO measurements throughout the 1999 - 2004 dataset are intermittent, with the instrument regularly failing during discharge events.

Assessment of water quality data from 2001 - 2002 indicates evidence of acid generation, and discharge, via advective groundwater processes (Figure 6.2). A small rainfall event in early 2002 produced an increase in drain water levels, from approximately – 0.4 m AHD to + 0.2 m AHD resulting in an increase in groundwater levels. This event is unlikely to have resulted in significant, long term floodplain inundation. Also, water levels in the months preceding this event are below floodplain level, indicating that floodplain inundation is likely to have been absent. In the weeks following the event, water levels continued to fall, providing a gradient for acidic groundwater to flow into the Seven Oaks drainage system.

Assessment of the Greenspan data indicates that acid generation in the Seven Oaks drainage area is a combination of both advective groundwater leachate acid, and long-term diffusion of acid into standing surface water.

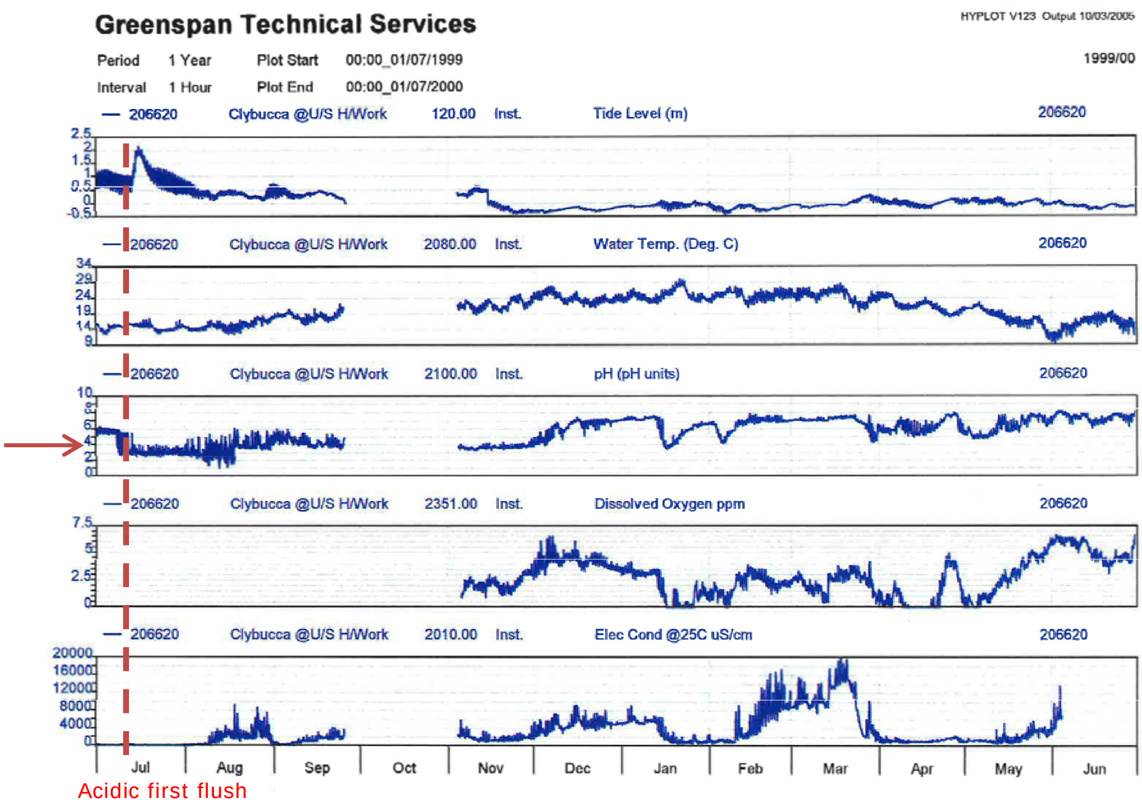


Figure 6.1: Water quality monitoring at Menarcobrinni floodgates 1999-2000

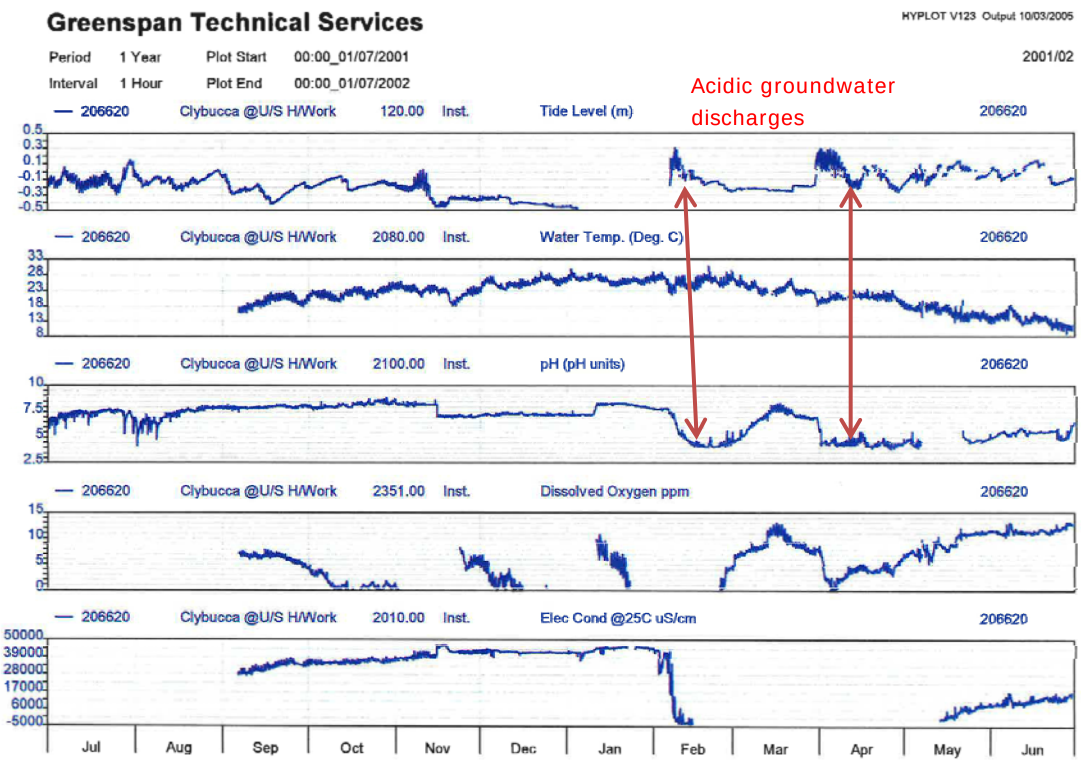


Figure 6.2: Water quality monitoring at Menarcobrinni floodgates 2001-2002

Highly acidic water quality from the floodplain is also characterised by anoxic 'black water' which is very low in dissolved oxygen (DO). Black water is due mainly to the rapid biological breakdown of organic matter in floodplain standing water. Black water events are typically more common following summer flood events as the biological breakdown process occurs faster in warmer temperatures. Drainage works on the floodplain have encouraged the establishment of flood-intolerant pasture species. These species are more prone to die off and decompose following flood events. The large fish kill event of March 2001 in the Macleay River is attributed to black water discharge from backswamp areas including the Collombatti-Clybucca floodplain (Walsh *et al.,* 2004).

The discharge of metals, specifically iron and aluminium, occurs as a by-product of acid sulfate soil oxidation. Bacteria in the acidic groundwater strips iron and aluminium from clay sediments which is transported as soluble iron and aluminium ions with the groundwater. Upon being discharged into the estuary, mixing with higher pH water cause flocculation of the metals out of solution. During the flocculation processes, further acid (H^+ ions) is released. Receiving water channels and the benthic ecosystem can become lined with extreme concentrations of iron and aluminium.

Mono-sulfidic black ooze, or MBO, is also a by-product of acid generation. Increased concentrations of iron and sulphur from acid discharges line the bed of receiving water channels resulting in the formation MBO. When mobilised during flood events, MBOs can strip oxygen from the water column nearly instantaneously, contributing to black water events.

Understanding the combination of these processes is critical in remediating the site. Due to diffusive acidification of standing water on the floodplain, and the potential for black water generation, any overland inundation must have natural buffering capacity. Inundation which is absent of buffering capacity will result in a large store of anoxic and acidic water, which can be discharged into the estuary during the first flush of a rainfall event.

6.4 Summary of Conceptual Model

6.4.1 Floodplain Processes

The site inspection, historical datasets and previous studies enable the development of a conceptual model of key processes across the Collombatti-Clybucca floodplain and wider Macleay River estuary. Understanding the acid generation and export mechanisms is critical to developing a feasible remediation strategy. The processes and mechanisms which produce acid discharges from the Collombatti-Clybucca floodplain are similar to other acidic backswamp locations on the east coast of NSW.

Currently, poor quality water is generated via a number of mechanisms:

1. Mobilisation of a large acidic reservoir;
2. Acidification of standing water via diffusion and MBO;
3. Oxygen consumption by biodegradation of organic matter in standing water; and
4. Groundwater drainage.

Acidic surface waters are flushed from the floodplain at the beginning of discharge events. Following the drainage of floodwaters, acidic groundwater discharges into the deeply incised drains of Seven Oaks Drain, East Drain and West Drain and other secondary floodplain drainage channels. Buffering and neutralisation of acidic surface and groundwater is inhibited by the

Menarcobrinni floodgates which restricts tidal waters from flushing the Collombatti-Clybucca area (Figure 6.3).

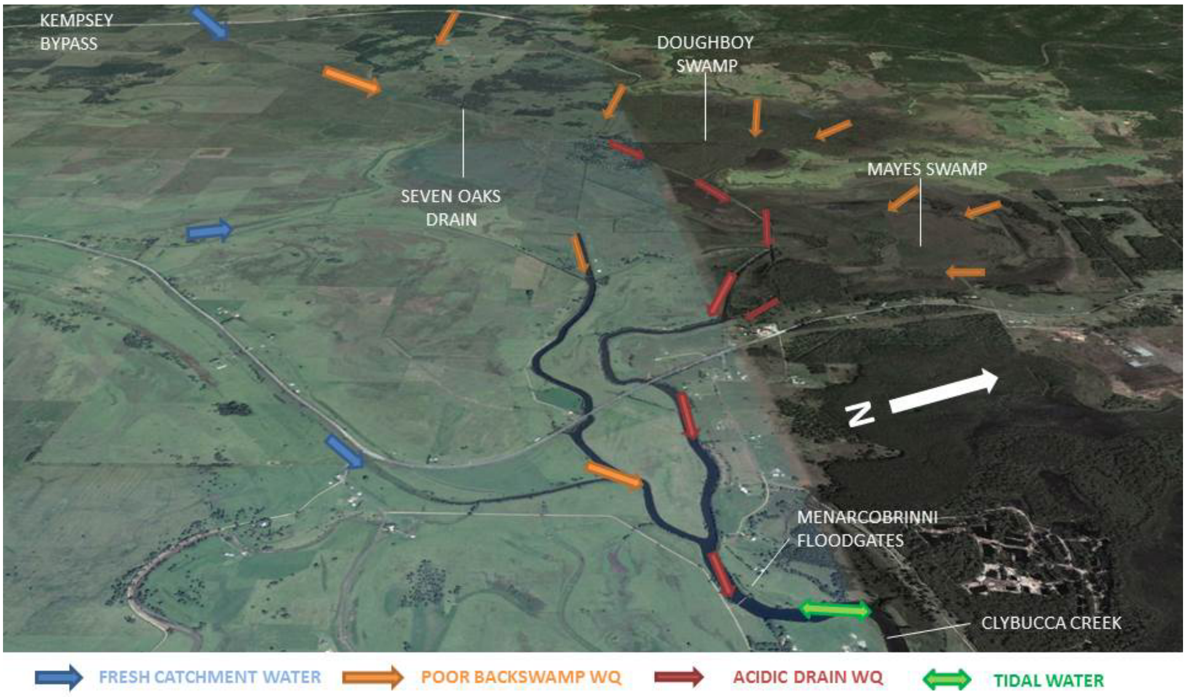


Figure 6.3: Existing site conceptual processes showing acid drain discharge and inhibited tidal flushing

Poor water quality in the form of anoxic 'black water' is also discharged from the site following periods of extended floodplain inundation. Black water results from the biodegradation of organic matter on the floodplain. Drainage of the backswamps has resulted in the establishment of pasture species that die easily when inundated and quickly decompose. Summer months are prone to black water events when temperatures accelerate the biodegradation processes.

Previous remediation efforts have been undertaken at the site including construction of weirs and earthen sills to maintain an elevated groundwater table, and revegetation of surface acid scalds (KSC, 2004; Bush *at al*., 2006). The efforts to remediate acid scalds were successful, however Bush *et al*. (2006) noted that the differences in pre and post works water quality at Clybucca were inconclusively associated with the remediation works, due to differences in rainfall patterns. Indeed, recent water quality measurements indicate that drain water quality remains highly acidic (pH = 3.5).

6.4.2 Estuarine Dynamics: Flooding and Drainage

The processes that occur within the drainage area impact the wider Macleay River estuary. Understanding how the estuary responds to wet and dry periods, in conjunction with floodplain discharges is critical to quantifying the impacts of the Collombatti-Clybucca drainage area on an estuarine scale.

While drain water can be highly acidic on a day-to-day basis, large plumes are not typically recorded within estuaries during dry conditions. However, large quantities of acid are often discharged following significant rainfall events in coastal NSW rivers. This typically occurs in the

5 to 14 days following the peak of a flood event. During other periods, the risk of widespread acidic contamination are confined to the local catchment.

During dry conditions the tidal range and extent increases into the estuary with decreasing catchment runoff. Tidal water contains natural neutralisation agents that can buffer acid discharged. Typically, low volumes of acid are discharged during these dry periods, and the natural buffering capacity of the open estuary is high, creating low acid risk conditions (Figure 6.4).

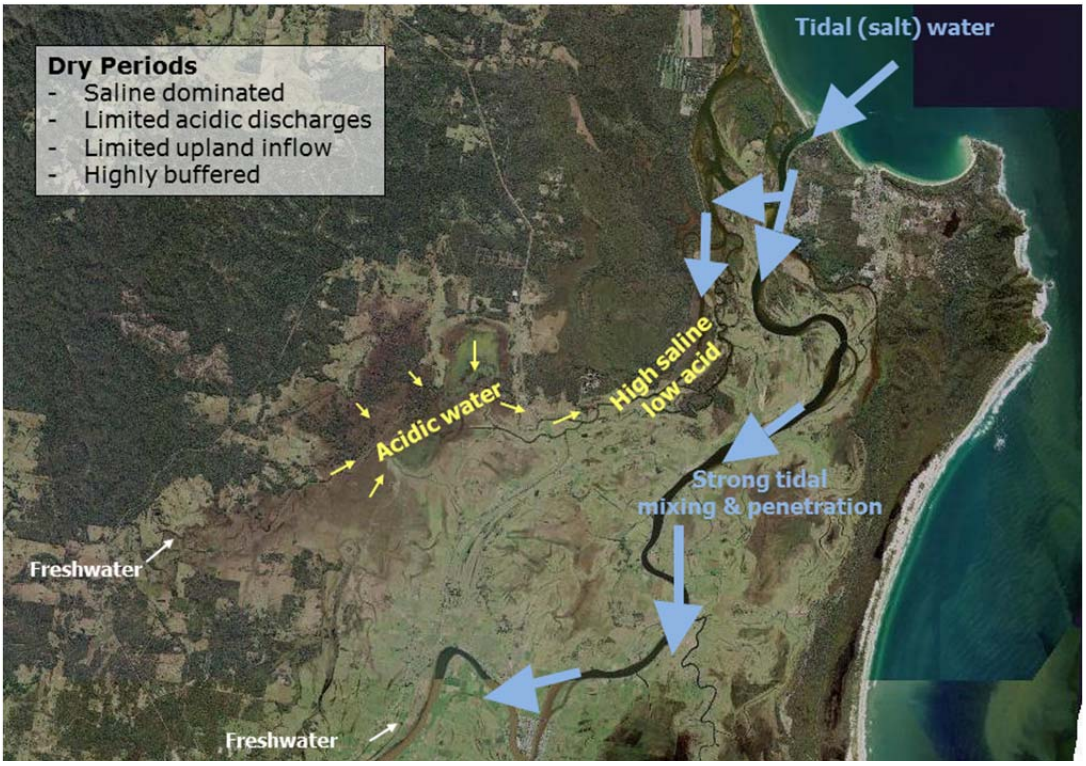


Figure 6.4: Dry periods characterised by high acid buffering and low acid risk to the estuary

During or immediately following a flood event, coastal floodplains are inundated with fresh floodwaters. As the floodwaters recede, large volumes of freshwater drain from the floodplain into the estuary. This process, in conjunction with large freshwater flows in the main river channel, reduces estuarine salinity. During these periods, acid is quickly flushed from the estuary and/or is highly diluted (Figure 6.5).

After the floodwaters have receded, tidal levels slowly re-establish. During this drying period, floodplain pastures are saturated and groundwater levels remain elevated, resulting in a steep gradient between drain water levels and the surrounding groundwater. With the assistance of tidal floodgates driving down water levels, this process mobilises acid from the soil towards drainage channels and receiving waters. As the natural buffering capacity of the estuary has been removed by the fresh floodwaters, acidic plumes comprised of low pH water and high soluble metal concentration remain in the open estuary (Figure 6.6).

This period has the most significant impact on the estuary. Low DO and acidic plumes remain persistent in the wider estuary, leading to degradation of aquatic flora and fauna. Flocculation of metals from floodplain discharges, such as iron and aluminium, are deposited on the estuary bed and filtered by molluscs such as oysters. Monitoring following the 2001 fish kill event on the Macleay River by NSW Fisheries indicated that pH levels and DO concentrations in tributaries remained below recommended levels for over four (4) weeks resulting in 180,000 dead fish observed along a 1.5 km stretch of river at South West Rocks (Walsh *et al.*, 2004).

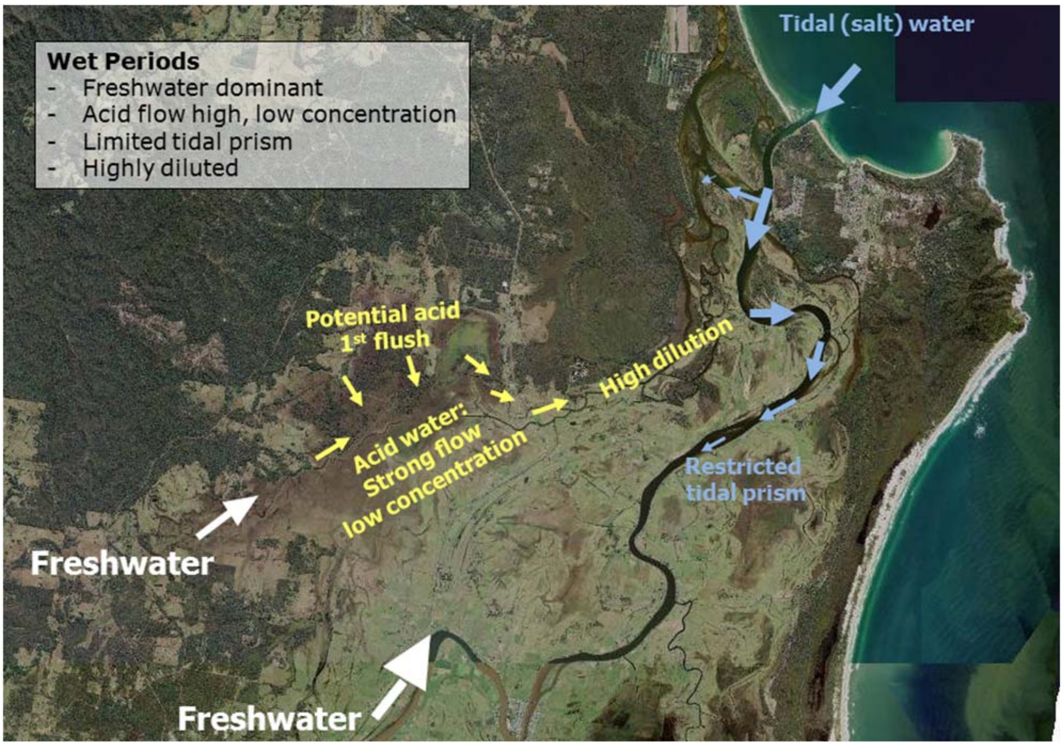


Figure 6.5: Wet periods characterised by high dilution

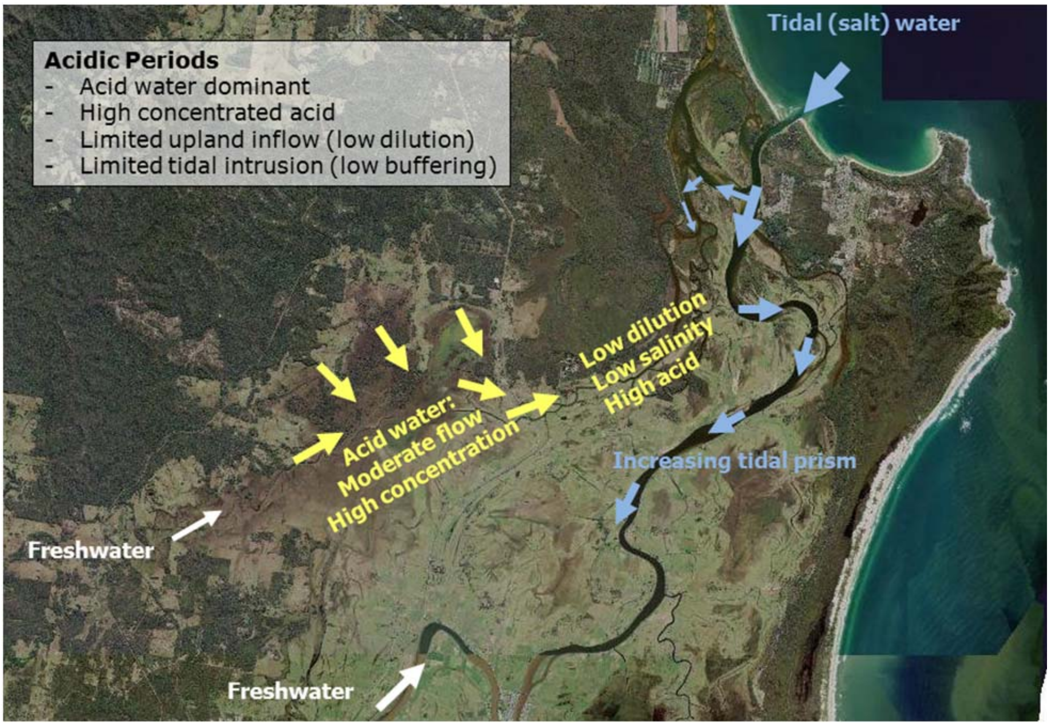


Figure 6.6: Draining periods characterised by high acid discharge

7. Legislative Considerations

7.1 Planning

There are three levels of planning policy which impact any proposed works on the Collombatti-Clybucca floodplain:

- State Planning;
- Regional Planning; and
- Local Planning.

7.2 State Planning

State Environmental Planning Policy 14 (Coastal Wetlands)
This policy applies to wetlands on the coastal fringe of NSW with the aim of protecting wetlands from infilling, clearing, draining and levee construction. Where such activities are proposed an Environmental Impact Statement (EIS) is required to be prepared whereby the full impact of the proposed works to hydrology, flora and fauna are assessed.

Similarly, works that propose the restoration of coastal wetlands through the clearing, infilling, modification or removal of drains, structures and levees also require an EIS to be completed. An EIS enables the impacts of additional works or remediation to be considered and impacts on not only the immediate area, but adjacent stakeholders, to be assessed.

Note that there are no designated SEPP14 wetlands in the Clybucca-Collombatti floodplain.

State Environmental Planning Policy (Rural Lands) 2008
This policy contains rural planning principles and rural subdivision principles which assist in the proper management, development and protection of rural lands. The policy was developed in response to fragmentation of rural areas which resulted in a loss in productivity and production of agriculture.

Protection of the Environment Operations Act (POEO Act) 1997
The *Protection of the Environment Operations Act 1997* aims to protect, restore and enhance the quality of the environment in NSW. In the context of the Collombatti-Clybucca floodplain, the POEO applies directly to the presence of acid sulfate soils. Works which disturb, expose or excavate acid sulfate soils without adequate remediation of the soils are liable for prosecution under the Act. The Act identifies acid sulfate soils as a hazardous waste which needs to be managed to ensure no detrimental impacts to the environment.

7.3 Regional Planning

The *Mid North Coast Regional Strategy 2006 to 2031* applies to the Kempsey Shire Council area and includes the Collombatti-Clybucca floodplain. The primary purpose of the Regional Strategy is to ensure that adequate land is available and appropriately located to accommodate the housing and employment needs for the mid north coast's population. This strategy identifies the rural values of the Collombatti-Clybucca area which is protected from urban development. This strategy is aligned with the Rural Lands 2008 State Planning Policy which aims to protect rural areas and agriculture.

