Terara Shoalhaven Sand
C/- Ernest Panucci

River Stability Assessment - Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Pig Island, Terara, NSW

martens consulting engineers

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P1806743JR01V01
March 2019

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to prepare a River Stability Assessment in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and Terara Shoalhaven Sand C/- Ernest Panucci (hereafter known as the Client). The scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

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All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Overview

1.1 Background

Martens and Associates (MA) have been engaged to prepare a River Stability Assessment (RSA) for a reach of the Lower Shoalhaven River, to support a proposal to expand existing sand extraction operations in the river bed vicinity to the west and south west of Pig Island.

This assessment has been prepared in accordance with Secretary's Environmental Assessment Requirements (SEARs ID No. 1234) dated June 7, 2018 and will form part of an Environmental Impact Statement (EIS) covering all aspects of the proposal and subsequent environmental impacts.

1.2 Scope

This report provides the following:

- Study Area Geomorphology (Section 2) – Discussion of the geomorphology of the study area and assessment of historical channel/island changes from the late 1940's to present.
- River Assessment (Section 3) - Analysis of historic and existing bank conditions, an assessment of recent bank changes, and likely velocity changes and impacts to the levee, tidal prism and seagrass beds.
- Conclusions (Section 4).

1.3 Proposed Development

Shoalhaven Sands Pty Ltd (the Client) propose to extend the existing dredging footprint around the western and north western portion of the Shoalhaven River mid-channel bar known as Pig Island. The proposed dredging expansion will allow for the extraction of up to 100,000 tonnes of river sand per annum, over a 29 year period. Figure 2, Attachment A shows the proposed extraction areas.

Previous consent to extend the sand extraction lease area was determined in 2014 (RA12/1001).

1.4 Statutory and Regulatory Requirements

The Secretary of the NSW Department of Planning and Environment (NSW DP&E) has consulted with relevant government agencies and has provided environmental requirements for the project (EAR1234, 2018). They are summarised in Table 1.

Table 1: Requirements from EAR1234.

Rehabilitation Management Plan Requirements	Section of Report
Shoalhaven City Council	
The EIS must address:	
o Include any known impacts occurred from the sand extraction under RA12/1001 such as; impacts to the seagrass beds within close proximity of dredging activities, water quality, and the integrity and stability of the riverbanks along Pig Island and give reference to any monitoring reports that have been produced to date.	Section 3, and Estuarine Water Quality Impact Assessment (MA, 2019b)
o In terms of flood behaviour, the dredging may not have an effect, however this will be required to be addressed to demonstrate this. The main concern would be geomorphic effect of the dredging as it may cause erosion to the river bank which could cause further sedimentation. In addition, Council has a levee system along this stretch of the river which could be compromised. A detailed assessment is required to determine the geomorphic effects the proposed dredging will have to the river and the banks.	Section 3, and Flood Assessment (MA, 2019c)
NSW Department of Primary Industries (Fisheries)	
EARs for this proposed expansion include:	
o An assessment of the likely impact of dredging what is effectively a deep channel around the western end and the north-western side of Pig Island, upon the distribution of tidal flows and the risk this poses to sand flat and riverbank stability in the general area over the long term including during flood events.	Section 3, and Flood Assessment (MA, 2019c)

2 Study Area Geomorphology

2.1 Site Setting

The *Shoalhaven River Estuary Data Compilation Study* (Umwelt Australia, 2005) described the lower Shoalhaven River as an infilled basin/floodplain complex. The estuary can be classified as a 'barrier estuary' at a mature stage of evolution, where the original water body has almost completely infilled with sediment, and fluvial sand is often discharged to the ocean during flood events.

The bedrock control for the River ends at Nowra. Seaward of Nowra, the river anabranches around various large alluvial deposits, one being Pig Island (Umwelt Australia, 2005). Here an extensive floodplain (approximately 120 km^2) has formed, predominately through lateral accretion (i.e. point bar formation) which has been overlain by sediments deposited from suspension during flood events (Umwelt Australia, 2005). Currently, the large floodplain area is predominately used for agricultural purposes.

Figure 1 (Attachment A) provides an overview of the lower Shoalhaven River system with morphological features noted. A survey (Johnson Proctor Surveyors, 2018) of the proposed extraction area is provided in Attachment B.

2.2 Pig Island Morphology

Pig Island is a lowland riverine feature formed primarily through alluvial deposition. According to the *Lower Shoalhaven River Floodplain Risk Management Study* (Webb, McKeown and Associates, 2008) the Island has been actively accreting since European settlement and, as a result, has increased in width (650 m to 850 m approximately) and in length (1,680 m to 2,400 m approximately).

The shape of the Island can be attributed to the migration of sediment downstream, which has resulted in two distinct accretion points: a subaqueous portion where alluvial deposition has led to formation of extensive sand and mudflat areas which are partially exposed during low tide; and a subaerial portion, where aeolian deposits have built up the Island via processes similar to dune formation.

2.3 Channel Bed Morphology

Given the depositional nature of the estuary, the channel bed is largely flat and shallow. According to the *Shoalhaven River Estuary Management Plan* (Umwelt Australia, 2006) the deepest part of the channel (the thalweg) runs north of Pig Island and then migrates south to against the south bank, before migrating north again. Bathymetry data received from Allen Price and Associates (2011) confirms this description.

2.4 Bed Sediment Characteristics

Bed sediment characteristics of the lower Shoalhaven River have been influenced by altered flow regimes caused by upstream dams (Umwelt, 2005). As a result, bed character of the estuary can be attributed to catchment areas below these dams (i.e. the 'effective' catchment area. Hazelton (1992) notes that the dominant soil materials of the Shoalhaven landscape consist of fine sandy loam overlying light sandy clay loam and sandy clays and some light to medium clays.

Site soils comprise Shoalhaven alluvial material, a sequence of medium and coarse quartoze and lithic sands with varying proportions of fine sands, interlaid by silts, clays and carbonaceous matter that were deposited after periods of flooding. Subsurface investigation to a maximum of 3.7 meters below ground level (surface level of -3.9 mAHD) identified sand, medium and coarse grained, with varying portions of fine-grained sand, brown-grey to dark grey in colour.

Salinity investigations indicated that potential acid sulfate soils occur across portions of the proposed changed excavation area (MA, 2019a).

Encountered conditions are described in more detail in the *Land Resources Assessment* (MA, 2019d).

2.5 Sediment Supply

Coarse sediments from the upper Shoalhaven catchment are trapped by Tallowra Dam, while fine grain material (silt and clays) are transported over the spillway (Umwelt, 2005). Sands, muds and gravels found on the bed of the lower Shoalhaven River are therefore derived from downstream sub-catchments, totalling an area of approximately 2,460 km^2 (to Pig Island).

