MIDCOAST council

MANNING RIVER ESTUARY & CATCHMENT

COASTAL WETLANDS MAPPING REPORT 2019

Annexure F

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Template 2.8.1

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Abbreviations

Abbreviation	Description
3D	Three dimensions
ADS	Airborne Digital Sensor
API	Aerial Photographic Interpretation
BAM	Biodiversity Assessment Method
BC Act	NSW Biodiversity Conservation Act 2016
CASA	Civil Aviation Safety Authority
DEM	Digital Elevation Model
DSM	Digital Surface Model
FM Act	NSW Fisheries Management Act 1994
EEC	Endangered Ecological Community
GIS	Geographic Information System
EPBC Act	Commonwealth Environment Protection and Biodiversity Conservation Act 1999
NPWS	National Parks and Wildlife Service

Abbreviation	Description
OEH	Office of Environment and Heritage
LGA	Local Government Area
RDP	Rapid Data Point
SEPP	State Environmental Planning Policy
TEC	Threatened Ecological Community
UAV	Unmanned Aerial Vehicle
VEC	Vulnerable Ecological Community
WON	Weed of National Significance

Executive Summary

Wetlands are amongst the most sensitive and significant vegetation communities in NSW and provide a range of ecosystem services including capture and storage of floodwater, nutrient cycling, and sedimentation. Wetlands are a critical component of biodiversity at both the regional and national level, providing critical habitat for a suite of threatened flora and fauna species. Wetlands also provide a range of services to the community including agriculture, fishing, lifestyle and tourism activities.

This study includes all coastal wetlands in the Manning River Catchment, with the exclusion of 'riparian' vegetation largely confined to areas upstream of Taree. This includes forested, freshwater and saline wetlands up to the tidal extent of the Manning River upstream of Taree.

This study has been undertaken to produce a fine-scale wetland type map and accurately describe coastal wetland types in the Manning River Catchment. This work will be used to assist MidCoast Council to work collaboratively with the NSW Government to update the Coastal State Environmental Planning Policy (SEPP) wetland mapping across the MidCoast Local Government Area. It will also be used to inform catchment protection and enhancement programs, biodiversity conservation initiatives and water quality improvement projects. One of the most important benefits that wetlands provide is their capacity to maintain and improve water quality. Wetland conservation and management should reflect these values.

A range of datasets were used in this wetland type mapping including previous surveys and mapping, as well as targeted surveys undertaken as part of this project. This project applied a number of innovative methods including three-dimensional aerial photographic interpretation in conjunction with digital elevation and surface models to determine wetland locations and extent, aerial video transects captured with a drone, and survey of many inaccessible wetlands from the water.

Coastal wetland types mapped include open freshwater lagoons dominated by floating macrophytes, to large sedgelands with impeded drainage, to saltmarshes characterised by grasses, rushes and chenopod herbs, open fringing mangrove forests and their characteristic mudflats; wet heathlands characterised by myrtaceous shrubs and a diversity of sedges and rushes; variable shrublands, through to forested wetlands characterised by *Eucalyptus robusta* (Swamp Mahogany), *Melaleuca quinquenervia* (Broad-leaved Paperbark) and *Casuarina glauca* (Swamp Oak).

Thirteen wetland types totalling 8,906 hectares were mapped as part of this project across three vegetation formations and six vegetation classes. A total of 51 discrete units have been mapped which includes a number of variants of wetland types and intergrades (complexes) which occur between them. Detailed wetland type descriptions have been developed. Wetlands were generally mapped in good/excellent condition (69%), whilst wetlands in fair condition accounted for 19% of the total area mapped and poor/very poor condition equated to 12%. The majority (86%) of all wetland types mapped are protected under State or Commonwealth legislation.

Wetland areas across the study area have been variously disturbed and modified since European occupation, however due to the waterlogged and saline soils, significant wetlands of considerable conservation significance still occur in the study area. This includes large wetlands at Taree (Dawson River), Kundle Kundle, Cattai Wetlands, Big Swamp, Manning Point and Crowdy Bay National Park.

Management considerations including environmental weeds, urban and agricultural development, accessibility, isolation and fragmentation, inappropriate fire regimes and climate change (particularly sea level rise) have been identified as major risks to coastal wetlands in the Manning River Catchment.

1. Introduction

1.1 What is a wetland?

A clear definition and understanding of what constitutes a wetland is critical for mapping and describing wetland types. Wetlands are areas of land which are temporarily, seasonally or permanently covered or saturated with generally slow moving fresh, brackish or saline water (OEH 2018a). Wetlands are characterised by plants and animals which have adapted to natural water cycles.

For the purposes of this study, the definition of a 'wetland' has been adopted from the Wallis Lake Wetland Strategy (Great Lakes Council 2010):

"Land, including marshes, mangroves, backwaters, billabongs, swamps, sedgelands, wet meadows or wet heathlands, that is naturally, permanently or seasonally inundated or waterlogged by shallow, static or flowing, fresh, brackish or saline surface or ground water (up to 2-metres in depth) and which such inundation or saturation occurs at a frequency or duration sufficient to influence the ecological processes and support habitat that is characterised by indicative soils and hydrophytic and aquatic (wetland) plants, but excluding seagrasses and open saline water bodies"

The Wallis Lake Wetland Strategy further clarifies that the upper edge of a wetland is where the understorey vegetation is dominated by plants from terrestrial habitats (Great Lakes Council 2010) which allows for the accurate delineation of wetland boundaries, regardless of the presence or absence of water.

For the purposes of this study, narrow riparian zones in the upper reaches of the Manning River catchment (upstream of Taree) have not been mapped as wetland types. This broadly conforms with the State-wide vegetation classification which generally assigns these communities to non-wetland vegetation formations and classes. These areas of riparian vegetation have been mapped under a separate project commissioned by Hunter Local Land Services.

1.2 The study area

For the purpose of this study, the 'study area' is defined as coastal area of the Manning River Catchment (the Manning River Estuary) with the additional inclusion of areas with impeded drainage in the Crowdy Bay National Park (Figure 1). The Manning River Estuary includes the Manning River and its tributaries up to the approximate tidal limit and the adjoining floodplain.

The Manning River catchment covers approximately 856,224 hectares of land and includes the towns of Taree, Wingham, Lansdowne, Gloucester, and Harrington and extends to Barrington Tops in the south-west of the catchment.

1.3 Purpose of the study

This study has been undertaken to produce a fine-scale wetland type map and accurately describe wetland types in the Manning River Catchment. This work will be used to assist MidCoast Council to work collaboratively with the NSW Government to update the Coastal State Environmental Planning Policy (SEPP) wetland mapping across the MidCoast Local Government Area (LGA).

Understanding the location, type and condition of wetlands is also essential to provide effective catchment management to improve ecosystem services through improving habitat condition, reducing habitat fragmentation by increasing connectivity, improving water quality through greater natural filtration and improving and maintaining fish habitat.

Finally, the study should be used to inform conservation planning and implementation projects. Additions of some wetland types to boost the adequacy and representativeness of the public conservation reserve system and to protect wild populations of regionally significant plant and animal species are required. Given the effects of legacy wetland loss in this region, in some landscapes and circumstances, there is benefit in wetland re-construction and restoration projects.

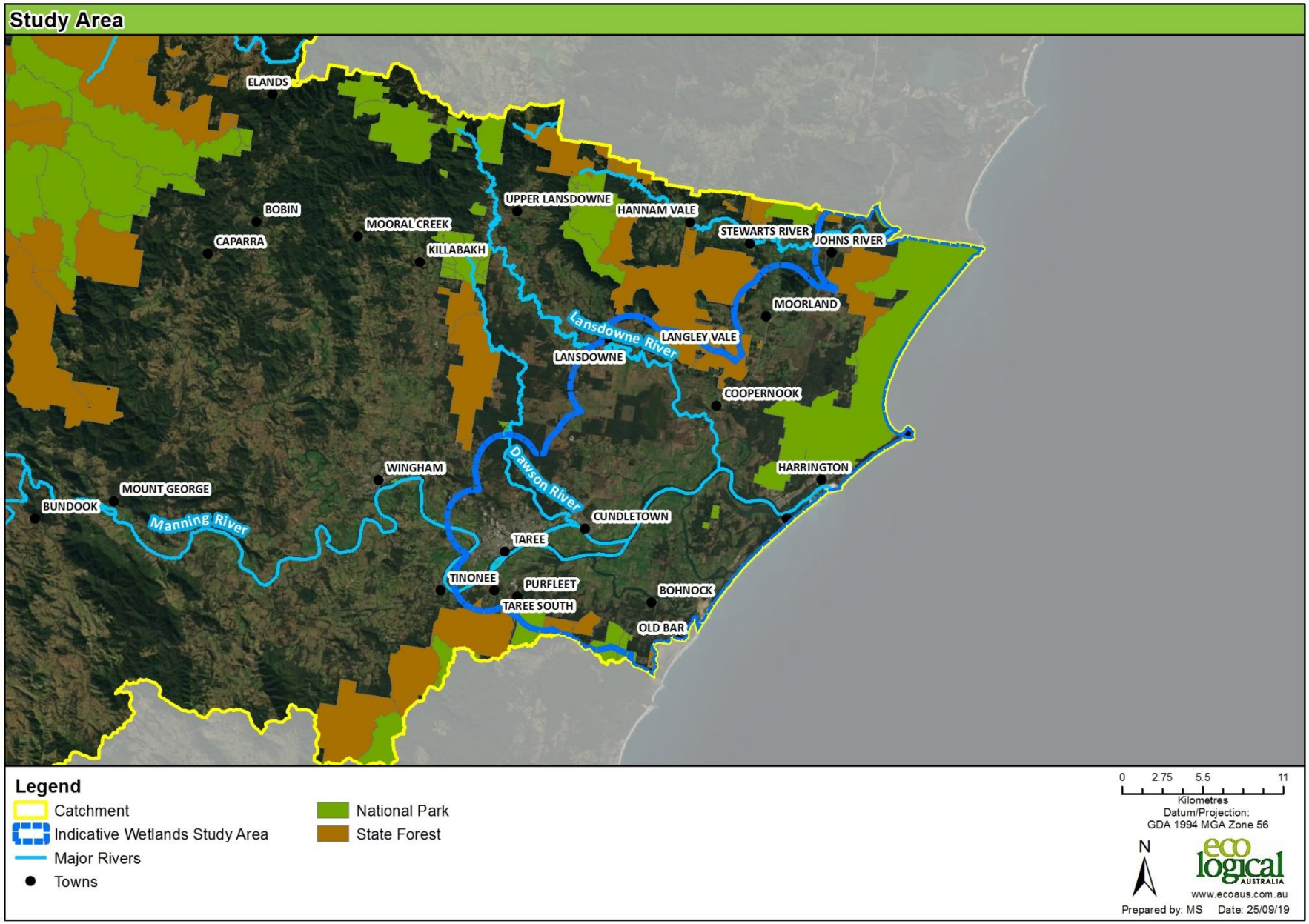

Figure 1: Study Area

2. Existing environment

2.1 Climate

The climate of the study area trends from subtropical on the coast, sub-humid on the slopes to a temperate climate in the uplands of the Barrington Tops (OEH 2016). Summers are hot with mean maximum temperatures of 27-30 degrees in January, with relatively mild winters having mean minimum temperatures of approximately 6 degrees in July (BOM 2019). Rainfall is consistent throughout the year with higher averages late summer through to an autumn/winter peak followed by a drier spring.

2.2 NSW Landscapes

NSW Landscapes are a system of ecosystem classification mapped at the 1:250,000 scale, based on a combination of soils, topography and vegetation (DECC 2008). NSW Landscapes are used in regional conservation planning in NSW and form a basis for the threatened component of the Biodiversity Assessment Method under the NSW Biodiversity Conservation Act 2016 (BC Act).

Twenty-three Mitchell Landscapes have been mapped across the study area (Figure 2), with three being of relevance to this study (Table 1).

Table 1: NSW Landscapes

Landscape	Description	Location
Manning – Macleay Channels and Floodplains	Channels, floodplain, terraces, swamps and estuary of the Manning and Macleay Rivers and other coastal streams on Quaternary alluvium. Extensive floodplain swamps at tributary junctions. General elevation 0 to 50m, local relief 15m. Dark organic loams and silty clay, organic mud in the estuary. Flooded Gum on alluvial river flats and River Oak along the banks. Large freshwater wetlands with Common Reed, Spike Rush, Water Couch, Broad-leaved Paperbark and Swamp Oak. The estuary includes; Grey Mangrove, River Mangrove, Milky Mangrove and Saltmarsh Communities.	Channels and floodplains adjacent to the Manning River and its tributaries upstream of Taree. These areas have been excluded from this study, but may contain 'wetland' vegetation by definition (i.e. riparian vegetation) but are considered unlikely to contain significant floodplain wetlands.
Manning – Macleay Coastal Alluvial Plain	Wide valleys, channels, floodplains, swamps, and terraces of the Manning and Macleay rivers and other coastal streams on Quaternary alluvium, general elevation 0 to 50m, local relief 15m. Dark organic loams and silty clay on the floodplain, gradational brown loams and yellow-brown texture-contrast soil on terraces, organic silty mud in swamps.	Low lying areas adjacent to the Manning River, Lansdowne River and Stewarts River downriver from Taree, Upper Lansdowne and Hannam Vale including low lying areas with impeded drainage from Crowdy Bay to Dunbogan
Manning - Macleay Barriers and Beaches	Beaches, dunes, swamps and lagoons on Quaternary coastal sands, with inner and outer barrier dune sequences, general elevation 0 to 25m, local relief 10 to 20m. Yellow or white single grain quartz sand on destabilised dunes, well developed iron and humic podzols with depth to pan varying with position in the dune sequence (age), topography and depth to groundwater. Outer barrier; foredune with coast Spinifex, Coast Wattle, and Coast Tea Tree. Hind dunes with Blackbutt, Pink Bloodwood, Old Man Banksia and rainforest elements including Blue Lilly Pilly, Green Tamarind, Native	Along coastline south of Crowdy Head to Old Bar.

Landscape	Description	Location
	Guava, Plum Pine, Tuckeroo, Bauerella and vines. Swampy lagoon zone of wet heath and swamp forest between the barriers with; dense Tea Tree, Paperbark, Swamp Oak, and Swamp Mahogany. Inner barrier dunes tall forest of; Blackbutt, Northern Scribbly Gum, Needlebark Stringybark and Red Bloodwood. Wet heath with Lemon Scented Tea Tree, Prickly Tea Tree, Swamp Banksia, rushes and sedges.	

2.3 Soil landscapes

Soil landscapes of the study area have been mapped at a 1:100,000 scale (OEH 2018b) (Figure 3). The dominant process for the development of soil landscapes relevant to this study include aeolian, alluvial, beach/barrier, estuarine, residual, swamp and transferral (Figure 3). Soil landscapes developed through these processes have formed in low parts of the landscape and support areas of deep to very deep poorly drained sandy, silty, clayey and often acidic soils. Seasonally or permanent saturated soils (hydrosols) are also common. Detailed soil descriptions have not been reproduced here, but can be found in OEH (2018b).

