REVISED WEST CULBURRA BEACH CONCEPT PLAN

AQUATIC ECOLOGY ASSESSMENT REPORT

February 2020 Flood Peak Line delineated by floating bushfire debris - site along the Billys Bay foreshore approximately in line with the revised Concept Proposal western limit line.

Report Prepared for Sealark Pty Ltd

Marine Pollution Research Pty Ltd

November 2020

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REPORT TITLE:	West Culburra Beach Concept Plan- Aquatic Ecology Assessment Report
CLIENT	Sealark Pty Ltd
MPR REPORT No:	MPR 1198C
REPORT DATE:	13 Nov 2020
Expert Witness Directions	I, Paul Anink, have read Part 31 of Division 2 of the *Uniform Civil Procedure Rules 2005*, Schedule 7 of the *Uniform Civil Procedures Rules 2005.* I understand my obligations to the Court and agree to abide by the rules in Part 31 and Schedule 7, as well as the Land and Environment Court expert witness policies. This report has been prepared in accordance with the Expert Witness Guidelines.
MPR APPROVAL: PAUL ANINK	Paul Anink

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EXECUTIVE SUMMARY

This report provides an assessment of the aquatic ecology impacts associated with the revised West Culburra Beach Concept Plan (the proposal). This assessment of impact on aquatic ecology is provided for the purposes of the Consent Authority assessing and determining the revised Concept Plan application, and it is noted that further development applications will need to be made and determined for individual stages of the Concept Plan to be carried out.

The Proposal comprises three precincts; a Town Centre expansion (14.24ha), an Industrial Centre expansion (6.32ha) and a new Residential Area (26.78ha), with a total urban development footprint area of 47.34 ha, including supporting infrastructure. The Proposal is located within forested lands west of Culburra Beach township that drains north to the Crookhaven River estuary, and there is a minimum 100m woodland buffer from the road reserve edge to the Crookhaven River estuary Mean High Water Mark (MHWM). Approximately 0.5 Ha (about 1 % of the development) related to a new roundabout and entrance road works on Culburra Road, drains south towards Wattle Creek in the Lake Wollumboola catchment.

Proposed staged construction has the added benefit of minimising the risk of physical and water quality impact to adjacent woodland and estuarine habitats, and future development approvals will include specific measures to ensure protection of adjacent ecological habitats and protect water quality for ecology and for the users of the Crookhaven River, including commercial oyster farmers and commercial and recreational fishers. The proposal does not include any construction works or direct access along the riparian estuary edge, or to the estuarine habitats, and the foreshore reserve will be managed to prevent direct water access and protect associated vegetation, habitats and biota.

Lake Wollumboola Catchment

In the revised Concept Plan, there is less than 0.5ha of associated road improvement/access works located in the Lake Wollumboola catchment and subsequently the proposal will have no impact on Lake Wollumboola aquatic ecology. Further, there are no aquatic ecology impacts expected for the watercourse locally known as Wattle Creek, as there are no freshwater aquatic ecology habitats or biota in the upper Wattle Creek catchment for at least 900m downslope of Culburra Road, and the current risk of adverse water quality impact for downstream Wattle Creek aquatic habitats from un-treated road runoff will be diminished by the proposed roundabout construction at the Wattle Creek culverts. Proposed treatment of the constructed roundabout runoff water includes a water bioretention basin structure for the collection and treatment of runoff water from the proposed roundabout and Culburra Road draining to Wattle Creek.

Crookhaven River Catchment

There are no freshwater aquatic habitats, no aquatic Groundwater Dependent Ecosystems (GDEs) and no obligate terrestrial GDEs in the proposal's Crookhaven River catchment. Detailed assessment of the saltmarsh fringe plus mangrove habitats around the perimeter of the shoreline, and of the mangroves stands and seagrass beds extending across to Billys Bay and into Curleys Bay shows that overall, the Crookhaven River and Curleys Bay estuary support high value and relatively stable distributions of the three main vegetation habitat types, with differences reflecting both the dynamic nature of the estuarine ecosystem and the difficulties inherent in accurate mapping of the edges and limits of these habitats. In regard to the protection of estuarine threatened species and listed ecological communities, there are green turtles reported from Curleys Bay, and listed wading and shore birds make limited use of the bay's southern shoreline as Curley Bay shore-bird use is concentrated on the wider North-East Bay mudflats - when available. Listed saltmarsh EEC stands occur all around the estuarine perimeter of the proposal. There are no direct impacts on any of these biota, populations or communities arising from the Concept Plan and its future construction works (subject to further development approvals for development), as all construction is confined to terrestrial lands separated from the estuarine habitats and biota by a minimum 100m woodland foreshore reserve buffer.

There is a good spread of water quality data for physical, nutrient, bacteriological and metal parameters available for the Crookhaven River and Curleys Bay waters that can be used for determining future baseline monitoring. Study of the sediment Nitrogen and Phosphorus concentrations ranges for the various edge riparian to sub-tidal vegetated habitats in Curleys Bay indicate a high resilience to variation in sediment nutrient concentrations. The intertidal habitats are also considered resilient to variations in water borne nutrient concentrations, and accordingly, the risk of impact on these vegetated estuarine habitats from altered stormwater volume and character arising from the proposal are low. Residual potential risk for impact on oyster aquaculture from operation of the completed development can be avoided, minimised and mitigated satisfactorily by:

a) appropriate control of stormwater quality and quantity within the proposal’s site area, including control of anthropogenic gross pollutants i.e., such as plastic debris and the like),
b) controlling stormwater distribution into the wooded foreshore reserve to "mimic" present distribution patterns,
c) appropriate control and management of sewer infrastructure within the proposal site to prevent sewage overflows into downstream wetlands and the bay, and

d) appropriate operational management plans to ensure these control measures are met and maintained in the long-term

Measures to achieve these objectives are described in detail in the revised Concept Plan Integrated Water Cycle Management Strategy (IWCMS).

The proposal includes the implementation of a targeted estuarine health monitoring program to provide early indications if impact is occurring (either via pulse impacts associated with construction related incidents or press impacts due to operational exceedances), and a pre-construction monitoring program for inclusion in subsequent development applications will incorporate 12 months of both estuarine health water quality and estuarine habitat condition monitoring.

Establishing long-term estuary health management measures is a key outcome for the proposal and these will be set out in an Operational Environment Management Plan (OEMP), which will include appropriate monitoring to both demonstrate compliance and provide for early intervention if there are deteriorations in estuarine health conditions. The monitoring program will be defined in the concept plan approval and implemented in future development approvals along with the above pre-construction monitoring program.

1 INTRODUCTION

The Sealark Pty Ltd West Culburra Beach Expansion Area Concept Plan is the subject of a NSW Land and Environment Court Merits Appeal against a refusal by the IPC in 2018 (NSW L&E Case Number 78149 of 2019). A Statement of Facts and Contentions (SOFAC) was prepared by IPC (24 May 19). The IPC SOFAC contended *inter alia* that the proposal must be refused due to the inadequacy of water quality modelling and impact assessment resulting in "*an unacceptable risk to water quality and water quantity, and therefore oyster aquaculture, protected wetlands, marine vegetation, and fish habitat in the Crookhaven River estuary*".

Marine Pollution Research Pty Ltd (MPR) was initially retained by Sealark Pty Ltd, to review the IPC contentions regarding inadequate aquatic ecology information and advise on the adequacy of aquatic ecology assessment for the Environmental Impacts Assessment (EIS). Subsequently MPR was requested to provide an aquatic ecology impact assessment for a revised West Culburra Beach Concept Plan (the proposal) and undertake additional field assessments as necessary.

The following report provides an assessment of the impact of the revised Concept Plan on aquatic ecology for the purposes of the consent authority assessing and determining the revised Concept Plan application. It is noted that further development applications will need to be made and determined for individual stages of the Concept Plan to be carried out.

1.1 West Culburra Beach Revised Concept Plan

Figures 1a is the revised Concept Plan (the proposal), and **Figure 1b** provides a schematic of the proposal. The proposal has an urban development footprint that has resulted in a greater than 50% reduction from 102.23ha for the former proposal to the current 47.34ha, whilst still providing a minimum of 100m buffer (approximately 16 ha foreshore reserve) from the road reserve edge to the Mean High Water Mark (MHWM). To ensure the Proposal is both viable and meets the needs of the future Culburra Beach community, higher residential densities and sporting facilities are located closer to the town centre.

The Proposal remains a staged mixed-use development, as originally lodged in the previous Concept Plan, and continues to relate to the land that is legally known as part Lot 5 & 6 of DP 1065111 (**Site**). The Proposal also includes part Lot 1 DP 631825 (part of Culburra Beach Sewerage Treatment Plant (**CBSTP)** that facilitates connection of the site to the town centre via a shared foot/cycle path in the foreshore reserve.

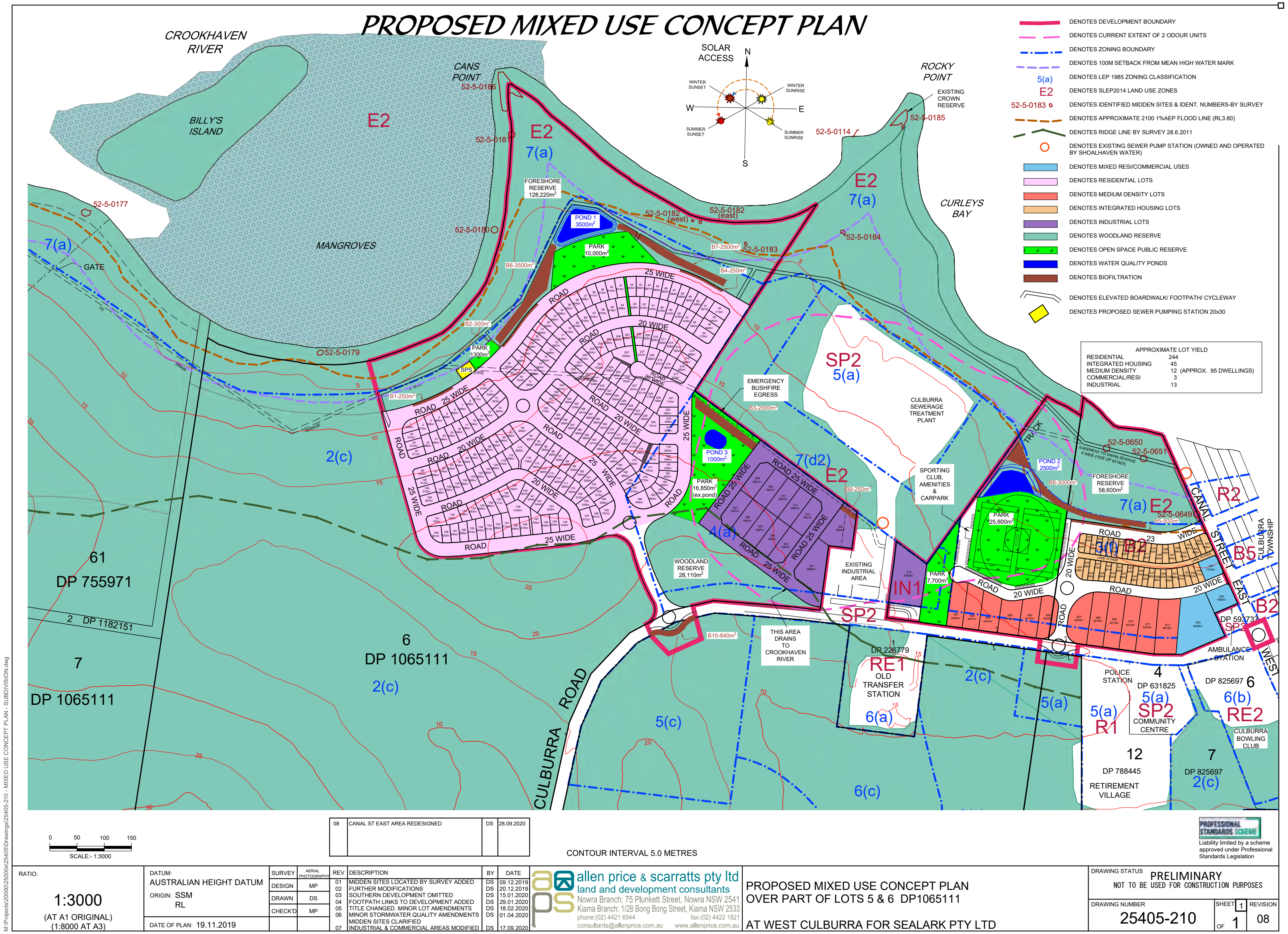

Figure 1a
Revised Concept Plan

The Proposal continues to be an application for Concept Plan approval which will involve a staged release / development of the Site to be undertaken over several years via separate future Development Applications (**DA**s) consistent with the revised Concept Plan. The exact layout of individual lots, roads, public reserves, etc will be addressed in subsequent DAs. Clearing of any vegetation, earthworks and on-site erosion controls will also be detailed in relevant DAs.

The Proposal can be described in 3 precincts with a total urban development footprint area of 47.34 ha (65.59ha when including foreshore & woodland reserve) with supporting infrastructure (see **Figure 1b** schematic below), being:

1. **Town Centre Expansion** (Business, residential & recreation land) which covers an approximate area of 14.24ha and incorporates:
    - 3 mixed use lots ranging in size from 1,319m^2 to 6,559m^2;
    - 45 integrated housing lots ranging in size from 350m^2 to 508m^2;
    - 12 medium density residential lots ranging in size from 2,401m^2 to 4,073m^2;
    - Sportsground (multi field capacity) with supporting amenities;
    - Parkland / Open Space area; and
    - Road areas.
2. **Industrial Centre Expansion** (industrial land) which covers an approximate area of 6.32ha (does not include area of lot within town centre expansion) and incorporates:
    - 13 industrial lots ranging from 1,937m^2 to 5,783m^2;
    - Parkland / Open Space area and,
    - Road areas
3. **New Residential Area** (Residential & Recreation land) which covers an approximate area of 26.78ha and incorporates:
    - 244 low density residential lots ranging in size from 511m^2 to 1,230m^2;
    - 20% of the low-density residential lots are assumed to have capacity for dual occupancy dwellings, therefore the precinct could provide up to 293 dwellings; and,
    - Provision of 2 Parkland / Open Space areas.
4. **Roads and access** which are provided in each precinct and incorporates:
    - Three roundabouts on Culburra Road that are the main entrance points to the residential and town centre areas;
    - Perimeter road for the residential areas;
    - Internal roads to access proposed lots in all stages;
    - Emergency egress fire trail; and,

- Relocation of the intersection of Regmoore Close, Strathstone Street and Culburra Road further eastward to avoid the potential of unnecessary traffic queuing.

5. **Supporting Infrastructure** which is provided in each precinct and incorporates:
    - drainage infrastructure;
    - drainage ponds to irrigate dedicated public reserves and sportsground;
    - new electrical substation near the industrial area;
    - various stormwater quality treatment devices;
    - water & sewerage infrastructure; and,
    - electricity & telecommunications infrastructure.

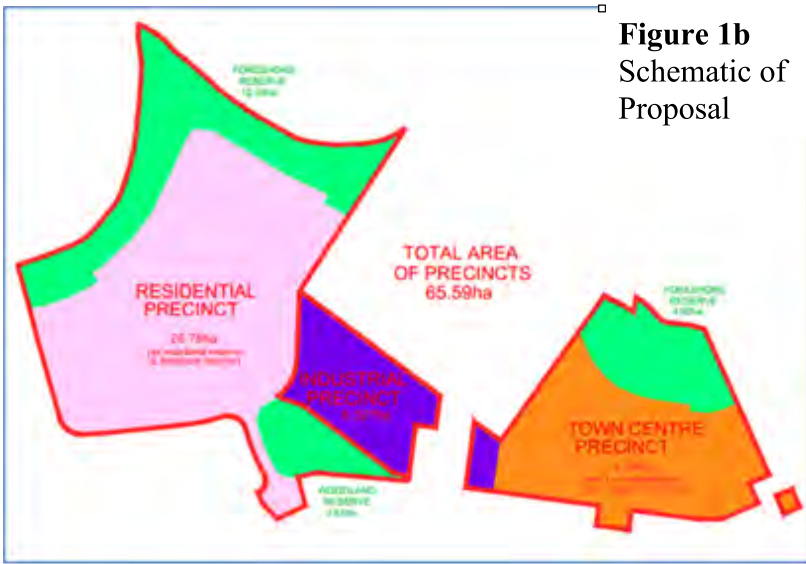

Figure 1b Schematic of Proposal

The proposal is located on forested lands west of Culburra Beach bounding Curleys Bay, in the Crookhaven River lower estuarine arm of the Shoalhaven River catchment. Whilst the majority of the Concept Plan drains to Crookhaven River, the Culburra Road entrance, roundabout plus associated biofiltration basin drain south to Lake Wollumboola via Wattle Creek:

- **Figure 2** provides naming conventions for locations, islands, headlands and water bodies for Crookhaven catchment as referred to in this report. For the purposes of this report Curleys Bay, which is an offshoot from the Crookhaven River is defined by a line from West Drain at Cactus Point to South-West Orient Point and including Billys Bay mangroves plus Crow Island mangroves). It has a perimeter of 9km, an area of 2.5km^2 and five tidal interconnections connections with the river.
- **Figure 3** shows the location of Wattle Creek sub-catchment in the Lake Wollumboola catchment (Called *Northern Creek* in Figure 3).

Figure 2 Apple Map Aerial View of Portion of the Crookhaven River Lower Catchment incorporating the West Culburra Development

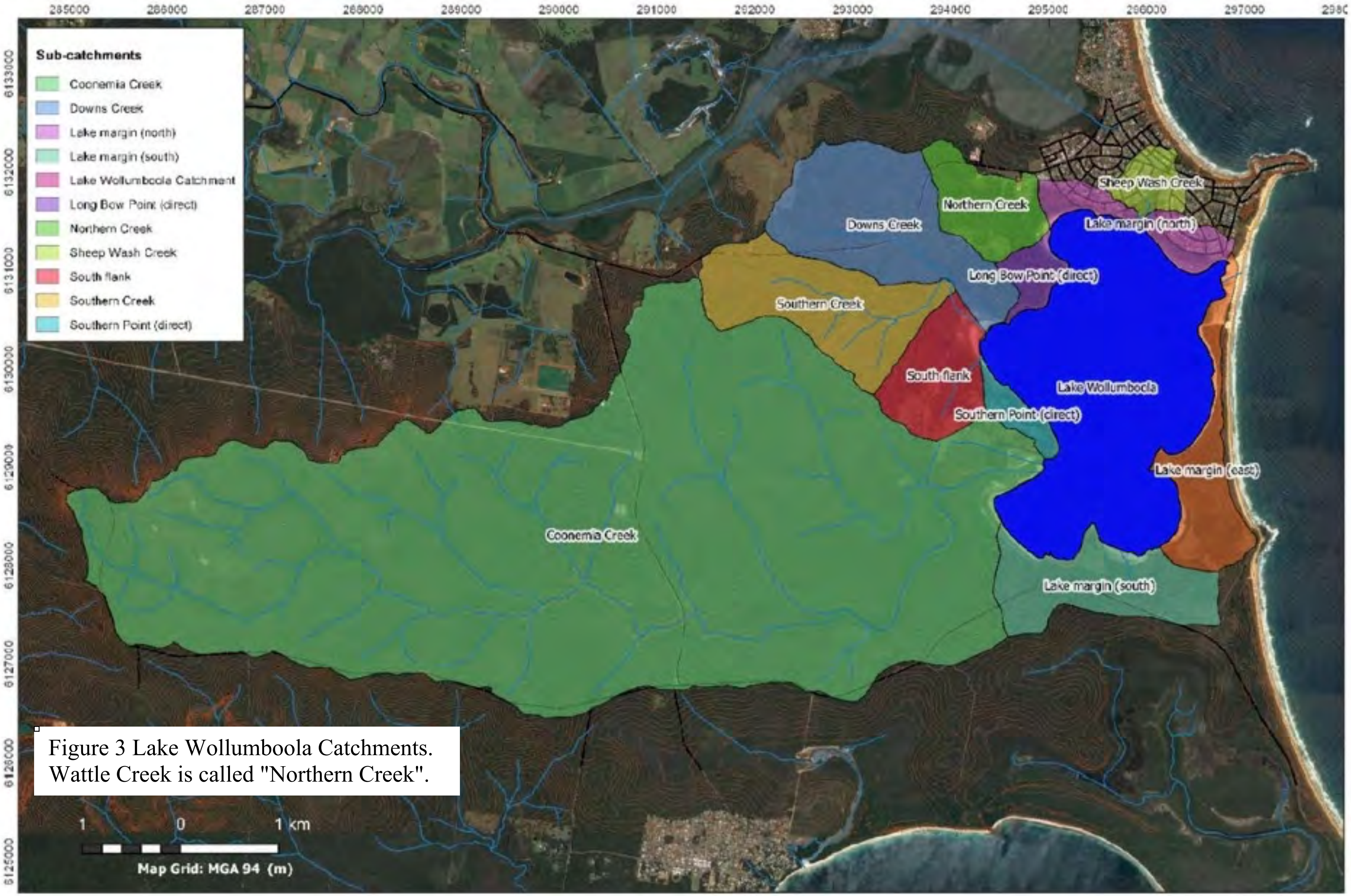

Figure 3 Lake Wollumboola Catchments.
Wattle Creek is called "Northern Creek".

The proposed development area is located in a generally wooded sub-catchment that drains north to Curleys Bay (as defined above - **Figure 2**). This sub-catchment drainage area includes about 10 Ha of developed land for the Culburra Sewage Treatment Plant (STP) and a small industrial estate. The revised Concept Plan comprises around 41 Ha urban development, 6.3 Ha industrial land and 18.6 ha of open space and forest woodland. The proposed Culburra Road Roundabout for the Concept Plan, an associated biofiltration basin plus a small section of the development road leading north from the roundabout (< 0.5Ha) are located in an un-named sub-catchment locally known as Wattle Creek that drains south from the development to Lake Wollumboola (called Northern Creek in **Figure 3**).

1.2 Site Location and Context

At between 7086 and 7300km^2, the Shoalhaven/Crookhaven River catchment[1] is the sixth largest coastal catchment in NSW (**Figure 4**). A combined floodplain area of 365km^2 drains to an estuary water area of around 21km^2 (**Figure 5**).

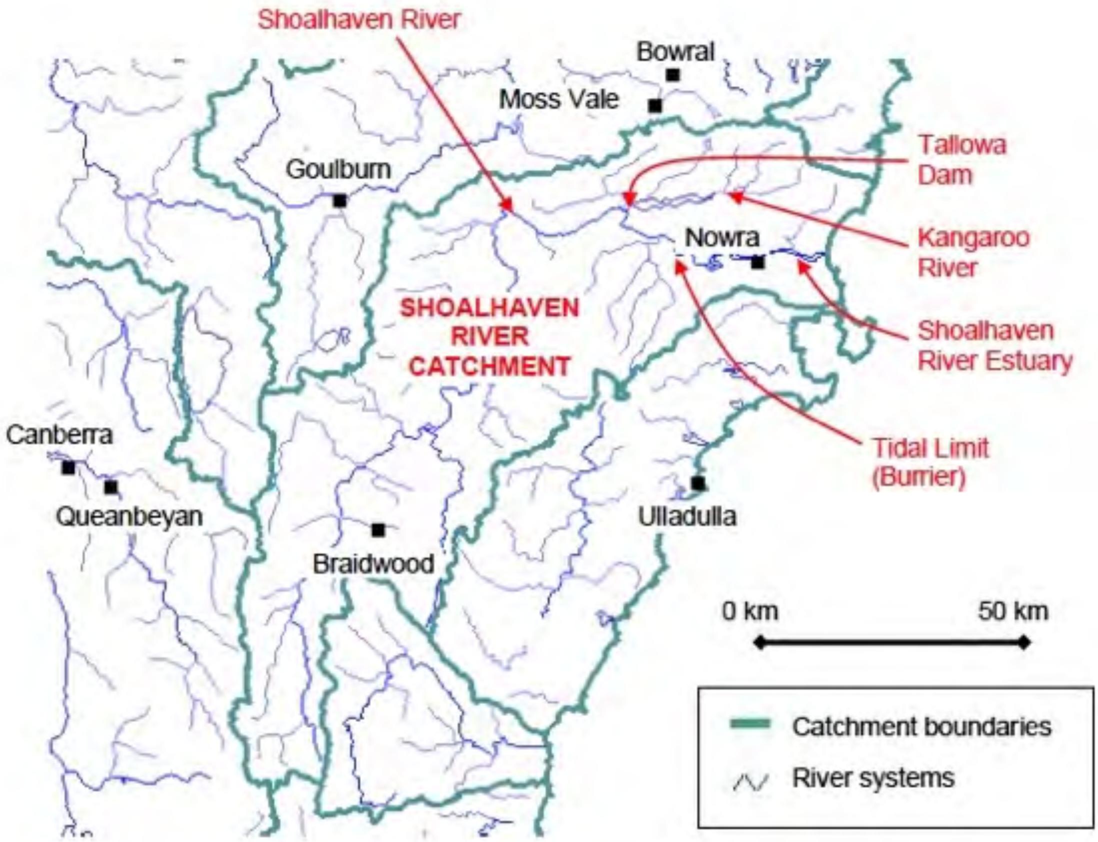

Figure 4 Shoalhaven River catchment showing extent of estuary (tidal limit) and location of the Tallowa Dam (from Boyes 2006).

[1] Roper et al (2010) 7086 km^2, Kumbier et al (2018) 7150 km^2, DNR (2006) 7300 km^2.

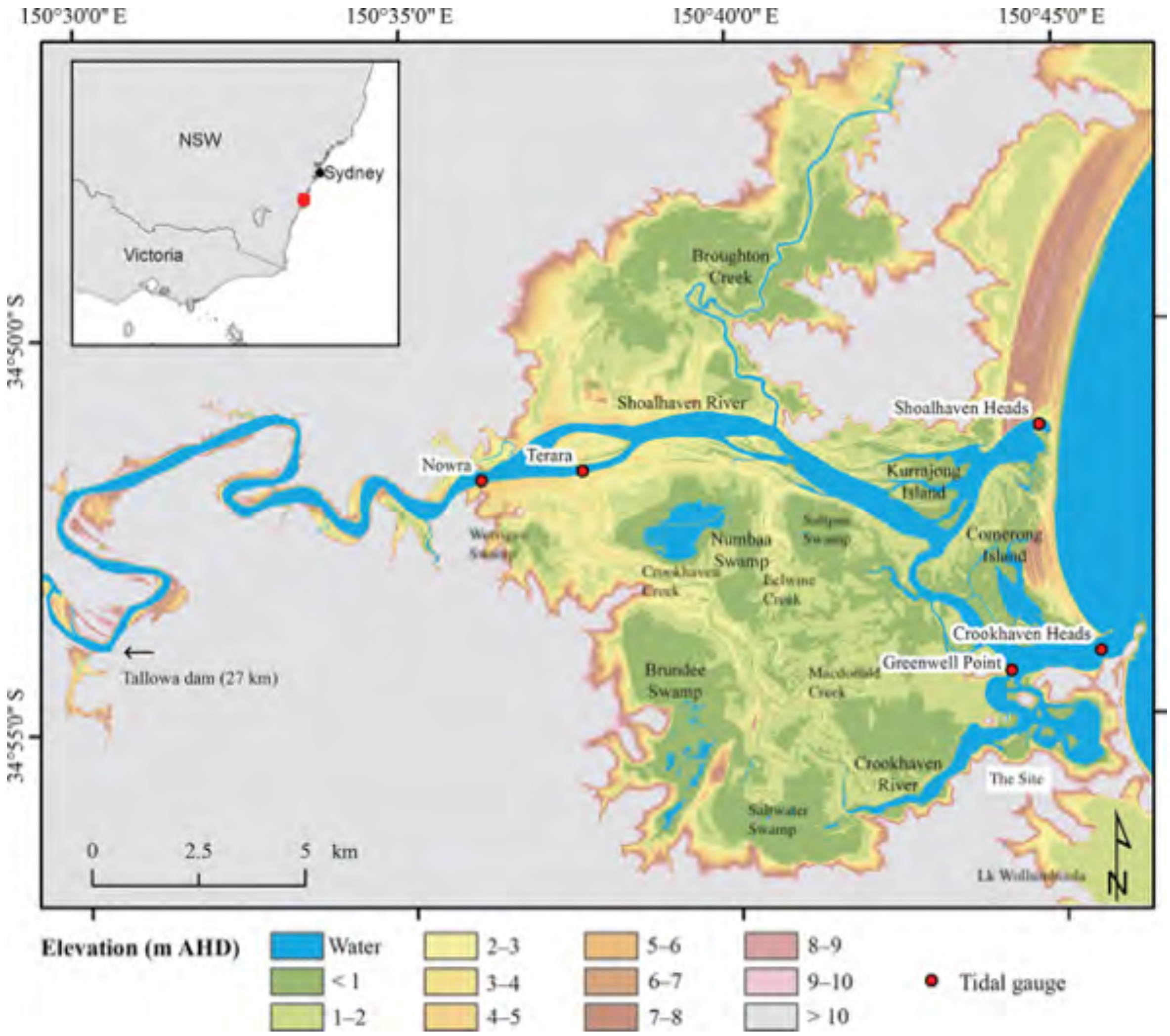

Figure 5 Shoalhaven/Crookhaven Estuarine Floodplain (after Kumbier et al (2108).

The Broughton Creek and Kurrajong Island floodplains north of the Shoalhaven River plus the narrow river floodplain upstream of Nowra to Burrier form the main estuary drainage catchment for the Shoalhaven River estuary, and most of the floodplain and wetlands to the south of the Shoalhaven River drain south-east to the Crookhaven River estuary mainly via the upper river and Crookhaven Creek.

The waterway of the Shoalhaven Estuary is quite unusual with a permanent opening at Crookhaven Heads and an intermittent entrance at Shoalhaven Heads. This environmental setting of two entrances of different nature results from the construction of the connecting Berrys Canal by landowner Alexander Berry in 1822. Originally, the estuary had its opening to the Pacific Ocean at Shoalhaven Heads, but with the construction of Berrys Canal the discharge has been redirected towards Crookhaven Heads, which is more protected from wave action and is permanently open. In consequence, Shoalhaven Heads turned into an intermittent opening, which only breaches during large storm events (Carvalho and Woodroffe, 2014).

The combined Shoalhaven River estuary is one of the most altered estuarine systems in the state with historic alteration of the estuary entrances (discussed above) plus a major water supply dam above the estuary (Tallowa Dam) that has smoothed out flash flood events into the estuary. There has also been considerable alteration of the estuarine floodplain via flood drainage channel construction and installation of floodgates (see **Figure 6** below), particularly the installation of floodgates on the Crookhaven River at the Culburra Road bridge.

Figure 6 Flood Mitigation Drains and Structures in Crookhaven River floodplains (from Glamore et al 2016).

The original West Culburra Proposal included segments draining to Lake Wollumboola via two sub-catchments - an unnamed portion of Downs Creek (named East Downs Creek for this assessment) and Wattle Creek (see **Figure 3**). A more detailed topographic map of these sub-catchments was provided by Allen Price & Scarratts (AP&S), and **Figure 7 is** a copy of this figure with the drainage lines indicated. The current proposal does not include any development in the Downs Creek sub-catchment and there is only a minor 0.5 Ha drainage associated with the roundabout and entrance road for the present proposal draining to Wattle Creek from Culburra Road.