Only a fraction of gross erosion within a catchment is transported and delivered to downstream estuaries (CSIRO, 2003). The Sediment

Delivery Ratio (SDR) is used to account for this reduction in a catchment and is expressed as follows:

$$SDR = Y/E$$

Where Y = average annual sediment yield, and
E = average annual erosion rate.

The *Soil Landscapes of the Kiama 1:100 000 Sheet* (Hazelton, 1992) provides an erosion rate of 10 t/ha/yr for the Shoalhaven soil landscape.

CSIRO (2001) and CSIRO (2003) suggests that the SDR's for catchments of similar size to the lower Shoalhaven can vary between 0.05 and 0.20. The Australian Natural Resources Atlas (2009) notes that the SDR for the Shoalhaven River is 0.33. Based on these collective findings, a SDR of 0.2 was assumed to estimate annual sediment yield to the Shoalhaven River estuary (at Pig Island).

Based on the above, the average annual sediment yield equates to 2 t/ha/yr. Assuming a catchment area of 2,460 km^2 (246,000 ha) the supply of sediment to the lower Shoalhaven is in the order of 492,000 t/yr.

2.6 Active Depositional Areas

Due to the increase in channel width (approximately 600 – 700 m) downstream of Nowra, the river area surrounding Pig Island is a preferential depositional area. The upstream extent of Pig Island was noted during field works as actively accreting. This is most likely due to sediment falling out of suspension as it moves downstream, when flow velocity is reduced as the river anabranches around the Island. It is also noted that historical intermediate scale flood events also have had an influence on sediment transport and the deposition of sediment in the lower Shoalhaven estuary (Umwelt, 2006).

3 River Bank Assessment

3.1 Historical Channel Conditions

A series of historical aerials were obtained from the NSW Department of Lands and Nearmap to provide a means of qualitative assessment of channel change since the 1940's. Table 2 summarises the finding of this assessment, with aerials provided in Attachment C.

Table 2: Historical Channel Changes; lower Shoalhaven River and Pig Island.

Aerial Year	River Channel change/description	Island change/description
1949	Both banks largely cleared for agricultural purposes. Dredging has not commenced.	Eastern and western tip of Island very thin with no vegetation/mangrove areas. Clear beach area surrounding most of the Island. Sub-tidal resource area appears to extend around entire western half of Island and halfway into northern and southern channel. Seagrass extent unclear due to photo resolution.
1961	Little channel change evident. No dredging activities.	Alluvial deposition at the Island's western tip. Possible erosion of resource to the Islands south – possibly due to recent flood event (6 months prior to aerial).
1970	Some deposition along the northern bank to the Islands north east. Some erosion noted along the southern bank to the Islands south east. No evidence of dredging.	Significant deposition to the Island's west, south west and south. Eastern end unchanged.
1979	Little change to channel form. First evidence of dredging activities.	Removal of some resource to the Island's south up to Island banks. Significant deposition of material to the Islands west and south, and deposition to northern, north eastern and south eastern banks.
1993	Little channel form change. Dredging has continued.	Deposit to the Island's west has vegetated. Smaller deposits further north west and south have also vegetated. Seagrass extent to the Islands south has been modified, however to the west and north west appears to have increased.
2001	Little channel form change. Dredging has continued.	Deposition has continued to the west and north west. Deposit has stabilised further with more vegetation. Western tip of Island has rounded. Seagrasses noted in inundated areas surrounding the sub-tidal deposit area.

Aerial Year	River Channel change/description	Island change/description
2010	Little channel form change. Dredging has continued.	Resource accretions and seagrass extents have expanded west to in line with Bomaderry Creek. Increased deposit on northern and eastern banks of the Island.
2018	Little channel form change. Dredging has continued. Additional resource deposition to west of Pig Island and extending further north.	Increased vegetation on deposition at western end of Pig Island, and on banks surrounding Pig Island.

The aerial photograph analysis demonstrates the following:

1. Channel form has been largely stable over the past 70 years.
2. There has been significant ongoing accretion at the south western, western and north-western extents of Pig Island.
3. Actively accreting areas are migrating sub-aerially and in places becoming colonised with sub-aerial vegetation.
4. There is no evidence of major bank erosion or position changes in recent years as dredging operations have been undertaken.

3.2 Observed Vegetation

The following observations were made with regards to vegetation within the study area:

1. Pig Island was predominantly vegetated with pasture grasses and some scattered trees.
2. The shallow aquatic environment surrounding Pig Island contained seagrass and seaweed species.
3. Intertidal zones contained mangrove and saltmarsh communities. Mangroves noted are mostly immature to juvenile, with various stands of uniform age, suggesting the area is prone to depositional events.
4. Casuarinas were noted at elevation on Pig Island and along some banks.
5. There was a lack of riparian vegetation, both on Pig Island and the mainland. Where vegetation had not been cleared, banks appeared more stable and erosion was minimal.

3.3 River Bank Conditions

A river bank photographic survey was undertaken of Pig Island. Bank features such as evidence of erosion, slumping and bank failure, existing protection works, riparian vegetation and depositional features were photographed and noted (refer to Figures 4 and 5, Attachment A). The survey is summarised in Table 3.

Table 3: Historical Bank Conditions: Mainland and Pig Island (2011 and 2018) (refer to Figures 4 and 5, Attachment A).

Reach Extent [1]	Mainland - Bank Conditions 2011	Mainland - Bank Conditions 2018	Pig Island - Bank Conditions 2011	Pig Island – Bank Conditions 2018
Reach 1 (adjacent to existing extraction area)	Localised rock protection along the bank. Bank generally 2 to 4 m high. Evidence of undercutting observed near Bomaderry Creek. Rock gabions adjacent to Shoalhaven Starches ethanol plant. Bank vegetation – trees, shrubs, grasses. Some fallen and dead trees observed on bank slopes and on the river's edge.	Little change from 2011 conditions.	Bank 1- 2 m high. Some undercutting of bank. Bank vegetation – grasses.	Bank 1 – 2 m high, stable and well vegetated. Mangroves and salt marsh areas in good condition. Bank vegetation – grasses, scattered trees and shrubs. Mangroves and salt marshes.
Reach 2	Bank generally 2 to 4 m high. Evidence of slumping and bank instability. Bank vegetation – trees, shrubs, grasses. Fallen and dead trees observed on bank slopes and on the river's edge.	Little change from 2011 conditions.	Bank appeared stable and well vegetated. Some undercutting of bank. Bank vegetation – grasses, scattered trees.	Bank 1 to 2 m generally appeared stable and well vegetated. Localised undercutting. Bank vegetation – grasses, trees and shrubs.
Reach 3	Bank generally 1 to 3 m high. Localised evidence of slumping. Bank vegetation – trees, shrubs, grasses, and mangroves. Some fallen and dead trees observed on bank slopes and on the river's edge.	Little change from 2011 conditions.	Bank appeared stable and well vegetated. Some undercutting of bank. Bank vegetation – grasses, scattered trees.	Bank generally appeared stable and well vegetated. Localised bank undercutting. Mangroves in good condition. Bank vegetation – grasses, trees and shrubs, and mangroves.