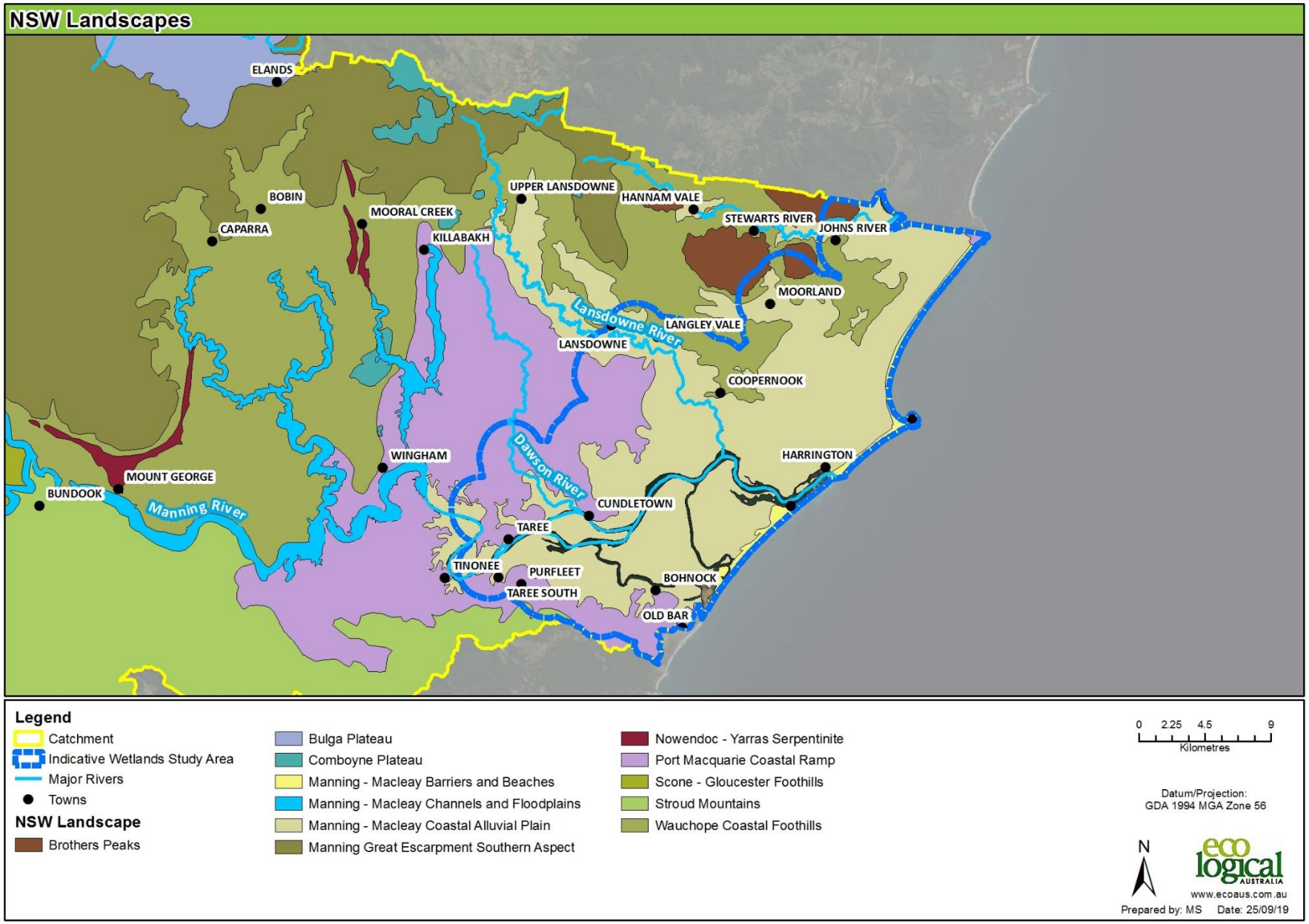

Figure 2: NSW Landscapes

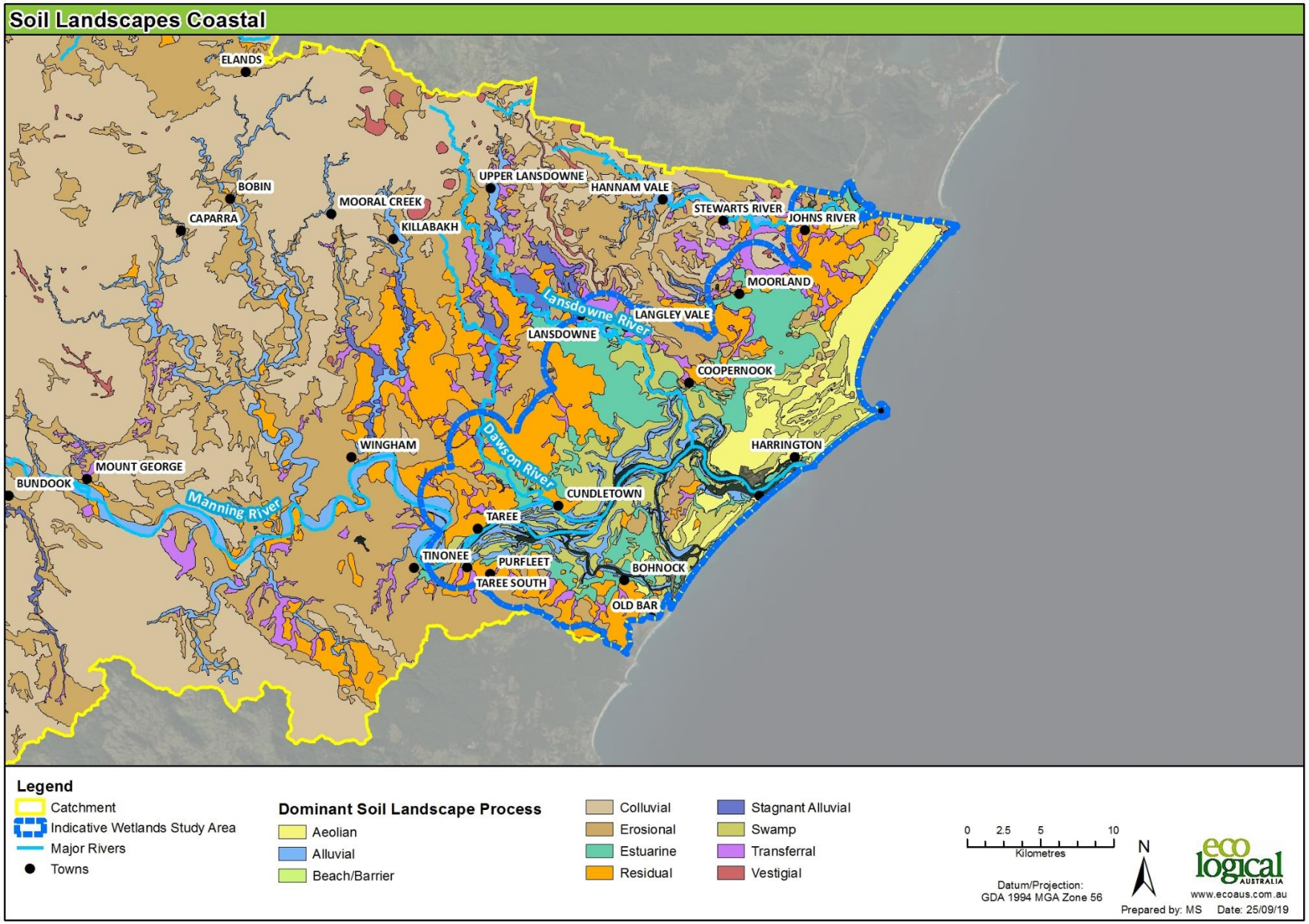

Figure 3: Soil Landscapes (coastal)

3. Methods

3.1 Previous survey and mapping

Vegetation surveys have previously been undertaken within the Manning River Estuary through numerous vegetation survey and mapping programs by MidCoast Council, the NSW National Parks and Wildlife Service (NPWS) and State Forests.

A total of 21 existing, full floristic vegetation plots were identified from the Vegetation Information System (VIS) flora survey module within the Bionet Atlas (OEH 2019) within wetland areas of the Manning River Estuary.

A range of vegetation mapping products were identified which included wetland vegetation in the study area:

- Old Bar Endangered Ecological Community Mapping (MidCoast Council, undated)
- Big Swamp Vegetation Mapping (Griffith, Wilson and Harre 2018)
- CRAFTI Lower North East Floristics VIS 1082. (OEH 2010)
- Mid North Coast Vegetation Mapping (DEC, undated)
- Coastal Vegetation of North East NSW VIS Map 3885 (Griffiths and Wilson, 2016, incorporating mapping by Griffiths and Wilson from 1984 to present).

These datasets collectively cover the coastal wetlands of the Manning River Catchment, however they have all been produced for specific purposes and generally not focussed specifically on wetlands, are of a variety of scales, dates, quality and level of ground truthing. For these reasons, a completely new fine-scale wetland vegetation map was required for the study area.

3.2 Datasets utilised

A range of datasets were used in this project including high resolution (50 cm) stereo Airborne Digital Sensor (ADS40) imagery, digital surface and elevation models, existing vegetation mapping, drainage mapping, full floristic vegetation plot data and rapid data point (RDP) data (Table 2).

Table 2: Data sources

Data	Purpose
MidCoast Council Local Government Area and Major Catchments	The MidCoast Local Government Area boundary was combined with the Major Catchments layer to identify the broader study area in which wetlands were to be mapped.
National Parks and State Forests	National Parks and State Forests were included in this study.
High resolution (50 cm) stereo ADS40 imagery for the Camden Haven and Wingham 1:100,000 scale map sheets.	District patterns in the imagery representing vegetation community boundaries were identified, linework digitised and attributed.
Digital Surface Model (DSM) and Digital Elevation Model (DEM)	A DSM was used to ensure high vertical positional accuracy was acquired during the creation of linework and was applied to all input datasets for consistency. A high resolution (10 cm) DEM was utilised to both identify areas of low slope (<# degrees) that could potentially support wetlands, as well as identifying boundaries

Data	Purpose
	between wetland and non-wetlands areas. The use of the DEM was essential in Crowdy Bay National Park where local topographical relief was minimal, but had a significant effect on the spatial distribution of wetland types.
Vegetation mapping products listed in Section 3.1.	Existing vegetation mapping products were reviewed for potential wetland types and for potential uplifting into this project. Only the Big Swamp mapping (Griffith, Wilson and Harre 2018) was uplifted due to the fine-scale mapping and recent completion of this work. The remaining datasets were utilised primarily for identifying potential wetland locations.
Vegetation survey data including: Previous vegetation survey data obtained from the VIS (OEH 2019) Survey data contained within the vegetation mapping products listed in Section 3.1. Supplementary vegetation survey plots and RDPs undertaken as part of this project.	Field survey data was used to identify wetland types, communities, classify soils and assign wetland types. Floristic data from previous surveys were used in the identification of wetland areas and development of the vegetation community profiles. All full floristic and rapid data point sites utilised in the development of this study are presented in Figure 4.
Contours and drainage (LPI 2015)	Topography, drainage and landscape position.
Geological mapping (DMR 2002)	Primary geological units informing soil classification.
Soil landscape mapping (OEH, 2016)	Soil landscape mapping, particularly major soil landscape grounds including transferral, alluvial, estuarine, lacustrine, aeolian and swamps were used to infer the likely location and extent of potential wetlands in the study area.

3.3 Vegetation survey

3.3.1 Vegetation plots and rapid data points

Twenty-two new targeted 20 x 20 m full floristic vegetation plots and over 280 Rapid Data Points (RDPs) were surveyed as part of this project between 15 July 2019 and 16 August 2019 by ELA botanist Martin Sullivan with support from ecologists Alex Pursche, Daniel Watts, Tomas Kelly and Liam Scanlan (Figure 4).

Priority was given to full floristic surveys in vegetation types that were deficient in existing plot data. Rapid data points were used to verify vegetation to aid aerial photograph interpretation. Data recorded in full floristic vegetation plots included all vascular plant species present, stratum, form, cover and abundance. In addition, ancillary information on vegetation structure and function was recorded in accordance with the NSW Biodiversity Assessment Method (BAM).

Vegetation surveys were undertaken in the field using mobile devices loaded with Collector for ArcGIS software and relevant Geographic Information System (GIS) datasets (existing plots, aerial photography, draft wetland mapping, tenure etc.).

At each RDP the dominant canopy, midstorey and groundcover species; structural cover condition; vegetation structure; wetland type; priority or environmental weed species and cover; threatened species and count; soil texture; fire history; vegetation condition; landform element and pattern; notes; photo number; surveyor, and data were recorded. RDPs are less comprehensive than full floristic

vegetation plots, however they allow for rapid identification of wetland types which could then be interpreted through API.

3.3.2 Boat-based surveys

Field surveys of the Manning River were enhanced through boat-based surveys and unmanned aerial vehicle (UAV) surveys to provide unprecedented access to wetland types. The use of a boat allowed far greater access to wetland areas, including through the addition of UAV surveys, than would have been possible through traditional means (i.e. land based access). Boat access allowed for inspection of the forward edge of wetlands adjoining the waterfront which would not have been possible on foot.

3.3.3 Unmanned Aerial Vehicle survey

A UAV survey, commonly referred to as a 'drone' was utilised to enhance the accuracy of wetland mapping. A DJI Mavic Air was flown by a registered operator in accordance with the Civil Aviation Safety Authority (CASA) standard operating conditions. The drone was used in the following manner:

- Approximately 100 high quality (4K) videos were flown in 13 flights across wetlands in the study area. The video transects allowed for post flight analysis of dominant canopy species, vegetation structure, condition, and transitions between wetland types.
- Over 400 high resolution photographs were taken across wetlands in the study area. Aerial photographs captured allowed for post flight analysis of dominant canopy species, vegetation structure, condition and interpretation of cover of various wetland types. Aerial photographs were captured at variety of angles including oblique and top-down to provide additional information not available in existing aerial photography.

While drones have been previously utilised in vegetation mapping projects (e.g. Cruzan et al. 2016), they typically have been used to create high resolution aerial photography mosaics, DEMs or spectral imagery. The use of a drone to support vegetation mapping in the manner undertaken for this project is relatively novel (having been trialled on previous wetland mapping of the Karuah and Myall river catchments) and has allowed far greater coverage of wetland areas than possible using traditional means (on foot).

This is particularly important for wetland areas which are notoriously difficult to traverse on foot due to their density, inundation and soft soils. Furthermore, in combination with high resolution stereo Aerial Photographic Interpretation (API), the DEM and on-ground vegetation survey, the final accuracy of mapping across the study area is considered exceptional.

Figure 5 shows the location of all aerial transects surveyed in the study area to help inform vegetation mapping while Figure 6 is an example of a single aerial transect with video recording and photographic locations shown. Spatially referenced videos and photographs allow for rapid viewing of visual information to inform vegetation mapping in a particular area.

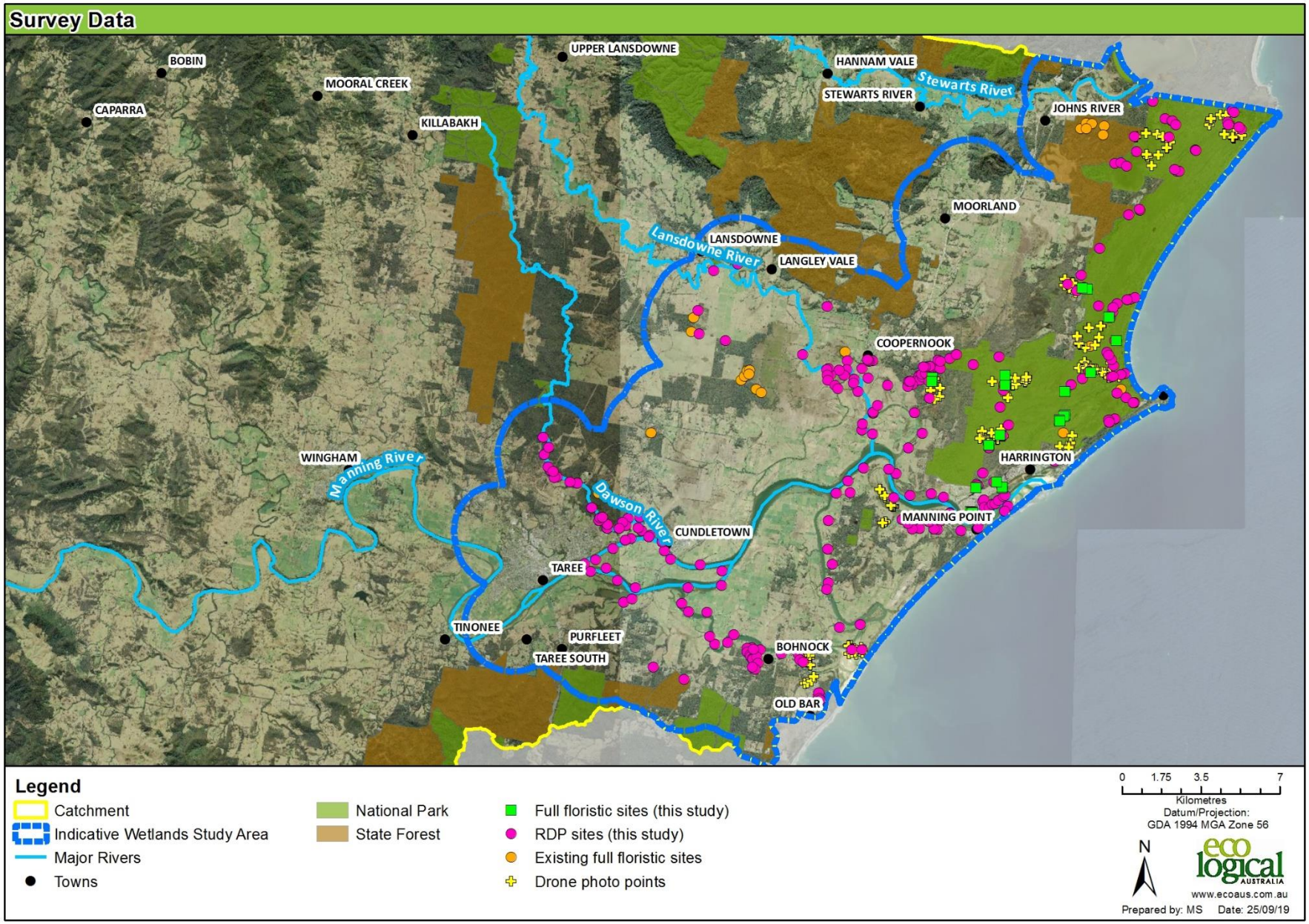

Figure 4: Survey data

3.4 Vegetation mapping

Vegetation mapping was undertaken using a 'heads-up' on screen digitising approach in ArcGIS10.2 and Summit Evolution at a scale of between 1:2,500 and 1:10,000. Spatial data were loaded into the Geographic Information System (GIS) and RDPs were combined with full floristic vegetation plots to form a combined dataset which was overlain on the high resolution three-dimensional (3D) ADS40 (50 cm) imagery.

