85-91 THOMAS STREET, PARRAMATTA NSW

Assessment of the Effects of Shading on Mangrove and Saltmarsh Vegetation Communities

For:

Conquest Group of Companies

November 2017

Final Report

cumberland ecology

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Report No. 16166RP2

The preparation of this report has been in accordance with the brief provided by the Client and has relied upon the data and results collected at or under the times and conditions specified in the report. All findings, conclusions or recommendations contained within the report are based only on the aforementioned circumstances. The report has been prepared for use by the Client and no responsibility for its use by other parties is accepted by Cumberland Ecology.

Version	Date Issued	Amended by	Details

Approved by: Dr David Robertson

Position: Director

Signed: David Robertson

Date: *22 November, 2017*

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Executive Summary

S1 Purpose

Cumberland Ecology Pty. Ltd. (Cumberland Ecology) has been commissioned by Conquest Group of Companies (Conquest) to assess the effect of shading on mangrove and saltmarsh communities adjacent to a proposed multi storey residential development at 85 - 91 Thomas Street, Parramatta (the “subject site”).

The purpose of this report is to assess the effect of shading on the vegetation and habitats protected under the NSW *Fisheries Management Act 1994* (FM Act). In particular, this report focuses on the concerns raised by NSW Fisheries in relation to the potential shading impacts that could arise as a result of the development on the mangrove and saltmarsh communities present in the adjacent Baludarri wetlands, located to the south to south-west of the subject site.

S2 Background

Conquest is seeking approval to build a multi storey residential building with a promenade and recreational areas along the Parramatta River foreshore. The planning proposal has been submitted for consideration to Parramatta Council. Due to the proximity of the site to the Parramatta River and associated wetlands, the Council referred the proposal to NSW Department of Primary Industries (DPI) - Fisheries NSW (hereafter “Fisheries”) for consideration. Fisheries responded and raised concerns about the potential of the proposal to shade wetlands and so impact two plant communities listed by the *Fisheries Management Act 1994*: Mangroves and Saltmarsh. In particular, Fisheries raised concerns about impacts to such vegetation within the nearby Baludarri Wetlands. The Baludarri wetland is located within the floodplain of the Parramatta River. The wetlands are situated on an alluvial floodplain and comprise a number of vegetation communities including Mangrove and Saltmarsh.

Prior to the preparation of this report, three previous assessments have been written by Cumberland Ecology in response to the concerns raised by Fisheries regarding potential effects of shading on saltmarsh and mangroves adjacent to the subject site. While these reports provided some relevant information, Fisheries prepared a written response calling for further details about impacts, including more detailed literature review and more detailed field assessments.

In order to clarify what Fisheries required to complete this assessment, a meeting was held on-site between staff of Fisheries, Conquest and Cumberland Ecology to discuss Fisheries' position regarding the shadowing assessment undertaken to date. It was made evident by Fisheries that additional information is required. Specifically, additional examples of mangrove and saltmarsh with natural and artificial shadowing, flora lists of these examples, categorical changes in the effects of shading, duration of shading, edge effects, sensitivity during the growth season, refinement of the vegetation mapping, addition shade modelling for Spring and Autumn and photographic evidence.

The current investigation was designed to address the aforementioned requirements of Fisheries.

S3 Methods

Cumberland Ecology designed an investigation to gather information that could address the potential negative effects of shading on mangrove and saltmarsh communities. A literature review was undertaken pertaining to shading of these communities along the Parramatta River and potential shading impacts during the Spring growth season. A desktop review was performed to identify areas along the Parramatta River and other wetland sites where mangrove and saltmarsh vegetation is likely to be present. Sites were selected where saltmarsh and/or mangrove were present with a northern shade source as what may be the case at the subject site. These examples of shading required both natural sources (e.g. rock cliffs, large trees) and artificial sources (e.g. bridges, buildings) for comparison. Transect and plot data was collected at intervals away from the shading source. An attempt was made to transect the cross section of floristic change on a north-to-south direction with the starting point of each transect beginning at the base of the shade source. A statistical analysis of this data was performed to determine the effect of shading on species diversity and representative cover according to decreasing shading. Also, an analysis was performed to assess the effect of shading of natural versus artificial sources.

S4 Key Findings

Based upon all information generated by this investigation, the partial shading the proposed development at 85-91 Thomas Street Parramatta will create on the adjacent wetlands will not significantly negatively impact the mangrove or salt marsh communities present in the Baludarri Wetland.

Detailed analysis of shadow diagrams shows that the proposed development will only shade the wetlands for part of each day (several hours) all winter, and for half of spring and half of autumn. Shading will not occur for the warmer months of the year (half of spring, half of autumn and all summer).

A range of existing situations with variable shading, including many areas that receive shading all year around were examined. Investigations by Cumberland Ecology found that the factors most significant in limiting the distribution of these communities at Baludarri Wetlands are elevation, salinity and nutrient availability.

Examination of a variety of existing riparian areas beside artificial structures (bridges and walkways), and natural vegetation (tall trees and shrubs with dense canopies) revealed:

- complete shading throughout the day (and year) excluded mangrove and saltmarsh communities. Areas beneath bridges and closed low-elevation walkways were denuded of both communities;

- full-midday sun for extended periods excluded some diagnostic species of saltmarsh communities; and

- partial shading at certain times of day throughout the year from either natural or artificial sources (dense tall trees) was found not to negatively impact saltmarsh or mangrove communities.

The limited amount of shading likely to be produced from the proposed development is unlikely to significantly impact upon reproduction and regeneration by either saltmarsh or mangrove plants. This is for two reasons. First, the limited shading is not likely to curtail flowering or seed set by characteristic species of mangroves and saltmarsh. Secondly, even if shading did have such an impact, propagules of mangroves and saltmarsh are largely water dispersed. As such propagules from upstream or downstream in less shaded environs would therefore be able to colonise the partially shaded areas.

Circumstantial evidence from other sites that were examined indicate that the dispersal mechanisms and pioneering character of the species comprising these communities has apparently enabled the distribution of the two communities to occupy both natural and artificial shaded environments. Sites shaded by elevated structures throughout part of the day did not lack mangrove and saltmarsh diagnostic species.

An assessment of significance was completed as required under Section 5A of the *Environmental Planning and Assessment Act 1979* to demonstrate that no significant detrimental impact was likely upon saltmarsh. This concluded no significant impact was likely and that no Species Impact Statement was warranted.

Considering the data analysis conducted and the examples of artificial and natural shading found in the area, we conclude that partial shading at certain times of the day is not a major driver of these communities and the plants they contain.

Chapter 1

Introduction

1.1 Purpose

Cumberland Ecology Pty. Ltd. (Cumberland Ecology) has been commissioned by Conquest Group of Companies (Conquest) to assess the effect of shading on mangrove and saltmarsh communities adjacent to a proposed multi storey residential development at 85 - 91 Thomas Street, Parramatta (the “subject site”).

The purpose of this report is to assess the effect of shading on the vegetation and habitats protected under the NSW *Fisheries Management Act 1994* (FM Act). In particular, this report focuses on the concerns raised by NSW Fisheries in relation to the shading impacts of the development on the saltmarsh community present in the adjacent Baludarri wetlands, located to the south to south-west of the subject site.

The specific aims of this report are to:

- Undertake a field survey and collect data to assess the effect of shading on mangrove and saltmarsh communities from natural and artificial shading sources within the Sydney Metropolitan Area and Greater Hunter;
- Review literature to detail the effects of shading on the distribution and productivity of mangrove and saltmarsh communities;
- Complete a statistical analysis of the data collected by Cumberland Ecology to determine the impact of shading by the proposed development on the distribution of Baludarri wetlands mangrove and saltmarsh communities; and
- Where relevant, recommend measures for mitigation in order to manage impacts on flora and fauna or habitats of conservation value.

1.2 Background

i. *Subject Site*

The subject site is located at 85 - 91, Thomas Street, Parramatta and consists of Lot 13, Lot 15 and Lot 16 of DP 1239 and Lot 141 and Lot 142 of DP 537053. The subject site is bordered by Thomas Street to the north, existing residential developments to the west and east and foreshore vegetation and pathways along the Parramatta River to the south (**Figure 1.1**).

The land within Lot 141 DP 537053 is zoned RE1 – Public Recreation while the remainder of the subject site is zoned R4 – High Density Residential under the Parramatta *Local Environment Plan 2011* (LEP). The northern half of Lots 13, 15 and 16 DP 1239 and Lot 142 DP 537053 contain existing residential developments that are fronted by Thomas Street. The southern half of Lots 13, 15 and 16 DP 1239 and Lot 141 DP 537053 consists of plantings from revegetation works. The revegetation areas of all four lots slope down towards the Parramatta River foreshore while the residential areas of all four lots are located on higher ground overlooking the river.

ii. Vegetation of the Subject Site

Cumberland Ecology (2017) undertook flora surveys and provided detailed vegetation mapping for the subject site and foreshore areas. As shown in **Figure 1.1**, the vegetation at the subject site and foreshore areas includes

- Mangroves,
- Mangrove-saltmarsh intergrade,
- *Juncus kraussii* saltmarsh,
- *Typha* wetland,
- *Carex* dominated wetland; and
- Exotic and revegetation plantings.

iii. Proposed Development

Conquest is seeking approval to build a multi storey residential building with a promenade and recreational areas along the foreshore.

Under the planning proposal prepared for the development, the southern half of Lot 3 DP 1239 (85 Thomas St) is to be rezoned to RE1 Public Recreation and added to the Land Reservation Acquisition Map (Local Open Space). The southern halves of Lot 15 and Lot 16 DP 1239 (89 – 91 Thomas St.) are to be dedicated to Council for addition to the Natural Resources – Biodiversity and the Natural Resources – Riparian Land Waterways zones under the Parramatta LEP.

The planning proposal has been submitted for consideration by Parramatta Council and because of the proximity of the site to the Parramatta River and associated wetlands, the Council referred the proposal to NSW Department of Primary Industries (DPI) - Fisheries NSW (hereafter "Fisheries") for consideration.

Fisheries responded and raised concerns about the potential of the proposal to shade wetlands and so impact two plant communities listed by the *Fisheries Management Act*

1994: Mangroves and Saltmarsh. In particular, Fisheries raised concerns about impacts to such vegetation within the nearby Baludarri Wetlands.

The Baludarri wetland is located in the Parramatta LGA and sits within the floodplain of the Parramatta River. The wetlands are situated on an undulating alluvial floodplain originally formed by the ancient river system draining the Wianamatta Group Shales of the Cumberland Lowlands. It comprises four vegetation communities and their intergrades being mangrove, saltmarsh, *Typha* wetlands and *Carex* dominated wetlands. The mangrove community is present along the extent of the shoreline with a narrow band of Mangrove-saltmarsh intergrade present towards the eastern extent of the surveyed cycleway. The saltmarsh occurs as a narrow band along the landward side of the mangroves and intergrades with other wetland communities and exotic vegetation. Mangrove saplings within this intergrading band suggest potential mangrove encroachment on the saltmarsh habitat. Weed encroachment also occurs from the landward side of this band. Mangrove and Saltmarsh communities are found in estuarine shoreline environments throughout the Parramatta River and Sydney Harbour. Whilst mangrove communities are relatively conspicuous, only recently have the major patches of saltmarsh been identified and mapped.

iv. Responses to Fisheries

Cumberland Ecology considered the response of Fisheries and has subsequently undertaken the following assessments on effects of shading on saltmarsh and mangroves:

- Cumberland Ecology (2016) 85-91 Thomas Street, Parramatta NSW. Saltmarsh Assessment prepared for Conquest Group of Companies (Final report 16166RP1, dated September 2016);

- Cumberland Ecology (2017) Ecological Assessment of Impact of Shading on Saltmarsh from proposed development at 85-91 Thomas Street Parramatta. Letter prepared by Cumberland Ecology Pty Ltd for NSW DPI | Fisheries NSW (Reference 16166-Let4, dated 3 March 2017);

- Cumberland Ecology (2017) Preliminary response to DPI Fisheries advice relating to impact overshadowing on coastal saltmarsh communities from a proposal to increase building height at 85-91 Thomas Street, Parramatta. Letter prepared for NSW DPI | Fisheries NSW (Reference 16166-Let6, dated 16 June 2017).

Fisheries NSW has responded to Cumberland Ecology's various assessments:

- Ganassin (2017b) Request for advice relating to impact overshadowing on Coastal Saltmarsh Communities from a potential proposal to increase building height at 85-91 Thomas Street, Parramatta. Letter issued by Carla Ganassin of NSW DPI | Fisheries NSW (Reference C17/215, dated 19 May 2017) to Parramatta City Council.

- Ganassin (2017a) Advice relating to impact of overshadowing on saltmarsh and mangrove communities from a potential proposal to increase building height at 85-91 Thomas Street, Parramatta. Letter issued by Carla Ganassin of NSW DPI |

Fisheries NSW (reference C17/310, dated 21 July 2017) to Cumberland Ecology Pty Ltd.

With regard to the most recent letter (Ganassin 2017a), a meeting was held on-site on 29 August 2017 between Fisheries, Conquest and Cumberland Ecology to discuss Fisheries' position and objections regarding the shadowing assessment undertaken to date. It was made evident by Fisheries that additional information is required.

Fisheries explained that the following information was required in order to clarify the potential impacts of shading:

- Additional examples of mangrove and saltmarsh with natural and artificial shading;
- Flora species list for areas of mangrove and saltmarsh used as examples;
- Description of the category of shading at each area of mangrove and saltmarsh used as example;
- Assessment of duration of shading at each area of mangrove and saltmarsh used as example;
- Information on edge effects caused by shadowing casted by bridges, buildings and naturally shaded saltmarshes;
- Effect of shading on saltmarsh during Spring, the growth season;
- Modification of vegetation map for the subject site to more accurately show vegetation distribution;
- Provision of additional figures showing the shading extent over vegetation communities at the subject site during Spring and Autumn;
- Provision of photographs showing shading over vegetation and including date, time, species shaded and type of shading.

This report summarises how each of these matters has been researched and dealt with by Cumberland Ecology.

Figure 1.1. Vegetation Mapping at the Subject Site

I:\...\16166\Figures\RP2\20171009\Figure 1.1. Vegetation Mapping at the Subject Site

Chapter 2

Methods

2.1 Rationale

Cumberland Ecology designed an investigation to gather robust information that could address the following questions regarding the potential negative effects of shading on mangrove and saltmarsh communities:

- Assuming that shadowing caused by man-made structures is the key factor affecting the long-term survival of mangrove and saltmarsh along the Parramatta River, is there a statistically significant difference in the number of species present in mangrove and saltmarsh areas with natural versus artificial shadowing?
- For areas where built structures exist (e.g. buildings, warehouses or other man-made structures) and produce shading over mangrove and saltmarsh vegetation:
  - Has the duration of shadowing on mangrove and saltmarsh vegetation negatively affected the number of species or the condition (vigour or health) of these vegetation communities?
  - Has the type of shadowing on mangrove and saltmarsh vegetation negatively affected the number of species or the condition (vigour or health) of these vegetation communities?
  - Have mangrove and saltmarsh vegetation communities been negatively affected so as to be of risk of local extinction?
  - Are there statistically significant differences in the number of species present in mangrove and saltmarsh areas during different seasons?

An investigation was completed to address the aforementioned questions as set out below:

2.2 Literature Review

Cumberland Ecology undertook a literature review of the effects of shading on saltmarsh and mangrove communities in previous letters and reports (Cumberland Ecology 2016, Cumberalnd Ecology 2017, Cumberland Ecology 2017). According to the information requested by Fisheries, additional information was searched for with regards to:

➢ Undertaking a literature review on effects of shading on saltmarsh and distribution of saltmarsh on the Parramatta River; and

➢ The effect of shading on saltmarsh during the Spring growth season.

The following peer reviewed scientific papers, including publications used by Fisheries as per letter C17/310 (dated 21 July 2017), were reviewed:

➢ Ball, M.C. and Critchley, C. (1982) Photosynthetic responses to irradiance by the Grey Mangrove, *Avicennia marina*, grown under different light regimes. *Plant Physiology* 90: 1101-1106.

➢ Clarke, L.D. and Hannon, N.D. (1971) The Mangrove Swamp and Salt Marsh Communities of the Sydney District: IV. The significance of Species Interaction. *Journal of Ecology* 59: 535-553.