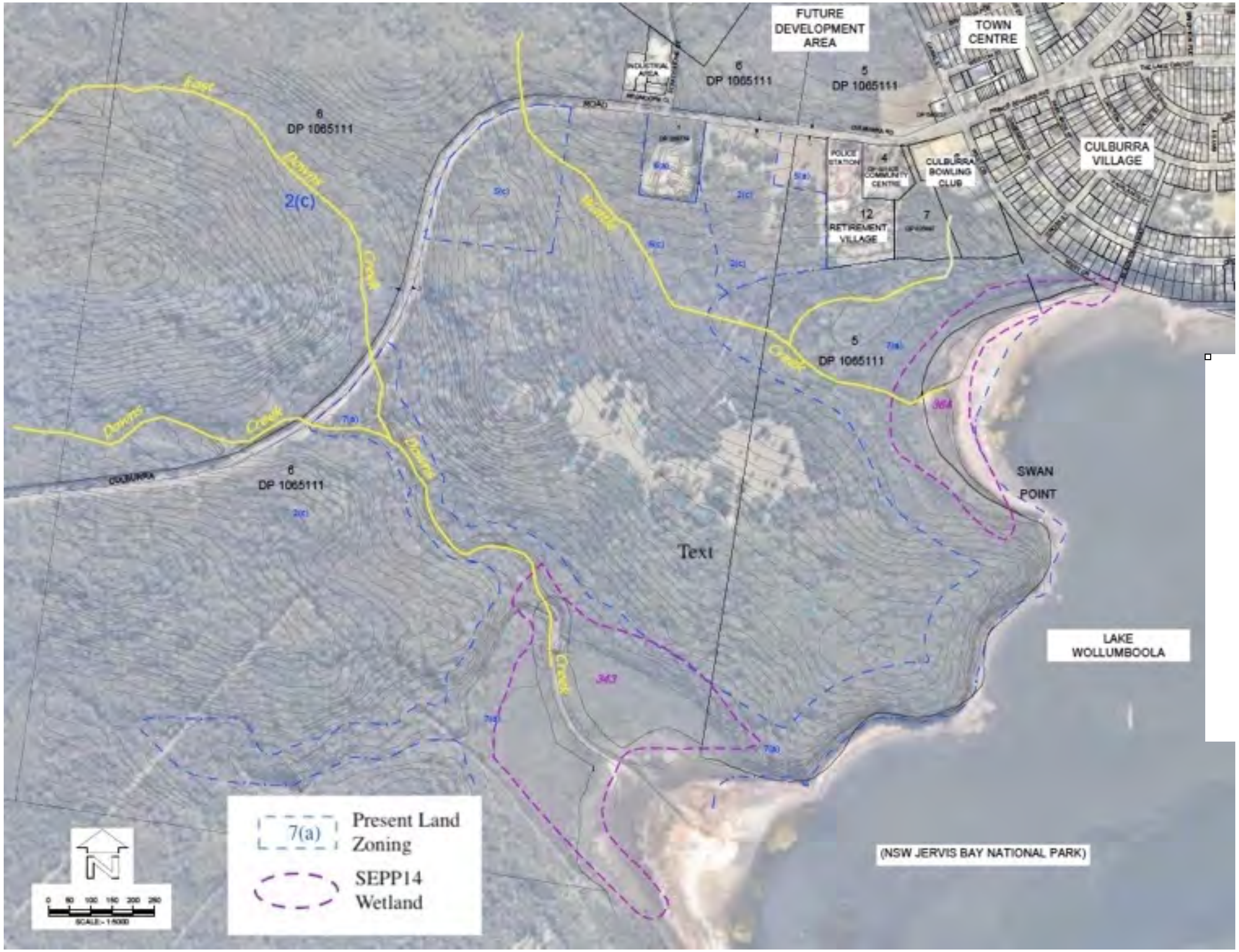

Figure 7 Location of East Downs and Wattle Creek Sub-catchment drainages to Lake Wollumboola (from AP&S Drawing 25405-227).

1.3 Relationship to DGRs and Respondent's SOFAC

Table 1 sets out how the Aquatic Ecology Assessment report addresses the following Original Director General's Requirements (DGRs) in the indicated report sections.

Table 1 Original Proposal DGRs and Responses to Issues as Contained in this Report.

Issue	Element	Description	Sections
General Issue 6	EPBC Act Consideration	Review of the EPBC Protected Matters Searches in regard to aquatic species and communities: Saltmarsh communities are listed under the EPBC and are identified as the only species or community of potential concern under the Act. However as there are no direct construction impacts on saltmarsh, and as there is a low risk of measurable impact due to indirect construction or post construction impacts arising from the revised Concept Plan, there is no necessity to refer the proposal to the Commonwealth on this matter.	2.5
		Key Issues	
1.2 & 2.4	NSW Coastal Policy 1997 & SEPP71 Coastal Protection	Whilst the Aquatic Ecology Impact report will not need to address SEPP (Coastal Management) 2018 owing to the transition clauses for these policies the report has been written having regard to Division 3 Clauses 13(1) and 13(2).	3
7.3	Impacts on, and mitigation measures for Oyster leases & aquaculture	There are no direct impacts on oyster lease infrastructure arising from the proposal and the main potential impacts on oyster aquaculture are associated with construction related, and operational runoff water quality and quantity. The revised proposal is 50% smaller than the original proposal, includes both between and within staging of construction to minimise the potential for adverse water quality runoff and provides a comprehensive integrated water cycle, sewage and management strategy to ensure no adverse runoff water quality or quantity impacts on adjacent oyster aquaculture, including mitigation measures to ensure early intervention for potential adverse construction or operational water quality outcomes.	2.7, 3.1 & 3.2
7.6	Presence and management for GDEs	The possibility of GDEs was investigated for this report and it was concluded that there are no aquatic GDEs in the Wattle Creek catchment for some 1 km downstream of the Culburra Road roundabout and that the provision of a bioretention basin plus GPTs for the roundabout construction and operation There are no aquatic GDEs and there are no obligate terrestrial GDEs in the proposal Crookhaven River catchment. Notwithstanding, the IWCMS includes measures for shallow soil recharge downstream of the bioretention swales to maintain shallow soil water retention following storms and it is concluded that there would be no measurable change to the overall distribution of boggy ground habitats in the lower parts of the 100m buffer area.	2.2.2
9.1	Terrestrial Flora & Fauna	Terrestrial flora and fauna descriptions and impact assessment are provided in previous Concept Proposal reports and impact assessment was undertaken against the relevant guidelines. The Terrestrial Ecology report also addresses key issues 9.2 to 9.5 in relation to terrestrial biota.	EIS Report

Issue	Element	Description	Sections
9.1	Aquatic flora and fauna	This report provides a review of previous aquatic studies, including previous assessments of potential impacts on threatened aquatic species, populations and ecological communities. The report provides the results of additional assessments for aquatic habitats and biota plus impact assessment of the revised Concept Plan for these habitats and biota.	This Report
9.2	Aquatic EECs and Threatened Flora	The only identified aquatic EEC identified for the proposal is the Saltmarsh habitat fringing the Curley's Bay shoreline, which is listed under both the TSC Act and the EPBC Act. This EEC and the adjacent protected mangrove and seagrass habitats have a minimum 100m wide woodland buffer between them and the revised Concept Plan development. The buffer woodland reserve is to be managed to protect these estuarine habitats and to protect the water quality of the associated estuarine waters. Targeted searches for threatened saltmarsh plants were undertaken at 19 transect sites and within saltmarshes between these transects and none were found.	2.3.4, 2.4 & 2.5 3.1 & 3.2
9.3	EEC management	Management of the Saltmarsh EEC includes fencing to prevent livestock access from the adjacent property and access to the saltmarsh from the revised Concept Plan development will be managed by in-perpetuity retention of the 100m woodland buffer under Council ownership and management.	2.3.4, 3.2
9.4	Protection of existing wildlife corridors	There are no developments proposed to be undertaken in the riparian edge and estuarine habitats, and the only development in the buffer woodland will be the provision of a walkway/cyclway linking the development to the rest of Culburra Beach to the east. The walkway/cycleway is to be managed by Council as part of its woodland reserve ownership and management and this management will include prohibiting access to the riparian and offshore zones from the path plus strict controls on use of the path for dog walking including no off-leash dogs and collection plus proper disposal of dog faeces. These measures are required to preserve the wildlife corridor attributes for the fringing riparian wetlands. The proponent is also extending the livestock exclusion fencing for its adjacent property to the west of the revised Concept Plan development which will further enhance the wildlife corridor utility of the fringing riparian habitats along the Crookhaven River edge.	3.1 & 3.2
9.5	EPBC Species	As per 9.2 above, Saltmarsh Ecological Communities are listed under the EPBC Act. See 9.2 and 9.3 for discussion.	3.2.4

Responses to SOFAC as per Respondent's Position Paper			
2	WQ (& Aq Ecology) Lk Wollumboola	All proposed development originally located in the Lake Wollumboola catchment has been excised for the revised Concept Plan with the only development related works being the 0.5 ha area of Culburra Road roundabout works in the upper Wattle Creek catchment, that will include a stormwater treatment pond thus improving the existing situation where untreated stormwater from Culburra Road is directed to the upper Wattle Creek catchment.	2.2.2, 2.2.3, 3.1 & 3.2
3	Inadequate Aq Ecology Assessment	This report has been produced to meet this response. It is based on additional field assessments and literature survey have been undertaken for impact assessment against the revised Concept Plan.	This report
4	Inadequate description of oyster aquaculture and impacts	Oyster aquaculture plus commercial and recreational fishing have been assessed for the present proposal and impacts considered. The report concludes that the IWCMS for the revised Concept Plan will provide the necessary and required protection for oyster aquaculture.	2.7, 3.1 & 3.2
5	Impacts of mangrove clearance	There is no mangrove clearance proposed for the revised Concept Plan and this report provides information on improvements underway by the proponent for mangrove and salt marsh habitat protection from cattle grazing off-site.	2.3.5, 3.1 & 3.2

1.4 Previous Aquatic Ecology Studies and Available Information

Aspects of aquatic ecology habitat mapping including NSW Government habitat mapping plus mapping related to oyster aquaculture, site physical descriptive data plus hydrology, groundwater and water quality data are provided in West Culburra Beach Reports produced between 2013 and 2017 for the original West Culburra Beach Concept Plan. **Annexure A** provides a summary review of the available EIS specific information relevant to understanding the aquatic ecology of the study area.

In terms of actual aquatic ecology habitat mapping and aquatic ecology descriptions for the original Concept Proposal there are two relevant reports, the *Culburra West Urban Development – Ecological and Riparian Issues and Assessment Report* (2013) by SLR Consultants (SLR 2013), and the *West Culburra Aquatic Ecology Impact Assessment: Proposed Mixed Use Subdivision Report (2017)* by Ecological (ELA 2017):

- SLR (2013) provided vegetation community maps (Figures 9A to 9D) which were surveyed in 2011 and used Nearmap aerial images from 2010. The report identified 15 main vegetation community types, including two estuarine communities; Coastal Saltmarsh (CSM) and Mangrove Forest (M).
- The ELA (2017) one day field survey included a descriptive survey of mangrove, seagrass and saltmarsh habitats at eight sites, by means of general observations and canoe mounted camera. The report included the following components;

- A desktop review of species and habitats (protected and threatened species searches for species or communities likely to occur within the area),
- A literature review of environmental tolerances of the key fish habitats (KFH) - seagrasses, mangroves and saltmarsh,
- Interpretation of water quality modelling results in terms of the potential impacts to estuarine flora and fauna.

In response to the original proposal's Statement of Facts and Contentions (SOFAC), the MPR preliminary review of the available reports, and of available aquatic ecology information agreed that there were inadequacies in the aquatic ecology assessment and concluded that there was a need to undertake additional aquatic ecology field investigations, specifically to better describe:

1. The aquatic ecology of drainage lines from the proposal towards Lake Wollumboola.
2. The zoning transitions from edge riparian vegetation through saltmarsh to mangrove or river sediment/seagrass assemblages around the Crookhaven River and Curleys Bay shoreline and the relationship to exposed rock and/or oyster reef habitats.
3. The saltmarsh and mangrove assemblage locations, speciation and condition around the Crookhaven River and Curleys Bay shoreline, including a better description of cattle damage to the intertidal edge habitats and recovery underway for areas that have been fenced off.
4. A more detailed physical description of the site surface and shallow sub-surface water runoff paths at the riparian/tidal interface including a description of how runoff waters drain through Billy's Bay mangroves at low tides.
5. A more detailed description of the seagrass beds around the perimeter of the property including both species composition, condition and associated mobile fauna assemblages.

The field studies were required to be able to provide the following assessments:

1. A determination as to whether there are any specific aquatic groundwater dependent ecosystems in receiving water sub-catchments.
2. Quantification or descriptions of changes in saltmarsh, mangrove and seagrass distribution compared to the previous DPI Fisheries' 2003 mapping for the sections of river plus Curleys Bay fronting the proposal area.
3. A more detailed description of the oyster leases plus their utilisation for the sections of the Crookhaven River plus Curleys Bay fronting the proposal area.

MPR (this report) undertook additional freshwater and estuarine aquatic ecology studies in both drought (October & September 2019) and post-drought flood conditions (February 2020), with study results provided in three Annexures to this report; **Annexure B** providing results of freshwater aquatic studies, **Annexure C** providing results of riparian edge and estuarine studies, **Annexure D** providing results of the February flood and tide metered water quality study, **Annexure E (**provides a review of available water quality data and **Annexure F** provides the results of an estuarine vegetated habitat sediment nutrients study**.**

In terms of general background information for the location, Shoalhaven City Council (SCC 2008) prepared an Estuary Management Plan (EMP) which was adopted in March 2008. The steps in the preparation of an EMP are set out in the NSW Estuary Management Manual (1992) and the process followed in the Shoalhaven was varied from the original concept by not including an Estuarine Process Study (EPS), as it was reasoned that there was sufficient information provided in two Data Compilation Studies (1999 and updated in 2005). nThe SCC Shoalhaven EMP (2008) references the updated Estuary Data Compilation Study as *Umwelt (2005)*, which details previous studies of the estuary, and there are some useful references and summaries provided in other Shoalhaven River Process reports from the same time (e.g., the DNR reports on Environmental Flows prepared by Boyes (2006a,b). Where applicable, these references will be noted in the following chapters, or when considering available literature for the various aquatic ecological habitats. More generally there are two state-wide reviews of estuarine values and risks (Roper et al 2011 and NSW DPI (2017), that both provide guides to specific relevant literature and provide state-wide comparisons.

2 AQUATIC ECOLOGY OF REVISED CULBURRA BEACH CONCEPT PLAN

The following Sections provide relevant literature reviews and summaries of existing aquatic ecology information for the revised Concept Plan proposal and summaries of the additional field studies undertaken for present proposal. Details of the additional field studies plus the full results of those studies are provided in three Annexures, **Annexure B** for freshwater aquatic ecology studies, **Annexure C** for estuarine ecology studies and **Annexure D** for wet weather/flood metered water quality and tide behaviour study.

2.1 Freshwater Aquatic Ecology Surveys

The original EA *Appendix O Flora and Fauna* Assessment (SLR 2013) concluded that there were no sub-catchment drainage lines or dammed sub-catchment waters on the site draining to the Crookhaven River, and "*all current drainage from the site to the Crookhaven River is by overland flow*". The report also noted "*there are a few minor drainage swales along the Crookhaven River frontage, but no formed creek lines*" and " *areas of "standing water" are few and highly ephemeral, and there are no ponds, swamps or permanent freshwater wetlands on the Project site*".

In relation to the revised Concept Plan freshwater drainage towards Lake Wollumboola, whilst there are no mapped first order creeks draining to Lake Wollumboola from the original West Culburra Concept Plan area, there were segments of the proposal that were located in the catchment of the mapped first order creek known as Downs Creek and in another un-mapped sub-catchment known locally as Wattle Creek (see **Figure 7** for sub-catchment drainage locations). The SLR (2013) report did not include consideration of the aquatic ecology of drainage lines in the Lake Wollumboola catchment. Cumberland Ecology (2017) identified the two drainage sub-catchments that drain from parts of the original and present revised Concept Plan towards Lake Wollumboola; An eastern tributary of Downs Creek (called East Downs Creek for this report) and Wattle Creek draining the Long Bow Point Golf Course proposal area. The report did not include any specific investigation of the aquatic ecology of these two watercourses.

For the present proposal there is now no longer any drainage to Downs Creek East and the only drainage to Wattle Creek is from the biofiltration basin for the Culburra Road roundabout and residential entry road.

Following an initial walk over inspection in July 2019, MPR undertook aquatic ecology investigations in Downs and East Downs Creek in relation to the previous West Culburra Beach Concept Plan proposal in August 2019 during the extended drought and additional studies were undertaken in the Wattle Creek sub-catchment in February 2020 at the tail end of the February 2020 Storms. Details and results of the MPR freshwater aquatic surveys are provided in the Freshwater Habitats Survey Report (**Annexure B**).

2.2 Sub-catchment Freshwater Aquatic Habitats and Ecology

For the purposes of describing the revised Concept Plan locality freshwater resources, the presence or absence of three surface water freshwater habitat types are assessed in **Section 2.2.1 and 2.2.2**, and Aquatic Groundwater Dependent Ecosystems (Aquatic GDEs) are considered in **Section 2.2.3**.

2.2.1 Sub-catchments Draining to Crookhaven River

Sub-catchment drainage lines that provide permanent, intermittent or occasional ponded waters or provide sufficient sub-surface baseflow confined to the drainage line to support aquatic or semi-aquatic vegetation.

- None were reported by SLR (2013) in the Crookhaven River sub-catchments considered for the previous proposal, and extensive searching by MPR in drought conditions (September 2019) and flood conditions (February 2020) also confirmed that there were none leading to the Crookhaven River from the original or present proposal site (see **Annexure B**). Given the relatively short distances and gentle slopes from the ridge line to the river this is not unexpected.

Naturally or constructed dammed sub-catchment water.

- There was only one constructed farm dam that met the definition of *constructed dammed sub-catchment water* found in the original extended study area for the previous Concept Plan. This dam was located on land draining to Crookhaven River from lands west of the original proposal. It is more than 1km WSW of the present proposal western boundary, is located at about 25m AHD and some 340m from Crookhaven River.
- The overflow drain from this dam does not provide permanent, intermittent or occasional ponded waters and does not support aquatic or semi-aquatic vegetation.

Swale or boggy areas that either pond surface waters occasionally or contain moist soils that are refreshed by stormwater runoff or shallow groundwater recharge and that provide habitat for aquatic or semi-aquatic vegetation.

- These habitat types were found in the lower, more level valley bottoms around the perimeter of the Crookhaven River shoreline during the flood survey in February

2020. They are considered too intermittent to support *aquatic or semi-aquatic vegetation* at any time.

- Notwithstanding, they do coincide with areas of terrestrial vegetation associated with moist soils and are often characterised by *Ghania* sword grass growth. For Crookhaven River sub-catchments these habitats are all located towards the riparian edge.

2.2.2 Sub-catchments Draining to Lake Wollumboola

Downs Creek has *sub-catchment drainage that provides permanent, intermittent or occasional ponded waters* from the Culburra Road crossing downstream to Lake Wollumbooola. Fish and Invertebrate sampling of Downs Creek during both the extended drought and post flood confirms that Downs Creek provides more or less permanent ponded waters in well-defined creek line erosion ponds that support diverse aquatic biota including native fish throughout the creek length for both the main and Eastern tributary creek lines from below the Culburra Road culverts downstream to Lake Wollumboola.

For Wattle Cree, the 220 m upstream section of Wattle Creek above Culburra Road crossing and the 900m section downstream of the road crossing is characterised by broad overland flow with the valley floor, when it can be located, being characterised by patches of *Ghania* sword grass growth. There are no defined drainage lines and no indications of ponding on the valley floor, although some localised and short-lived pooling during and immediately following rainfall was observed during the February flood surveys.

The broad and flat valley floor between 700m and 980m downstream of the road supports a paper bark swamp habitat that receives stormwater drainage from the eastern arm of Wattle Creek (**Figure 7**) draining the developed north-eastern portion of the sub-catchment (the Retirement Village, Police Station, Bowling Club.
The combined drainage from the Eastern Wattle Creek Arm and paper bark swamp with the Wattle Creek North swale drainage then forms an incised creek section downstream to the lake. This lower section of creek does "*provide permanent, intermittent or occasional ponded waters*" and during the February post flood sampling it supported few aquatic plants and only early colonising invertebrates - indicating that these sections were dry pre-flood.

2.2.3 Threatened Species, Groundwater Dependent Ecosystems & Key Fish Habitat

Threatened Freshwater Aquatic Species

In terms of aquatic biota there were no threatened freshwater aquatic species as listed under the NSW FMA or Commonwealth EPBC Act found during the aquatic ecology surveys of either the Lake Wollumboola or Crookhaven River sub-catchment drainages and none were or are expected. It is noted that there has been Green and Golden Bell frog listings (*Endangered* under the NSW BCA and *Vulnerable* under the EPBC Act) from Culburra Beach village, in the Lake Wollumboola drainage catchment and around the shoreline including *Wattle Corner Creek* (SLR 2013, Daly 2014 and Cumberland Ecology 2017). Based on habitat and population ecology aspects provided by these authors, Green and Golden Bell Frogs are not expected from the Wattle Creek upper sub-catchment within the present proposal footprint or at best until well downstream of the proposal footprint (i.e., more than 1km downstream), if at all. None were found or are expected in the proposal's Crookhaven River drainage sub-catchment (SLR 2013) and none have been found in the Culburra Golf Course proposal area since 2001 (Cumberland Ecology 2017).

Groundwater Dependent Ecosystems (GDEs)

Consideration of the results of MPR field work, observations provided in **Annexure B** and the results summarised above, lead to the conclusion (consistent with the conclusions of Martens 2020), that there are no aquatic GDEs in the proposal's Crookhaven River drainage catchment and that the terrestrial ground vegetation communities associated with the moist soil areas in the Crookhaven River sub-catchment are not considered obligate GDEs, i.e., *they are not dependent on the occasional moist or boggy soils resulting from direct infiltration or perched groundwater within the soil profile* (SKM 2012 and Serov et al 2012).

In relation to the high ridge sub-catchments in the upper reaches of Wattle Creek and Downs Creek draining towards Lake Wollumboola, it is concluded that Wattle Creek to at least 900 m downstream from Culburra Road, and Downs Creek above Culburra Road crossing do not provide sufficient intermittent ponded water from rainfall or groundwater to support aquatic biota for any extended time, and are not classified as Aquatic GDEs (also consistent with conclusions in Martens 2020). The fact that the lower Wattle Creek reaches were apparently dry through the extended drought period would indicate that there are no aquatic GDEs downstream as well.

Given the maturity of the fish and macroinvertebrate assemblages plus aquatic plant growth observed and recorded in Downs Creek below Culburra Road during the extended drought, it is likely that Downs Creek ponded water is sustained by long-tail ground water flow or seepage from intermittently perched saturated soil areas, and that these ponds are more likely to be obligate aquatic GDEs. Similarly, the terrestrial moist vegetation (paperbark) communities located around 1km downstream of the Wattle Creek headwaters may also be obligate terrestrial GDEs.

The above conclusions are also consistent with the hydrogeology descriptions of the Shoalhaven area as reviewed and summarised in Hgeo (2017), that identified three broad groundwater environments; fractured basement rocks of Ordivician and Devonian age (these rocks are not exposed in the study area); porous sedimentary rocks of Permian age; and unconsolidated alluvial deposits of Quaternary age. These latter include alluvial and estuarine deposits and dune sands. Hgeo (2017) noted that the dominant groundwater flow path is likely to be within the regolith (soils and weathered rock). Surface water infiltrating the soil will accumulate on, and flow laterally down-gradient along the interface between weathered and unweathered rock and may form locally (seasonally) perched saturated zones within the soil profile and weathered rock interface. As these are shallow (typically <5m), they may be subject to direct evaporation and evapotranspiration. Therefore, perched systems where they occur are ephemeral and become rapidly depleted during dry periods.

NSW Fisheries Key Fish Habitat (KFH) classification
In terms of freshwater aquatic habitats, there are four named creek-lines draining to Lake Wollumboola indicated on the state 1:25000 topographic map and only one of these (Coonemia Creek) is shown as KFH on the NSW DPI (Fisheries) Shoalhaven KFH mapping (**Figure 8**). However, the KFH map includes lower catchment wetlands for Coonemia/Wollong Creeks and for Downs Creek plus the lake fringing wetlands for Wattle Creek.

From the MPR assessments of Downs and Wattle Creek freshwater habitats presented in **Annexure B** and above, and in terms of habitat KFH classification definitions presented in the DPI (Fisheries) 2013 *Policy and Guideline* (and shown in italics below), it is concluded that:

- There are no freshwater aquatic KFHs within or downstream of the Culburra Beach Concept Plan footprint within the Crookhaven River Catchment.
- Both Downs Creek eastern tributary upstream of Culburra Road plus Wattle Creek sub-catchment to some 900m downstream of Culburra Road would be classified as Class 4 *Unlikely Fish Habitats*, owing to the *lack of defined drainage channel and little to no free-standing water or pools post rain events, and no aquatic flora present*.
- Downs Creek downstream of Culburra Rd is classified as a *Class 2 Moderate KFH*, as it is *an intermittent stream with clearly defined banks and semi-permanent to permanent pools supporting aquatic vegetation*.

- The lower swale reaches in Wattle Creek, located from 900m downstream of Culburra Road through to the paperback wetland interface are *Class 3 Minimal KFH* as they *interconnect with identified wetlands,* and the remainder of the incised creek below the paperbark wetland drainage confluence down to Lake Wollumboola do meet the definition of Class 2 KFH, as the lower freshwater section of the creek does support some aquatic vegetation.

Figure 8 Portion of DPI (Fisheries) Shoalhaven KFH Map showing freshwater to brackish water FKHs draining to or fringing Lake Wollumboola. Note that the Crookhaven River and Lake Wollumboola are both KFH by virtue of being estuary or ICOLL systems and much of the fringing shorelines of both systems are KFH by virtue of extensive saltmarsh and mangrove habitats.

2.3 Estuarine Habitats - Curleys Bay & Crookhaven River

As per **Section 1.4** item 7 above, all studies reviewed to date have used estuarine vegetation mapping (saltmarsh, seagrass and mangrove) provided by DPI (Fisheries) based on aerial mapping in 2000 and ground truthing in 2003 and, up to the end of 2019, this was still the only mapping available from the DPI (Fisheries) web site and the various NSW Government mapping tools (i.e., SEPP (Coastal Management) and NSW Fisheries Spatial Tool). Accordingly, the October 2019 field work included shore normal transect work to delineate saltmarsh areas plus drone photography to enable better delineation of mangrove stands and seagrass beds.

The NSW Government Spatial Data Tool was updated in January 2020 and there is now a more recent mapping of estuarine vegetation for Shoalhaven River available. **Figures 9 and 10** below compare the earlier 2003 and 2010 mapping results for Crookhaven River. Changes over time plus any other changes identified from the 2019 MPR field work are discussed in the relevant habitat sections below, using **Figure 11** below that provides a more detailed estuarine vegetation map for the Curleys Bay study area (also from the 2010 Spatial Data Map).

In terms of overall estuarine vegetation area estimates for the Shoalhaven/Crookhaven River, the only estimates available for both rivers separately are provided by West et al 1995 (**Table 2**). Creese et al (2009) compared more recent estuarine vegetation mapping for NSW estuaries against the original mapping, but area estimates for the Shoalhaven River are for both rivers combined. Roper et al (2011) and DPI (2017) also provide combined Shoalhaven estuarine vegetation totals. These results are also summarised in **Table 2**.

Table 2 Comparison of Catchment and Estuary Habitat Areas (km^2)

Comparison	West et al 1985			Others	
	Shoalhaven	Crookhaven	Total	Min	Max
Total Catchment				7086	7300
Estuary Catchment					365
Estuarine Water	12.9	7.9	20.8	21*	
Intertidal Flats					0.8**
Mangroves	0.67	2.81	3.48	4.18*	4.49***
Seagrass	0.34	0.678	1.018	4.239**	5.39***
Saltmarsh	0.146	1.396	1.542	2.058**	2.13***

Note: Data sources Creese et al 2009*, Roper et al 2011**, DPI (2017)***

From the **Table 2** *West et al 1985* comparisons, it is clear that whilst the Crookhaven estuary water area is only 32 % of the total Shoalhaven estuary, it supports most of the estuarine vegetation; 80% of the mangroves, two thirds of the seagrass and 90% of the saltmarsh habitat. This has particular importance for the estuarine fish assemblages of the Crookhaven River and Curleys Bay, as fish move from the seagrass to the adjacent mangrove and saltmarsh during spring tides, taking advantage of high abundances of zooplankton, and use seagrass as a refuge during lower tides (see for example Saintilan et al 2007).

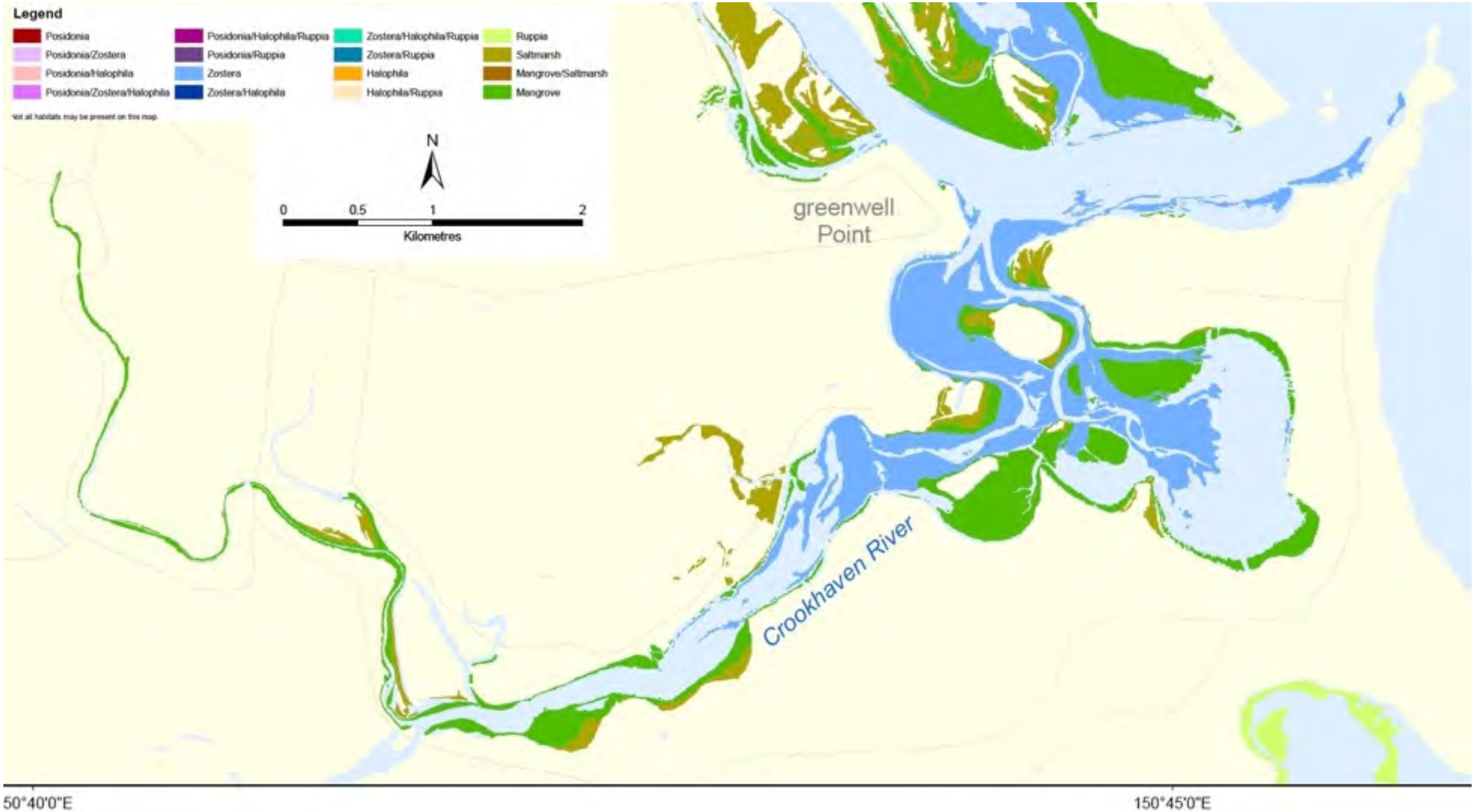

Figure 9 DPI Fisheries' Estuary Vegetation Mapping for Crookhaven River (part Map 47a). Aerial Photo 2000 and Field surveys 2003.