A number of rules were developed prior to the commencement of mapping:

- The minimum polygon size is 0.01 ha (e.g. 10 m x 10 m)
- The minimum polygon width is 10 m
- Derived communities (e.g. native grasslands) are generally excluded
- Non-native vegetation is excluded
- Scattered paddock trees will not be mapped unless they conform to the above rules and are generally in groups of 10 or more trees that are no more than 20 m apart.

RPDs and vegetation plots were used as an initial guide to identify wetland types. API was then used to generate linework in 3D based on distinct patterns in the imagery representing vegetation community boundaries with the most appropriate community attributed. Three broad condition states were allocated based on both field validation (where possible) and API:

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

The final mapped product is considered accurate at a 1:5,000 scale. Supplementary datasets such as the DSM were used to help inform the API and to delineate boundaries between vegetation communities. Attributing and mapping vegetation communities in three dimensions (3D) provides a level of accuracy unable to be achieved in two dimensions (i.e. standard orthorectified imagery) (Plate 1 and 2). Individual tree species, canopy height, midstorey structure as well as grassy/shrubby understoreys are readily identifiable in 3D, with landscape position, elevation and topographical features greatly assisting in the accurate identification of vegetation communities. Fine-scale differences between wetlands with homogenous (or heterogenous) shrublands, including shrub heights over sedge understoreys can also be readily identified in 3D.

The fine scale nature of the available imagery and the features of mapping in 3D allowed for the identification of wetlands across the landscape based on landscape position, signature and structure.

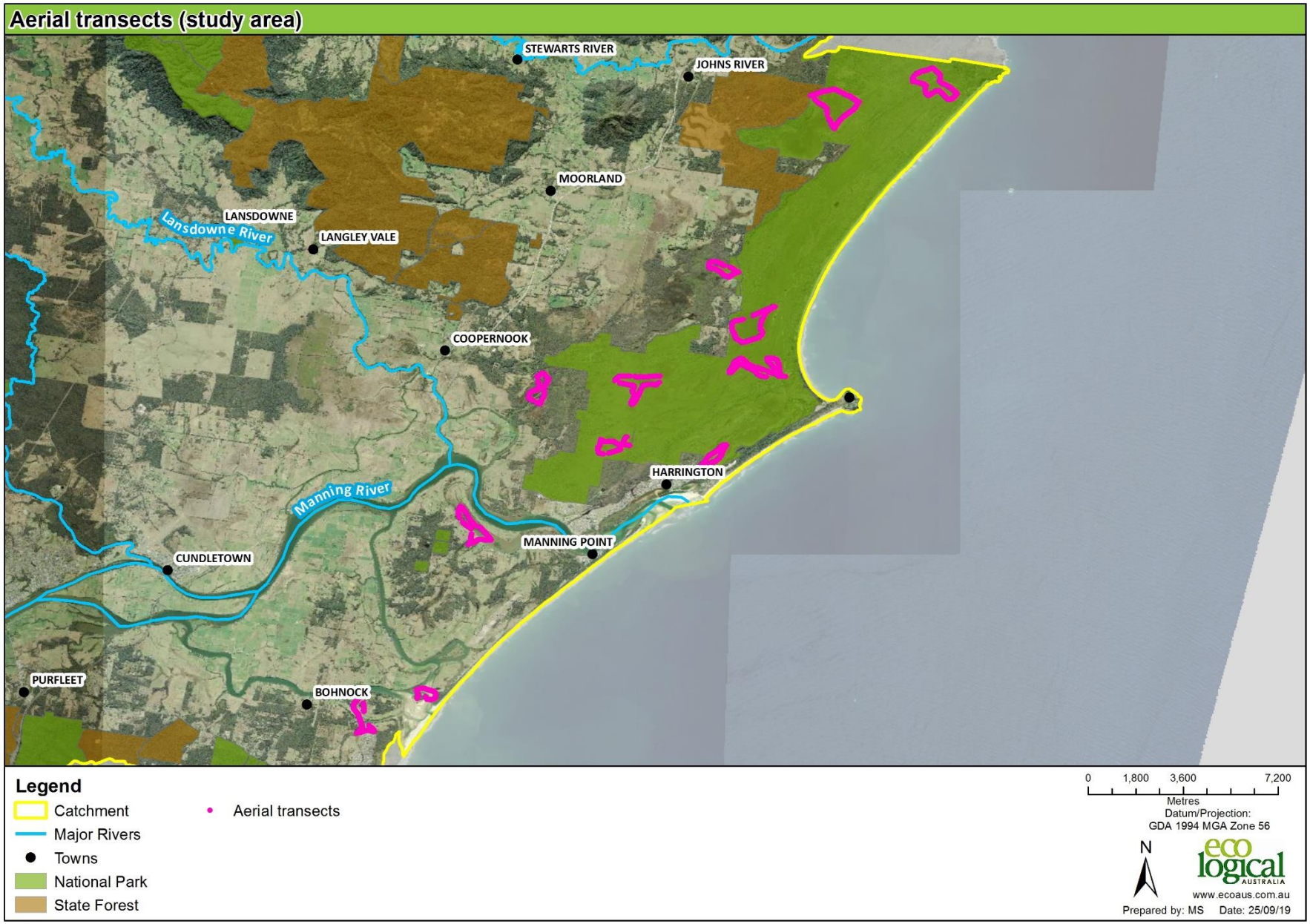

Figure 5: Aerial transects (study area)

Figure 6: Aerial transects (example)

Wetland types (map units) were attributed in accordance with the MidCoast Council naming convention. This convention is based on the dominant flora species of the canopy layer and the community structure (e.g. Swamp Mahogany/ Broad-leaved Paperbark Swamp Sclerophyll Forest and Woodland, Baumea Freshwater Sedgeland, etc). Where a particular wetland type was particularly diverse a number of map unit variants were described. Within the variant attribution, the original wetland type was classified as 'type' if it reflected the major wetland grouping, otherwise the variant was listed.

- Each polygon was assigned the following attributes:
- FIELDNAME – abbreviated wetland type
- CONDITION - e.g. poor/very poor, fair or good/excellent
- CONFIDENCE – mapping confidence:
  - 1 - Very high confidence (Field Validated)
  - 2 - Very high confidence (API)
  - 3 - Moderate confidence (API)
  - 4- Low confidence (API)
- HECTARES – polygon area in hectares
- SOURCE – ELA 2019 (this study) or Griffith, Wilson and Harre (2018)
- MAJORGROUP – Major wetland grouping (Wetland Types)
- STRUCTURE – Vegetation structure
- VARIANT – The type, or mapped variant of each wetland type
- FORMATION – NSW Vegetation formation
- CLASS – NSW Vegetation class
- NSW– Community name and listing status under the BC Act or FM Act
- EPBC - Community name and listing status under the EPBC Act

Plate 1. Visualisation of 3D mapping utilising Summit Evaluation Software

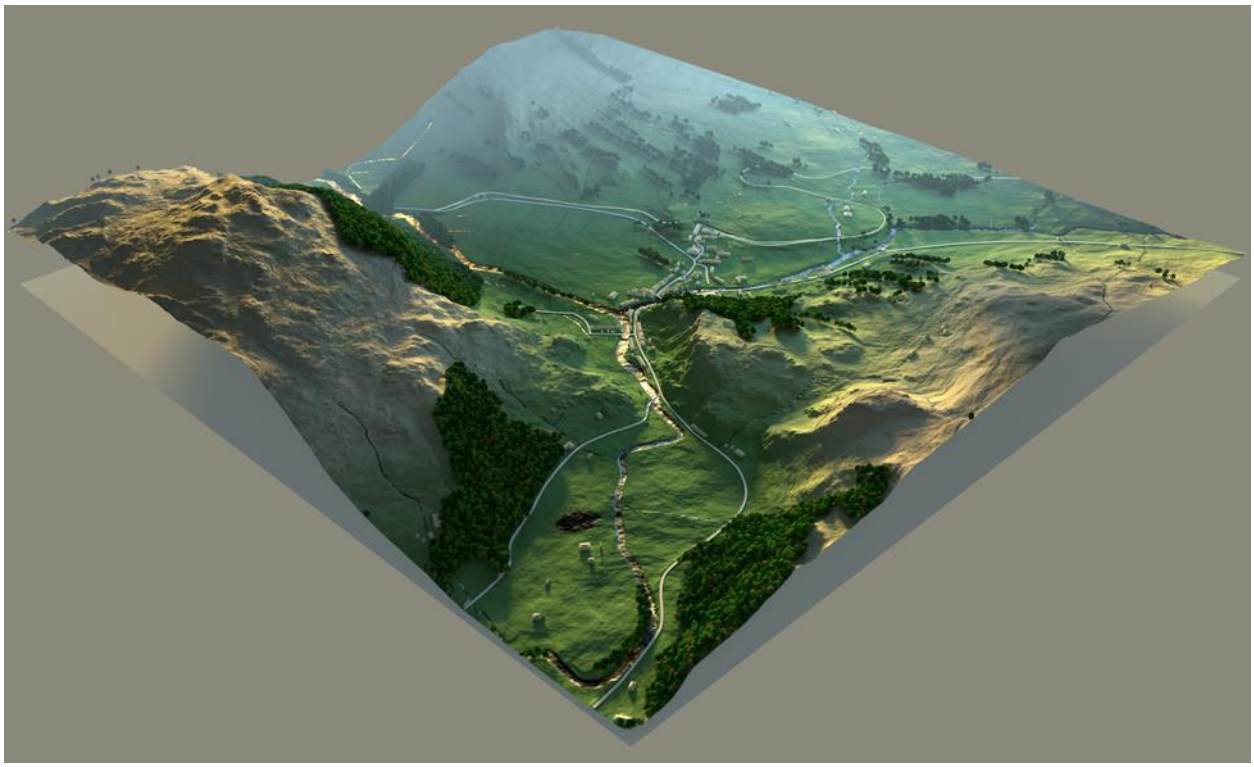

Plate 2. Conceptualisation of the 3D mapping process including the ability to visualise vegetation structure, landscape position, elevation and topography. © Owen Powell

4. Results

Thirteen wetland types totalling 8,906 hectares were mapped as part of this project across three vegetation formations and six vegetation classes (Table 3). Including wetland type variants and complexes (intergrades between types), a total of 51 discreet units have been mapped (Table 4). Detailed wetland type descriptions have been developed and are included in Appendix A and a consolidated species matrix including sites surveyed for this project as well as those from background studies is included in Appendix B. Figure 7 provides an overview map to major wetland types, with an associated series of fine-scale maps provided in Figure 8 to Figure 14. Spatial data has been provided for optimal interrogation of wetland type mapping.

Structurally wetland types mapped include open freshwater lagoons dominated by floating macrophytes, to large sedgelands with impeded drainage, to saltmarshes characterised by grasses, rushes and chenopod herbs, open fringing mangrove forests and their characteristic mudflats; wet heathlands characterised by myrtaceous shrubs and a diversity of sedges and rushes; variable shrublands, through to forested wetlands characterised by *Eucalyptus robusta* (Swamp Mahogany), *Melaleuca quinquenervia* (Broad-leaved Paperbark) and *Casuarina glauca* (Swamp Oak).

The majority (86%) of all mapped coastal wetland types (by type) are protected under State or Commonwealth legislation as either Threatened Ecological Communities or protected vegetation (Table 5 and Table 6). The notable exceptions are wetlands within Crowdy Bay National Park on aeolian sediment with impeded drainage which do not form part of the Coastal Floodplain. This includes the wet heaths and shrublands. Four Endangered Ecological Communities (EECs) under the BC Act account for 80% of all mapped wetland types. Swamp Oak is equivalent to a Commonwealth EEC which accounts for 31% of mapped wetlands, whilst Saltmarsh is equivalent to a Commonwealth Vulnerable Ecological Community (VEC) which accounts for 4% of mapped wetlands. Furthermore, two wetland types Saltmarsh and Grey Mangrove accounting for 6% of mapped wetlands are protected under the NSW *Fisheries Management Act 1994* (FM Act). The equivalence between each wetland type and threatened communities is presented in Table 6.

Wetlands were generally mapped in good/excellent condition (69%), whilst wetlands in fair condition accounted for 19% of the total area mapped and poor/very poor condition equated to 12%.