7.4 Local Planning

The *Kempsey Shire Council Local Environmental Plan 2013* (KSC, 2013) provides planning intent for the local council area. The newly adopted plan follows the NSW Government's new standard format for planning schemes. The Collombatti-Clybucca floodplain falls within this area. The Collombatti-Clybucca LEP zones are covered by primary production (RU1) and rural (RU2) on the coastal floodplain area, with forestry (RU3) in the upland catchments (Figure 7.1). The Oxley Highway to Kempsey Pacific Highway Upgrade project falls under infrastructure (SP2).

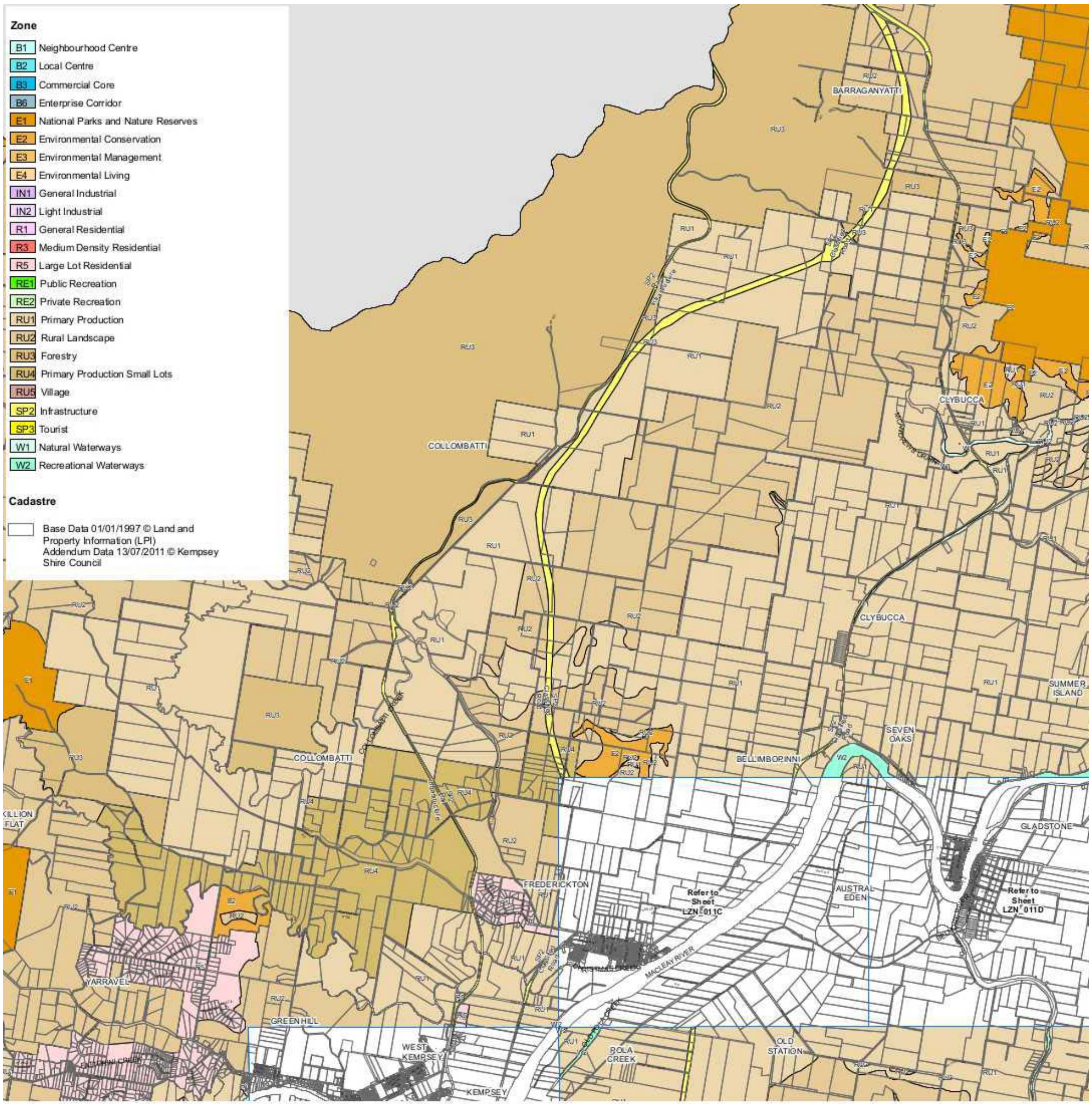


Figure 7.1: Planning Zones (KSC, 2013)

7.5 Legislation and Policy Relating to Menarcobrinni Floodgates

There is a range of legislation, statutes and planning instruments that relate to weirs and flow control structures.

Water Management Act 2000

The Drainage Act was repealed in 1990 with Drainage unions now administered as Private Drainage Boards under the *Water Management Act 2000*. The functions and responsibilities of the drainage board includes the preparation, review and implementation of a management program for its drainage district, to maintain the drainage works in a state of efficiency, and renew such drainage works, if necessary. The Seven Oaks Drainage Union operates under Section 200 of the Act.

Crown Lands Act 1989

The *Crown Lands Act 1989* provides a regime for the ownership and management of Crown Land. The Menarcobrinni floodgates are located on a tidal river bed belonging to the Crown as land located below the mean high water mark belongs to the Crown. As structures are repaired, replaced or upgraded NSW Crown Land seek authorisation to be addressed via a suitable tenure. Any proposed works on the Menarcobrinni floodgates that require statutory approval should be referred to NSW Crown Land.

With respect to land on the Collombatti-Clybucca floodplain, the placement of a structure across or within a tidal water body that has the effect of restricting tidal flow upstream does not necessary alter the title of the land. Furthermore the removal or modification of the Menarcobrinni floodgates which results in partial or full tidal flushing of the floodplain or drainage network (or part thereof) also does not change the title of the land. If a structure has prevented tidal flow for an extended period of time, such that the water body runs dry, the course of the water body as surveyed previously is then identified as Crown land (former tidal waters) (per coms David McPherson, NSW Crown Lands).

Fisheries Management Act 1994 and NSW Fisheries Policy and Guidelines 1999

Works that involve dredging or reclamation of the creek bed or banks, or that block fish passage require a permit under Part 7 of the *Fisheries Management Act 1994*. Additionally, works that involve construction, alteration, or modification of the Menarcobrinni floodgates will trigger Section 218 of the *Fisheries Management Act 1994*.

The *Aquatic Habitat Management and Fish Conservation 1999 Policy and Guidelines* requires NSW Fisheries to be notified for:

1. Floodgates which have deteriorated (such that fish passage is possible) and are proposed for repair;
2. Floodgates proposed for repair on creeks, rivers, and other natural waterways; and
3. Floodgates which currently exclude fish by require major on-site works.

Notification is not required for:

4. Repair of floodgates affected by vandalism;
5. Repair of floodgates damaged by accident;
6. Repair of floodgated blocked or opened by debris; and
7. Minor repairs to flap, hinge and seal replacements whereby the above guidelines 1 and 2 do not apply.

NSW Weirs Policy 1997

The goal of the *NSW State Weir Policy 1997* is to halt and, where possible, reduce and remediate the environmental impact of weirs.

The goal is to be supported by the adoption of the following management principles:

- The construction of new weirs, or enlargement of existing weirs, shall be discouraged;
- Weirs that are no longer providing significant benefits to the owner or user shall be removed;
- Taking into consideration the environmental impact of removal; and
- Where retained, owners shall be encouraged to undertake structural changes to weirs to reduce their environmental impact on the environment.

Environmental Planning and Assessment Act 1979

Works to alter, repair, or remove the Menarcobrinni floodgates will require an assessment under either Part IV or Part V of the *Environmental Planning and Assessment Act 1979* to determine the impact of the proposed works on flora and fauna of conservation concern. A s5A assessment under the EP&A Act covers assessment requirements of threatened species listed under the *Threatened Species Conservation Act 1995* that may be significantly impacted by the proposed works.

The EP&A Act 1979 and the EP&A Regulation 2000 also make provisions for the continuance of existing uses (a use that is lawfully commenced but subsequently becomes prohibited under a new LEP or other environmental planning instruments). However, Section 107 *Continuance of and limitations on existing use* does no authorise any alteration or extension to, or rebuilding of the floodgates, or any enlargement or expansion or intensification of the existing use of the floodgates.

8. Conservation Benefits of Wetland Remediation Proposal

This wetland offset proposal attempts to take advantage of a once in a generation opportunity to remediate a large portion of the worst acid affected land on the NSW coast. Whilst a like-for-like offset is ideal for the conservation of the individual species or community affected, the conservation benefit of the like-for-like offset is somewhat limited to a local, paddock scale. Conversely, this wetland proposal will generate significant net conservation benefits for a wide range of communities including terrestrial and aquatic species at catchment and estuary wide scales (Figure 8.1).

Figure 8.1: Scale of conservation benefits in the Macleay Valley

Paddock Scale Conservation Benefits

Paddock scale refers to the localised area of pastures and hydrological units within the Collombatti-Clybucca floodplain. The paddock scale conservation benefits include:

- Improved species diversity;
- Increased habitat for endangered ecological communities including:
    - o Approximately 1,090 ha mid-tidal range species (i.e. mangroves)
    - o Approximately 450 ha high-tidal range saltmarsh (i.e. saltmarsh)
    - o Approximately 630 ha above tidal range (i.e. swamp sclerophyll forest);
- Enhanced and expanded existing local vegetation communities (draft vegetation mapping from Niche Ecological (2014) is attached in Appendix C);
- Carbon storage, specifically by saltmarsh and mangrove species which store up to 200% more carbon per area than tropical and temperate forests;
- Improved soil structure; and
- Improved groundwater quality and reduced acid export, from current pH ~ 3 to near neutral pH.

Local Catchment Scale (Collombatti-Clybucca floodplain) Conservation Benefits

Local catchment scale benefits are those that impact the entire Collombatti-Clybucca floodplain and associated waterways and drainage channels. The catchment scale conservation benefits include:

- Improved surface water quality
    - pH increase from current pH ~ 3 to near neutral
    - reduced iron concentrations
    - reduced aluminium concentrations
    - reduction in volume of acidic water discharged from Seven Oaks area;
- Retention of sediment otherwise flushed into estuary;
- Reduced black water events with overall improvements in dissolved oxygen (DO);
- Conservation of aboriginal heritage sites within the Collombatti-Clybucca area;
- Restoration of 10 – 15 km of acidic drainage channels;
- Restoration of fish habitat to 10 – 15 km of waterways; and
- Approximately 1,540 ha of tidal flats, open water, tidal vegetation communities for estuarine primary production and migratory wader bird habitat.

Estuary Wide Scale Conservation Benefits

Estuary wide benefits extend beyond the Collombatti-Clybucca floodplain and affect the wider Macleay River estuary and tributaries. The estuary scale conservation benefits include:

- Habitat connectivity between wetlands in the Macleay River estuary;
- Significantly increased primary production;
- Enhanced recovery of estuarine water quality following large rainfall events with existing discharge events from the Clybucca floodplain impacting over 50 km of estuary in Clybucca Creek, Andersons Inlet, Macleay Arm and the main Macleay River (Hurrell *et al*., 2009);
- Interaction between regional habitats;
- Significant improvements to aquaculture and fishery industry production yield; and
- Improvements to regional ecotourism and recreation aquatic activities including boating and recreational fishing.

Global Scale Conservation Benefits

Global scale benefits impact global issues such as climate change and migratory species conservation. The global scale conservation benefits include:

- Generation of migratory wader bird habitat which satisfies Australia's commitment to the bilateral agreements of JAMBA, CAMBA, ROKAMBA, the Bonn Convention, the Ramsar Convention and ACAP;
- Significant carbon sequestration by intertidal vegetation communities (in comparison to other terrestrial vegetation types); and
- The ability to adapt and evolve to climate change and sea level rise as a single hydrological unit.

9. Implementation of Plan of Management

The processes of remediating acid sulfate soil affected areas of the Collombatti-Clybucca floodplain is similar to other sites on the NSW coast. Similar sites include the nearby Yarrahapinni wetlands (Glamore *et al*., 2012), Big Swamp near Taree (Glamore *et al*., 2014), Hexham and Tomago wetlands on the Hunter River (Rayner and Glamore, 2011) and Broughton Creek on the Shoalhaven River (Glamore *et al*., 2014).

Remediation options, and a subsequent remediation strategy, are typically developed through detailed numerical model scenario testing in combination with site field data collection. The modelling of various remediation options enables risk to the environment, stakeholders and neighbouring landholders to be quantified and measures taken to mitigate any risks. To ensure that all risks are considered, consultation with the community, Working Group partners and constant consideration of State, regional and local legislation and policy occurs throughout the project (Figure 9.1).

Currently, the Clybucca Working Group is comprised of:

- North Coast Local Land Services;
- NSW Office of Environment and Heritage (Planning and Infrastructure);
- Kempsey Shire Council;
- NSW Department of Primary Industries (Fisheries);
- NSW Office of Environment and Heritage (National Parks and Wildlife Services);
- NSW Roads and Maritime Services; and
- NSW Office of Environment and Heritage (Environmental Protection Agency).

Representation from the a range of community groups is currently being sought, including but not limited to:

- Floodplain farming industry (cattle graziers);
- Seven Oaks Drainage Union;
- Aquatic Industries (oyster farmers, professional fishers);
- Macleay Valley Landcare;
- Community (Save our Macleay River, SPADCO);
- Kempsey Local Aboriginal Land Council;
- Other Research institutions (UNE, SCU);
- Other State Government agencies (SES); and
- Recreational fishing representatives (SWR SeaBreeze Pro-Am Fishing Club, NSW Recreational Fishers, EcoFishers).

A staged approach, as outlined in Figure 9.1, ensures that the remediation of the Collombatti-Clybucca floodplain is based on sound science and engineering, and considers all risks and stakeholder concerns. The stages of the project are summarised as follows:

Stage 1: Development of a remediation strategy (or options). Potential remediation options are developed to be tested in detail during Stage 2 of the project. Options are based on conceptual models of the site and relevant background including land tenure and heritage, in conjunction with ecology, soil science and hydrologic context. The remediation strategy is based on current site conditions, hydrology, land owner consultation and the required outcomes. During this stage of the project, all available data and literature are reviewed and any data requirements for later project stages identified.

Stage 2: Remediation Scenario Testing. This stage of the project aims to assess and quantify, in detail, the impacts of various remediation options. This is undertaken using a range of engineering techniques and software including rainfall-runoff models, overland hydrodynamic models, GIS and desktop hydraulic calculations. During this stage of the project, the outcomes of each remediation scenario can be quantified and risks to stakeholders identified with mitigation measures included in scenario tests.

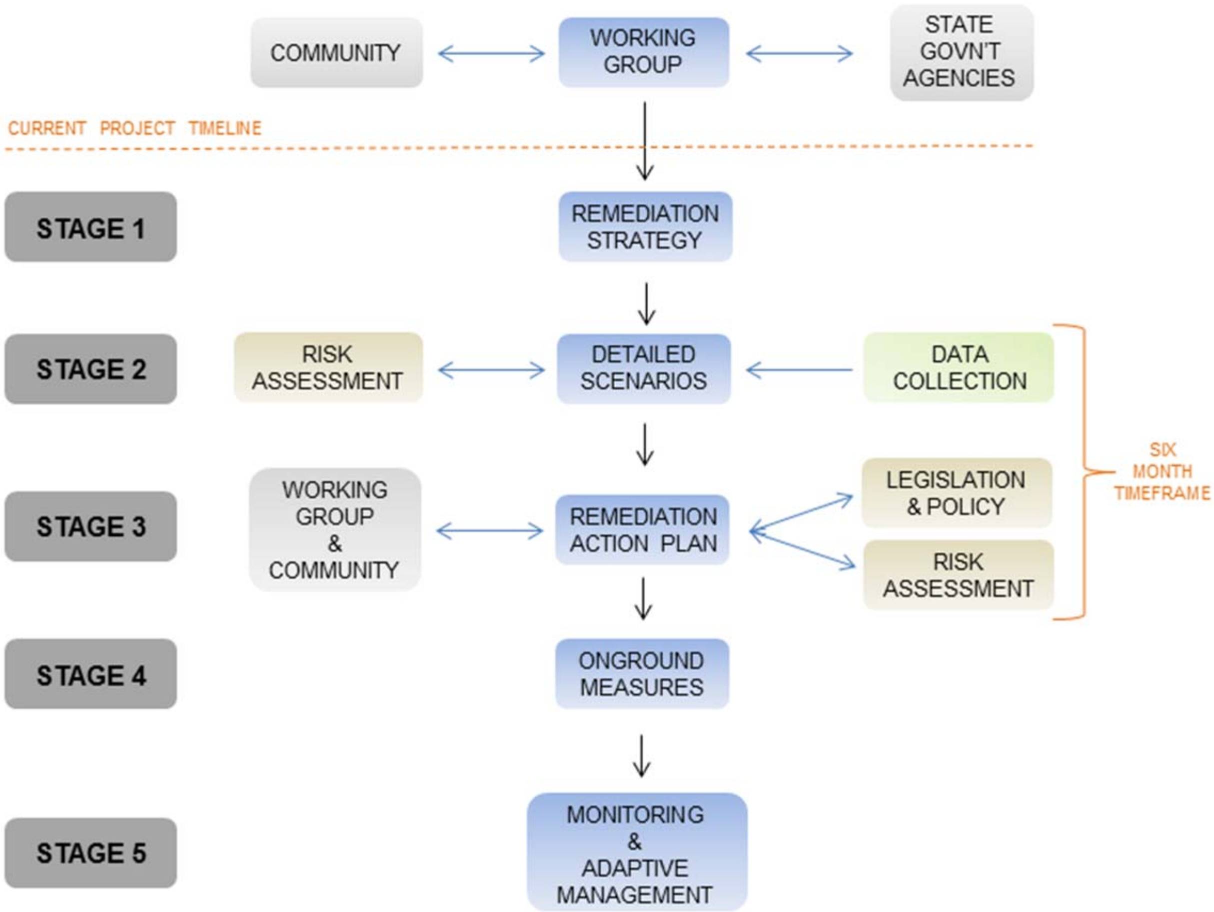


Figure 9.1: Outline of a co-ordinated management approach

Stage 3: Remediation Action Plan. The Remediation Action Plan (RAP) details the preferred management outcome and forms the basis for ongoing works. Including extensive consultation with the Working Group and representatives of the community, a final remediation option and strategy for implementation is developed and finalised. Detailed concept designs for all required on-ground works, and indicative costs for the works, are included in the RAP. All relevant policy and legislative requirements are considered (and further investigation undertaken if required) prior to proceeding with on-ground works (Stage 4). A monitoring plan is also developed for the project to assess the impact of remediation and site response. Key instrumentation and monitoring equipment is deployed prior to on-ground works to establish a base case for later comparison, enabling the progress of site remediation to be quantified. A future plan of management is also developed at this stage of the project.

Stage 4: On-ground implementation of Remediation Action Plan. Following sign off of the RAP, on-ground works are undertaken by contractors to construct or remove any structures required. Earthworks are also undertaken at this stage of the project which may include levee construction/reinforcement, drain infilling and drain reshaping.

Stage 5: On-going monitoring, evaluation and adaptive management. On-going monitoring of the site is designed to provide feedback on the long-term effectiveness of the management plan. The monitoring should provide an early warning of any environmental degradation and be adaptable to evaluate and modify the management of the project as necessary (Tulau, 2007). Adaptive management is the variation of the existing management plan in response to observed changes to the site. The ability to adaptively manage remediated acid affected sites such as the Clybucca floodplain is critical to the long-term success of the project.

Although purely speculative, future management of the site would ideally be undertaken by an institution with incorporation of regional or state environmental obligations. This would enable the site to be managed in alignment with other restored wetlands and migratory bird habitats along the east Australasian flyway.

10. Floodplain Remediation Option

The acquisition by NSW Roads and Maritime Services (RMS) includes approximately 850 hectares of historically vibrant wetlands in Doughboy Swamp and Mayes Swamp. This presents a once in a lifetime opportunity for long-term remediation of the Collombatti-Clybucca floodplain. The areas of Doughboy Swamp and Mayes Swamp are the lowest lying, most acid affected areas in the lower Macleay floodplain and have long been identified as one of the worst acid area in NSW. Prior to drainage, the backswamps formed the largest contiguous wetland on the north coast of NSW.

For the first time in the history of the Collombatti-Clybucca floodplain, a single landholder has ownership of the worst acid affected areas. The low-lying floodplain areas of the RMS properties currently do not form part of the highway offset strategy. However, significant conservation benefit could be achieved on an estuary wide scale if the low lying floodplain areas of the RMS properties are remediated into a natural wetland system.

Until now, implementation of long-term remediation strategies has been hindered by the agricultural land use of the floodplain. Successful large scale remediation of similar sites, such as the nearby Yarrahapinni wetlands and Big Swamp near Taree, has been achieved through changing land management practices. Previous efforts to remediate the Collombatti-Clybucca floodplain have failed to reach agreement with the large number of previous landholders. Landholders agreement is critical to ensure that the site is remediated as a single hydrological unit.

This section presents a sustainable remediation strategy for the RMS acquisition areas of the Collombatti-Clybucca floodplain. Note that consultation with adjacent landholders, the Clybucca Working Group and the wider community is recommended as part of the remediation process.

10.1 Tidal Option

The greatest conservation benefit for the site can be achieved through the re-introduction of tidal waters. This strategy would neutralise acidic waters at the source and create large areas of endangered ecological communities (EEC). For this strategy to be implemented, further property acquisitions of other low lying areas of the floodplain are required to minimise on-ground works and enable the management of the site as a single hydrological unit. Decommissioning the Menarcobrinni floodgates is critical to implementing this strategy. Removal of the existing tidal flaps, whilst the concrete structure of the headworks remains, may be a feasible option. A number of smaller structures and on-ground works would be required to mitigate impacts to adjacent landholders.

Potential habitat produced through the tidal remediation option is outlined in Table 10.1. The full conservation benefits of this strategy are outlined in Section 7 of this report.

Table 10.1: Potential habitat area (indicative only) on the Clybucca-Collombatti floodplain based on controlled tidal inundation

Habitat	Area (ha)	Length (m)
Floodplain fisheries	1,540	
In-channel fisheries		16,000
Low to mid-tidal	1,090	
Mid to high tidal	450	
Above tidal range below 20 m AHD	570	
Above 20m AHD	60	

10.2 Full Tidal Remediation

Decommissioning of the Menarcobrinni floodgates without additional on-ground works would result in full, uncontrolled inundation of the Collombatti-Clybucca floodplain (Figure 10.1). This would generate the largest conservation benefit with maximised terrestrial and aquatic habitat production. This would also remediate acid generation in the Collombatti-Clybucca floodplain. To facilitate this, a significant area of land would need to be acquired to ensure that land management shifts from agriculture to conservation.

Implementation of this strategy requires acquisition of the entire floodplain and is therefore unlikely.

10.3 Controlled Tidal Remediation

10.3.1 Additional Property Acquisition

The existing RMS property boundaries cover a significant portion of Doughboy Swamp and Mayes Swamp, the worst acid affected land. Utilising the existing RMS properties, in conjunction with additional supplementary acquisitions, would facilitate the remediation of the lowest lying backswamp area. However, the existing RMS property does not include the full areas of Doughboy Swamp and Mayes Swamp.

It is therefore proposed that low lying areas adjacent to the existing RMS properties be acquired. With this acquisition, the majority of Doughboy Swamp and Mayes Swamp would be controlled by a single landholder, and significantly reduce the scale of on-ground works required. These additional acquisition areas are presented in Figure 10.2. A total additional area of approximately 900 hectares across three priority areas is recommended.

The proposed acquisition areas have been identified based on simplistic ‘bucket’ GIS modelling. The priority acquisition areas are not based on cadastral information. Additional land acquisition or control structures may be required at the north of Doughboy Swamp. Further detailed hydrodynamic modelling is required to confirm the full extent of tidal influence and subsequent land acquisitions or control structures.

If further acquisitions are not possible, then significant on-ground works would be required to ensure risk to adjacent landholders is mitigated. The scale of on-ground works required is likely to be cost prohibitive, and significantly increase the long-term management of a remediated site.

10.3.2 Risk Mitigation Structures

If tidal flows could be restored to Doughboy and Mayes Swamps, additional on-ground works would be required in other locations to limit inundation on adjoining properties (Figure 10.3). Construction of five additional, small floodgate control structures would enable floodwaters to drain from adjacent floodplain properties, whilst limiting tidal intrusion. Indicative tidal inundation is presented in Figure 10.4.