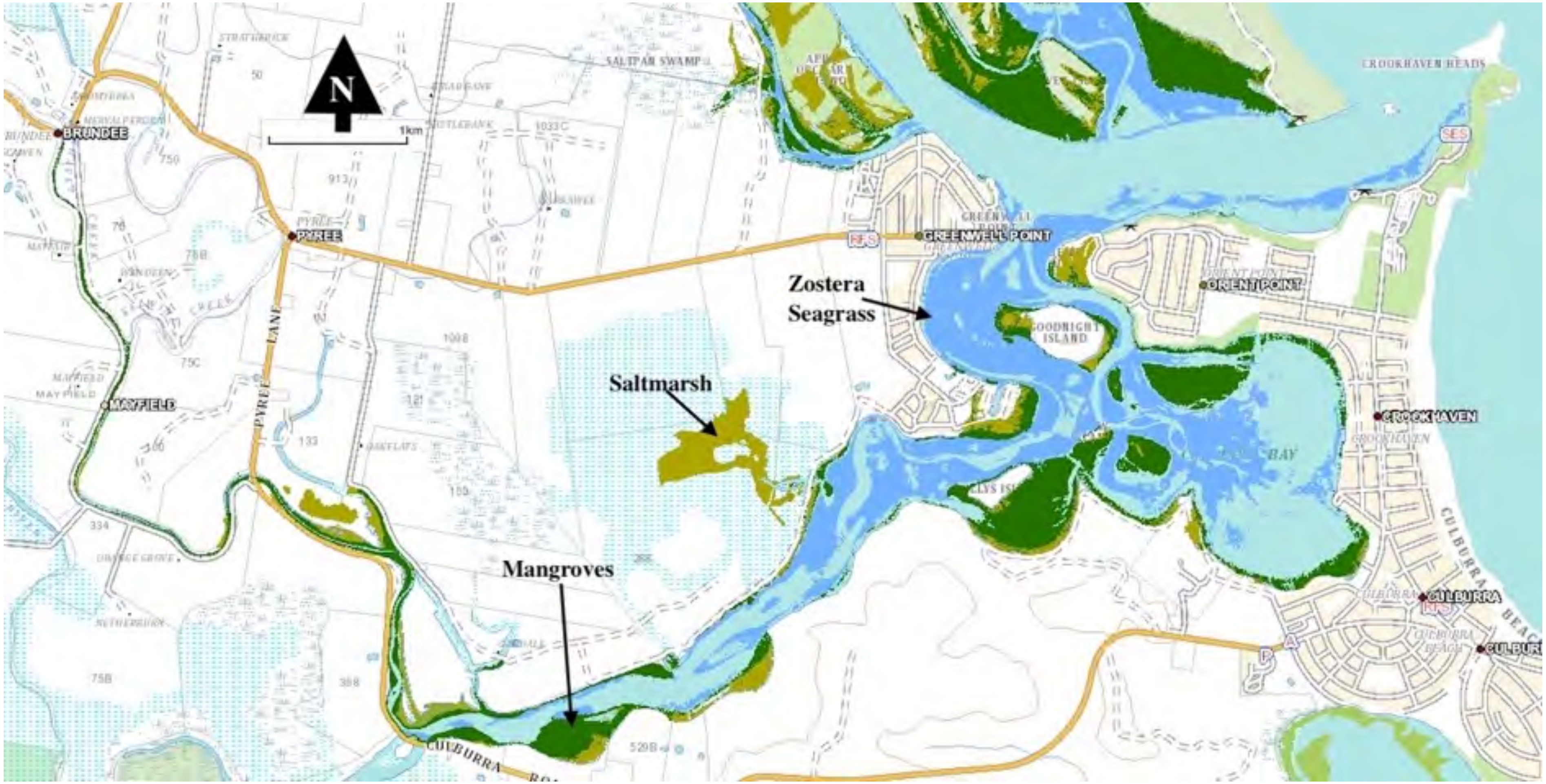

Figure 10 DPI Fisheries' Estuary Vegetation Mapping for Crookhaven River (part Shoalhaven Map). Aerial Photo 2009 and Field surveys 2010.

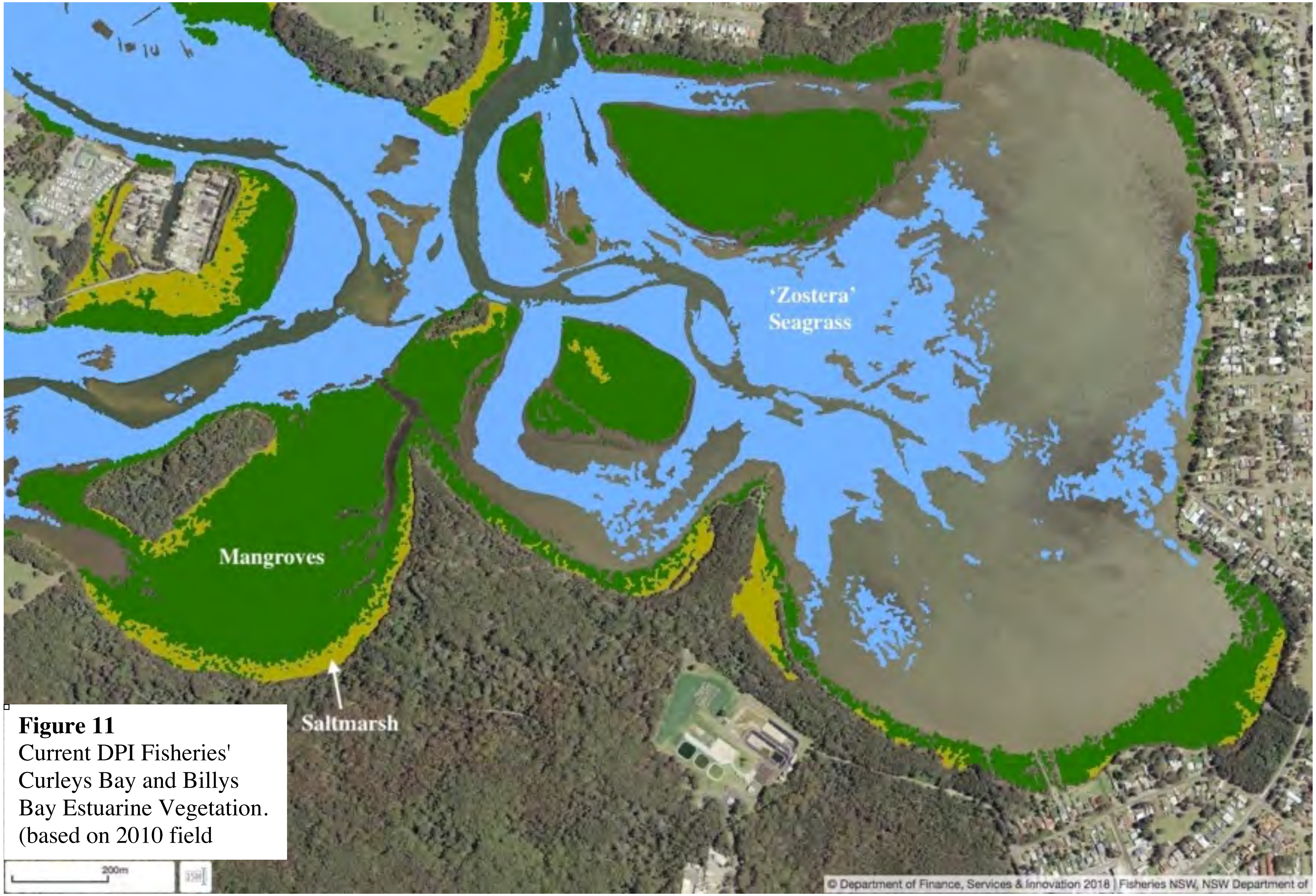

Figure 11
Current DPI Fisheries' Curleys Bay and Billys Bay Estuarine Vegetation. (based on 2010 field

Inspection of the various total macrophyte habitat estimates in **Table 2** would appear to indicate an overall increase in all habitat areas over time:

- Umwelt (2005) and Creese et al (2009) have provided explanation for a proportion of the increases based on improved mapping methodology.
- Whilst changes in mapped *Zostera* seagrass beds can be expected due to seasonal and event-based changes in above-ground seagrass shoot and blade biomass, there remains the possibility that some of the long-term change may be real, i.e., that there have been increases in seagrass extent. Notwithstanding, changes in seagrass beds can also arise from changes in sediment growth conditions such as, for example, increases in sediment sulphide concentrations arising from unfavourable environmental conditions (Ugarelli et al 2017).
- Umwelt (2005) also notes that changes in mangrove and saltmarsh distribution have been related to both anthropogenic and physical change:
    - Preferential growth due to water quality or sediment chemistry change - see for example Lovelock et al (2009) plus Reef et al (2010) for nutrient enrichment impacts on mangroves, Zedler et al (1995) for saltmarsh plant zonal organisation and more generally, Saintilan and Williams (2000) on NSW saltmarsh decline). Sediment nutrient quality is also mentioned in relation to 'dwarfism' in mangroves (see reviews by Naidoo (2006 and 2009), a phenomenon evident in the high tide mangrove zone along the Billys Bay shoreline.
    - Physical change due to flood or altered estuarine hydraulics leading to localised erosion or accretion (Umwelt 2005) or physical change due to livestock browsing or trampling; see Minchinton et al (2019) for cattle impact on Crookhaven River mangroves in 2006 and Hoppe-Speer & Adams (2015) for a more general review of livestock and mangrove collecting impacts on mangroves.
- Changes in intertidal zonal gradients and/or changes in tidal ranges for any of the above reasons (including climate change) are linked to a phenomenon called *coastal squeeze* where (most usually) mangroves shift their zonation up slope displacing the lower saltmarsh zonation whilst saltmarsh zonation becomes narrower as they are unable to penetrate the higher zonal limit due to competition with native riparian woodlands (e,g, smothering by she-oak needles) or because of physical obstructions (reclamations for roads, seawalls and agricultural lands behind fences where clearing plus stock damage limit saltmarsh colonisation upslope, see for example Saintilan & Williams (1999), Wilton (2002) Ross & Adam (2013), Mills et al (2016). see also Saintilan & Rogers (2013) in regard to climate change implications.

- Saltmarsh estimates in particular can also vary significantly by virtue of the inclusion or exclusion of sub-types made by researchers, a point made by Boon (2012) who noted that there is a large variety of fringing vegetation classes that are left in or out of estuarine wetland inventories; a case in point being the inclusion or exclusion of saltflats into the Shoalhaven River saltmarsh inventories (see also Adam et al (2010).

It is clear from the above considerations that there are a multitude of inter-related factors leading to changes in estuarine vegetation biomass estimates over time and that it is more advisable to treat the different total areal extent statistics provided for the Shoalhaven River in **Table 2** as estimates of essentially the same marine vegetation biomass area with attention focussed on changes in the pattern and location of various estuarine vegetation habitats. This is in line with the conclusions of the field work undertaken for this study that indicate some distinct differences in observed saltmarsh and mangrove distribution between the latest public mapping (**Figures 10 and 11**), as described in **Annexure C** and summarised in the following sections.

2.3.1 Estuarine Field Studies

As detailed in **Annexure C** , after an initial site inspection on the 5th July 2019, and following a preliminary desktop assessment of the available estuarine ecology data (as summarised in **Section 1.4** above), initial estuarine field work was concentrated on investigating the riparian transition from terrestrial habitats through intertidal (saltmarsh, mangroves) to shallow sub-tidal and inshore seagrass beds along 19 shore-normal transects established for the Crookhaven River catchment of the original staged proposal (i.e. from Cactus Point around to Culburra Beach township). **Figure 12** shows the location of the shore normal transects and other estuarine study sites. This study was undertaken between 4th and 6th September 2019, and completed during a second field survey between 15th and 18th October 2019. The long section transects are presented in the Supplementary Data Section for **Annexure C.**

The second field task was to gain a better understanding of the presence, speciation and condition of mangrove forests, and the majority of this field work was completed in the September survey and completed during October 2019 survey. This study included the following tasks:

- Extensions of the shore-normal surveys into the mangrove forest from the riparian foreshore transects.
- Overall mapping of mangrove forests facilitated by drone aerial photography.

- A study to ascertain how mainland stormwater runoff water would drain through the Billy's Bay mangrove forest during low tides (undertaken on 15th October 2019 prior to commencing shore-normal transect surveys of the mangrove habitat).

Drone aerial photography was also used to detail rocky shore habitats, in-shore plus offshore oyster farm infrastructure, the transitions from mangrove habitats to shallow intertidal sediment and seagrass habitats. This work was generally undertaken during suitable low tides in the late afternoons during the October 2019 surveys.

Pilot surveys were also undertaken to describe the seagrass beds (species present, overall density and evenness plus shoot lengths and density, including descriptions of the cryptic and smaller fish plus mobile invertebrate assemblages of the seagrass beds.

The scheduled February 2020 survey period coincided with a major flood, and this curtailed additional drone surveys that were scheduled for the predicted king low tides. The flood opportunity was instead used to undertake metered water quality profiles at multiple sites within Curleys Bay and the Crookhaven River near Billy's Island to provide tidal water quality change data plus tidal range and lag information (**Annexure D).**

Review of existing water quality data for the previous Concept Plan indicated that there were a number of public and government data bases of water quality for the Shoalhaven/Crookhaven River system, with some of these data sources utilised to provide overall river water quality statistics for estuarine modelling purposes. For the present revised project, MPR was able to access these data and **Annexure E** provides a more comprehensive account of the available water quality data, with a view that these data can be used for devising a Project Estuarine Ecology and Shellfish Habitat Health Monitoring Program.

Studies of the water quality of receiving waters provide a partial understanding of where and how water borne nutrients become available for plant growth and there are currently no data available on sediment nutrients for the Crookhaven River. **Annexure F** provides the results of a sediment study undertaken on 10 and 11 September 2020, which had as its aim the provision of base-line sediment character and nutrient status data for the various zoned vegetated estuarine habitats around Curleys Bay. These data provide quantification of the range of nutrient loads in sediments for riparian edge, intertidal and sub-tidal vegetation for considering potential ecological impacts of spatial changes to sediment quality associated with predicted estuarine water quality outcomes arising from the revised estuary or ‘receiving waters’ model - i.e., to show whether modelled water quality outcomes would have a ‘neutral effect’ in terms of estuarine ecology. s

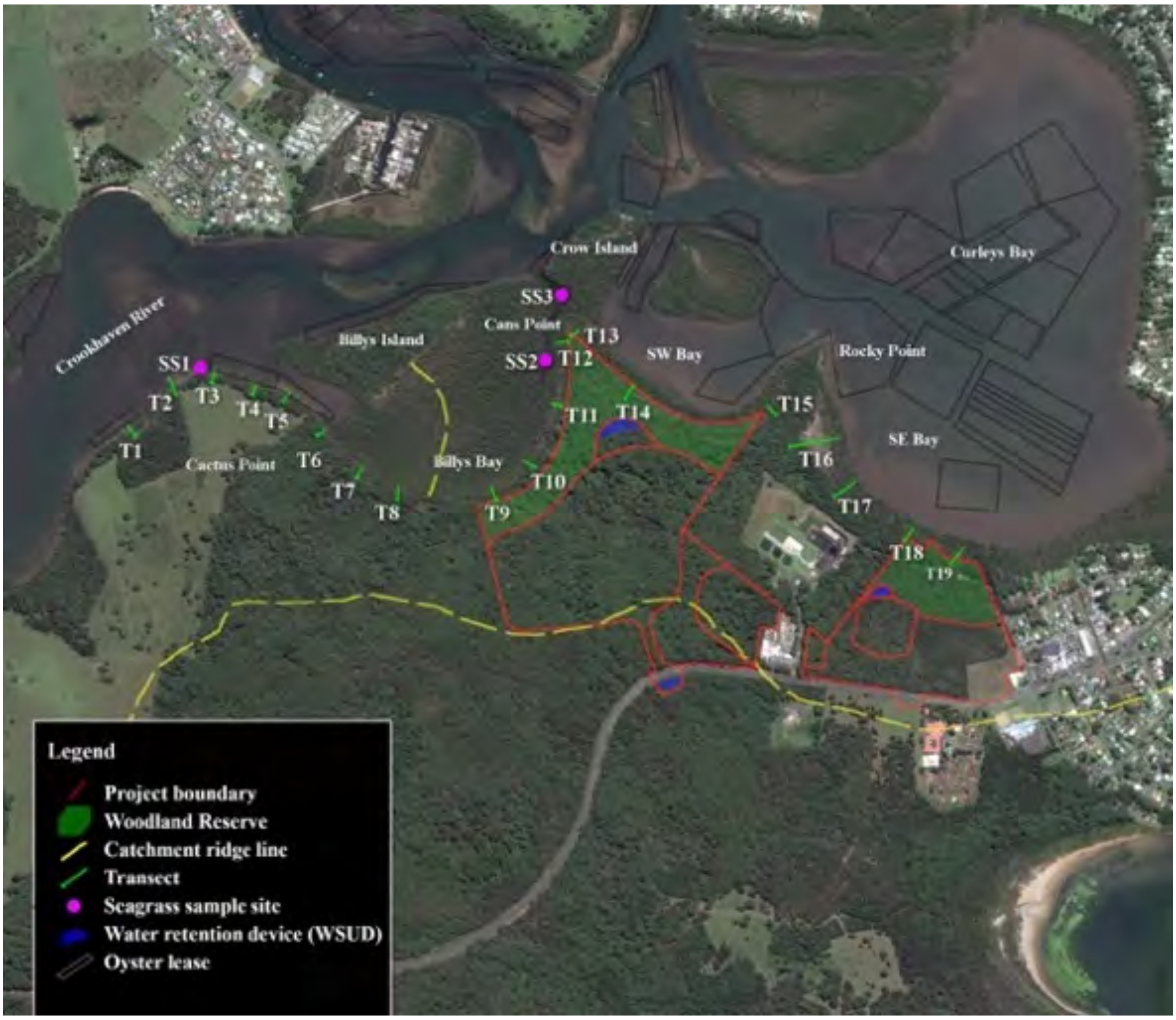

Figure 12 Estuarine aquatic ecology habitat assessment sites boarding the revised West Culburra Beach Concept Plan site. Note the delineation of mangrove drainage catchment areas inshore in Billys Bay (long dashed yellow line).

2.3.2 Lower Riparian Fringe

The lower riparian zone for the revised Culburra Beach Concept Plan includes the edge assemblages on the transition from freshwater/terrestrial habitats to estuarine habitats, and the intertidal habitats are zoned by tidal depth influence from saltmarsh inshore through mangroves to mud-flats offshore. Interspersed throughout this zonation there are sections of exposed basement rock with some rock rubble.

SLR (2013) provides field notes about the lower riparian transition zone on four photo-transects (see SLR 2013 Appendix D at Tab B003.017.004) and notes saltmarsh species occupying the understorey (groundcover) in SOCF: "*Species in low-lying, slightly more saline, areas include Bare Twig Rush, Leptinella longipes, Salt Couch, Sea-blite, Sea Rush and Swamp Goodenia*".

MPR surveys (**Annexure C**) provide detailed descriptions of the ecotone transition from riparian terrestrial edges into the shallow intertidal zone, based on the 19 shore-normal survey transects and longitudinal shore line surveys undertaken in August and September 2019 (**Figure 12**). These surveys indicate that for the most part there is a gentle slope at the transition from riparian to intertidal estuarine vegetation with some overlap of brackish and saline tolerant species at the top of the intertidal. The main exception to this is an eroded section of shoreline from Cactus Point east and into Billys Bay (Transects T1 to T5 and to a lesser extent T6) that has been destabilised by cattle grazing and trampling in the past. The eastern extent of this impact has been checked in the past with the extension of the existing property fence line out over the intertidal basement rock between the open grazing land and the retained woodland (just east of T5 in **Figure 12**). As noted in February 2020 there is new shore-parallel cattle exclusion fence line extending from the above property fence line and west around the shoreline past Cactus Point (**Figure 13**).

Figure 13

New Shoreline cattle exclusion fence at Cactus Point

The shore normal transect surveys also highlighted several areas of double intertidal transitions where there is an inner transition from mainland shoreline riparian habitats into intertidal saltmarsh habitat followed by a raised land section offshore supporting a generally she-oak dominated vegetation complex that then transitions back downslope towards the bay side through saltmarsh to mangrove zones (T14 around to T16 at Rocky Point). T16 is also associated with an extended inshore salt flat that has been degraded by vehicle tracks and human trampling (the STP Salt flat).

2.3.3 Intertidal & Sub-tidal Rock and Sediment Habitats

Rock habitats include natural and placed rock rubble reefs and associated biota (mainly algae, attached and mobile invertebrates and fish). Oyster reefs may be found on rock as natural and free-standing reefs (i.e., self-supporting on older oyster shell) or constructed - generally as part of historic oyster aquaculture.

Neither the SLR or ELA reports considers or comments on sub-tidal rock reef, oyster reefs or other hard substratum habitat that may support algae, and there is the unstated assumption that marine algae habitat does not occur or is infrequent in the study area. ELA (2017) alludes to hard substratum habitat with the remark that "*other marine vegetation (macroalgae and seaweeds) may occur, but was not an abundant habitat type in the surveyed area*". Whilst this conclusion is legitimate given the extent of saltmarsh and mangrove habitat in the lower estuarine river, the possibility of rocky or other hard substratum habitat (such as oyster reefs and oyster lease infrastructure) supporting algae could not be discounted.

The MPR surveys (**Annexure C**) noted that there are two areas of exposed rock habitat, a 400m section of river shoreline east from Cactus Point extending into Billys Bay West Drain (associated with foreshore sediment loss to cattle trampling and grazing - see **Section 2.3.2** above) and the presumed natural 90m shoreline either side of Rocky Point. There are also built sandstone boulder configurations at Cactus and Rocky Points and along the shorelines of SW and SE Bays that are used for (and continue to be used for) catching Sydney Rock Oysters in these locations. This is a traditional method for the natural collection of oyster spat (see also **Section 2.7.1** below). Most of these structures supported a simple invertebrate assemblage dominated by accumulated oyster growth and, with the exception of the gastropod *Bembicium melanostomum,* there were no other marine invertebrates and no marine algae observed - although the crevice habitats within and throughout the oyster reefs are expected to provide suitable habitat for a range of marine invertebrates such as polychaete worms, small crustaceans and other small bivalve molluscs.

Intertidal sediment habitats are mainly associated with benthic (sediment dwelling) biota; crustaceans, molluscs and polychaete worms, the shore/wading birds that prey on them at low tide and the fish that prey on them during tidal inundation. The MPR habitat surveys (**Annexure C**) noted that for the most part there are few bare sediment habitats in the upper intertidal with most of the upper intertidal supporting transition riparian vegetation to saltmarsh habitats. Similarly, the drone surveys (**Annexure C**) indicate that there are only narrow bare intertidal sediment banks at the lower side of the intertidal extent of mangrove growth which is more or less continuous along the foreshore shoreline. Whilst there are no local studies of the intertidal sediment habitats, Finegan and Brown (2000) provided an inventory of macroinvertebrate species of estuarine wetlands in the Shoalhaven Region using data collected from six estuaries south of the Shoalhaven River.

2.3.4 Saltmarsh Habitats

DPI Fisheries have produced estuarine vegetation maps of the Crookhaven and Shoalhaven River estuary as part of their state-wide estuary habitat mapping project (described in Creese et al 2009). **Figure 10** shows the DPI Fisheries Estuarine Vegetation Mapping for Crookhaven River, based on aerial photographs from 2002 and field assessments in 2003 that was used for estuarine vegetation mapping in all previous reports.

In regard to saltmarsh and mangrove habitats, SLR (2013) provided vegetation community maps (Figures 9A to 9D) which were surveyed by Environmental InSites in 2011, based on Nearmap aerial images from 2010. The report identified 15 main vegetation community types, including two estuarine communities; Coastal Saltmarsh (CSM) and Mangrove Forest (M). SLR (2013) provided no assessments of the health or condition of the saltmarsh or mangrove communities. Mapping of saltmarsh and mangroves was compared to the DPI Fisheries' mapping (Shoalhaven Heads Map 47a from 2003), and the mapped areas of mangroves provided in SLR (2013) are generally consistent with the DPI Fisheries' mapping.

The SLR (2103) saltmarsh habitats are noted as "*fringing the shoreline above the mangrove limits, and for the most part, they occupy the understorey along the lower fringes of the SOCF community*". The main CSM area bounding Rocky Point is generally consistent between the SLR and DPI Fisheries' mapping, with subtle variations in detail around the CSM boundaries. SLR (2103) also identified additional CSM areas that are not shown in the DPI Fisheries map;

- Three small patches of CSM to the east of Rocky Point,
- Two very narrow and small patches immediately to the west of Rocky Point (inshore in SW Curleys Bay),
- Two relatively large CSM patches along the shoreline inshore from Billys Island, between Cactus Point and Cans Point (Billys Bay).

ELA (2017) stated that "*Saltmarsh is uncommon along the southern shore of the estuary. It occurs in two locations near the Culburra Wastewater Treatment Plant*". Their one surveyed saltmarsh site on the eastern side of Rocky Point (the *STP Saltpan* in **Figure 1** above and at **T16 in Figure 12**) is described as follows: "*The larger of the two patches (Site*

05) is mostly bare sediment with Sporobolus virginicus (Saltwater Couch) and scattered Avicennia marina (Grey Mangrove) in the tidal inundation zone; and Juncus kraussii subsp. australiensis (Sea Rush) and Casuarina glauca (Swamp Oak) along the fringes". ELA (2017) did not produce any additional saltmarsh distribution mapping and provided no commentary on saltmarsh condition, other than to note that "*bare sediment has abundant crab burrows, an indicator of a healthy environment*".

The results of the MPR shore-normal transect surveys (**Annexure C**) support the overall SLR (2013) description and confirm that there is a transitional saltmarsh ecotone between the terrestrial riparian edge and in the upper intertidal above the mangrove zone for the compete extent of the shoreline surveyed from Cactus Point around to SE Bay. The MPR study also extends the saltmarsh species list for the locality and despite extensive searches the species do not include any species currently listed under the endangered species provisions of the State *Biodiversity Conservation Act 2016* (BCA) or of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act).

The saltmarsh fringe is more or less continuous from the cattle exclusion fence east of Cactus Point, around the Billy's Bay foreshore to Cans Point, and continuous around the shoreline of SW Bay from Cans Point to Rocky Point and around the shoreline of SE Bay from Rocky Point to Culburra Beach Township at Canal Street East. The width of the saltmarsh habitat varied from 6.6m at Transect 6 (just inside the cattle exclusions fence) to 137m (the STP saltpan) with a mean width of 32.3m, and there is an estimated 9.9Ha of saltmarsh habitat between Cactus Point and Culburra township.

The MPR survey could not confirm the SLR (2013) *two relatively large CSM patches along the shoreline inshore from Billys Island, between Cactus Point and Cans Point*, but, given the broad expanse of juvenile and dwarf mangroves now observed in the original SLR saltmarsh locations, it is also likely that previous saltmarsh areas have been colonised by encroaching mangroves. This same explanation could explain the mapping of those areas as saltmarsh in the 2010 DPI (Fisheries) mapping (see **Figure 11**) as discussed in **Section 2.3** above). Whether this is an example of *coastal squeeze* - as also discussed in **Section 2.3** above - or is related to changes in sediment chemistry and/or to slow accretion of sediments along this portion of the shoreline is not known. One way or another the change would appear to be a slow change - possibly over a decade.

The MPR field survey (**Annexure C**) also noted that eight of the ten characteristic saltmarsh species named under the *Fisheries Management* (*General*) *Regulation 2010* were recorded from the study area transects. Sea rush (*Juncus kraussii*) and sea couch (*Sporobolus virginicus*) were the most common saltmarsh species recorded from the study area transects (14 and 12 transects respectively), and particularly along the shoreline of Billys Bay. Both these species also had the highest tidal range. *Baumea juncae*, *Suaeda australis* and *Selliera radicans* were the next most common species being recorded from six transects each.

Saltmarsh species diversity was highest around Rocky Point (7 species) with 5 species recorded from transects in Billys Bay. Whilst *Sarcocornia quinqueflora* and *Triglochin striata* were noted all around the shoreline, both were found in smaller patch sizes than the other plants, so were underrepresented on the actual transect counts. As noted previously the impact of cattle grazing noted for Transects 1 to 5 meant that only one small patch of salt couch was recorded from these transects.

The width of the saltmarsh zone around the Billys Bay shoreline between Transect 6 and Transect 12 varied from 6.6m at Transect 6 (a 'recovering' transect that had been open to cattle grazing in the past) to 27m at Transect 9 in the eastern portion of Billys Bay, and the mean width was 18m. This compares to a width of around 40m shown on the present Fisheries mapping (**Figure 11**). The SW Bay saltmarsh zone widths varied between 6.4 m and 41.5m (mean 28.5m) whilst the NSW Fisheries mapping shows no saltmarsh for the T13 and T14 locations. The SE Bay (Rocky Point) saltmarsh zones varied from 17 to 54m width (mean 34m). The Rocky Point mean does not include the STP Saltpan (Transect 16) which had a total saltmarsh zone width of 137m (which matches the Fisheries mapping shown in **Figure 11**).

2.3.5 Mangrove Habitats

SLR (2013) describes mangrove habitats as a *Grey Mangrove Forest,* and this is accurate in the sense that Grey Mangroves (*Avicennia marina*) are clearly the dominant species in the study area. SLR (2013) describe the mangroves as a "*closed forest community with a generally low canopy height (to approximately 10m), and occasionally emergents. There is no shrub layer or groundcover*". The report does not discuss condition of mangroves.

ELA (2017) note that "*mangroves are abundant across the entire foreshore of the study area, with forests ranging in width between 10 – 500 m*". and "*mangroves in the surveyed area are a monoculture of Avicennia marina (Grey Mangrove), although Aegiceras corniculatum (River Mangrove) may occupy landward areas. However, River Mangrove may have been historically harvested for 'oyster sticks', resulting in a dominance of Grey Mangrove (Dwyer 2014)*".

ELA (2017) surveyed mangroves at two sites within the wide mangrove stand between the mainland and Billys Bay and makes the following comments on mangrove condition; *"Mangroves observed during the survey are in good condition because regeneration appears successful, with abundant seedling/juveniles and a variety of trunk girths (diameter at breast height) with no obvious gaps in recruitment events caused by disturbance",* and that "*canopy cover is dense and extensive, covering all available habitat."*

The MPR field studies (**Annexure C**) located River Mangroves at three places, a patch on the southern side of Crow Island, numerous stands of mixed maturity trees along the Culburra Beach Curleys Bay eastern foreshore, and a single specimen along the foreshore near Transect 14 (**Figure 12**). The disparate distribution of these occurrences lends credence to the above ELA (2017) suggestion of historic collection of River Mangroves as "oyster sticks" from the Curleys Bay southern shore at least.