Table 3: Vegetation Formations and Classes

Formation	Class	Hectares
Forested Wetlands	Coastal Floodplain Wetlands	2,818.4
	Coastal Heath Swamps	2,431.0
	Coastal Swamp Forests	2,647.5
Freshwater Wetlands	Coastal Freshwater Lagoons	54.5
Saline Wetlands	Mangrove Swamps	564.4
	Saltmarshes	390.4
Total		**8,906.3**

Table 4: Wetland types, variants and condition

Wetland Type	Variant	Condition (ha)			Total (ha)
		Low	Moderate	High	
Broad-leaved Paperbark	Freshwater Wetland			0.4	0.4
	Heath-leaved Banksia		1.7	3.8	5.5
	Sedgeland	1.3	1.4	563.5	566.2
	Shrubland		5.2	31.3	36.5
	Swamp Mahogany		1.9	75.1	77.0
	Swamp Oak			21.6	21.6
	Type	22.5	45.8	1,124.6	1,192.8
	Wet Heath		0.4	42.8	43.2
Forest Red Gum	Melaleuca Thicket			28.1	28.1
	Type			3.2	3.2
Freshwater Wetland	Melaleuca Thicket		3.6		3.6
	Swamp Oak			1.4	1.4
	Type	25.1	0.6	23.9	49.6
Grey Mangrove	Saltmarsh	10.2	10.9	0.3	21.4
	Swamp Oak	128.2	40.1	65.4	233.8
	Type	115.0	146.3	47.8	309.2
Heath-leaved Banksia	Sedgeland			12.7	12.7
	Type		7.2	219.7	227.0
	Wet Heath			5.4	5.4
Melaleuca Thicket	Type	43.6	37.9	152.3	233.8
Reedland	Swamp Oak			0.4	0.4
	Type	0.8	12.8	14.9	28.5
Saltmarsh	Freshwater Wetland / Swamp Oak			11.0	11.0
	Swamp Oak	22.4	10.1	21.1	53.6
	Swamp Oak / Broad-leaved Paperbark			20.0	20.0
	Type	212.2	63.8	29.9	305.9
Sedgeland	Shrubland	0.6		83.9	84.5
	Type	4.0	3.3	1,088.6	1,095.8
	Wet Heath			12.2	12.2
Shrubland	Sedgeland			1.6	1.6
	Type	45.0	4.7	319.6	369.3
	Wet Heath			16.9	16.9
Swamp Mahogany	Broad-leaved Paperbark			90.2	90.2
	Melaleuca Thicket			38.2	38.2

Wetland Type	Variant	Condition (ha)			Total (ha)
		Low	Moderate	High	
	Shrubland			57.4	57.4
	Swamp Oak	1.6		45.8	47.4
	Type	2.7	1.5	228.1	232.3
	Wet Heath			4.8	4.8
Swamp Oak	Broad-leaved Paperbark	2.0	59.4	166.6	227.9
	Heath			9.1	9.1
	Mangrove	2.3	3.8	24.7	30.8
	Mangrove / Saltmarsh			3.8	3.8
	Melaleuca Thicket	5.2	19.6	27.5	52.3
	Open Water	4.4	7.0	4.3	15.7
	Saltmarsh	1.9	15.3	29.0	46.2
	Swamp Mahogany			4.8	4.8
	Type	1,055.7	539.6	772.5	2,367.8
Wet Heath	Heath-leaved Banksia			2.8	2.8
	Sedgeland			71.8	71.8
	Shrubland			58.0	58.0
	Type			473.1	473.1
Total		**1,706.6**	**1,044.0**	**6,155.7**	**8,906.3**

Table 5. Threatened Ecological Communities

Threatened Ecological Community[#]	Total (ha)
Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act) / Marine Vegetation (FM Act) / Subtropical and Temperate Coastal Saltmarsh (EPBC Act)	390.4
Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act)	1,276.0
Marine Vegetation (FM Act)	564.4
River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act)	31.3
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act) / Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland (EPBC Act)	2,758.3
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act)	2,647.5
Total	**7,667.8**

 # The designation of wetland types as Threatened Ecological Communities requires detailed consideration of both the occurrence on coastal floodplains and alluvial soils. Wetland types have been mapped on soil landscapes derived from aeolian processes which may not qualify as TECs. Detailed consideration at the site scale is required in these patches should development be proposed in these areas

Table 6: Wetland Types by Listed Ecological Communities

Wetland Type	Community	Status	Total area (ha)
Broad-leaved Paperbark	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	BC Act Endangered	1,943.3
Forest Red Gum	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	BC Act Endangered	31.3
Freshwater Wetland	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	BC Act Endangered	54.5
Grey Mangrove	Marine Vegetation	FM Act Protected	564.4
Melaleuca Thicket	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act)	BC Act Endangered	233.8
Reedland	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act)	BC Act Endangered	28.9
Saltmarsh	Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act) / Marine Vegetation (FM Act) / Subtropical and Temperate Coastal Saltmarsh (EPBC Act)	BC Act Endangered, EPBC Vulnerable, FM Act Protected	390.4
Sedgeland	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act)	BC Act Endangered	1,192.6
Swamp Mahogany	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	BC Act Endangered	470.4
Swamp Oak	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act) / Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland (EPBC Act)	BC Act & EPBC Act Endangered	2,758.3
Total			**7,667.8**