Construction of new levees and reinforcement of existing drain levee banks would also be required. The height and scale of constructed levees would be designed such that normal tidal levels would not overtop the levees. Constructing the lowest crest level possible is critical to minimising any impact to local flood levels and flood drainage time. Note that further detailed investigation is required to detail specific design specifications. Detailed hydrodynamic modelling, survey levee crest elevations and stakeholder consultation is required prior to finalising the required risk mitigation structures.

Initial estimates suggest the proposed works would cost in the order of $1,000,000 to $2,000,000, in-line with similar projects in NSW.

10.3.3 Outcomes

Successful application of this remediation strategy would result in significant habitat creation for endangered ecological communities (EEC). A range of potential habitats based on tidal range are presented in Figure 9.5. The potential habitats include:

- 1,090 hectares of low to mid-tidal habitats. These areas are potential mangrove and open water habitat. Areas of Mayes Swamp are likely to feature areas of open water due to the low elevation of the Swamp favourable for migratory bird species. Large areas on the fringe of Mayes Swamp and the eastern area of Doughboy Swamp form low to mid-tidal habitat.
- 450 hectares of middle to high tidal habitats for EEC such as saltmarsh. The fringe of Mayes Swamp and the large western and northern portions of Doughboy Swamp form significant areas for high tidal habitats.
- Areas with elevations in excess of approximately 0.9 m AHD form habitat for coastal floodplain freshwater vegetation, such as swamp sclerophyll forest.
- All tidal areas form fisheries habitat, with inundated floodplain areas likely to produce significant areas of primary production (1,540 hectares) and provide fish passage for over 16 km of previously restricted waterways.

A summary of the local and regional conservation benefit of a tidal remediation strategy is presented in Section 8.

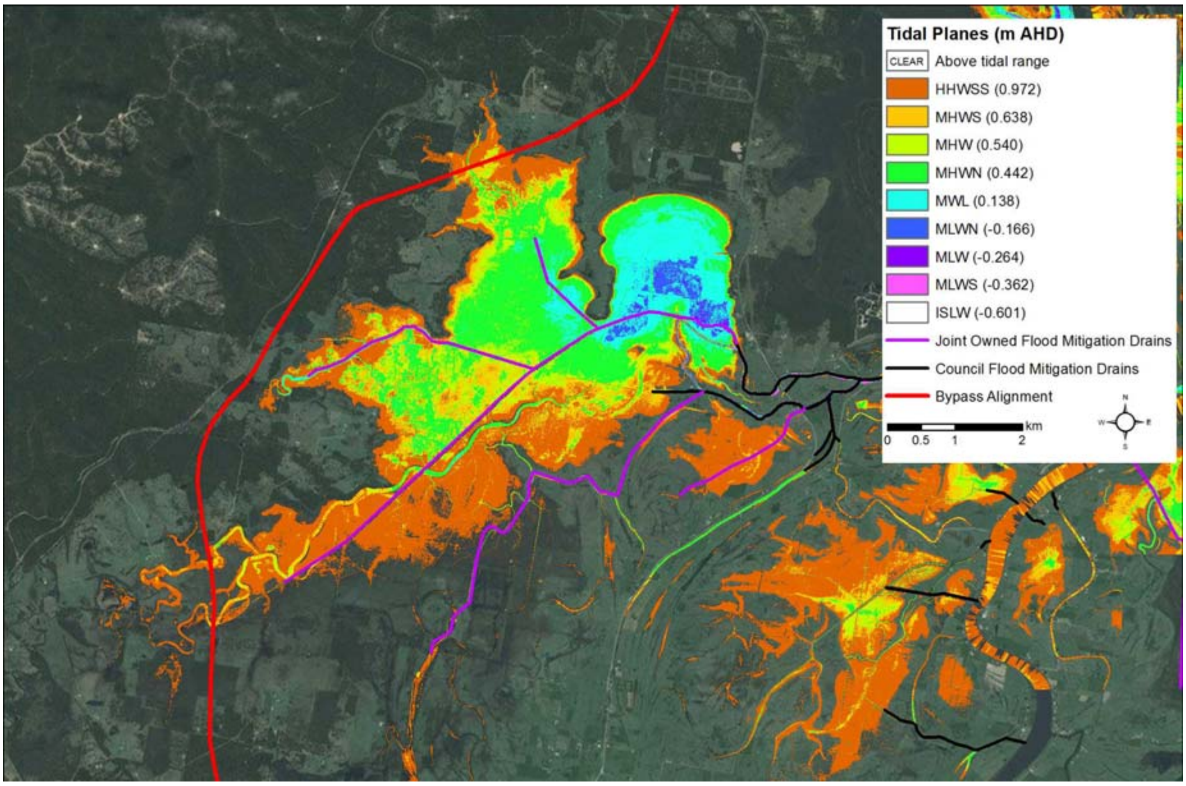


Figure 10.1: Full tidal inundation based on tidal planes at Menarcobrinni floodgates (MHL, 2004)

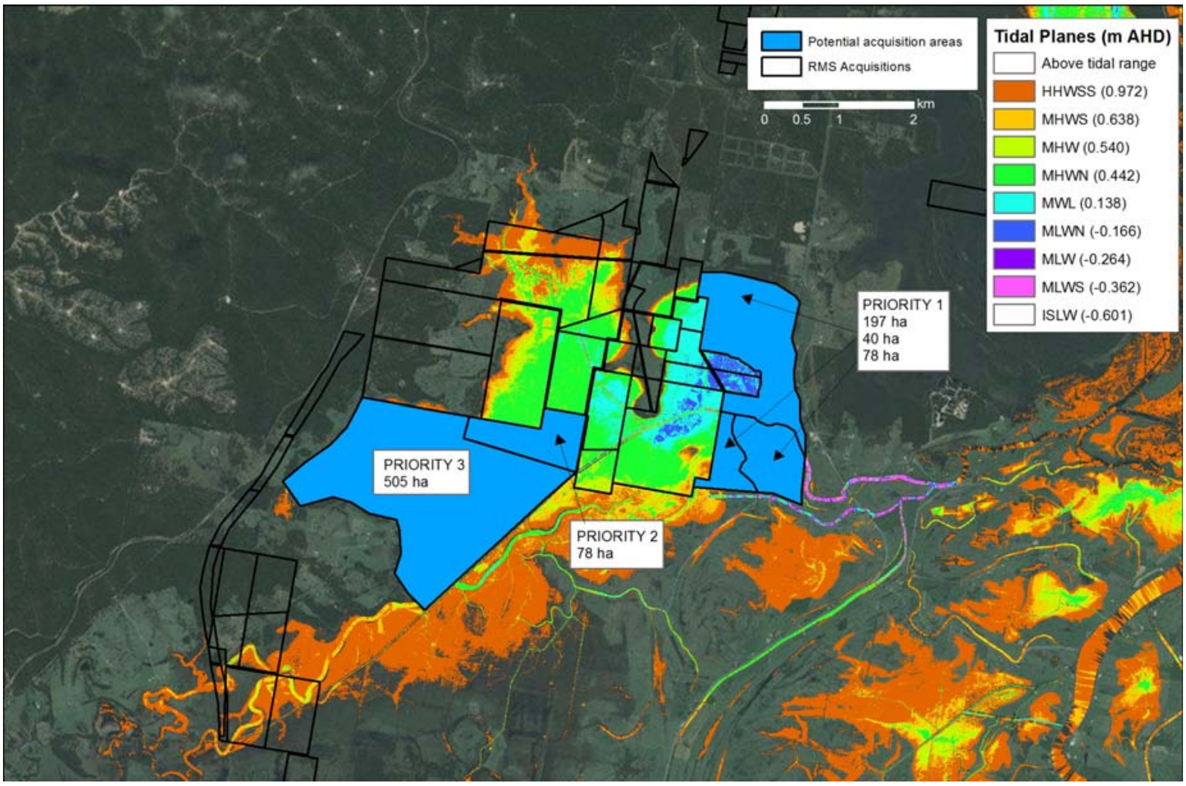


Figure 10.2: Current RMS property extent with priority acquisitions recommended

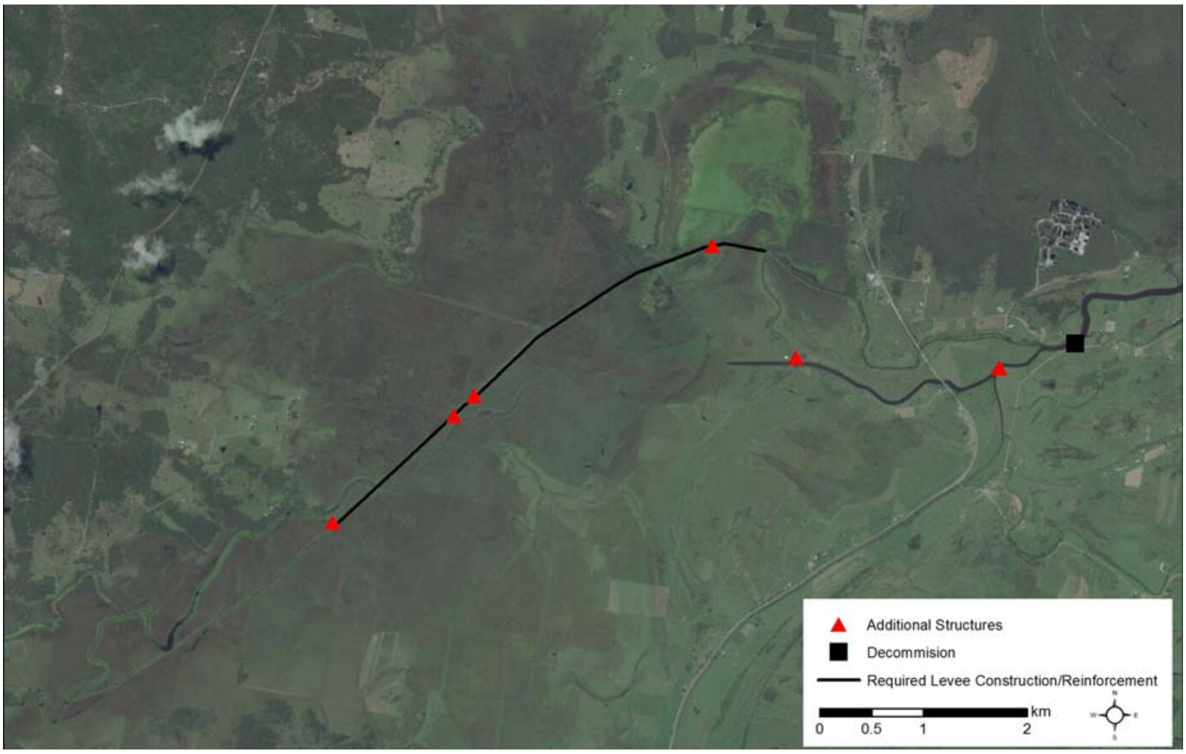


Figure 10.3: Proposed on-ground works required to mitigate risk to neighbouring properties (based on acquisition of priority areas 1, 2 and 3)

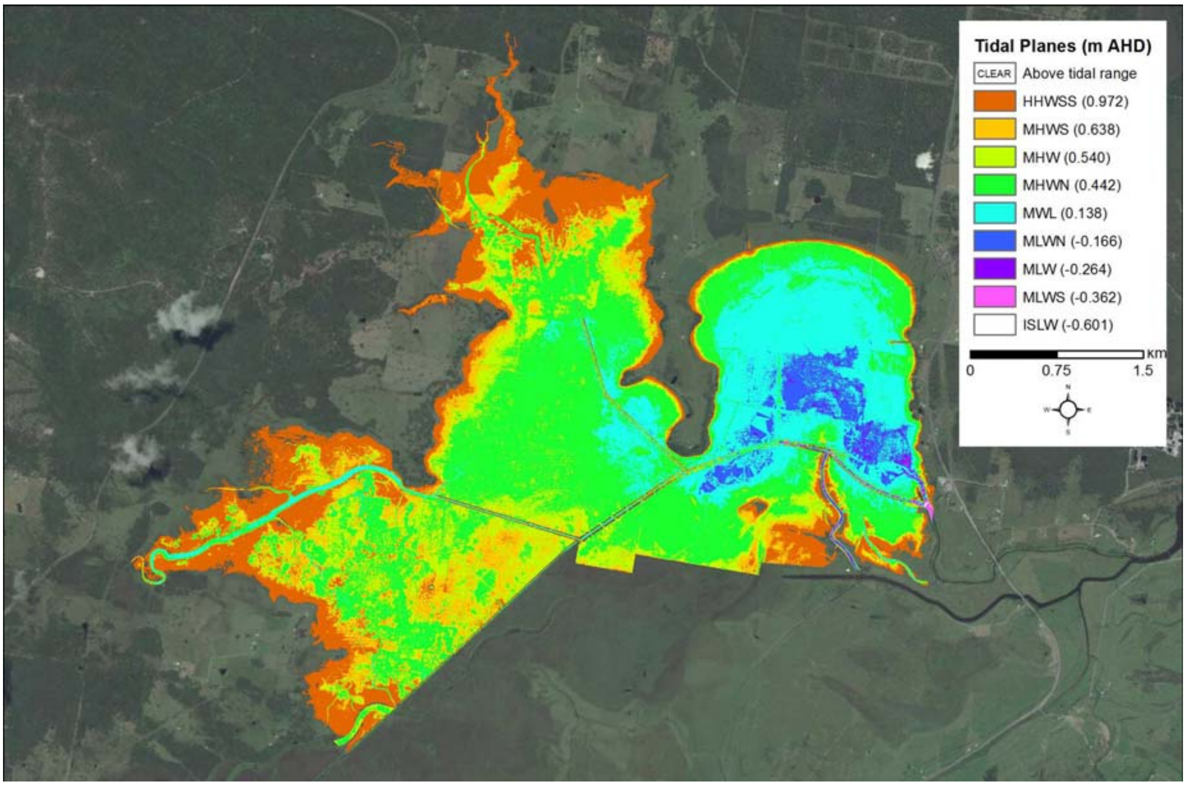


Figure 10.4: Resulting inundation based on additional acquisitions and on-ground works

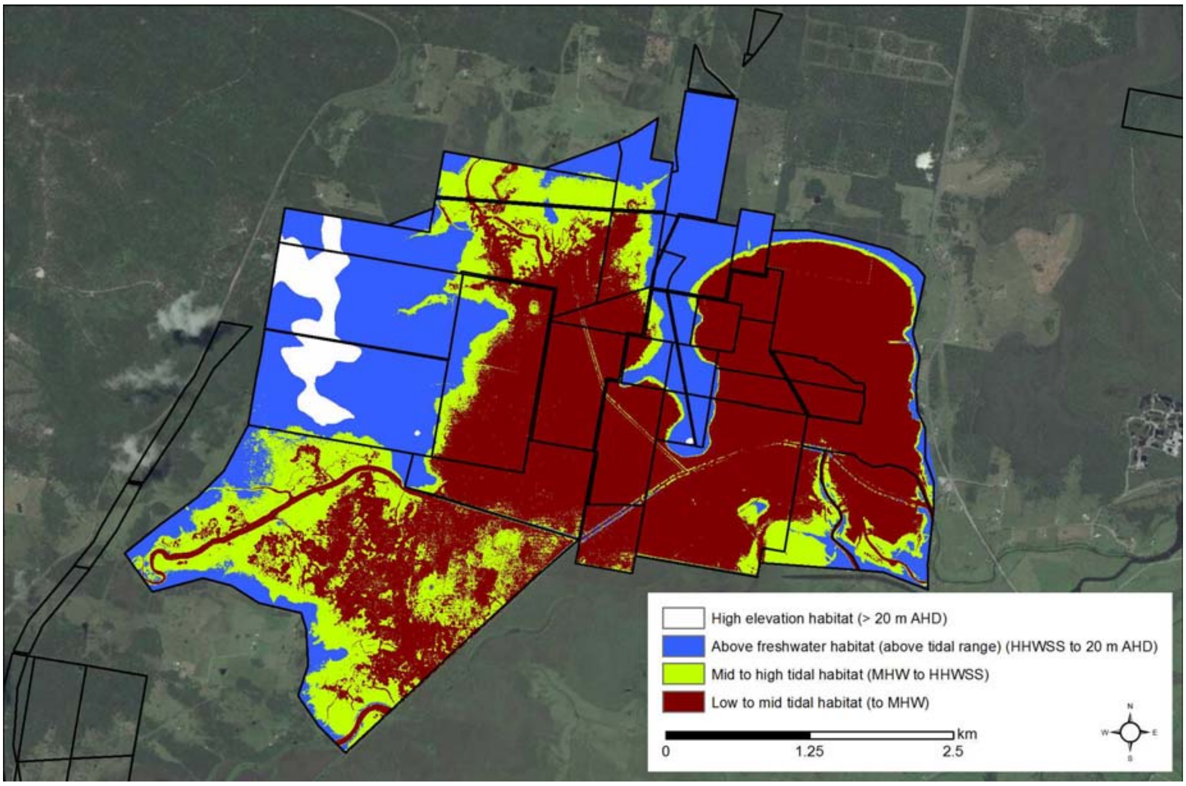


Figure 10.5: Potential habitat distribution following remediation

11. Conclusion

The wetlands of the Collombatti-Clybucca floodplain were once thriving with life. Extensive drainage works in the late 1960s and early 1970s established an efficient network of drainage channels. The drainage infrastructure connected the Macleay Arm of the Macleay River estuary to the Collombatti-Clybucca floodplain via Andersons Inlet. The construction of the Menarcobrinni floodgates inhibited tidal flushing of the drainage network and backswamps. The drainage works permanently altered the hydrology of the Collombatti-Clybucca floodplain and its' backswamp wetlands. The drainage works and expansion of agriculture on the floodplain backswamps resulted in a range of impacts to the wetlands and the wider Macleay River estuary.

Impacts of the drainage works include:

- Clearing of vegetation
- Loss of native flora and fauna
- Loss of fish passage/habitat
- Poor water quality
- Oxidation of acid sulfate soils
- Consolidation of soils
- Low dissolve oxygen discharge
- Erosion and loss of sediment

Efforts and public calls to remediate the site have been ongoing for decades. As early as the mid-1980s, wetland experts recommended that the acid affected area of Mayes Swamp be acquired by the government in an attempt to limit the impact of the area on the wider estuary. Remediation efforts in the late 1990s and early 2000s reduced the severity of surface scalding to paddocks and improved agricultural productivity. However, despite these efforts poor water quality characterised by low pH, low DO and high metal concentrations continues to be discharged from the floodplain. The backswamps of the Collombatti-Clybucca floodplain wetlands have been identified as the highest environmental priority for the Macleay River valley (Geolink, 2010, 2012). Broad-acre site remediation is unlikely unless the current land use practices are changed.

To date, large-scale remediation of the site has been hindered by the number of landholders on the floodplain. Recent land acquisitions by NSW Roads and Maritime Services as part of the offset requirements for the Oxley Highway to Kempsey Pacific Highway Upgrade project have resulted in a single landholder owning a large portion of the worst acid affected areas of the floodplain. These acquisitions present a once in a lifetime opportunity to permanently remediate one of the most important backswamp areas in NSW.

Currently, discharge events from the floodplain impact over 50 km of the lower Macleay River estuary. During normal conditions, with a drain water level at mean sea level (0 m AHD) the drainage network holds approximately 500 ML of acidic water that is low in dissolved oxygen and has high concentrations of aluminium and iron. This equates to approximately 220 Olympic swimming pools of acidic water that is discharged at the first flush of a rainfall event.

Site remediation via the implementation of a tidal strategy would result in significant conservation benefits to the local Collombatti-Clybucca area and the wider Macleay River estuary. Outcomes of the strategy would include:

- Creation of approximately 1,540 ha of intertidal EEC habitat and 630 ha of freshwater habitat;
- Restoration of approximately 16 km of acidic waterways;
- Restoration of approximately 16 km of in-channel fish habitat;

- Approximately 1,540 ha to tidal flats, open water, tidal vegetation communities for primary production and migratory bird habitat;
- Enable habitat connectivity between wetlands in the wider Macleay River Valley;
- Reduce acidic discharges by buffering acid at the source;
- Provide significant carbon storage; and
- Create migratory bird habitat which fulfils Australia's bilateral agreements.

The proposed tidal remediation strategy provides the opportunity for large scale remediation of the wetlands. The re-introduction of tidal flushing would neutralise acid at the source and create significant EEC habitat. Detailed investigations are required to determine the full extent of tidal inundation, potential habitat distributions, and on-ground works required to mitigate impacts to adjacent landholders. Preliminary GIS 'bucket' modelling indicates that on-ground works in the order of $1,000,000 to $2,000,000 may be required.

Cost effective implementation of the tidal remediation strategy requires further land acquisition of adjacent low-lying backswamp properties. Currently, RMS properties extend for the majority of the low-lying areas of Doughboy Swamp and Mayes Swamp, with adjacent areas operated as private holdings. Implementing a tidal strategy without further acquisitions would require significant on-ground works to mitigate risks to adjacent properties. Additional acquisitions would enable the site to be operated as a single 'hydrological unit' and limit on-ground works required.

This report outlines the significant impact that drainage of the Collombatti-Clybucca floodplain has had on the local wetlands and wider Macleay River estuary. Although remediation has been attempted at a 'paddock scale', the site remains acidified and continues to discharge poor quality water into the Macleay River estuary. Large scale remediation of the site is possible if current land use practices are changed.

12. References

Andrews, K., Dewhurst, P., Grogan, T., Phillips, J., and Sumpter, C., (2005), Survey of how sediment profiles change across vegetation and scaled acid sulfate soils, Undergraduate project report, Australian National University

Aaso, T., (2000), 'Towards sustainable landuse within acid sulfate soil landscapes: A case study on the Maria River', New South Wales, Lund University, Sweden

Bureau of Meteorology (BoM), www.bom.gov.au/climate/data, 10/8/2014

Birch, M., (2010), Macleay River Estuary and Floodplain Ecology Study, Aquatic Science and Management

Blunden, B.G., 2000, Management of acid sulfate soils by groundwater manipulation, PhD Thesis, University of Wollongong, NSW Australia.

Bush, R.T., Keene, A., Sullivan, L.A., and Bush, M.L., (2006), Water Quality Analysis of ASS Hot Spots, Southern Cross University

Chartres, C., Hanrahan, D., Hughes, J. and Williams, S., (2005), Occurrence and influence of sub-surface shell material on acid sulfate soil processes in relation to surface scalding, Undergraduate project report, Australian National University

Cheeseman, P., Fifield, G., Godwin, P., Maish, A., Wellington, S., (2004), NSW Environmental Services Scheme, A Case Study: 'Illalong' owned by R. & G. Yerbury, Report, Australian National University

Department of Environment and Climate Change (DECC) (2008), What are the effects of acid sulfate soils?, NSW Government

Department of Environment and Climate Change and Water (DECCW) (2010), NSW Climate Change Impact Profile, NSW Government

Department of Resources and Environment (DERM) (2009), What are acid sulfate soils?, QLD Government

Enginuity Design, (2003), Collombatti-Clybucca Acid Sulfate Soil "Hot Spot" Area Management Plan Final Report, Prepared for Kempsey Shire Council

GeoLINK, (2010), Macleay River Estuary Management Study

GeoLINK, (2012), Macleay River Estuary Coastal Zone Management Plan

Glamore, W.C., (2003), Evaluation and analysis of acid sulfate soil impacts via tidal restoration, PhD Thesis, Faculty of Engineering, University of Wollongong

Glamore, W.C., Wasko, C.D. and Smith, G.P., (2012), Rehabilitation of Yarrahapinni Wetlands National Park: Hydrodynamic Modelling of Tidal Inundation, Water Research Laboratory, WRL Technical Report No. 2011/21

Glamore, W.C., Ruprecht, J.E., Rayner, D.S. and Smith, G.P., (2014), Big Swamp Rehabilitation Project: Hydrological Study, Water Research Laboratory, WRL Technical Report No. 2012/23

Glamore, W.C., and Rayner, D.S., (2014), Lower Shoalhaven River Drainage Remediation Action Plan, Water Research Laboratory, WRL Technical Report No. 2012/25

Hurrell, G., Barbour, E. and Kauffeldt, A., (2009), Macleay River Estuary Processes Study, WMA Water

Johnston, S., Kroon, F., Slavich, P., Cibilic, A. and Bruce, A., (2003), Restoring the balance: Guidelines for managing floodgates and drainage systems on coastal floodplains, NSW Agriculture, Wollongbar, Australia

Kempsey Shire Council (KSC), (2004), Collombatti-Clybucca Acid Sulfate Soil Hot Spot Final Report

Kempsey Shire Council (KSC), (2013), Kempsey Shire Local Environment Plan (LEP)

Kennelly, S.J. and McVea, T.A. (Ed), (2002), Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001

Naylor, S., Chapman, G., Atkinson, G., Murphey, C., Tulau, M., Flewin, T., Milford, H. and Moran, D., (1995), Guidelines for the use of acid sulfate soil risk maps, Soil Conservation Service, Sydney

Niche Ecological, (2014), Existing vegetation on NSW Roads and Maritime property acquisitions on the Collombatti-Clybucca floodplain (draft vegetation figures only)

North Coast Environment Centre, 1999, Macleay Wetlands Management Plan Draft

Macleay Argus, Saturday 2 November 1974, Flood work blamed. Land values decreasing.