As discussed in **Section 2.3.4** above, the greatest disparity between the combined DPI Fisheries 2010 mapping plus mapping provided by SLR (2013) and the present 2019 field work would appear to be the *possible* alteration of a swath of wide saltmarsh distribution located approximately between and either side of Transects T7 and T8 in **Figure 12**, to a generally dwarf or stunted Grey Mangrove forest in 2019 (see **Figures 14 and 15** below). The presence of stunted or dwarf mangroves could also provide an explanation of the ELA (2017) reference to regeneration (quoted above) as one of their sites is located within the area indicated in **Figure 15** that is identified as Dwarf Grey Mangrove habitat.

The shore normal transect studies undertaken for this report (**Annexure C**) provide the width of mangrove stands for 12 of the 19 shore-normal transects (as the remaining seven 60m transects were in the Billys Bay mangrove forest that continued beyond the 60 m transect length across to Billys Island). The width of the Cactus Point mangrove zone varied from 10 to 28 m with a mean width of 17m. The mean width for SW Bay mangrove zone was 49m and the mean width for SE Bay mangrove zone was 39m. These widths are generally in line with mangrove zone widths on the NSW Fisheries mapping (**Figure 11**).

Mangrove mudflats supported a high crab population as evidenced by burrow densities, with red-fingered mangrove crab *Parasesarma erythodactyl* most common. There were also several gastropod littorinid snails noted on the mud flats, and one littorinid snail, *Littorina scabra* noted on mature tree trunks. Mangrove pneumatophores (peg roots) are known to provide suitable habitat for macroalgae (Laursen and King 2000) and are common on Curleys Bay mangrove peg roots. They have an important role as primary producers in the estuarine ecosystem, through the production of organic material and contribution to nutrient cycling and have also been considered as bioindicators of estuarine contamination (Melville & Pulkownik (2006, 2007). Peg roots also provide habitat for oysters with the presence of oysters related to tidal submersion depths and for Curleys Bay are generally confined to the outer mangrove pneumatophore fields, i.e., at the mangrove habitat depth limits. Peg roots have also been suggested as bioindicators for metal contaminants (Nath et al 2014).

Figure 14 Close up view of Stunted or Dwarf Grey Mangroves between T7 and T8, (Photo 15 October 2019).

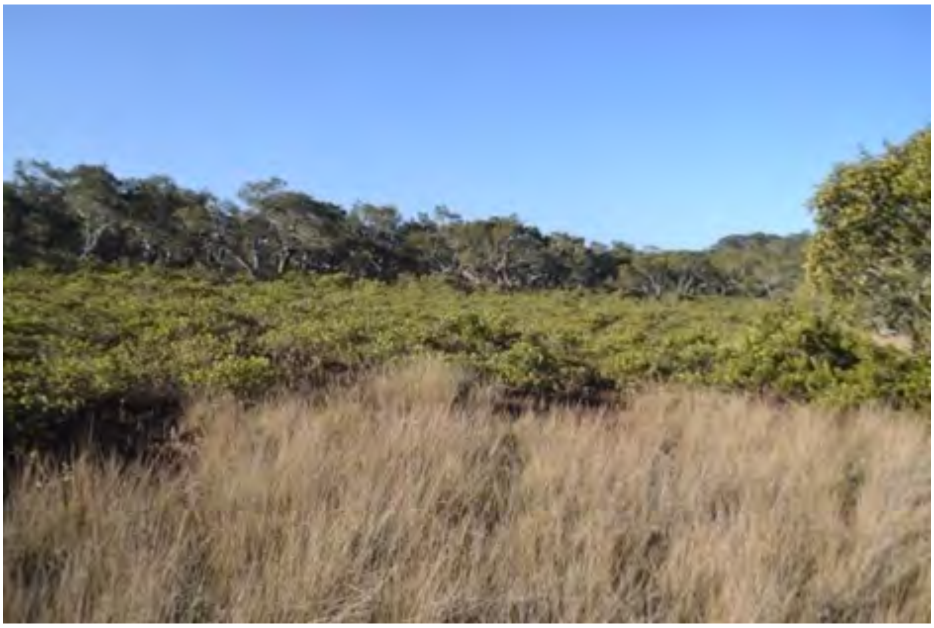

Figure 15 View of Stunted Grey mangrove stand east of T8, and offshore from an inshore *Juncus* dominated saltmarsh stand (Photo 15 October 2019).

2.3.6 Seagrass Beds

Seagrass habitats include the vegetation habitat itself and the assemblage of fauna that inhabit the seagrass beds; invertebrates within the bed and in the bed sediments, fish and smaller biota that colonise seagrass leaves (epibiota).

SLR (2013) reproduces the DPI Fisheries seagrass mapping (see **Figure 10** above) with no further comment on seagrass bed composition or condition. The ELA (2017) report also reproduces the DPI Fisheries Crookhaven River mapping. They refer to the Fisheries' mapping as 2009 but the mapping is the original 2003 mapping with the reference being to the Creese et al (2009) paper that discusses the Estuarine Habitat Mapping Program. They state that the estuary has an *extensive seagrass community, dominated by Zostera capricorni (Ribbonweed)* [2]. They do not discuss which species, if any, are sub-dominant.

The ELA (2007) field work included a survey of seagrass at five sites at high tide accessed by canoe and observed by means of a canoe-tethered underwater camera. They provide 'typical' leaf length, bed cover and leaf epiphyte cover statistics but do not provide the data from which these statistics are derived:

- They do provide underwater photos from all five sites that indicate a variable density of *Zostera* seagrass, a probable difference in site mean leaf length and a variable cover of epiphytes plus silt on seagrass blades.
- They note that *bioturbation from benthic infauna was evident at all (seagrass) sites, indicating sediment quality suitable to support aquatic organisms.*
- They conclude that "*meadows appear reasonably healthy, due to high density (cover), large extent, long leaf length, and minor-moderate epiphyte cover*":

The 19 shore-normal riparian to intertidal zone transects for the present study were extended seawards to include mangrove and seagrass beds with a 30m tape laid out from the end of the mangrove pneumatophore (peg root zone) zone for each transect where there was seagrass to survey. Survey results are provided in **Annexure C** and are summarised as follows:

- Scattered cover *Zostera* Seagrass beds were found along the Cactus Point Crookhaven River foreshore offshore from Transects 1 to 3 with bed widths between 6 and 24m, shoot lengths between 12 and 28cm and shoot densities between 5.5 and 9.3 shoots/100cm^2. Zostera was the only seagrass encountered.

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[2] Most legislation refers to Family *Zostereacea* or *Zostera* seagrass, generally meaning *Zostera capricorni*.This name is currently regarded as a synonym of Zostera muelleri subsp. capricorni (Ascherson) S.W.L.Jacobs, (See Jacobs et al 2006), and is retained for this report.

- There was no seagrass in West Billys Bay Drainage Channel offshore from Transects 4 to 6.
- Transects 7 to 11 are continuous mangrove zones across to Billys Island.
- There is an even *Zostera* seagrass bed across the 22m wide Billys Bay West Drainage Channel (Transect 12) with 25 cm shoot lengths and shoot density of around 7 shoots/100cm^2.
- There was no *Zostera* seagrass immediately offshore from mangroves for the SW Bay Transects 13 to 15 but there is scattered *Zostera* in deeper waters offshore.
- There is scattered cover of *Zostera* seagrass offshore of Rocky Point East side (Transect 16) and this bed extends well offshore. Mean shoot length was 16 cm with a low shoot density of 3.4 100cm^2.
- There was no bed off T17 for 30 m offshore at least, but there were some small isolated *Zostera* patches. The patch that was measured had only 2 shoots in the 100cm^2 quadrat.

Whilst the overall distributions are similar to the distributions indicated on the NSW Fisheries 2010 mapping (**Figure 11**), the NSW Fisheries mapping does not provide an indication of seagrass density or bed evenness and, as summarised above, for most of the inshore beds surveyed, the seagrass cover was scattered rather than even.

Seagrass beds provide a complex habitat for epibiota (biota living on the plants themselves - Borowitzka et al 2005) or biota associated with the seagrass plants (e.g., West and Jones 2001, Rotherham & West 2002). Seagrass beds are commonly utilised by juveniles and adults of many species of fish and provide a nursery habitat for early life forms of fish. Shokri et al (2009) using 8m by 2m (1 mm mesh) seine nets for 37 *Zostera* bed locations in four NSW Central Coast estuaries reported 73 species from 35 families, with syngnathids (seahorses, pipefish and the like) represented by one seahorse and six pipefish species.

Pilot sampling of *Zostera* beds for mobile fauna was undertaken in Crookhaven River for this study using hand-net sweep sampling, one site in the Crookhaven River bed between Transects 2 and 3, one from the Billys Bay East Drainage Channel near Transect 12 and one from Crow West Channel (see **Figure 12** for site locations). The three *Zostera* bed samples yielded 13 small or juvenile fish specimens; 5 Gobies, 4 Luderick, 2 Fortescue and 2 Pipefish. There were 41 prawns and shrimp collected and a variety of molluscs including a sea slug, 8 squid and 47 gastropod snails. Given the limited meshing undertaken. the results indicate a relatively good diversity and abundance of mobile species in the *Zostera* beds of Crookhaven River.

2.3.7 Water Column and Sub-tidal Sediment Habitats

The water column itself is another habitat that links all the fixed habitats and supports additional marine biota including plankton, swimming or mobile invertebrates and fish. All the resources of these combined habitats are then important for a variety of other animals (e.g., turtles, marine mammals, sea birds, little penguins, shore birds and waders). Whilst neither of the studies considers the water column habitat in terms of plankton ecology or fish assemblages, both imply that as the main fish habitats are generally in good health then they should also support good fish and invertebrate assemblages. This is in line with conclusions of West and Jones ((2001) who studied the shallow water fish communities of south coast estuaries including Shoalhaven River over two seasons (summer and winter) in 1998 and over both seasons there were 26 species from *Zostera* seagrass beds *near the Shoalhaven River entrance*. *Ambassis jacksoniensis* was the most common species (60% of abundance), followed by three Gobies; *Gobiopterus semivestitus (6%)* and *Afurcagobius tamarensis* plus *Pseudogobius olorum* (4% each).

There is also extensive sub-tidal estuarine sediment habitat in Curleys Bay and the Crookhaven River, and this habitat generally supports a diverse assemblage of bottom dwelling (benthic) infauna. Whilst neither of the former proposal ecology reports considered these habitats *per se*, the ELA (2017) report comments on the abundance of burrows in mangrove sediments and observations of bioturbation in seagrass beds *indicating sediment quality suitable to support aquatic organisms*. In terms of relevant studies of the sediment benthos, there are some early studies of Shoalhaven River estuarine benthic studies undertaken by The Ecology Lab and summarised in Boyes (2006b) as follows:

The Ecology Lab (1995) sampled benthic macroinvertebrates in the lower estuary. In general, greater diversity of species and greater numbers of individuals were found closer to the mouth of the river, compared to sites further upstream. Polychaetes dominated the fauna, with bivalve molluscs also abundant. The data indicated that salinity, and to a lesser extent depth were the most important factors in explaining complex distribution patterns.

Boyes (2006b) also reviews a further Shoalhaven River estuary benthic study by The Ecology Lab (1996) that *identified 38 species of benthic macroinvertebrates. All of the species found were typical of estuarine fauna and none were considered rare or endangered. Considerable variation was observed in the patterns of distribution and abundance of the benthic macroinvertebrates across the study sites, and this was found to correlate strongly with variations in salinity.*

2.4 Shore, Wading and Fishing Birds in Curleys Bay

Intertidal sediment habitats are an important feeding habitat for shore and wading birds and the study area intertidal sediment habitats are located half way between internationally important and well recognised wader, shorebird and seabird habitats at Comerong Island to the north and Lake Wollumboola to the south. The SLR (2013) report assesses *water and wading birds which forage in or along the margins of estuaries and rivers (eg waders, herons, cormorants and oystercatchers)* and SLR (2013 Appendix L (Tab B003.017.012) provides records of water and wading bird sightings for the various studies reviewed or undertaken by SLR. The report provides the following conclusion regarding water bird use of the estuarine habitats:

> *Individuals of an array of wading and wetland bird species would utilise the mudflats, mangrove forests and small areas of Coastal Saltmarsh to the immediate north of the subject site at Culburra West. A wide variety of such species have been recorded within the Crookhaven River and Shoalhaven River estuaries and/or in Lake Wollumboola and it is anticipated that a number of such species would utilise the mudflats and mangrove forests to the immediate north of the subject site. There are, however, no records of any roosting by wetland and wading species on the subject site itself, and the subject site per se does not contain even potential roosting resources for any such species. The overwhelming majority of the estuarine habitats are located well to the north of the proposed development footprint.*

The observations of little or no use of the Curleys Bay mud flats in SW and SE Bays is confirmed by our own surveys where, aside from a single Heron on the SW Bay mud flat and a single small black cormorant in waters of SW Bay over the complete field study period, there were no sightings of any shore, wading and other fishing birds noted from these areas at the low tide sampling periods. Further, whilst there have been sightings of foraging shore-birds on the more extensive mud flats in NE Curleys Bay during very low tide exposure, there were no shorebirds observed in SE or SW Bays at those times.

The low utilisation of the SE and SW Bay mud flats by wading and shore birds can be related back to the relatively narrow width of the intertidal mud flats immediately offshore from mature mangrove trees around 5 to 6 m high. Straw (2007) notes that use of mudflats by most waders and other shorebirds is dependent on adequate sight lines from the feeding positions over adjacent trees for predator avoidance, and he notes that from empirical evidence for a tree line of 5m height waders will prefer to be some 55m away. Analysis of mean width of drying mud flats off-shore from the mangrove distributions in SW Bay show that the mangrove pneumatophores (peg root) beds extend some 14 m offshore from the mature mangrove forest tree line and that the intertidal mud banks offshore dry out to a distance of around 40m for mean tides. Thus, there is around 54m distance from the mangroves to the edge of the mudflats at mean low tide, meaning that shore and wading birds are not likely to settle and feed inshore from the outer edge of the mudflat but may feed beyond that mean tidal limit during lower spring low tides. As shore and wading birds are also known to prefer to feed on optimal feeding habitat during king low tides, it is more likely that these birds will utilise the known high -quality habitats of Lake Wollumboola and Comerong Island in preference to southern Curleys Bay.

2.5 Protected & Threatened Aquatic Species, Communities and Populations

Aquatic habitats, flora and fauna of conservation significance are protected under both State and Federal legislation. In NSW, and at the time of the original Concept Proposal Application, the subject of the present Land and Environment proceedings, threatened species, populations and ecological communities of animals and plants were protected under the Threatened Species Conservation Act (TSC Act), and this Act still applies to this present application. Threatened species, populations and ecological communities of fish and marine vegetation are protected under the *Fisheries Management Act 1994* (FMA). The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) protects wetlands of international importance, Commonwealth Marine Areas, nationally threatened species and ecological communities and migratory species.

The FMA, TSC Act and EPBC Act require that any proposed activity be assessed with respect to its potential impact on species or ecological communities listed as threatened under the Threatened Species Schedules or listed as migratory species under the various Acts. This review has, for completeness, considered current threatened species schedules under the present *Biodiversity Conservation Act 2016* (BCA), the FM and EPBC Acts.

2.5.1 Previous Assessments

The SLR (2013) report considers water-associated threatened bird species and the saltmarsh EEC and concluded that whilst there are listed threatened species in the locality that could be utilising the estuarine resources, this utilisation is confined to the estuary habitats that are isolated from the proposal by the 100m buffer vegetation.

The ELA (2017) report Section 4.3 considered threatened estuarine aquatic species and communities (but not aquatic bird species), and ELA Appendix E provides a *Likelihood of Occurrence Table* for twelve threatened species and for the Saltmarsh threatened community. They indicate that a number of sharks and fish that are known or expected from offshore waters or from the Shoalhaven River are *not in the region,* without specifying what the region limit is. The Section also states that t*here are no threatened plant species observed in the study area,* without providing any guidance as to which threatened plants may have been expected (e.g.*, Wilsonia spp* in the saltmarsh patches).

Section 4.3 of ELA (2017) then provides a similar conclusion to the SLR (2013) report, with the added comments that *the likelihood of the main groups of threatened aquatic fauna to occur in the area are:*

- *Fish – unlikely as no suitable habitat, or no records in catchment*
- *Sharks & rays – sharks unlikely to come this close to shore in shallow water; rays may pass through, but there is ample foraging habitat throughout the estuary*
- *Turtles – may briefly explore area, especially in seagrass beds*
- *Whales & dolphins – too shallow, unlikely this close to shore.*
- the *two patches of saltmarsh* near the Culburra Wastewater Treatment Plant would not be impacted by the proposal.

The combined assessments for species listed under the NSW BCA and under the Commonwealth EPBC Act are reviewed in the proposal EIS, and the following Section provides an update review for several estuarine species including saltmarsh EEC.

2.5.2 Update Review for Listed Estuarine Biota

There are a number of marine and estuarine shark and teleost fish species listed under the FMA and EPBC Acts that are known from the general locality and the potential for their presence and dependence on the estuarine habitats of Crookhaven River and Curleys Bay is reviewed below. All Syngnathiformes (seahorses, sea-dragons, pipefish, etc) are protected under the EPBC Act and the FMA and their utilisation of the locality is also reviewed below:

- Given depth limits in Curleys Bay and the distance upstream from the estuarine mouth, it is considered that listed Grey Nurse and Great White shark species would not be expected to visit Curleys Bay or if they do, it would be rarely.
- There is no suitable rock habitat for adult Black Rock Cod *Epinephelus daemelii* in the Crookhaven River estuary upstream of Greenwell Point, but juvenile Black Rock Cod could be expected to occur as rare transients between seagrass beds and the lower estuarine and ocean rocky shores. They are unlikely to occur in Curleys Bay seagrass beds except as rare transients.
- The Shoalhaven River system supported populations of Macquarie Perch and Australian Grayling (Gherke et al 2001, 02) that were both reported in 1978

from below Tallowa Dam where Australian Grayling upstream migration to freshwater habitats was inhibited by the dam (Bishop and Bell 1978).

- The Macquarie Perch population is limited to the upper Shoalhaven River and is not expected in the more estuarine Crookhaven River.
- Australian grayling is a migratory species that spawns in the lower freshwaters of coastal rivers and spends approximately 6 months in coastal seas as larvae/juveniles before migrating back into freshwater rivers and streams where they remain for the rest of their lives (Riches et al 2016). The Australian grayling population above the dam was considered extinct in 2001, and none were caught below the Dam at that time (Gherke et al 2001). It is considered highly unlikely that Australian graylings would be found in the estuarine habitats of Crookhaven River.

Of the 31 species Syngnathiformes known from East Coast Australian waters, White's seahorse *Hippocampus whitei*, Coleman's seahorse *Hippocampus colemani* and the pygmy pipehorse *Idiotropiscis sp*.), are endemic to NSW and White's seahorse has recently been listed under the FMA as *endangered* in NSW waters:

- White's seahorse is known from NSW estuaries south to Sussex Inlet, and are found in water depths between 1m (shallow seagrass beds and rocky reef algae habitats) to 18m deep (natural reefs or structures with complex sponge-type habitats). In Port Stephens White's seahorse is commonly found in *Posidonia* seagrass habitats. In Sydney Harbour White's seahorse is generally found on artificial structures that provide an abundance of camouflage habitat (e.g., dense macro-algae beds or diverse encrusting fauna). Specific searches were made in the Crookhaven River *Zostera* seagrass beds during the seagrass surveys undertaken for this report (**Section 2.3.6** above) and none were found. It is considered that the relative sparse and uneven nature of much of the *Zostera* seagrass distribution in Curleys Bay is such that it there is insufficient camouflage habitat available, and it is unlikely that White's seahorse would occur, at least in these bed types.
- Several species of pipe fish are commonly found in *Zostera* seagrass beds and specific searches for Syngnathids in the Curleys Bay seagrass habitats, confirmed that these beds do support pipefish.

Three seagrass species known from upper South Coast estuaries, *Posidonia australis*, *Zostera capricorni* and *Halophila ovalis*, are protected under the FMA, and *Posidonia australis* seagrass is also listed under the Commonwealth EPBC Act as an Endangered Ecological Community. No *Posidonia* seagrass have been reported from Shoalhaven River, none have been found at the site and *Posidonia* is not expected in the Shoalhaven River estuary. Whilst not reported, and to date not noted during studies in Curleys Bay to date, *Halophila* species are commonly found as understory species in *Zostera* seagrass beds and are expected in the Crookhaven River seagrass beds, most likely as a sub-dominant.

Saltmarsh is listed under the EPBC Act and the BCA, and is protected as Key Fish Habitat (KFH) under the FMA. A number of individual saltmarsh species are also listed under the BCA, of which two *Wilsonia* species are known from the locality (including Lake Wollumboola). MPR saltmarsh characterisation field work to date has included inspections for these species and none were found (**Section 2.3.4** above).

Six of the world's seven species of marine turtles occur in Australian waters (DE&E 2017). The Loggerhead Turtle (listed as endangered under the BCA and EPBC Act) is reported from coastal waters off shore from the Shoalhaven River and Green turtles (listed as *vulnerable* under the BC*A* and EPBC Act) are known or reported from the waters of Crookhaven River and Curleys Bay. Loggerhead turtles prefer open water of coastal habitats and are unlikely to penetrate into the Crookhaven River estuary to Curleys Bay.

Green turtles that have been sighted in both Crookhaven River and Curleys Bay are generally late *juvenile-adult* stage turtles. Green turtle *post-hatchling/young juveniles* are hatched in Coral Sea nurseries - generally off the Queensland Coast, but with some recent expansion to northern NSW locations. They spend the first 5-10 years in oceanic waters of the southern Pacific Ocean, utilising floating seaweed rafts and opportunistically feeding on gelatinous organisms, before returning to shallow inshore foraging habitats (DE&E 2017). These *Juvenile-adults* feed in a diverse range of tidal/sub-tidal habitats along the whole east Australian coast - coral reef, mangrove, sand, rocky reefs and mudflats where there are algal turfs or seagrass meadows present, and a proportion of turtles may also remain resident in the open ocean.

Whilst there is no potential risk for Green turtle nesting in the southern waters of NSW including the Shoalhaven estuary, individuals in southern estuaries remain at risk from vessel strike and ingestion of marine debris. Given the tidal and oyster infrastructure hinderances to vessel speed in Curleys Bay and much of Crookhaven River, it is concluded that there would be no increased collision risk for green turtles feeding in Curleys Bay from the limited increased use for recreational fishing. The risk for green turtles and other aquatic biota arising from ingesting anthropogenic rubbish (plastics in particular) sourced directly from the development is considered low as these are to be controlled at source. Whilst there is a limited additional risk for aquatic biota from ingestion of plastic debris or discarded hooks plus fishing lines from increase numbers of recreational fishers or boaters, this general risk is already being mitigated by education including placement of appropriate signage at launching sites and at bait shops and discouraging the use of plastic bags for brought bait.

It is concluded that other than saltmarsh habitat and utilisation of seagrass beds for feeding by Green Turtles, there are no aquatic EECs or threatened species known or residing within the near vicinity of the revised Culburra Beach Concept Plan proposal site, and use of intertidal mud flats by listed wading and shore birds would be opportunistic, limited by inadequate predator sight lines from the shore to the available feeding areas, and limited by wind wave and tidal restrictions (as discussed in **Section 2.4** above).

2.6 Key Fish Habitat Assessment

With regard to the sensitivity classification (as defined in Table 1 of Fisheries NSW 2013) of the specific habitats within the estuarine waters along the shoreline of the revised Culburra Beach Concept Plan, the following key points are made:

- The patches of *Zostera* along the shoreline fronting the proposal area in the Crookhaven River, Crow West channel, SE Bay and SW Bay are classified as Type 1 “highly sensitive KFH” as bed sizes are greater than $5m^2$**.**
- Similarly, the mangroves and coastal saltmarshes identified throughout the study area are classified as Type 1 “highly sensitive KFH” as saltmarsh stands and mangrove forests are greater than $5m^2$ in area.

2.7 Aquaculture in Crookhaven River Estuary

Aquaculture includes both in-stream and off-stream practices. There are no off-stream aquaculture activities in the Crookhaven River and the nearest known off-stream aquaculture activity in the estuary is a marine algae cultivation facility at Bomaderry on the Shoalhaven River near Nowra where green algae are grown using nutrient-rich agricultural wastewater from Shoalhaven Starches at Manildra to produce a range of pharmaceutical and food products.

The Shoalhaven River supports a relatively extensive in-stream aquaculture industry in the lower Shoalhaven/Crookhaven River estuary based mainly around cultivation of two oyster species; Sydney Rock Oysters *Saccostrea glomerata* (SRO) and Pacific Oyster *Crassostrea gigas* (PO). SROs are grown from both hatchery and estuary-collected spat whilst PO aquaculture is based on hatchery produced juvenile seed-stock of 100% triploid (sterile) POs that are imported from authorised hatcheries operating under mandated NSW DPI

Fisheries Shellfish Hatchery Production and Translocation Protocols under the NSW *Biosecurity Act 2015*.

In 2012 oyster farmers in the Shoalhaven River developed an Environmental Management System (EMS) to highlight the industry's environmental priorities and to guide improvements in the estuary and surrounding catchment SRO (2012). The EMS was updated in 2014 with a review in 2015 (SROF 2015).

2.7.1 General Oyster Farming Practices in the Estuary

SRO (2012) provides a comprehensive description of the oyster farming methods utilised in the Shoalhaven/Crookhaven River. Whilst individual oyster farmers will vary their collection, growth and harvesting practices dependent on lease locations, species under cultivation and river plus weather conditions, most cultivation tasks will be governed by oyster biology/life cycle and commercial harvest timing requirements. A case study presented in Ogburn (2011) provides a detailed description of the temporal and spatial single seed farming methods utilised by one farm in the Crookhaven River Estuary for SRO spat collected on slats in the year 2000. This is summarised in *Figure 26* of Ogburn (2011) which is reproduced below as **Figure 16.** Over the period February 2000 to April 2003, slats were set for spat collection at the beginning of the year and harvested in September 2000, stocked into tumblers then thinned out over seven months. They were then transferred to trays and the trays are manipulated and shifted around the estuary for a further 16 months (including transfers upriver and keeping stock elevated in the water column to avoid *winter mortality* in May 2002), then transferred to 'pillows' on leases downstream in *rough (turbulent) water* for a month prior to harvesting over five months.

Importantly, the use of tumblers and pillows over sticks and trays have given oyster farmers more mobility/flexibility in relation to shifting stock between leases to maximise oyster growth whilst minimising both risk of loss to disease and risk of condition loss due to premature spawning.

2.7.2 Management of Oyster Aquaculture in Crookhaven River

Oyster aquaculture in NSW is managed via the NSW DPI Oyster Industry Sustainable Aquaculture Strategy. OISAS (2016) estimated that sustainable production level for oysters in NSW estuaries is 7500 tonnes, and the principal aim of OISAS is to establish the regulatory environment within which the industry can grow to this level, based on establishing a physical set of boundaries for oyster lease locations set estuary by estuary, resulting in a series of estuarine maps setting out the Priority Oyster Aquaculture Areas (POAA):

- The total POAA lease area in NSW was 3585Ha in 2014/15 with 2587 Ha in North Coast estuaries and 998 Ha in South Coast Estuaries (DPI 20126), and the Crookhaven River ranks as the 7th largest POAA in NSW and ranks 2nd, just under Clyde River (192 Ha) for the south coast oyster production areas.
- For the Shoalhaven/Crookhaven River, the majority of the leases are located in the Crookhaven River (143 Ha - see POAA Lease areas in **Figure 17** below), with just over 13 Ha in the lower Shoalhaven River.

2.7.3 Crookhaven River Oyster Production

SRO production in the Shoalhaven/ Crookhaven system has varied considerably over time, with peak production rates achieved in the 1980s and 90s accounting for half of the states total production of SROs at the time. Over the past four years the overall Crookhaven River proportion of the total annual production for the NSW oyster industry has varied between 3.7% and 6.0% for SROs and 4.6% and 28.9% for POs. Total production fluctuated between 374,699 dozen oysters in 2017/2018 down to the present 267,131 dozen oysters in 2018/2019 (**Figure 18** below), with most of the decrease in production being for POs following the outbreak of Pacific Oyster Mortality Syndrome (POMS) between 2010 and 2013.

2.7.4 Oyster Aquaculture Water Quality requirements

Oysters are filter feeders and, on average, a farmed Sydney Rock Oyster will filter between 0.5 to 1 ML of estuarine water in its lifetime (Ogburn 2011), removing large quantities of suspended material, chiefly nutrients bound in phytoplankton. This means that oysters are important in maintaining healthy estuaries, but in performing this role they are exceedingly vulnerable to poor estuarine water quality, particularly in relation to the ingestion of water-borne faecal matter and plankton that are toxic to humans. Whilst generally not a risk to the oysters, the oysters that ingest these materials can become a risk to the human population that consumes oysters. Accordingly, OISAS provides a set of Guidelines for management, water quality and flow objectives for oyster aquaculture areas that, if met, will provide for the healthy growth of oysters that are safe for human consumption. The current guidelines are as follows:

- DPI Food Authority 2015 *Marine Biotoxin Management Plan*,
- Gipple & Sachs 2017 *DPI Healthy estuaries for healthy oysters- guidelines*,

- DPI Food Authority 2018 *NSW Shellfish Industry Manual*,
- DPI Food Authority 2019 *Phytoplankton and Biotoxins in NSW Shellfish Aquaculture Areas Risk Assessment*).

The *Phytoplankton and Biotoxins* report states that *in NSW shellfish aquaculture areas, significant phytoplankton blooms have been infrequent. Harvest area closures have been primarily due to rainfall and/or salinity exceeding the trigger levels used as indicators of microbial and viral water quality. However, increasing demand on coastal resources from an increasing population ... and the potential for spatial and temporal distributions of harmful phytoplankton species to be altered dramatically by a changing climate... are key future challenges.*

The combined guidelines listed above are used to provide specific Harvest Area Management Plans on an Estuary by Estuary basis and currently there are five separate harvest areas in the Crookhaven/Shoalhaven (see **Figure 17** above), each with its own designated water and oyster quality monitoring locations for water quality and phytoplankton testing and for harvesting of oyster samples for pathogen testing (see **Figure 19** for monitoring locations).

These plans combined with estuarine monitoring data determine whether harvesting can occur, with formal instructions for closure and reopening of harvest areas provided by NSW Food Authority:

- For the Curleys Bay Harvest Area there are three shellfish testing locations and there are three water quality sampling locations; two inshore near urban shorelines at Orient Point (site 11) and off Culburra Beach (site 2) and one site in SW Bay (site 10). Sites 10 and 11 are on the boundary line between Curleys Bay and Goodnight Island Harvest areas.
- The closest phytoplankton monitoring site is in Crookhaven River Harvest Area north-east of Billys Island (site 35).

Real time water temperature, salinity and depth data from the Shellfish Monitoring Network operated by NSW Food Authority Shellfish program are stored on an agriculture data management application called *The Yield* that can be accessed by oyster farmers for up to four week's previous data, to allow farmers to manage the movement of their stock between leases.