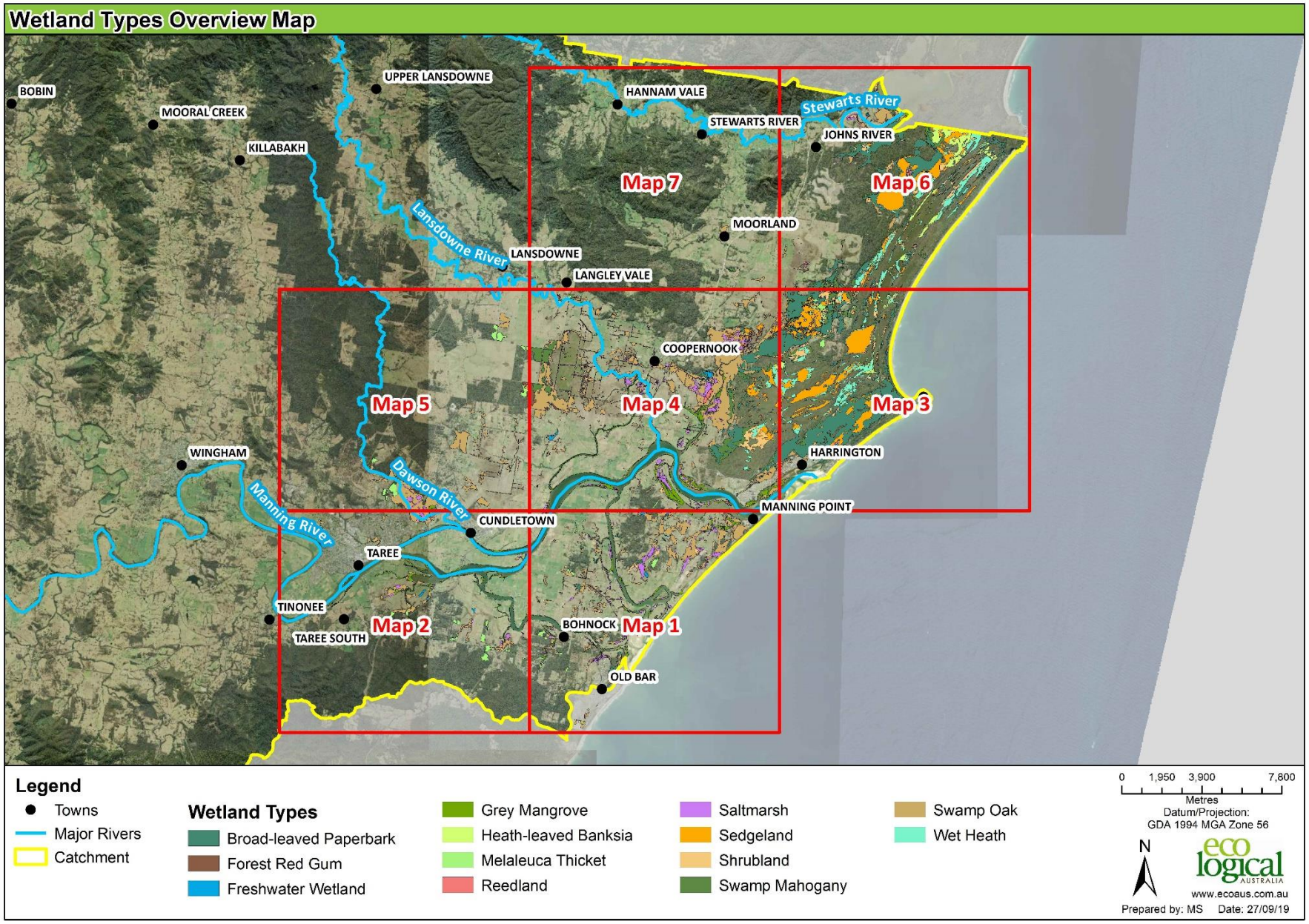

Figure 7: Wetland Types Overview Map

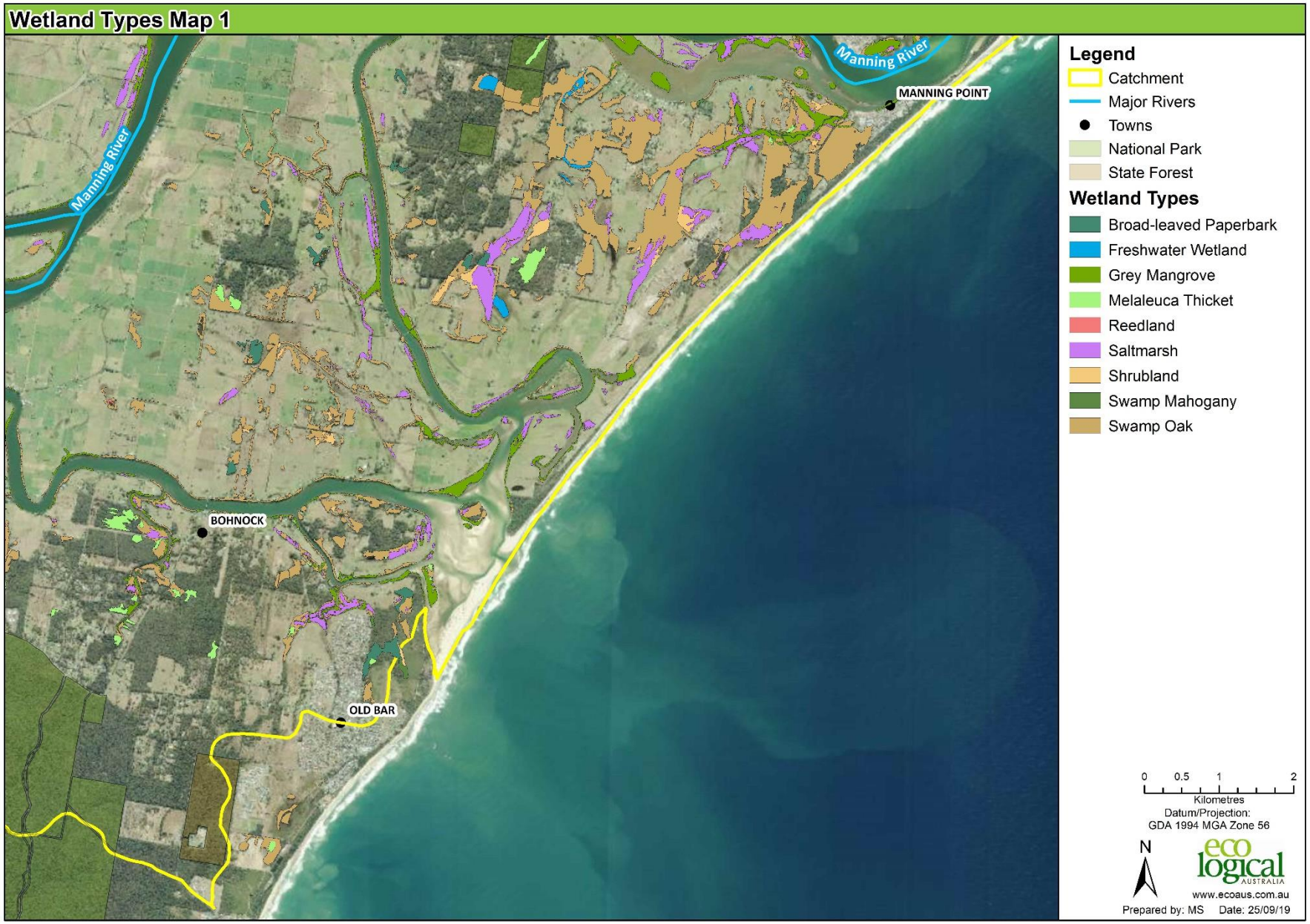

Figure 8: Wetland Types Map 1

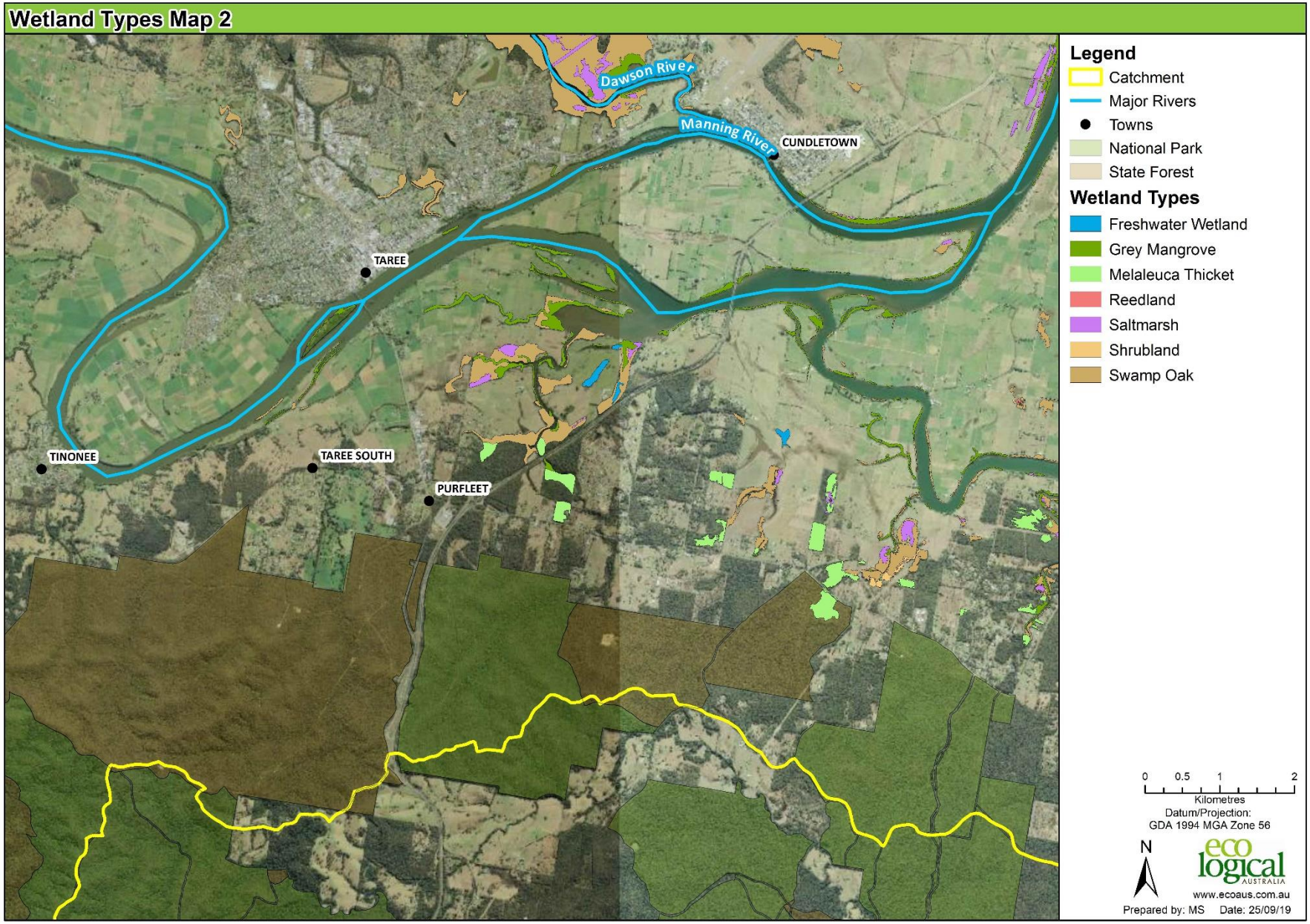

Figure 9: Wetland Types Map 2

Figure 10: Wetland Types Map 3

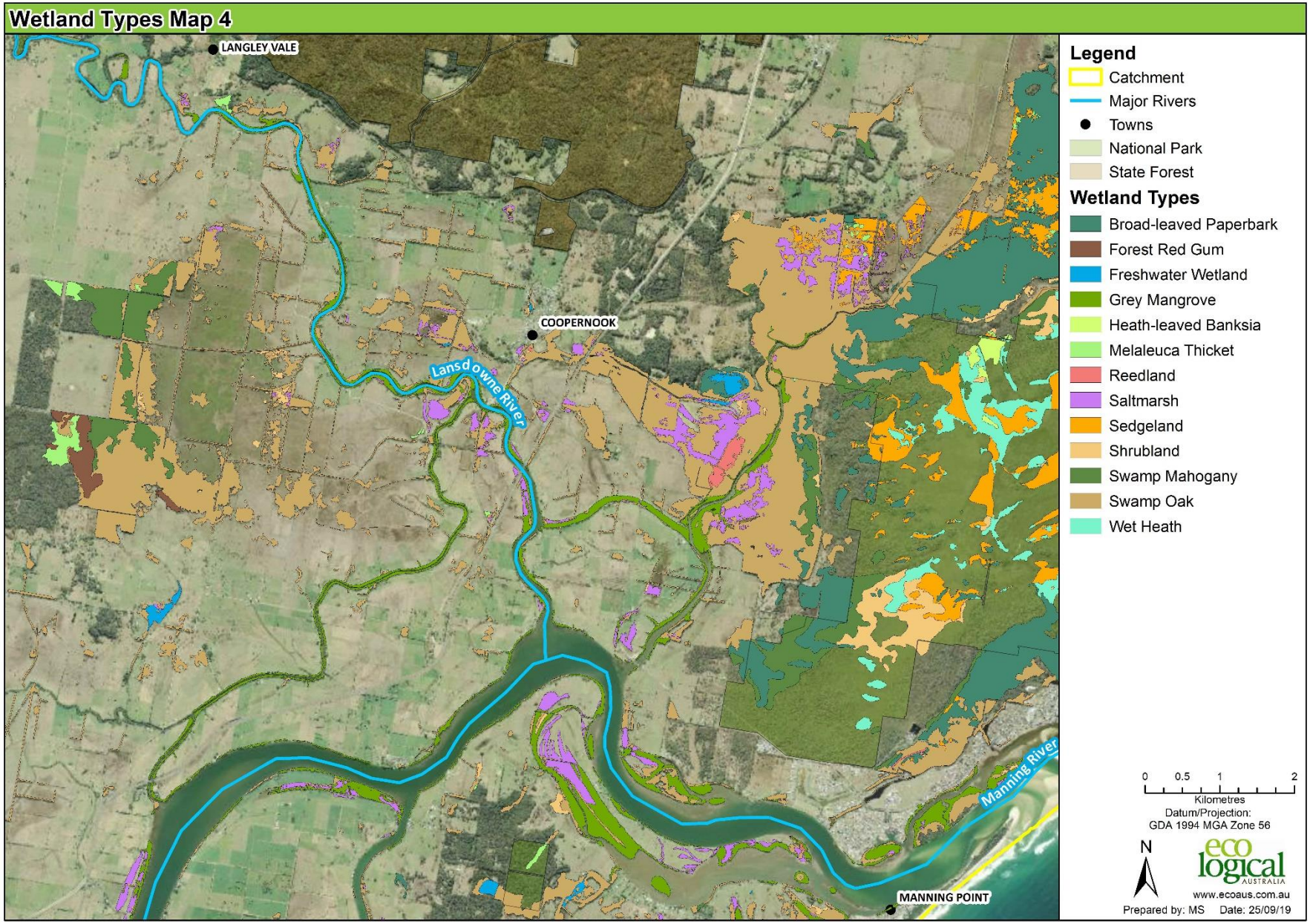

Figure 11: Wetland Types Map 4

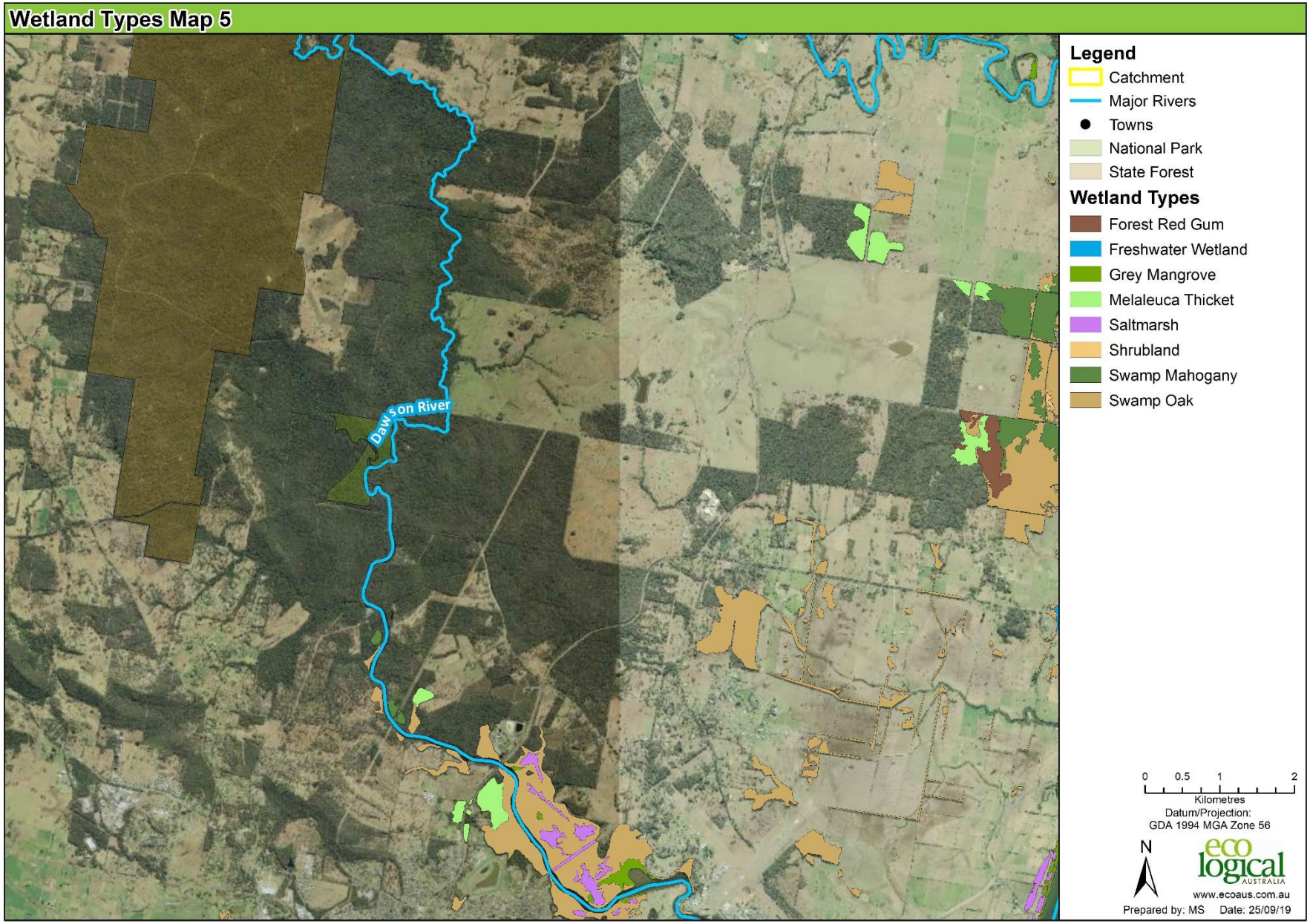

Figure 12: Wetland Types Map 5

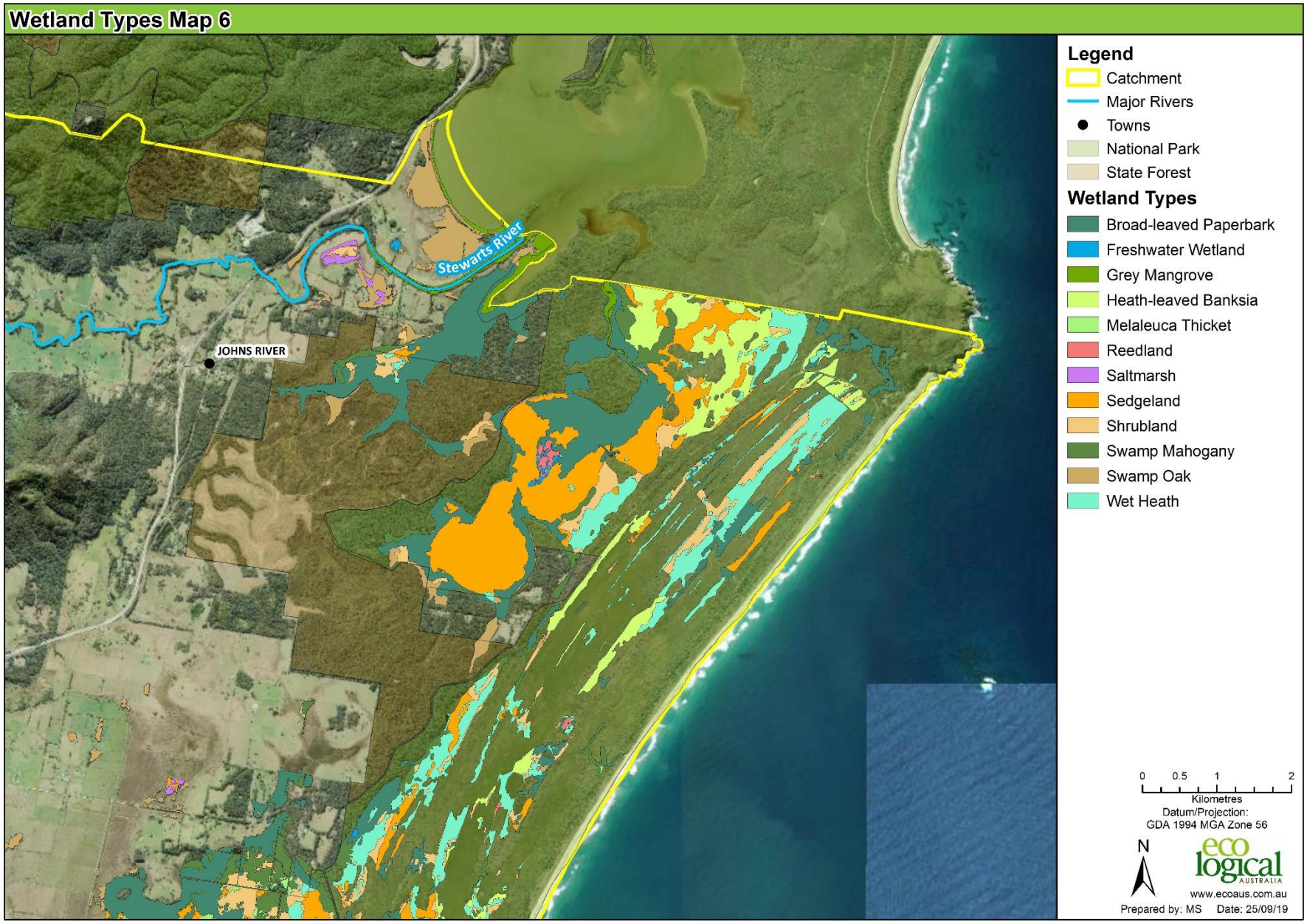

Figure 13: Wetland Types Map 6

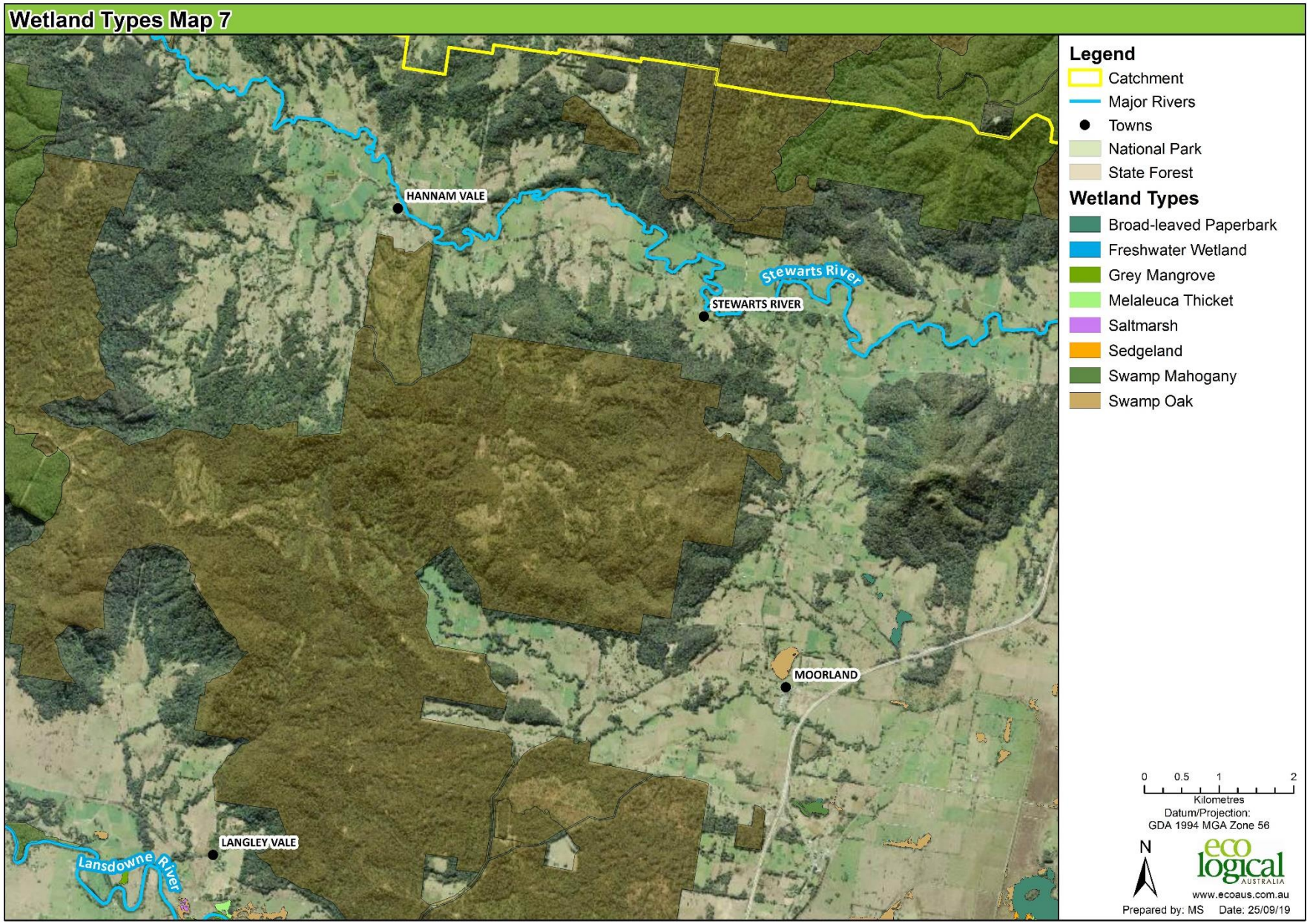

Figure 14: Wetland Types Map 7

5. Discussion

5.1 Crowdy Bay National Park Wetlands

Mapping wetlands in the Manning River Catchment, particularly those within Crowdy Bay National Park was challenging. Floodplain wetlands such as Broad-leaved Paperbark, Swamp Oak, Swamp Mahogany, Mangrove and Saltmarsh have distinctive structure (height and cover) and visual signatures (colour and patterning) which can be readily identified through API. Wetlands in Crowdy Bay National Park occur on a coastal sandmass with impeded drainage that has very little topographic relief (generally less than 10 m), and while some wetlands such as sedgelands are clearly evident on aerial photographs (Figure 15), other wetland types such as wet heath and shrublands are less easily identified through traditional API techniques. These wetlands are also rainfall or groundwater fed, as opposed to floodplain wetlands which are fed through overbank flow during flooding, rainfall and groundwater.

Compounding the issue is the likely groundwater dependence (ranging from opportunistically to entirely dependent) of most of the vegetation within Crowdy Bay National Park (Rutherford, Griffith and Warwick 2013). To understand the wetland distribution in Crowdy Bay National Park, a combination of resources were used to inform wetland mapping. A high resolution 10 cm DEM was manipulated to highlight the small-scale topographic differences (i.e. 20cm increments) which are considered to have a direct effect on the determination of 'wetland' in accordance with the objectives of this project (Figure 16). As can be seen on Figure 16, low areas in blue (approximately 2 m in height) are distinct from yellow (approximately 5 m) and high areas in red (approximately 7 m). While some areas have a long transition from high to low representing a gradual gradient, other areas are more clearly defined.

It is acknowledged that these transitional areas have the potential to be opportunistically drawing on groundwater resources, but in general they area much drier (relatively) and don't typically meet the definition of a 'wetland'.

A much higher degree of understanding of local wetland distribution can be determined when API and the DEM is combined with field data including vegetation validation points as well as aerial transects (Figure 17). The power that these combined methods offers results in a highly precise wetland type map (Figure 18).

Mapping wetlands in this way was an iterative process, with the DEM needing to be regularly manipulated to highlight local topographical features. Figure 19 shows a perched wetland clearly visible in the lower right corner (south-east) of the original aerial photograph (Figure 15). This wetland is perched, and located approximately 3 m higher than the remaining wetlands in the locality. By manipulating the DEM in this specific location, it's form in relation to the surrounding topography clearly shows a broad depression with narrow gradual connectivity to those wetlands in lower areas.