Manly Hydraulics Laboratory, (2004), DIPNR Macleay River Estuary Tidal Data Collection April – May 2003, Report No. 1250

McLennan, M., Higgins, A., Hermawan, H., Thang, T.V., and Nghiem, N.T., (2005), Spatial variability of water chemistry in Mayes Swamp: Examination of correlations between water chemistry and vegetation, Undergraduate project report, Australian National University

NSW Department of Planning and Infrastructure, Acid sulfate soil planning maps, Accessed: 18/11/2014, www.planning.nsw.gov.au/spatial-data-download

NSW Department of Public Works (PWD), (1978), Environmental Impact Statement Additional drainage: Seven Oaks area

Rayner, D.S. and Glamore, W.C., (2011), Tidal inundation and wetland restoration of Tomago Wetland: Hydrodynamic modelling, Water Research Laboratory, WRL Technical Report No. 2010/30

Smith, R.J., 1997, Installation of temporary water retention structures to manage acid sulfate soils, Final project report, R.J. Smith & Associates

Smith, R.J., (1999), Hastings, Floodgates and Drains: Possible improvements in management, Information bulletin # 2, February 1999

Tulau, M.J., and Naylor, S.D., (1999), Acid sulfate soil management priority areas in the lower Macleay floodplain, Report, Department of Land and Water Conservation, Sydney

Tulau, M.J., (2007), Acid sulfate soils remediation guidelines for coastal floodplains in New South Wales, Department of Environment and Climate Change, DECC Report No. 2007/321

Tulau, M., (2011), 'Lands of the richest character: agricultural drainage of backswamp wetlands on the North Coast of New South Wales, Australia : development, conservation and policy change : an environmental history', PhD thesis, Southern Cross University, Lismore, NSW

Telfer, D., (2005), Macleay River Estuary Data Compilation Study, GECO Environmental

Telfer, D. and Birch, M. (2009) Lower Nambucca River Estuary Water Quality Study

Webb McKeown & Associates, (1997), Lower Macleay floodplain management study

Walker, P.H., (1961), Groundwater characteristics of the Kempsey District NSW, CSIRO Division of Soils, Divisional Report 1/61

Walker, P.H., 1963, A reconnaissance of soils in the Kempsey district NSW, CSIRO Soils and Land Use Series No 44, Melbourne

Walker, P.H., (1972), 'Seasonal and stratigraphic controls in coastal floodplain soils', Australian Journal of Soil Research, 10, 127-142

Walsh, S., Copeland, C. and Westlake, M., (2004), Major fish kills in the northern rivers of NSW in 2001: Causes, impacts and responses, NSW Department of Primary Industries, Fisheries Report No. 68

WetlandCare Australia, (2010), Clybucca Floodplain Wetlands Concept Management Plan

Wilkinson, K.E., (2014), The ecohydrology and restoration of an enclosed estuarine wetland, PhD thesis, University of New England

Appendix A – EPA Correspondence

NSW EPA

Your reference:
Our reference: Doc14/305286
Contact: Brett Nudd, (02) 6640 2501

Mr David Ledlin
Roads and Maritime Services
59 Darby and Queen Streets
NEWCASTLE NSW 2300

Dear Mr Ledlin

I refer to your email dated 10 November 2014 and subsequent email dated 25 November 2014outlining the Roads and Maritime Services' (RMS) biodiversity offset proposal for the Oxley Highway to Kempsey (OH2K) Pacific Highway Upgrade project. I apologise for the delay in responding.

The Environment Protection Authority (EPA) has reviewed the proposed offset package and offers the following advice.

Based on the information currently available the EPA understands that the proposed offset package comprises:

- 960 ha of offset land is required and the RMS currently own 1483ha;
- 12ha of Freshwater Wetlands are required;
- 523ha of Freshwater Wetland has been acquired; and
- there is a 494ha deficit in Wet Sclerophyll forests for the OH2K project biodiversity offset requirements (pending resolution of any offset contribution from Cairncross State Forest).

From the assessment undertaken by the EPA of the proposed package, it is evident that the proposal will deliver a significant surplus of freshwater wetlands and a significant deficit of wet sclerophyll forests. Further, it is understood that RMS is proposing a major freshwater wetland offset due to the significant conservation outcomes that would be gained from managing these wetlands as a single entity.

Whilst there are conservation gains to be made from securing and remediating these wetlands, it is important to acknowledge that there will also be conservation losses for other ecosystems, primarily dry and wet sclerophyll forest types. If it is agreed to progress the proposed package, then it will be essential that the benefits and costs, in environmental terms, are clearly documented and tracked. All stakeholders must be able to determine that the proposal represents a 'net conservation benefit'.

Typically, the EPA would seek a like for like offset package. This principle is reflected in both state and commonwealth offset policies and is also embedded in the OH2K Biodiversity Offset Strategy which form part of the project approvals.

PO Box 498 Grafton NSW 2460
NSW Government Offices
49 Victoria Street Grafton NSW
Tel: (02) 6640 2500 Fax: (02) 6640 2539
ABN 30 841 387 271
www.environment.nsw.gov.au

Given the current proposal is not consistent with this 'like for like' principle, a strong case will need to be made for adopting the proposed approach. It is also noted that the decision making framework proposed in the biodiversity offset strategy for the project will also need to be addressed. Central to this will be demonstrating the extent to which the offset package has complied with the rule set in the strategy and achieved the like for like principle and, where it has not met this principle, the conservation gains that will result.

In this context the EPA notes that there is a significant deficit in the area of wet sclerophyll forests currently secured and recommends that efforts will need to be made to address at least a portion of this deficit. These efforts should focus on forest types that are currently under-reserved in the State's conservation system. The EPA notes the inclusion of Cairncross State Forest in the RMS acquired land calculations. To date the EPA has not been made aware of any proposal to acquire this land nor any of the conservation values present on site.

If the proposal is to be progressed it is also essential that it can be demonstrated and agreed that it will deliver a 'net conservation benefit'. This approach is consistent with the NSW Biodiversity Offsets Policy for Major Projects and is similar to trading into an offset community that *"is under the same or greater level of threat"*. However consideration will only be given to alternative offsets after *"all reasonable steps have been taken to secure the number and types of species and ecosystem credits impacted at the development site"*.

In order to clearly demonstrate the 'net conservation benefit' expert advice from wetland experts regarding the potential conservation gains will be critical.

Additionally, there are some significant logistical and management issues which will need to be addressed if the proposal is to be considered in the context of an effective offset package. These issues include the ability to manage parts versus the whole catchment, potential saltwater impacts on adjacent private landowners, and effective land management arrangements which focus on conservation outcomes.

It is acknowledged that it is unlikely that these issues can be addressed at this stage in the process. However, it is important that these are addressed as soon as possible in order to be fully informed when assessing the net conservation benefits from the proposal.

In response to your comments regarding the generation of 'credits', I note that there is no mechanism within the Biodiversity Offset Strategy to facilitate this. The EPA expects that the vegetation on the offset property must either be in moderate to good condition to meet the requirements of the *EPBC Act* offset policy and the OH2K Biodiversity Offset Strategy. The proposed package will therefore need to include implementation of agreed management strategies to address the ASS issues and to improve the water quality and ecological values of the wetlands.

In summary, the EPA recommends that the framework for further considering the proposed biodiversity offset package includes:

- Clear acknowledgment of the agreed policy framework and principles against which the proposal must be assessed.
- Transparent accounting of the current offset package, including the extent to which the like for like principle has been satisfied and any residual offset which is proposed to be offset via the wetland proposal.
- Clear demonstration of the conservation benefits associated with the wetland proposal, which should clearly explain the net benefits of moving away from the like for like principle.
- Demonstrating that a co-ordinated management approach, involving the Clybucca Working Group, in the implementation of management strategies to address the ASS issues and thereby improve the water quality and ecological values of the wetlands, can be delivered.
- Demonstrating the ability to manage the catchment in part versus the entire catchment (eg. salt water impacts on private landowners) and effective land management arrangements in perpetuity, are achievable.

- Conservation assessments of all proposed land parcels including vegetation type, condition and fauna habitat values are completed. The EPA recommends using a field assessment similar to the BioBanking assessment which was successfully utilised by the RMS on the Bungawalbin offset property (Devils Pulpit upgrade).

In relation to the wetland proposal, the EPA notes that the NSW National Parks Establishment Plan 2008 states that coastal floodplains and estuaries are a priority for protection. The NPWS reservation targets database is updated every year for the upper and lower north east of NSW as additions and subtractions are made to the reserve system. The database indicates that freshwater wetlands are 54% towards Comprehensive Adequate Representative (CAR) targets for the NSW upper north east and notes that 100% of remaining wetlands are required to meet this target.

In comparison, Blackbutt/Tallow-wood forest types are 40% towards target in the NSW lower north east and 74% in the NSW upper north east. The OH2K and K2E projects fall within the lower north east of NSW and, therefore, these types are underrepresented in the conservation reserve system.

Finally, the EPA is willing to meet with the various stakeholders to discuss the offset proposal and the framework proposed above, if you consider that there would be merit in doing so.

If you have any further enquiries please contact me on (02) 6640 2501 or at brett.nudd@epa.nsw.gov.au.

Yours sincerely

10 DECEMBER 2014

BRETT NUDD
Manger North Coast Region
Environment Protection Authority

cc.
NSW Fisheries – Marcus Riches
OEH – John Schmidt
NPWS – Russell Madeley

Appendix B – Water Quality Monitoring at Menarcobrinni Floodgates 1998 -2004 (KSC, 2004)

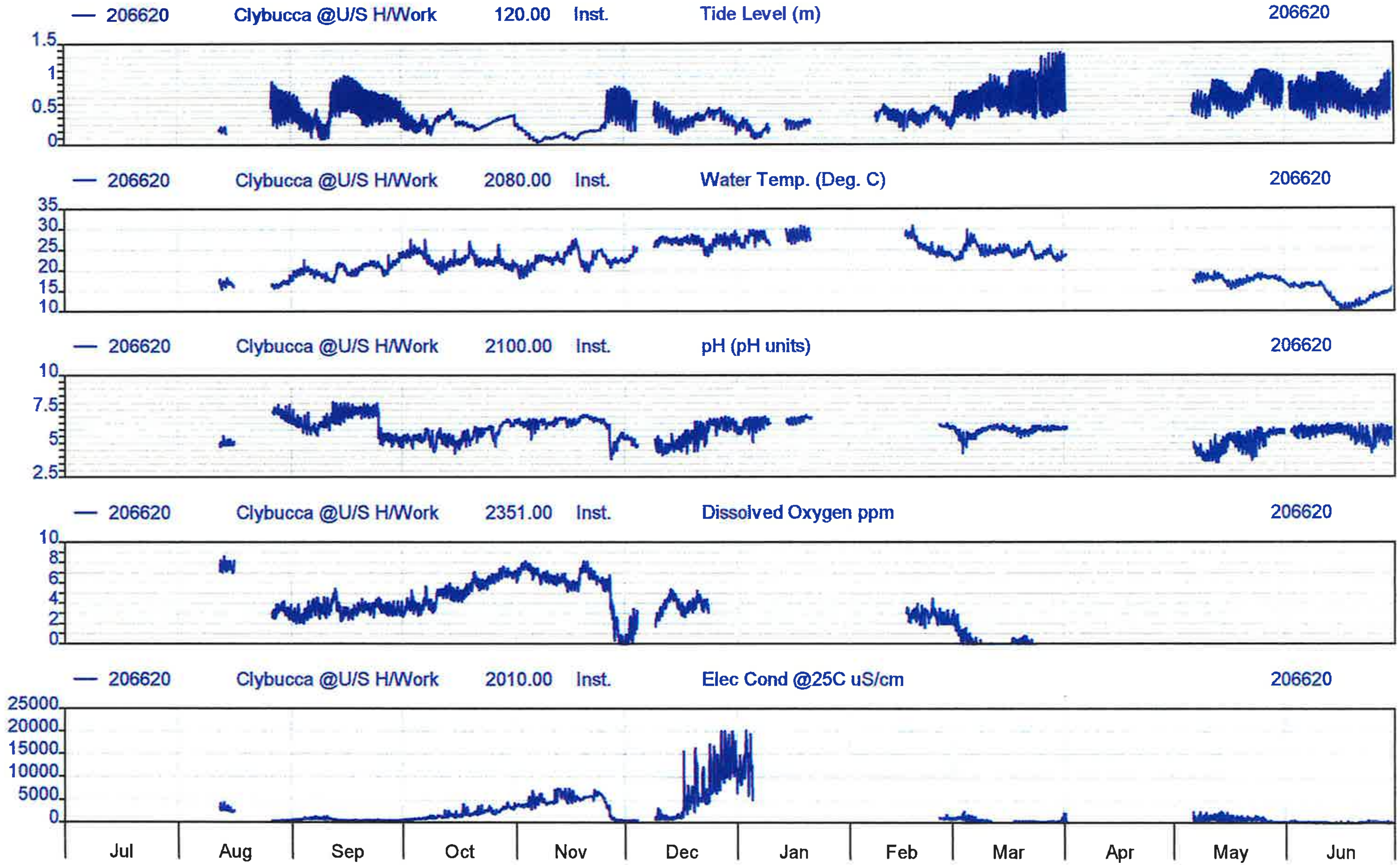
Greenspan Technical Services

HYPLOT V123 Output 10/03/2005

Period 1 Year Plot Start 00:00_01/07/1998

Interval 1 Hour Plot End 00:00_01/07/1999

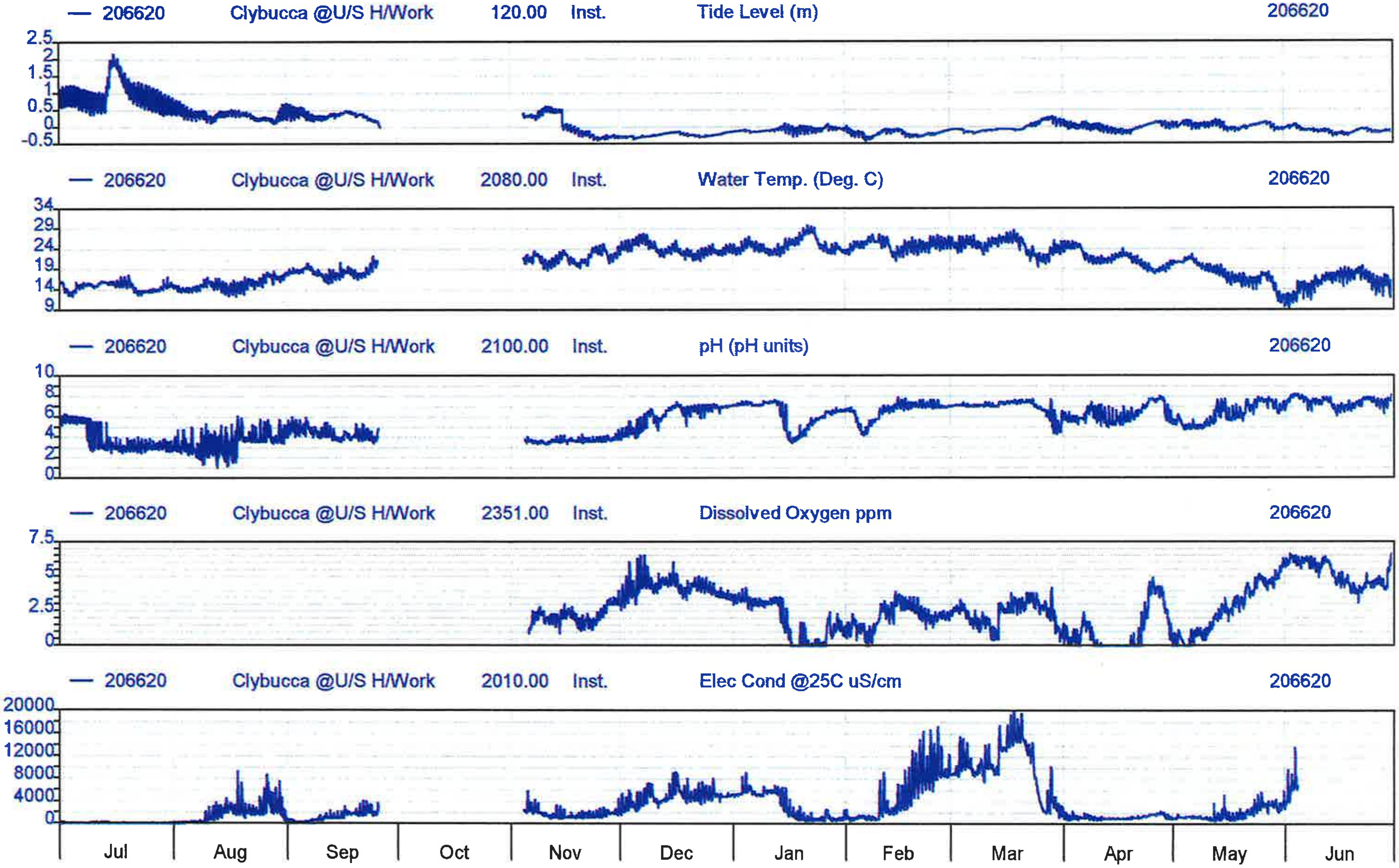
1998/99



Greenspan Technical Services

HYPLOT V123 Output 10/03/2005

Period	1 Year	Plot Start	00:00_01/07/1999	1999/00
Interval	1 Hour	Plot End	00:00_01/07/2000	



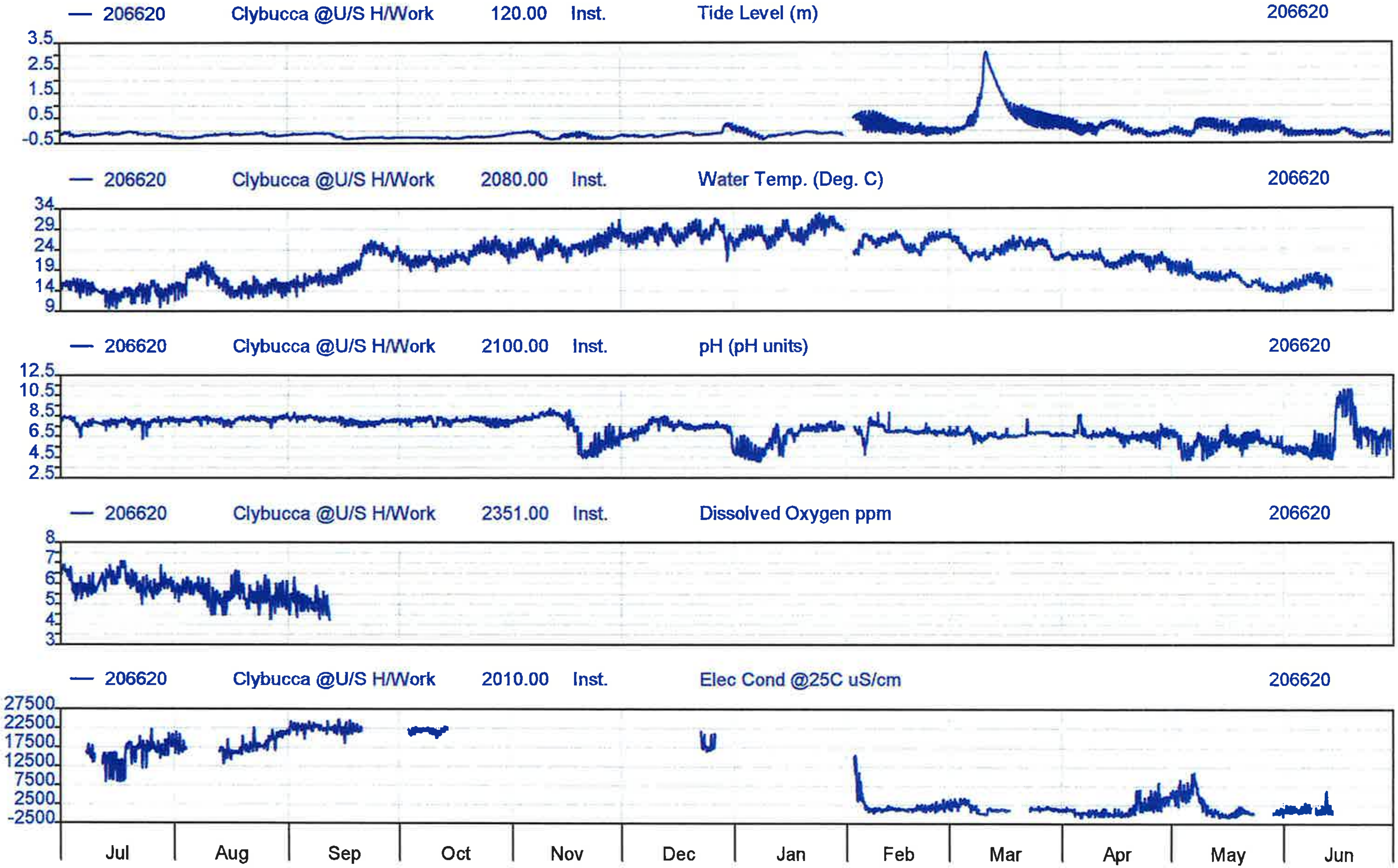
Greenspan Technical Services

HYPLOT V123 Output 10/03/2005

Period 1 Year Plot Start 00:00_01/07/2000

Interval 1 Hour Plot End 00:00_01/07/2001

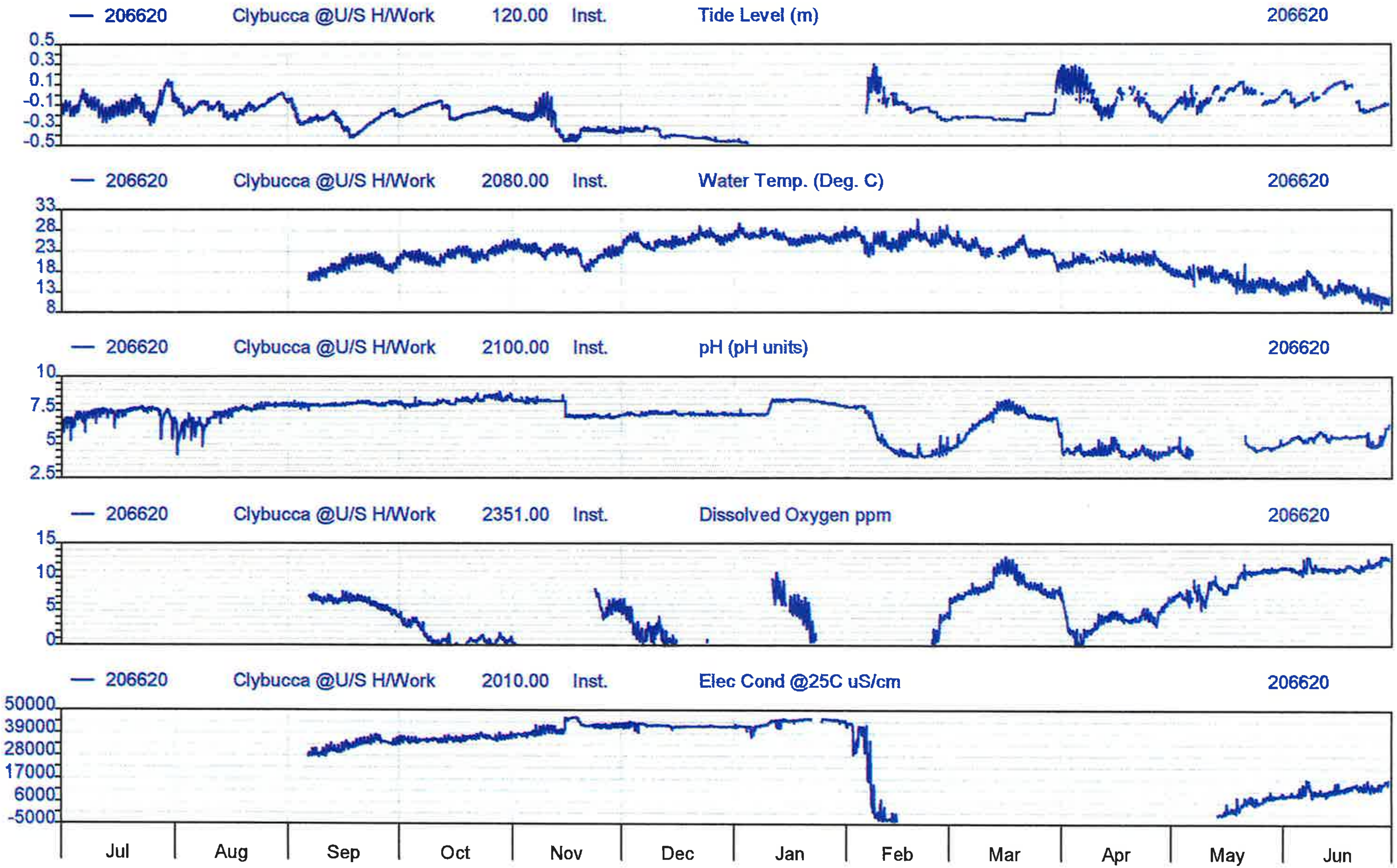
2000/01



Greenspan Technical Services

HYPLOT V123 Output 10/03/2005

Period	1 Year	Plot Start	00:00_01/07/2001	2001/02
Interval	1 Hour	Plot End	00:00_01/07/2002	