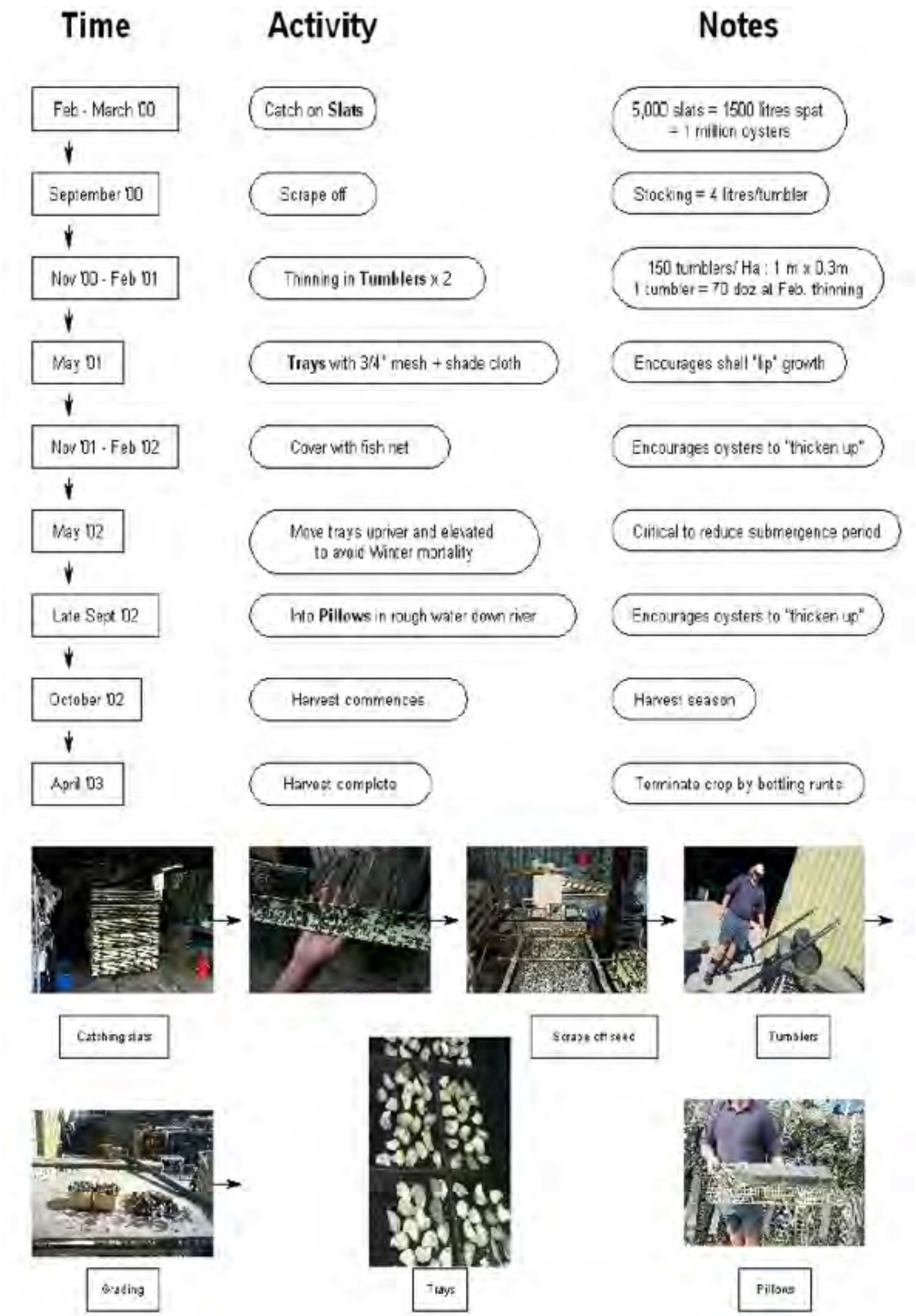


Figure 16 Oyster farming system used in the Crookhaven Estuary based on the year 2000 oyster spat collection - From Figure 26 in Ogburn (2011) and courtesy of Shoalhaven Oyster Services Pty Ltd.

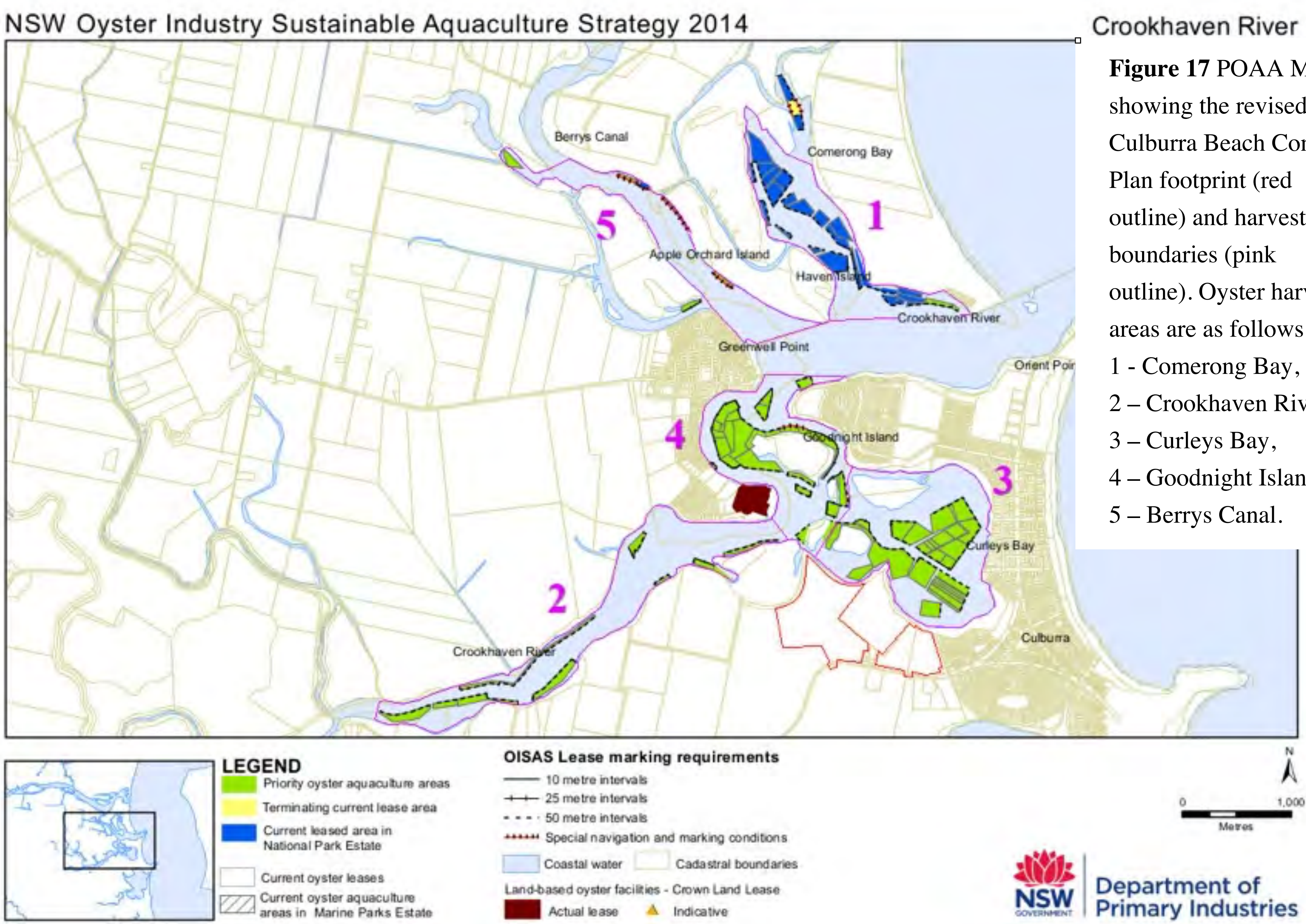


Figure 17 POAA Map showing the revised Culburra Beach Concept Plan footprint (red outline) and harvest area boundaries (pink outline). Oyster harvest areas are as follows;
1 - Comerong Bay,
2 – Crookhaven River,
3 – Curleys Bay,
4 – Goodnight Island,
5 – Berrys Canal.

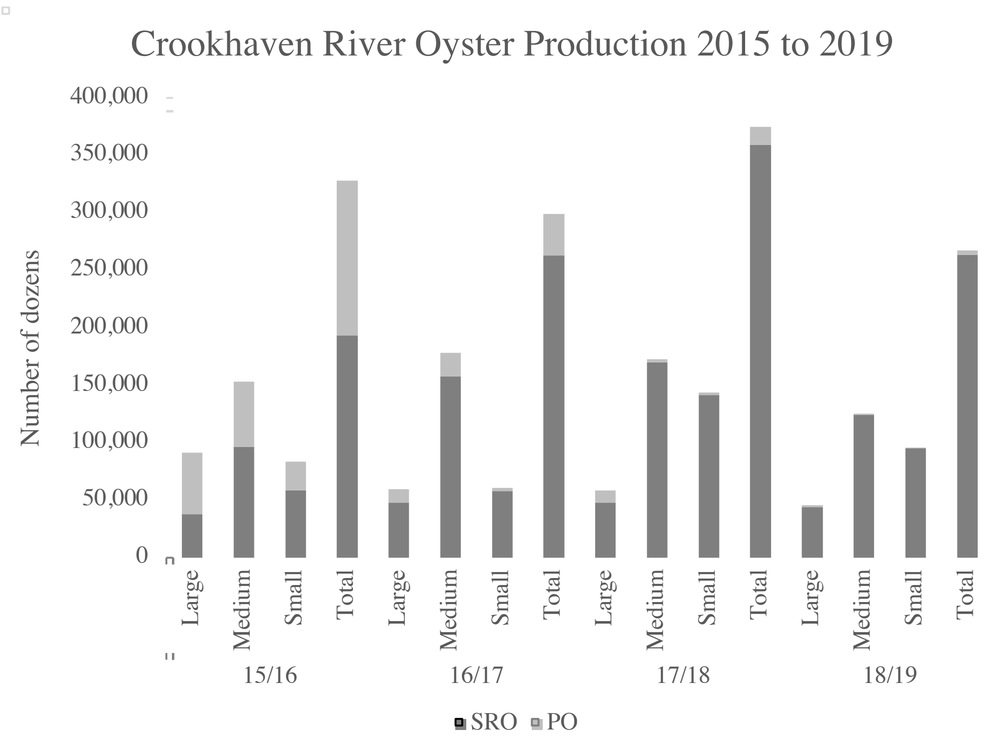


Figure 18 Crookhaven River oyster production figures over the last four years (data source: NSW DPI 2020)

- The NSW Food Authority administered harvest area classification and approval levels are periodically reviewed, with *conditionally approved* status regarded highly among oyster growers, and to this end the Curleys Bay oyster farmers are working to have the Curleys Bay harvest area conditionally approved for direct harvest.

The current Harvest Management Plans for Curleys Bay, Crookhaven River and Goodnight Island Harvest Zones are provided in **Annexure C Supplementary Data**:

- The Goodnight Island and Comerong Bay harvest areas are currently the only locations in the Shoalhaven/ Crookhaven estuary classified as 'conditionally approved' under the NSW Shellfish Quality Assurance Program to sell oysters direct to the public (i.e. without depuration) due to their ability to meet strict water quality criteria.
- There is also a small but growing Australian oyster export market, of which Comerong Bay is one of only 23 export approved harvest areas in NSW (DPI 2016).
- For the Crookhaven River and Curleys Bay Harvest Areas, the level of pathogenic organisms that may lead to food safety concerns are controlled by a process called 'depuration' where oysters are placed in tanks with known high quality and well-oxygenated waters for at least 36 hours to promote purging of any possible contaminants by the oysters prior to sale.

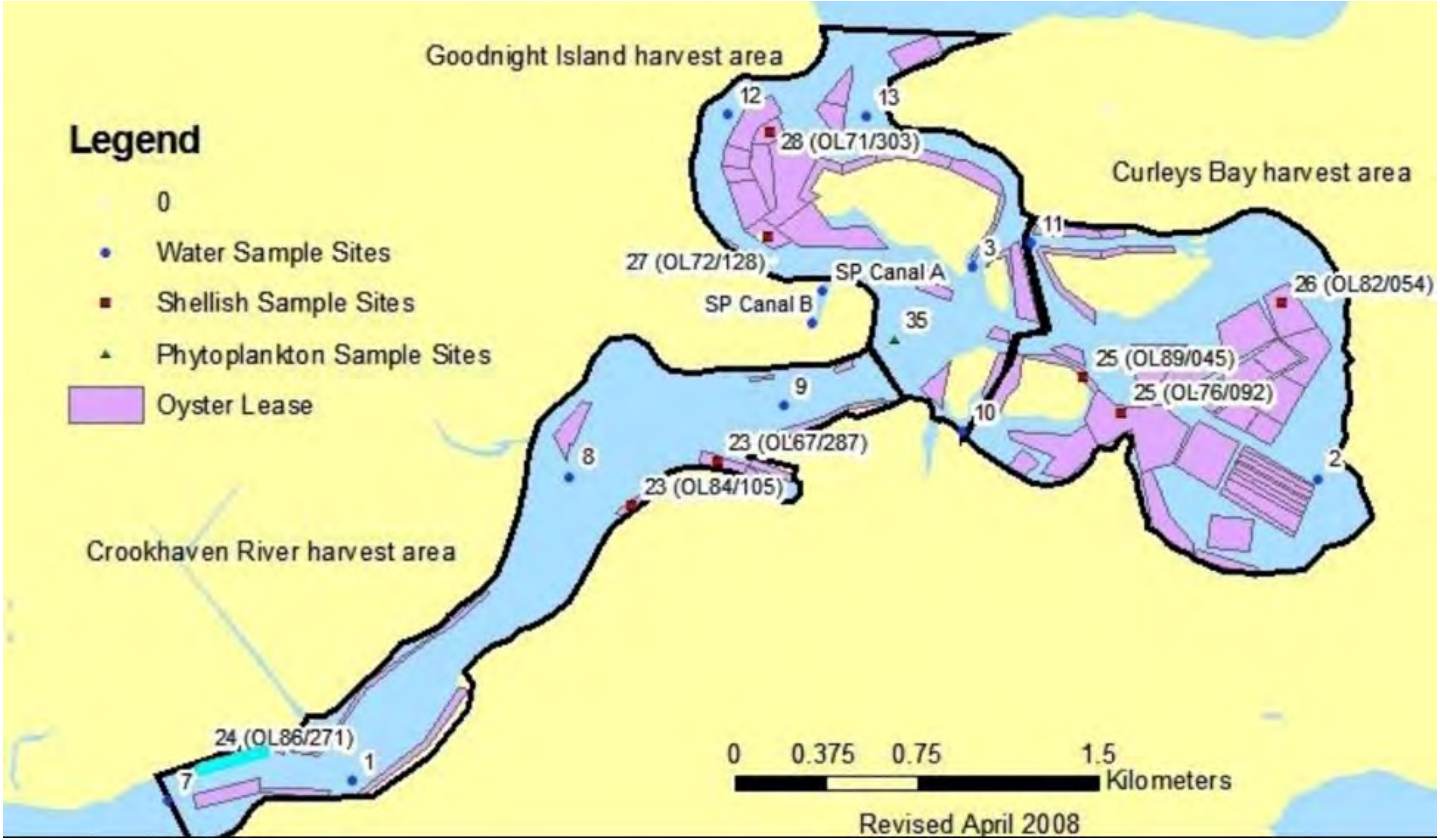


Figure 19 Shoalhaven River Shellfish Program Crookhaven River Sample Sites

Accordingly, there is a high expectation by Oyster Farmers that water quality associated with the present proposal at both the construction and long-term operational phases must be able to be controlled so as not to jeopardise this outcome. In this respect Martens (2020) *Section 3.2.4* has analysed Crookhaven River Harvest Area closures for the period 2010 to 2019. Closures were most commonly triggered by high rainfall events or by reported sewage discharge events, with proportionally more closures in the Curleys Bay Harvest Area. (almost 78 days/year for rainfall and 67 days/year for sewage). Other factors including high algae levels (blooms), positive biotoxin results, high oyster meat microbiological counts or low salinity were generally responsible for less than 5 to 10 days closure for all Harvest Areas. Monitoring compliance for each of the Harvest Areas was very high with less than 2 days/year closure for Curleys Bay and Crookhaven River Harvest areas.

2.8 Commercial Fishing in Crookhaven River

While many south coast estuaries have been closed to commercial and some recreational fishing practices, the Shoalhaven River estuary (including the Crookhaven River estuary) is one of the few estuaries where both commercial and recreational fishing coexist with aquaculture. Neither of the Proposal Ecology reports (SLR 2013 or ELA 2017) provide any information on these activities.

Commercial fishing in the Crookhaven River adjacent to the proposal (upstream of Greenwell Point) is regulated under the FMA and commercial fishers are regulated under the *Estuary Genera*l endorsement, which provides licensing for several species of fish and crustaceans using a variety of fishing methods such as purse seine and mesh netting, eel and mud crab trapping, and hand gathering. Carter (1995) indicates Hauling, Meshing and Prawning as the main commercial fishing activities in Curleys Bay and Crookhaven River.

In a study to determine seasonal differences in retained and discarded commercial gillnet fish catches, Gray *et al* (2005) provides commercial catch data for the Shoalhaven River (undertaken in 2001). The following points are taken from the Shoalhaven River estuary findings:

- A total of 43 commercial gillnet catches were taken over the 1-year period.
- Catch structure did not vary between seasons 1 (January to April) and 3 (September to December) and seasons 1 and 2 (May to August), with the highest proportion of discards (undersized or bycatch species) occurring in winter.
- Luderick (*Girella tricuspidata*) contributed the greatest to similarity between seasonal catches.

- The other main commercial species which contributed to gillnet catches were yellowfin bream (*Acanthopagrus australis*), sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*), sand whiting (*Sillago ciliata*) and dusky flathead (*Platycephalus fuscus*) however some of these species catch values were very low.

It is NSW Fisheries policy that where there are small numbers of commercial fishers (less than 5) operating in the river or region for various endorsements, specific catch statistics cannot be released, so the annual catch data cannot be sub-divided to show Crookhaven catch data alone. Notwithstanding, commercial fishing is undertaken throughout the lower estuary of the Shoalhaven that includes Crookhaven River at and around the revised Culburra Beach Concept Plan site, however it is considered unlikely that netting practises are undertaken in Curleys Bay given the limiting depths and considerable area of oyster lease infrastructure.

The annual total reported catch under the Estuary General endorsement in the Shoalhaven/ Crookhaven system has ranged between 96,083 kg and 215,103 kg over the past five years, with 87% of landings coming under the Estuary General meshing, prawning and category-one hauling (general purpose hauling nets plus species specific nets for trumpeter whiting, pilchard, anchovy, baitfish and garfish) endorsements (NSW Fisheries, pers. comm 30/10/2019).
Since 2017, conditional Estuary General commercial and recreational fishing closures have been implemented in the entire Crookhaven River for weekend netting and for traps and set meshing nets at the Crookhaven River entrance from its confluence with the South Pacific Ocean upstream to a line drawn from the western extremity of Orient Point, generally north-easterly to the south-eastern extremity of Haven Island, then generally easterly to the western extremity of the training wall of Comerong Island.

2.9 Recreational Fishing

Recreational fishing in the area is a major tourism drawcard particularly in the summer months. Miles and West (2011) undertook a comprehensive 12-month survey of recreational fishing in the Shoalhaven region and the main findings as they relate to the West Culburra Beach Concept Plan area as follows:

- The annual recreational fishing effort was estimated at approximately 212,500 hours with the fishery split almost evenly between local anglers and visitors from outside the immediate region.
- Whilst a significant proportion of fishers were not targeting a specific species (33.7%), flathead and bream made up the most popular targeted angling species (at

31.3% and 23.6% respectively. Each of the other species made up less than 5% (luderick, jewfish (*Argyrosomus japonicus*), whiting, tailor, leatherjacket and estuary perch (*Macquaria colonorum*).

- The lower section of the estuary (Berrys Canal and the Crookhaven entrance from Greenwell Point), including Crookhaven River upstream from Greenwell Point and Curleys Bay, were the most popular fishing locations in the estuary.
- Boat based fishing was the most popular type followed by shore-based fishing from banks and structures (pontoons and jetties).

The most popular land-based fishing spots within these areas include the public wharves and breakwalls at Greenwell Point, Orient Point, Crookhaven Heads and Comerong Island, and boat-based fishing is also popular in the Crookhaven River among oyster lease infrastructure (Johnson 2017), with Curleys Bay and the Crookhaven River from Cactus Point to Greenwell Point being well-regarded for flathead, bream, luderick and whiting.

Miles and West (2011) also note that there has been some general concern noted among recreational fishers in the Shoalhaven/Crookhaven River about the effect of increased commercial fishing pressure on fish stocks, given that many other surrounding estuarine systems had been closed to commercial fishing.

2.10 Water Quality & Hydrodynamics of Crookhaven River

In terms of the priorities for potential impact assessment with regard to aquatic ecology, the main thrust of the revised Culburra Beach Concept Plan has correctly focused on protection of Crookhaven River water quality for environmental and oyster aquaculture protection, and the main thrust of the agency assessments has maintained the same focus. Detailed review of Crookhaven River water quality and related estuarine processes are now provided in the Martens (2020) *Integrated Water Cycle Management Strategy Report* prepared for the revised Culburra Beach Concept Plan (see also **Section 2.10.1** below).

The following review provides a guide to earlier, site-specific data and assessments that are found in the many reports previously presented to the Court for several water quality related topics:

Site Clearing History

- The original 2013 Heritage Report Tab B003.011 indicates that much of the vegetation on the subject property is secondary growth with historic selective clearing for timber and for grazing activities but with no evidence of early farming or dwellings.

- The 2013 Site Contamination Report Tab B003.013 and the original Ecology Report (SLR 2013) Section 1.2 make a similar conclusion, describing the site vegetation as mostly regrowth from partial clearing or thinning for agricultural purposes.
- Aerial photographs from 1949, 1961, 1974, 2002 and 2008 are presented and discussed in the 2013 Site Contamination Report Tab B003.013 and for the SLR (2013) ecology report (Tabs B003.017 Section 1.2, B003.017.002 & B003.017.002b).

Site physical characteristics in regard to site topography, site surface water runoff, groundwater interactions and site water quality:

- The Site Contamination Appendix Tab B003.103 provides the original site survey plans at Attachment A. These include the upper portions of the sub-catchments draining to Lake Wollumboola.
- The original Geotechnical Report (Appendix J - Tab B003.012 provides a description of the geomorphology and soils testing based on 16 boreholes and 8 back-hoe test pits (Attachment A plan) from November 2010. This report also presents most of the geotech data collected for the proposal including borehole water quality data (part of Attachment F), but not groundwater level data.
- The physiographic site is described as follows: "the majority of the site is elevated >5m AHD above the Crookhaven River estuary. Immediate foreshore areas are moderately steep and transitional between the study area and the estuary. Relief across the site is approximately 20m with slopes ranging from 2.5 – 5.0%. Site drainage ranges from good to poor, with poor draining areas characteristically associated with lower points of elevation in the landscape. Site drainage likely consists of both infiltration and overland flow (sheet and concentrated).
- Subsurface investigations characterise the site mantle as 1.3 to 1.5m deep with sandy/silty soils 0 to 0.3m, medium to high plasticity clays derived from weathering of the underlaying siltstone 0.3 to 1.3m depth and weathered siltstone 1.3 to >5.5m.
- Testing of 30 borehole soil samples indicated soils to be generally non-saline (except for low elevation soils at the far eastern end of the site next to Canal Street - BH6). The soils were also acidic with pH ranging between 4.5 to 5.7 pH units for the majority of samples and several outliers at 6.1 pH units in clay at BH6 2.5m deep and 8.1 pH units in clay at BH1, 1.5m deep (Attachment D of Tab B003.012).
- ASS testing was also undertaken and the report concluded that "soils are neither Active ASS or Passive ASS but are inherently acidic soils derived from in-situ weathering of the underlying siltstone lithology and pedogenic processes". The laboratory testing data are contained at Attachment F.
- Attachment F of Tab B003.012 also provides general water quality analysis results for three bore hole samples (BH1, BH2 and BH6). Samples were collected on 25

Nov 2010 and the laboratory prepared and analysed the samples on 30 Nov 2010. There were a scattering of elevated nutrient and metal results.

- Table 2 in the Original Site Contamination Report (Appendix K, Tab B003.013) provides the groundwater level measurements from three of eight bores sampled daily from 23 to 26 Nov 2010. The other five bores were dry.
- Groundwater level data and additional hydraulic conductivity(k) testing results (from 2014) are presented in the November 2016 Water Cycle Management Report Tab B009.009.
- The 2016 Tab B009.009 Water Cycle Management report states that there are broadly two water bearing strata; shallow sub-surface residual clays and the deeper weathered siltstone layer at variable depths from 3m to 7m below ground level, and the report concludes that shallow aquifers are likely to be ephemeral in some areas, and permanent in low lying areas and areas with low grades.

Receiving waters hydrodynamic characteristics in regard to bathymetric mapping, tidal exchange and circulation characteristics:
The 2016 Estuarine Processes Modelling Report (EPM) at Tab B005.007), provides the following relevant information:

- Reasonably detailed bathymetric data for the Crookhaven River and Curleys Bay was prepared by NSW Department of Naturel Resources for the Estuary Management Program, based on hydro-surveys undertaken between Sep 05 and Nov 06. These plans have been reproduced as Attachment I for the EPM Report.
- Summary tide statistics for the Greenwell Point Tide Gauge from data provided in the 2005 Shoalhaven River Date Compilation Study (Umwelt 2005). Comparison of their summary data with more recent MHL Greenwell Point tidal gauge analysis (to 09/10) indicated slight increases in all statistics, but all original means were within the mean ± standard deviations for the recent data.
- Specific water level, flow and salinity monitoring data collected for the proposal in 2015 are used to examine differences in tide behaviours for two main study transect sites, one located north of Billys Island, and a *reference site* at Greenwell Point. Additional Conductivity Temperature & Depth (CTD) site data were obtained from a further four sites (at the Greenwell Creek confluence, off Cactus Point, in middle Curleys Bay and in the west Greenwell Point Channel), which indicted further slight variation of tidal behaviour in relation to the reference Greenwell Point behaviour.
- Haskoning Australia (2015) Crookhaven ADCP Transect Study (Attachment H for the EPM Report at Tab B005.007) also provides tidal prism calculations for the two Greenwell Point and Billys Island Transect river locations.

Receiving water quality:

- As there is no ponded water on the site sub-catchments leading to either the Crookhaven River or Lake Wollumboola, the receiving waters for Crookhaven River are the tidal waters of the Crookhaven River. For Lake Wollumboola the immediate receiving waters are possible ponded waters in the lower parts of Wattle Creek some 1km downstream of Culburra Road.
- The 2016 EPM report (Tab B005.007) Section 11 provides a listing of the available Crookhaven River water quality data sourced from the Shoalhaven Council water quality monitoring program, from the NSW Food Authority Shellfish Quality Assurance Program (SQAP) and some discrete sample data from two sites in Crookhaven River between 2004 and 2006. These data were used for compiling total estuary means for modelling purposes and statistical mean data are provided in Table 1 of the main Tab B005.007 report.
- HGeo (2017) provides some metered surface water quality information for Downs Creek and Wattle Creek in the Lake Wollumboola catchment.
- The only other Crookhaven River receiving water quality data that appears to have been collected for the proposal prior to the present studies is the metered and nutrient water quality results presented for eight bottom water sites sampled for the ELA (2017) report (Appendix B) from Seagrass, Mangrove and Saltmarsh habitats.

2.10.1 Review of Water Quality Studies for the Present Proposal

There have been several water quality sampling programs undertaken for the present revised Culburra Beach Concept Plan and further reviews of existing publicly available or Agency provided river water quality data:

- The freshwater aquatic studies undertaken in the Lake Wollumboola catchment in Downs and Wattle Creeks included metered water quality (Temperature, Conductivity/Salinity, Dissolved Oxygen, Turbidity (as NTU) and pH. Results are provided in the **Annexure B** Freshwater Ecology Report.
- Metered water quality profiles and Tide Variation sampling was undertaken during the Crookhaven River flood in February 2020. The survey measured tidal variation at five fixed sites on oyster aquaculture infrastructure with measured tide heights adjusted to AHD and repeated metered water quality profile monitoring of Depth, Temperature, Conductivity/Salinity, Dissolved Oxygen, pH, Turbidity (as NTU) and ORP at these five sites and at another five Curley Bay and Crookhaven River sites. Results of that survey are provided in **Annexure D** to this report.
- Martens (2020) provided an initial review of the relatively extensive water quality monitoring program undertaken by Shoalhaven City Council and the SCC data are publicly available through the *Aqua Data* website. **Annexure E f**or this report

provides a summary of these data which extends from 1992 to 2020, **Figure 20** shows sample sites relevant to the present proposal and the data set is summarised as follows:

- Data have been collected from eight sites in total, including three sites in the Crookhaven River upstream of Billys Island, three sites in Curleys Bay and two sites at the Crookhaven River entrance.
- Sample frequency varies between years and sites. Temperature, dissolved oxygen (DO), pH, salinity, turbidity, enterococci and faecal coliforms have been sampled most regularly, with less frequent sampling for chlorophyll-a, total nitrogen and total phosphorous.
- Site E-454 in the Crookhaven River near Billys Island has the overall highest number of sample events (over 100 samples for temperature, salinity, DO, pH and turbidity). Most of the other Crookhaven River and Curleys Bay sites have been sampled less often (<60 samples).
- Sites E-455, E-456 and E-457 are located in close proximity to the Culburra West development proposal.

- NSW Food Authority Shellfish Program has made the *Yield* plus the Crookhaven Oyster farmer water quality data available for this present study and the latter data are summarised in **Annexure E**. Sampling sites are shown in **Figure 20** and the data set is summarised as follows:
  - The Yield data provides automated water temperature, salinity and depth results at 10-minute intervals starting in December 2017. The Yield automated logger is located in the Crookhaven River on the northern side of Goodnight Island opposite the Orient Point Boat ramp and the data supplied was through to July 2020.
  - The Crookhaven Oyster farm water quality data have been collected from 2003 onwards from 17 NSW Shellfish Program monitoring sites situated over three harvest areas, and while it contains fewer water quality parameters than other long-term monitoring programs (temperature, salinity, *Escherichia coli* (*E. coli*) and phytoplankton), the sample frequency is more consistent.
  - The number of samples ranges between 153 and 230 over all monitoring sites, providing a considerable long-term baseline data set.
  - Sites 2, 10, 23, 25 and 35 are the closest sites to the Culburra West development proposal.