5.2 Manning River Floodplain

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

Figure 15: Mapping wetlands in Crowdy Bay National Park (Aerial)

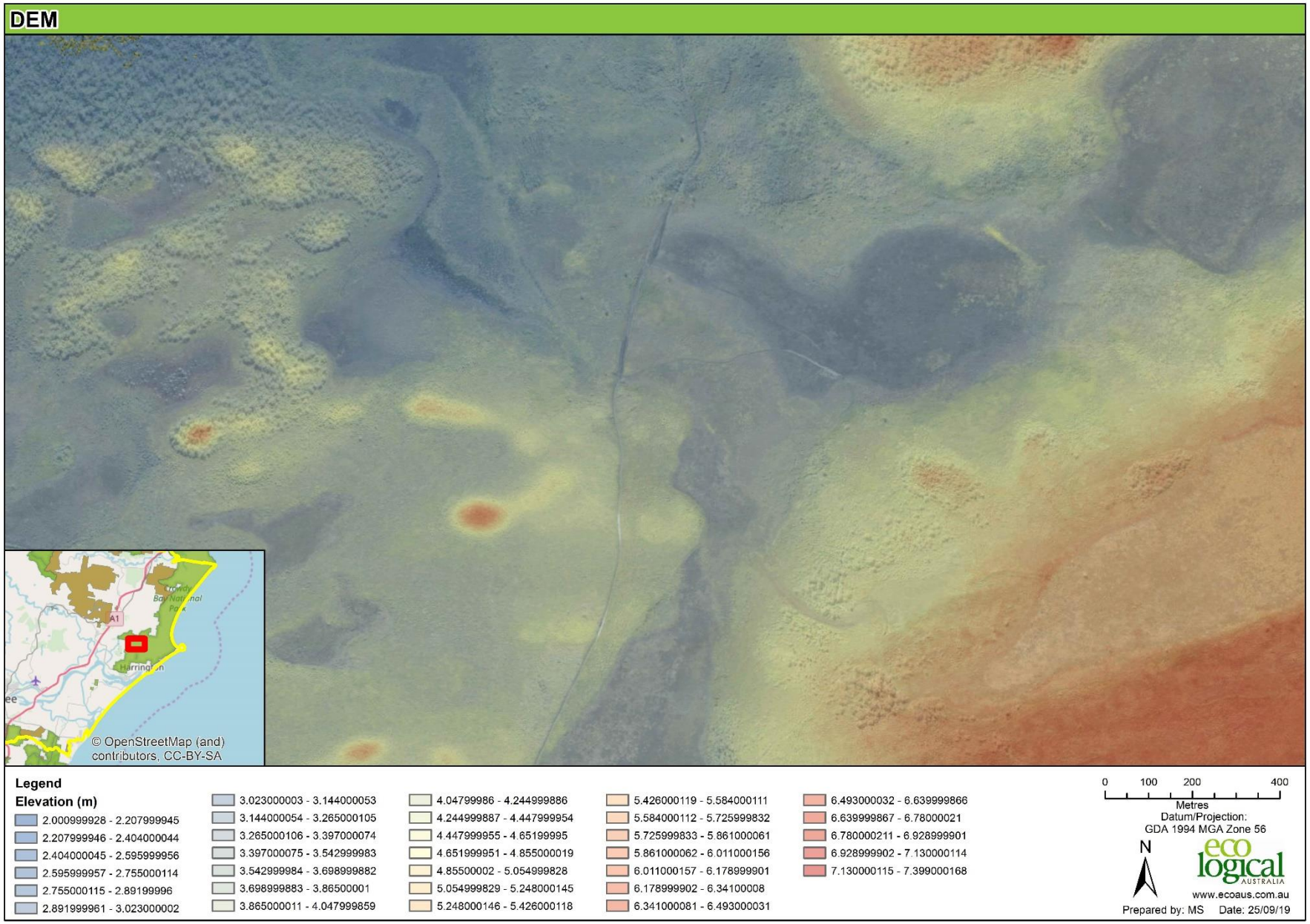

Figure 16: Mapping wetlands in Crowdy Bay National Park (DEM)

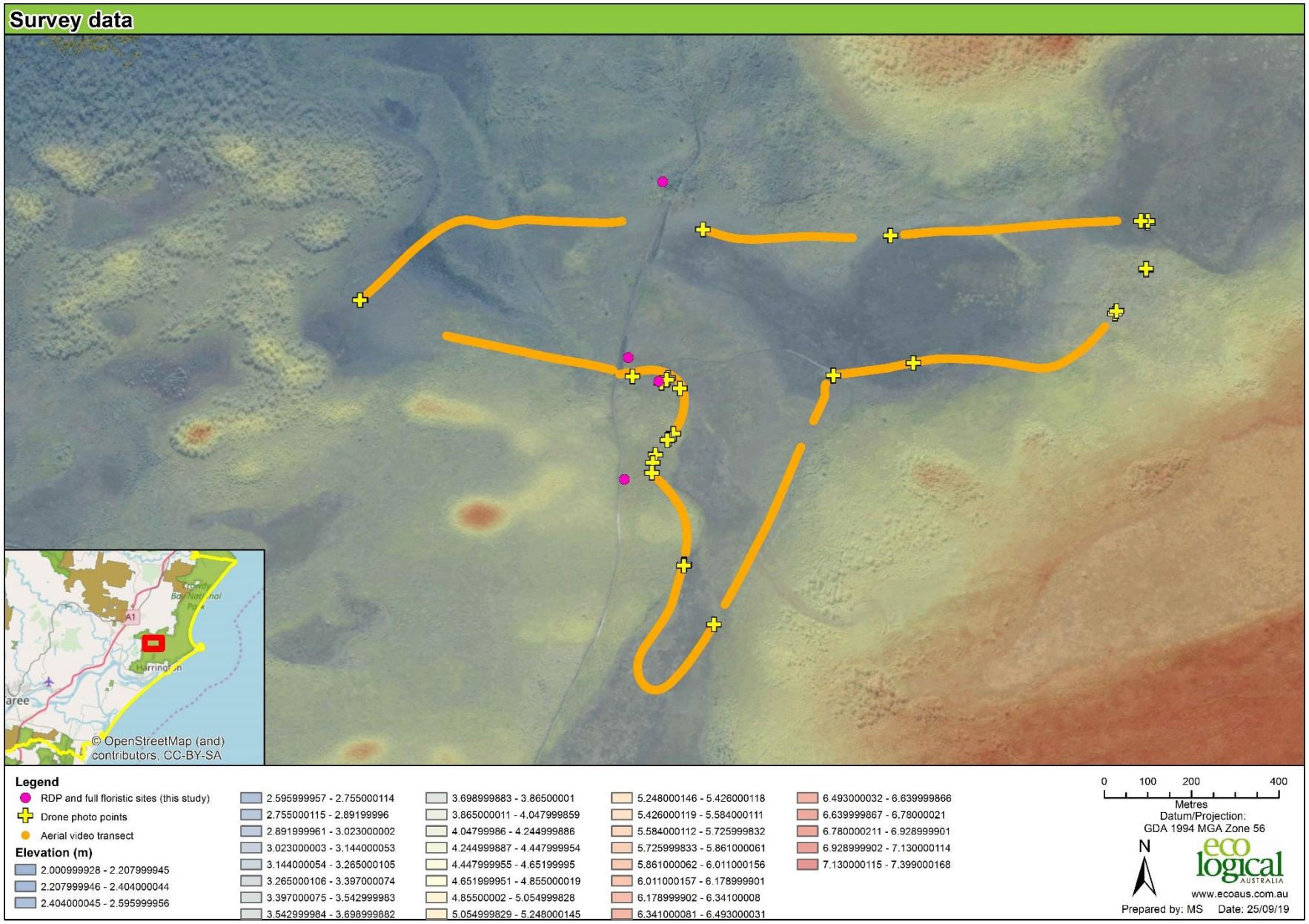

Figure 17: Mapping wetlands in Crowdy Bay National Park (Survey Data)

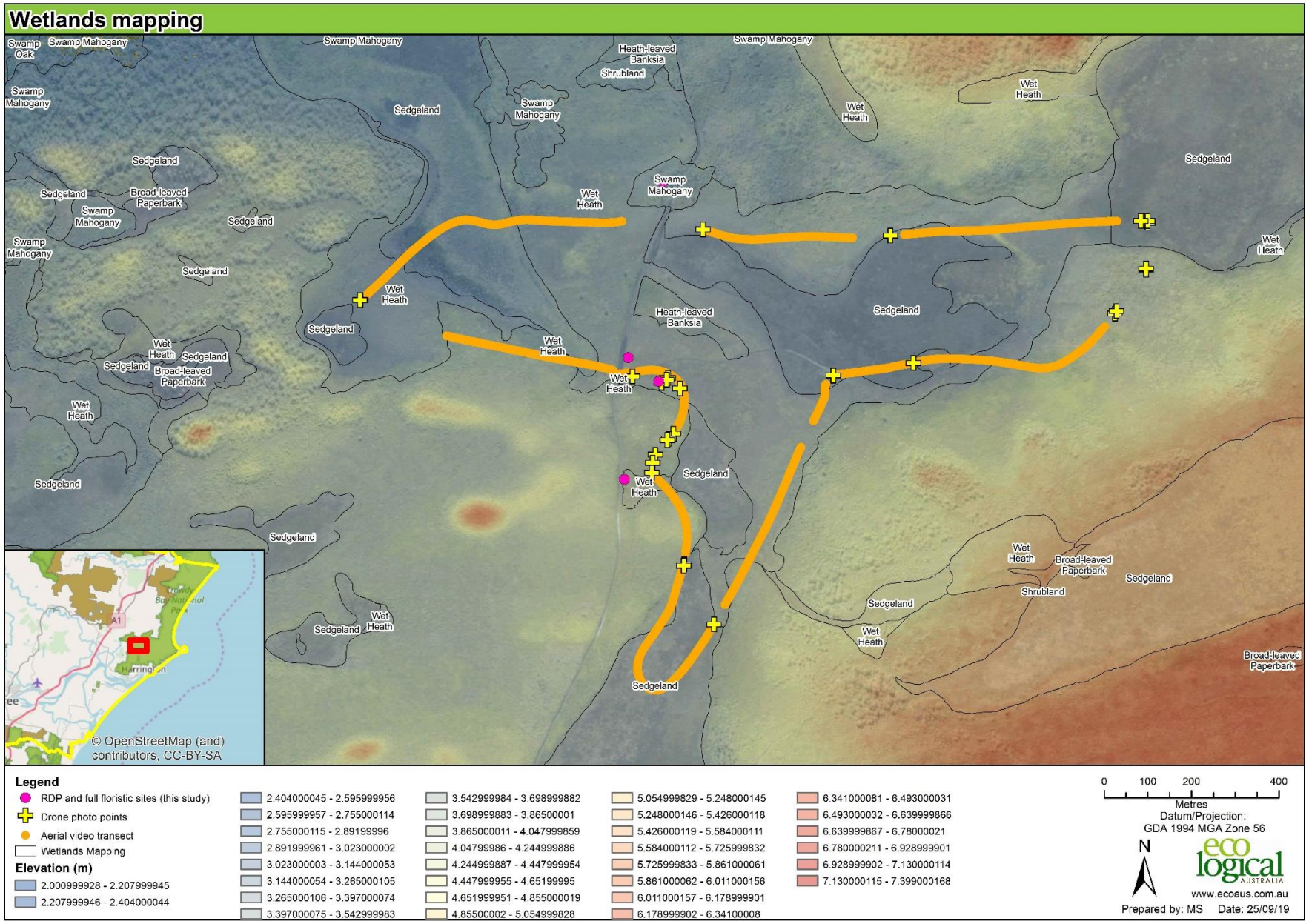

Figure 18: Mapping wetlands in Crowdy Bay National Park (Wetlands Mapping)

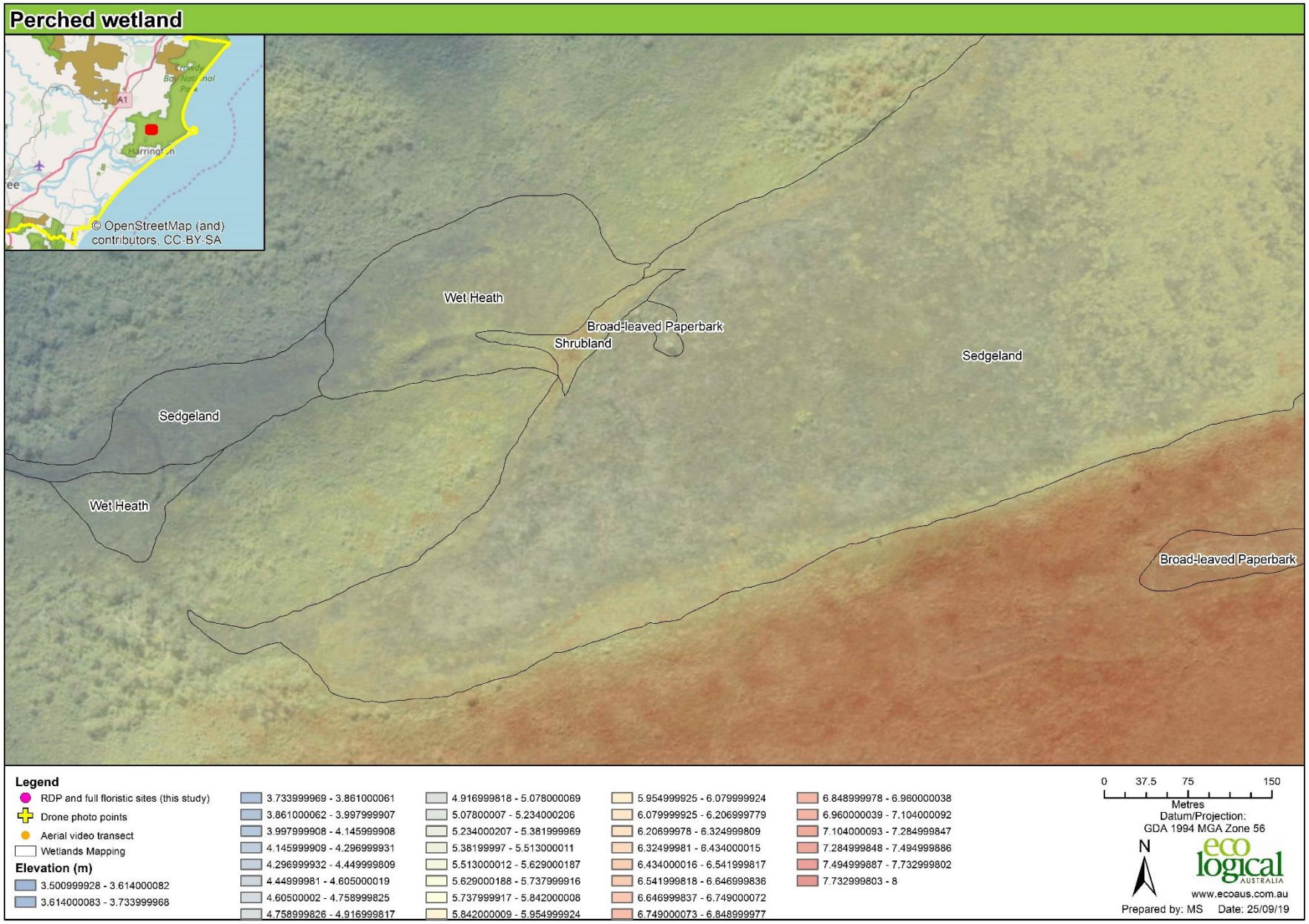

Figure 19: Mapping wetlands in Crowdy Bay National Park (Perched wetland)

The Manning River Floodplain exhibits evidence of previous extensive clearing. Constructed and /or modified floodplain drainage is clearly apparent with large, linear drains dominating the landscape. In many cases the major drains have been colonised by Swamp Oak which has created a linear patchwork of this community across the floodplain. While an attempt was made to map the majority of these linear patches, not all patches met the minimum mapping rules due to their very narrow and small spatial extent.