Reach Extent [1]	Mainland - Bank Conditions 2011	Mainland - Bank Conditions 2018	Pig Island - Bank Conditions 2011	Pig Island – Bank Conditions 2018
Reach 4	Levee and localised rock wall protection works implemented along reach. Bank well vegetated with grasses, shrubs, trees, and mangrove areas.	Little change from 2011 conditions.	1 m high bank. Some undercutting and slumping. Bank vegetation – grasses.	Bank 1 to 3 m high. Slumping in some areas, other areas stable and well vegetated. Banks more stable and well vegetated further downstream. Bank vegetation – grasses, scattered trees and shrubs.
Reach 5	Levee and localised rock wall protection works implemented along reach. Bank well vegetated with grasses, shrubs, trees, and mangrove areas.	Little change from 2011 conditions.	1 – 2 m high bank. Some undercutting and slumping. Bank vegetation – grasses, shrubs and scattered trees.	Bank 1 to 3 m high. Some slumping and bank instability. Portions of the bank stable and vegetated. Bank vegetation – grasses, scattered trees and shrubs.
Reach 6	Levee and localised rock wall protection works implemented along reach. Bank well vegetated with grasses, shrubs, trees, and mangrove areas.	Little change from 2011 conditions.	1 – 2 m high bank. Some undercutting. Bank vegetation – grasses.	Bank 1 to 2 m high. Slumping in some areas. Bank vegetation – grasses, scattered trees and shrubs.
Reach 7 (adjacent to existing extraction area)	Levee and localised rock wall protection works implemented along reach. Bank well vegetated with grasses, shrubs, trees, and mangrove areas.	Little change from 2011 conditions.	Bank relatively well vegetated. Bank 1 – 2 m high. Some undercutting. Bank vegetation – grasses.	Bank well vegetated. Mangroves and salt marsh areas in good condition. Bank 1 m high in some areas. Localised slumping. Bank vegetation – grasses, scattered trees and shrubs. Mangroves and salt marshes.

Notes:

[1] Refer to Attachment A, Figure 5 for reach extents, and Figure 4 for bank condition photos.

The assessment indicates the following:

1. Whilst there is some evidence of bank instability, this has not changed between 2010 and 2018.

2. Banks are largely stable as demonstrated by their historical stable position.

3. Recent dredging operations do not appear to have had any material effect on bank stability.

3.4 Likely Velocity Changes

Hydraulic modelling prepared for the flood study (MA, 2019c) calculated peak velocities for both existing and post dredging expansion river channel velocities (m/s) for seven observation locations (refer to Figure 3, Attachment A).

Table 4 indicates the percentage (%) difference for existing vs future channel velocity changes at 7 locations within the river channel for 1 in 10, 100, 200, 500 year average recurrence interval (ARI) and probable maximum flood (PMF) flood events.

Table 4: Hydraulic modelling – existing and proposed velocity changes (%).

Point	10[1]	100[1]	200[1]	500[1]	PMF[1]
1	0.4%	0.5%	0.1%	0.1%	0.0%
2	-0.6%	-1.8%	-1.5%	-0.8%	-0.2%
3	0.3%	7.3%	8.3%	7.9%	6.2%
4	-0.4%	2.0%	2.7%	3.2%	3.3%
5	-0.1%	1.3%	1.8%	2.5%	5.5%
6	-1.7%	0.0%	0.5%	1.3%	1.9%
7	0.8%	1.2%	1.4%	1.3%	1.3%

Notes:

[1] Positive values indicate an increase in velocity; negative values indicate a decrease in velocity.

The assessment of velocity changes indicates that:

1. The proposed extraction works are not anticipated to have a significant impact on existing river bank erosion due to impact scour, as river velocities are not anticipated to be significantly changed as a result of the proposed expansion to extraction works.

2. No detrimental velocity impacts due to the proposed expansion to dredging operations, and no bank erosion due to impact scour are expected.

3.5 River Bank Protection Works Impacts

Based on our riparian bank survey, existing bank and toe protection works are evident on left and right river banks of the lower Shoalhaven. Where in place, protection works generally appear to be successful.

Methods of bank protection works noted during field investigations included:

- Vegetated batters (levees);
- Sand sausage (sandbag);
- Gabion baskets;
- Rock walls;
- Rip-rap toe protection; and
- A mixture of gabion baskets and rip-rap.

No significant detrimental impacts are anticipated from the proposed dredging extraction works on the river banks or the bank protection works, based on the historically stable bank position and the ongoing success of the existing bank protection works.

3.6 Tidal Prism Impacts

The tidal prism of the Shoalhaven River estuary at spring tide is around 23 x 10^6 m^3 (Carvalho & Woodroffe, 2017). No impacts on the tidal prism, and therefore the tidal behaviour is expected because:

1. The majority of extraction occurs below low water spring tide level.
2. The intended volume to be extracted is very small, around 10^4 m^3, or approximately 0.09%.
3. There would be no material change to the tidal penetration range experienced by the river.

3.7 Seagrass Beds

Seagrass beds are provided on the survey (Johnson Proctor Surveyors, 2018) in Attachment B.

A 25 m setback to seagrasses and 15 m setback to mangrove areas has been provided to mitigate against any potential environmental impacts of dredging operations. The setback was based on detailed slope stability modelling undertaken for consent RA12/1001, and approved on 28 August, 2114. This application does not seek to alter the previously approved setback.

The proposed dredging extraction works are therefore not expected to impact on seagrass bed areas.

4 Conclusions

The following conclusions are made regarding the potential impacts of the proposed dredging excavation works on river bank stability:

1. The impacts of proposed works on riverine vegetation are anticipated to be insignificant, based on assessment of historical dredging operations impacts.

2. Historical extraction works do not appear to have been a significant cause of existing bank erosion in the study area.

3. Flow velocity changes due to extraction works would be insignificant and are unlikely to lead to a change in sedimentation / erosion processes along the river bank.

4. The proposed expanded extraction area is outside of areas with significant existing aquatic vegetation (seagrass and seaweed) and works are not expected to impact on these areas. An adequate buffer will be applied.

A Rehabilitation Management Plan (RMP) has been prepared to provide a range of environmental management strategies to mitigate and protect the long-term environmental and ecological values of areas of the Shoalhaven River in the vicinity of the proposed resource extraction works (MA, 2019e).