➢ Hutchings, P. And Saenger, P. (1987) *The Ecology of Mangroves*. University of Queensland Press.

➢ Kelleway, J., Williams, R.J., and Allen, C.B. (2000). An assessment of the Saltmarsh of the Parramatta River and Sydney Harbour. NSW Department of Primary Industries: Cronulla Fisheries Research Centre of Excellence.

➢ Krauss, K.W., Lovelock, C.E., McKee, K.L., Lopez-Hoffman, L., Ewe, S.M.L. and Sousa, W.P. (2008) Environmental drivers in mangrove establishment and early development: A review. *Aquatic Botany* 89: 107-127.

2.3 Desktop Assessment of Potential Field Sites

i. Preliminary Site Selection

The following steps were taken to identify candidate sites for field investigation:

➢ Undertake a desktop review to identify areas along the Parramatta River and other wetland sites where mangrove and saltmarsh vegetation are likely to be present.

➢ Contacted Fisheries (Mr Gregory West) to obtain the shapefile of distribution of saltmarsh and mangroves across the Sydney Metropolitan Area (including the Parramatta River, Georges River and Hawkesbury River) and Greater Hunter.

➢ Prepare field maps for the selected sites. The criteria used to select sites included the following:

    - Select sites where saltmarsh and/or mangrove are likely to be present on a north-to-south aspect. This criterion was chosen because the shading to be casted by the proposed development will have a north-to-south aspect;

- Each selected site was chosen due to being mapped for mangroves and saltmarsh as well as having a significant degree of shading either from natural or artificial sources;
- Select sites where shading on saltmarsh and/or mangrove is caused by naturally occurring structures (e.g. rock cliffs, larger trees, steep slopes, etc).
- Select sites where shading on saltmarsh and/or mangrove is caused by man-made structures (such as bridges, buildings, etc.).

ii. Selected Survey Sites

Based on the desktop assessment, a total of seven sites were selected for field surveys. The locations of these sites are indicated in Figure 2.1 and Figure 2.2 and include:

- Baludarri Wetlands at Thomas Street, Parramatta;
- Bobbin Head at Ku-ring Gai Chase National Park;
- Salt Pan Creek at Salt Pan Reserve, Padstow;
- Landing Lights Wetlands, Cooks Cove;
- Blacksmith Wetlands, Blacksmith;
- Wentworth Point for Newington Reserve at Sydney Olympic Park; and
- Rhodes Park, Concord.

2.4 Field Survey and Data Collection

Cumberland Ecology's aquatic ecologist and botanist undertook the following scope of works for each site identified as likely to contain saltmarsh/mangroves:

- Use a handheld Geographic Positioning System (GPS) to record the location and extent of the saltmarsh and mangrove vegetation;
- Undertake photographic records of each site. As requested by Fisheries, for each photograph the following information will be provided: shading over vegetation, date, time, species shaded and type of shading;
- Record time of the day, man-made structures present and whether or not these are casting shadowing on the vegetation;
- Undertake a flora survey at each saltmarsh and mangrove site. The survey consisted of sampling five quadrates along a transect, as follows:
  - Transects and Plots: Each Transect consisted of five 1 m2 plots (i.e. 1m by 1m quadrates) spaced at 1 m intervals away from the shading source.

- An attempt was made to select areas where transects on a north-to-south direction were available. As mentioned above, this direction was chosen to make the data comparable to the shading to be produced by the proposed development on saltmarsh community, which will have a north-to-south aspect.

- The starting point of each transect was at the base of the shading source, except for one transect where the estuary occurred at the base of the shading source and the transect was started at the shoreline south of the shading source.

- Floristic Data: On each 1 m^2 plot, the flora species present and their respective cover abundance was collected. Wherever, bare soil and leaf litter were present, the cover abundance of these habitat elements was also recorded.

- Where available, 1m by 1m plots were surveyed to assess duration of shading. This was done by selecting two areas with no shading (as controls for no-shading), two areas with natural shadowing and two areas with artificial solid shading.

- Other environmental data that was aimed to be collected at each area included: height of plot and transect (AHD), distance of plot from the river's edge; distance of plot from the closest structure casting shadowing and slope. As requested by Fisheries, descriptions of the category of shading will also be provided; and

- Where buildings and bridges are found shadowing saltmarshes, assessment of edge effects will be undertaken. This was done by surveying two 1m by 1m plots in the shaded area and two plots of the same dimension in areas of free of artificial shading.

2.5 Statistical Methods and Analyses

2.5.1 Statistical Methods

i. Non-metric multidimensional scaling

Non-parametric statistical analyses were undertaken in software PRIMER v7 (Clarke K.R. et al. 2014, Clarke K.R. and Gorley R.N. 2015). A similarity matrix was created using Bray-Curtis index (Bray J.R. and Curtis J.T. 1957), followed by a non-metric multidimensional scaling (nMDS) ordination that constructs a "map" or configuration of the samples in two-dimensions whose inter-point distances have the same rank order as the corresponding dissimilarities between samples. The stress value of the 2-dimensions nMDS provides an indication of how well the graphic "map" of samples represents the real distribution of similarities of the samples. A rough rule of thumb for 2-dimensional nMDS is that a stress value of <0.05 gives an excellent representation with no prospect to misinterpretation, a stress value of <0.1 gives a good ordination with no real prospects of a misleading interpretation, a stress value of <0.2 still gives a potentially useful 2-dimensional picture and a stress value of >0.3 indicates that the points are close to being arbitrarily placed in the 2-dimensiional ordination space.

ii. Analysis of similarities

An analysis of similarities (ANOSIM) was undertaken to test for differences among levels of a given factor similarly to an analysis of variance, but for multivariate datasets. The routine ANOSIM of PRIMER v7 (Clarke K.R. and Gorley R.N. 2015) allows testing hypothesis of differences for one-way, two-way and three-way sets of data. Predictions were tested for cover abundance data of the species of plants using a non-parametric multivariate analysis of variance (routine ANOSIM (Clarke K.R. et al. 2014) with Bray-Curtis dissimilarities (Bray J.R. and Curtis J.T. 1957). The dissimilarities of the assemblages of plants in each 1m by 1m quadrant are graphically presented in a non-parametric multi-dimensional (nMDS) plot generated with PRIMER (Clarke K.R. et al. 2014, Clarke K.R. and Gorley R.N. 2015).

2.5.2 Statistical Analysis

i. Analysis 1: Effect of Type and Level of Shading on Saltmarsh

The hypotheses that the type of shading (natural vs. artificial) and the level of shading (high, moderate-high, moderate, low-moderate and low) affects saltmarsh communities was tested with a two-way multivariate test (nMDS and ANOSIM). Transects perpendicular to the river's edge were undertaken at locations where the level of shading reduces from high to low towards the river's edge.

A total of 18 transects were sampled (16 North-to-South and two West-to-East) in five locations –

- Thomas Street, Parramatta (the subject site),
- Bobbin Head in Ku-ring-gai Chase National Park,
- Salt Pan Creek at Padstow,
- Landing Lights Wetland in Cooks Cove and
- Blacksmith Wetlands at Blacksmith.

Each transect was 10m long and sampled approximately in a North-South direction from a shade source, the same aspect as the proposed building at the subject site. Additional West-to-East transects were sampled at Thomas Street and Salt Pan Creek for the one-way multivariate analysis. A total of five 1m by 1m quadrates were sampled along each transect. Transects were sampled at natural sources and at artificial sources of shading. Natural sources of shading were sampled at Thomas Street (three transects shaded by mature trees), at Bobbin Head in Ku-ring-gai Chase National Park (two transects shaded by mature mangroves and rock cliffs), Landing Lights Wetland (two transects shaded by small trees) and at Blacksmiths Wetlands (six transects shaded by mature trees). Artificial sources of shading were sampled near the subject site (one transect shaded by James Ruse Drive) and at Salt Pan Creek (two transects shaded by the M5 Motorway). Cover and abundance floristic data was collected from each of five 1m by 1m quadrates along the 10 m transect at 1 m intervals.

ii. Analysis 2: Effect of Aspect of Transect on Saltmarshes

It was noted that shading produced by the proposed building at the subject site would most likely shade saltmarsh located upper from the Parramatta River's edge, closer to the currently present boardwalk rather than close to the mangrove zone located adjacent to the river. It was also noted that a patch of Swamp Oaks with a west-to-east distribution is present close to the boardwalk and that saltmarsh species are present in close proximity under the Swamp Oaks. It was therefore, hypothesised that if shading by Swamp Oaks *per se* is a determining factor affecting the assemblage of saltmarsh then the assemblage of saltmarsh under Swamp Oaks sampled on a west-to-east transect would differ to the assemblage of saltmarsh species along the north-to-south transect shading gradient.

The tree transects sampled on a north-to-south aspect at the subject site is described in Analysis 1. Also, two additional transects were sampled on a west-to-east direction immediately adjacent to the Swamp Oak trees. A one-way multivariate analysis was undertaken for aspect of transect in two levels; 1. North-to-South, and, 2. West-to-East.

2.6 Shading Modelling

Fisheries requested provision of additional figures showing the shading extent over vegetation communities at the subject site for Spring and Autumn seasons.

The following scope of work was undertaken to collate the information and produce the additional figures.

- Cumberland Ecology would identified locations as having shadowing and these locations were provided to the client to engage a modeller to produce projections of shading at 9:00hrs, 12:00hrs and at 15:00hrs on a single day on each of the four seasons (Spring, Summer, Autumn and Winter).
- The Client has obtained a model of the shading extent in Spring and Autumn. That information has been subsequently provided to Cumberland Ecology.
- Cumberland Ecology added the Spring and Autumn shading on the vegetation layer to produce the following figures:
    - Shading Extent of Vegetation Communities Spring
    - Shading Extent of Vegetation Communities in Autumn

I:\...\16166\Figures\RP2\20171009\Figure 2.1. Location Sites Sydney Metropolitan Area

Figure 2.1. Location of the selected sites within the Sydney Metropolitan Area

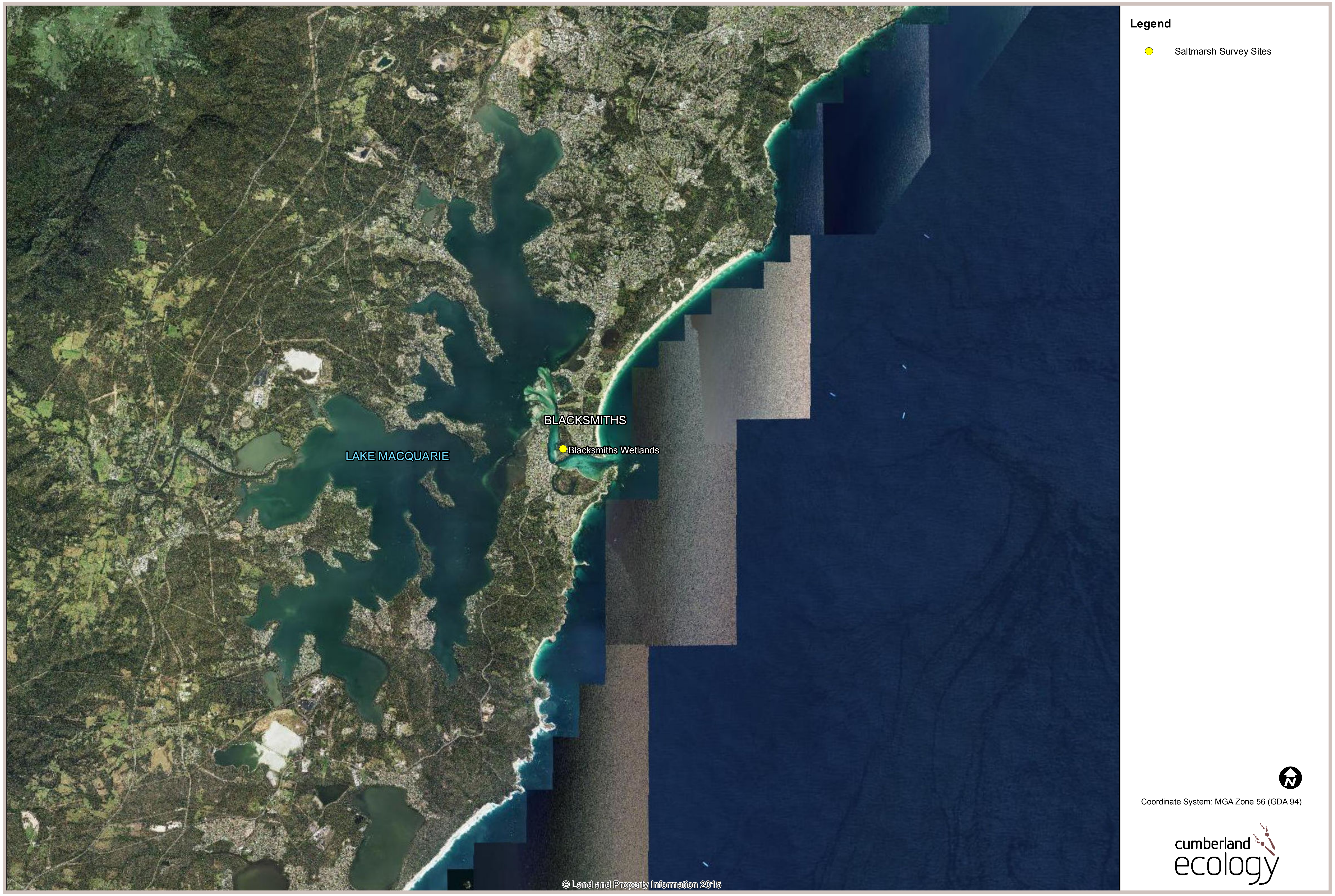

Figure 2.2. Location of the selected site within the Greater Hunter

I:\...\16166\Figures\RP2\20171009\Figure 2.2. Location Site Greater Hunter

Chapter **3**

Results

3.1 Literature Review

Cumberland Ecology undertook a review of literature regarding effects of shading on saltmarsh and mangroves. This included searching both general and topic-specific document databases with relevant search terms. This information is provided in sub-sections below.

3.1.1 Effects of Shading on the distribution of Mangrove and Saltmarsh communities

There is little literature with direct reference to the effects of shading on saltmarsh and mangroves communities though a number of documents cover shading as a contributing factor (covariate) in respect to other analyses. In general, the available literature confirms that reduced radiation can limit the productivity of wetland environments, however other factors have similar effects to shading and these effects cannot be easily discriminated from those associated with shading. These other factors include salinity, elevation and nutrient availability.

Clarke and Hannon (1971) make direct reference to the mangrove and saltmarsh communities of the Sydney district. Their study used three light intensity treatments to test species interactions typical of the zonation found in mangrove and saltmarsh communities. In brief, *Avicennia* mangroves that developed under shaded conditions were healthier though smaller than those in the full light treatments. *Aegiceras* was also favoured by shaded conditions when air temperatures increased in spring. In the field, healthy mangrove seedlings are found in shaded situations underneath the parent trees. Yellow, spotted-leaved seedlings were found in full sun in the *Arthrocnemum* (Samphire) zone. All saltmarsh species except mangroves were found to grow best at the highest light intensity. In the case of *Arthrocnemum* (Samphire) and *Suaeda* (Seablite), the requirement for high light is significant enough to play an important role in the distribution of these species since they cannot tolerate heavy shading for any length of time. Other saltmarsh species also were favoured by the highest light intensity used, but their growth was retarded rather than prevented by shading, indicating that they could survive at low intensities for long periods. Both *Juncus* and *Casuarina glauca* typically form a continuous cover with low light intensity at ground level.. As such, *C. glauca* would probably have as much difficulty in establishing under the *Juncus* cover as within established *C. glauca* stands.