Despite the current relative dominance of Swamp Oak, evidence of other communities such as Lowland Rainforest was observed in small isolated and degraded remnants on the banks and small rainforest islands in the channel of the Manning River, and large remnant *Ficus macrophylla* (Moreton Bay Fig) retained particularly near homesteads. Other floodplain forest vegetation dominated by species such *Eucalyptus tereticornis* (Forest Red Gum) is also considered likely to have once been more widespread.

5.3 Disturbance

A wide range of disturbances have affected the spatial distribution, structure, composition and function of coastal wetland communities in the Manning River Estuary. These disturbances include floodplain clearing and drainage, bank stability and erosion, extensive sandmining in Crowdy Bay National Park east of Crowdy Bay and Diamond Head roads, fire, drought, flooding and weed and pest invasion.

Wetlands mapped as part of this project were mapped as they were observed through aerial photography, acknowledging that these disturbances have affected many of the wetlands to varying degrees. Even in predominantly natural systems such as many of the wetlands in Crowdy Bay, recent fire has altered the structure of communities so that what appears as a shrubland in aerial photographs presents as a low heathland in the field. The wetland types in Crowdy Bay are likely to be continually changing and developing as a result of natural disturbances such as fire and flooding.

The majority of wetlands surveyed as part of this project were dry due to widespread drought conditions being experienced in the region. The notable exception to this was the large freshwater lagoon at Harrington, and a number of smaller freshwater wetlands that are likely groundwater fed. A potential effect of both fire and drought is the proliferation of *Banksia ericifolia* subsp. *macrantha* (Heath-leaved Banksia) throughout wetland types in Crowdy Bay National Park. Relatively young (4-5 year old) juvenile Heath-leaved Banksia plants were consistently observed to have germinated on a massive scale and in wetland types such as sedgelands, which would usually not typically support this species in the long term due to the effects of flooding. It is expected that these juvenile plants would die back following the next major flooding event in Crowdy Bay National Park.

Dieback in *Melaleuca quinquenervia* (Broad-leaved Paperbark) was observed to be occurring in a wide variety of wetlands, occasionally at a massive scale (for example the large freshwater lagoon at Harrington). Dieback was observed in wetlands that are currently dry, as well as those that are currently saturated. Dieback could be due to natural conditions such as drying and wetting, but could also be driven by other factors including Myrtle Rust, other pathogens, insect attack or water quality amongst other things.

The occurrence of Broad-leaved Paperbark in some of the wetland types in Crowdy Bay National Park is considered to be the result of a single recruitment event under wetter conditions, with many stands being single aged. Broad-leaved Paperbark is not considered to be a natural component of some

wetland types including sedgelands, wet heaths and shrublands, but rather a colonising species. This is particularly evident through the establishment of this species in old drains created when roads were originally cut through Crowdy Bay National Park.

Weeds were generally restricted to the wetlands of the Manning River floodplain, where historical clearing and current agricultural practices create ideal conditions for weed invasion and colonisation. Several Swamp Oak and Mangrove Forests were observed to be dominated by an understorey of *Juncus acutus* (Sharp Rush) which looks superficially similar to the native *Juncus kraussii* subsp. *australiensis* (Sea Rush) which grows in the same communities. Managing Sharp Rush is likely to require a range of intensive and ongoing weed control techniques.

Crowdy Bay National Park is relatively weed free, apart from disturbed edges and along roadsides, with the notable exception of the large freshwater lagoon at Harrington (Figure 10) which was observed to have up to 30% cover of *Salvinia molesta* (Salvinia), a Weed of National Significance.

6. Management considerations

Wetland systems provide an array of valuable services for the MidCoast community and for the environment. Aside from providing habitat for a diverse assemblage of dependent plants and animals, wetlands are very important for protecting and enhancing water quality, reducing erosion and flooding and storing 'blue' carbon. Wetlands are also highly productive landscapes. They are economically valuable as fish and prawn nursery areas and for their environmental services to water quality that supports tourism and production.

Broadly, wetlands in NSW have suffered from a legacy of being considered wasted lands. As a consequence, there is lengthy history of wetland draining, clearing and destruction. The loss of wetland systems has had associated biodiversity, water quality, catchment health and productivity consequences.

There is increasing recognition of the values of wetlands and the need for wetland protection and enhancement programs. The goods and services values of wetlands have been assessed in economic terms, with scientific papers identifying the immense value of wetlands. Schuyt & Brander (2004) identified that the ecosystem services provided by sediment wetlands were valued at $374 per hectare per year and ecosystem services provided by freshwater wooded wetlands were valued at $206 per hectare per year. Therefore these wetlands provide between $1.8M and $3.3M of economic value through provision of ecosystem services each year (based on Schuyt & Brander calculations). Such figures support the provision of public wetland acquisition and landholder incentives for wetland protection and active management.

Funding wetland conservation is an investment in natural capital rather than a cost. The remediation and management of over 2,500 hectares of wetlands within the 'Big Swamp' and 'Cattai Wetlands' involved a $2M Federal Government Grant under the *Caring for our country* initiative to specifically address Acid Sulfate Soil issues created through the previous widespread clearing of forested wetlands from these lands.

Other references identify the economic value of wetland systems. For instance, the Water Quality Improvement Plan for Wallis, Smiths and Myall Lakes identified that wetland conservation (that is, increasing the area of healthy wetlands) in Wallis Lake has a net economic value of $13,700 per hectare and wetland protection for water quality has a significant, positive cost benefit ratio (of 2.2:1). Wetland protection and restoration was ranked in the top five management actions for improving water quality in Wallis Lake (together with riparian rehabilitation and protection and groundcover management).

The Manning River catchment contains significant wetland assets. A total of 8,906 hectares of wetlands have been mapped in this study (not including riparian areas upstream of Taree), which comprises less than 1% of the entire catchment landscape. Whilst wetland areas across the study area have been variously disturbed and modified since European occupation, due to the waterlogged and saline soils there are significant wetland areas of considerable conservation significance still represented in the study area. This includes large wetlands at Taree (Dawson River), Kundle Kundle, Cattai Wetlands, Big Swamp, Manning Point and Crowdy Bay National Park.

While some of these wetlands are under Council control (e.g. Cattai Wetlands), in National Park, on Crown Land or are protected by some form of active private conservation instrument, many of these wetlands are unprotected and either not actively-managed or are threatened by unsympathetic land use and management.

Examples of degraded and modified wetlands were observed, which were subject to stock damage and drainage modification, and where the inherent ecosystem services and ecological benefits of those systems were impaired. Despite this, the majority of wetlands in the study area were of good condition and require little in the way of active management other than the prevention of threatening processes.

Weed abundance within mapped wetlands is relatively low. Environmental weeds such as Sharp Rush, Lantana, Bitou Bush, Tree Pear, Coastal Morning Glory and Cassia were becoming established in some wetlands, particularly in floodplain wetlands. Active management of current infestation will assist in the future management of all wetlands. Unprotected wetlands remain at risk of land use intensification and changed practice. Further, being in low-lying coastal areas, the effect of climate change in terms of sea level rise is likely to be the major impact on these wetlands in the next 50 years.

The NSW Government's NSW Wetland Policy (DECC 2010) clearly recognised the values of wetlands and detailed the principles with which wetland's should be managed and conserved. These principles include:

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

12. Regular reporting of wetland extent and condition is vital to assess management performance and understand wetland dynamics.

The wetlands of the Manning River catchment should be managed in accordance with these principles. In addition, the study has identified a number of key management recommendations:

1. Wetland conservation and active management should be prioritised in the Myall River catchment. This should include a range of tools, including Council and NSW Government wetland acquisition. Acquired wetlands should be subject to active management. Council should investigate innovative approaches to conservation of wetlands such as the use of revolving funds or participation in development offset markets. To assist this process, Council should develop a prioritisation framework to review and prioritise wetlands based on their size, perimeter to area ratio, condition and threats (pressures), extent within the catchment and more broadly in NSW, as well as listing status.
2. Update to Planning Controls: Wetlands should be mapped and identified on Council's Local Environment Plan wetland map overlay (clause 7.8).
3. Council should liaise with the NSW Government to revise the coastal wetland boundaries in the Coastal Management SEPP.
4. Given the likely negative impacts of climate change and sea level rise, a landward retreat analysis should be undertaken in future coastal and catchment management planning.
5. This study has not included comprehensive pest species surveys. Deer, fox, hares and gambusia are known to be present in Cattai Wetlands (Greater Taree City Council, 2014). It is recommended that regular pest surveys including pest fish species be undertaken in locally significant wetlands. Active, strategic actions for pest controls should be a key feature of the management of wetlands in the future.
6. Priority and environmental weed control is important in affected wetlands including Salvinia, Sharp Rush, Lantana, Bitou Bush, Tree Pear, Coastal Morning Glory and Cassia. Active weed management is an important aspect of wetland conservation and management.
7. The continued development around urban areas including Harrington, Old Bar and Taree is likely to cumulatively impact receiving wetlands through pollution, altered hydrological regimes and encroachment. Ensuring that development near wetlands is regulated in a manner that preserves the integrity and function of downstream and proximal wetlands is very important.
8. Agricultural impacts and development throughout the catchments are contributing to poor water quality, weed invasion and vegetation clearing. Active protection and management of wetlands to prevent such impacts is very important through wetland acquisition, wetland conservation and adoption of regenerative agricultural practices.
9. Research into dieback in Broad-leaved Paperbark (including mapping) is recommended to ensure this functional, structurally important and dominant species is not lost from these wetlands.
10. Further research into the groundwater dependence of wetlands in general, including those within Crowdy Bay National Park would further the ecological understanding of these communities and help to manage future impacts.
11. Given their restricted distribution, historical disturbance, ecological significance and threats due to climate change, consideration of listing wet heathlands and shrublands as Endangered Ecological Communities is warranted.
12. Prepare and implement a wetland conservation strategy for the Manning River catchments.

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Appendix A Wetland Type Profile

Swamp Oak Forest

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Floodplain Wetland
Vegetation structure:	Forest
Conservation status:	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act EEC) / Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland (EPBC EEC))
Area mapped	2,758.3
Swamp Oak Forest ranges from a low open woodland to Forest and is dominated by *Casuarina glauca* (Swamp Oak), occasionally with *Melaleuca quinquenervia* (Broad-leaved Paperbark), *Eucalyptus robusta* (Swamp Mahogany) or *Avicennia marina* subsp. *australasica* (Grey Mangrove). The midstorey is marked by the vine *Parsonsia straminea* (Common Silkpod). The understorey is typically simple being dominated by *Juncus kraussii* subsp. *australiensis*, however more well-developed examples in backwater swamps have greater understorey diversity. This community includes large areas of open water.	
Characteristic trees	*Casuarina glauca,* occasionally with *Melaleuca quinquenervia*, *Eucalyptus robusta* or *Avicennia marina* subsp. *australasica*
Characteristic midstorey	*Parsonsia straminea* marks the midstorey of this community. Some patches have a midstorey including *Melaleuca ericifolia, Melaleuca nodosa* and *Melaleuca styphelioides*
Characteristic groundcovers	*Blechnum indicium, Centella asiatica, Commelina cyanea, Cynodon dactylon, Gahnia clarkei, Gahnia sieberiana, Histiopteris incisa, Hydrocotyle* spp., *Juncus kraussii* subsp. *australiensis Opercularia diphylla, Persicaria strigosa, Phragmites australis, Ranunculus inundatus*
Map unit variants	Broad-leaved Paperbark Heath Mangrove Mangrove / Saltmarsh Melaleuca Thicket Open Water Saltmarsh Swamp Mahogany
Mean native richness	18 ± 10
Exotic species	*Andropogon virginicus, Ipomoea cairica, Ochna serrulata, Senna pendula* var. *glabrata*
Condition	Low, Moderate and High
Distribution and example locality	Widespread on poorly drained floodplains. Example locality: Dawson River wetland
Equivalent Plant Community Types	PCT 1145, 1235, 1727, 1728, 1729,

Swamp Oak Forest

Soil type	Loam, Sandy Loam, Loamy Sand
% remaining in NSW	43% (average)
Threats	Climate change, frequent fires, feral animals and weeds
No. sites sampled	ELA sites Plot 11, Plot 12, Plot 16, VIS Sites BRIM0003, CSI900 SE24, SE23, SE18, SE19, SE22, SE20, SE21, CSI906

Forest Red Gum Forest

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Floodplain Wetland
Vegetation structure:	Forest
Conservation status:	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act EEC)
Area mapped	31.3 hectares
Forest Red Gum Forest is typically a forest dominated by *Eucalyptus tereticornis*, commonly with *Casuarina glauca*. Only a small area of Forest Red Gum Forest has been mapped as this community is typically a floodplain forest which is infrequently inundated and is not typically a 'wetland'. Small areas of this wetland type have been mapped in low lying areas where they directly adjoin Swamp Oak Forest. Due to the spatial distribution, this community may be better considered a variant of Swamp Oak Forest.	
Characteristic trees	*Eucalyptus tereticornis, Casuarina glauca*
Characteristic midstorey	*Melaleuca linariifolia, Melaleuca styphelioides, Parsonsia straminea*
Characteristic groundcovers	*Gahnia clarkei; Ischaemum australe; Juncus kraussii* subsp. *australiensis*
Map unit variants	Melaleuca Thicket
Mean native richness	Not recorded
Exotic species	Not recorded
Condition	High
Distribution and example locality	Highly restricted. Example locality: Kundle Kundle
Equivalent Plant Community Types	PCT 1235
Soil type	Poorly drained alluvial soils
% remaining in NSW	25%
Threats	Climate change, frequent fires, feral animals and weeds
No. sites sampled	Not surveyed, rapid data points only

Sedgeland

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Heath Swamp
Vegetation structure:	Sedgeland
Conservation status:	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act EEC)
Area mapped	1,192.6 hectares
Sedgelands are a variable wetland type dominated by a range of sedges, restios, wet heath shrubs and *Xanthorrhoea fulva*. A range of wet heath shrubs occur, more typically towards the drier edges, but occasionally throughout. Species diversity varies considerably with inundation frequency, depth and soil type. Sedgelands occur in the lowest parts of the landscape and are frequently inundated. They range from floodplain wetlands recharged through overbank flow (flooding), freshwater lagoons recharged through groundwater, to sites with impeded drainage on the coastal sandmass recharged through rainfall and groundwater.	
Characteristic trees	Generally absent
Characteristic midstorey	Very sparse to sparse and may include *Banksia ericifolia* subsp. *macrantha, Callistemon pachyphyllus, Leptospermum juniperinum, Leptospermum liversidgei*
Characteristic groundcovers	*Baloskion tetraphyllum, Baumea rubiginosa, Blechnum indicum, Chorizandra sphaerocephala, Eleocharis sphacelata, Entolasia stricta, Epacris obtusifolia, Eurychorda complanata, Gahnia sieberiana, Leptocarpus tenax, Selaginella uliginosa, Sphagnum cristatum, Sprengelia incarnata, Xanthorrhoea fulva, Xyris operculata*
Map unit variants	Shrubland Wet Heath
Mean native richness	17 ± 7
Exotic species	*Salvinia molesta* (one site)
Condition	High
Distribution and example locality	Restricted to Crowdy Bay National Park
Equivalent Plant Community Types	780, 1741, 1742, 1911
Soil type	Loamy sand, sandy loam
% remaining in NSW	33% (average)
Threats	Invasion by woody shrubs, climate change, frequent fires and feral animals
No. sites sampled	ELA Sites Plot 02, Plot 04, Plot 14, VIS sites EA_CB25

Shrublands

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Heath Swamp
Vegetation structure:	Shrubland
Conservation status:	Not Listed
Area mapped	387.8
Shrublands are a variable wetland type dominated by heathy shrubs such as *Banksia ericifolia subsp. macrantha*, *Banksia robur*, *Callistemon pachyphyllus*, *Leptospermum juniperinum* and *Melaleuca sieberi*. Shrublands are typically taller (2m or higher) than wet heathlands but are closely related. Shrublands occur in slightly elevated positions (relatively) in a mosaic with Sedgelands and Wet Heath and contain many of the same species, especially in the ground layer. A separate wetland type Heath-leaved Banksia Shrubland has been mapped due to its unique aerial signature but forms part of this unit.	
Characteristic trees	Occasional emergent *Eucalyptus robusta, Melaleuca quinquenervia*
Characteristic midstorey	*Acacia elongata, Almaleea paludosa, Banksia ericifolia* subsp. *macrantha, Banksia robur, Callistemon pachyphyllus, Epacris obtusifolia, Hakea teretifolia, Leptospermum liversidgei, Leptospermum juniperinum, Leptospermum polygalifolium, Melaleuca sieberi, Melaleuca thymifolia*
Characteristic groundcovers	*Cassytha glabella, Chorizandra sphaerocephala, Dillwynia floribunda, Entolasia stricta, Gahnia sieberiana, Gymnoschoenus sphaerocephalus, Leptocarpus tenax, Liparophyllum exaltatum, Selaginella uliginosa, Symphionema paludosum, Xanthorrhoea fulva, Xyris operculata*
Map unit variants	Sedgeland Wet Heath
Mean native richness	24 ± 9
Exotic species	None recorded
Condition	High
Distribution and example locality	Restricted to Crowdy Bay National Park
Equivalent Plant Community Types	PCT 1297
Soil type	Loamy sand to sandy loam
% remaining in NSW	25%
Threats	Climate change, frequent fires, feral animals
No. sites sampled	ELA sites Plot 05, Plot 07, Plot 17

Heath-leaved Banksia Shrubland

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Heath Swamp
Vegetation structure:	Shrubland
Conservation status:	Not listed
Area mapped	245 hectares

Heath-leaved Banksia Shrubland is typically a closed shrubland up to 4 m in height dominated by *Banksia ericifolia* subsp. *macrantha*. It has been separated from the Shrublands wetland type due to its unique aerial signature. It contains many of the same species as Wet Heath, but has been separated on structure and a slightly higher landscape position. Fire plays a significant role in the structure of this community, with many areas having been recently burnt and presenting more as a wet heath than shrubland. It is likely that this variability represents natural successional stages.