5 References

Allen, Price & Associates (2011) bathymetry data.

Australian Natural Resources Atlas (2009) *Soils – Shoalhaven River* www.anra.gov.au/topics/soils/erosion/nsw/basin-shoalhaven-river-se.hml

Bureau of Meteorology (2000) *Wind Speed and Direction Rose: Nowra (Site Number 68076).*

Carvalho, R.C. and Woodroffe, C.D. (2017) *Modifications to the Shoalhaven estuary and the coastal sediment budget over the past 40 years.* Australasian Coasts and Ports Conference: Coasts and Ports 2017 (pp. 1-7).

Commonwealth Scientific and Industrial Research Organisation (2001) *The Assessment of River Conditions (ARC) – An Audit of the Ecological Condition of Australian Rivers.*

Commonwealth Scientific and Industrial Research Organisation (2001) *Sheet and Rill Erosion and Sediment Delivery to Streams: A Basin Wide Estimation at hillslope to Medium Catchment Scale.*

Commonwealth Scientific and Industrial Research Organisation (2003) *Waterborne Erosion – an Australian Story.*

CSIRO (2001) *Waterborne Erosion – An Australian Story – Content for the Australian Natural Resources Atlas Storyboards.*

CSIRO (2003) *Sheet and Rill Erosion and Sediment Delivery to Streams: A Basin Wide Estimation at hillslope to Medium Catchment Scale.*

Hazelton, P.A. (1992) *Soil Landscapes of the Kiama 1:100 000 Sheet.*

Johnson Procter Surveyors Pty Ltd (2018*) Plan of Sea Grass Location and Level Spot Heights within the Shoalhaven River for Shoalhaven Sand Pty Ltd.* (ref 14152(F)).

Landcom (2004) *Managing Urban Stormwater – Soils and Construction.*

Martens & Associates (2019a) *Acid Sulfate Soils Assessment: Proposed Expansion of Sand Dredging Operations at Terara Sands, NSW* (ref P1806743JR02V01).

Martens & Associates (2019b) *Estuarine Water Quality Impact Assessment: Proposed Expansion of Sand Dredging Operations, Terara, NSW* (ref P1806743JR06V01).

Martens & Associates (2019c) *Flood Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Nowra, NSW* (ref P1806743JR04V01).

Martens & Associates (2019d) *Land Resource Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Pig Island, Terara, NSW* (ref P1806743JR07V01).

Martens & Associates (2019e) Rehabilitation Management Plan*: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Pig Island, Terara, NSW* (ref P1806743JR08V01).

Martens & Associates (2012a) *River Impact Assessment – Proposed Expansion of Sand Extraction Area; Pig Island Lower Shoalhaven River, NSW* (ref P1103077JR01V03).

Martens & Associates (2012b) *Supplementary Environmental Details – Proposed Expansion of Sand Extraction Area; Pig Island Lower Shoalhaven River, NSW* (ref P1103077JR04V02).

NSW Public Works (April 1990), *Lower Shoalhaven River Flood Study.*

Packman, J.J., Comings, K.J. and Booth, D.B. (1999) *Using Turbidity to Determine Total Suspended Solids in Urbanizing Streams in the Puget Lowlands.*

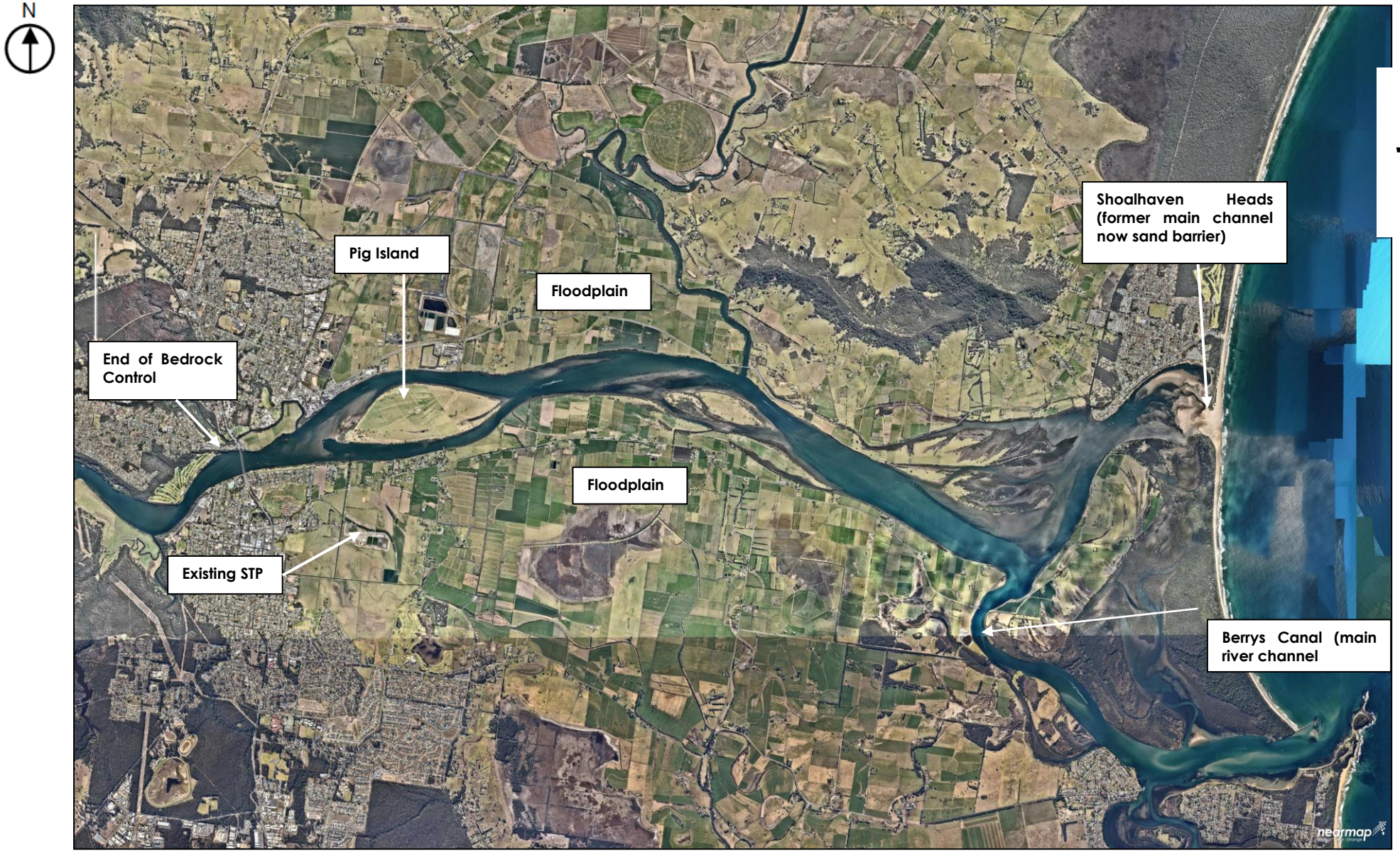
Umwelt (Australia) Pty Ltd (2005) *Shoalhaven River Estuary Data Compilation Study.*