A number of Northern hemisphere studies investigate the importance to passive shading on marsh surfaces though few studies address the impact of shading on the productivity of mature saltmarsh vegetation (SIBP 1997). Kearney *et al.* (1994) investigated the impacts of artificial shading on saltmarsh vegetation along the Connecticut coast. This study evaluated plant height and density under docks in order to develop methodology that could be used to define the ideal height of docks that would reduce the effect on saltmarsh vegetation. The density and average height of three dominant plant species beneath the docks were measured and compared to measurements of these species adjacent to the structure. The amount of photosynthetically active radiation (PAR, i.e. direct sunlight and reflective light) reaching plants beneath and adjacent to each structure was also measured. It was found that the height of the dock was an important factor controlling the amount of direct and reflective light reaching the vegetation under the dock. This was also apparent in the relative productivity of vegetation under and adjacent to structures. It was shown that a dock of less than 30 cm severely limited the productivity, while a height of 70 cm showed no effect to the three dominant plant species.

Kelleway *et al.* (2007) undertook a comprehensive field survey of the Parramatta River and Sydney Harbour estuary shoreline and identified a large number of saltmarsh patches. ‘Saltmarshes of all sizes could be located and mapped, regardless of canopy cover and shading, saltmarsh plant density or species composition’ (Kelleway 2007). The study found a number of areas of saltmarsh that are not mapped.

The available literature suggests the main drivers effecting the distribution of saltmarsh are salinity, elevation and nutrient availability. Complete shading is shown to exclude the community though partial shading is shown to effect productivity of certain species within salt marsh communities.

3.1.2 The impact of shading on Saltmarsh communities during the spring growth season

Huiskes et al. (1995) studied the dispersal of halophyte propagules by tidal currents in transects along the tidal gradient in a salt marsh in the Netherlands using standing nets fixed to the soil surface and floating nets. Significant interspecific differences were found in propagules caught in standing or in floating nets. The transport of propagules was mainly determined by the tidal currents: neither wind direction or speed nor the height of the high tide played a significant role. In the vegetated marsh a net upward transport of propagules with the flood currents was found. Comparatively few propagules were transported into the marsh from elsewhere with the incoming tide; a significantly higher number of propagules were transported out of the marsh with the ebb currents. There was substantial exchange of propagules within the marsh. The export of propagules especially of species growing in the lower parts of the marsh indicates a potential exchange between different salt marshes.

3.1.3 Literature used by Fisheries to provide advice

As described in Section 2.2, Cumberland Ecology reviewed the peer reviewed scientific published literature used by Fisheries (Ganassin 2017a) to provide advice on effects of shading on saltmarsh and mangrove vegetation.

The following sub-sections provide a summary of information provided in those peer reviewed documents.

i. Ball and Critchley (1982)

Ball and Critchley (1982) undertook a small study to assess the effect of shading on leaves of *Avicennia marina* at Cullendulla Creek, NSW. They collected a total of 12 seedlings, six of which were collected from a naturally exposed site and six from a naturally shaded understorey site. Those 12 seedlings were subdivided in three groups of four seedlings each, consisting of two seedlings from the naturally exposed and two seedlings from the naturally shaded sites. One group of seedlings were used to obtain gas exchange and fluorescence measurements immediately upon arrival to the laboratory on the same day of collection (25th February 1980). Another group was placed outdoor under full daylight (high light); whereas the third group was placed outdoors and beneath shade cloth in such way that only 6% incident light was available (low light). The latter two groups were watered until the third leaf pair was used for measurements. The authors found that:

- Figure 1A shows that there were variations in the quantum flux density of direct, vertical, diffuse and reflected light in the natural environment between 8:00 and 18:00 hrs on the 25th February 1980.
- Figure 1B shows that there were variations in the quantum flux density incident on the adaxial surface of experimental leaves 1 and 2 from the seedlings in the naturally exposed site. The pattern of quantum flux measured appears resembling the pattern of quantum flux in the environment (Figure 1A).
- Figure 1C shows the quantum flux incidence on leaves 1 and 2 collected from each of the seedlings sourced from the naturally shaded site. Comparison of Figure 1B and 1C shows that there is clearly less amount of light reaching leaves of seedlings in naturally shaded site compared with light incidence on leaves sourced from the naturally exposed site.
- A linear association was found between assimilation rate as a function of intercellular CO_2 concentration in leaves of A. marina seedlings collected from naturally exposed ($r = 0.99$) and naturally shaded understorey ($r = 0.96$).
- The effect of irradiance on gas exchange characteristics of leaves is provided graphically in Figure 3. The following was found:
    - There was a tendency for the average light saturated rate of assimilation in leaves grown under the low light regime to be lower than those of leaves grown under either the high light regime or under naturally exposed or naturally shaded sites. No statistically significant differences were found.
    - There were no statistically significant differences between apparent light compensation points or apparent quantum yields of naturally occurring and experimentally grown leaves despite their different light histories.
    - Stomatal conductance declined with light intensity in much the same manner as the assimilation rate. The stomatal conductance of leaves grown under

low light were significantly lower than those of leaves grown under either the high light or naturally exposed and shaded sites.

- Regarding fluorescence properties, it was found that there were no obvious effects of light conditions experienced during leaf growth on the Chl fluorescence induction kinetics.

- The authors concluded that:

  - The light environment had no effect on the light compensation point and that high and low light leaves showed no substantial differences in concentration of chlorophyll a and b. These results show that *A. marina* does not respond to light intensity in the same manner as other species and suggest that *A. marina* might have only a limited ability to acclimate to different light levels.

  - The leaves grown in the understorey shade environment possessed several attributes of shade species. However, unlike the responses of other species grown in understory conditions, both the gas exchange and chlorophyll fluorescence characteristics of the understorey leaves were undistinguishable from those on leaves grown in exposed habitats.

  - It appears that exposure to high intensity sunflecks may be sufficient to induce understory leaves to develop a photosynthetic capacity equivalent to that of exposed leaves.

The information as presented in this scientific paper clearly indicates that the Grey Mangrove (*A. marina*) does not behave in similar manner to other plant species with regards to responses to light regime. A very important point discussed therein is the role that sunflecks of full sunlight intensity have in vegetation forest with open structure, such as the open mangrove forest from which the seedlings used originated from. It notes that for individual mangrove plants grown under shading, the exposure to sunflecks appears to be sufficient for the plant to have a photosynthetic capacity similar to plants under constant exposure to full sunlight.

This is considered to be relevant for mangroves located near man-made infrastructure, such as the proposed building, where solid permanent shading of mangroves will not occur. Based on the findings of this study, it is expected that the daily and seasonal exposure of mangroves to sunflecks of full sunlight intensity would be sufficient to allow these trees to grow similarly to trees under constant exposed sunlight.

ii. Clarke and Hannon (1971)

Clarke and Hannon (1971) studied the significance of species interactions--via phytotoxic exudates, shading and associated growth--to assess their roles in causing the sharp zonation that often occurs between the dominant species of the Sydney mangrove and saltmarsh communities. Three light intensity treatments were used to test shading and species interaction typical of the zonation found in mangrove and saltmarsh communities. The growth of *Arthrocnemum australasicum* (Chenopodiaceae) was reduced and its mortality was increased in association with *Avicennia marina* or *Juncus kraussii*. The survival rate of the larger *Arthrocnemum australasicum* seedlings diminished in deep shade but not in medium shade. *Avicennia marina* seedlings showed a slight reduction in leaf production and shoot mass as a result of reduced light intensity, though, the shaded plants were very healthy and there was no reduction in survival or shoot height due to shading. This result indicates mangroves have a degree of shade tolerance and can establish under a canopy. The older *Juncus kraussii* seedlings showed a small reduction in shoot mass and survival rate due to increased shading. The younger *Juncus kraussii* showed a reduction in germination, height and vigour with increased shading, The study shows no evidence of inhibition of *Arthrocnemum* by leachates or macerates of mangrove bark, leaves or soil, but the higher light requirement of all the species of the *Arthrocnemum* zone, compared with *Avicennia* or *Juncus*, was shown to prevent their migration into the adjacent zones where these other species are dominant. No reciprocal diminution in growth or survival of *Avicennia* or *Juncus* occurred when in association with *Arthrocnemum*. Survival and growth of seedlings of both *Casuarina glauca* and *Juncus* were inhibited by the presence of a layer of *Casuarina* litter on the soil surface but not by leachates or macerates of fresh *Casuarina* cladodes or *Casuarina* litter. The biotic factor exerts an important influence on species distribution in these communities, as does salinity and waterlogging, which have been previously examined. The growth in association of dominant species from each zone along an artificial gradient of elevation, salinity, soil and waterlogging produced a species zonation pattern which closely resembled the zonation pattern that occurs in the field. An assessment is made of the factors restricting the landward and seaward migration of all the prominent species in these communities under present day conditions; consideration of the past history and future developments of these communities is foreshadowed.

iii. Hutchings and Saenger (1987)

The Ecology of Mangroves (Hutchings and Saenger 1987) is a celebrated text, part of the Australian Ecology Series, which explores the origin of mangroves, their ecology, the evolution of the community as a whole and the species it contains. It is cited within Australian literature pertaining to past, present and future changes in vegetation.

According to the text, mangrove community turn-over throughout the Quaternary Ice ages was influenced by dramatic changes in sea-level due to significant amounts of sea-water being locked up in Northern Hemisphere glaciers and the Western Ice Shelf of Antarctica. These changes influenced global distribution of mangrove and associated saltmarsh communities.

During glacial periods the available shoreline for mangrove colonisation throughout the world increased due to the drop in sea-level. Palynological records show increases in the fossil pollen of mangrove species during these long glacial periods. The patterns and processes of mangrove species have been shaped by these past processes and are reflected in their current distribution and their remarkable tolerance to saline environmental conditions.

iv. Krauss et al (2008)

Krauss *et al* (2008) reviews the eco-physiological and growth constraints to the establishment and early development of mangrove seedlings in the intertidal zone. Mangroves have a global distribution within coastal tropical and subtropical climates, and have even expanded to some temperate locales. Where they do occur, mangroves provide a plethora of goods and services, ranging from coastal protection from storms and erosion to direct income for human societies. This is a critical life stage for mangroves, i.e., the period between dispersal and recruitment to the sapling stage. Krauss *et al* (2008) begins with some of the research that has set the precedent for seedling-level eco-physiological research in mangroves, and then focuses on recent advances (circa. 1995 to present) in the understanding of temperature, carbon dioxide, salinity, light, nutrient, flooding, and specific biotic influences on seedling survival and growth. They take a new approach in describing seedling response to global factors (e.g. temperature) along with site-specific factors (e.g. salinity). All variables will strongly influence the future of seedling dynamics in ways perhaps not yet documented in mature forests. Furthermore, understanding how different mangrove species can respond to global factors and regional influences is useful for diagnosing observed mortality within mangrove wetlands, managed or natural. Krauss *et al* (2008) provides an updated eco-physiological knowledge base for future research and reforestation activity, and for understanding important links among climate change, local physio-chemical condition, and establishment and early growth of mangrove seedlings.

3.1.4 Conclusion of Literature Review

After reviewing the available literature on saltmarsh and mangrove ecology and scientific published literature used by Fisheries (Ganassin 2017a) regarding the effects of shading on saltmarsh and mangrove vegetation, we conclude the most significant factors limiting the distribution of these wetland communities are elevation, salinity and nutrient availability (Hutchings and Saenger 1987).

The most significant factor is elevation at an appropriate gradient to allow sedimentation and alluvial deposition within the intertidal zone. Salinity is an abiotic factor yet the biotic tolerance of the species that comprise these wetland communities ensures less tolerant species are excluded from the intertidal zone thus ensuring the salt-tolerant character of these communities. Finally, nutrient availability is fundamental for the turn-over from mangrove to saltmarsh communities through the capture of detritus and decaying biomass.

The available literature pertaining to the direct effects of shading on these communities is limited though indirect reference to shading and its effects have been assessed. What we do know is that most of the species in these two communities are to a degree shade-tolerant and are able to propagate under a canopy. This character is reflected in the current broad distribution and establishment of mangrove communities throughout the sub-tropical regions of the world. The occurrence of salt marsh is more complex and requires the shoreward establishment of mangrove communities to capture adequate sediments for saltmarsh to establish effectively. The dependence of saltmarsh communities on the occurrence of shoreline mangrove communities usually is accompanied by a significant mangrove canopy early in establishment. Although shade intolerant saltmarsh species are numerous, pioneering saltmarsh species are fundamental for early establishment of the community on the landward side of a mangrove canopy. For this reason shoreline disturbance, either natural or artificial, usually results in the removal of mangroves and associated saltmarsh communities. Although due to pioneering nature and high dispersal ability of mangroves and salt marsh species, once appropriate intertidal areas become available for colonisation, mangrove and saltmarsh species soon follow.

3.2 Selected Sites

The locations of the seven selected sites are shown in **Figures 2.1 and 2.2**. A summary of conditions at each selected site is provided below.

3.2.1 Baludarri Wetlands

At the Baludarri Wetlands, the shoreline is to the south and mature *Casuarina glauca* (Swamp Oak) trees provided natural sources of shading. Three transects, T1 to T3 (**Figure 3.1**), were collected at Baludarri Wetland. The James Ruse Drive Bridge over the Parramatta River shaded small pockets of saltmarsh and mangroves east of the subject site, a transect (i.e. T4, see **Figure 3.1**) was collected therein. Plot data was collected from the three naturally shaded transects and one artificially shaded transect is presented in **Table B.2**.

3.2.2 Bobbin Head

At Bobbin Head, the shoreline is toward the north and mature *Casuarina glauca* (Swamp Oak) and *Avicennia marina* (Grey Mangrove) trees provided natural sources of shading. Two transects, i.e. were surveyed at Bobbin Head. Plot data was collected from two naturally shaded transects, T1 and T2 shown in **Figure 3.2** and flora presented in **Table B.3**.

3.2.3 Salt Pan Creek

At Saltpan Creek, the shoreline is toward the north and the Motorway Bridge over Salt Pan Creek provided an artificial source of shading. Plot data was collected from two artificially shaded transects (**Table B.4**, see transects T1 and T2 in **Figure 3.3**).

3.2.4 Landing Lights Wetlands, Cooks Cove

At Cooks Cove, saltmarsh at the Landing Lights Wetland were chosen. Mature *Casuarina glauca* (Swamp Oak) and *Acacia falcata* (Hickory Wattle) trees provided natural sources of shading. Plot data was collected from two naturally shaded transects, T1 and T2 as shown in **Figure 3.4** and flora list presented in **Table B.5**.

3.2.5 Blacksmiths Wetlands

At Blacksmiths Wetlands, the shoreline is toward the north and mature *Casuarina glauca* (Swamp Oak) and *Avicennia marina* (Grey Mangrove) trees provided natural sources of shading. Plot data was collected from six naturally shaded transects, i.e. T1 to T6 shown in **Figure 3.5** and data listed in **Table B.6**.

3.2.6 Wentworth Point

As suggested by Fisheries during the meeting held on-site on the 29 August 2017, Wentworth Point was included as a site. Saltmarsh and mangrove is present at Newington Nature Reserve, which is part of Sydney Olympic Park. Floristics of saltmarsh and mangrove at Newington Nature Reserve were not collected due to access restrictions.