Characteristic trees	*Banksia ericifolia* subsp. *macrantha*, occasional *Banksia aemula*
Characteristic midstorey	None
Characteristic groundcovers	*Boronia* spp., *Gahnia sieberiana*, *Empodisma minus*, *Epacris microphylla*, *Hakea teretifolia*, *Leptospermum liversidgei, Leptospermum polygalifolium*, *Sporadanthus interruptus*, *Xanthorrhoea fulva*
Map unit variants	Sedgeland Wet Heath
Mean native richness	Not surveyed, rapid data points only
Exotic species	None recorded
Condition	High
Distribution and example locality	Restricted to Crowdy Bay National Park
Equivalent Plant Community Types	PCT 1297
Soil type	Loamy sand to sandy loam
% remaining in NSW	25%
Threats	Climate change, frequent fires, feral animals
No. sites sampled	Not surveyed, rapid data points only

Wet Heaths

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Heath Swamp
Vegetation structure:	Shrubland
Conservation status:	Not Listed
Area mapped	605.6
Wet Heaths are typically an open to closed heath with a major sedge component. Wet heaths are variable with common heathy shrubs including *Banksia ericifolia* subsp. *macrantha, Callistemon pachyphyllus, Dillwynia floribunda, Epacris microphylla, Epacris obtusifolia, Leptospermum liversidgei, Melaleuca thymifolia, Sprengelia incarnata* and *Sprengelia sprengelioides*. Wet Heaths typically occur in low parts of the landscape (higher than sedgelands, but lower than shrublands). As for shrublands, fire plays a significant role in shaping the structure of this wetland type.	
Characteristic trees	Occasional emergent *Eucalyptus robusta, Melaleuca quinquenervia*
Characteristic midstorey	*Banksia ericifolia* subsp. *macrantha, Callistemon pachyphyllus, Dillwynia floribunda, Epacris microphylla, Epacris obtusifolia, Leptospermum juniperinum, Leptospermum liversidgei, Melaleuca thymifolia, Sprengelia incarnata, Sprengelia sprengelioides*
Characteristic groundcovers	*Boronia polygalifolia, Chorizandra sphaerocephala, Empodisma minus, Entolasia stricta, Eurychorda complanata, Gahnia sieberiana, Gymnoschoenus sphaerocephalus, Haemodorum corymbosum, Leptocarpus tenax, Selaginella uliginosa, Xanthorrhoea fulva, Xyris operculata*
Map unit variants	Heath-leaved Banksia Sedgeland Shrubland
Mean native richness	22 ± 1
Exotic species	None recorded
Condition	High
Distribution and example locality	Restricted to Crowdy Bay National Park
Equivalent Plant Community Types	PCT 1297, 1734
Soil type	Loamy sand
% remaining in NSW	60% (average)
Threats	Climate change, frequent fires, feral animals
No. sites sampled	ELA Sites Plot 01, Plot 09

Broad-leaved Paperbark Forest

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Swamp Forest
Vegetation structure:	Forest
Conservation status:	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act EEC)
Area mapped	1,943.3 hectares
Broad-leaved Paperbark Forest varies from open woodland to forest with a canopy dominated by *Melaleuca quinquenervia* occasionally with *Eucalyptus robusta* and/or *Casuarina glauca.* Typically, this wetland type has an understorey dominated by sedges. Broad-leaved Paperbark Forest is highly variable and includes a range of variants. This is a highly variable wetland type which includes a number of variants from which it shares floristic elements. Canopy dieback was observed to be occurring in a wide variety of wetlands, occasionally at a massive scale.	
Characteristic trees	*Melaleuca quinquenervia,* occasionally with *Eucalyptus robusta* and/or *Casuarina glauca.*
Characteristic midstorey	Generally consisting of *Melaleuca quinquenervia*, occasionally *Banksia ericifolia* subsp. *macrantha* or *Callistemon pachyphyllus* in wet heath/shrubland/sedgeland variants. *Parsonsia straminea* is a common vine.
Characteristic groundcovers	*Baloskion pallens, Baumea rubiginosa, Blechnum indicium, Chorizandra sphaerocephala, Eleocharis sphacelata, Entolasia stricta, Eurychorda complanata, Gahnia clarkei, Gahnia sieberiana, Hemarthria uncinata, Leptocarpus tenax, Liparophyllum exaltatum, Schoenus brevifolius, Selaginella uliginosa, Sphagnum cristatum, Xyris operculata.*
Map unit variants	Freshwater Wetland Heath-leaved Banksia Sedgeland Shrubland Swamp Mahogany Swamp Oak Wet Heath
Mean native richness	20 ± 7
Exotic species	*Chrysanthemoides monilifera* subsp. *monilifera, Lantana camara, Senna pendula* var. *glabrata*
Condition	Moderate to High
Distribution and example locality	Mostly restricted to the north of the Manning River. Example Locality: Big Swamp
Equivalent Plant Community Types	1717, 1721, 1724, 1725
Soil type	sand, loamy sand, sandy loam, loam

Broad-leaved Paperbark Forest

% remaining in NSW	55% (average)
Threats	Myrtle rust, climate change, altered hydrological regimes, frequent fires, feral animals and weeds
No. sites sampled	ELA sites Plot 03, Plot 06, Plot 08, Plot 13, Plot 15, Plot 18, VIS sites VMP2EA31, EA_ST30, LRN06Q0D, LRN07Q0V, LRN02Q0V, LRN01Q0D, LRN05Q0D, LRN03Q0D

Melaleuca Thicket

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Swamp Forest
Vegetation structure:	Shrubland
Conservation status:	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act EEC)
Area mapped	233.8
Melaleuca Thickets are typically tall shrublands dominated by one or more Melaleuca species. This wetland type is generally drier than other wetland types and typically occurs higher (relatively) in the landscape and typically includes emergent Eucalypts species which are not typically associated with wetlands. The exception is thickets dominated by *Melaleuca ericifolia* (Swamp Paperbark) which occur in much wetter areas, often in standing water.	
Characteristic trees	*Melaleuca decora, Melaleuca ericifolia, Melaleuca linariifolia, Melaleuca nodosa, Melaleuca styphelioides* with occasional emergent *Eucalyptus* spp.
Characteristic midstorey	*Parsonsia straminea*
Characteristic groundcovers	*Gahnia aspera*
Map unit variants	None described
Mean native richness	Not surveyed, rapid data points only
Exotic species	None recorded
Condition	High
Distribution and example locality	Widespread. Example locality: Cattai Wetlands
Equivalent Plant Community Types	PCT 1064, 1715, 1716, 1726
Soil type	Loam, Clay Loam
% remaining in NSW	33% (average)
Threats	Climate change, altered hydrological regimes, frequent fires, feral animals and weeds
No. sites sampled	VIS Sites CSI904, CSI903

Swamp Mahogany Forest

Vegetation formation:	Forested Wetland
Vegetation class:	Coastal Swamp Forest
Vegetation structure:	Forest
Conservation status:	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act EEC)
Area mapped	470.4
Swamp Mahogany Forest varies from a heathy low open woodland to forest dominated principally by *Eucalyptus robusta* but can also be dominated by *Melaleuca quinquenervia* and/or *Casuarina glauca.* The understorey is typically characterised by *Baloskion tetraphyllum* subsp. *meiostachyum, Blechnum indicum* and *Gahnia clarkei.* This is a highly variable wetland type which includes a number of variants from which it shares floristic elements.	
Characteristic trees	*Eucalyptus robusta* with occasional *Melaleuca quinquenervia* and/or *Casuarina glauca*
Characteristic midstorey	*Acacia elongata, Acacia longifolia, Banksia ericifolia* subsp. *macrantha, Banksia robur, Blechnum indicum, Callistemon pachyphyllus, Elaeocarpus reticulatus, Glochidion ferdinandii, Leptospermum juniperinum, Leptospermum polygalifolium, Melaleuca sieberi, Melaleuca nodosa, Melaleuca styphelioides.*
Characteristic groundcovers	*Baloskion tetraphyllum* subsp. *meiostachyum, Blechnum indicum, Gahnia clarkei, Xanthorrhoea fulva,*
Map unit variants	Broad-leaved Paperbark Melaleuca Thicket Shrubland Swamp Oak Type Wet Heath
Mean native richness	42 (one site)
Exotic species	*Ageratina adenophora, Paspalum mandiocanum, Senna pendula* var. *glabrata*
Condition	Moderate to High
Distribution and example locality	Widespread on poorly drained floodplains. Example locality: Big Swamp
Equivalent Plant Community Types	PCT 1230, 1649, 1717, 1718, 1721, 1722, 1725,
Soil type	Sand, sandy loam, loamy sand and loam
% remaining in NSW	46% (average)
Threats	Climate change, altered hydrological regimes, frequent fires, feral animals and weeds
No. sites sampled	ELA Site Plot 10

Freshwater Wetland

Vegetation formation:	Freshwater Wetland
Vegetation class:	Coastal Freshwater Lagoon
Vegetation structure:	Sedgeland / Herbland / Grassland
Conservation status:	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act EEC)
Area mapped	54.5 hectares
Freshwater wetlands are highly variable and the floristics depend on a combination of frequency of inundation, depth of inundation and soil types. Freshwater wetlands include a variety of floating, emergent and submerged macrophytes.	
Characteristic trees	Occasional emergent *Melaleuca quinquenervia* and *Melaleuca ericifolia*
Characteristic midstorey	None
Characteristic groundcovers	*Baumea articulata, Cladium procerum, Eleocharis sphacelata, Lepironia articulata, Persicaria* spp., *Phragmites australis, Typha orientalis*
Map unit variants	Melaleuca Thicket Swamp Oak
Mean native richness	Not recorded
Exotic species	*Salvinia molesta, Nymphaea* spp.
Condition	Moderate to High
Distribution and example locality	Eastern parts of the study area, Harrington Lagoon
Equivalent Plant Community Types	PCT 1737, 1740, 1741, 1742, 1808
Soil type	Sand, mud and peat
% remaining in NSW	36% (average)
Threats	Climate change, altered hydrological regimes, frequent fires, feral animals
No. sites sampled	Not surveyed, rapid data points only

Reedland

Vegetation formation:	Freshwater Wetlands
Vegetation class:	Coastal Freshwater Lagoons
Vegetation structure:	Reedland
Conservation status:	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (BC Act EEC)
Area mapped	28.9
Reedland is typically dominated by either *Phragmites australis* or *Typha orientalis*. This wetland type would have previously been more extensive as part of a mosaic of floodplain wetlands. Disturbance through historical clearing and drainage works means examples may not represent the natural occurrence of this wetland type.	
Characteristic trees	Emergent *Casuarina glauca*
Characteristic midstorey	None
Characteristic groundcovers	*Phragmites australis, Typha orientalis*
Map unit variants	Melaleuca Thicket
Mean native richness	Not recorded
Exotic species	*Senna pendula* var. *glabrata*
Condition	Moderate to High
Distribution and example locality	Scattered in the study area. Example Locality: Cattai Wetlands
Equivalent Plant Community Types	PCT 1808
Soil type	Loam
% remaining in NSW	59%
Threats	Climate change, altered hydrological regimes, frequent fires, feral animals
No. sites sampled	Not surveyed, rapid data points only

Grey Mangrove Forest

Vegetation formation:	Saline Wetland
Vegetation class:	Mangrove Swamp
Vegetation structure:	Forest
Conservation status:	Marine Vegetation (FM Act Protected)
Area mapped	564.4
Grey Mangrove Forest is a low open to closed forest dominated by *Avicennia marina* subsp. *australasica* (Grey Mangrove) with a midstorey characterised by *Aegiceras corniculata* (River Mangrove). The understorey is generally bare and characterised by mangrove pneumatophores.	
Characteristic trees	*Avicennia marina* subsp. *australasica* with occasional *Casuarina glauca*. Some patches had littoral rainforest elements such as *Cupaniopsis anacardioides*
Characteristic midstorey	*Aegiceras corniculatum*
Characteristic groundcovers	*Juncus kraussii* subsp. *australiensis*, *Sporobolus virginicus*
Map unit variants	Saltmarsh Swamp Oak
Mean native richness	3
Exotic species	*Juncus acutus, Ehrharta erecta*
Condition	Moderate to High
Distribution and example locality	Widespread on the banks of the Manning River and its tributaries. Example locality: Millers Creek (Mitchell's Island).
Equivalent Plant Community Types	PCT 916, 918, 1747
Soil type	Saline estuarine muds
% remaining in NSW	30% (average)
Threats	Climate change, altered hydrological regimes, weed invasion
No. sites sampled	ELA sites Plot 19, Plot 20, Plot 22

Saltmarsh

Vegetation formation:	Saline Wetland
Vegetation class:	Saltmarsh
Vegetation structure:	Sedgeland / Shrubland / Grassland
Conservation status:	Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (BC Act EEC) / Marine Vegetation (FM Act Protected) / Subtropical and Temperate Coastal Saltmarsh (EPBC Act VEC)
Area mapped	564.4
Saltmarsh occurs as either a sedgeland dominated by *Juncus kraussii* subsp. *australiensis* (Sea Rush) a shrubland dominated by *Sarcocornia quinqueflora* (Samphire) or a grassland dominated by *Sporobolus virginicus* (Sand Couch), or a complex mosaic of all three. It occurs on saline estuarine sediments subject to periodic inundation and is associated with both Grey Mangrove Forest and Swamp Oak Forest. Significant areas of Saltmarsh derived from clearing of Swamp Oak Forest have been mapped.	
Characteristic trees	Emergent *Aegiceras corniculata, Avicennia marina* subsp. *australasica*, *Casuarina glauca*
Characteristic midstorey	None
Characteristic groundcovers	*Juncus kraussii* subsp. *australiensis, Sarcocornia quinqueflora, Sporobolus virginicus, Suaeda australis.*
Map unit variants	Freshwater Wetland / Swamp Oak Swamp Oak Swamp Oak / Broad-leaved Paperbark
Mean native richness	5 (one site)
Exotic species	*Juncus acutus*
Condition	Moderate to High
Distribution and example locality	Widespread in periodically inundated estuaries. Example locality: Cattai Wetlands
Equivalent Plant Community Types	PCT 1125, 1746
Soil type	Saline estuarine sediments
% remaining in NSW	54% (average)
Threats	Climate change, altered hydrological regimes, weed invasion, grazing, feral animals
No. sites sampled	ELA Site Plot 21

Appendix B Flora species matrix

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