Umwelt (Australia) Pty Ltd (2006) *Shoalhaven River Estuary Management Plan.*

Webb, McKeown and Associates (2008) *Lower Shoalhaven River: Floodplain Risk Management Study.*

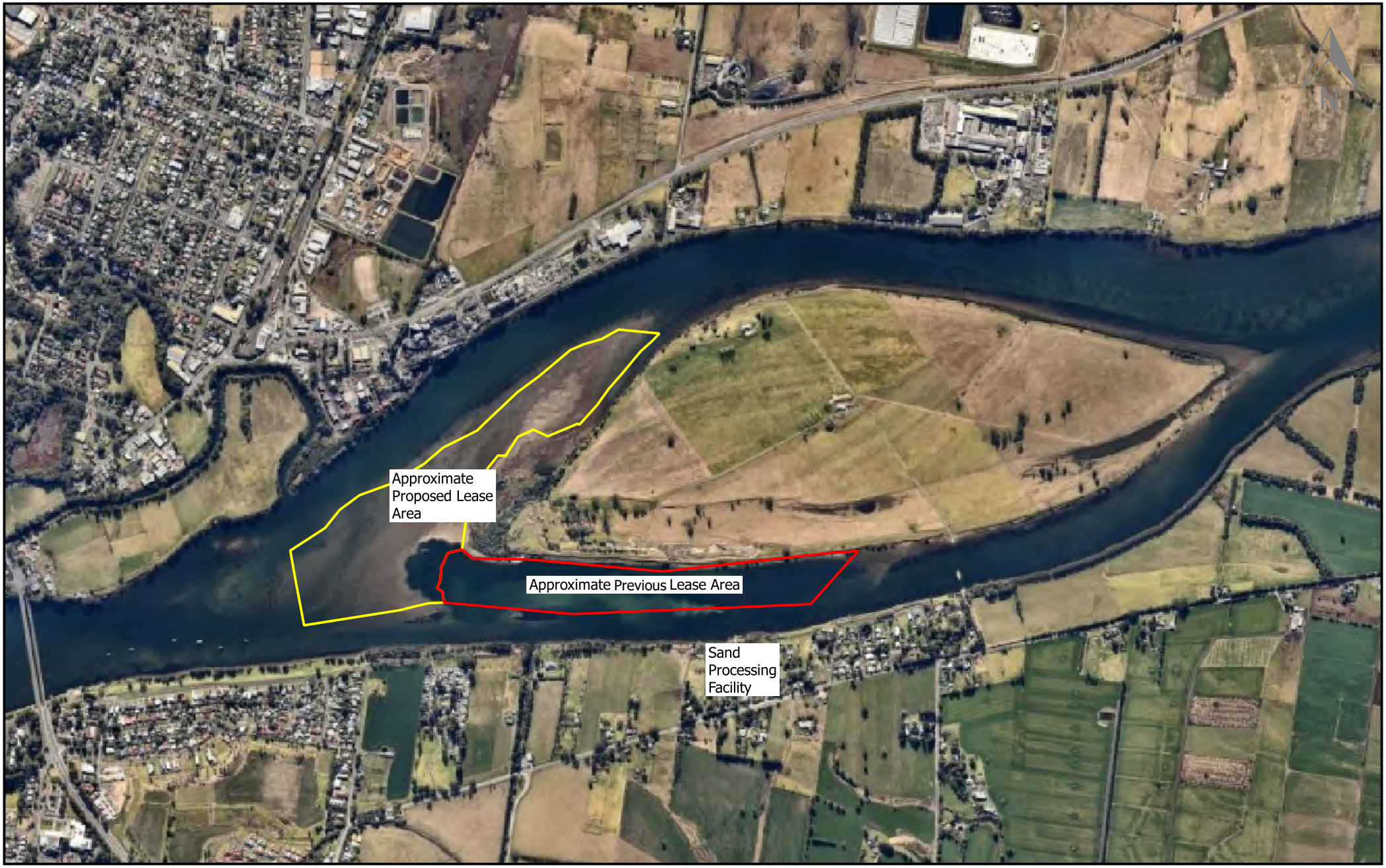
http://en.wikipedia.org/wiki/Hjulström_curve (September 2011).

6 Attachment A - Figures



martens

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	CS	**Study Area – Geomorphic Setting** **Shoalhaven River, NSW** Image Source: Nearmap (2018)	Drawing No: **Figure 1**
Approved:	JF		
Date:	March 2019		
Scale:	Not to Scale		Job No: P1806743



martens

0 250 500 750 1000 m

1:15,000

Approximate Extents of the Previous and Proposed Dredge Lease Areas Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 2

martens

0 250 500 750 1000 m

1:15,000

Hydraulic Modelling - Study Area & Velocity Observation Points
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 3

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	CS	**River Bank Condition Photos (2018 and 2011)** **Lower Shoalhaven River and Pig Island, NSW** Image Source: Nearmap (2018) and MA	Drawing No: **Figure 4**
Approved:	JF		
Date:	March 2019		
Scale:	Not to Scale		Job No: P1806743