3.2.7 Rhodes Park

Rhodes Park is located to the north of the Concord Repatriation Hospital, Concord. At Rhodes Park, the shoreline is towards the north-east and mature *Avicennia marina* (Grey Mangrove) trees provided natural sources of shading. No transects were conducted due to the limited extent of saltmarsh. Only three 1m^2 plots on a west-east aspect were collected at this site. The saltmarsh species in these plots were *Samolus repens* and *Triglochin striata.*

Figure 3.1. Transect Locations and Vegetation Communities at Baludarri Wetlands

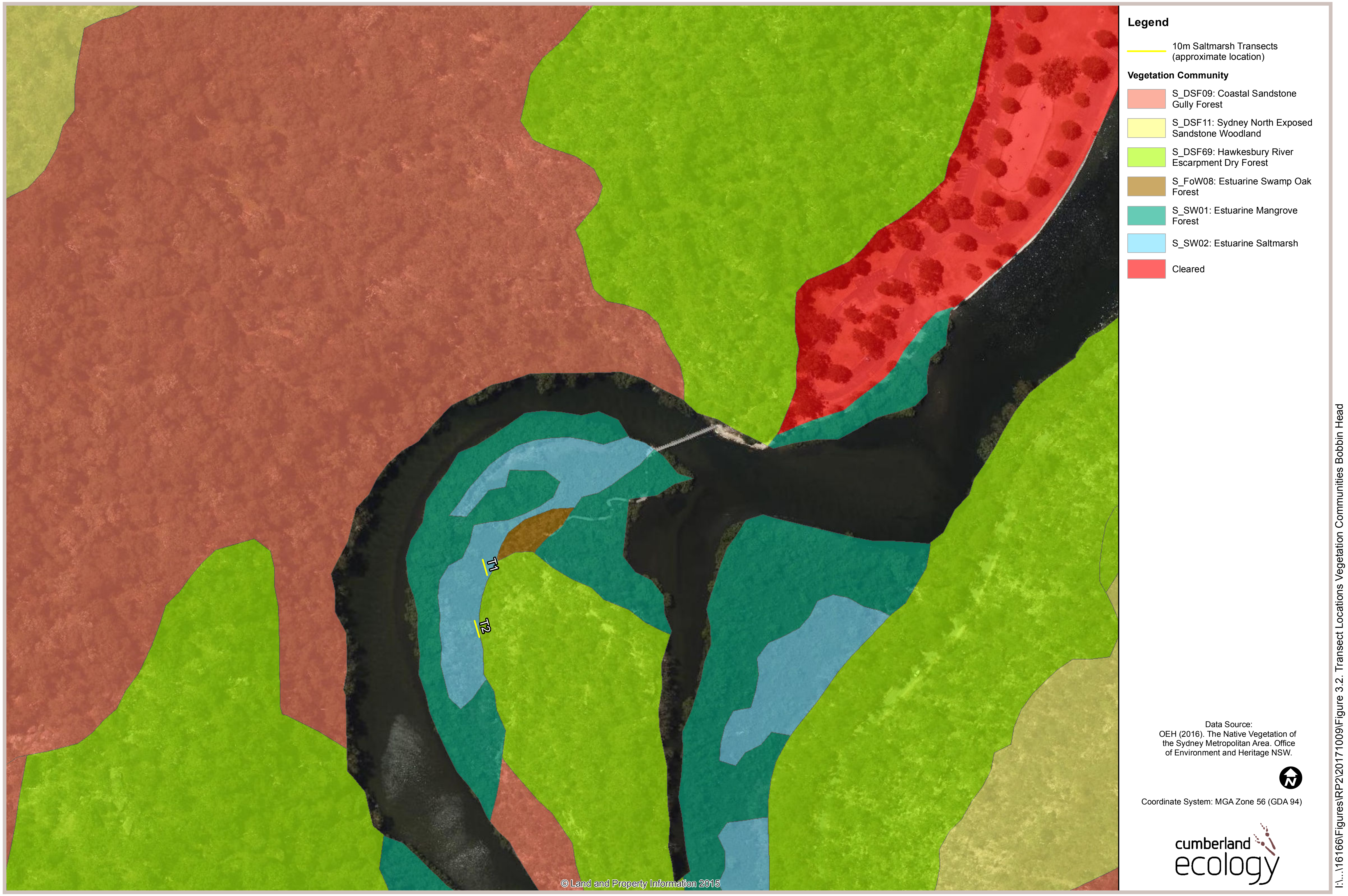

Figure 3.2. Transect Locations and Vegetation Communities at Bobbin Head

Figure 3.3. Transect Locations and Vegetation Communities at Salt Pan Creek

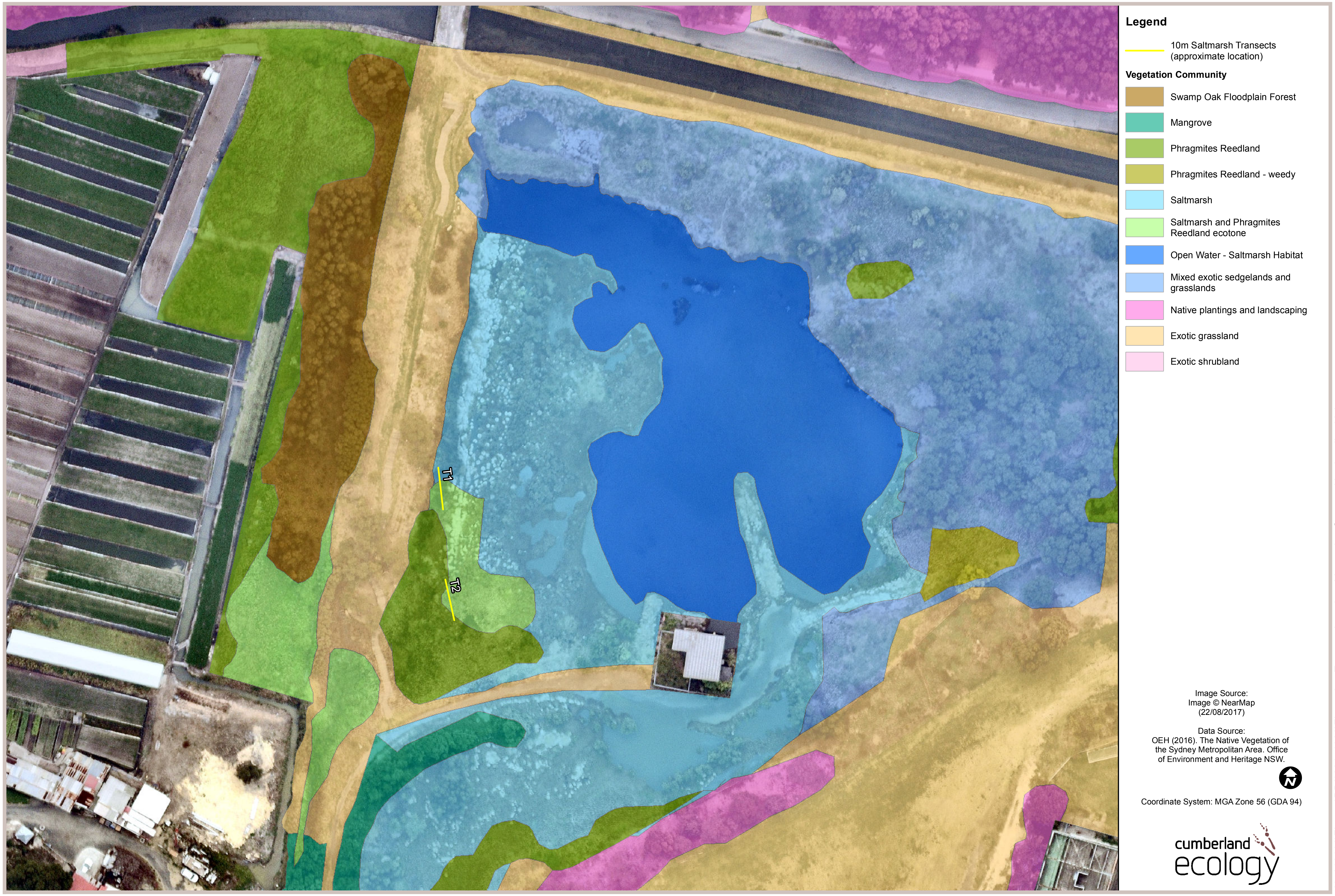

Figure 3.4. Transect Locations and Vegetation Communities at Landing Lights Wetlands

0 10 20 30 m

Figure 3.5. Transect Locations and Vegetation Communities at Blacksmith Wetlands

3.3 Field Survey

A total of 90 plots in sixteen north-to-south transects and two west-to-east transects were undertaken from five sites (Baludarri Wetland, Bobbin Head, Salt Pan Creek, Landing Lights Wetland and Blacksmith Wetland).

A summary of surveyed locations and GPS coordinates for each north-to-south transect is provided in **Table B.1 (Appendix B).**

3.4 Flora Species

A total of 61 flora species were identified throughout the five sites - 22 native and 39 exotic species. A flora list for the five sites is provided in **Table A.1** (**Appendix A**). Across the sixteen north-to-south transects surveyed at the five sites, a total of 31 flora species were identified along the 16 north-to-south transects within the five sites - 17 native and 14 exotic species. The flora list of each transect within each site is provided in **Table B.2 – B.6** (**Appendix B**).

The number of flora species present was highest at Thomas Street, followed by Salt Pan Creek, Landing Lights Wetlands, Bobbin Head and Blacksmiths Wetland. However, weeds were dominant at Thomas Street (59%), Salt Pan Creek (56%) and Landing Lights Wetlands (52%) compared to the number of native species at those sites (see **Figure 3.6**).

Flora data for each plot within transects is provided in **Tables B.2 to B.6** (**Appendix B**).

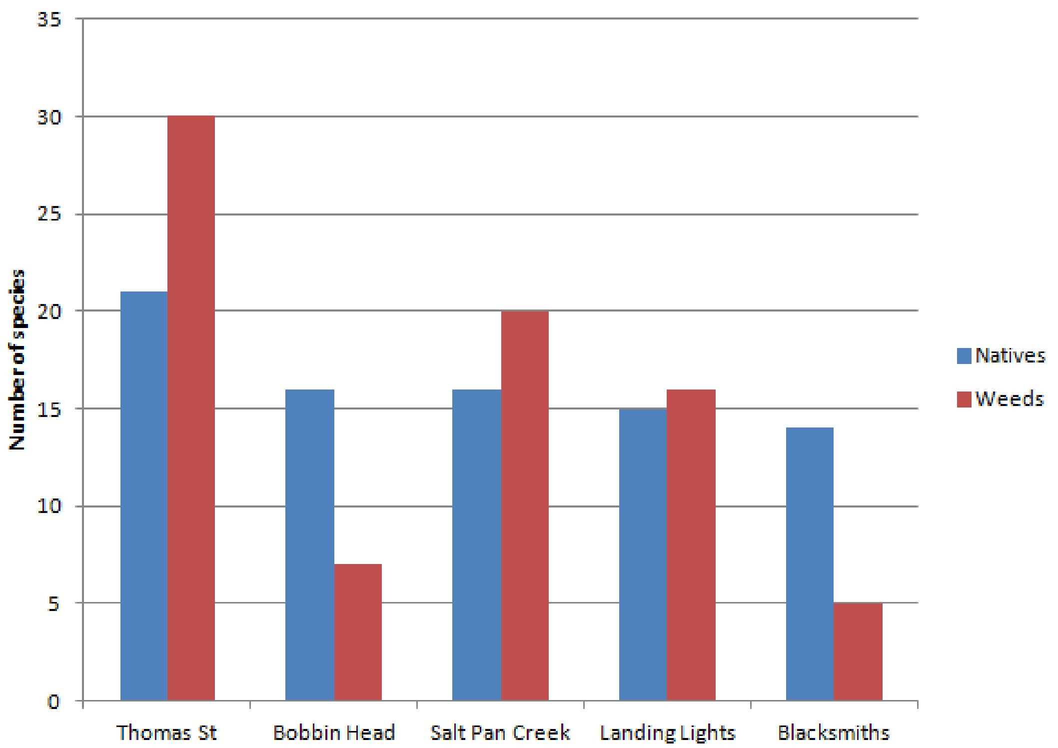

Figure 3.6 Number of native and weed species present at the five sites where north-south transects was surveyed

3.4.1 Vegetation Communities in North-South Transects

The north-south transects sampled the communities bordered by the saltmarsh with Mangrove (SW01) along the shoreline, Saltmarsh (SW02) within the intertidal and Estuarine Swamp Oak Forest (FoW08) on the landward side of the shoreline. Particular attention was payed to the respective coverage of the positive diagnostic species of each community (**Table 3.1**).

Table 3.1 The positive diagnostic species of three endangered ecological communities that were sampled during the field collection

Species Name	Common Name	Mangrove (SW01)	Saltmarsh (SW02)	Estuarine Swamp Oak Forest (FoW08)
Aegiceras corniculatum	River Mangrove	*	*	
Avicennia marina	Grey Mangrove	*	*	*
Baumea juncea				*
Casuarina glauca	Swamp Oak		*	*
Ficinia nodosa	Knobby Club-rush			*
Juncus kraussii	Sea Rush		*	*
Phragmites australis	Common Reed			*
Samolus repens	Creeping Brookweed		*	*
Sarcocornia quinqueflora subsp. quinqueflora	Samphire		*	
Suaeda australis	Seablite		*	*
Tetragonia tetragonioides	Warrigal Greens		*	*

** Denotes the positive diagnostic species of the respective community.*

i. Estuarine Mangrove Forest (SW01)

Stands of mangroves form a low closed to open forest on mudflats in Sydney's harbour, river coves and estuaries. There are two mangrove species found in Sydney. Grey mangrove (*Avicennia marina*) is the taller and more common, often seen in pure stands. Stands of grey mangrove comprise very few species other than the canopy, with the understorey mostly an open mudflat sometimes with scattered saltmarsh herbs. The second mangrove species is river mangrove (*Aegiceras corniculatum*). It is more often a small tree or shrub found scattered amongst swathes of grey mangrove or along upper reaches of coastal riverbanks. It occurs where freshwater influences from runoff or rivers cause lower salinity levels (OEH 2016).

ii. Estuarine Saltmarsh (SW02)

Saltmarshes consist of low succulent herbs and rushes on tidally inundated land. These marshes form plains that adjoin open water and mangroves. Throughout the marsh salinity varies greatly according to tidal influence, evaporation and fresh water accumulation. Some of the areas are flooded regularly, while at slightly higher elevations flooding is rare. After rain fresh water accumulates and adds extra water to the marsh, leaving pools of standing water when the tide recedes. Chenopod species dominate areas more frequently inundated by the tides, while sea rushes (*Juncus kraussii*) occupy the more elevated terrestrial margin. Local scalds occur in small depressions where intensely saline deposits accumulate from the evaporation of tidal waters preventing the growth of any plants at all (OEH 2016).

iii. Estuarine Swamp Oak Forest (FoW08)

Estuarine Swamp Oak Forest is widespread along the coast of the Sydney basin where it is rarely found at more than two meters above sea level. In the zonation from mangroves to terrestrial sclerophyll and mesophyll forests and woodlands, Estuarine Swamp Oak Forest occurs immediately above tidal influence. It fringes the margins of saline waterbodies that include rivers, lagoons and tidal lakes. Swamp oak (*Casuarina glauca*) forms dense monospecific stands above a thick ground cover of salt-tolerant herbs, rushes and sedges. The shrub layer is low-growing and sparse, comprising a mix of terrestrial species while others typical of wetlands. It is a community of relatively low species diversity (OEH 2016).

3.4.2 Baludarri Wetlands: Vegetation Communities and Shading

At Baludarri Wetlands, Mangrove, Saltmarsh and Estuarine Swamp Oak Forest were found. These vegetation communities were found to include a high proportion of weed species (59%). This is most likely due to its close proximity to urban development in addition to waste being wave deposited due to tidal and aquatic vehicle waves created along the river edge.

The James Ruse Drive Bridge over the Parramatta River shaded small pockets of saltmarsh and mangroves to the east and west from the elevated road. Plot data was collected from three naturally shaded transects and one artificially shaded transect.

At the Baludarri Wetlands, the following examples of shading were found:

- Natural Shading:
  - Baludarri Wetlands are located to the west from James Ruse Drive, including the subject site at Thomas Street. Therein, natural shading due to mature *Casuarina glauca* (Swamp Oak) trees on saltmarsh species *Suaeda australis*, *Sarcocornia quinqueflora*, *Juncus kraussii*, *Triglochin striata* and *Samolus repens* were observed (see **Photograph 3.1**).
- Artificial Shading due to the James Ruse Drive:
  - The Baludarri Wetlands are located immediately to the west of James Ruse Drive. The James Ruse Drive shades mangrove and weedy vegetation therein. Under the James Ruse Drive (north lanes), planted flora species are maintained under. This vegetation was not sampled because its occurrence is not natural.

- Janes Ruse Drive (south lanes) to the north shades mangrove vegetation present immediately to the east. A gap of bare ground exists between the elevated wall and mangroves to the east (see **Photograph 3.3**). This mangrove vegetation appears to be in good condition despite being shaded for the majority of the day by James Ruse Drive.

- The James Ruse Drive (south lanes) over the Parramatta River shaded pockets of saltmarsh and mangrove vegetation. Mangroves seedlings and young trees were observed established immediately adjacent to James Ruse Drive and in the area shaded by this elevated structure (see **Photograph 3.2**).