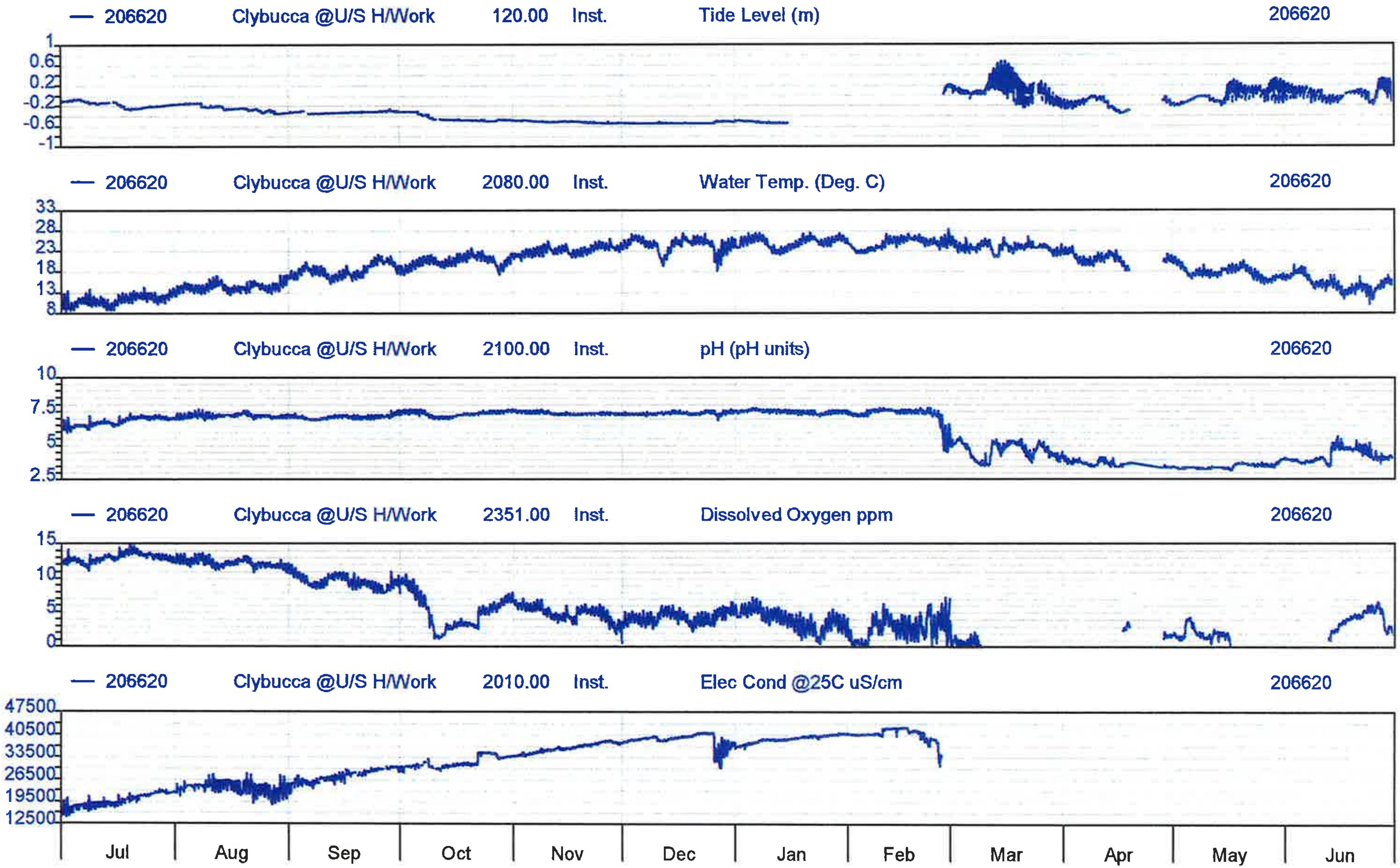
Greenspan Technical Services

HYPLOT V123 Output 10/03/2005

2002/03

Period 1 Year Plot Start 00:00_01/07/2002

Interval 1 Hour Plot End 00:00_01/07/2003



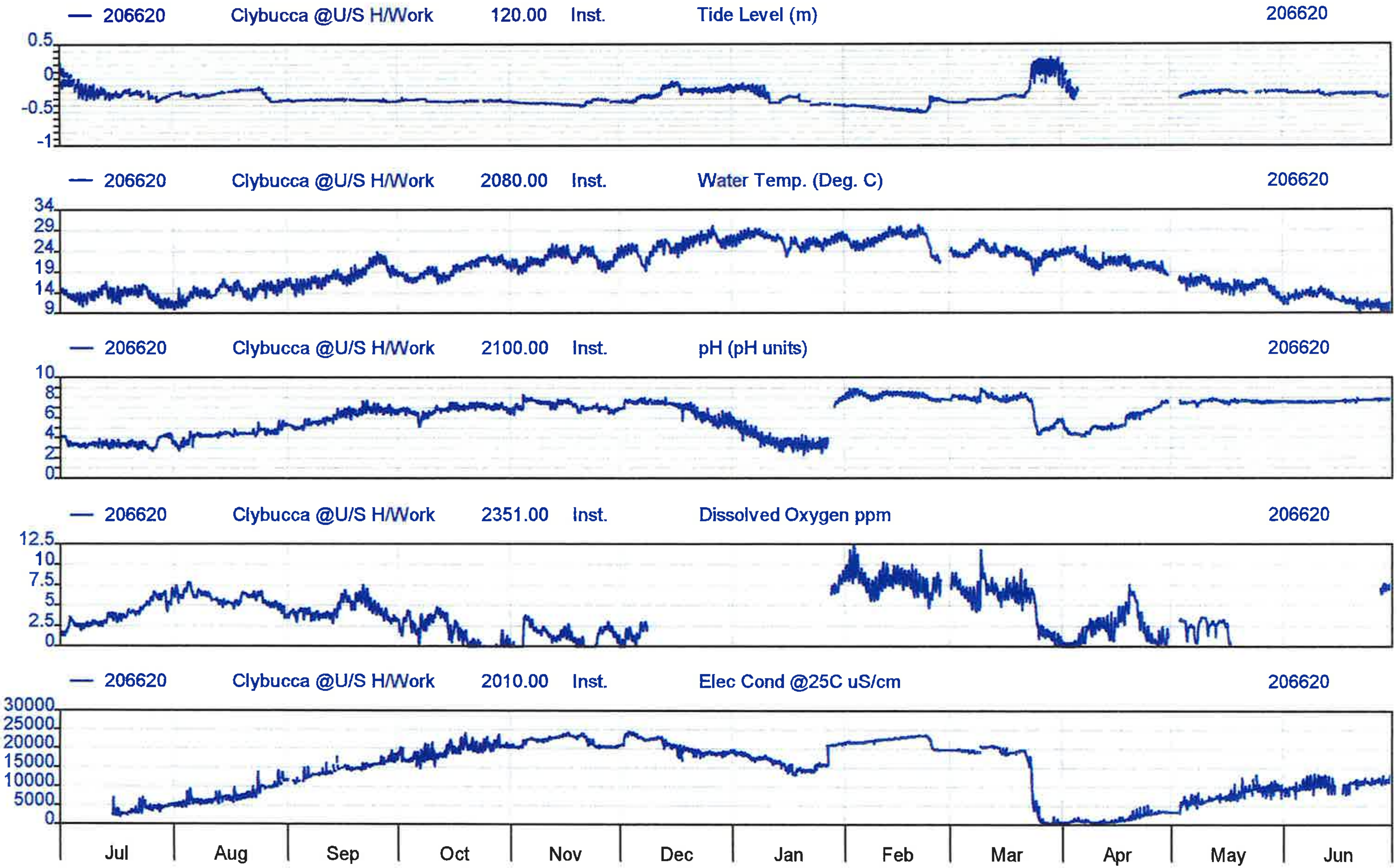
Greenspan Technical Services

HYPLOT V123 Output 10/03/2005

Period 1 Year Plot Start 00:00_01/07/2003

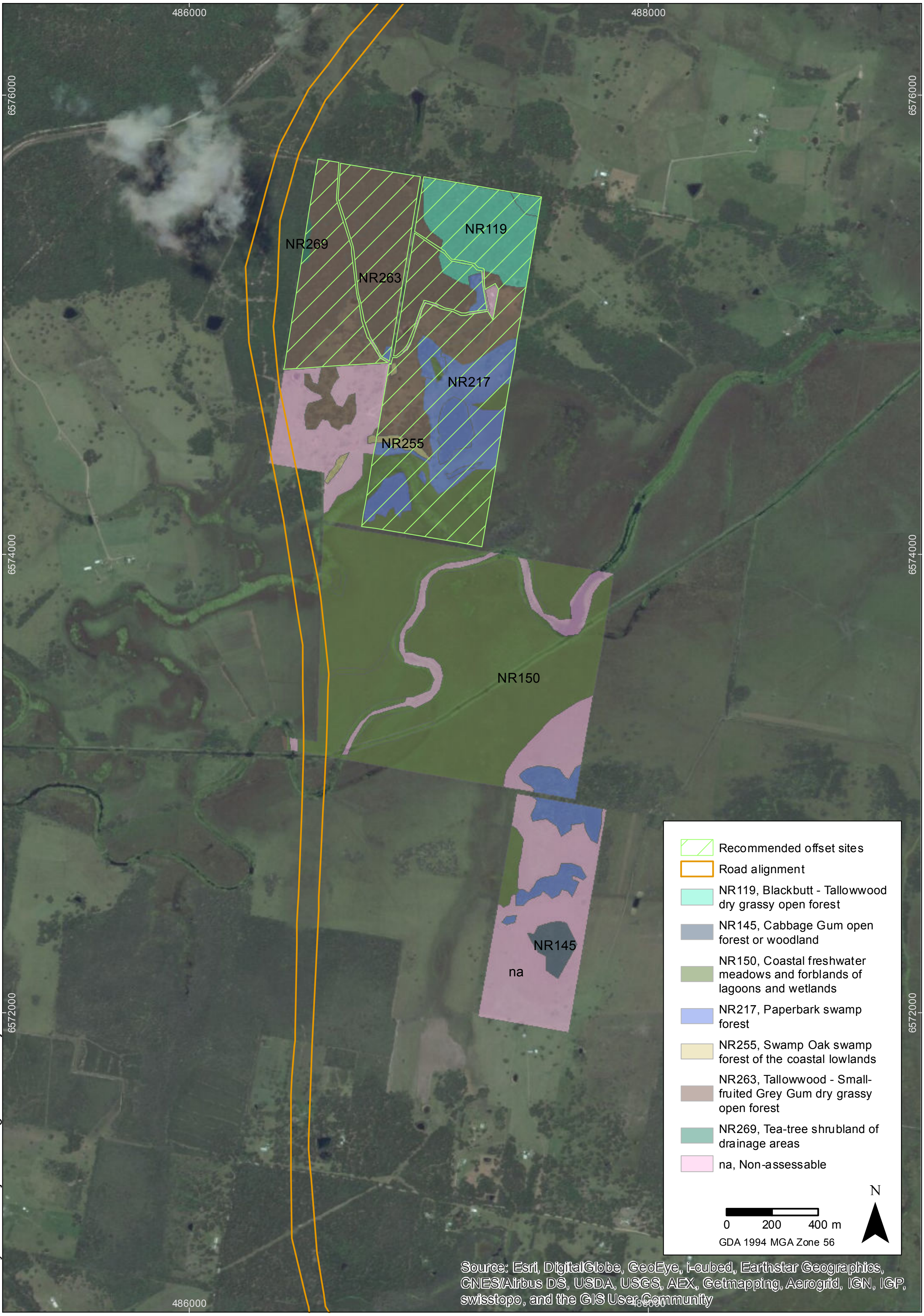
Interval 1 Hour Plot End 00:00_01/07/2004

2003/04



Appendix C – 2014 RMS Property Vegetation Mapping (Niche Ecological, 2014)

Drawn by: RJ Project Manager: RH Project Number: 2079 Date: 13/11/2014



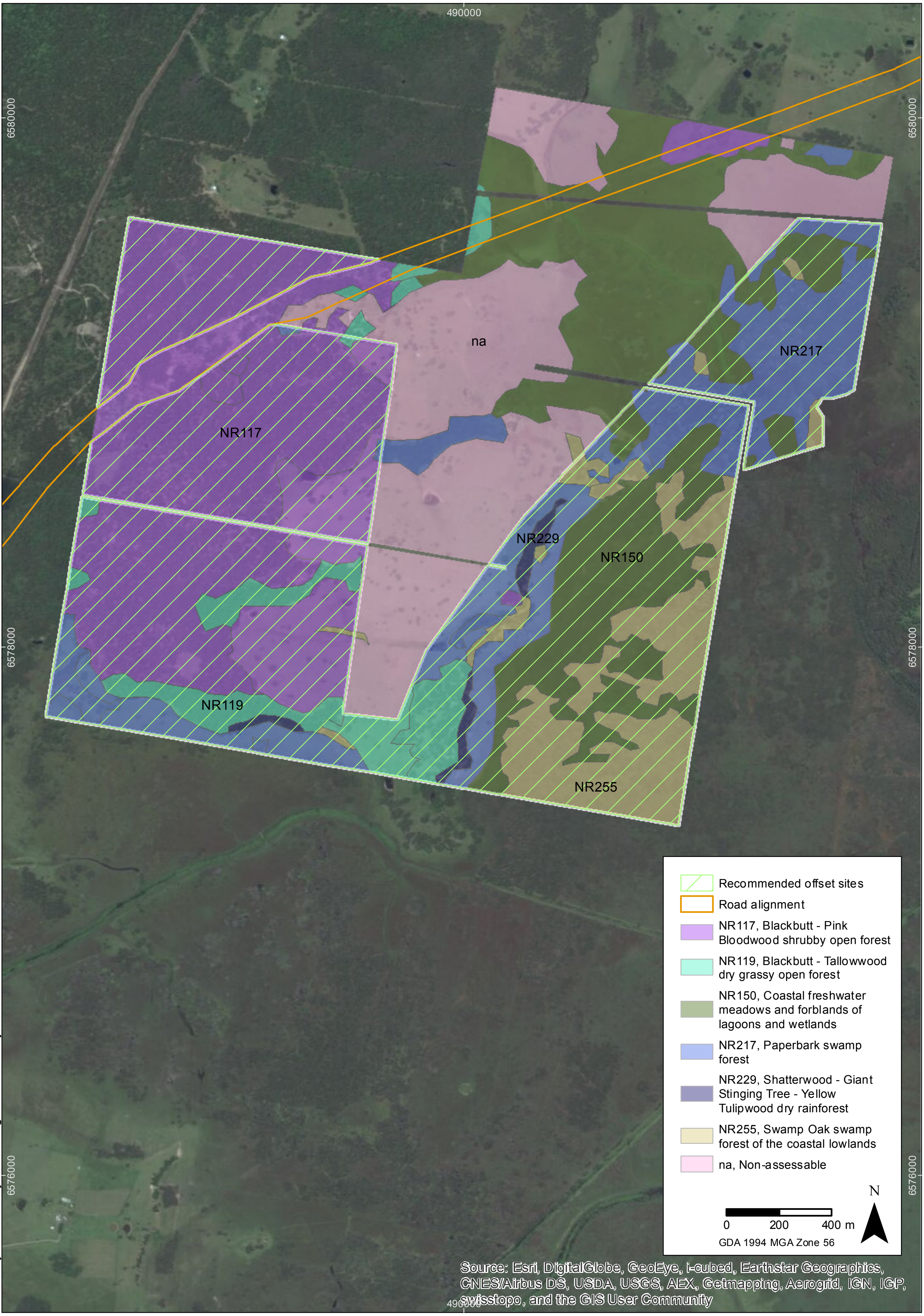
Offset site and vegetation mapping - Ainsworth

Oxley Highway to Kempsey Biodiversity Offset Management Plan

FIGURE 2

niche Environment and Heritage

Path: T:\spatial\projects\a2000\a2079_OH2K_BOMP\Maps\report\2079_Figure_2_Ainsworth.mxd



Drawn by: RJ Project Manager: RH Project Number: 2079 Date: 13/11/2014

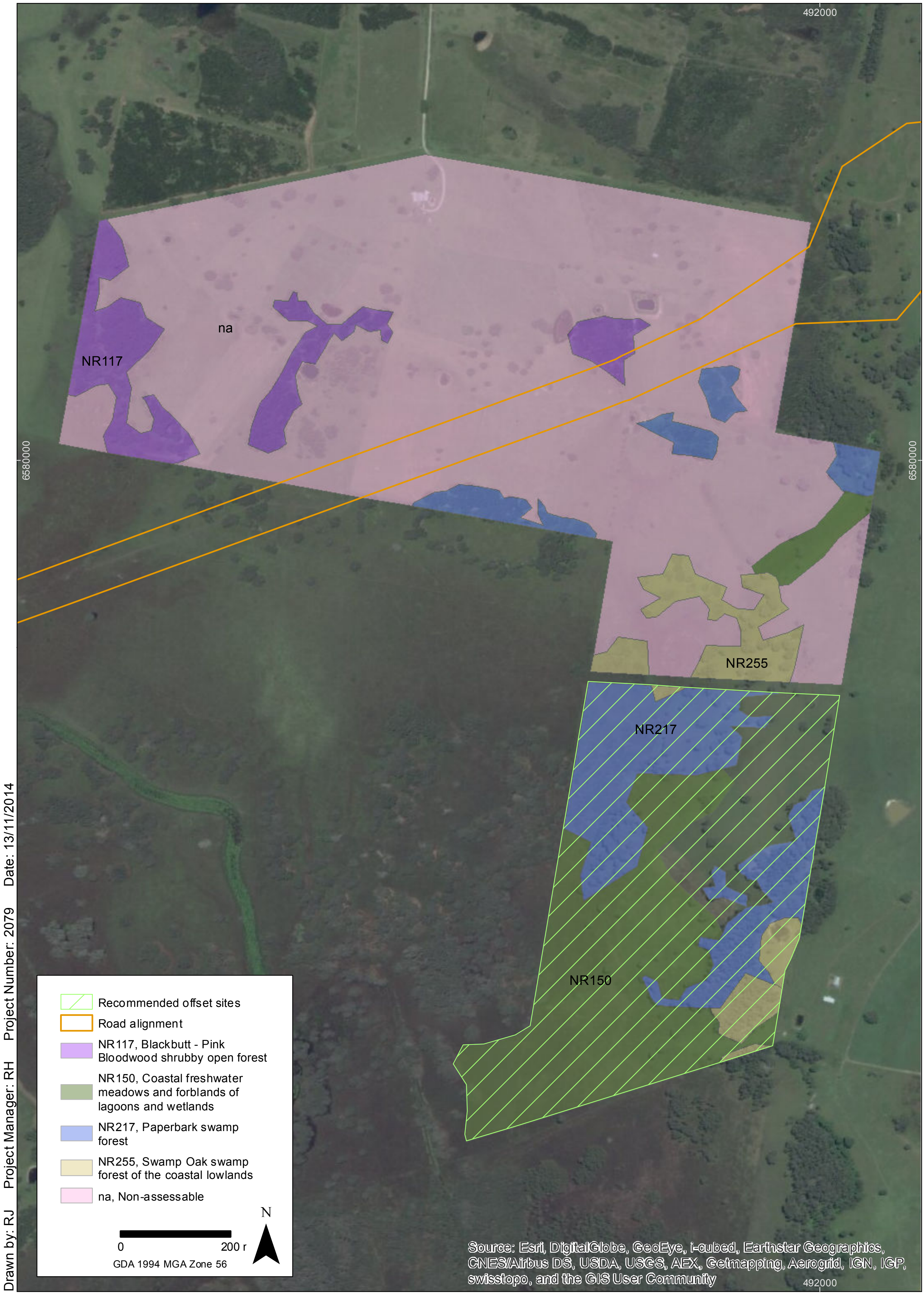
Offset site and vegetation mapping - Blair

Oxley Highway to Kempsey Biodiversity Offset Management Plan

niche Environment and Heritage

FIGURE 3

Path: T:\spatial\projects\a2000\a2079_OH2K_BOMP\Maps\report\2079_Figure_3_Blair.mxd



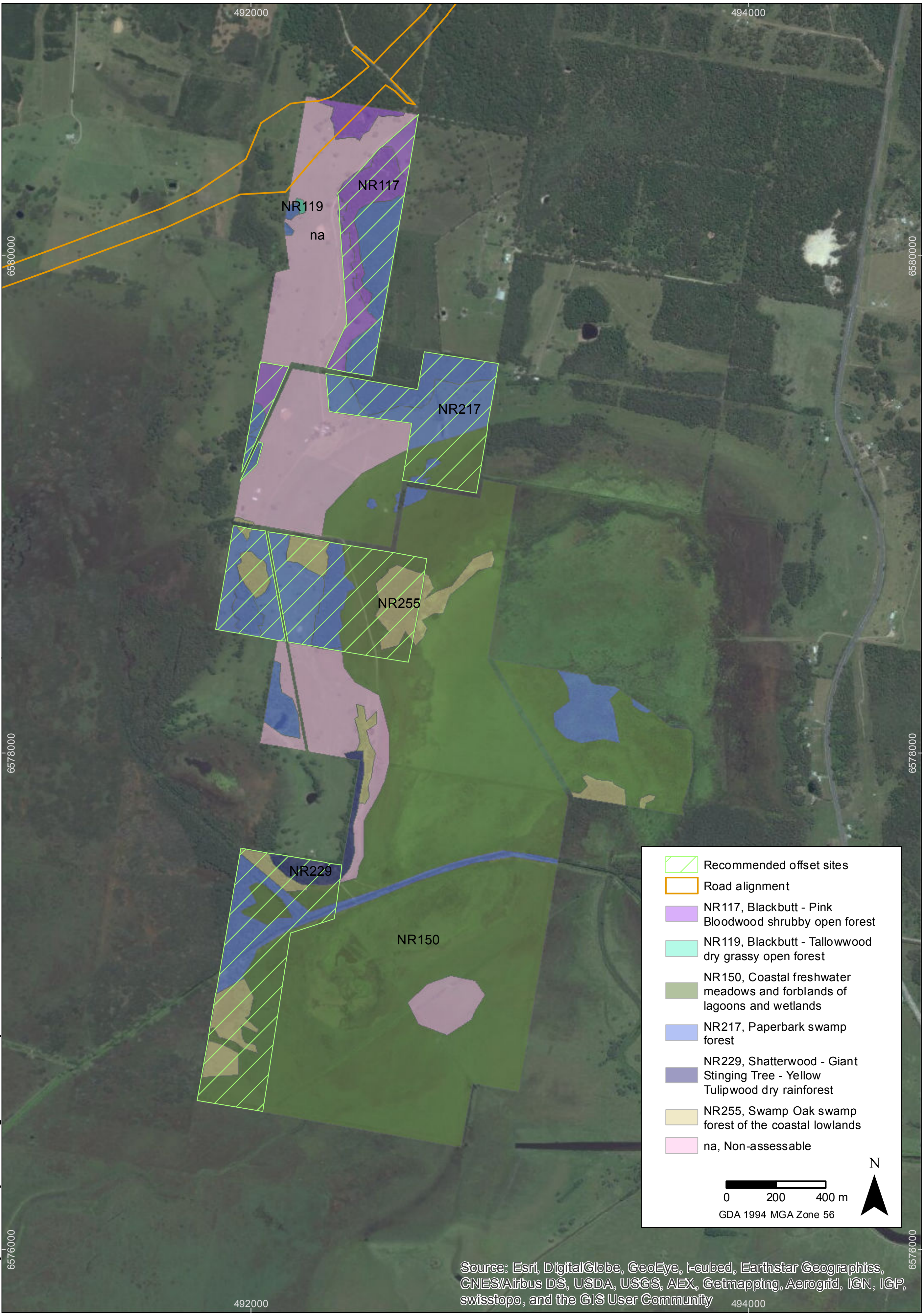
Offset site and vegetation mapping - Whalen

Oxley Highway to Kempsey Biodiversity Offset Management Plan

niche Environment and Heritage

FIGURE 7

Path: T:\spatial\projects\a2000\a2079_OH2K_BOMP\Maps\report\2079_Figure_7_Whalen.mxd



Drawn by: RJ Project Manager: RH Project Number: 2079 Date: 13/11/2014

Offset site and vegetation mapping - Yerbury

Oxley Highway to Kempsey Biodiversity Offset Management Plan

niche Environment and Heritage

FIGURE 8

Path: T:\spatial\projects\a2000\a2079_OH2K_BOMP\Maps\report\2079_Figure_8_Yerbury.mxd

Appendix D – Feasibility Options Memorandum (28th Oct 2014)

To: John Schmidt (NSW OED) and Max Osborne (NCLLS)
From: William Glamore
Subject: Collombatti-Clybucca Floodplain Feasibility Options

Date: 28th October 2014
Ref: WRL2014056 M20141028

Background

The Collombatti-Clybucca wetland complex was historically one of the largest coastal freshwater backswamp areas in NSW. Currently, the Collombatti-Clybucca is heavily drained by the Seven Oaks drainage system which discharges through the large Menarcobrinni floodgates (Figure 1). These floodgates inhibit tidal flushing within the Collombatti-Clybucca floodplain area. The drainage system and floodgates have resulted in extremely poor water quality (pH < 3.5), large acid scalds, and extensive degradation of the historic site.