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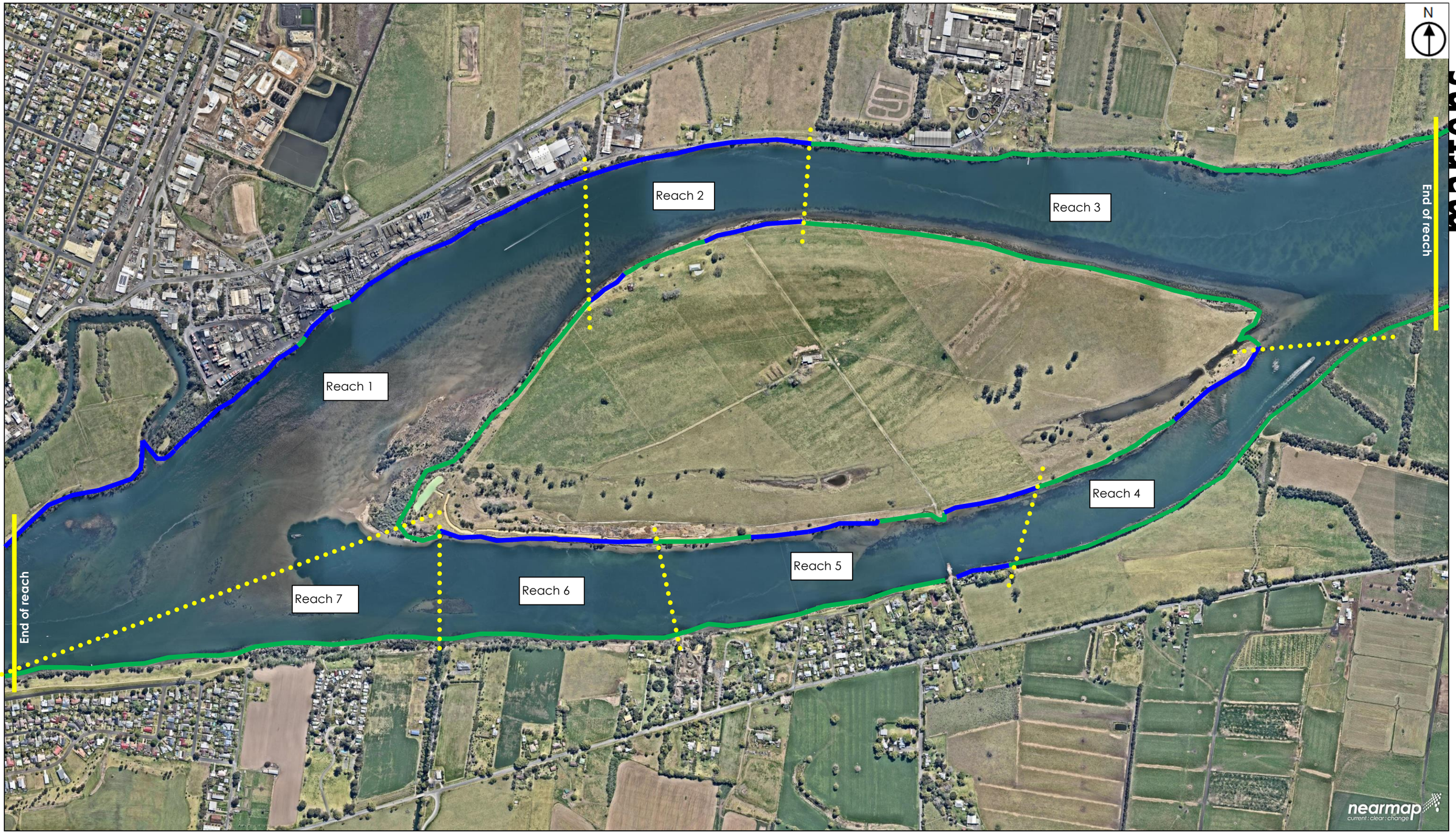

KEY

Oversteepened / some undercutting

Generally stable / vegetated / protection works

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	CS	**River Bank Condition** **Lower Shoalhaven River and Pig Island, NSW** Image Source: Nearmap (2018)	Drawing No: **Figure 5**
Approved:	JF		
Date:	March 2019		
Scale:	Not to Scale		Job No: P1806743

7 Attachment B – Plan of Sea Grass Location and Level Spot Heights within the Shoalhaven River for Shoalhaven Sand Pty Ltd (Johnson Proctor Surveyors Pty Ltd, 2018)

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PLAN OF SEA GRASS LOCATION AND LEVEL SPOT HEIGHTS WITHIN THE SHOALHAVEN RIVER FOR SHOALHAVEN SAND PTY. LTD.

DATE : 5 DECEMBER, 2018
DATUM : SEE NOTES
LEVEL ORIGIN : SEE NOTES
REDUCTION RATIO : 1 : 2000 (A1) 1 : 4000 (A3)
SURVEYORS REFERENCE : 14152 (G)
ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE STATED

Point	Easting	Northing	Height
1	280384.202	6139758.149	10.436
2	280368.679	6139718.228	10.468
3	280358.784	6139697.679	10.388
4	280355.091	6139683.548	9.253
5	280359.592	6139668.359	9.936
6	280366.621	6139656.862	9.645
7	280368.124	6139639.419	9.739
8	280371.634	6139625.912	9.737
9	280374.984	6139621.882	9.739
10	280382.122	6139661.729	9.778
11	280382.229	6139684.692	9.823
12	280380.737	6139694.118	9.763
13	280383.965	6139707.332	9.668
14	280383.828	6139713.594	9.714
15	280385.826	6139719.037	9.818
16	280388.847	6139727.267	9.869
17	280382.171	6139735.289	9.973
18	280356.188	6139743.681	10.863
19	280350.238	6139731.874	10.398
20	280384.238	6139761.162	10.485
21	280373.388	6139634.420	9.649
22	280323.694	6139538.888	9.985
23	280382.274	6139523.647	9.849
24	280380.609	6139518.844	9.543
25	280366.341	6139664.598	7.859
26	280382.263	6139664.888	6.835
27	280385.982	6139646.792	5.848
28	280370.436	6139598.788	3.539
29	280354.336	6139681.545	5.178
30	280364.858	6139628.895	3.992
31	280386.361	6139788.230	5.165
32	280355.935	6139491.369	7.888
33	280384.898	6139723.389	7.578
34	280329.885	6139638.549	9.293
35	280368.364	6139783.138	9.811
36	280368.468	6139837.370	9.148
37	280721.409	6139888.341	8.235
38	280798.906	6139935.633	8.488
39	280382.858	6139996.365	9.772
40	280358.938	6140845.475	9.373
41	280358.472	6140893.149	9.831
42	280384.884	6139839.681	10.476
43	280374.487	6139875.617	10.548
44	280379.376	6140815.481	9.732
45	280378.733	6140889.236	9.342
46	280344.595	6140857.968	9.388
47	280348.333	6140838.144	7.738
48	280365.892	6140857.495	7.998
49	280437.387	6140878.854	9.281
50	280492.731	6140468.685	7.845
51	280681.318	6140363.449	9.362
52	280366.767	6140823.992	9.860
53	280385.978	6140858.232	9.381
54	280383.897	6140827.882	9.939
55	280491.653	6140818.288	9.681
56	280437.736	6140838.691	9.532
57	280387.248	6140825.357	10.809
58	280371.939	6140877.799	10.122
59	280385.378	6140841.385	10.863
60	280343.806	6140861.386	10.397
61	280296.279	6140844.825	10.324
62	280367.369	6139994.298	10.857
63	280343.638	6139981.816	10.256
64	280319.215	6139953.898	10.369
65	280357.118	6139962.882	11.245
66	280345.679	6139983.366	11.874

NOTE:
POINTS 6, 7, 8, 10, 11 WERE REMARKED ON THE 23 OF SEPTEMBER, 2016

Key
Approximate extent of seagrass beds

NOTE:
1. GRIDS SHOWN ARE ON M.G.A. ORIENTATION.
2. AZIMUTH HAS BEEN CALCULATED USING PM 127396 TO PM 17321
(219°58'27" - 1976.260 M.G.A. GRID) (219°58'27" - 1976.256 BY SURVEY)
3. THE CO-ORDINATES OF PM 17322 HAVE BEEN ADOPTED FOR THIS SURVEY
(E. 281637.468 N. 6139336.220)
4. PM PWD No. 837 AS SHOWN ON APA SURVEYORS PLAN REF.No. 51519-0, SHEET 1 OF 4 DATED FEB, 2007 HAS BEEN ADOPTED THIS SURVEY
(PM PWD No. 837 R.L. 13.413)
5. SURVEY IS NOT ON A.H.D. (APPROX. 10.25 ABOVE A.H.D.)