- A mangrove and saltmarsh vegetation patch is present to the east from the southern portion of James Ruse Drive. Both, the saltmarsh and mangrove therein are shaded by James Ruse Drive. Additionally, saltmarsh vegetation is shaded by a canopy of *Avicennia marina* (Grey Mangrove) (see **Photographs 3.4 and 3.5**).

Photograph 3.1 Baludarri Wetlands (view southwest: 27/09/2017 at 13:00 hrs.) showing the cross-section of vegetation communities and shading of *Casuarina glauca* (Swamp Oak) on saltmarsh species

Photograph 3.2 Saltmarsh and mangrove shaded by James Ruse Drive over the Parramatta River (view northwest: 27/09/2017 at 13:37 hrs.)

Photograph 3.3 Saltmarsh and mangrove shaded by James Ruse Drive over the Parramatta River (view northeast: 27/09/2017 at 13:35 hrs.)

Photograph 3.4 Pockets of saltmarsh shaded by a canopy of mangrove and James Ruse Drive over Parramatta River (view north: 27/09/2017 at 13:39 hrs.)

Photograph 3.5 Saltmarsh and mangrove communities adjacent to James Ruse Drive Bridge over the Parramatta River (view northeast: 27/09/2017 at 13:45 hrs.)

3.4.3 Bobbin Head

At Bobbin Head, Mangrove, Saltmarsh and Estuarine Swamp Oak Forest were observed. The Mangrove community was dominated by *Avicennia marina* (Grey Mangrove). The Saltmarsh community consisted of *Suaeda australis*, *Juncus kraussii, Triglochin striata*, *Ficinia nodosa, Baumea juncea and Samolus repens*. *Casuarina glauca* (Swamp Oak) were sparsely distributed amongst the rush vegetation within the higher elevations of the intertidal zone. Flora at this site had a larger number of native (70%) than weed species (30%). This is most likely due to on-going maintenance as part of Ku-ring-gai National Park. A well-used access path behind the mangrove communities displaced a portion of the saltmarsh vegetation present.

At Bobbin Head, the following examples of shading were found:

- Natural Shading: Grey Mangrove (*Avicennia marina*) and Swamp Oak (*Casuarina glauca*) trees on saltmarsh species *Suaeda australis*, *Juncus kraussii, Triglochin striata*, *Ficinia nodosa, Baumea juncea and Samolus repens* were observed (see **Photographs 3.6 and 3.7**).

Photograph 3.6 Saltmarsh shaded by *Avicennia marina* (Grey Mangrove) at Bobbin Head (view north: 26/09/2017 at 15:22 hrs.)

Photograph 3.7 Saltmarsh shaded by *Casuarina glauca* (Swamp Oak) at Bobbin Head (view northeast: 26/09/2017 at 15:56 hrs.)

3.4.4 Salt Pan Creek

At Salt Pan Creek, Mangrove and Saltmarsh were observed. The Mangrove community was dominated by *Avicennia marina* (Grey Mangrove). The Saltmarsh community consisted of *Suaeda australis*, *Juncus kraussii, Triglochin striata and Samolus repens*. Flora at this site had a larger number of weeds (56%) than native species (44%). It was observed that weed species appear to be located in gaps where direct sunlight reaches the ground under the South Western Motorway (M5). Within areas of higher shading fewer weed species were observed.

At Salt Pan Creek, the following examples of shading were found:

- Artificial Shading due to the M5 Motorway: Grey Mangrove (*Avicennia marina*) seedlings and saplings were observed within the heavily shaded area directly under the motorway (see **Photograph 3.8**). Also, saltmarsh consisting of *Triglochin striata* and *Samolus repens* diagnostic species was observed in heavily shaded conditions (see **Photographs 3.9** to **3.12**). *Suaeda australis* and *Juncus kraussii* occupied shaded areas that only were subject to brief periods of midday-sun. Interestingly, *Samolus repens* and *Triglochin striata* was excluded from these areas apparently due to an intolerance to the intensity of light as this time of day.

Photograph 3.8 Saltmarsh and mangrove communities shaded by the M5 Motorway at Salt Pan Creek (view north: 27/09/2017 at 14:58 hrs.)

Photograph 3.9 Saltmarsh and mangrove communities shaded by the M5 Motorway at Salt Pan Creek (view northeast: 27/09/2017 at 14:59 hrs.)

Photograph 3.10 Saltmarsh and mangrove communities shaded by the M5 Motorway at Salt Pan Creek (view east: 27/09/2017 at 15:00 hrs.)

Photograph 3.11 Saltmarsh and mangrove communities shaded by the M5 Motorway at Salt Pan Creek (view southeast: 27/09/2017 at 15:19 hrs.)

Photograph 3.12 Saltmarsh and mangrove communities shaded by the M5 Motorway at Salt Pan Creek (view northeast: 27/09/2017 at 15:09 hrs.)

3.4.5 Landing Lights Wetlands, Cooks Cove

At the Landing Light Wetlands, Saltmarsh vegetation was observed. The saltmarsh community consisted of *Suaeda australis, Sarcocornia quinqueflora, Juncus kraussii and Baumea juncea*. Flora at this site had a larger number of weeds (52%) than native species (48%). This site appears to have a long history of disturbance as judged by the presence of demolition waste, e.g. bricks, bitumen, concrete, metals, plastic etc. The site appears to be subject to a vegetation management plan because, around the periphery of the wetlands, revegetation and cultivation of endemic species was evident.

At Landing Lights Wetland, the following examples of shading were found:

- Natural Shading due to a sub-canopy of *Acacia falcata* (Hickory Wattle) and *Casuarina glauca* (Swamp Oak) trees over a saltmarsh community consisting of *Suaeda australis, Sarcocornia quinqueflora, Juncus kraussii and Baumea juncea* (see **Photographs 3.13, 3.14** and **3.15**).

- Artificial shading due to a Red-brick structure over a saltmarsh community consisting of *Suaeda australis, Samolus repens* and *Casuarina glauca* (see **Photographs 3.16**).

Photograph 3.13 Shading of saltmarsh by *Acacia falcata* (Hickory Wattle) at Landing Lights Wetlands (view south: 27/09/2017 at 16:52 hrs).

Photograph 3.14 Shading of saltmarsh by *Casuarina glauca* (Swamp Oak) at Landing Lights Wetlands (view southeast: 27/09/2017 at 16:52 hrs).

Photograph 3.15 Shading of saltmarsh by *Casuarina glauca* (Swamp Oak) at Landing Lights Wetlands (view southeast: 14/07/2016 at 16:04 hrs).

Photograph 3.16 Artificial shading of saltmarsh by structure at Landing Lights Wetlands (view north: 14/07/2016 at 12:52 hrs).

3.4.6 Blacksmiths Wetlands

At Blacksmiths Wetlands, the shoreline is toward the north and mature *Casuarina glauca* (Swamp Oak) and *Melaleuca quinquenervia* (Broad-leaved Paperbark) trees provided natural sources of shade. Plot data was collected from six naturally shaded transects.

At Blacksmiths Wetlands, Mangrove, Saltmarsh and Estuarine Swamp Oak Forest were surveyed. The mangrove community was dominated by *Avicennia marina* (Grey Mangrove). The Estuarine Swamp Oak Forest consisted mainly of *Casuarina glauca* (Swamp Oak) and *Melaleuca quinquenervia* (Broad-leaved Paperbark). The saltmarsh community consisted of *Juncus kraussii*, *Samolus repens*, *Lomandra longifolia*, *Lobelia anceps*, *Chorizandra cymbaria* and *Baumea juncea*. Flora at this site had a larger number of native (74%) than weed species (26%).

At Blacksmiths Wetlands, the following examples of shading were found:

- Natural Shading due to a canopy trees of *Casuarina glauca* (Swamp Oak) and *Melaleuca quinquenervia* (Broad-leaved Paperbark) over a saltmarsh community of *Juncus kraussii*, *Samolus repens*, *Lomandra longifolia*, *Lobelia anceps*, *Chorizandra cymbaria* and *Baumea juncea* (see **Photographs 3.17** to **3.19**).

Photograph 3.17 Shading of saltmarsh by *Melaleuca quinquenervia* (Broad-leaved Paperbark) and *Casuarina glauca* (Swamp Oak) at Blacksmiths Wetlands (view northeast: 27/09/2017 at 15:20 hrs)

Photograph 3.18 Shading of saltmarsh by *Casuarina glauca* (Swamp Oak) at Blacksmith Wetlands (view southeast: 7/09/2017 at 15:25 hrs).

Photograph 3.19 Shading of saltmarsh by *Casuarina glauca* (Swamp Oak) at Blacksmith Wetlands (view southeast: 7/09/2017 at 15:33 hrs).

3.5 The effect of shading on the distribution of Saltmarsh

i. Analysis 1: Effect of Type and Level of Shading on Saltmarshes

The nMDS map of the dispersion of 1m by 1m quadrates (see **Figure 3.7**) shows that there is overlap in distribution of quadrates from saltmarsh in naturally shaded and artificially shaded locations. The level of dispersion had a stress value of 0.08, which suggest that the quadrats are close to being arbitrarily placed in the 2-dimensional nMDS map.

There were no statistically significant differences in assemblages of plant species sampled in naturally shaded vs. artificially shaded plots (ANOSIM, average R = 0.198, significance level statistic 0.3%). Similarly, there were no statistically significant differences in assemblages of plants sampled in 1m by 1m quadrates at different level of shading (see **Figure 3.8**; ANOSIM, average R = -0.021, significance level statistic 79.6%).

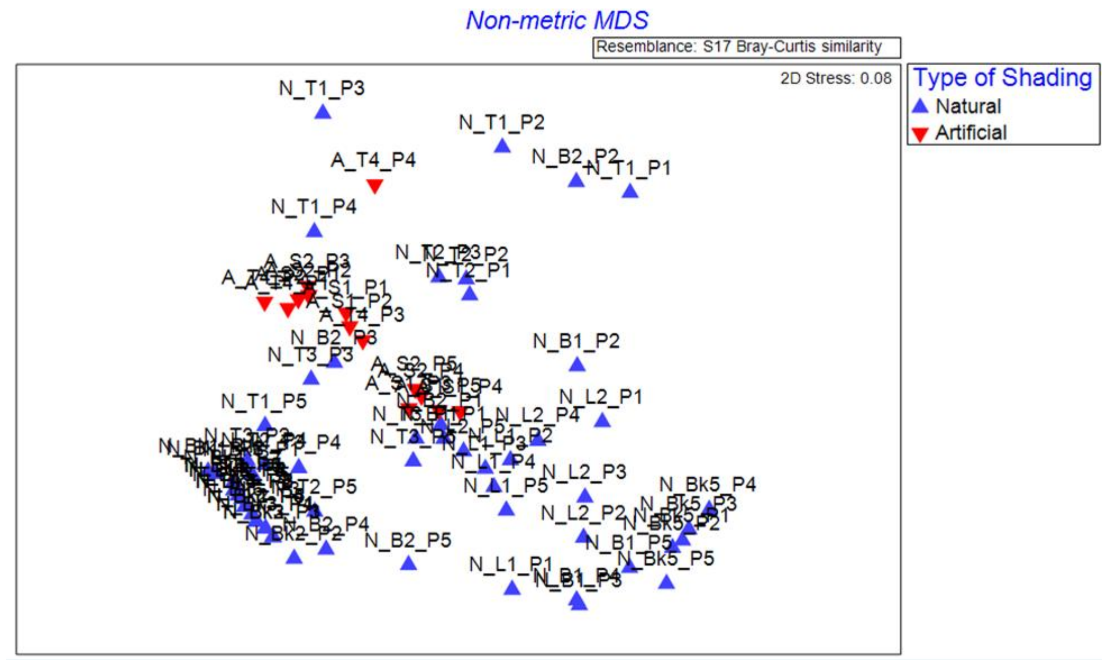

Figure 3.7 nMDS of saltmarsh assemblages in naturally occurring and artificially shaded plots (stress = 0.08).

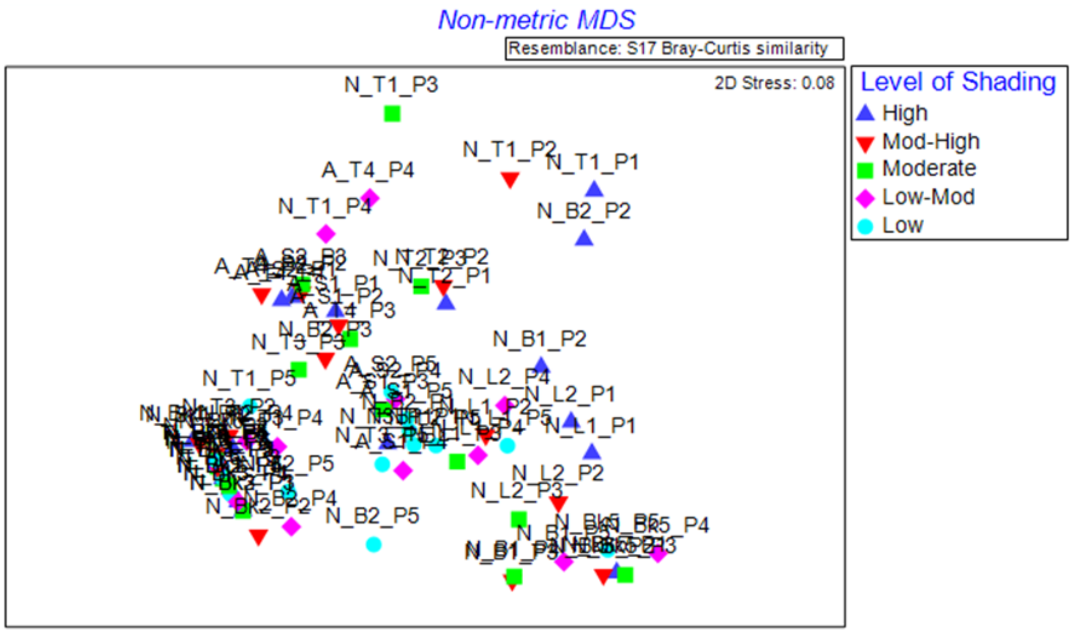

Figure 3.8 nMDS of saltmarsh assemblages in plots at different levels of shading (stress = 0.08)

The above results indicate that the assemblages of species in saltmarsh vegetation surveyed at different levels of shading and in naturally versus artificially shaded plots are not different, in spite of some sites, e.g. James Ruse Drive and Salt Pan Creek, being shaded by man-made structures. The presence of saltmarsh species under the M5 Motorway at Salt Pan Creek suggests that even in conditions of solid shading, saltmarsh species are present.

ii. Analysis 2: Effect of Aspect of Transect on Saltmarsh

The nMDS map of the dispersion of 1m by 1m quadrats (see **Figure 3.9**) shows that there is overlap in distribution of quadrats from transects with North-to-South and West-East aspect. The level of dispersion had a stress value of 0.1, which suggest that the quadrats are close to being arbitrarily placed in the 2-dimensional nMDS map.

There were no statistically significant differences in assemblages of plant species sampled along transects with North-to-South and West-to-East aspect (ANOSIM, average R = 0.035, significance level statistic 24.1%).

These results suggest that the aspect of shading is not a main factor affecting the presence of saltmarsh species. Saltmarsh species are present in areas shaded on a north-south and west-east aspect and their assemblages of species are not different. Other factors, whether environmental and/or biological might be synergistically acting and influencing the patterns of distribution of saltmarsh, but aspects of shading per se does not appear to be a determining factor.