The current condition of the Collombatti-Clybucca floodplain impacts the wider estuary. Recent studies identified the Collombatti-Clybucca floodplain as having a long history of contributing poor water quality and acid discharge to the estuary, leading to fish kills, oyster mortality, low oyster production, reduced estuary productivity and overall diminished estuary health. Indeed, for the past 20 years various attempts have been made to restore the site.

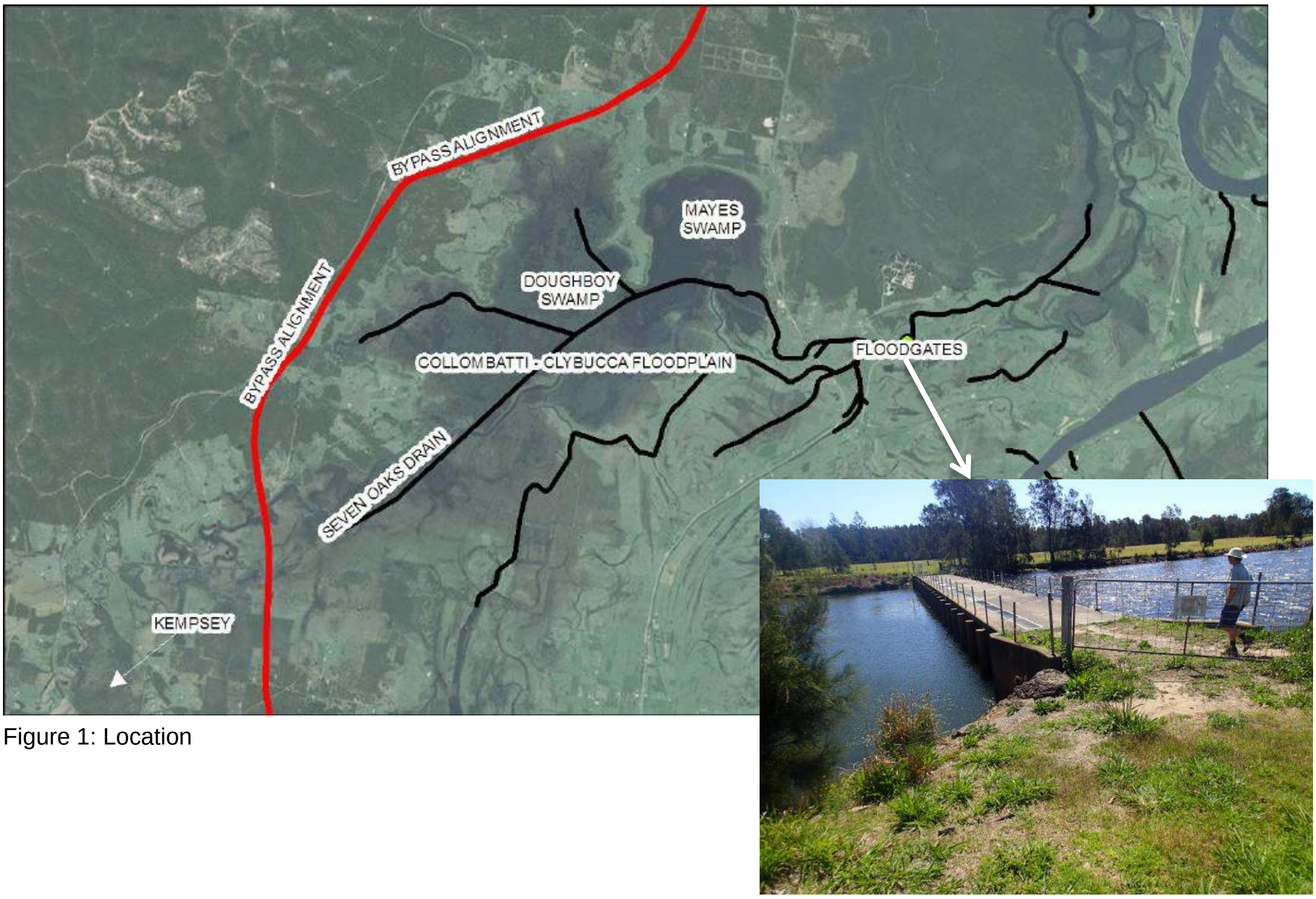


Figure 1: Location

Key considerations

Remediating the Collombatti-Clybucca wetland complex is largely dependent on land management. Traditionally, these low-lying floodplain landscapes were used as a grazing refuge during dry periods. Successful large scale restoration of acid affected floodplains is achieved when alternative land management practices are adopted.

RMS has purchased a large number of properties that cover much of the low lying areas of the Collombatti-Clybucca floodplain (see Figure 2 below). RMS currently owns approximately 800 ha of land below 1 m AHD in the Mayes and Doughboy Swamp areas (Figure 3). Note that the total area of floodplain under 1 m AHD is approximately 2,300 ha. RMS is currently drafting management strategies for these acquired properties to meet their biodiversity offsets for highway corridor impacts. The offset assessment will largely focus on non-wetland species and potentially result in the resale of the land most impacted by acid sulfate soils.

Restoration of the swamp areas of the RMS acquisitions would enable a large area of the lowest lying, most degraded land, to be remediated. The acquisition of these properties is a significant opportunity worth pursuing.

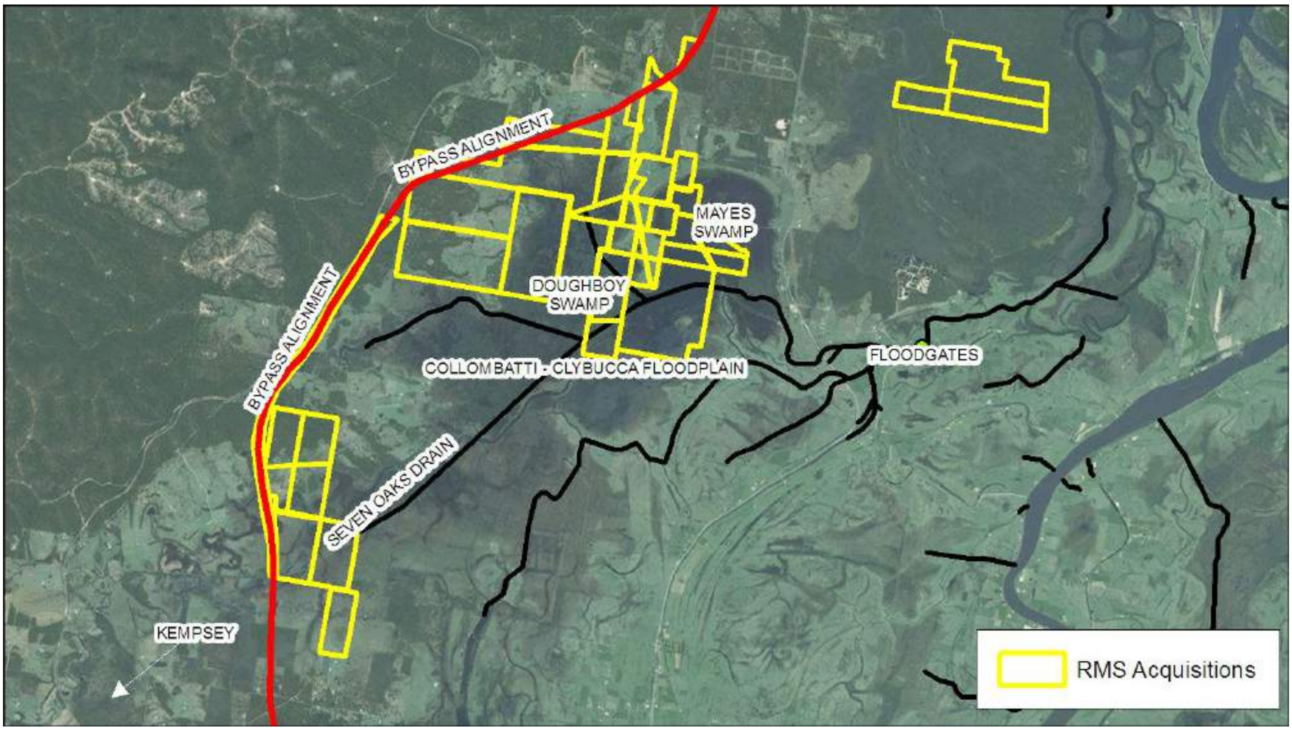


Figure 2: RMS land acquisitions.

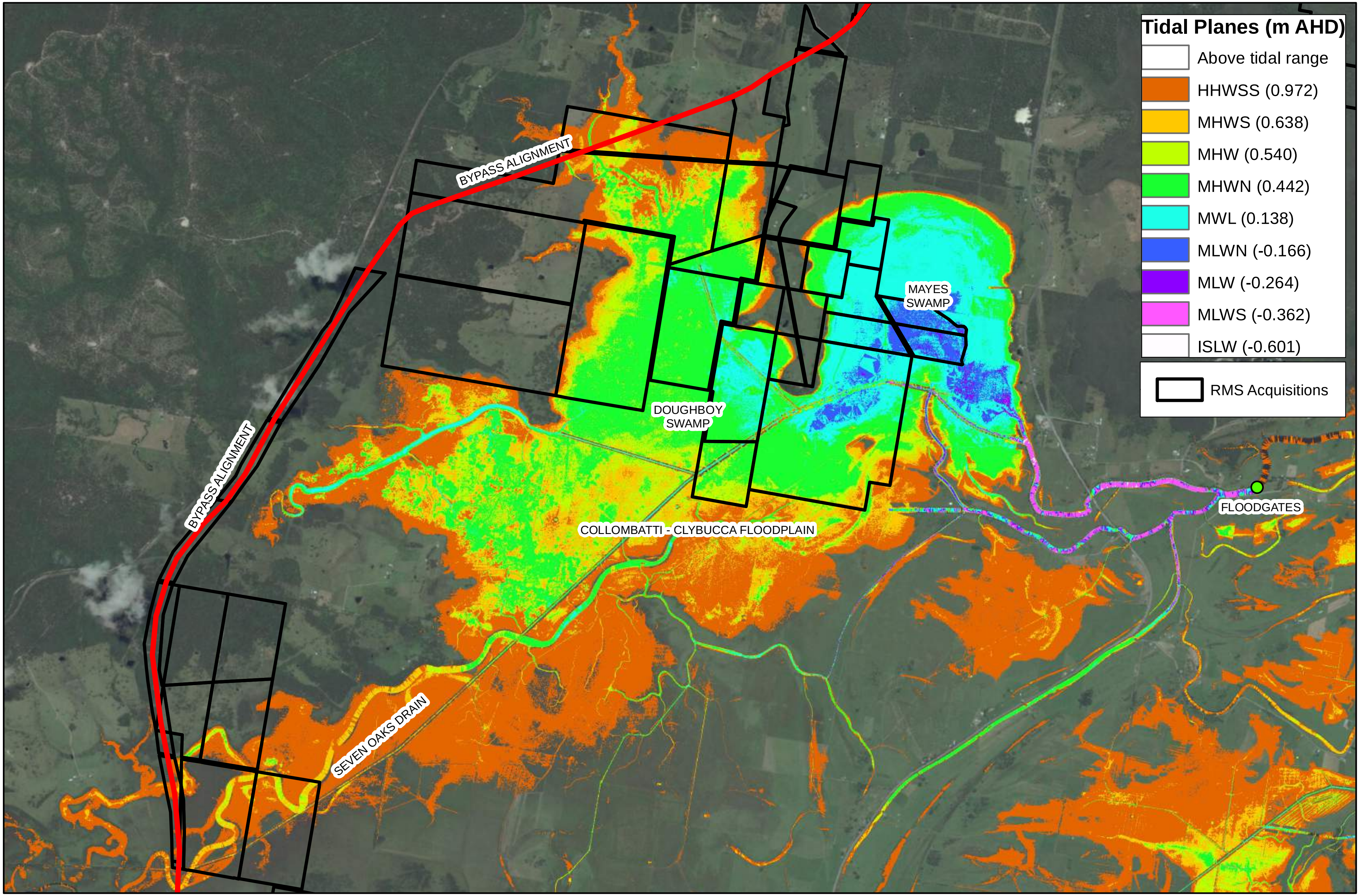


Figure 3: RMS acquistions on Collombatti-Clybucca floodplain with tidal planes

On-ground Options

The Collombatti-Clybucca floodplain has significant potential for remediation. There are a broad range of rehabilitation options to consider. A selection of potential options includes:

1. Do nothing.
2. Implement partial tide to Seven Oaks drain with no overland inundation.
3. Convert RMS floodplain land to a freshwater (albeit acidic) system and maintain exiting floodgate structure.
4. Implement full tidal flushing across floodplain by removing existing floodgates.
5. Implement controlled tidal flushing across RMS floodplain areas.
6. Combination of option 2 and 3. In-drain tidal flushing with freshwater retention on RMS land.

The pros and cons of each option are summarised in Table 1. Note that the finer details of each option are not considered here.

Table 1: Assessment of potential options

Option	Cons							Pros							Costs		
	Ongoing poor water quality	Risk of tidal inundation to pastures	Loss of agricultural productivity/impact to landholders	Maintain acid drainage	High cost to maintain existing floodgates	Varied drainage for adjacent landholders	Impacts to estuarine health	Saltmarsh, mudflat, mangrove habitat creation	Fish habitat/passage	Freshwater wetland habitat	Buffer acidic water	Improved water quality	Low impact to landholders	Preservation of Aboriginal sites	Costs to upgrade or remove existing floodgates	Moderate (on-ground works + structures)	Higher (land acquisitions + on-ground works)
1	✓			✓	✓		✓						✓		✓		
2		✓			✓	✓			✓		✓	✓	✓		✓	✓	
3	✓			✓	✓	✓	✓			✓			✓	✓	✓	✓	
4		✓	✓			✓		✓	✓		✓	✓		✓	✓		✓
5		✓				✓		✓	✓		✓	✓		✓	✓		✓
6		✓			✓	✓			✓		✓	✓		✓	✓	✓	

The “do nothing” option is not a viable long-term solution. To achieve remediation using existing RMS acquisitions, on-ground works would be required to isolate adjacent landholders. Acquisition of directly adjacent, low-lying floodplain areas would enable large hydrologic wetland units to be remediated and transformed into natural wetland systems. The prioritised proposed acquisition areas are presented in Figure 4.

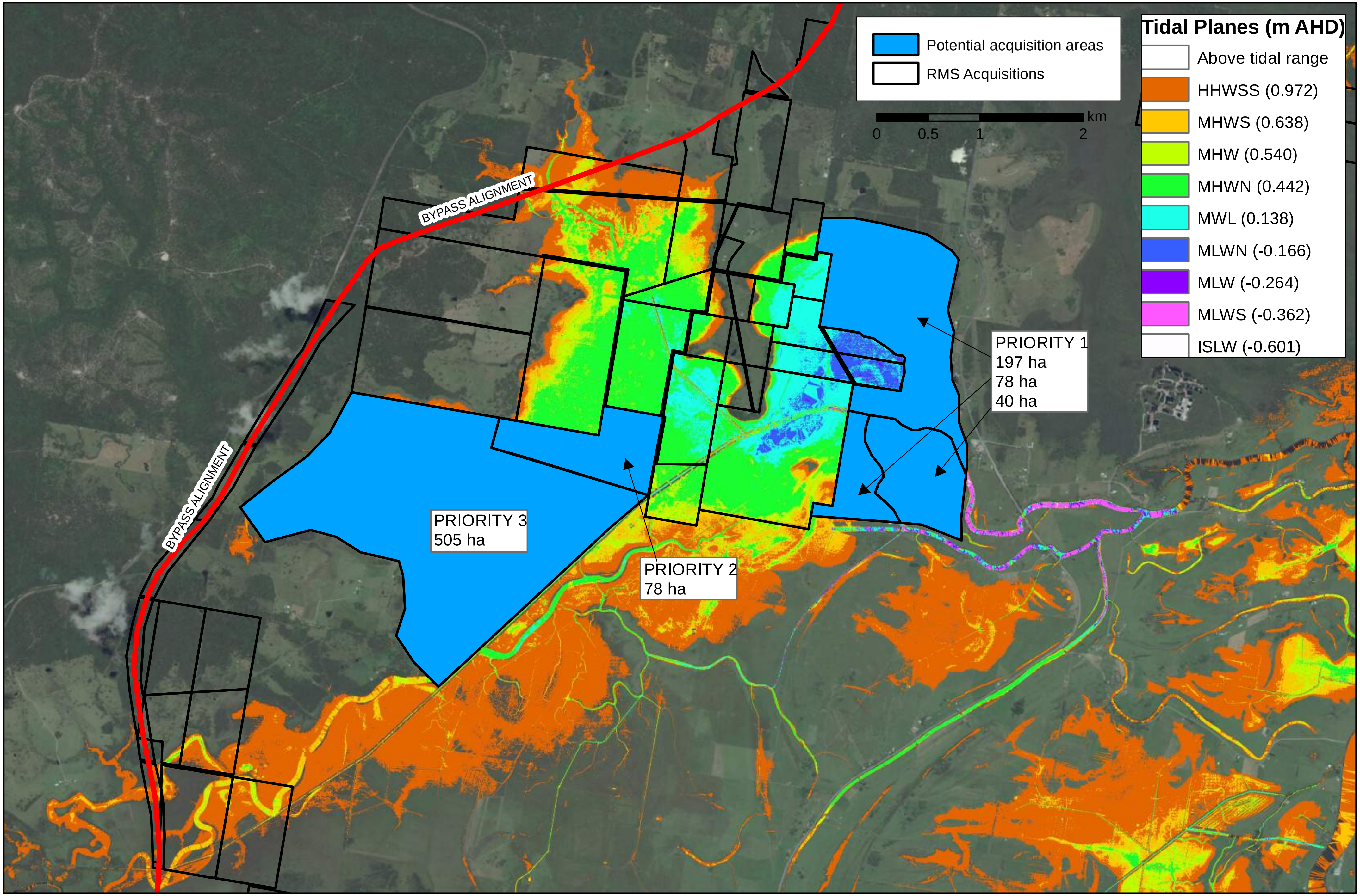


Figure 4: Current RMS acquistions on Collombatti-Clybucca floodplain with prioritised future potential acquisitions

Appendix E – Offset Purchase Justification Memorandum (19th Nov 2014)

To: John Schmidt (NSW OEH)
From: William Glamore
Subject: Collombatti-Clybucca Floodplain Offset Purchase Justification

Date: 19th November 2014
Ref: WRL2014056 M20141113

The Problem

Since being extensively drained and floodgated for agriculture in the 1960s, the Collombatti-Clybucca floodplain has negatively impacted both the local Clybucca region and the larger Macleay River estuary (Telfer, 2005). Indeed, reduced aquatic productivity, including extensive fish kills, have been reported in Clybucca Creek for many years. Further, the Menarcobrinni floodgates, located within the Seven Oaks drain, impede tidal ingress, resulting in reduced fish passage, and extensive acidification of the lower Macleay River estuary (Figure 1). An overview of the floodplain is presented in Figure 2.

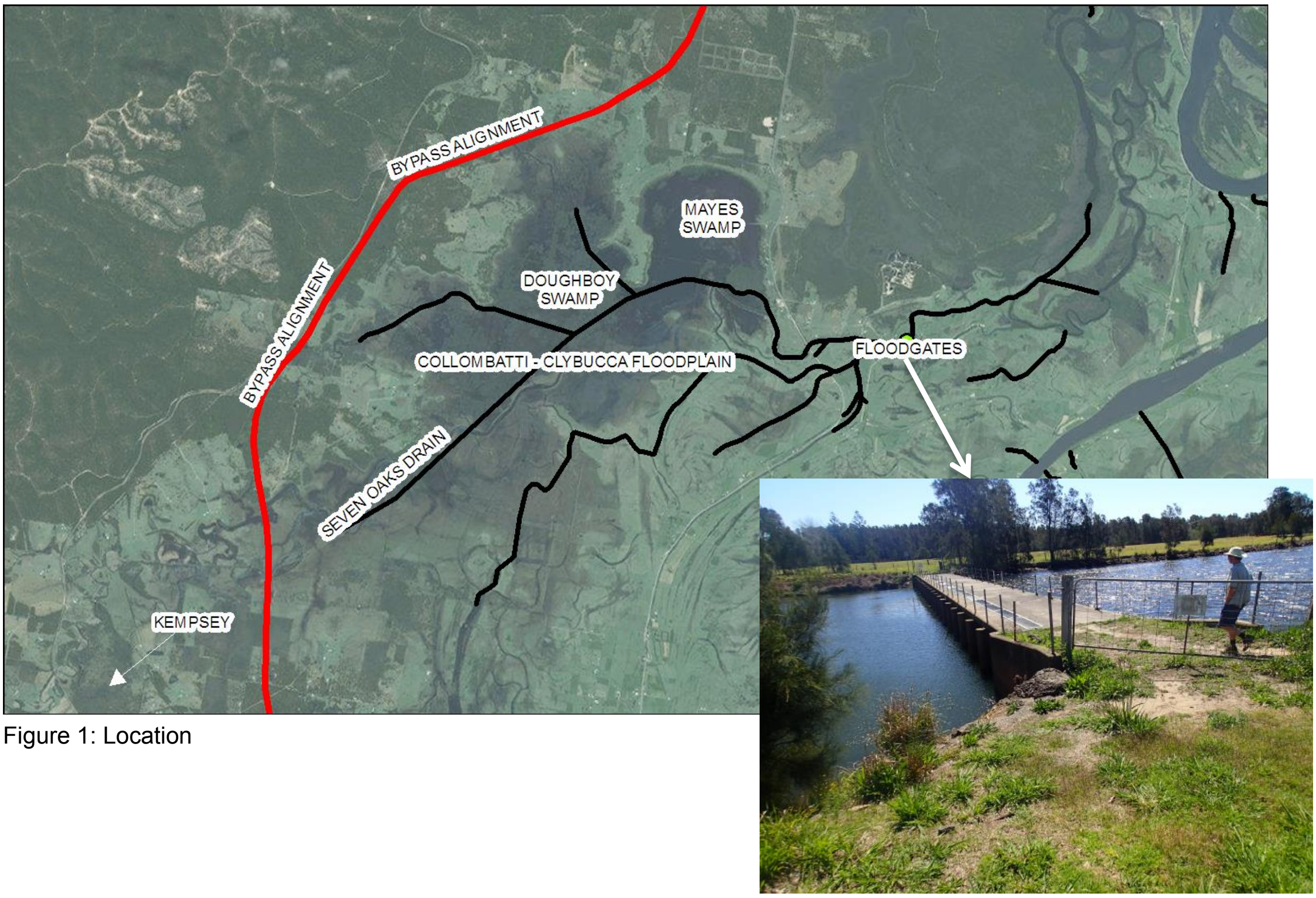
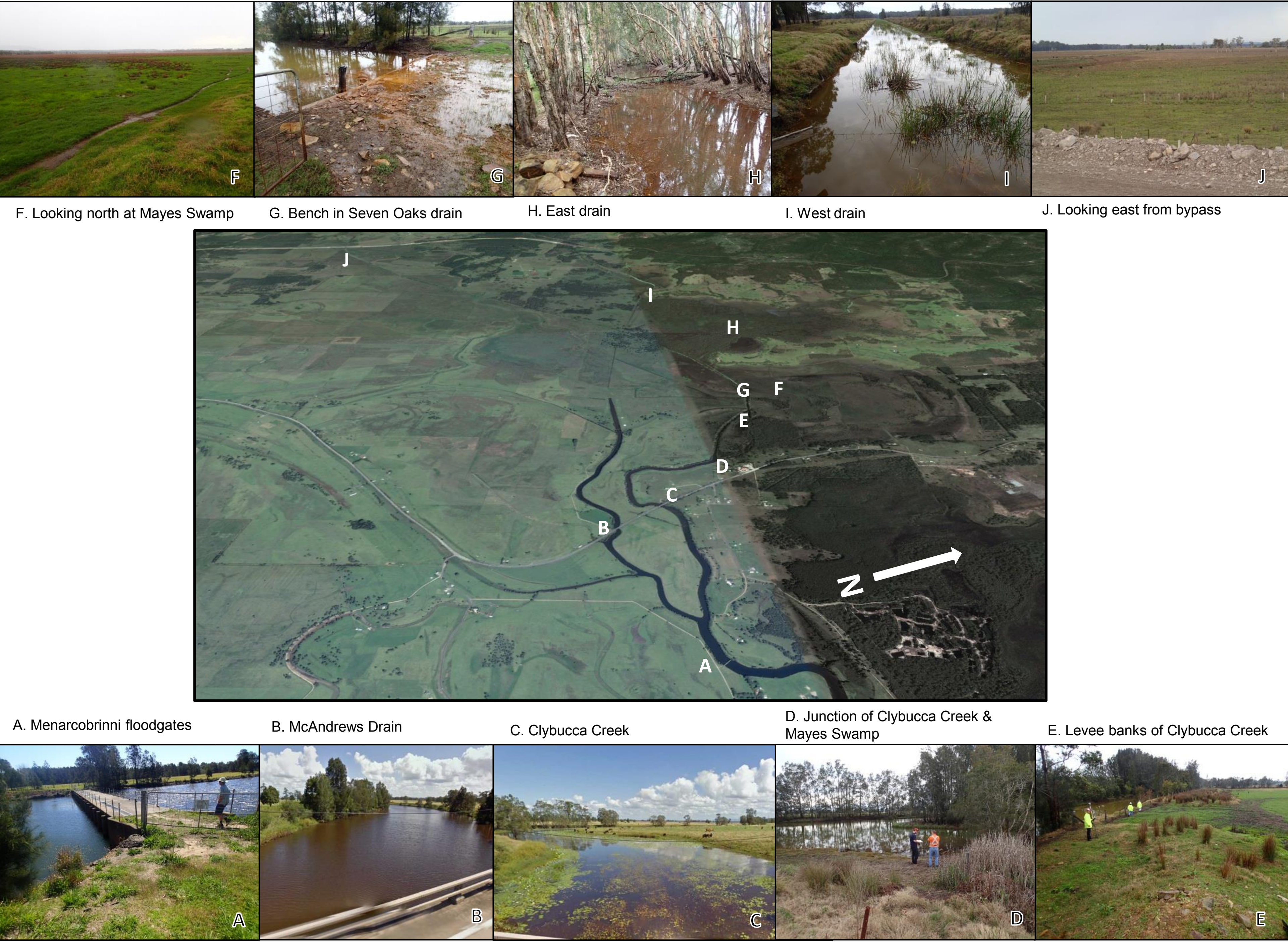