Point	Easting	Northing	Height
113	280357.359	6139742.336	11.78
114	280476.313	6139559.834	5.13
115	280384.732	6139567.436	5.14
116	280382.815	6139556.382	4.64
117	280280.462	6139518.829	9.66
118	280384.338	6139458.228	8.59
119	280281.392	6139482.648	5.85
120	280287.953	6139457.461	8.66
121	280288.974	6139455.814	5.45
122	280282.389	6139457.228	8.43
123	280282.488	6139517.137	9.72
124	280279.680	6139548.669	5.85
125	280286.859	6139558.979	5.66
126	280281.308	6139457.817	8.54
127	280283.486	6139444.184	8.13
128	280289.841	6139488.788	8.48
129	280348.338	6139467.869	7.75
130	280299.895	6139388.497	8.31
131	280349.273	6139362.181	8.62
132	280338.388	6139338.483	4.81
133	280332.653	6139326.472	5.21
134	280382.852	6139784.299	5.49
135	280387.274	6139748.623	10.56
136	280382.816	6139738.464	10.32
137	280382.473	6139698.657	10.29
138	280374.678	6139688.738	10.25
139	280350.824	6139689.847	10.86
140	280361.986	6139698.781	10.14
141	280441.841	6139678.837	5.77
142	280436.968	6139617.621	5.67
143	280471.657	6139468.847	4.63
144	280476.684	6139454.788	8.05
145	280370.873	6139462.283	8.36
146	280341.888	6139381.362	4.85
147	280325.987	6139359.868	4.28
148	280286.749	6139305.829	3.81
149	280258.678	6139278.483	4.04
150	280255.718	6139301.354	3.87
151	280198.481	6139396.728	4.66
152	280277.988	6139446.284	7.63
153	280257.722	6139386.596	8.66
154	280325.693	6139729.119	6.85
155	280335.347	6139616.529	3.59

Point	Easting	Northing	Height
67	280497.808	6140396.379	9.178
68	280493.804	6140387.833	9.736
69	280544.538	6140342.382	10.801
70	280458.404	6140385.384	10.859
71	280236.823	6140861.747	10.839
72	280260.451	6140868.662	9.894
73	280279.325	6140838.596	10.268
74	280250.881	6140883.598	10.872
75	280240.875	6140803.893	9.863
76	280211.438	6140818.882	9.885
77	280325.472	6140832.838	9.438
78	280214.622	6140897.367	9.889
79	280280.815	6139986.377	9.814
80	280284.804	6140061.572	10.386
81	280248.354	6140143.736	10.232
82	280439.952	6140392.765	9.909
83	280469.836	6140172.948	9.232
84	280306.346	6140329.941	8.886
85	280281.821	6139736.188	10.549
86	280263.558	6139746.867	10.339
87	280259.946	6139686.694	10.835
88	280261.365	6139681.230	9.605
89	280196.888	6139587.574	9.848
90	280188.987	6139557.188	9.859
91	280178.698	6139557.485	9.463
92	280645.881	6139369.287	9.862
93	280644.597	6139335.552	8.959
94	280659.357	6139646.689	9.574
95	280738.162	6139747.882	9.891
96	280779.983	6139782.676	9.885
97	280768.766	6139881.482	9.458
98	280898.867	6139932.448	9.369
99	280890.268	6139986.387	9.787
100	280938.932	6139916.667	10.829
101	280888.089	6139891.811	10.138
102	280836.893	6139862.813	10.391
103	280845.865	6139732.288	10.505
104	280832.324	6139689.981	10.219
105	280263.878	6139727.357	5.688
106	280371.412	6139714.793	5.382
107	280286.888	6139725.975	5.401
108	280874.326	6139667.234	5.782
109	280281.467	6139640.981	5.876
110	280878.079	6139605.791	5.230
111	280412.576	6139518.927	8.851
112	280364.842	6139598.616	8.842

SCALE 1 : 1000

SHOALHAVEN RIVER
SHOALHAVEN RIVER
PIG ISLAND
DREDGED AREA
SEA GRASS
PROPOSED
EXISTING
M.G.A.