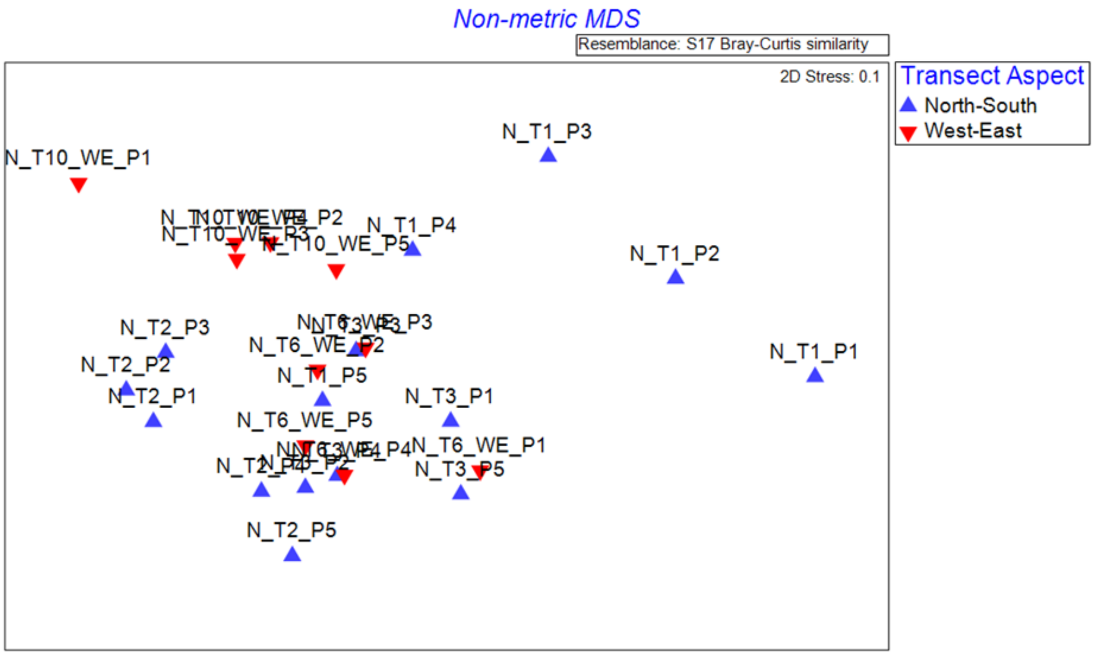

Figure 3.9 nMDS of saltmarsh plots in transects sampled with a North-South and West-East aspect (stress = 0.1)

3.6 Shading Modelling

As requested by Fisheries at the on-site meeting held on 29 August 2017, shading modelling for all seasons is provided for the subject site (see **Figure 3.10 to 3.13**). Shading by the proposed development will occur:

- Shading during the winter months:

- Saltmarsh: A small portion of saltmarsh will be shaded at 9:00am and 12:00hrs.
- Mangrove: A moderate area of mangrove will be shaded at 9:00, with a much smaller area to be shaded at 12:00hrs and 15:00hrs.

➢ Shading in Spring:

- Saltmarsh: An insignificant area of saltmarsh will be shaded at 9:00hrs. No shading will occur at other time of the day.
- Mangrove: no shading will occur.

➢ Shading in Summer:

- Saltmarsh: no shading will occur.
- Mangrove: no shading will occur.

➢ Shading in Autumn:

- Saltmarsh: An insignificant are of saltmarsh will be shaded at 9:00hrs. No shading of saltmarsh will occur at other times of the day.
- Mangrove: no shading will occur.

No comparable sites were found that justified additional modelling, although, the plot data collection along transects of high to low shading, and subsequent statistical analysis, offer a downscaled example of the effect of shading on these two communities.

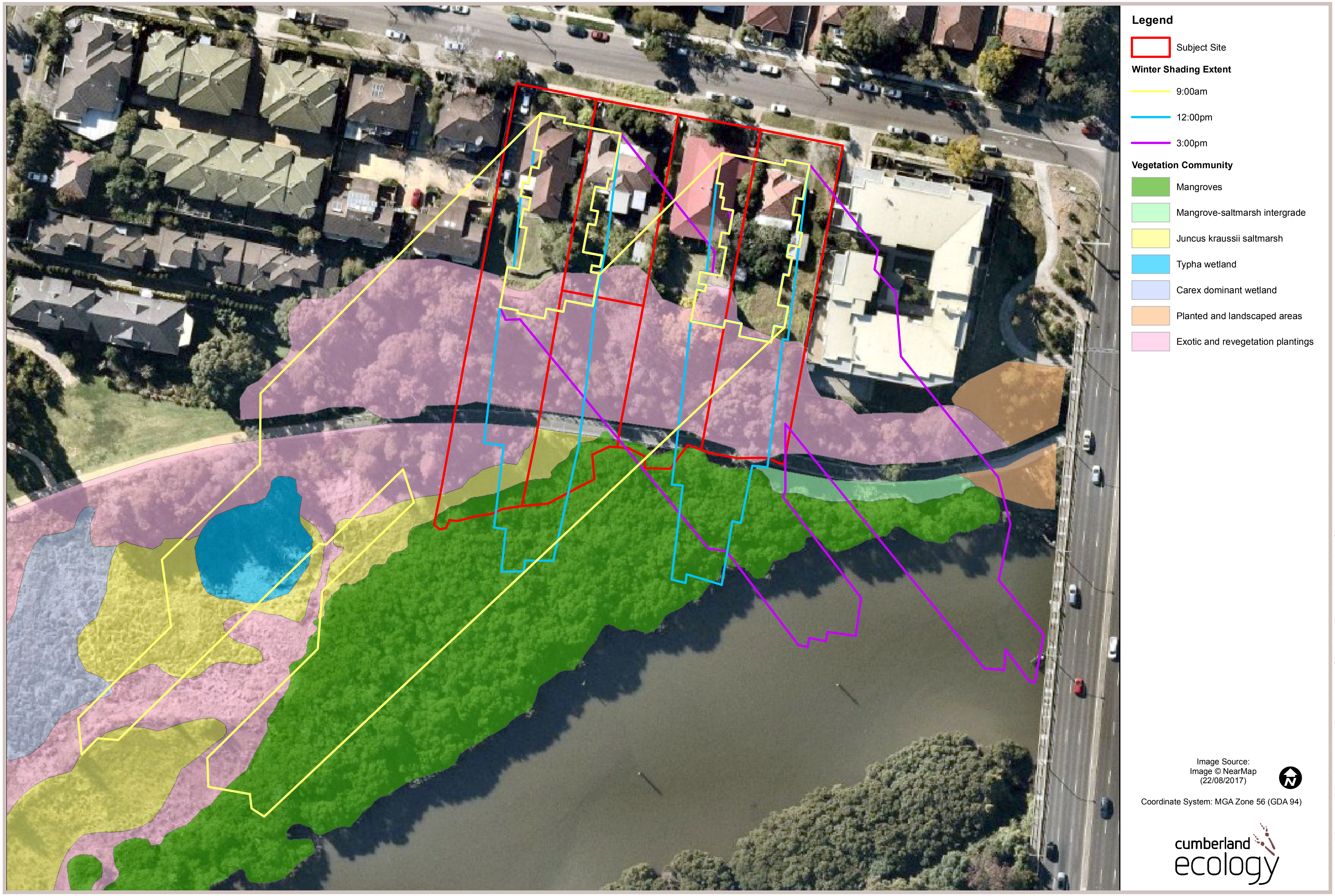

Figure 3.10. Shading Extent of Vegetation Communities during Winter

Figure 3.11. Shading Extent of Vegetation Communities during Summer

I:\...\16166\Figures\RP2\20171009\Figure 3.11. Shading Extent Vegetation Communities Summer

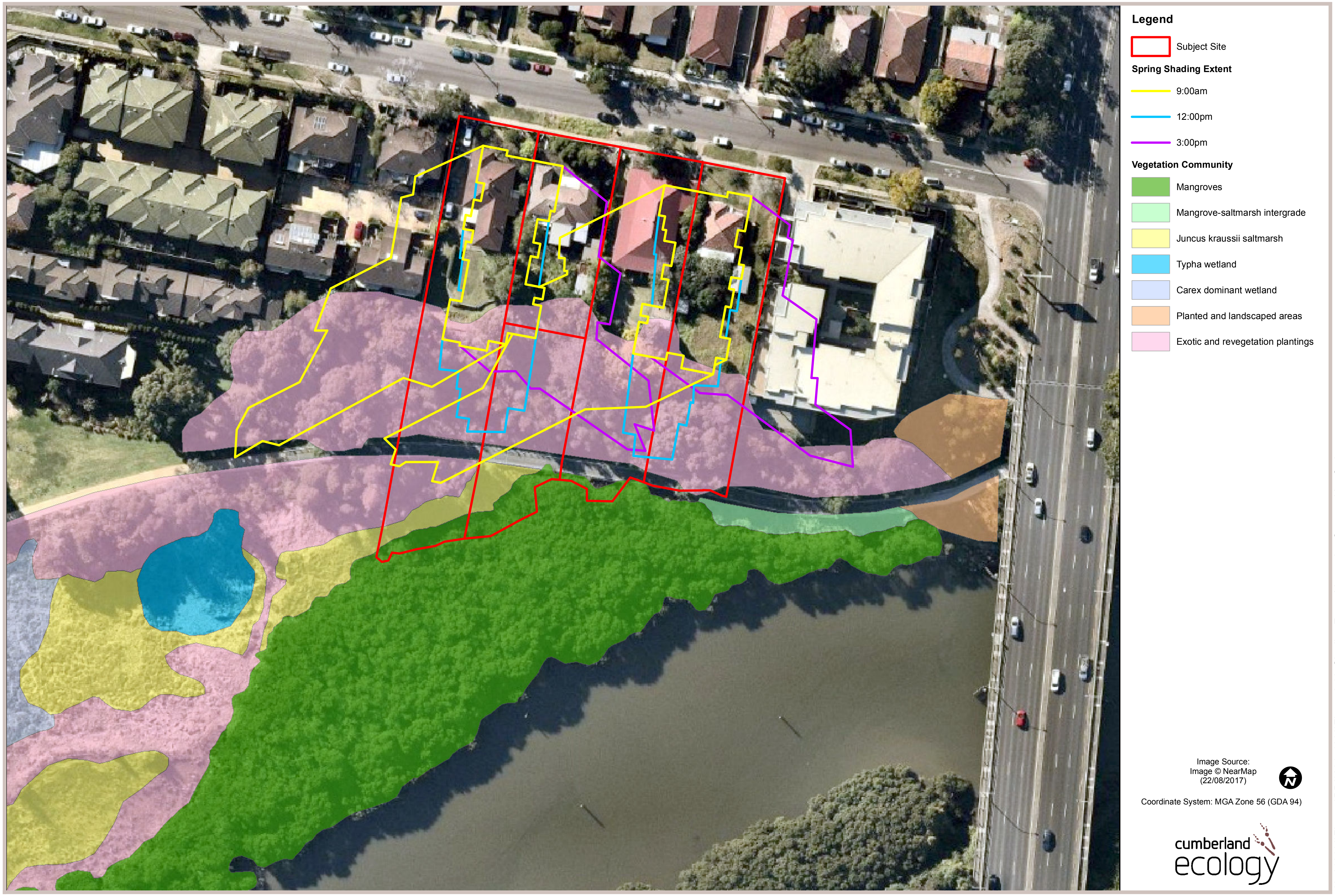

Figure 3.12. Shading Extent of Vegetation Communities during Spring

0 10 20 30 m

I:\...\16166\Figures\RP2\20171009\Figure 3.12. Shading Extent Vegetation Communities Spring

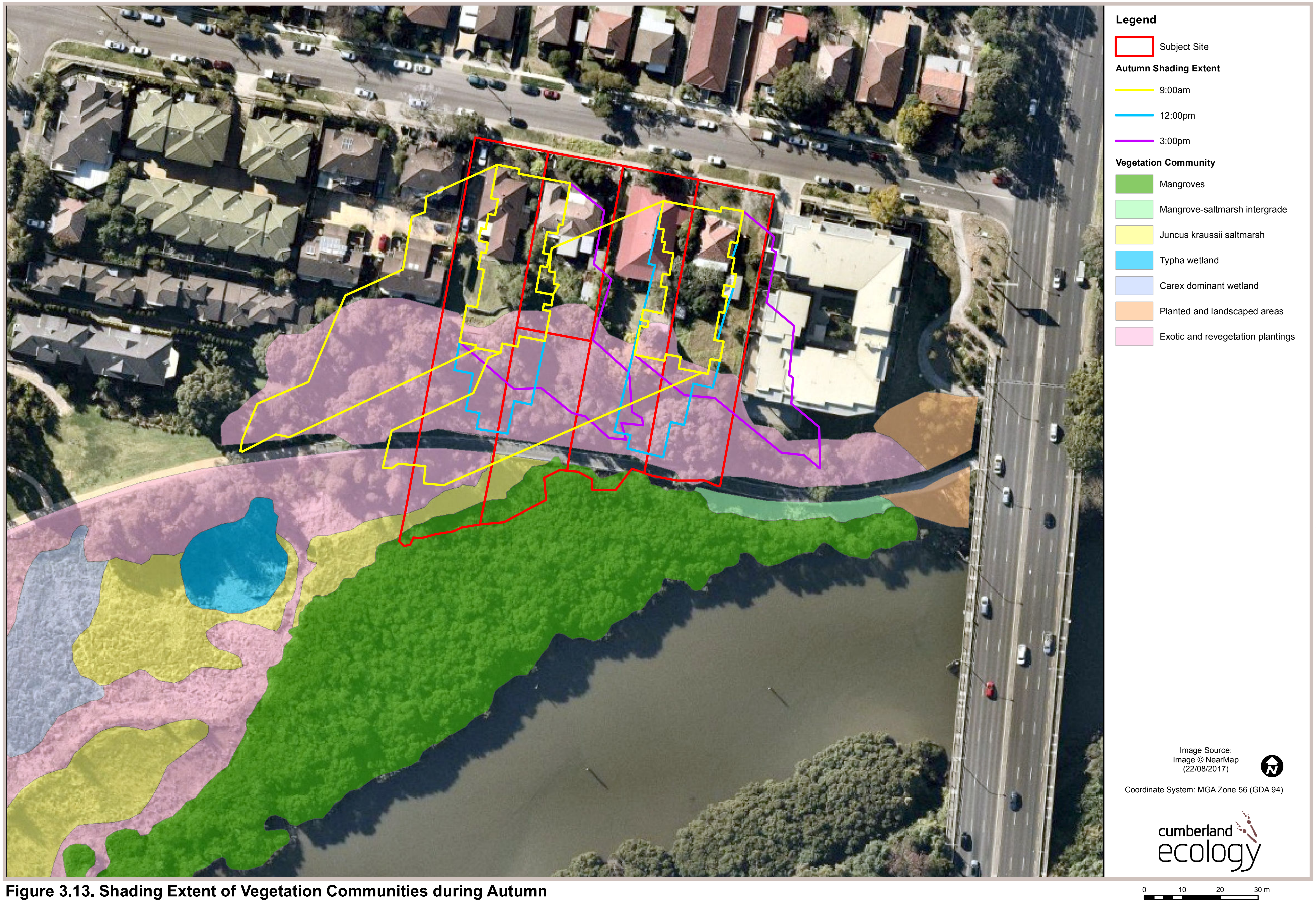

Figure 3.13. Shading Extent of Vegetation Communities during Autumn

I:\...\16166\Figures\RP2\20171009\Figure 3.13. Shading Extent Vegetation Communities Autumn

Chapter 4

Saltmarsh and Mangrove Vegetation at the Subject Site

4.1 Amended Vegetation Mapping at Baludarri Wetland

Cumberland Ecology previously prepared vegetation mapping for Baludarri Wetlands (subject site) and foreshore area at the subject site (**Figure 1.1**). As requested by Fisheries during the on-site meeting held on 29 August 2017, additional surveys were undertaken to update the vegetation mapping at the subject site. It was found that the vegetation mapping previously undertaken (i.e. **Figure 1.1**) is accurate and modification of the vegetation mapping was not required.

Effects of Shading on Saltmarsh Vegetation

5.1 Saltmarsh and Mangrove Assemblages in Natural versus Artificially Shaded Areas

Cumberland Ecology endeavoured to address the question "Is there a statistically significant difference in the number of species present in mangrove and saltmarsh communities within areas affected by natural versus artificial shadowing?" The assumption that partial shadowing caused by man-made structures is the main driver affecting the long-term survival of mangrove and saltmarsh along the Parramatta River is addressed. The two diagnostic species of mangrove communities occurred at every site and in the two shade condition. For this reason, special attention has been payed to the eight diagnostic species of saltmarsh communities and the driver affecting their distribution.

5.1.1 Data Availability

A total of sixteen transects in saltmarsh communities were analysed as described in **Section 3.5**. The transects attempted to collect the cross-section of floristic change from the edge of the mangrove communities along the shoreline to the landward side of the inter-tidal zone - in most cases represented by Estuarine Swamp Oak Forest. The raw data is available for each site where transects data was collected in Appendix B (see **Table B.2 – B.6**).