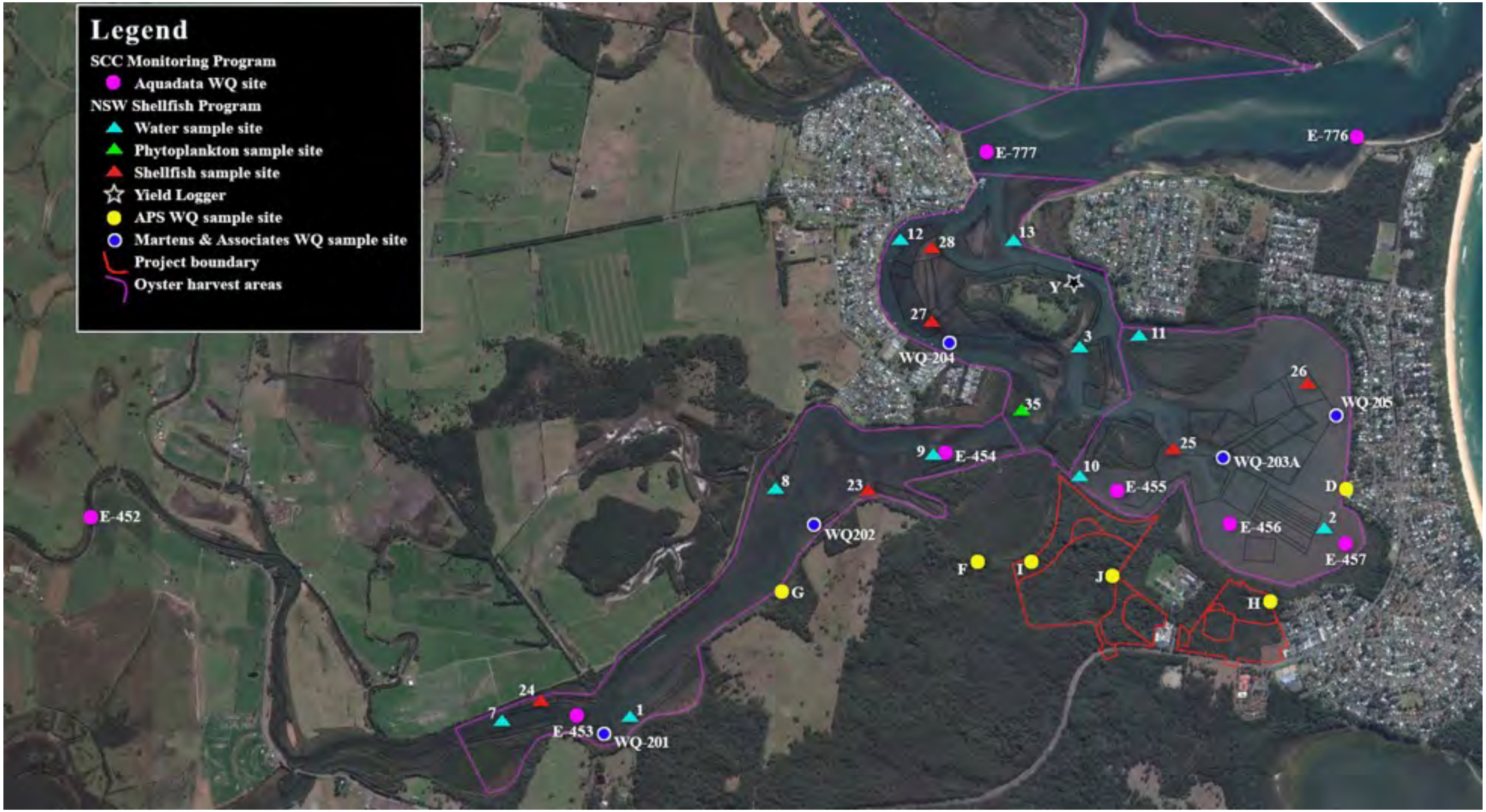


Figure 20 Combined Crookhaven River Water Quality Sampling Sites

- Martens (2020) sampled an additional five estuary sites in the Crookhaven River and Curleys Bay over eight monthly events between October 2019 and May 2020. Data are summarised in **Annexure E** with sampling sites shown in **Figure 20**, and the data set is summarised as follows:
    - Data have been collected from three sample sites in the Crookhaven River that extend from site WQ-201, 2.5km upstream of Billys Island, downstream to WQ-205 (opposite Goodnight Island), plus two sites in Curleys Bay.
    - A broad suite of analytes was tested including nutrients, dissolved metals, electrical conductivity (EC), pH, major ions and ionic balance, alkalinity, *E. coli* and faecal coliforms, however total suspended solids were not analysed.
- APS (2020) collected wet weather surface runoff samples from five sites between November 2018 and August 2020 and these data are summarised in **Annexure E,** sampling sites are shown in **Figure 20** and the data set is summarised as follows:
    - Sample frequency varied between sites. Site G is located near the Crookhaven River foreshore upstream of Cactus Point and was sampled on seven occasions (November 2018 to July 2020), site F is located in Billys Bay foreshore near the western boundary of the development proposal and was sampled once (August 2020).
    - Sites I, J and H are located within the development proposal boundary and were sampled between three and five occasions between February 2020 and July 2020.
    - Site D is located on the eastern shore of Curleys Bay and was sampled on eight occasions between November 2018 and August 2020.
    - Between November 2018 and June 2019, the sample analysis included pH, EC, suspended solids and nutrients, and this was extended for subsequent sample events to include metals, faecal coliforms and enterococci.

The combined analyses of the available data by both Martens (2020) and this report indicate that there is a large accessible data base of water quality for the Crookhaven River estuary against which tailored water quality sampling programs can be designed for pre-construction, staged construction and post construction operational monitoring for the Revised West Culburra Beach Concept Plan. The water quality database resource contains sufficient temporal and spatially scaled background information to develop site specific baseline water quality criteria from which staged performance measures can be assessed, and appropriate response plans can be implemented.

2.10.2 Estuarine Sediment Characteristics Study

The majority of the zoned estuarine vegetated habitats in Crookhaven River/Curleys Bay are rooted plants and the nutrient status of the sediments is likely to be important for organisation and character of the various zoned habitats (see for example Clarke 1985 and Boon & Cain 1988 for saltmarsh nutrients, Lovelock et al 2009 and Reef et al 2010 for mangrove nutrient relationships, Borum 1985, Maxwell et al 2015, Ferguson et al 2016 for seagrass, sediment and epiphyte nutrient relationships).

MPR (this study) collected cored sediment samples from riparian edge and inter-tidal vegetated habitats from four locations around Curleys Bay (two forested riparian catchments and two urban riparian catchments) and sub-tidal cored sediments samples from four seagrass bed sites to determine a range of sediment characteristics (particle size distribution, total organic carbon and nutrients) for the selected habitat classes (edge Casuarina, saltmarsh, inner mangroves, dwarf mangroves, mid tidal range mangroves plus *Zostera* seagrass). Study sites are shown on **Figure 21**, full results of the study are provided in **Annexure F.** Results are summarised graphically in **Figures 22 to 26** below with habitat and location ranges summarised in **Table 3** below.

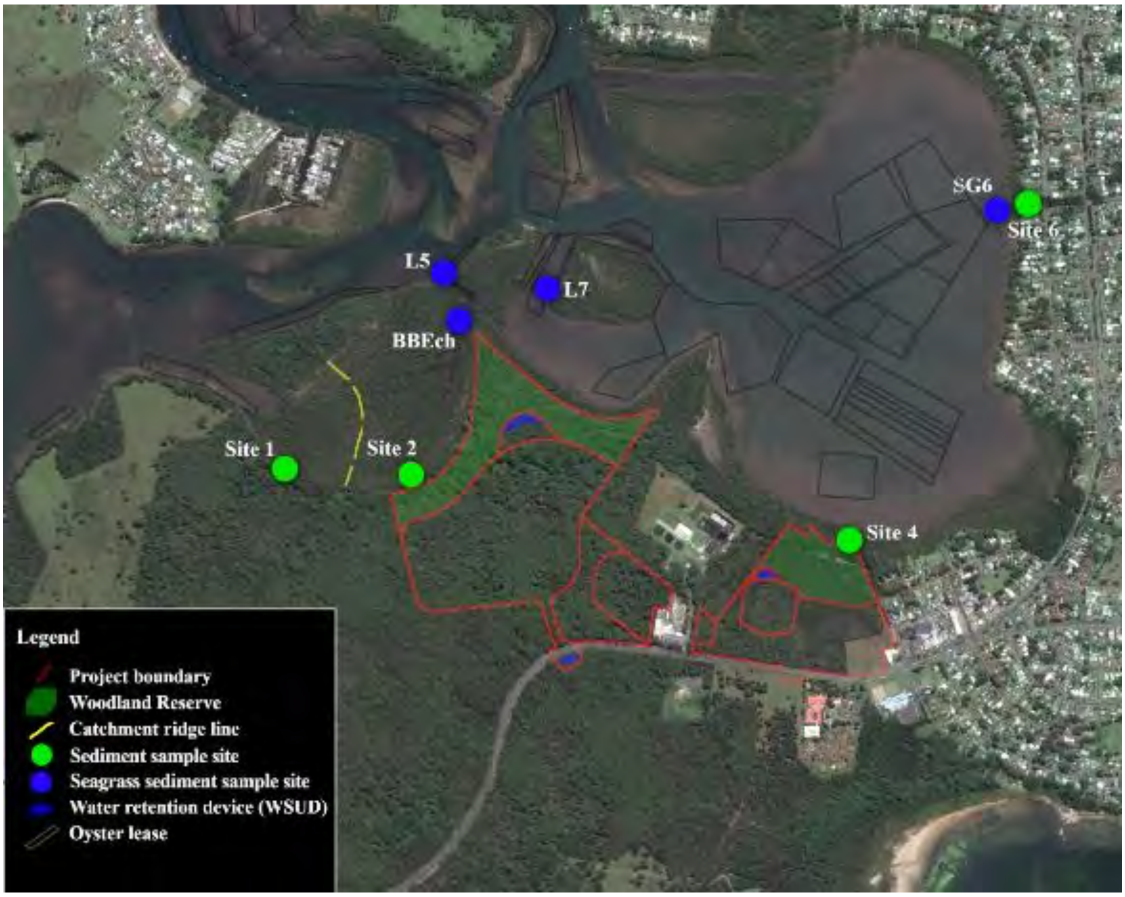


Figure 21 Vegetated Estuarine Habitat Sediment Study Sites (see Key on following page)

Key to Sites for Figure 21:

Riparian Casuarinas Sites: RC

Saltmarsh Upper Limit Sites: SU

Dwarf Mangrove Sites: MD

Inner Zone (Juvenile) Mangrove Sites: MJ

Mid Zone Mangrove Sites: MM

Seagrass Sites: BBEch, Lease 5, Lease 7 and SG6

Table 3 Concentration Ranges for Estuarine Sediments (mg/kg)

Analyte	Range	Cas	Salt Marsh	Mangroves	Seagrass	All
% silt	Min	20	54	16	12	12
	Max	81	78	71	22	81
	Mx/Mn	4.1	1.4	4.4	1.8	6.8
TOC	Min		6.5	1.5		1.5
	Max		15.0	18.4		18.4
	Mx/Mn		2.3	12.5		12.5
NOx	Min	0.3	0.3	0.1	0.1	0.1
	Max	6.7	2.6	1.2	0.4	6.7
	Mx/Mn	22.3	8.7	12.0	8.0	134.0
NH3N	Min		1.2	0.1		0.1
	Max		8.4	14.4		14.4
	Mx/Mn		7.0	144.0		144.0
TN	Min	4450	3780	570	440	440
	Max	17200	9490	10500	660	17200
	Mx/Mn	3.9	2.5	18.4	1.5	39.1
React P	Min		<0.1	<0.1		<0.1
	Max		<0.1	0.2		0.2
TP	Min	295	589	75	177	75.0
	Max	1090	1270	1030	462	1270.0
	Mx/Mn	3.7	2.2	13.7	2.6	16.9
TN:TP	Min	12.9	5.2	5.4	1.1	1.1
	Max	24.3	14.6	10.2	3.6	24.3
	Mx/Mn	1.9	2.8	1.9	3.3	22.5

In terms of overall ranges for sediment characteristics for the various vegetated habitats, it is clear that the various tidally zoned vegetated habitats are capable of growing over wide ranges of sediment characteristics, with the majority of ranges over 2 times (% silt for saltmarsh and seagrass, TN for seagrass and TN:TP ranges for Casuarina and Mangroves being the exceptions). Ranges for % silt were the lowest (2 to 4.5X), Saltmarsh plus Seagrass habitat sediment characteristics showed the overall least range variations with the widest ranges found in Mangrove and Casuarina habitats. In spite of the wide ranges in actual TN and TP concentrations the TN and TP ranges were generally similar over the different vegetation categories and as a result the TN:TP ratio ranges were more similar over the vegetated habitats (1.9X to 3.3X).

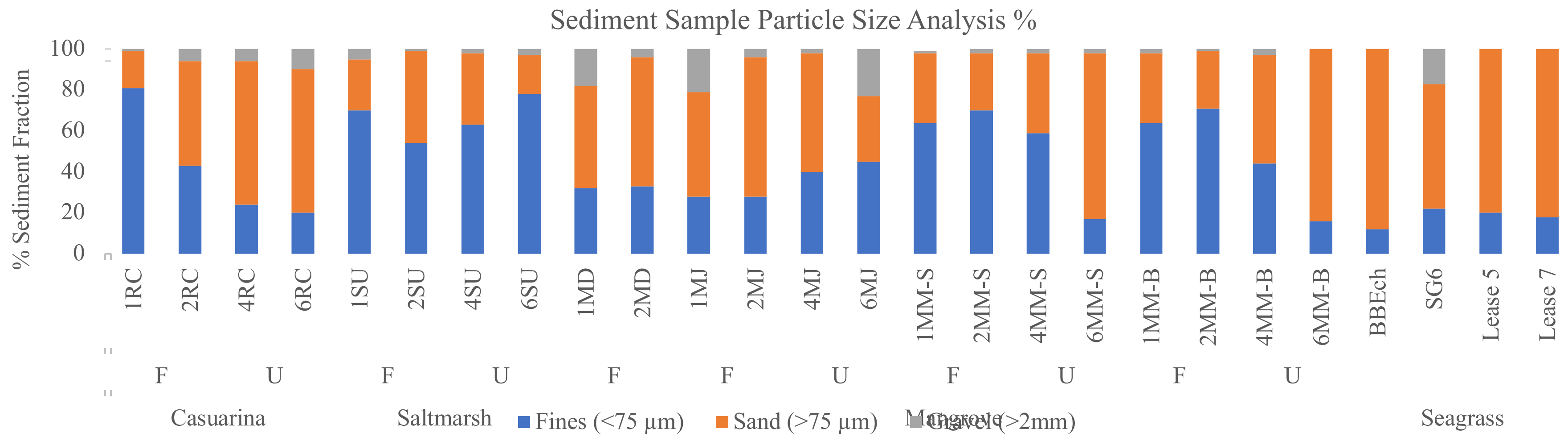


Figure 22 Sediment sample particle size distribution (% total)

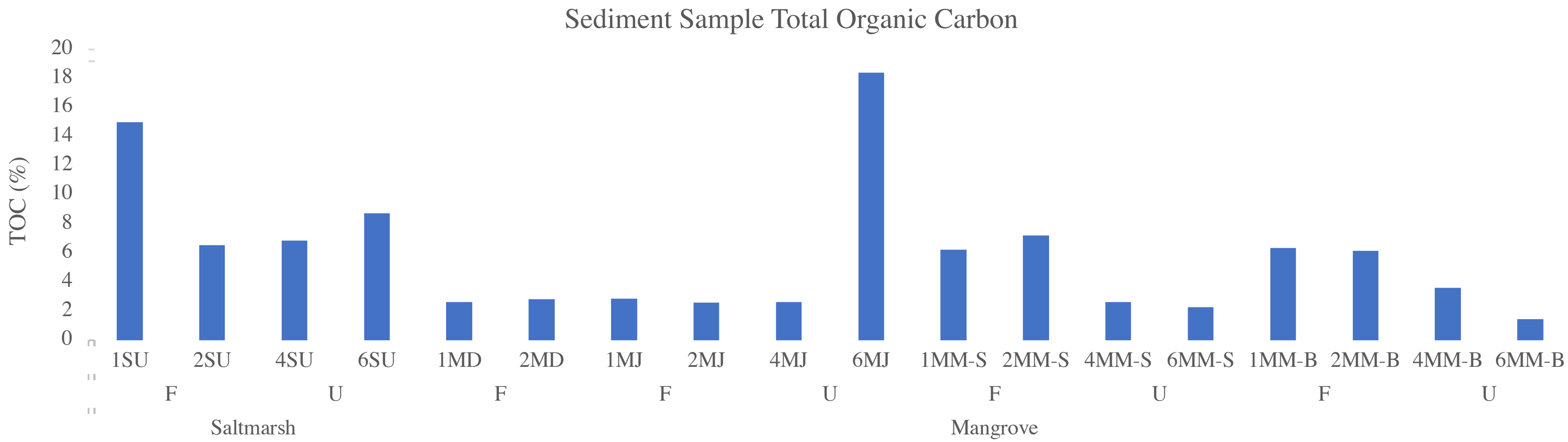


Figure 23 Sediment sample Total Organic Carbon distribution (%TOC)

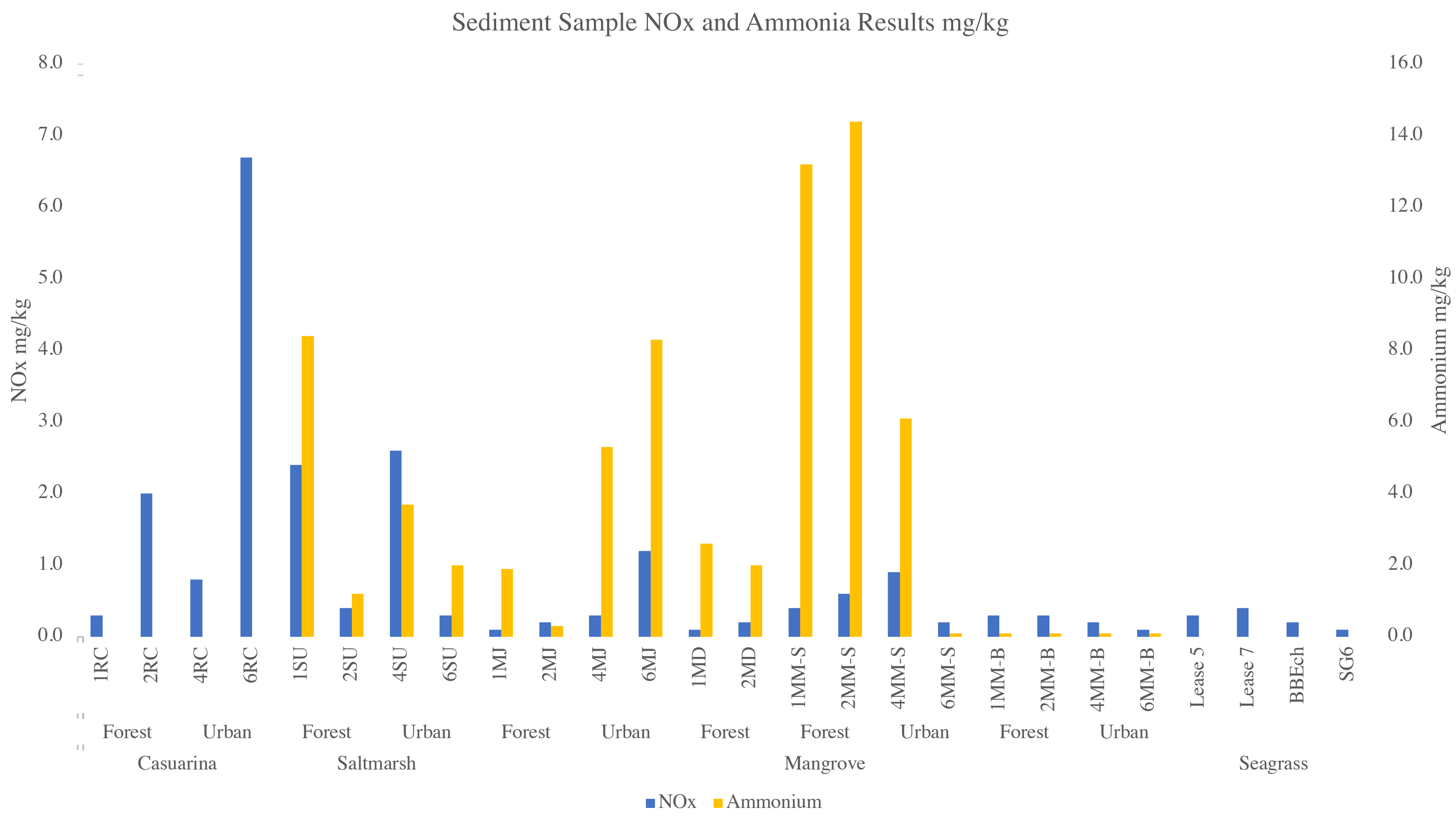


Figure 24 Sediment sample Nitrous Oxides (NOx) and Ammonia concentrations

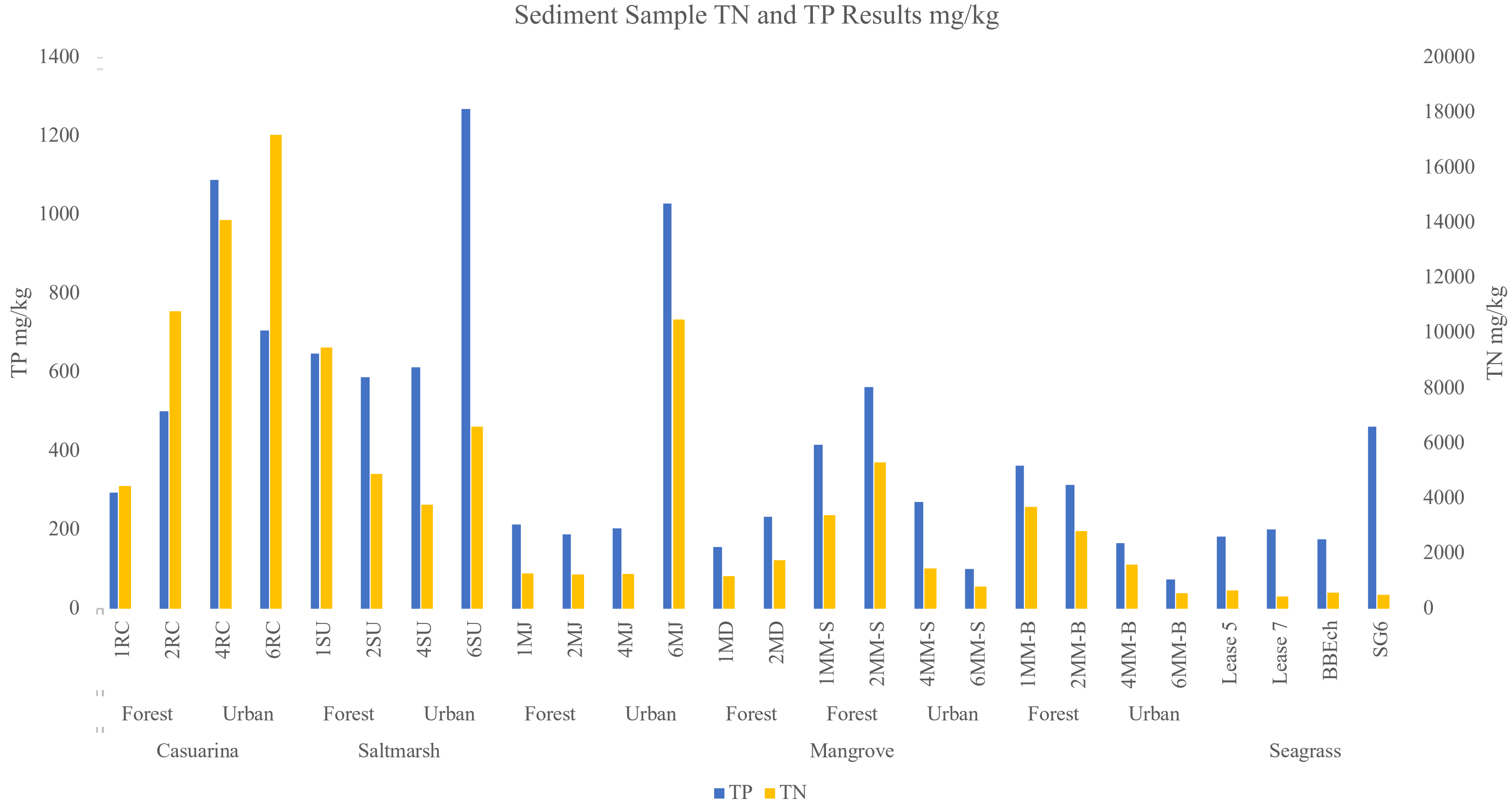


Figure 25 Sediment sample Total Nitrogen (TN) and Total Phosphorus (TP) Concentrations (log scale)

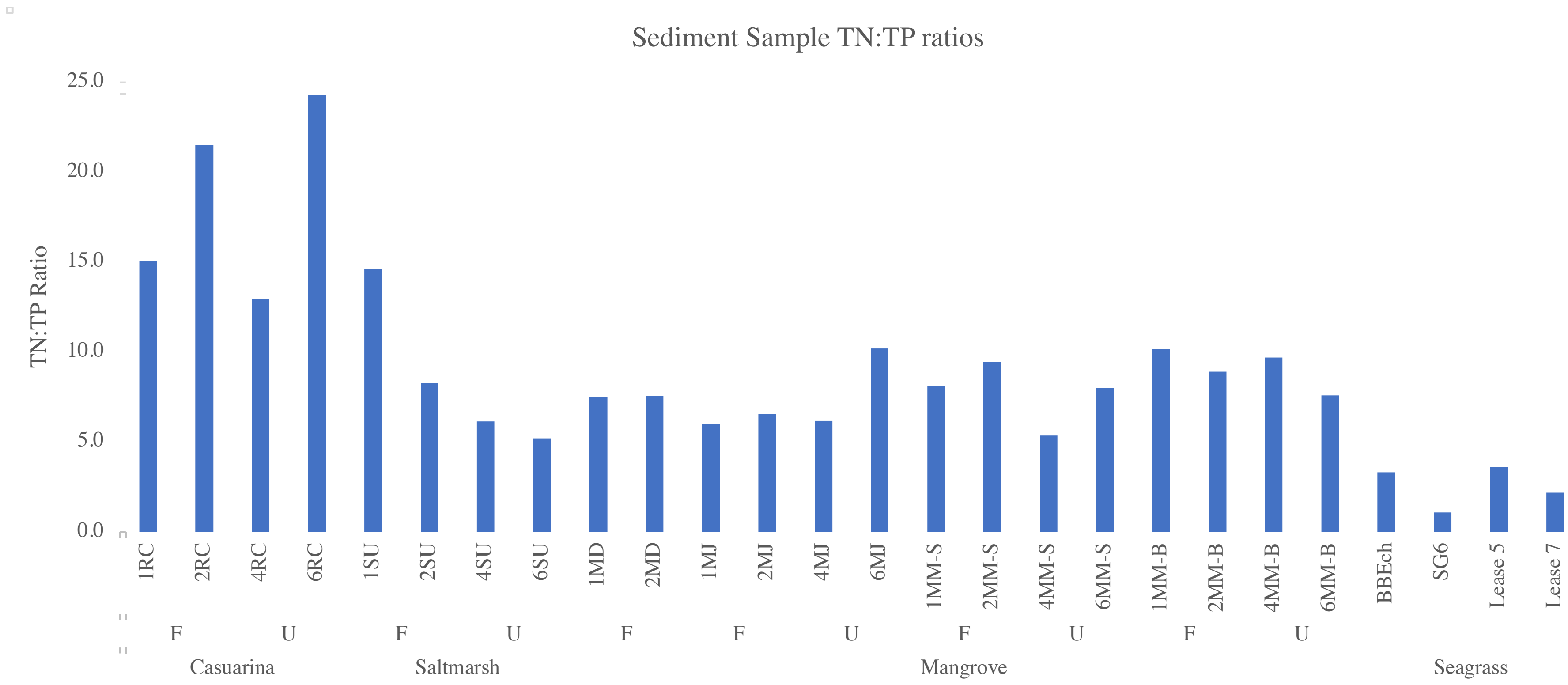


Figure 26 Sediment sample TN to TP ratios

3 AQUATIC ECOLOGY IMPACT ASSESSMENT

Section 1.1 and **Figure 1** provide a description of the revised West Culburra Beach Concept Plan. In terms of comparison with the previous proposal the present proposal has been reduced in scale by about half, and has more detail on staging plus stormwater and sewage management. In terms of location there is now no development proposed within the Lake Wollumboola catchment with the exception of the upgrade of Culburra Road to provide a roundabout plus main entrance road for the revised Concept Plan. This portion of the proposal will drain around 0.5Ha of upper Lake Wollumboola catchment towards Wattle Creek.

The present proposal footprint in the Crookhaven River catchment includes about 41 Ha residential development, 6.3 Ha of industrial land and around 18.6 Ha of open space and parkland that drains to the eastern shoreline of Billys Bay, SW Bay shoreline and a small portion of SE Bay shoreline (see **Figure 2** for estuary naming conventions). The Proposal includes a public walkway/cycleway through the woodland to connect the future residential area to the rest of Culburra Beach township to the east.

Martens (2020) *Annexure P* provides a staging plan for the revised Concept Plan that indicates nine stages for residential area delivery, two stages for the industrial area and two stages for the town centre.

3.1 Construction Impacts

The main construction components for the staged Concept Plan to be considered in regard to protection of adjacent aquatic habitats, biota and estuary utilisation (mainly oyster aquaculture) are as follows:

- Provision of temporary construction roads for site access for initial land clearing.
- Construction of the entire woodland walkway/boardwalk.
- Provision of lower silt fencing between the development and the estuary.
- Construction of temporary sediment ponds.
- Provision of temporary Asset Protection Zones (APZ) and temporary emergency bushfire egress tracks.
- Land clearing and levelling operations.
- Staged construction of Biofiltration Swales and structures.
- Construction of Stage 1 Water Quality Ponds (Residential and Town Centre) and associated public reserves/playing fields.
- Provision of downslope silt fencing around each staged segment.

- Construction of the Stage 1 SPS and sewer rising main realignment.
- Trenching for the provision of utilities (sewer, water, re-use water, power and telecommunications.
- Road construction and roundabout/Wattle Creek stormwater drain construction.
- Conversion of temporary Wattle Creek roundabout sediment pond to final water quality pond.
- Individual Lot /sporting club/carpark developments.
- Landscaping (progressing throughout all stages) including provision of public amenities for the walkway and parks.

3.1.1 Assessment of Potential Construction Impacts of the Proposal

There are no aquatic ecological habitats, fauna or communities directly impacted by the proposal, as it is wholly situated within terrestrial habitat and isolated from aquatic habitats by substantial native woodlands for both the Culburra Road main entrance roundabout works in the Lake Wollumboola catchment and for the main developments draining to Crookhaven River/Curleys Bay.

Potential indirect impacts are summarised as follows, and management for these impacts is provided in **Section 3.1.2** below:

1) Adverse stormwater water quality and increased sediment loads and/or increased freshwater quantities downstream of the development footprint, generated from construction activity for each of the proposal stages.
2) Disturbance of retained woodland habitats and overland stormwater drainage paths within those woodlands arising from boardwalk/walkway construction.
3) Disturbance of wading or shore-birds on adjacent shoreline mud flats from construction noise.
4) Degradation of groundwater quality and changes in groundwater quantity due to construction activities.
5) Potential leakage or spills of fuels and oils from mobile and stationary plant and equipment.
6) Loss or dumping of bushland clearing debris and of initial road construction debris.
7) Loss or dumping of soils and cleared debris from land levelling.
8) Potential spills or dumping of excess construction related concrete slurries.
9) Loss or dumping of construction related litter, especially plastic wrapping and offcuts and food wastes plus wrapping.

Martens (2020) *Section 8* details construction staging and management and references Annexure Q which provides a preliminary plan of staged sediment and erosion control (SEC plan) for each of the delivery stages. The SEC plan will be used to guide and refine the detailed development application process for the Staged developments, and includes recommendations for independent auditing of ESC compliance and performance.