DIAL 1100 BEFORE YOU DIG www.1100.com.au

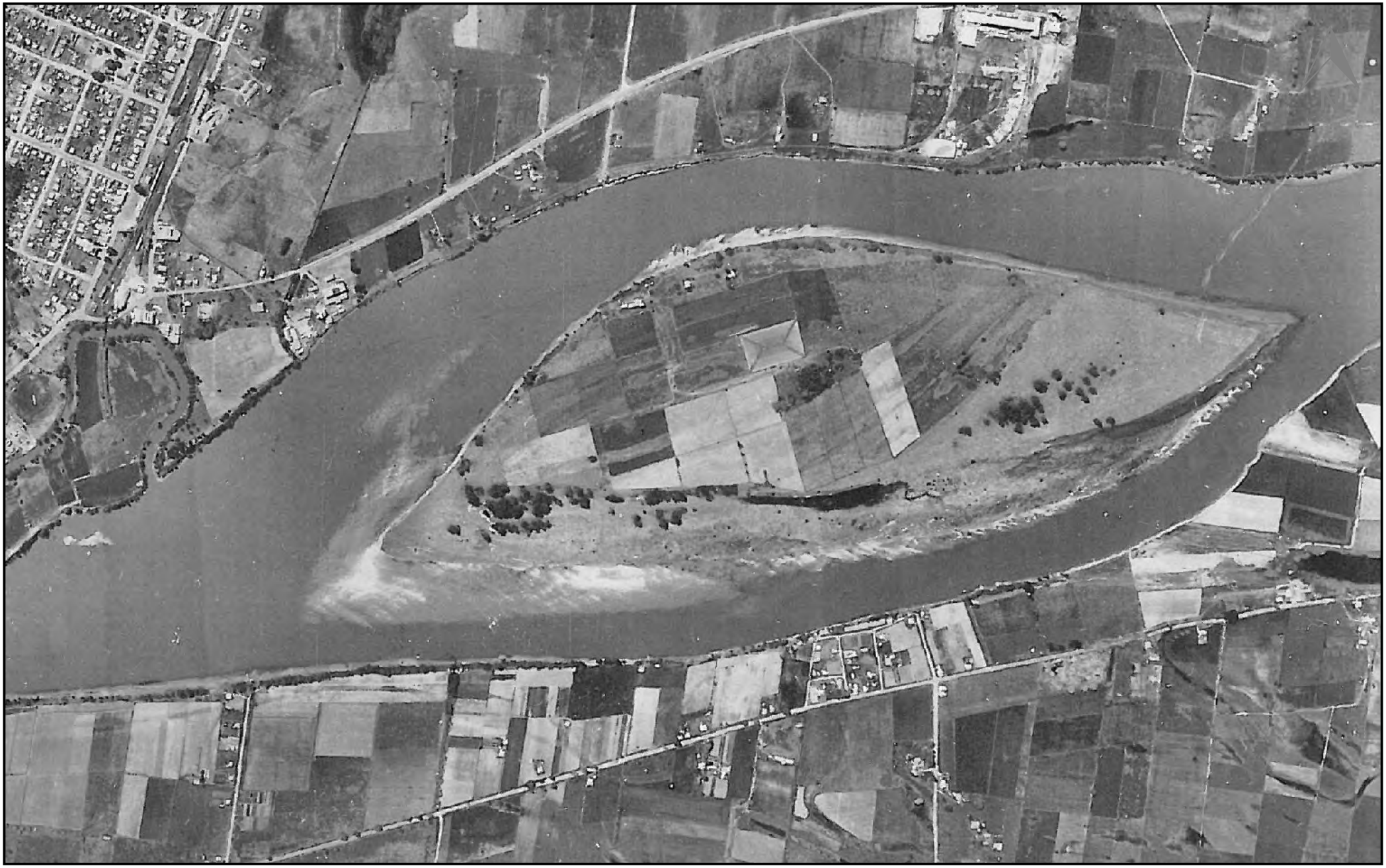
8 Attachment C - Historical Aerials

martens

0 250 500 750 1000 m

1:12,500

1949 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 6



martens

0 250 500 750 1000 m

1:12,500

1961 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 7

martens

0 250 500 750 1000 m

1:12,500

1970 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 8

martens

0 250 500 750 1000 m

1:12,500

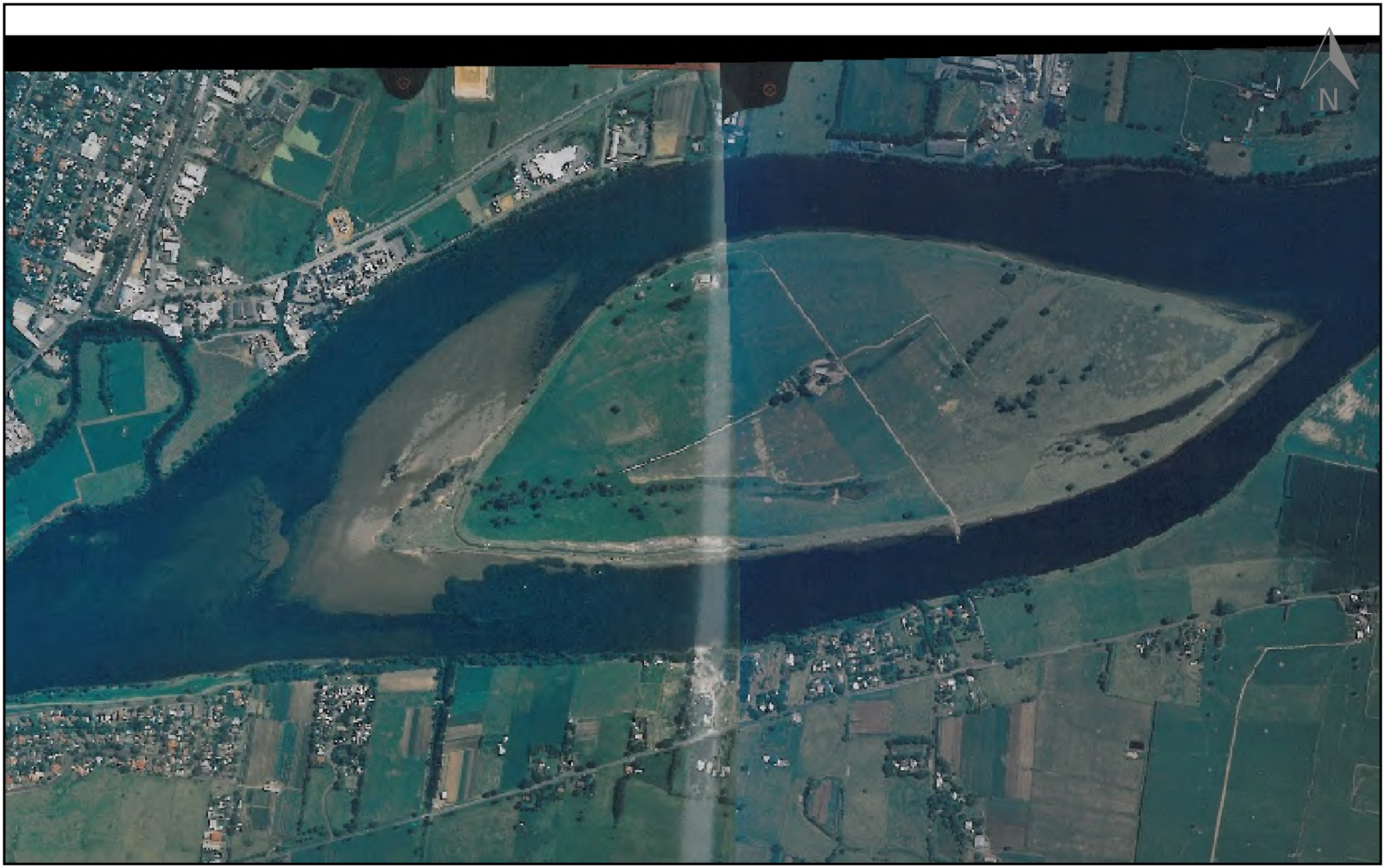
1979 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 9

martens

0 250 500 750 1000 m

1:12,500

1993 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 10



martens

0 250 500 750 1000 m

1:12,500

2001 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 11

martens

0 250 500 750 1000 m

1:12,500

2010 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 12

martens

0 250 500 750 1000 m

1:12,500

2018 Aerial Imagery
Pig Island, Shoalhaven River, NSW
19/02/2019
Figure 13