5.1.2 Mangroves

Transects in mangrove areas were not undertaken as no sites with naturally occurring shading on mangroves were found. The mangroves present under James Ruse Drive appear to be in good health (i.e. colour and vigour visually observed) and similar to mangroves in non-shaded areas. Similarly, mangroves observed growing under the M5 Motorway (at Salt Pan Creek site) appear to have similar colour and vigour than mangroves present in non-shaded areas at Salt Pan Creek. Both diagnostic mangrove species were observed to propagate underneath a canopy or man-made structure.

5.1.3 Saltmarsh

As showed in Section 3.5, representative cover in 1 x 1 m quadrates of diagnostic saltmarsh species were surveyed along transects in both natural and artificial shade conditions. Results of nMDS and ANOSIM statistical analyses indicate no significant differences between assemblages of saltmarsh surveyed under naturally shaded *versus* assemblages under artificially shaded conditions. Also, no statistically significant differences were found amongst plots sampled at five differing levels of shading (P1 High, P2 Medium-High, P3 Medium, P4 Low-Medium and P5 Low shading).

5.2 Saltmarsh and Mangrove Assemblages and Duration of Shadowing

Cumberland Ecology proposed to assess the following question:

> *Has the duration of shadowing on mangrove and saltmarsh vegetation negatively affected the number of species or the condition (vigour or health) of these vegetation communities?*

5.2.1 Data limitations

Cumberland Ecology was unable to find more than three locations where shading by man-made structures co-occurred with natural shading and the wetland communities under study. Therefore, statistical analysis testing for differences in saltmarsh and/or mangrove vegetation cover area in plots/transects shaded by man-made structures, naturally shaded and non-shaded was not balanced. Two locations where permanent shading was observed occurred at James Ruse Drive bridge (Baludarri Wetlands) and at the M5 Motorway (Salt Pan Creek).

5.2.2 Mangroves

At James Ruse Drive, mangrove seedlings and young trees were observed growing/established at close proximity to the bridge and in area expected to be shaded on a daily and seasonal basis in accordance with sun movement.

Similar observations were made at the M5 Motorway intersection with Salt Pan Creek, where mangrove seedlings and young trees are present in areas expected to be daily and seasonally shaded under the M5 Motorway.

The above described observations suggest that permanent non-solid shading produced by man-made structures such as elevated road and bridges do not preclude the establishment and growth of mangrove communities.

5.2.3 Saltmarsh

At James Ruse Drive, saltmarsh was found to be shaded by James Ruse Drive and a canopy of *Avicennia marina* (Grey Mangrove). The saltmarsh community consisted of native *Aegiceras corniculatum, Avicennia marina, Suaeda australis* and *Samolus repens* and included exotic *Rubus fruticosus sp. agg., Ageratina riparia, Lantana camara, Parietaria judaica* and *Ipomoea cairica*. The character of shading on this saltmarsh would be from both permanent solid shading from James Ruse Drive and non-solid shading by a mature mangrove canopy. In spite of this high level of shading, saltmarsh vegetation was diverse and appeared to have good health and vigour.

Similarly, at the M5 Motorway intersection with Salt Pan Creek, the saltmarsh community under the motorway consisted of native *Juncus kraussii, Triglochin striata, Avicennia marina, Suaeda australis* and *Samolus repens*. The health and vigour of the saltmarsh species was similar to individuals growing in non-shaded areas within the same site.

A naturally shaded saltmarsh community found at Concord, consisted of *Triglochin striata, Avicennia marina, Suaeda australis* and *Samolus repens* and again represented a diverse saltmarsh community despite being heavily shaded.

The above described observations suggest that the permanent solid shading produced by man-made structures such as elevated road and bridges do not preclude the establishment and growth of saltmarsh communities. Interestingly, the diagnostic species *Triglochin striata* and *Samolus repens* were shown to be light sensitive and were excluded from areas of direct sunlight. Furthermore, patches of saltmarsh with similarly low number of characteristic saltmarsh species can be found in naturally heavily shaded conditions such as those observed at Concord. This suggests that the composition of saltmarsh species at any given point is most likely a result of the concurrent effect of several factors (i.e. salinity, elevation, nutrient availability) rather than just shading. Furthermore, the high dispersal ability of mangroves and saltmarsh species enables early-establishment of disturbed areas and this pioneering nature ensures a regular influx of propagules into shade affected environments. Therefore, it is not considered that shading is the main driver of saltmarsh distribution and, with partial light availability, shading is unlikely to restrict the establishment or negatively affect saltmarsh communities to such an extent as to put this community at risk of local extinction.

Chapter 6

Impact Assessment

An assessment of significance on the effects of shading on saltmarsh have been undertaken and is provided in **Appendix C**. It has been concluded, that the impact that the partial shading the proposed development will create on the Baludarri Wetland has been inferred though modelling to be negligible. This is the case because the proposed development will cast non-solid shading on a small portion of the saltmarsh during winter months. Therefore, it is considered that the limited amount of shading likely to be produced from the proposed development will not significantly impact upon reproduction and regeneration by either saltmarsh or mangrove plants. This is for two reasons. First, the limited shading is not likely to curtail flowering or seed set by characteristic species of mangroves and saltmarsh. Secondly, even if shading did have such an impact, propagules of mangroves and saltmarsh are largely water dispersed. As such propagules from upstream or downstream in less shaded environs would therefore be able to colonise the partially shaded areas.

Circumstantial evidence from other sites that were examined indicate that the dispersal mechanisms and pioneering character of the species comprising these communities has apparently enabled the distribution of the two communities to occupy both natural and artificial shaded environments. Sites shaded by elevated structures throughout part of the day did not lack mangrove and saltmarsh diagnostic species.

It is recognised that the assessment of mangrove and saltmarsh productivity undertaken here is done so indirectly through the study of species diversity and representative vegetation cover. No measures of photosynthesis were taken from the plants present in each shading condition as this was not part of the scope of the study. It is anticipated that changes in ecosystem productivity may occur as a result of the proposed development though the potential loss of productivity would be insignificant and most likely undetectable.

Chapter 7

Mitigation Measures

The results of this investigation indicate that the impacts of shading are likely to be insignificant and may not be detectable. For this reason, mitigation measures or offsetting are not likely to be required. However, should it be determined that some precautionary measures are required, mitigation measures may involve increased monitoring and weed management of the Baludarri Wetland.

While on site significant areas of weed infestation were observed. Interestingly, these infestations were in areas with no sources of shading. We also observed at the other sites under study that increased sunlight often was accompanied with increased prevalence of weeds. A thorough weed management program at the Baludarri Wetlands would allocate more resources (i.e. nutrient and habitat availability) to the wetland communities present and may offset the potential small loss of productivity incurred as a result of the proposed development.

Chapter 8

Conclusions

The information gathered as part of this investigation suggest that the limited partial shading to be produced by the proposed development on the Baludarri Wetland will not significantly negatively impact the distribution of the diagnostic species of either mangrove or salt marsh communities.

Detailed analysis of shadow diagrams shows that the proposed development will only shade the wetlands for part of each day (several hours) all winter, and for half of spring and half of autumn. Shading will not occur for the warmer months of the year (half of spring, half of autumn and all summer). This will result in the shading to be produced at any one spot on the wetlands in winter (i.e. during the worse time of year) effectively be for a minimal period of time, most likely a few minutes. This would mean a reduction in just direct sunlight and does not account for the significant amount of reflective light that the surrounding structures and vegetation would provide. Therefore, it is considered that the net amount of shading to be produced over the wetlands by the proposed development will be minimal.

To compare this scenario we undertook a comprehensive field survey and data collection to elucidate the effect of shading from both natural and artificial sources at seven locations in the Sydney Metropolitan Area and Greater Hunter. Examination of a variety of existing riparian areas beside artificial structures (bridges and walkways), and natural vegetation (tall trees and shrubs with dense canopies) revealed:

- near-complete shading throughout the day (and year) did not excluded mangrove and saltmarsh communities. Although a reduction in number of species is apparent in areas beneath bridges and closed low-elevation walkways, these areas were not completely denuded of both communities;

- full-midday sun for extended periods excluded some diagnostic species of saltmarsh communities; and

- partial shading at certain times of day throughout the year from either natural or artificial sources (dense tall trees) was found not be statistically different. This is, shading did not significantly negatively impact saltmarsh or mangrove communities.

The above listed observations suggest that shading is not the most important factor affecting the distribution of saltmarshes in shaded areas. In congruence with peer review literature, it is expected that other factors, such as salinity, elevation and nutrient availability are factors most likely determining the patterns of distribution of this wetland vegetation community.

Circumstantial evidence from other sites that were examined indicate that the dispersal mechanisms and pioneering character of the species comprising these communities has apparently enabled the distribution of the two communities to occupy both natural and artificial shaded environments. Sites shaded by elevated structures throughout part of the day did not lack mangrove and saltmarsh diagnostic species.

Considering the data analysis conducted and the examples of artificial and natural shading found in this study, we conclude that partial shading at certain times of the day is not a major driver of these communities and the plants they contain.

An assessment of significance was completed as required under Section 5A of the *Environmental Planning and Assessment Act 1979* to demonstrate that no significant detrimental impact was likely upon saltmarsh. This concluded no significant impact was likely and that no Species Impact Statement was warranted.

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Appendix A

Flora List

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Table A.1 Flora list from the five sites where North-South transects data was collected.

Form and Family	Status	Scientific Name	Common Name	Baludarri Wetlands	Bobbin Head	Salt Pan Creek	Landing Lights Wetlands	Blacksmiths Wetlands
Sub-canopy								
Acanthaceae		*Avicenna marina* subsp. *australasica*	Grey Mangrove	X	X	X	X	X
Casuarinaceae		*Casuarina glauca*	Swamp Oak	X	X	X	X	X
Fabaceae (Mimosoideae)		*Acacia falcata*	Hickory Wattle				X	
Shrubs								
Acanthaceae		*Avicenna marina* subsp. *australasica*	Grey Mangrove	X	X	X	X	X
Primulaceae		*Aegiceras corniculatum*	River Mangrove	X	X	X		X
Casuarinaceae		*Casuarina glauca*	Swamp Oak	X	X		X	
Pittosporaceae		*Pittosporum undulatum*	Sweet Pittosporum	X	X	X		
Pittosporaceae		*Pittosporum revolutum*	Rough Fruit Pittosporum		X			
Verbenaceae	*	*Lantana camara*	Lantana	X				X
Sapindaceae		*Cupaniopsis anacardioides*	Tuckeroo	X				
Herbs - Climbers								
Rosaceae	*	*Rubus fruticosus* sp. agg.	Blackberry	X		X		

Table A.1 Flora list from the five sites where North-South transects data was collected.

Form and Family	Status	Scientific Name	Common Name	Baludarri Wetlands	Bobbin Head	Salt Pan Creek	Landing Lights Wetlands	Blacksmiths Wetlands
Sapindaceae	*	*Cardiospermum grandiflorum*	Balloon Vine	X				
Fabaceae (Faboideae)		*Kennedia rubicunda*	Dusky Coral Pea	X				
Dicots (Herbs)								
Asparagaceae	*	*Asparagus aethiopicus*	Ground Asparagus	X		X	X	
Asteraceae	*	*Ageratina riparia*	Mistflower	X			X	
Asteraceae	*	*Cotula coronopifolia*	Water Buttons	X			X	
Aizoaceae		*Tetragonia tetragonioides*	New-Zealand Spinach	X	X	X	X	
Apiaceae	*	*Apium graveolens*	Sea Celery	X			X	
Apiaceae	*	*Cyclospermum leptophyllum*	Slender Celery	X		X		
Apiaceae	*	*Foeniculum vulgare*	Fennel	X				
Araliaceae	*	*Hydrocotyle bonariensis*	Large-leaf Pennywort			X	X	
Asteraceae	*	*Bidens pilosa*	Cobbler's Pegs	X		X	X	X
Asteraceae	*	*Cirsium vulgare*	Spear Thistle	X				
Asteraceae	*	*Conyza sumatrensis*	Tall Fleabane	X		X	X	
Asteraceae	*	*Hypochaeris radicata*	Catsear	X	X		X	
Asteraceae	*	*Lactuca saligna*	Willow-leaved Lettuce			X		

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Table A.1 Flora list from the five sites where North-South transects data was collected.

Form and Family	Status	Scientific Name	Common Name	Baludarri Wetlands	Bobbin Head	Salt Pan Creek	Landing Lights Wetlands	Blacksmiths Wetlands
Asteraceae	*	*Sonchus asper*	Sow Thistle	X	X			
Asteraceae	*	*Sonchus oleraceus*	Milk Thistle		X			
Brassicaceae	*	*Cardamine hirsuta*	Flick weed	X				
Caryophyllaceae	*	*Cerastium glomeratum*	Mouse-ear Chickweed	X		X	X	X
Chenopodiaceae		*Sarcocornia quinqueflora* subsp. *quinqueflora*		X		X	X	
Chenopodiaceae	*	*Atriplex prostrata*		X				
Convolvulaceae	*	*Ipomoea cairica*	Coastal Morning Glory	X			X	
Chenopodiaceae		*Suaeda australis*	Seablite	X	X	X	X	X
Fabaceae (Caesalpinioideae)	*	*Senna pendula* var. *glabrata*		X			X	
Fabaceae (Faboideae)	*	*Medicago polymorpha*	Burr-medic	X		X		
Fabaceae (Faboideae)	*	*Vicia sativa*	Common Vetch	X		X		
Lobeliaceae		*Lobelia anceps*		X				X
Oxalidaceae	*	*Oxalis corniculata*				X		
Plantaginaceae	*	*Plantago lanceolata*	Lamb's Tongues	X		X		
Polygonaceae	*	*Acetosa sagittata*	Turkey Rhubarb		X			
Primulaceae	*	*Lysimachia arvensis*	Scarlet Pimpernel	X				

Table A.1 Flora list from the five sites where North-South transects data was collected.

Form and Family	Status	Scientific Name	Common Name	Baludarri Wetlands	Bobbin Head	Salt Pan Creek	Landing Lights Wetlands	Blacksmiths Wetlands
Primulaceae		*Samolus repens*	Creeping Brookweed	X	X	X	X	X
Urticaceae	*	*Parietaria judaica*	Pellitory			X		
Verbenaceae	*	*Lantana camara*	Lantana	X			X	
Monocots (Grasses)						X		
Poaceae	*	*Bromus catharticus*	Prairie Grass	X	X	X		
Poaceae	*	*Cenchrus clandestinum*	Kikuyu	X		X	X	X
Poaceae	*	*Cynodon dactylon*	Couch	X	X	X	X	X
Poaceae	*	*Ehrharta erecta*	Panic Veldtgrass	X			X	
Poaceae	*	*Eragrostis curvula*	African Lovegrass			X		
Poaceae	*	*Hyparrhenia hirta*	Coolatai Grass	X		X		
Poaceae	*	*Paspalum dilatatum*	Paspalum	X		X		
Poaceae		*Sporobolus virginicus*	Sand Couch	X	X	X	X	X
Poaceae		*Imperata cylindrica*	Blady Grass	X				
Monocots (Other)						X		
Commelinaceae		*Commelina cyanea*	Scurvy Weed		X			X

Table A.1 Flora list from the five sites where North-South transects data was collected.