In regard to potential Construction Impacts (1) and (5) to (9), it is concluded that these potential impacts can be avoided, managed or mitigated successfully, so that there are no adverse impacts on adjacent downstream woodland habitats and values, no impacts on fringing SEPP14 wetlands - including riparian Sedge and She-oak habitats, intertidal saltmarsh, mangroves, mudbanks and oyster beds, no impacts on sub-tidal seagrass beds and no impacts on estuarine water quality or quantity that could potentially impact oyster cultivation. This can be achieved by the provision of best practice land construction management as detailed in **Section 3.1.3** below.

The walkway/cycleway alignment will utilise existing tracks and available cleared land through the woodlands where possible, and the construction is to be managed and operated to minimise disturbance of soils and overland stormwater flow paths. There will be no impacts on aquatic habitats or vegetation from the construction and the final design and construction will managed through future development approvals

In regard to impact (2) the construction and operation of the woodland walkway will need to be managed to minimise disturbance of existing woodlands by utilising the existing tracks through the woodland where possible, and using construction methods to avoid or minimise soil and plant disturbance and to avoid disruption of overland stormwater flow paths.

In regard to potential impact (3) above, this report has outlined the infrequent usage of fringing shoreline habitats by shore and wading birds for feeding (during low tides) and roosting (during high tides) due to the relatively narrow bare intertidal feeding sediment habitat availability on the lower bay-side of mature mangrove stands and the low use of the fringing saltmarsh areas between the riparian edge and the mature mangrove stands due to the height of inshore riparian woodland trees that inhibit bird sight lines for overflying predators. Further, as most of the construction requires machinery that produces constant motor noise rather than impact noise (such as pile driving for example), there is less impulse startling noise. Accordingly, the combination of low usage due to adverse tides plus the low usage due to potential predator-avoidance means that the risk to shore and wading birds from construction noise is low.

In regard to potential impact (4) Martens (2020) *Section 5* provides a detailed review of site groundwater characteristics and the results of detailed modelling of the impact on groundwater arising from the revised Culburra Beach Concept Plan. The report concludes that construction impacts on groundwater can be minimised by proposed appropriate staging of the construction of the bioretention basins that will be detailed in each staged Development Application.

3.1.2 Management of Potential Construction Impacts

Management of staged construction impacts is detailed in Martens (2020 Section 8 and Annexure P which provide templates for the management of construction impacts for subsequent Development Application Approvals including the following:

Construction Environment Management Plan (CEMP) that details how the construction proposal will be managed to avoid, minimise and mitigate impact on the natural retained habitats downslope of, and adjacent to the development footprint, and how the construction will be managed to avoid, minimise and mitigate adverse water quality and quantity impacts on the adjacent estuarine waters, particularly in relation to avoidance of adverse water quality for adjacent oyster aquaculture. The CEMP will also set out the general requirements to avoid, minimise or mitigate the impacts listed in **Section 4.1** above.

Subsequent Development Application CEMPs will include the following management plans to be developed and provided for each staged Development Application:

- **Sediment and Erosion Management Plan** that provides details of staging and implementation of the various construction tasks detailed above.
- **Site Vegetation Management Plan** for managing the clearing, reuse and or retention of vegetation within the proposal construction footprint.
- **Construction Waste Management Plan** that details how waste generated by the construction proposal is to be minimised, contained, collected and stored within the site and how the wastes will be re-used/re-purposed, or disposed offsite.

3.2 Assessment of Post Construction Operational Impacts

The revised Culburra Beach Concept Plan is located on lands set back a minimum of 100m from the estuarine water's edge of Curleys Bay, Crookhaven River and the buffer area contains relatively undisturbed woodlands adjacent to intertidal and shallow sub-tidal estuarine saltmarsh, mangrove, mudflat and seagrass habitats within Curleys Bay, generally protected under SEPP14. In the long-term the woodland reserve is to be managed by

Council. Accordingly, there are no aquatic ecological habitats, fauna or communities **directly** impacted by the proposal, as it is wholly situated within terrestrial habitat and isolated from aquatic habitats by substantial native woodlands for both the Culburra Road main entrance roundabout works in the Lake Wollumboola catchment and for the main developments draining to Crookhaven River/Curleys Bay.

3.2.1 Stormwater Runoff, Groundwater Impact and Receiving Water Quality

Martens (2020) Integrated Water Cycle Management Strategy (IWCMS) sets out how the revised Concept Plan can be managed to protect natural environmental values, adjacent waterway water quality and minimise impact on oyster aquaculture in Crookhaven River. The IWCMS has been developed in response to an almost 50% reduction in the Proposal footprint as well as some internal reconfiguration of the proposed development layout and staging. It includes a more detailed proposal layout that allows a better definition of the stormwater treatment system, which has been designed on Water Sensitive Urban Design (WSUD) principles. These include the following:

- Management of stormwater at or near source
- Treat stormwater prior to release to the environment using terminal ponds, stormwater dispersal systems and groundwater recharge.
- Integrate stormwater management with the built environment.
- Rainwater capture via rain-water tanks and stormwater capture and re-use via and within public spaces and other suitable areas within the development area.
- No direct stormwater piped connections to Crookhaven River.
- Best practice reticulated sewer.

Modelling of the stormwater scheme is also detailed in the Martens (2020) IWCMS, and this modelling demonstrates that there will be no material or significant impacts on the downstream environment including the Crookhaven River and Estuary or Lake Wollumboola. Specifically, the report demonstrates that pollutant load reduction targets are achieved, the potential for pathogen impacts is mitigated, and *NorBe water quality criteria* are satisfied because the development will have no identifiable potential impact on water quality.

In regard to potential groundwater impact Martens (2020) *Section 5* provides a detailed review of site groundwater characteristics and the results of detailed modelling of the impact on groundwater arising from the revised Culburra Beach Concept Plan. The proposed IWCMS includes recharge of groundwater below both the development and the Wattle Creek roundabout works to comply with the NDSW Aquifer Interference Policy.

It is concluded that:

- Groundwater flow regimes and directions are effectively maintained by the Proposal and are not likely to result in any adverse environmental outcomes.
- Groundwater flow budgets to the Crookhaven River and Lake Wollumboola with a recharge system in place are closely matched to current conditions.
- The proposed exfiltration rate of 0.25 mm/hr from stormwater management measures is ecologically sustainable and will not result in any detrimental harm to the existing groundwater system or downstream receiving environments.

3.2.2 Alterations to Tidal and Flood Regimes

There are no direct impacts arising from the revised Culburra Beach Concept Plan on the tidal and flood characteristics of the Crookhaven River as there are no construction works in or near the river and there are no stormwater related impacts that could result in increased sediment loads to the river such that there could be localised erosion or accretion in the shoreline shallows.

The revised Concept Plan is some 50% smaller than the original proposal, and there is now a more detailed IWCMS that includes a swath of WSUD measures as detailed in **Section 3.2.1** above, that include stormwater retention, treatment, reuse and controlled release downstream and into groundwaters via biofiltration swales. Accordingly, there will not be any material difference to the freshwater volume reaching the estuary and therefore no measurable change to the salinity regime of the Crookhaven River and Curleys Bay.

3.2.3 Water Quality and Sewage Overflows

Lake Wollumboola

The present, albeit small risk of adverse water quality impact for downstream Wattle Creek aquatic habitats from un-treated road runoff at the present Wattle Creek Culburra Road culvert drain will be diminished by the construction of the proposed roundabout construction at that location, which will include treatment of the constructed roundabout runoff water quality via gross pollutant traps and a water bioretention basin structure.

Crookhaven River and Curleys Bay

The potential for, and risk of water quality impact on the estuarine aquatic ecology of the Crookhaven River from the proposal is considered low, and the potential for impact on the oyster aquaculture of the Crookhaven River and Curleys Bay from operation of the completed proposal can be avoided, minimised and mitigated satisfactorily by implementation of the proposed IWCMS as detailed in Martens (2020). The IWCMS stormwater control concepts for the revised Concept Plan include *inter alia:*

- water sensitive urban design (WSUD) principles including stormwater treatment at or near source;
- Stormwater/sediment control ponds linked to overflow and sub-flow drainage swales that will both provide treated water for re-use within public reserves.
- Environmental water for the 100m foreshore reserve will occur via distribution of treated stormwater into overflow swales to mimic the existing combined overland flows plus shallow soil infiltration transport of stormwaters to the riparian ecosystems and bay waters.
- The 100m vegetated buffer zone will provide additional protection for adjacent waterways, estuarine biota and oyster aquaculture by filtering, trapping and treating remnant sediments, nutrients, pathogens and other contaminants.

Martens (2020) IWCMS *Section 7* provides a detailed assessment of sewage management. The revised Concept Plan area will be serviced by a reticulated sewage management scheme owned and operated by Shoalhaven Water in accordance with the recommendations of the Healthy Estuaries Guideline. The sewage management scheme includes:

- Reticulated sewer connection to all urban development areas.
- The western portion of the revised Concept Plan will require a new sewage pumping station (SPS).
- The eastern portion of the revised Concept Plan will drain into the existing Culburra Beach sewer network.

Protection of estuarine ecology and water quality for ecology and oyster aquaculture from the impacts of sewage will be achieved by implementation of a best practice reticulated sewerage system with appropriate detention. Further, remote monitoring and back-up systems are to be implemented to prevent dry weather overflows and minimise any wet-weather overflows, including measures to control and mitigate the impact of any overflows, should they occur.

Accordingly, it is concluded that the potential for, and risk of water quality impact on the estuarine aquatic ecology of the Crookhaven River from the proposal is considered low, and the potential for impact on the oyster aquaculture of the Crookhaven River and Curleys Bay from operation of the completed development can be avoided, minimised and mitigated satisfactorily by:

- appropriate control of stormwater quality and quantity, including control of anthropogenic gross pollutants i.e., such as plastic debris and the like),

- controlling stormwater distribution into the wooded parklands to "mimic" present distribution patterns,
- appropriate control and management of sewer infrastructure to prevent sewage overflows into downstream wetlands and the bay, and
- appropriate operational management plans to ensure these control measures are met and maintained in the long-term.

3.2.4 Disturbance of Adjacent Riparian and Aquatic Habitats

Lake Wollumboola Catchment

As there is less than 0.5ha of the Proposal located in the Lake Wollumboola catchment, there are no associated aquatic ecology impacts expected to the watercourse locally known as Wattle Creek. There are no freshwater aquatic ecology habitats or biota in the upper Wattle Creek catchment for 1 km downslope of Culburra Road and the remaining creek line leading to the lake is an intermittent drainage with the majority of stormwater carried by this section of Wattle Creek generated from an eastern tributary draining a portion of the existing Culburra Beach township east of the Retirement Village.

The current risk of adverse water quality impact for downstream Wattle Creek aquatic habitats from un-treated road runoff will be diminished by the proposed roundabout construction, as treatment of the constructed roundabout runoff water quality includes a water bioretention basin structure for the collection and treatment of runoff water from the proposed roundabout. Inclusion of GPTs will also reduce the present risk of anthropogenic gross pollutants from road runoff within the Culburra Road Wattle Creek catchment migrating down-slope from the present road culvert. These measures provide a beneficial impact as they will improve the existing water quality drainage into Wattle Creek below Culburra Road.

Crookhaven River Catchment

The proposal does not include any construction works or direct access along the riparian estuary edge, or to the intertidal and shallow sub-tidal estuarine saltmarsh, mangrove, mudflat and seagrass habitats within Curleys Bay, and the intention of Council - as the proposed future buffer reserve landowner - is to prohibit any direct water access, to protect associated vegetation, habitats and biota.

The proposal includes a public walkway/cycleway through the woodland to connect the development to the rest of Culburra Beach township to the east. This is to to utilise existing tracks and available cleared land through the woodlands where possible, and the construction will be managed and operated to minimise disturbance of soils and overland stormwater flow paths to ensure no impacts on aquatic habitats or vegetation from the construction. Future use of the pathway is to be managed by Council, as the proposed eventual owner of the reserve, and risk of debris loss and dog faeces would likely be minimised by the now common combination of education, signage, provision of rubbish bins and monitoring by Council rangers, with strict policing of owner responsibility for dog faeces collection and appropriate disposal as per the Council's *Access for Dogs Policy*.

3.2.5 Potential Impact of Increased Population

The main residual potential impact on estuarine values arises from the increase in Culburra Beach population. The increased population can be expected to lead to an increase in expectation for recreational use of local waterways for power-boat-based fishing and also for passive boat usage - e.g., kayaks and SUPs, which has the potential for increased disturbance of estuarine habitats and increased use of estuarine resources.

There are currently no (and are not proposed to be) suitable launching places around the shoreline located approximately 100m from the revised Concept Plan footprint, and there are none along the remaining shorelines around the Crookhaven River west and Curleys Bay east for any vessels motorised or otherwise, and recreational fishing from boats originating from the development area will be expected to increase use of the two closest public launching ramps located at Orient Point; one providing access to the river channel between Orient Point and Goodnight Island - where there is a 4 knot speed limit, and the main regional public boat ramp that provides direct access to the river entrance channel and the sea. As the majority of fishers launching from these ramps fish in the main river, river entrance or immediately offshore, it is concluded that there is not likely to be a significant increase in boating or recreational fishing pressure in Curley Bay, particularly given the limiting tidal depths and obstructing oyster infrastructure within Curleys Bay.

Whilst it can be expected that there would be some increased recreational boat fishing in the rest of Crookhaven River, the same tidal and oyster infrastructure limitations to speed and shoreline access that exist in Curley's Bay are present in Crookhaven River upstream of Goodnight Island. Further, whilst there are currently no speed or wash limits for the upper Crookhaven River, interaction with commercial fishers and oyster farmers, and their requirements for low speeds and wash are well known and enthusiastically enforced.

Launching of smaller portable watercraft direct from the 100m wide foreshore buffer reserve to Curleys Bay (especially via the proposed boardwalk) is not likely due to the difficulty of actual launching via the extended bushland to the riparian edge plus the saltmarsh, mangrove and mud banks offshore from the riparian edge that need to be negotiated to reach open water. Launching from the Billys Bay side of the development area is not possible (or at best limited) due to thick bushland between the pathway and the shore and mangrove growth extending from the shore across to Billys Island. Further, as noted above, the intention of Council - as the proposed future buffer reserve landowner - is to prohibit any direct water access, to protect associated vegetation, habitats and biota.

It is therefore concluded that increased use of Curleys Bay and the upper Crookhaven River due to increased population pressure will not be sufficient to increase the risk of disturbance to inshore saltmarsh stands, protected mangrove stands and occasional use by shore/wading and fishing birds of the shoreline and mudflats. Risk of propeller scour and anchor scour from boat usage over the Curleys Bay seagrass beds is also not likely to be increased over the present low risk and can be mitigated by proper education including signage at the two public boat ramps.

Given the tidal and oyster infrastructure hinderances to vessel speed in Curleys Bay and much of Crookhaven River it is concluded that there would be no increased collision risk from the limited increased use for recreational fishing for green turtles feeding in Curleys Bay. The risk for green turtles and other aquatic biota arising from ingesting anthropogenic rubbish (plastics in particular) sourced directly from the development area is considered low as these are to be controlled at source. Whilst there is a limited additional risk for aquatic biota from ingestion of plastic debris or discarded hooks plus fishing lines from increase numbers of recreational fishers or boaters, this general risk is already being mitigated by education including placement of appropriate signage at launching sites and at bait shops and discouraging the use of plastic bags for brought bait.

3.3 Estuarine Monitoring Program

Whilst the impact analysis provided above has concluded that the risk of impact for the riparian and estuarine environment plus use of the estuary for oyster aquaculture is low - provided the detailed best practice construction proposals for the project are adopted - risk is never nothing and therefore proposals require appropriate surveillance monitoring to ensure continued low risk and provide early warning if impact should occur.

Monitoring programs can be designed to consider *sources* and/or *pathways* of impact risk (in this case altered water quality and quantity via land runoff to the estuary) and/or *effects* of impact (in this case adverse changes to estuarine ecosystems or to oyster aquaculture practice). For the former, water quality monitoring of receiving waters is usual, and for the latter, choices of what *effects* to monitor are made on the basis of a consideration of habitats or aquaculture locations considered most sensitive to the potential impacts. The following sub-sections provide a rationale for the design and implementation of an appropriate ecosystem health monitoring program for the Revised Culburra Beach Concept Plan.

3.3.1 Ecosystem Resilience

In order to provide an appropriate monitoring program that will provide early warning requires consideration of *ecological resilience* defined as "the capacity of an ecosystem to absorb repeated disturbances or shocks and adapt to change without fundamentally switching to an alternative stable state”. Resilience relates to how an ecosystem resists stressors, and how it recovers from loss or degradation, i.e., resilience = resistance and recovery. Unsworth et al (2015) provides a conceptual model or framework for assessment of resilience in the context of seagrass ecosystems that is applicable to the consideration of whole estuarine resilience modelling and this model is further developed by the work of O'Brien et al (2018).

As developed by Unsworth et al (2015) natural ecosystems respond to drivers over variable timescales. Responses are separated into ‘fast’, *threshold like* responses to stressors such as floods, and ‘slow’ *linear* responses to slowly developing pressures such as fishing, elevated nutrients or rising global temperatures. Non-linearity can make the response of systems difficult to predict, particularly in the presence of multiple drivers of change. Slow, *chronic drivers* may occur simultaneously, and may be highly interactive with each other, causing cellular or physiological responses that are not readily quantified. In contrast, fast drivers (e.g., large storm events or periods of extreme temperature) are episodic disturbances or shocks that quickly push the system away from its equilibrium state. When chronic levels of stress (slow drivers of change) are low (below a threshold) a seagrass ecosystem may have features that provide it with the capacity to recover from an acute, fast-acting disturbance (**Figure 27**).

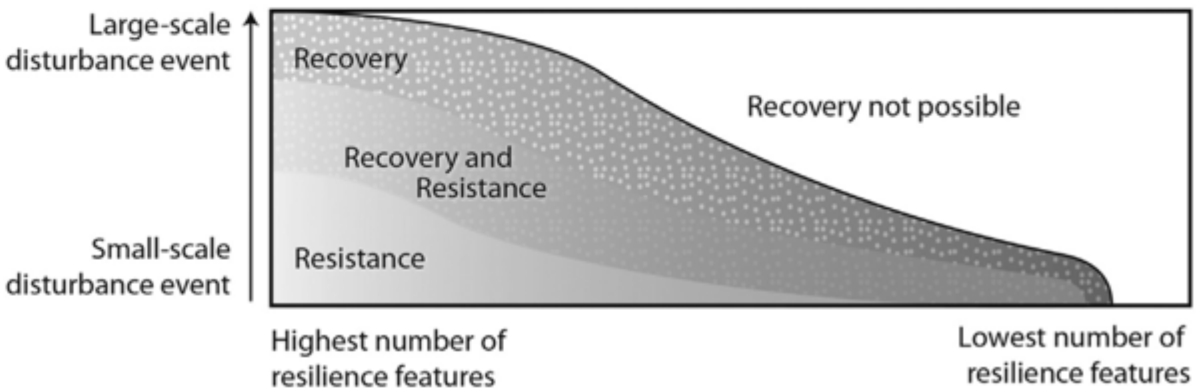


Figure 27 Conceptual Model of Ecosystem Resilience (from Unsworth et al 2015).

O'Brien et al (2018) expand on this model and provide a conceptual schema for the consideration of stressors in relation to seagrass meadow resilience over different time scales and meadow sizes (**Figures 28 and 29**). Disturbance intensity, duration, spatial extent, timing and recurrence can affect degradation trajectory. The characteristics of the disturbance (e.g. dredging, storm- floods, eutrophication or exposure to toxicants) and the intensity (e.g. depth of burial, degree of light reduction, storm intensity, concentration of nutrients or toxicants) influence the resistance time, i.e. how long before damage occurs. For example, the greater the severity of light reduction, the more likely the disturbance will cause biomass decline and damage, and impact seagrass at medium to large scales. If the intensity is low, damage is more likely to be reversible: in some cases, acclimation may even be possible.

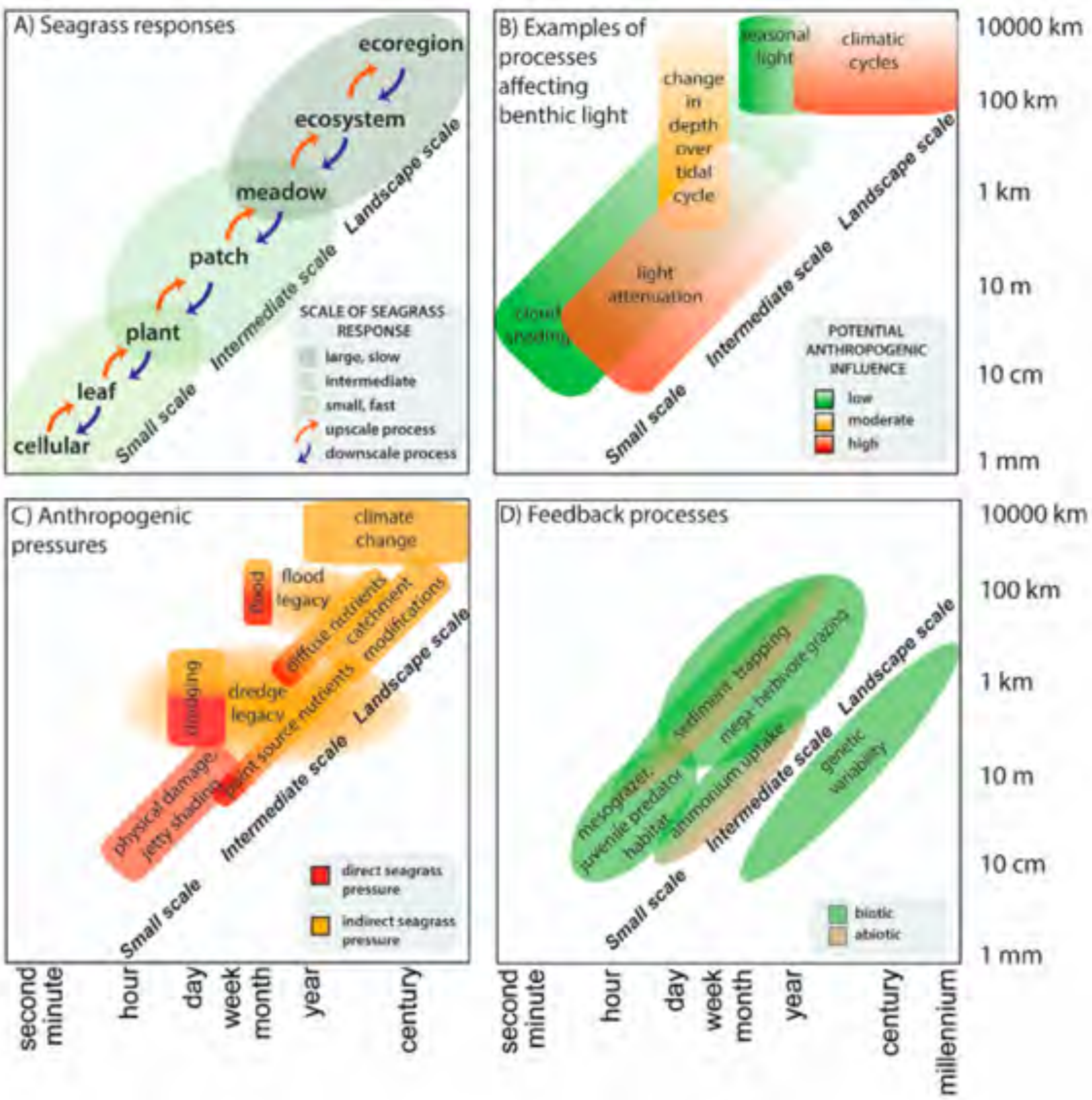


Figure 28 O'Brien et al (2018) The trajectories of degradation and recovery observed in seagrass ecosystems arise from cumulative responses to natural and anthropogenic processes, interacting across a range of temporal and spatial scales.

Kilminster et al (2015) provide a further level of consideration for the measurement of resilience in their review of complexity in Australian seagrass ecosystems. They note that seagrass communities are formed from species whose life history strategies can be described as colonising, opportunistic or persistent. They occupy habitats defined by the range and variability of their abiotic environment.

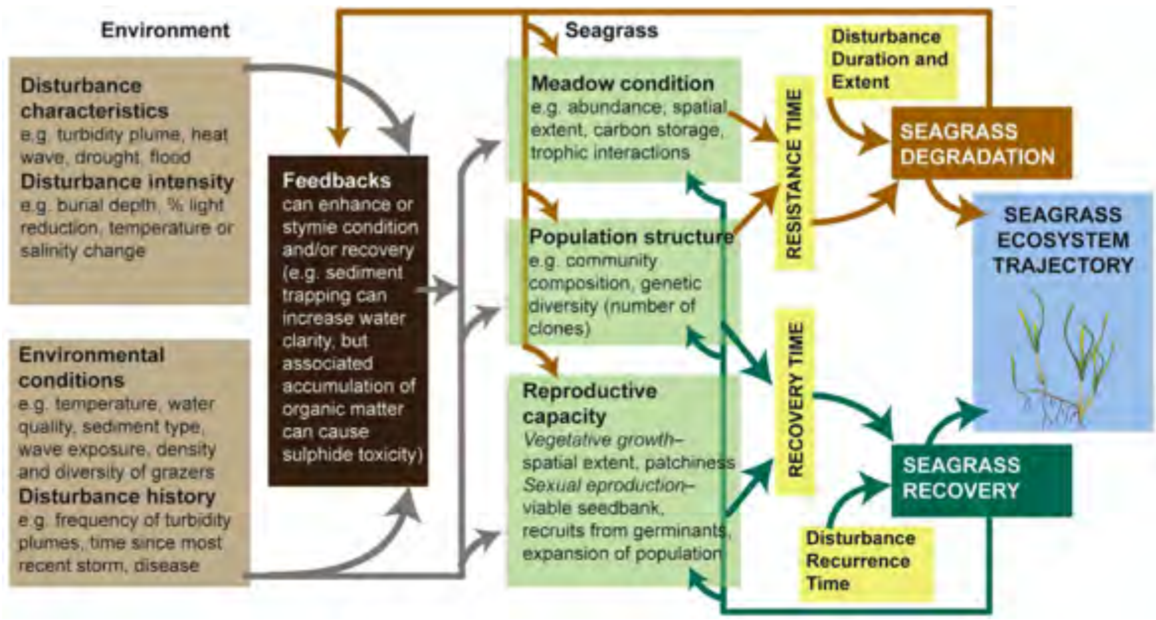


Figure 29 O'Brien et al (2018). The trajectory of a seagrass ecosystem in response to disturbance depends on the degree of degradation and recovery which in turn depend on the relative timescales of resistance, recovery and disturbance.

This results in seagrass meadows that are either *transitory* or *enduring*. Transitory meadows may come and go and are able to re-establish from complete loss through sexual reproduction. Enduring meadows may fluctuate in biomass but maintain a presence by resisting pressures across multiple scales. This contrast reflects the interaction between the spatial and temporal aspects of species life history and habitat variability. These concepts are exemplified in the work of Maxwell et al (2015) who developed and tested resilience models for the *Zostera* seagrass beds in Morton Bay for predicting the locations and probably survival of enduring and transitory beds (see **Figure 30**).

This concept of enduring and transitory meadows is directly applicable to Crookhaven River where the variations in long-term estuary wide mapping of *Zostera* seagrass beds in the estuary may be at least partially explained by the presence or absence of transitory beds over time, and the concept is clearly applicable to Curleys Bay where there are identifiable enduring beds in the deeper tidal channels and transitory beds in the bay inshore shallows.

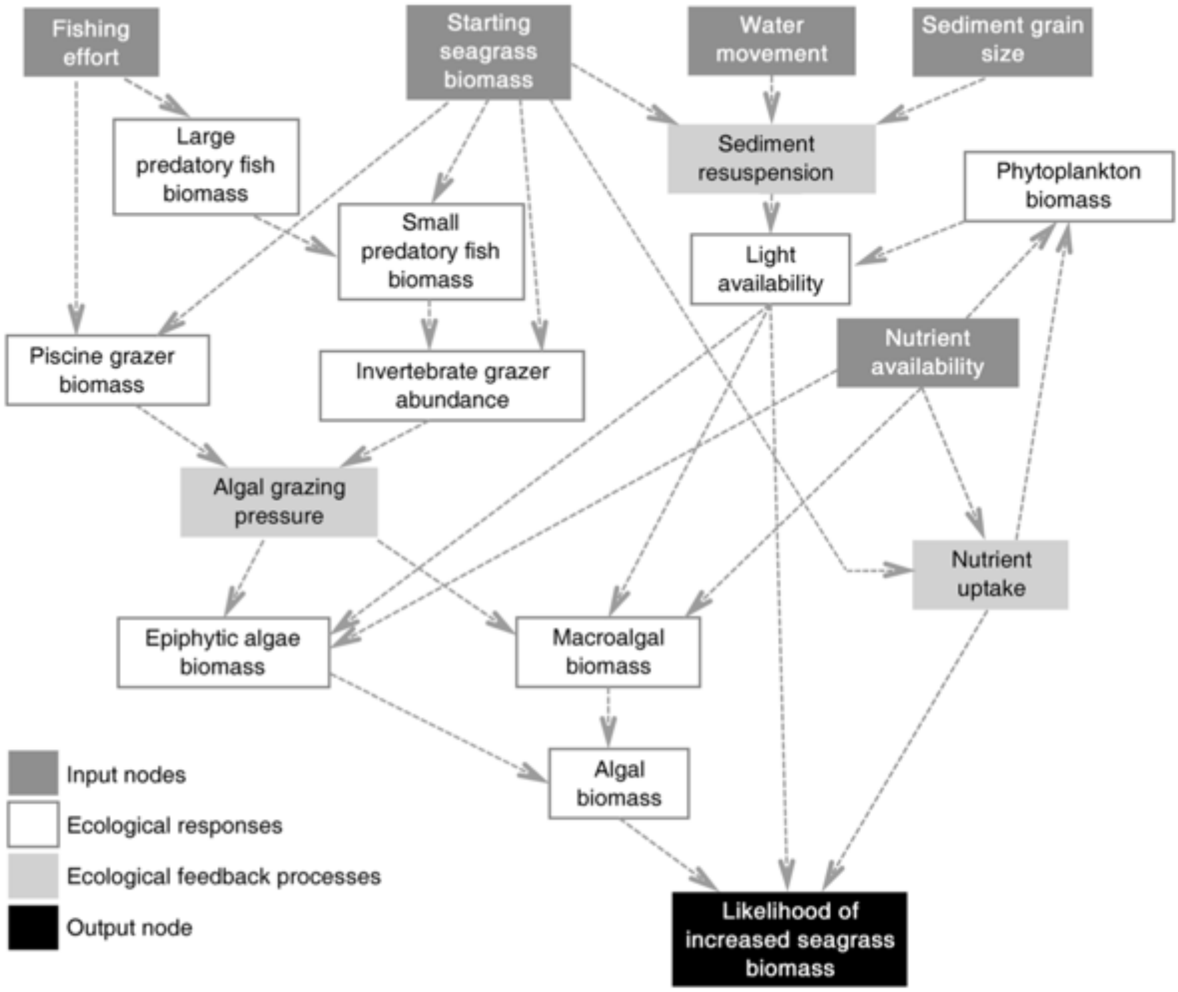


Figure 30 Bayesian Network Conceptual Framework for *Zostera* seagrass resilience in Moreton Bay (Maxwell et al 2015).