Figure 1: Location

Water Research Laboratory
School of Civil and Environmental Engineering | UNSW AUSTRALIA | 110 KING ST MANLY VALE NSW 2093 AUSTRALIA
T +61 (2) 8071 9800 | F +61 (2) 9949 4188 | ABN 57 195 873 179 | www.wrl.unsw.edu.au | Quality System Certified to AS/NZS ISO 9001
Innovative answers for tomorrow's water engineering questions, today | Since 1959



F. Looking north at Mayes Swamp

G. Bench in Seven Oaks drain

H. East drain

I. West drain

J. Looking east from bypass

A. Menarcobrinni floodgates

B. McAndrews Drain

C. Clybucca Creek

D. Junction of Clybucca Creek & Mayes Swamp

E. Levee banks of Clybucca Creek

Figure 2: Overview of the Collombatti-Clybucca floodplain wetland complex

Discharges from the Collombatti-Clybucca system are generally:

- Highly acidic (pH < 3.0)
- Very low dissolved oxygen (hypoxic)
- High concentrations of metals (iron and aluminium)

Numerous studies undertaken over several decades (Walker, 1972; Ecology Lab, 1996; Naylor, 1996; Webb McKeown, 1997; Talau and Naylor, 1999; KSC, 2004; Telfer, 2005; Bush et al., 2006; Birch, 2010; GeoLINK, 2010; GeoLINK, 2012; Haines, 2014) have identified extensive acid sulfate soils in the Collombatti-Clybucca floodplain and the significant water quality and biodiversity impacts from the floodplain on the wider estuarine health and productivity. Indeed, Hurrell et al. (2009) noted that the most critical habitats for maintaining estuarine ecological health occur within the Macleay Arm.

In 2002, the Collombatti-Clybucca floodplain was nominated by the NSW Government as one of seven acid 'Hotspots' requiring immediate remediation. For many years, a large acid scald (approximately 400 hectares) in the area of Mayes Swamp remained void of all vegetation. Recent efforts have shown that significant improvements can be obtained via on-ground mitigation works; however no solution to the large scale discharge of acid from the Collombatti-Clybucca floodplain has been achieved. The drainage system currently has no acid buffering, with each rainfall event flowing through the drainage network and across the floodplain, becoming acidified, and then being discharged into the Macleay River estuary (Figure 3).

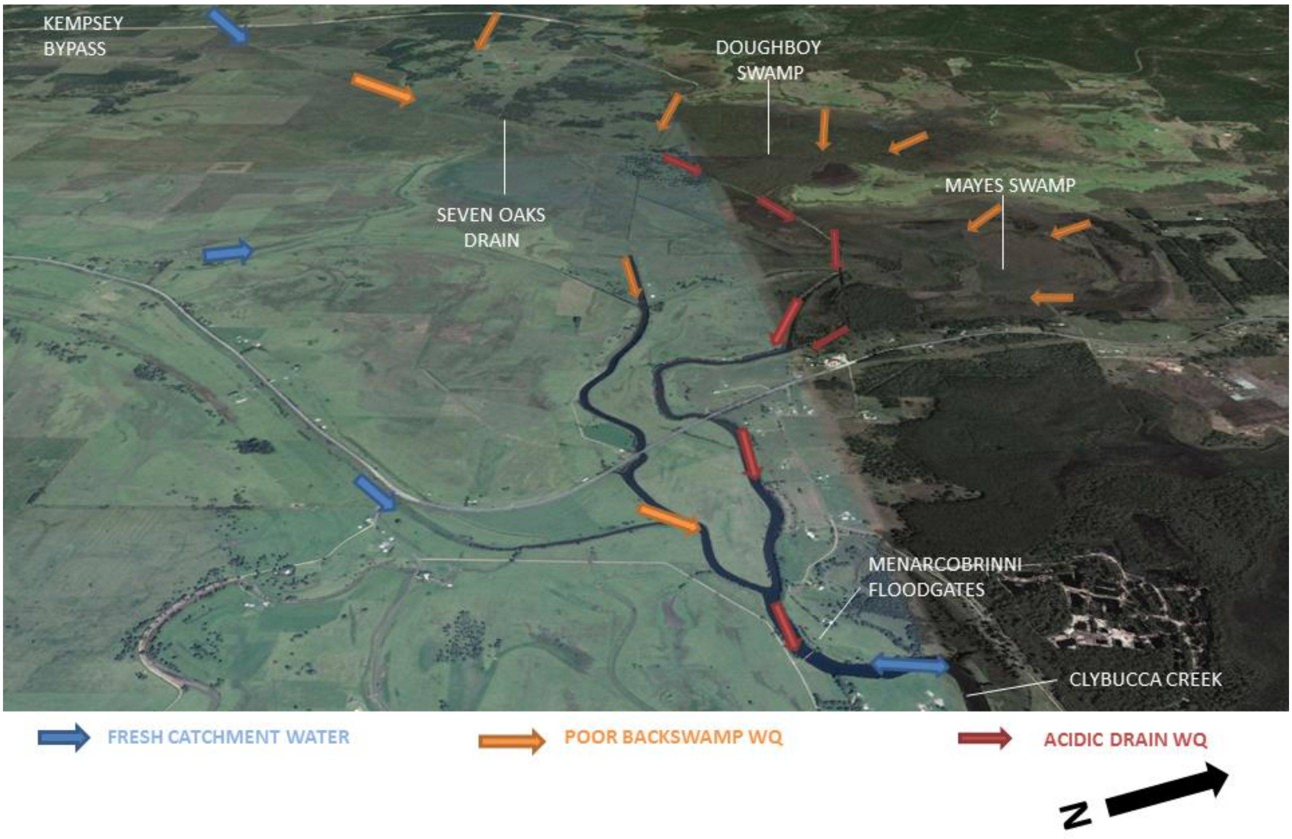


Figure 3: Existing site conceptual processes showing acid drain discharge and inhibited tidal flushing.

Remediation

Proven experience (Rayner and Glamore, 2011; Glamore et al., 2012; Glamore et al., 2014) at other sites has shown that effective remediation of these extremely acidic backswamps can be achieved through a change in land management. The most effective solution includes the reversion of the lowest lying, most acid affected land from agricultural to an Endangered Ecological Community recognized by NSW. Undertaking remediation across entire hydrological units (i.e. continuous swamp/wetland areas) provides the most practical and cost effective remediation, and the greatest environmental outcome.

The Opportunity

Until now progress within the Collombatti-Cybucca floodplain and Seven Oaks drain area has been impeded by the complexity of gaining consensus from a large number of private landholders. This impediment has compromised remediation works and limited any environmental improvements achieved on-ground. As such, the only significant means for reducing water quality impacts, increasing estuarine productivity and restoring EEC's requires a catchment wide solution.

RMS recently purchased a number of properties within the Collombatti-Cybucca floodplain as biodiversity offsets for highway construction works (Figure 4). For the first time since the initial settlement of the Collombatti-Cybucca area, a single landholder owns the majority of the worst affected acid land. The RMS properties extend from higher ground, to low-lying backswamp floodplain areas. These properties were purchased to utilize the higher elevation land as biodiversity offsets with the low-lying wetland area (approximately 2,300 ha) not included within the offset requirements.

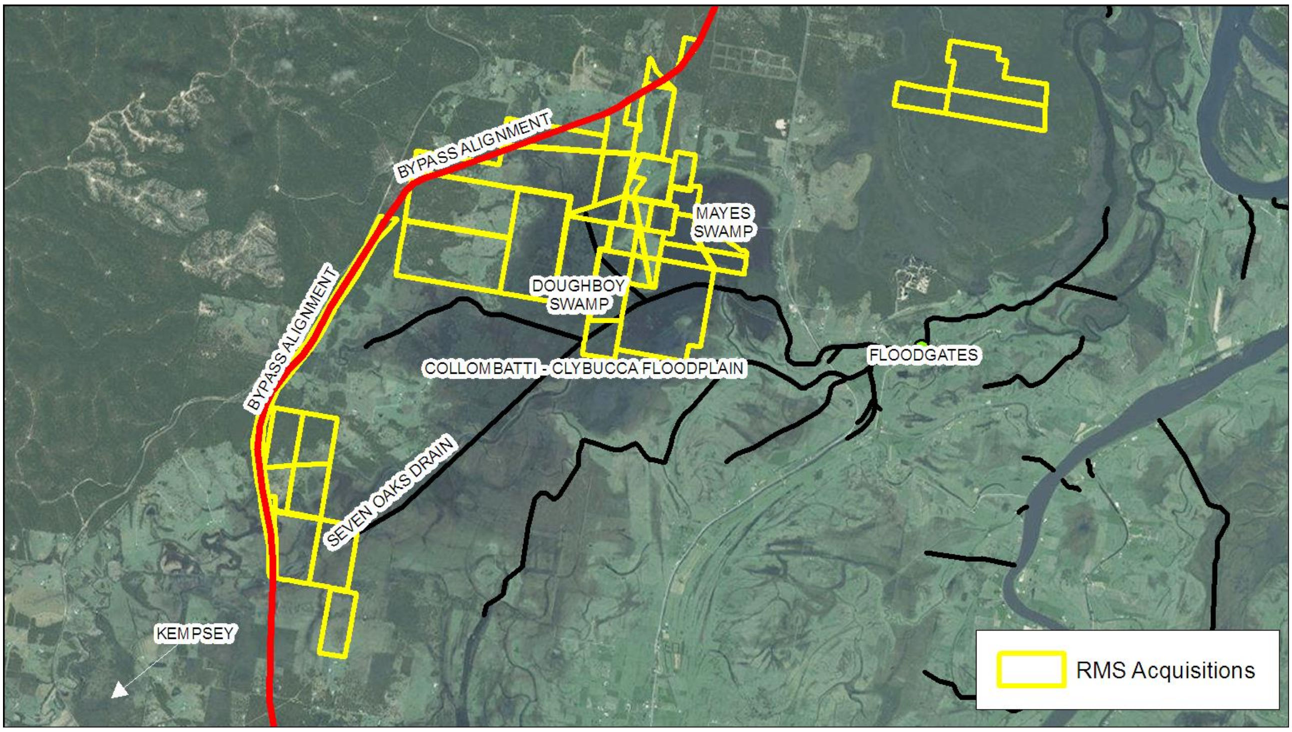


Figure 4: Current RMS land acquisitions.

The recent purchase of properties by NSW RMS is a rare, once-in-a-lifetime opportunity to rehabilitate the degraded landscape. Remediation of the low-lying acidic areas of Mayes and Doughboy swamps from poor agricultural land to a dynamic saline wetland would provide:

- The creation of higher order community/EEC habitat (saltmarsh and mangroves) and subsequent improvements in terrestrial and aquatic biodiversity;
- Significant improvements in water quality within the adjacent waterways and broader Macleay River estuary with improved acidity and dissolved oxygen, reduced iron and aluminium loads and reduced turbidity;
- Reduced sediment loads being discharged into the Macleay River estuary;
- A high level of positive change to the existing degraded environment;
- Significant increases in aquatic biodiversity and primary productivity; and,
- Improve health and productivity of the wider Macleay River estuary.

For this to occur, the RMS properties require recognition as a Supplementary Measure offset. If possible, the purchase of additional directly adjacent floodplain properties would enable all directly connected wetland areas to be remediated and reduce the on-ground work requirements (Figure 5). These additional acquisitions enable the lowest lying, worst acid affected land to be remediated and managed as a single, continuous hydrological unit.

Note that there is potential interest from NSW National Parks and Wildlife Division within OEH to provide long-term management of the site provided it is a single, continuous area. This would ensure ongoing management costs will be significantly reduced compared to a disjointed site with directly adjacent private landholders. If the current RMS properties were remediated to a natural wetland system, additional on-ground works would be required to manage water without impacting the existing adjacent landholders. This option is also likely to add additional management costs into the future.

The Outcome

Remediation of Mayes and Doughboy Swamps to a tidal wetland system would provide an Endangered Ecosystem Community, regularly flushed by tidal waters. Due to the site topography, a range of habitats could be established, with areas of permanent open water, regularly inundated, and rarely inundated tidal/fresh water environments. A conceptual diagram of the proposed site is presented in Figure 6.

Site Management

Large scale remediation of acid affected coastal floodplains has been successfully achieved elsewhere. Similar sites include:

- Yarrahapinni Wetlands, located 6 km to the north-east of the Collombatti-Clybucca floodplain.
- Big Swamp on the northern floodplain of the Manning River near Taree.
- Tomago Wetlands on the Hunter River north of Newcastle.

The above sites are currently, or have been agreed to be managed, by NSW Parks and Wildlife Division. On-going management by Parks would meet the required conservation goals but is only possible if:

1. The wetland areas of the exiting RMS properties are recognised as a supplementary measure offset; and,
2. Additional adjacent floodplain properties are purchased to provide a single, continuous hydrological unit.

Further discussion would be required with NSW PWD as an immediate priority. Additional design and hydraulic works would be required to confirm existing concept designs.

Repercussion of Inaction

If no action is undertaken, the site will remain degraded with ongoing impacts. These include:

- Loss of rare opportunity to provide a permanent improvement to the health and productivity of the Macleay River estuary;
- Ongoing poor water quality; and,
- Application of limited remediation options with comparatively minor benefit to the wetland and estuary.

References

Birch, M., 2010, Macleay River estuary and floodplain ecology study, Aquatic Science and Management in association with GeoLINK

Bush, R.T., Keene, A., Sullivan, L.A., and Bush, M.K., 2006, Water quality analysis of ASS hot spots, Prepared for NSW Department of Natural Resources, Centre for Coastal Management, Southern Cross University

Ecology Lab Pty Ltd, 1996, Lower Macleay floodplain management strategy: Aquatic ecology and fisheries. Review of existing information

GeoLINK, 2010, Macleay River estuary: estuary management study

GeoLINK, 2011, Macleay River estuary: coastal zone management plan

Glamore, W.C., Wasko, C.D. and Smith, G.P., 2012, Rehabilitation of Yarrahapinni Wetlands National Park: Hydrodynamic modelling of tidal inundation, Water Research Laboratory, WRL Technical Report 2011/21

Glamore, W.C., Ruprecht, J.E., Rayner, D.S. and Smith, B., 2014, Big Swamp Rehabilitation Project Hydrological Study, Water Research Laboratory, WRL Technical Report 2012/23

Haines, I., 2014, Macleay River oyster farmers environmental management system, Macleay River Oyster Farmers

Hurrell, G., Barbour, E. and Kauffeldt, A., 2009, Macleay River Estuary Processes Study, WMA Water, Sydney

Kempsey Shire Council (KSC), 2004, Collombatti-Clybucca acid sulfate soils hot spot final report

Naylor, S.D., 1996, The Macleay River floodplain: Land use and acid sulfate soils, Department of Land and Water Conservation, Sydney

Rayner, D.S. and Glamore, W.C., 2011, Tidal inundation and wetland restoration of Tomago Wetland: Hydrodynamic modelling, Water Research Laboratory, WRL Technical Report 2010/30

Talau, M.J. and Naylor, S.D., 1999, Acid sulfate soil management priority areas in the Lower Macleay floodplain, Department of Land and Water Conservation, Sydney

Telfer, D., 2005, Macleay River estuary data compilation study, GECO Environmental, August 2005

Walker, P.H., 1972, Seasonal and stratigraphic controls in coastal floodplain soils, Aust. J. Soil Res. 10: 127-42

Webb, McKeown & Associates Pty Ltd., 1997, Lower Macleay Floodplain Management Study, Kempsey Shire Council

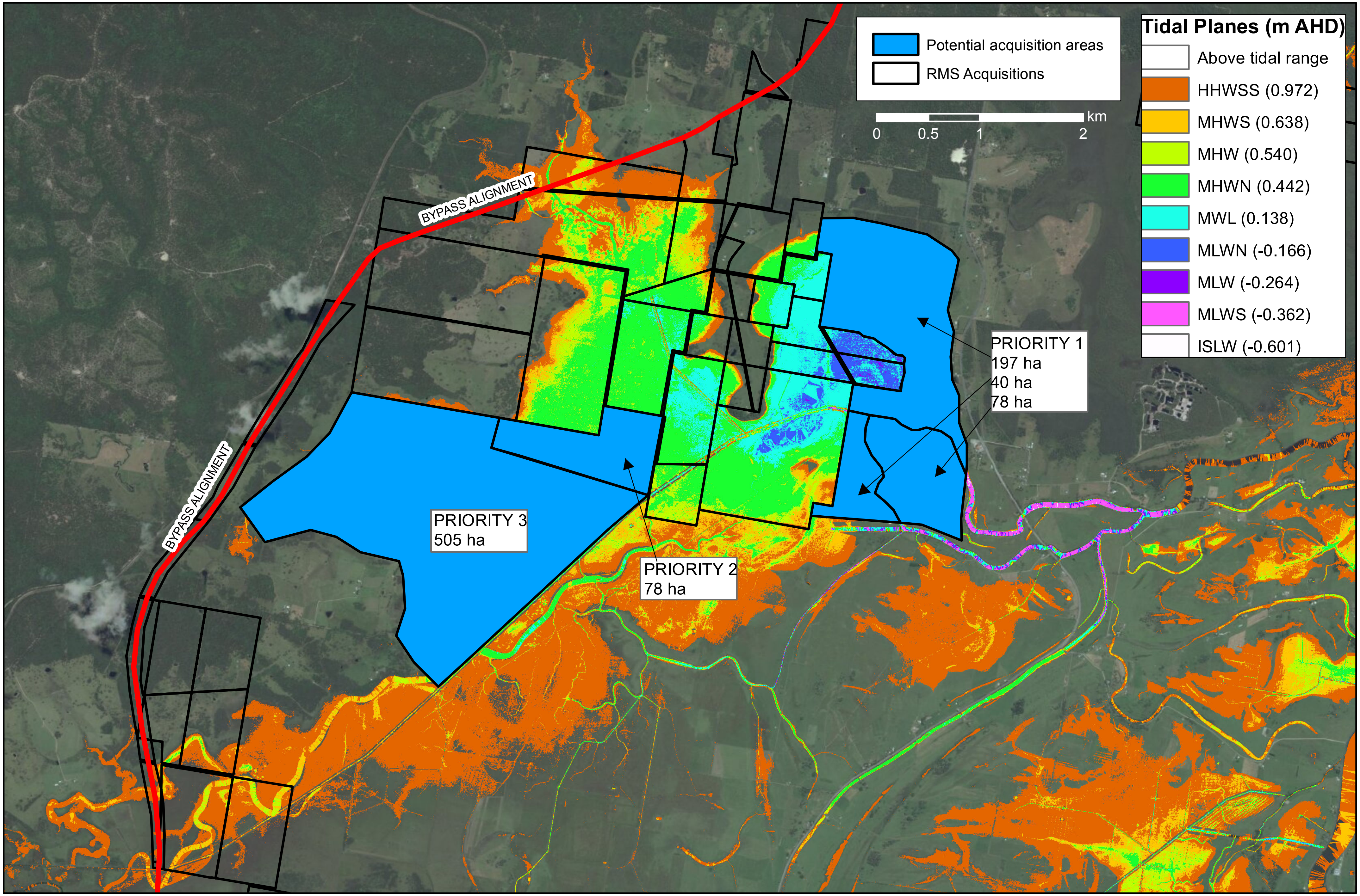


Figure 5: Current RMS acquistions on Collombatti-Clybucca floodplain with prioritised future potential acquisitions to enable a single, continuous remediated hydrological unit

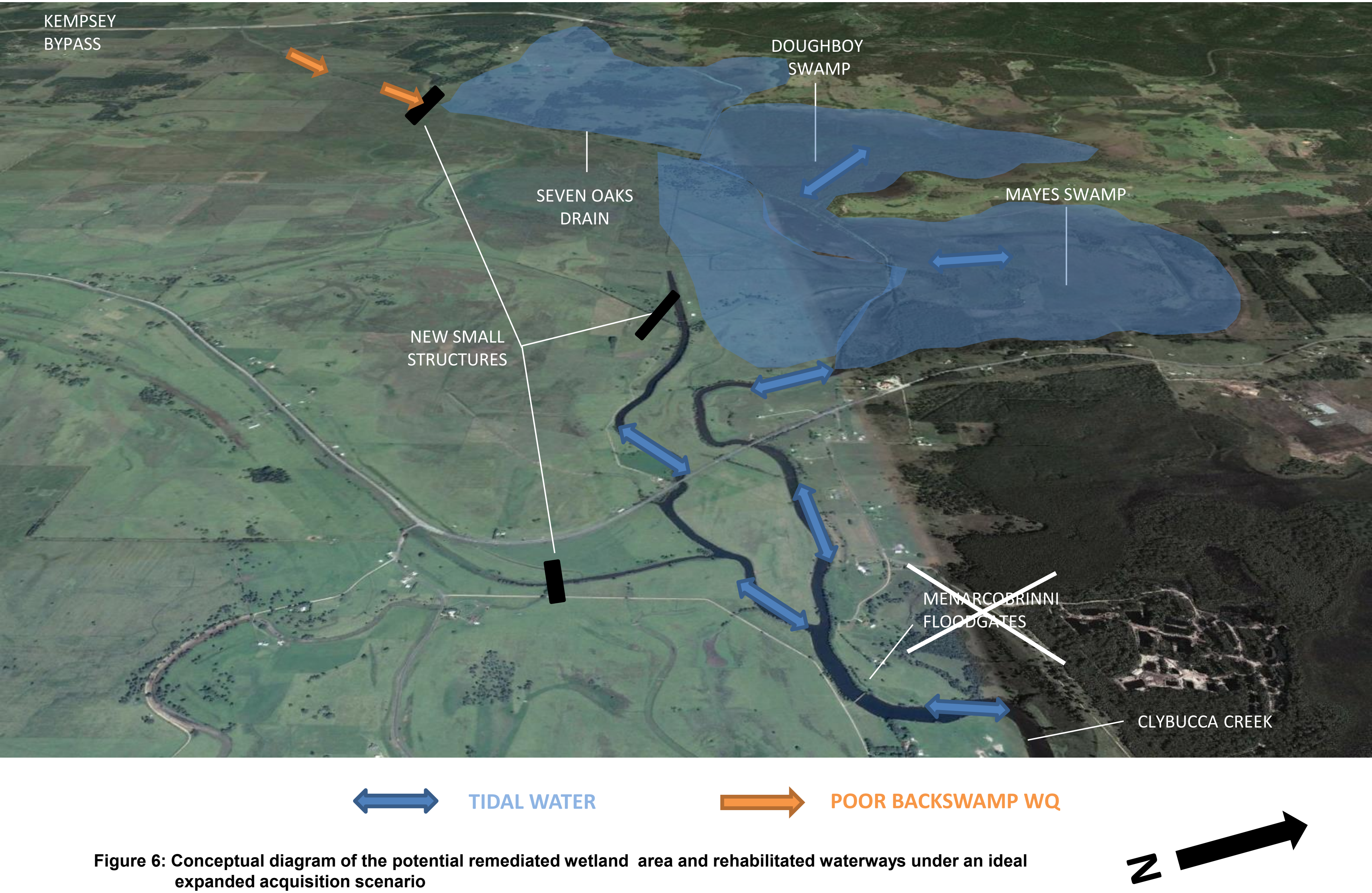


Figure 6: Conceptual diagram of the potential remediated wetland area and rehabilitated waterways under an ideal expanded acquisition scenario

Appendix F – Habitat Potential Memorandum (4th Mar 2015)

"This project is supported by North Coast Local Land Services, through funding from the Australian Government."