Form and Family	Status	Scientific Name	Common Name	Baludarri Wetlands	Bobbin Head	Salt Pan Creek	Landing Lights Wetlands	Blacksmiths Wetlands
Cyperaceae		*Baumea juncea*		X	X	X	X	X
Cyperaceae		*Chorizandra cymbaria*		X			X	X
Cyperaceae	*	*Cyperus eragrostis*	Umbrella Sedge		X	X		
Cyperaceae		*Ficinia nodosa*	Knobby club-rush	X	X	X	X	X
Juncaginaceae		*Triglochin striata*	Streaked Arrowgrass	X	X	X	X	
Juncaceae	*	*Juncus acutus*	Sharp Rush				X	
Juncaceae		*Juncus kraussii*	Sea Rush	X	X	X		X
Lomandraceae		*Lomandra longifolia*	Spiny-headed mat-rush	X			X	X

Appendix B

Plot Data

Table B.1 Data Summary for North-South Transects

Site	Transect Number	Plot Number	Date	Time (HH:MM:SS)	Easting	Northing	Elevation (m AHD)	Aspect	Type of Shading
Baludarri Wetland	1	P1	26/09/2017	11:14:31	316809	6256721	11	N-S	N
	1	P2	26/09/2017	11:20:27	316812	6256716	12	N-S	N
	1	P3	26/09/2017	11:24:13	316811	6256718	13	N-S	N
	1	P4	26/09/2017	11:29:07	316810	6256715	13	N-S	N
	1	P5	26/09/2017	11:33:49	316811	6256712	12	N-S	N
Baludarri Wetland	2	P1	26/09/2017	11:49:27	316761	6256656	10	N-S	N
	2	P2	26/09/2017	11:57:17	316762	6256656	10	N-S	N
	2	P3	26/09/2017	12:02:12	316763	6256654	10	N-S	N
	2	P4	26/09/2017	12:02:40	316764	6256655	9	N-S	N
	2	P5	26/09/2017	12:05:59	316765	6256652	9	N-S	N
Baludarri Wetland	3	P1	27/09/2017	11:08:09	316856	6256719	23	N-S	N
	3	P2	27/09/2017	11:13:50	316815	6256718	27	N-S	N
	3	P3	27/09/2017	11:15:43	316815	6256714	26	N-S	N
	3	P4	27/09/2017	11:18:01	316814	6256715	25	N-S	N
	3	P5	27/09/2017	11:30:40	316817	6256720	19	N-S	N
Baludarri Wetland	4	P1	27/09/2017	12:16:24	317002	6256657	6	N-S	A
	4	P2	27/09/2017	12:19:24	316995	6256651	6	N-S	A
	4	P3	27/09/2017	12:21:31	316999	6256652	5	N-S	A

Table B.1 Data Summary for North-South Transects

Site	Transect Number	Plot Number	Date	Time (HH:MM:SS)	Easting	Northing	Elevation (m AHD)	Aspect	Type of Shading
	4	P4	27/09/2017	12:24:16	316998	6256648	6	N-S	A
	4	P5	27/09/2017	12:25:54	317002	6256648	7	N-S	A
Bobbin Head	1	P1	26/09/2017	2:37:21	328924	6273558	-2	N-S	N
	1	P2	26/09/2017	2:41:08	328925	6273557	-2	N-S	N
	1	P3	26/09/2017	2:45:24	328924	6273555	-3	N-S	N
	1	P4	26/09/2017	2:48:55	328926	6273553	-4	N-S	N
	1	P5	26/09/2017	2:52:31	328927	6273553	-3	N-S	N
Bobbin Head	2	P1	26/09/2017	3:16:03	328912	6273516	1	N-S	N
	2	P2	26/09/2017	5:23:15	323391	6254539	-2	N-S	N
	2	P3	26/09/2017	5:26:10	323391	6254541	-1	N-S	N
	2	P4	27/09/2017	11:08:09	316856	6256719	23	N-S	N
	2	P5	27/09/2017	11:13:50	316815	6256718	27	N-S	N
Salt Pan Creek	1	P1	27/09/2017	1:46:48	318818	6242678	2	N-S	A
	1	P2	27/09/2017	1:52:39	318822	6242674	1	N-S	A
	1	P3	27/09/2017	1:54:09	318821	6242673	1	N-S	A
	1	P4	27/09/2017	1:55:59	318821	6242678	1	N-S	A
	1	P5	27/09/2017	1:58:42	318820	6242671	1	N-S	A
Salt Pan Creek	2	P1	27/09/2017	2:06:52	318814	6242677	1	N-S	A

Table B.1 Data Summary for North-South Transects

Site	Transect Number	Plot Number	Date	Time (HH:MM:SS)	Easting	Northing	Elevation (m AHD)	Aspect	Type of Shading
	2	P2	27/09/2017	2:06:56	318815	6242678	1	N-S	A
	2	P3	27/09/2017	2:08:34	318812	6242674	0	N-S	A
	2	P4	27/09/2017	2:11:14	318808	6242672	1	N-S	A
	2	P5	27/09/2017	2:12:03	318814	6242671	1	N-S	A
Landing Lights Wetland	1	P1	27/09/2017	3:36:47	329283	6242318	-2	N-S	N
	1	P2	27/09/2017	3:42:56	329282	6242315	-2	N-S	N
	1	P3	27/09/2017	3:43:12	329285	6242314	-2	N-S	N
	1	P4	27/09/2017	3:45:51	329283	6242312	-3	N-S	N
	1	P5	27/09/2017	3:51:03	329284	6242310	0	N-S	N
Landing Lights Wetland	2	P1	27/09/2017	3:53:55	329280	6242289	-1	N-S	N
	2	P2	-	-	-	-	-	N-S	N
	2	P3	-	-	-	-	-	N-S	N
	2	P4	-	-	-	-	-	N-S	N
	2	P5	-	-	-	-	-	N-S	N
Blacksmiths Wetland	1	P1	27/09/2017	3:06:45	373373	6338941	3	N-S	N
	1	P2	-	-	-	-	-	N-S	N
	1	P3	-	-	-	-	-	N-S	N
	1	P4	-	-	-	-	-	N-S	N

Table B.1 Data Summary for North-South Transects

Site	Transect Number	Plot Number	Date	Time (HH:MM:SS)	Easting	Northing	Elevation (m AHD)	Aspect	Type of Shading
	1	P5	-	-	-	-	-	N-S	N
Blacksmiths Wetland	2	P1	27/09/2017	3:13:18	373368	6338951	2	N-S	N
	2	P2	-	-	-	-	-	N-S	N
	2	P3	-	-	-	-	-	N-S	N
	2	P4	-	-	-	-	-	N-S	N
	2	P5	-	-	-	-	-	N-S	N
Blacksmiths Wetland	3	P1	27/09/2017	3:18:08	373352	6338986	1	N-S	N
	3	P2	-	-	-	-	-	N-S	N
	3	P3	-	-	-	-	-	N-S	N
	3	P4	-	-	-	-	-	N-S	N
	3	P5	-	-	-	-	-	N-S	N
Blacksmiths Wetland	4	P1	27/09/2017	3:22:10	373343	6338984	0	N-S	N
	4	P2	-	-	-	-	-	N-S	N
	4	P3	-	-	-	-	-	N-S	N
	4	P4	-	-	-	-	-	N-S	N
	4	P5	-	-	-	-	-	N-S	N
Blacksmiths Wetland	5	P1	27/09/2017	3:28:42	373369	6338972	0	N-S	N
	5	P2	-	-	-	-	-	N-S	N

Table B.1 Data Summary for North-South Transects

Site	Transect Number	Plot Number	Date	Time (HH:MM:SS)	Easting	Northing	Elevation (m AHD)	Aspect	Type of Shading
	5	P3	-	-	-	-	-	N-S	N
	5	P4	-	-	-	-	-	N-S	N
	5	P5	-	-	-	-	-	N-S	N
Blacksmiths Wetland	6	P1	27/09/2017	3:39:12	373411	6338923	-2	N-S	N
	6	P2	-	-	-	-	-	N-S	N
	6	P3	-	-	-	-	-	N-S	N
	6	P4	-	-	-	-	-	N-S	N
	6	P5	-	-	-	-	-	N-S	N

Notes: N - natural; A - artificial; N-S - North-South; W-E - West-East

![cumberland ecology]

Table B.2 **Baludarri Wetlands – three naturally shaded and one artificially shaded transects showing plot data from P1 (more shaded) to P5 (less shaded).**

Transect and Shade Type	1 Natural Shade					2 Natural Shade					3 Natural Shade					4 Artificial Shade				
Plot1 - Plot5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
Casuarina glauca	5	10																		
Aegiceras corniculatum									5	30						5	10	5		
Avicennia marina									2							5	15	10	20	
Suaeda australis						10					65		5	15	45			15		
Sarcocornia quinqueflora						70	80	60	10	5										
Juncus kraussii					50				70	30	5	80	20	70	10					
Triglochin striata						5	5	2												
Samolus repens				30	40	3	5	15			5	5	60	5		25	70	35		
Tetragonia tetragonioides													5							
Cupaniopsis anacardioides	1																			
Cynodon dactylon		15	80	60																
**Rubus fruticosus sp. agg.*																				1
**Ehrharta erecta*	5	2																		
**Plantago lanceolata*	1	10																		
**Cotula coronopifolia*				1																
**Ageratina riparia*																				30
**Lantana camara*																				20

Table B.2 Baludarri Wetlands – three naturally shaded and one artificially shaded transects showing plot data from P1 (more shaded) to P5 (less shaded).

Transect and Shade Type	1 Natural Shade					2 Natural Shade					3 Natural Shade					4 Artificial Shade				
**Parietaria judaica*																				10
**Ipomoea cairica*																				5
Leaf litter	80	50							5		25					1	1	20	20	4
Bare earth	8	13	20	9	10	12	10	23	8	35	0	15	10	10	45	64	4	15	60	30

** denotes an exotic species*

Table B.3 Bobbin Head – two naturally shaded transects showing plot data from P1 (more shaded) to P5 (less shaded).

Transect and Shade Type	1 Natural Shade					2 Natural Shade				
Plot1 - Plot5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
Casuarina glauca		2					10	10		
Avicennia marina						2				
Suaeda australis	35	5				40				
Juncus kraussii								10	20	10
Samolus repens								20		
Ficinia nodosa		50	5	10					5	
Baumea juncea		2	20	20	40					10
Leaf litter	60		50	30	50	35	30		35	40
Bare earth	5	41	25	40	10	23	60	60	40	40

Table B.4 Salt Pan Creek – two artificially shaded transects showing plot data from P1 (more shaded) to P5 (less shaded).

Transect and Shade Type	1 Artificial Shade					2 Artificial Shade				
Plot1 - Plot5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
Avicennia marina	10	5			10	10	10	15	2	5
Suaeda australis	5	10	30	70	40				30	30
Juncus kraussii			2							
Triglochin striata	2	10	2			10	5	5		2
Samolus repens	30	45	10			40	30	30	10	10
**Apium graveolens*	5							2		
Leaf litter	5	5	5	5		5	5	3	30	30
Bare earth	43	25	51	25	50	35	50	45	28	23

** denotes an exotic species*

Table B.5 Landing Lights Wetland, Cooks Cove – two naturally shaded transects showing plot data from P1 (more shaded) to P5 (less shaded).

Transect and Shade Type	1 Natural Shade					2 Natural Shade				
Plot1 - Plot5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
Casuarina glauca						10				
Suaeda australis		20	40	20	10			10	10	40
Sarcocornia quinqueflora				10	10					
Ficinia nodosa									10	
Baumea juncea	10	5	10	10	10	30	30	50		
Cynodon dactylon						5				
Acacia falcata	2									
**Juncus acutus*	10	15	30	15	30	5	20		25	15
**Cenchrus clandestinum*		10				10	5			
**Asparagus aethiopicus*	5									
**Atriplex prostrata*		1						4		
**Hydrocotyle bonariensis*								1		
Leaf litter	63	39	10	30	30	35	40	30	30	40
Bare earth	10	10	10	15	10	5	5	5	25	5

** denotes an exotic species*

Table B.6 Blacksmiths Wetlands – six naturally shaded transects showing plot data from P1 (more shaded) to P5 (less shaded).

Transect and Shade Type	1 Natural Shade					2 Natural Shade					3 Natural Shade					4 Natural Shade					5 Natural Shade					6 Natural Shade				
Plot1 - Plot5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Juncus kraussii	100	90	50	40	40	30	20	60	65	40	35	50	30	35	55	50	70	65	60	50						65	60	45	65	65
Samolus repens																										1				
Baumea juncea																					50	50	40	20	80					
Lomandra longifolia																					45	30	60	70	10					
Lobelia anceps																					1	1								
Chorizandra cymbaria																								10						
Leaf litter																														
Bare earth	0	10	50	60	60	70	80	40	35	60	65	50	70	65	45	50	30	35	40	50	4	19	0	0	10	34	40	55	35	35

Appendix C

Assessment of Significance

C.1 Coastal Saltmarsh

Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions is listed as an Endangered Ecological Community under the TSC Act, a Vulnerable Ecological Community under the EPBC Act and also protected under the FM Act.

Coastal Saltmarsh occurs in the intertidal zone on the shores of estuaries and lagoons that are permanently or intermittently open to the sea. It is frequently found as a zone on the landward side of mangrove stands. Characteristic plants include *Baumea juncea*, Sea Rush (*Juncus kraussii* subsp. *australiensis*), Samphire (*Sarcocornia quinqueflora* subsp. *quinqueflora*), Marine Couch (*Sporobolus virginicus*), Streaked Arrowgrass (*Triglochin striata*), Knobby Club-rush (*Ficinia nodosa*), Creeping Brookweed (*Samolus repens*), Swamp Weed (*Selliera radicans*), Seablite (*Suaeda australis*) and Prickly Couch (*Zoysia macrantha*). Occasionally mangroves are scattered through the saltmarsh. Tall reeds may also occur, as well as salt pans (NSW Scientific Commitee 2016).

a) in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction

Not applicable.

b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction

Not applicable.

c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

- *(i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or*
- *(ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

Coastal Saltmarsh adjoins the subject site, within Council land to the south of the Parramatta Cycleway. No Coastal Saltmarsh will be removed by the proposed development, however, the buildings will act to shade the community. Depending on the time of day and the season, approximately 0.03 ha of *Juncus kraussii* Saltmarsh and 0.02 ha of Mangrove-saltmarsh intergrade will be shaded at some point in the day. The minor shading is not likely to reduce the area of occupancy of this community.

The shading processes are already in operation, with the Coastal Saltmarsh present in areas adjoining the subject site, including shading from the cycleway, the encroaching mangroves and the existing building to the east of the proposed development. Furthermore, weed invasion is evident, particularly from *Hydrocotyle bonariensis* which is currently threatening the Coastal Saltmarsh.

As such the Proposal is not likely to have an adverse effect on the extent of the community such that its local occurrence is likely to be placed at risk of extinction.

As discussed above, the shading processes, mangrove encroachment and weed invasion are currently impacting on the Coastal Saltmarsh, and the proposal is not likely to significantly exacerbate the effects of these impacts. The potential for a minor increase in shading is not likely to substantially and adversely modify the composition of this community such that a local occurrence would be placed at risk of extinction.

d) *in relation to the habitat of a threatened species, population or ecological community:*
- *(i)* *the extent to which habitat is likely to be removed or modified as a result of the action proposed, and*
- *(ii)* *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*
- *(iii)* *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*

No Coastal Saltmarsh will be removed by the proposed development, however, the buildings will act to shade the community. Depending on the time of day and the season, approximately 0.03 ha of *Juncus kraussii* Saltmarsh and 0.02 ha of Mangrove-saltmarsh intergrade will be shaded at some point in the day. The increased impacts in shading have the potential to modify the community present, to some extent, however, the existing impacts, including weed invasion and mangrove encroachment are likely to have a greater potential to modify the community composition. Therefore it is not likely to be substantially modified for the Proposal.

The proposed development will not act to fragment or isolate an area of habitat.

e) *whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)*

No critical habitat for this critically endangered ecological community has currently been identified by the Director-General of the OEH.

f) *whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*

No threat abatement plan or recovery plan has been drafted or gazetted for this community.

A number of recovery activities for this community have been listed by OEH, and including reducing the spread of weed invasion through active control, management of sediment and stormwater runoff and mangrove encroachment (OEH 2014). None of the recovery activities include managing impacts from shading.

g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The Proposal is not likely to exacerbate any threatening processes, beyond current conditions.

Conclusion

The proposed development will not remove any area of Coastal Saltmarsh, although a small area, totalling 0.05 ha (consisting of 0.03 ha of *Juncus kraussii* Saltmarsh and 0.02 ha of Mangrove-Saltmarsh intergrade), could potentially be modified through shading. However, the Saltmarsh present will not be completely shaded throughout the day (the length of time will vary throughout the year). Existing impacts from weed invasion, mangrove encroachment and shading from existing vegetation and buildings are likely to present greater risks to the local occurrence of Coastal Saltmarsh. In consideration of all criteria above, the proposal development is not likely to have a significant impact on Coastal Saltmarsh. No Species Impact Statement is required.