To: David Ledlin (NSW RMS) and Brett Nudd (NSW EPA)
Date: 4th March 2015
From: William Glamore
Ref: WRL2014056 M20150304
Subject: Potential habitats of a remediated Collombatti-Clybucca floodplain

1. Purpose of this Memorandum

In late January 2015, WRL produced a draft report that assessed the feasibility of remediating the Collombatti-Clybucca floodplain (WRL Technical Report 2015/01 'Collombatti-Clybucca Floodplain Remediation Study'). A meeting was held with the Clybucca Working Group at Kempsey on Wednesday, 10th February 2015 to discuss the findings of this report and identify requirements to progress the project.

Key issues identified at this meeting include:

1. The resulting habitat areas based on various remediation options and land acquisition configurations (requested by RMS); and,
2. Description and timeline of habitat transition based on each remediation scenario (requested by EPA).

The purpose of this memorandum is to address these key issues and provide supporting documentation.

2. Summary of the Current Situation

The NSW Roads and Maritime Services (RMS) recently purchased a number of properties within the Collombatti-Clybucca floodplain as biodiversity offsets associated with the Oxley Highway to Kempsey (OH2K) Pacific Highway Upgrade project (Figure 1). The RMS properties extend from higher ground to low-lying backswamp floodplain areas. These properties were purchased to utilize the higher elevation land as biodiversity offsets with the low-lying wetland area (approximately 2,300 ha) not included within the offset requirements.

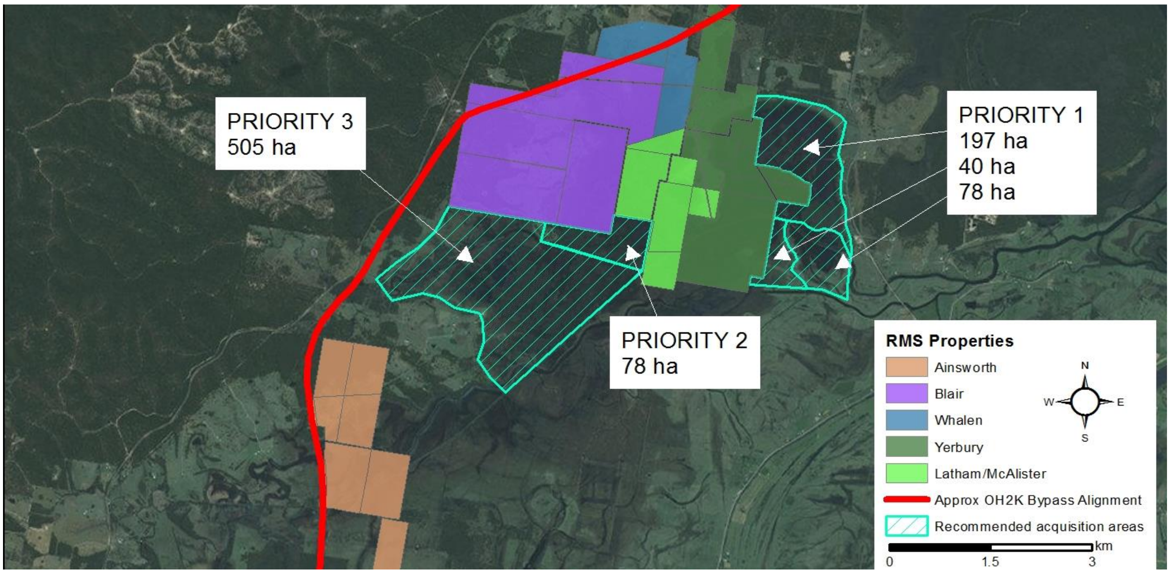


Figure 1: RMS acquisitions on Collombatti-Clybucca floodplain with prioritised recommended acquisitions.

Water Research Laboratory
School of Civil and Environmental Engineering | UNSW AUSTRALIA | 110 KING ST MANLY VALE NSW 2093 AUSTRALIA
T +61 (2) 8071 9800 | F +61 (2) 9949 4188 | ABN 57 195 873 179 | www.wrl.unsw.edu.au | Quality System Certified to AS/NZS ISO 9001
Innovative answers for tomorrow's water engineering questions, today | Since 1959

As per Glamore and Rayner (2015), the acquisition of the low-lying land provides a rare opportunity to rehabilitate the degraded landscape. Further acquisitions of additional adjacent floodplain properties would enable all directly connected wetland areas to be remediated and managed sustainably. This option provides the optimal long-term management option for the site.

Currently, the OH2K project and existing related property acquisitions have resulted in an over allocation of freshwater wetlands (12 ha required with 523 ha acquired) and a 494 ha deficit of Wet Sclerophyll forest. For the wetlands (fresh or tidal) to be utilised as a biodiversity offset in place of a Wet Sclerophyll forest, a supplementary measure (non like-for-like) offset is required. For this to occur, a number of key issues must be addressed as outlined in EPA's letter dated 10th December 2014. The key requirements are repeated below:

1. Clear acknowledgment of the agreed policy framework and principles against which the proposal must be assessed.
2. Transparent accounting of the current offset package, including the extent to which to 'like-for-like' principle has been satisfied and any residual offset which is proposed to be offset via the wetland proposal.
3. Clear demonstration of the conservation benefits associated with the wetland proposal, which should clearly explain the net benefits of moving away from a 'like-for-like' principle.
4. Demonstrating that a coordinated management approach, involving the Clybucca Working Group, in the implementation of management strategies to address the acid sulfate soil issues and thereby improve the water quality and ecological values of the wetlands, can be delivered.
5. Demonstrating the ability to manage the catchment in part versus the entire catchment (e.g. saltwater impacts on private landowners) and effective land managements in perpetuity are achieved.
6. Conservation assessments of all proposed land parcels including vegetation type, condition and fauna habitat values are completed.

These items were addressed within Glamore and Rayner (2015) and at the recent Clybucca Working Group meeting.

3. Habitat Areas Versus Freshwater or Tidal Restoration Options

To enable efficient accounting of offset habitats, RMS requires the spatial extents of different habitats that will likely result from different land and floodgate management options. For this study, these habitat areas were assessed based on tidal elevations measured at the Menarcobrinni floodgates by MHL (2004) and using a GIS bathtub model approach.

The habitat areas calculated are based on the following properties only, plus additional acquisitions as presented in Figure 1:

- Ainsworth
- Blair
- Whalen
- Yerbury
- Latham/McAlister

A total of 8 different remediation scenarios were identified and assessed. These options include tidal and freshwater scenarios. Under a tidal scenario, tidal flushing is permitted via the Menarcobrinni floodgates. For the existing or freshwater scenario, the management of the Menarcobrinni floodgates remains unchanged.

- Existing RMS properties (freshwater or tidal)
- Existing RMS properties + acquisition of priority area 1 (freshwater or tidal)
- Existing RMS properties + acquisition of priority areas 1 and 2 (freshwater or tidal)
- Existing RMS properties + acquisition of priority areas 1, 2 and 3 (freshwater or tidal)

The resulting freshwater and tidal scenario habitats are presented in Table 1 and Table 2, respectively. Note that due to its natural elevation the Ainsworth property is unlikely to be directly influenced by any tidal restoration options.

Table 1: Habitat areas based on freshwater (Menarcobrinni floodgate management unchanged)

Habitat Description	Habitat Code	Existing RMS**	Existing RMS + Priority 1	Existing RMS + Priority 1 & 2	Existing RMS + Priority 1, 2 & 3
Non-accessible (not mapped)^^	n/a	330.6 ha	330.6 ha	330.6 ha	330.6 ha
Low Elevation Freshwater					
Coastal freshwater meadows and forblands of lagoons and wetlands	NR150	541.0 ha	Existing RMS + 280 ha	Existing RMS + 300 ha	Existing RMS + 515 ha
Swamp Oak swamp forest of the coastal lowlands	NR255	165.6 ha	Existing RMS + 33 ha*	Existing RMS + 45 ha*	Existing RMS + 130 ha*
Paperbark Swamp forest	NR217[#]	141.8 ha			
Higher Elevation Freshwater					
Shatterwood – Giant Stinging Tree – Yellow Tulipwood dry rainforest	NR229	7.9 ha	Existing RMS	Existing RMS	Existing RMS
Blackbutt – Tallowwood dry grassy open forest	NR119	49.0 ha	Existing RMS	Existing RMS	Existing RMS
Blackbutt – Pink Bloodwood shrubby open forest	NR117	212.1 ha	Existing RMS	Existing RMS	Existing RMS
Paperbark Swamp forest	NR217[^]	95.6 ha	Existing RMS	Existing RMS	Existing RMS
Cabbage Gum open forest or woodland	NR145	3.1 ha	Existing RMS	Existing RMS	Existing RMS
Tea-tree shrubland of drainage areas	NR269	0.2 ha	Existing RMS	Existing RMS	Existing RMS
Tallowwood - Small-fruited Grey Gum dry grassy open forest of the foothills of North Coast	NR263	69.0 ha	Existing RMS	Existing RMS	Existing RMS
Intertidal					
Saltmarsh complex of the North Coast	NR225	0 ha	0 ha	0 ha	0 ha
Mangrove - Grey Mangrove low closed forest of the NSW Coastal Bioregions *(Avicennia marina* var. *Australlasica)*	NR182	0 ha	0 ha	0 ha	0 ha
Mangrove - Milky Mangrove low closed forest of the North Coast *(Excoecaria agallocha)*	NR183	0 ha	0 ha	0 ha	0 ha
Mangrove - River Mangrove low closed forest of the NSW Coastal Bioregions *(Aegiceras corniculatum)*	NR184	0 ha	0 ha	0 ha	0 ha

*NR255 and NR217 occupy similar topographic areas and hydrology. Additional areas are likely to occupied by NR255 and NR217.

** Based on mapping undertaken by Niche Ecological (2014) and Lewis Ecological Surveys (2013).

[#] At elevations below 2 m AHD.

[^] At elevations above 2 m AHD.

^^Non-accessible areas appear to be largely comprised of pasture grass species.

Table 2: Habitat areas based on tidal flushing (changing management of Menarcobrinni floodgates)

Habitat Description	Habitat Code	Existing RMS**	Existing RMS + Priority 1	Existing RMS + Priority 1 & 2	Existing RMS + Priority 1, 2 & 3
Non-accessible (not mapped)^^	n/a	250.6 ha	250.6 ha	250.6 ha	250.6 ha
Low Elevation Freshwater					
Coastal freshwater meadows and forblands of lagoons and wetlands	NR150	122.5 ha existing	122.5 ha existing	122.5 ha existing	122.5 ha existing
Swamp Oak swamp forest of the coastal lowlands	NR255	1.3 ha existing (Ainsworth) + 114 ha*	1.3 ha existing (Ainsworth) + 148 ha*	1.3 ha existing (Ainsworth) + 150 ha*	1.3 ha existing (Ainsworth) + 212 ha*
Paperbark Swamp forest	NR217[#]	20.0 ha existing (Ainsworth) + 114 ha*	20.0 ha existing (Ainsworth) + 148ha*	20.0 ha existing (Ainsworth) + 150 ha*	20.0 ha existing (Ainsworth) + 212 ha*
Higher Elevation Freshwater					
Shatterwood – Giant Stinging Tree – Yellow Tulipwood dry rainforest	NR229	7.9 ha	Existing RMS	Existing RMS	Existing RMS
Blackbutt – Tallowwood dry grassy open forest	NR119	49.0 ha	Existing RMS	Existing RMS	Existing RMS
Blackbutt – Pink Bloodwood shrubby open forest	NR117	212.1 ha	Existing RMS	Existing RMS	Existing RMS
Paperbark Swamp forest	NR217[^]	95.6 ha	Existing RMS	Existing RMS	Existing RMS
Cabbage Gum open forest or woodland	NR145	3.1 ha	Existing RMS	Existing RMS	Existing RMS
Tea-tree shrubland of drainage areas	NR269	0.2 ha	Existing RMS	Existing RMS	Existing RMS
Tallowwood - Small-fruited Grey Gum dry grassy open forest of the foothills of North Coast	NR263	69.0 ha	Existing RMS	Existing RMS	Existing RMS
Intertidal					
Saltmarsh complex of the North Coast	NR225	180 ha	227 ha	232 ha	457 ha
Mangrove - Grey Mangrove low closed forest of the NSW Coastal Bioregions *(Avicennia marina* var. *Australlasica)*	NR182	180 ha[##]	227 ha[##]	232 ha[##]	457 ha[##]
Mangrove - Milky Mangrove low closed forest of the North Coast *(Excoecaria agallocha)*	NR183				
Mangrove - River Mangrove low closed forest of the NSW Coastal Bioregions *(Aegiceras corniculatum)*	NR184				

*NR255 and NR217 occupy similar topographic areas and hydrology. Additional areas are likely to be occupied by NR255 and NR217.

** Based on mapping undertaken by Niche Ecological (2014) and Lewis Ecological Surveys (2013).

[#] At elevations below 2 m AHD.

[^] At elevations above 2 m AHD.

^^Non-accessible areas appear to be largely comprised of pasture grass species.

[##] All mangrove species are found within the Macleay River estuary

4. Transition of Floodplain Habitats

The existing vegetation of the Collombatti-Clybucca floodplain is comprised of low-lying freshwater and upland freshwater species. The hydrology and topography of the floodplain, in combination with land management practices, determines the vegetation distribution and density. The topography of the floodplain is generally very low-lying, with large areas of the floodplain below mean sea level. Prior to drainage, vegetation consisted of extensive freshwater lagoons and wetlands. Construction of the flood mitigation infrastructure, namely the Seven Oaks Drain, East Drain, West Drain, Andersons Inlet, McAndrews Drain and the Menarcobrinni floodgates, permanently altered the hydrology of the floodplain. Following these drainage works in the 1970s, agricultural pasture species were promoted across the floodplain, with upland areas comprised of pasture and stands of open woodland.

The historic and existing impacts of clearing and draining the Collombatti-Clybucca floodplain on the local vegetation and wider Macleay River estuary are widely documented. Glamore and Rayner (2015) summarize these impacts and outline three on-ground management strategies; (i) remain as per existing, (ii) convert to freshwater wetland or (iii) convert to intertidal wetland. The implications of these strategies on floodplain vegetation communities and water quality is discussed below and summarised in Table 3. A schematic outlining vegetation and water quality transitions over time is presented in Figure 2.

Table 3: Predicted outcomes for vegetation communities and water quality under different on-ground management scenarios

Scenario	Pasture Vegetation	Freshwater Wetland Vegetation	Intertidal Wetland Vegetation	Catchment Water Quality
Existing (no change onsite)	Existing distribution remains	Existing pockets persist	None likely onsite	Poor water quality persists
Freshwater remediation	Decreasing over 5 year period	Increasing over 3 - 10 year period	None likely onsite	5 - 15+ year improvement
Tidal remediation	Immediate transition to wetland species	Some transistion areas maintained	Establish over 3 – 5 year period	Immediate improvement

4.1 Existing (no change to current practices) Scenario

If the Collombatti-Clybucca floodplain was to remain agricultural and not be restored, whereby existing RMS properties are sold and used for grazing, the floodplain would continue to function in its current state. That is, degraded pasture land and poor water quality would continue to discharge from the site. Recent fish kills resulting from a 'blackwater' event and on-going soil and drain water acidity highlights the poor state of the existing site.

Based on this scenario, there would be no transition of vegetation or aquatic communities. The existing vegetation of the low-lying floodplain comprising of extensive areas of degraded pasture, coupled with some regularly inundated backswamp areas that support patches of freshwater wetland, would persist. The on-going local and regional environmental degradation caused from the poor management of this site would continue.

4.2 Long-term Freshwater Scenario

This scenario is based on the remediation of the RMS acquired properties, and that of any further acquisitions, to a permanent freshwater wetland. Note that the management of the Menarcobrinni floodgates remains unchanged for this scenario.

Remediation to a freshwater wetland would provide long-term conservation benefits for the local Collombatti-Clybucca floodplain and wider Macleay River estuary. Historically, the backswamp areas of Doughboy Swamp and Mayes Swamp were inundated due to inflows from Collombatti Creek flooding the swamps and backwater flooding from the Macleay

River. Upland catchment inflows, however, now bypass the backswamps and flow through the Seven Oaks Drain. Subsequently, restoration of Doughboy Swamp and Mayes Swamp to freshwater would rely on inundation from large flood events and local catchment rainfall. This is likely to result in the intermittent wetting and drying of the backswamps. The transition of the floodplain from pasture grasses, to freshwater wetland species would occur gradually over an extended period of time (approximately 5 to 20 year period).

Improvements in water quality of the areas restored in a freshwater remediation scenario rely on two key factors:

1. Establishment of water tolerant vegetation that does not rapidly decay and create blackwater; and,
2. Deposition of organic matter and reducing conditions to reduce onsite acidity.

Establishment of water tolerant vegetation will likely occur over an approximate 5 to 10 year period. This will assist in maintaining elevated dissolved oxygen concentrations and hence, the gradual reduction of blackwater event frequency and severity. On-ground works may be required to assist in redirecting flows and promoting water retention.

Surface and groundwater acidity at the restored properties would also reduce gradually over a 5 to 15 year period due to increased organic matter on the bed of the wetland and containment of acid. However, reductions in acidity are only feasible after the development of a substantial layer of organic matter. No improvements in acid concentrations in the broader Seven Oaks Drainage system (upstream of the Menarcobrinni floodgates) are likely to result from this scenario.

4.3 Intertidal Flushing Scenario

This scenario is based on the restoration of existing low-lying areas, and any additional acquired properties, to an intertidal system. Changes to the current management of the Menarcobrinni floodgates are required for this remediation scenario.

Transition of the backswamp vegetation from pasture to intertidal species is likely to occur over a 1-5 year period due to the daily flushing of tidal waters. Based on experiences at similar sites in NSW, tidal flushing of the floodplain will result in the establishment of aquatic and saltmarsh/mangrove species within a short period, with extensive coverage expected after a 5 year period. Following establishment of the intertidal flora, benthic invertebrates are likely to establish shortly thereafter. These benthic species attract migratory wader bird species and have been shown to improve fish stocks.

A salinity gradient is likely to naturally establish from the upstream reaches of the site to lower backswamps. Upstream areas are likely to be predominantly freshwater with increased salinity near the downstream extent of the floodplain, and brackish in-between. This salinity gradient will be dynamic, changing with freshwater inflows and the tidal dynamics of the wider Macleay River estuary. The natural salinity gradient will result in a range of overlapping species with different salinity tolerances, from fully freshwater to fully saline tolerant. Based on similar sites in NSW, the vegetation gradient is likely to reach a dynamic equilibrium within a 5 to 15 year period.

The water quality of the RMS properties, and any additional properties, will improve due to the introduction of tidal flushing to the Collombatti-Clybucca floodplain and associated drainage system. Initial die-off of existing vegetation is likely to occur, however daily flushing and careful management can reduce the likelihood of a blackwater event. During dry periods the acidic water in the drainage network, and on the floodplain, would be buffered by tidal waters each tide. Further, the drain waters of the wider Seven Oaks drainage network will also improve immediately following restoration. As large reserves of acidity will remain in the soil profile, some periods of acidity are likely to continue following flood events when tidal buffering has yet to return to the estuary. However, the day-to-day water quality of the drain and floodplain is likely to be similar to the wider Macleay River estuary.

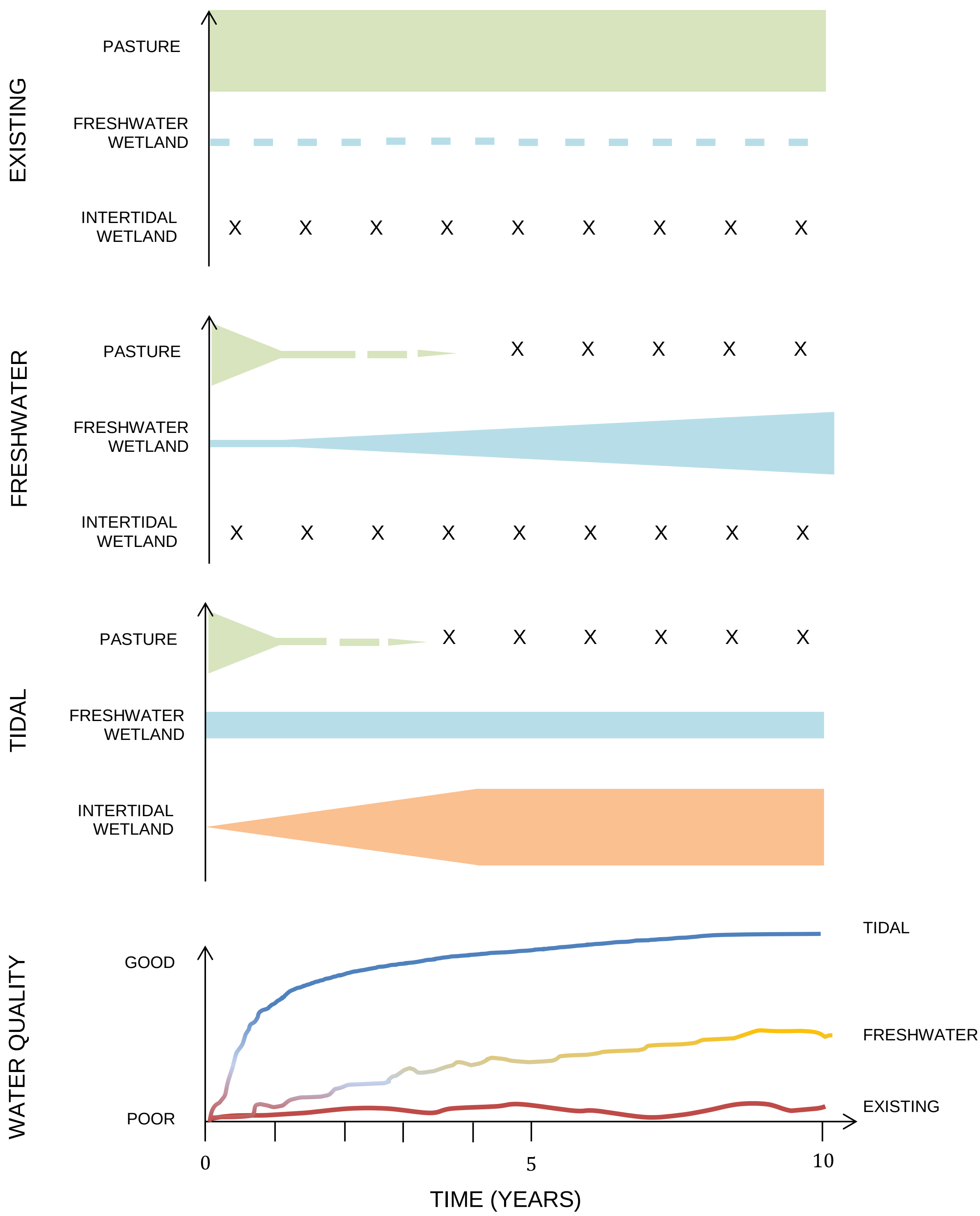


Figure 2: Schematic of vegetation and water quality over time based on different management scenarios

5. References

Glamore, W.G. and Rayner, D.S., 2015, Collombatti-Clybucca Floodplain Remediation Feasibility Study, Water Research Laboratory, Technical Report 2015/01, Draft, 30th January 2015

Lewis Ecological Surveys, 2013, Kempsey to Eungai Biodiversity Offset Strategy: McAlister and Latham Candidature Sites, Letter to NSW RMS, 26th August 2013

Manly Hydraulics Laboratory, 2004, DIPNR Macleay River Estuary Tidal Data Collection April – May 2003, Report No. 1250

Niche Ecological, 2014, Existing vegetation on NSW Roads and Maritime property acquisitions on the Collombatti-Clybucca floodplain (draft vegetation figures only)