3.3.2 Resilience of Curleys Bay southern shore estuarine habitats

One of the main drivers of resilience for estuarine ecosystems is *fragmentation and connectivity* of the various zoned estuary habitat types. Whilst there are many examples of fragmentation and loss of connectivity for the riparian to shallow sub-tidal vegetated habitats along the urbanised eastern shoreline of Curleys Bay (including loss or degradation of riparian and saltmarsh habitats to reclamation/clearing and weed invasion, clearing plus fragmentation of mangrove stands) the estuarine habitats along the southern shoreline of Curleys Bay are more or less intact and have the additional benefit of a wide more or less natural forested woodland buffer between the estuary ecosystems and the proposed development, with no direct stormwater connections to the estuary. The relative isolation of the southern habitats including the forested buffer also means that there is less potential for loss or degradation of riparian and saltmarsh habitats to weed invasion and physical damage.

In regard to resilience to *water quality stressors*, all the sub-tidal habitats (seagrass beds and bottom sediment habitats) of Crookhaven River and oyster aquaculture are susceptible to eutrophication and flood related stress (freshets, physical damage, sedimentation smothering, turbidity and elevated nutrients) due to the historic alterations of the river catchment for agriculture (wholescale clearing, cattle/dairy farming, stock damage to riparian habitats, flood mitigation drainage and impoundments). In additional, the eastern urbanised intertidal habitats plus near-shore mud flats and seagrass beds of Curleys Bay are subjected to pulse eutrophication impacts associated with urban stormwater discharges and occasional sewer infrastructure overflows. The southern Curleys Bay habitats (at least west of the Canal Street drain) are less susceptible to localised urban stormwater runoff and will remain so for the proposal, given the retention of the forested buffer and proposed high level of stormwater treatment. Notwithstanding, the habitats between Billys Bay and the mainland have one vulnerability, which is the relative isolation of the shallow inshore intertidal habitats for wind wave mixing (high for eastern and SE Bay shoreline habitats, moderate for SW Bay habitats and low for Billys Bay). However, tidal exchange for Billys Bay is still comparatively good and similar to SW and SE bays which reduces the potential for ponding and pooling of runoff waters which in turn reduces the potential for sediment anoxia under stagnant waters.

The sheltered Billy Bay shoreline is a strength in regards to possible inshore erosion of intertidal habitats from floods and high wind wave activity which can (and have) resulted in localised erosion of inshore habitats; for example the loss of riparian edge sediments and saltmarsh habitat along parts of the upper Crookhaven River including the southern shoreline of Billys Bay western drain where cattle have both destabilised inshore sediments and reduced vegetation cover by grazing. This has resulted in erosion of the inshore sediments down to bed rock with loss of saltmarsh, juvenile and mature mangroves, continuing erosion of the riparian Casuarina toe soils and consequent loss of edge Casuarinas. Whilst this impact has been, and continues to be mitigated by exclusion fencing for stock, both continuing bank erosion and habitat rehabilitation require active management - a good example of resilience loss.

3.3.3 Outline for an Estuarine Health Monitoring Program

The concepts of risk plus resilience for the various tidally zoned vegetated habitats offshore from the proposal can be used to provide the parameters for an estuarine health monitoring program to both demonstrate compliance with predictions and provide for early intervention if there are deteriorations in estuarine health conditions. The estuary heath monitoring concept follows recommendations developed in Fairweather (1999) and applied by Scanes et al (2007, 2010):

- *Pathways* analysis indicates that the main connection between the development and estuarine environments is via runoff water via direct overland or shallow aquifer flows through the forest buffer.
- *Contaminants of Concern* analysis indicates that the main COCs are water-borne nutrients sediments and faecal bacteria, with lower concerns (or more likely longer-term concerns) for metals and organic compounds (for bioaccumulation). Given the width of the forested buffer between the development and the estuarine edge habitats, the potential risk of weed seed transport to saltmarsh habitats as examined by Geedicke (2019), is considered low.
- *Receiver analysis* indicates that the health of high-zoned and intertidal vegetation communities (edge riparian Casuarinas, saltmarsh and mangroves) are more likely related to changes in sediment character, whilst the health of the seagrass beds, attached algae, oysters and the waters themselves (as habitat for phytoplankton and other biota) are predominantly related to water characteristics.
    - Intertidal sediment character (Casuarinas saltmarsh and mangrove habitats) would generally be related more to direct deposition during low tides than secondary deposition from the water column for wind exposed sites, but for Billys Bay sites that are predominantly sheltered from wind, secondary deposition from the water column is more likely.
    - Whilst seagrass receiver heath is predominantly governed by water quality, over time sediment accumulations from both secondary deposition and reworking of inshore fine sediments offshore by tide and wind could alter below-ground growth characteristics for seagrass root and rhizome systems. This however is considered a very long-term concern and generally only relevant for high persistent runoff pollutant loads.
- The results of the pilot sediment study indicate that there is considerable scope for most of the vegetated estuarine communities in the receiving paths and waters from the development to absorb varying nutrient concentrations in the sediments and so these communities are not considered as *sensitive receivers* for monitoring purposes.
- The health of the seagrass beds is however sensitive to the nutrient concentrations and sediment loads of the waters, as are macroalgae which, in Curleys Bay, are confined to intertidal mangrove peg roots.
- Oyster aquaculture health is critically dependent on food availability (mainly phytoplankton and detritus/seston), water salinity change and bacteriological loads. Therefore, whilst increased nutrient and silt loads may be beneficial to oyster aquaculture, higher bacterial loads (whilst not detrimental to oysters directly) are detrimental for harvesting and sale. Whilst aquaculture oysters are not appropriate

for estuary monitoring (as they are harvested), wild oysters can be considered, and the main stock of wild oysters that are available for monitoring for this study are those growing on mangrove peg roots and oysters growing on historic seed rock structures. These may also be appropriate for longer term metal accumulation monitoring (Robinson et al 2005).

The outcome of this analysis is that the proposed pre-construction monitoring program for inclusion in subsequent development applications should incorporate 12 months of both estuarine health water quality and habitat condition monitoring which addresses:

- Selecting *Zostera* seagrass as the most sensitive receptors for the habitat condition monitoring, and that measurements of *Zostera* seagrass blade attached biota and silt loads (epiphytic biomass) be considered as the most sensitive receptor for measuring storm-water borne nutrient and turbidity/siltation impacts.
- *Zostera* epiphyte load monitoring sites should also be selected with particular regard to important shellfish aquaculture locations. in proximity to the development site.
- Oyster shellfish will also be considered for sentential monitoring, particularly for other potential stormwater derived pollutants such as metals (Robinson et al 2005). In this respect the outer-mangrove to bare-sediment transition zone peg root oysters are considered the most suitable sentential monitoring candidates.
- *Zostera* bed pipefish assemblages are to be monitored as a 'flagship' group for evaluating potential impacts on seagrass bed fish assemblages (Shorki et al 2009).
- Intertidal vegetated habitats (riparian edge casuarinas and saltmarsh plus mangroves) are considered less sensitive to water quality stress but may be marginally more sensitive to change in sediment Nitrogen to Phosphorus ratios and are to be monitored by a combination of seasonal assessments of species and density on or in fixed transects/quadrats plus annual drone aerial photography for overall changes in inter-tidal plus seagrass bed distribution. The drone photography can also include use of fixed quadrats for enabling comparisons between years.

4 CONCLUSIONS

Modelling of the stormwater scheme provided in the Integrated Water Cycle Management Strategy (IWCMS) for the revised West Culburra Beach Concept Plan (the Proposal) demonstrates that there will be no material or significant impacts on the downstream environment including the Crookhaven River or Lake Wollumboola, as pollutant loads will be reduced compared to existing conditions and the hydrological character of overland flows leaving the Proposal will not be detrimentally altered compared to existing conditions (Martens 2020). Accordingly, provided construction impacts for the Staged Development Applications are properly implemented and controlled, there is a low risk of impact on the aquatic ecology and oyster aquaculture of the receiving waters.

The potential impact for the freshwater aquatic ecology of Wattle Creek in the Lake Wollumboola catchment from the Proposal's future construction and operation of a roundabout on Culburra Road would have no impact on the aquatic ecology of Wattle Creek or Lake Wollumboola, and the inclusion of a bioretention swale plus GPTs will result in an overall improvement of water quality leading to Wattle Creek from the catchment and road runoff.

The potential impact from the Proposal to the estuarine aquatic ecology and Curleys Bay/Crookhaven River oyster aquaculture from future construction activities can be successfully controlled by appropriate staging of both the development as a whole and by staging of the internal elements of each construction stage, as detailed in other companion reports, and that will be set out in Construction Environment Management Plans (CEMPs).

The potential for, and risk of water quality impact on the estuarine aquatic ecology and for oyster aquaculture in the Crookhaven River from the Proposal is considered low, as water quality impact on Crookhaven River and Curleys Bay can be avoided, minimised and mitigated satisfactorily by implementation of the proposal's IWMCS that includes:

a) appropriate control of stormwater quality and quantity, including control of anthropogenic gross pollutants i.e., such as plastic debris and the like),
b) controlling stormwater distribution into the wooded parklands to "mimic" present distribution patterns, and with no direct stormwater connections to the estuary,
c) appropriate control and management of sewer infrastructure to prevent sewage overflows into downstream wetlands and the bay, and
d) appropriate operational management plans to ensure these control measures are met and maintained in the long-term.

Accordingly, there will be negligible aquatic impact on the Crookhaven River estuarine ecology and oyster cultivation from future operation of the built revised Concept Plan, and residual risk for the aquatic ecology of the site, for receiving waters plus oyster aquaculture activities are considered minimal and are manageable via appropriate Conditions of Development Consent, implementation of an Estuarine Health Monitoring Program as outlined in this report, and site management via an Operational Environmental Management Plan (OEMP).

Increased use of Curleys Bay and the upper Crookhaven River due to increased population pressure is not expected to increase the risk of disturbance to inshore saltmarsh stands, protected mangrove stands and seagrass beds and occasional use by shore/wading and fishing birds of the shoreline and mudflats, and presents a low risk to use of the estuarine habitats by green turtles, shore and fishing birds due to restrictive and difficult access to these areas. Residual risk for protection of estuarine values, minimising plastic debris risk to marine fauna, minimising pet related faecal pollution, protection of oyster aquaculture infrastructure and practices from boat traffic/wash and minimising potential conflicts with commercial fishers can be managed by best practice public awareness programs including relevant signage at the public walkway/cycleway and boat ramp locations, and included as provisions in the OEMP for long term risk management.

5 REFERENCES

Adam, P. (2010).

Australian saltmarshes. *Wetlands Australia*, 1(1), pp.8–10.

Adam, P. (2010).

Saltmarsh plants of New South Wales. *Wetlands Australia*, 1(1), pp.11–19.

Adam, P., Wilson, N.C. and Huntley, B. (2010).

The phytosociology of coastal saltmarsh vegetation in New South Wales. *Wetlands Australia*, 7(2).

ANZECC / ARMCANZ (2000).

Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand.

AP&S (2017)

SEE 18-Hole Championship Golf Course for the Halloran Trust Lots 5 & 6 DP106511 Culburra Beach, December 2017.

AP&S (2020)

West Culburra Beach Revised Concept Plan - Environmental Impact Statement.

Arnold W. R. (2005).

Effects of dissolved organic carbon on copper toxicity: Implications for saltwater copper criteria. *Integrated Environmental Assessment and Management* 1(1): 34-39.

Baiada C, Scanes P, Ferguson A (2018)

Detection of Groundwater Inputs to Lake Wollumboola, NSW. Report to OEH Regional Operations Group by OEH Estuary and Catchments Science Team Revised Version May 2018

Bishop and Bell (1978).

Observations on the fish fauna below Tallowa Dam (Shoalhaven River), NSW) during river flow stoppages. Aust J Mar Freshwater res. 29: 543-549

Boon P (2012)

Coastal wetlands of temperate eastern Australia: will Cinderella ever go to the ball? Mar & Freshwater Res 63: 845-855.

Boon P & Cain S (1988)

Nitrogen cycling in saltmarsh and mangrove sediments in Western Port, Victoria. Aust J Mar Freshwater Res. 39:607 - 623.

Borowitzka M, Lavery P, van Keulen M (2005)

Epiphytes of Seagrasses. Chap 19 in Larkum et al. (eds.), Seagrass Biology, Springer.

Borum J (1995)

Development of epiphytic communities on eelgrass(Zosteramarina) along a nutrient gradient in a Danish estuary. Marine Biology 87:211-21.

Boyes, B. (2006a).

Determining and managing environmental flows for the Shoalhaven River, Report 1 - Environmental Flows Knowledge Review. NSW Department of Natural Resources, May 2006.

Boyes, B. (2006b).

Environmental water requirements for the Shoalhaven River estuary. Discussion Paper, Shoalhaven Environmental Flows Scientific Advisory Panel. NSW Department of Natural Resources, March 2006.

Carter S (1995)

Coastal Resource Atlas for Oil spills from Bass Point to Wheelers Point. NSW EPA report 95/8, January 1995.

Carvalho, R. C., and Woodroffe, C. D. (2014).

The sediment budget as a management tool: The Shoalhaven coastal compartment, southeastern NSW, Australia', In *23rd Coastal Conference*, Shoalhaven, 2014.

Clarke P (1985)

Nitrogen Pools and soil characteristics of a temperate estuarine wetland in eastern Australia. Aquatic Botany 23(3):275-290.

Coull, B.C. (1999)

Role of meiofauna in estuarine soft-bottom habitats. Australian Journal of Ecology, 24:327-343.

Coysh, J., Norris, R., Kotlash, A. and Davies, C. (2005)

Ecological and physical characteristics of the Shoalhaven River catchment: towards a conceptual understanding. Working paper prepared by the Cooperative Research Centre for Freshwater Ecology to support the Shoalhaven Environmental Flows Scientific Advisory Panel.

Creese, R.G., Glasby, T.M., West, G. and Gallen, C. (2009).

Mapping the habitats of NSW estuaries. Report to the Hunter Central Rivers Catchment Management Authority, HCRCMA Project No. HCR 07-458, September 2009, Industry & Investment NSW. Fisheries Final Report Series No. 113

Cumberland Ecology (2017).

Culburra Golf Course. SIS Addendum Report. Prepared for Allen Price & Scarratts, December 2017.

Daly, G. (2014).

From rags to riches and back again: fluctuations in the Green and Golden Bell Frog *Litoria aurea* population at Nowra on the south coast of New South Wales. *Australian Zoologist* 37:(2): 157-172

DE & E (2017).

Recovery Plan for Marine Turtles in Australia. Department of the Environment and Energy, Commonwealth of Australia 2017.

DECC (2009).

Environmentally Friendly Seawalls, A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries. DECC Report 2009/328 prepared on behalf of Sydney Metropolitan Catchment Authority, June 2009.

Dexter, D M. (1984).

Temporal and spatial variability in the community structure of the fauna of four sandy beaches in south-eastern NSW. *Aust. J. Mar. Freshwater. Res.*, 35: 663-672.

DPI Food Authority (2015)

Marine Biotoxin Management Plan

DPI (2017)

NSW Marine Estate Threat and Risk Assessment – background environmental information. Second edition: September 2017.

DPI Food Authority (2018)

NSW Shellfish Industry Manual,

DPI Food Authority (2019)

Phytoplankton and Biotoxins in NSW Shellfish Aquaculture Areas Risk Assessment

Dwyer, P. (2014).

Historical harvesting of River Mangrove for use as 'oyster sticks' in NSW (Video file). Retrieved from http://sydney.edu.au/environment-institute/videos/patrick-dwyer-historical-harvesting-ofriver- mangrove-for-use-as-oyster-sticks-in-nsw/ (19 January 2017).

ELA (2017)

West Culburra Aquatic Ecology Impact Assessment: Proposed Mixed Use Subdivision. Prepared by Eco Logical Australia 2016 for The Halloran Trust.'

Fairfull, S. (2013). Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management (2013 update). NSW Dept Primary Industries.

Fairweather, P.G. (1999)

Determining the "health" of estuaries: Priorities for ecological research. Australian Journal of Ecology 24, 441-451

Faraghers, R.A. (1999)

A survey of the threatened fish species, Australian grayling *Prototroctes maraena Gunther*: distribution and abundance in New South Wales. CRC for Freshwater Ecology, NSW Fisheries Research Institute, NSW, Australia.

Finegan, A., & Brown, S. (2000)

Macroinvertebrate survey for Shoalhaven Wetland Inventory Project. Prepared for SCC by Novo-Eco & SWC Consultancy.

Ferguson A, Gruber R, Orr M Scanes P (2016)

Morphological plasticity in *Zostera muelleri* across light, sediment, and nutrient gradients in Australian temperate coastal lakes. Mar Ecol Prog Ser. 556: 91-104

Geedicke I (2019)

Anthropogenic impacts on mangrove and saltmarsh communities in eastern Australia. PhD thesis, Hamberg and Macquarie Universities.

Gehrke, P.C., Gilligan, D.M. and Barwick, M. (2001

Fish communities and migration in the Shoalhaven River - Before construction of a fishway. Report by NSW Fisheries.

Gehrke, P.C., Gilligan, D.M. and Barwick, M. (2002)

Changes in fish communities of the Shoalhaven River 20 years after construction of Tallowa Dam, Australia. River Research and Applications, 18:265-286.

Gipple & Sachs 2017

DPI Healthy estuaries for health oysters guidelines

Glamore, W., Rayner, D., Massie, R., Ghetti, I., and Ruprecht, J. (2016).

Prioritising Floodplain Restoration Under a Changing Climate. Paper presented at 8th International Acid Sulfate Soils Conference, July 17-23 2016 At University of Maryland, College Park, MD, USA.

Gray, C., Johnson, D., Broadhurst, M, and Young, D. (2005).

Seasonal, spatial and gear-related influences on relationships between retained and discarded catches in a multi-species gillnet fishery. *Fisheries Research*. 75: 56-72.

Haine B, Scanes P, McSorley A (2011)

An Ecological Health Assessment of the Karuah River. NSW Office of Environment and Heritage. Report prepared for Great Lakes Council. 107pp.

Hgeo (2017).

West Culburra groundwater assessment. Preliminary Report (Stage 1), prepared for Shoalhaven City Council, HGEP Pty Ltd Report D17262 dated 28 June 2017.

Hoppe-Speer S & Adams J (2015)

Cattle browsing impacts on stunted *Avicennia marina* mangrove trees. Aquatic Botany 121 (2015) 9–15

Jackson K & Ogburn D (1999)

Review of Depuration and its Role in Shellfish Quality Assurance. for NSW Shellfish Quality Assurance Program. FRDC Project No. 96/355.

Jacobs, S. W. L., Les, D. H., and Moody, M. L. (2006).

New combinations in Australasian Zostera (Zosteraceae). Telopea. 11. 127–128.

John Toon (2017)

West Culburra Mixed Use Concept Plan Major Project 09-0088 Environmental Assessment John Toon Pty Limited March 2013

Kilminster et al (2015)

Unravelling complexity in seagrass systems for management: Australia as a microcosm. Science of the Total Env. 535: 97-109. (12 authors).

Kingsford R (1990)

The effects of human activities on shorebirds and water birds of Comerong Island, at the mouth of the Shoalhaven River. Wetlands (Australia). Wetland (Aust) 9(1); 7-12.

Kumbier K, Carvalho R, Vafeidis A, Woodroff C (2018)

Investigating compound flooding in an estuary using hydrodynamic modelling: a case study from the Shoalhaven River, Australia. Nat. Hazards Earth Syst. Sci., 18, 463–477, 2018

Lovelock, C.E., Feller, I.C., McKee, K.L., Engelbrecht, B.M.J., Ball, M.C., (2004).

The effects of nutrient enrichment on growth, photosynthesis and hydraulic conductance of dwarfed mangroves in Panama. Funct. Ecol. 18, 25–33.

Laursen and King (2000)

The distribution and abundance of mangrove macroalgae in Woolooware Bay, NSW, Aust. Botanica Marina 43:377-384.

Martens (2020)

Integrated Water Cycle Management Strategy, Mixed Urban Use development at Eest Culburra, NSW. Prepared for Sealark Pty Ltd, November 2020.

Maxwell P, Pitt K, Olds A, Rissik D, Connolly R (2015)

Identifying habitats at risk: simple models can reveal complex ecosyetm dynamics. Ecological Applications 25(2): 573-587.

Mazumder D, Saintlan N & Williams R (2005)

Temporal Variations in Fish Catch Using Pop Nets in Mangrove and Saltmarsh Flats at Towra Point, NSW, Australia, Wetlands Ecology and Management.

Mazumder D, Saintilan N, Williams R (2006)

Fish assemblages in three tidal saltmarsh and mangrove flats in temperate NSW, Australia: a comparison based on species diversity and abundance. Wetl Ecol Manag 14(3):201–209

McNeill S E, Worthington D G, Ferrell D J and Bell J D (1992)

Consistently outstanding recruitment of five species of fish to a seagrass meadow in Botany Bay, NSW. Aust. J. of Ecol. 17: 359 - 366.

Melville F & Pulkownik A (2006)

Investigation of mangrove macroalgae as bioindicators of estuarine contamination. Marine Pollution Bulletin 52, 1260e1269.

Melville F & Pulkownik A (2007)

Seasonal and spatial variation in the distribution of mangrove macroalgae in the Clyde River, Australia. Estuarine, Coastal and Shelf Science 71 (2007) 683-690

Miles, N. (2005)

The distribution and abundance of Australian grayling in coastal catchments of southern New South Wales. School of Earth and Environmental Sciences, University of Wollongong, Wollongong 2522, Australia.

Miles N & West R (2011)

Recreational fishing in the Shoalhaven Region, NSW, Australia: optimising survey methods and assessing sustainability. Final Report, (NSW Recreational Fishing Trust), ANCORS, University of Wollongong, NSW, Australia.

Mills et al (2016)

Reconciling Development and Conservation under Coastal Squeeze from Rising Sea Level. Conservation Letters. 2016, 9(5), 361–368

Minchinton et al (2019)

Impacts of Cattle on the Vegetation Structure of Mangroves. Wetlands (2019) 39:1119–1127

Mitchel, M.L. and Adam, P., 2009.

The relationship between mangrove and saltmarsh communities in the Sydney region. *Wetlands Australia*, 8(2), pp.pp. 37–46.

Middleton M. J, Bell J D, Burchmore J J, Pollard D A and Pease B C (1984)

Structural differences in the fish communities of *Zostera capricorni* and *Posidonia australis* seagrass meadows in Botany Bay, NSW. Aquatic Botany 18: 89-109. Volume 13, pages 457–467(2005)

Mobsby, D (2018)

Australian fisheries and aquaculture statistics 2017, Fisheries Research and Development Corporation project 2018-134, ABARES, Canberra, December

Naidoo, G (2006).

Factors contributing to dwarfing in the mangrove Avicennia marina. Ann. Bot.-London 97, 1095–1101.

Naidoo, G (2009).

Differential effects of nitrogen and phosphorus enrichment on growth of dwarf Avicennia marina mangroves. Aquat. Bot. 90, 184–190.

Naidoo, G.(2010).

Ecophysiological differences between fringe and dwarf Avicennia marina mangrove. *Trees* 24, 667–673.

Nath B, Birch G, Chaudhuri P (2014)

Assessment of sediment quality in Avicennia marina-dominated embayments of Sydney Estuary: The potential use of pneumatophores (aerial roots) as a bio-indicator of trace metal contamination. Science of the Total Enviroment 472 12010-1022.

NSW DPI (2015).

Australian Grayling - *Prototroctes maraena* September 2015, Primefact 162. Second edition Aquatic Ecosystems Unit, Port Stephens Fisheries Institute.

NSW DPI (2016).

NSW Oyster Industry Sustainable Aquaculture Strategy Third Edition 2016. NSW Department of Primary Industries, Port Stephens Fisheries Institute, Nelson Bay NSW.

NSW Fisheries (2013).

Policy and Guidelines for Fish Habitat Conservation and Management (2013 update), NSW Department of Primary Industries, June 2013.

O'Brien et al (2018)

Seagrass ecosystem trajectory depends on the relative timescales of resistance, recovery and disturbance. Mar Poll Bull 134: 166-176 (18 authors)

Ogburn D, White I, McPhee D (2007)

The Disappearance of Oyster Reefs from Eastern Australian Estuaries—Impact of Colonial Settlement or Mudworm Invasion? Coastal Management, 35:271–287

Ogburn, D. M. (2011).

The NSW oyster industry: A risk indicator of sustainable coastal policy and practice, Ph.D. Thesis, Australian National University, Canberra.

Ralph et al (2007)

Impact of light limitation on seagrasses. Journal of Experimental Marine Biology and Ecology 350 (2007) 176–193. Authors: P.J. Ralph, M.J. Durako S. Enríquez, C.J. Collier, M.A. Doblin.

Reef R, Feller I, Lovelock C (2010).

Nutrition of mangroves. Tree Physiology 30: 1148 - 1160.

Riches M, Gillian D, Danaher K, Pursey J (2016)

Fish Communities and Threatened Species Distributions of NSW. NSW DPI 2nd edition May 2016.

Robinson, W, Maher W, Krikowa F, Nell J, Hand R (2005)

The use of the oyster *Saccostrea glomerata* as a biomonitor of trace metal contamination: intra-sample, local scale and temporal variability and its implications for biomonitoring. Journal of Environmental Monitoring 7:208–223.

Roper et al (2011)

Assessing the condition of estuaries and coastal lake ecosystems in NSW, Monitoring, evaluation and reporting program, Technical report series, Office of Environment and Heritage, Sydney, prepared by Roper T, Creese B, Scanes P, Stephens K, Williams R, Dela-Cruz J, Coade G, Coates B & Fraser M.

Ross P and Adam P (2013).

Climate Change and Intertidal Wetlands. Biology 2: 445-480.

Rotherham D & West R (2002)

Do different seagrass species support distinct fish communities in south-eastern Australia? Fisheries Management and Ecology, 9,:235–248

Saintilan, N., and Rogers, K. (2013).

The significance and vulnerability of Australian saltmarshes: implications for management in a changing climate. *J. Mar and Freshwater Res* 64 (1), 66-79.

Saintilan and Williams (1999).

Mangrove transgression into saltmarsh environments in south-east Australia, *Global Ecology and Biogeography*. 8: 117-124 pp.

Saintilan and Williams (2000).

The decline of saltmarshes in South-east Australia: results of recent surveys. *Wetlands* (Australia) 18: 49-54 pp.

Saintilan N, Hossain K Muzumfder D (2007)

Linkages between seagrass, mangrove and saltmarsh as fish habitat in the Botany Bay estuary, New South Wales. Wetlands Ecol Manage (2007) 15:277–286.

Scanes, P., Coade G., Doherty M., Hill R. (2007)

Evaluation of the utility of water-quality based indicators of estuarine lagoon condition in NSW, Australia. Estuarine Coastal and Shelf Research 74, 306-319.

Scanes P, McCartin B, Kearney B, Floyd J, Coade G (2010)

Ecological Condition of the Lower Myall River Estuary. Report prepared for Great Lakes Council. Coastal Waters Science Unit DECCW December 2010, 132pp.

Scanes P, Ferguson, A, Potts J (2013)

Environmental Sensitivity of Lake Wollumboola: Input to Considerations of Development Applications for Long Bow Point, Culburra. NSW Office of Environment and Heritage, Sydney.

SCC (2008)

Shoalhaven River Estuary Management Plan (Shoalhaven City Council Adopted March 2008), Prepared by Umwelt (Australia)

Serov, P., Kuginis, L., Williams, J., and Byrne, G. (2012).

Risk Assessment Guidelines for Groundwater Dependent Ecosystems, Volume 1 “The Conceptual Framework”. Report prepared for National Water Commission. and published by NSW DPI Office of Water.

Shokri M, Gladstone W, Jelbart J (2009)

The effectiveness of seahorses and pipefish (Pisces: Syngnathidae) as a flagship group to evaluate the conservation value of estuarine seagrass beds. Aquatic Conserv: Mar. Freshw. Ecosyst. 19: 588–595

SKM (2012).

Culburra Golf Course SIS Addendum Report Summary Report for NWC NSW Coastal Groundwater Dependent Ecosystem and Groundwater Quality Project. Report prepared for NSW DPI Office of Water.

SLR (2013).
Culburra West Urban Development Project Culburra Beach. Ecological & Riparian Issues & Assessment Report. SLR Consulting Pty Ltd March 2013

SRO (2012).
Environ Manage System. Shoalhaven River Oysters Incorporated. Oct 2012 - V1.

SROF (2015).
2015 Environmental Update for Environmental Management System (EMS) prepared by Shoalhaven River Oyster Farmers.

Straw (2007).
Marine ecological investigations of the Shoalhaven Estuary near Shoalhaven Paper Mill. Report to Gutteridge, Haskins & Davey Pty Ltd.

The Ecology Lab (1993b).
Marine ecological investigations of the Shoalhaven Estuary near Shoalhaven Paper Mill, Supplementary Report. Report to Gutteridge, Haskins & Davey Pty Ltd.

The Ecology Lab (1995).
Shoalhaven River Effluent Discharge Assessment - Marine Ecological Investigations. Report to Manly Hydraulics Laboratory, October 1995.

The Ecology Lab (1996).
Shoalhaven Water Supply Augmentation EIS: Aquatic Ecology and Fisheries Downstream of Burrier. Report to Dames and Moore, October 1996.

Ugarelli, K, Chakrabarti S, Laas P, Stingl U (2017).
The seagrass holobiont and its microbiome. Microorganisms 5 (81) 28pp

Umwelt (2005).
Shoalhaven River Estuary Data Compilation Study. Prepared for Shoalhaven City Council, Umwelt (Australia) July 2005.

Unsworth R, Collier C, Waycott M, Mckenzie L, Unsworth L (2015)
A framework for the resilience of seagrass ecosystems. Mr Poll Bull 100 (1): 34-46.

Williams, R. J., West, G., Morrison, D., and Creese, R. G. (2006).
Estuarine Resources of New South Wales, prepared for the Comprehensive Coastal Assessment (DoP) by the NSW Department of Primary Industries, Port Stephens.

West, R. J., and Jones, M. V. (2001).
FRDC 97/204 Final Report: Shallow water fish communities of New South Wales south coast estuaries. Report Series Nos. 2001/1. Ocean and Coastal Research Centre, University of Wollongong, Australia.

West, R. J., Thorogood, C. A., Walford, T. R., and Williams, R. J. (1985).
An Estuarine Inventory for NSW, Australia. *Fisheries Bulletin 2*. Dept. Agriculture, NSW, Australia. 140pp. Wilton (2002).

Wilton K (2002)

Coastal wetland habitat dynamics in selected NSW estuaries. PHd thesis, School of Arts and Sciences (NSW) Australian Catholic University (February 2002).

Zedler J, Nelson P, Adam P (21995).

Plant community organization in NSW saltmarshes: Species mosaics and potential causes. Wetlands (Aust) 14:1-18

ANNEXURE B

WEST CULBURRA

FRESHWATER AQUATIC HABITATS

AND ECOLOGY

1 INTRODUCTION

After an initial site inspection on the 5th July, a preliminary desktop assessment of the sub-catchment drainage lines bounding the proposal that were most likely to contain surface water was undertaken. This was done by identifying the largest sub-catchment areas draining to and from the project area using the contour and topography maps and assessing aerial imagery for potential wetland or swamp vegetation communities. It was also noted in the SLR (2013) Ecology & Riparian Issues Report, that “On the Culburra West Project site, areas of “*standing water*” are few and highly ephemeral, and there are no ponds, swamps or permanent freshwater wetlands on the Project site.”

From the desk-top study it was decided that the initial field work should concentrate on investigating the riparian transition from terrestrial habitats through intertidal to shallow sub-tidal habitats along 20 shore-normal transects for the Crookhaven River catchment as selected from available topographic information (see **Figure 1**).

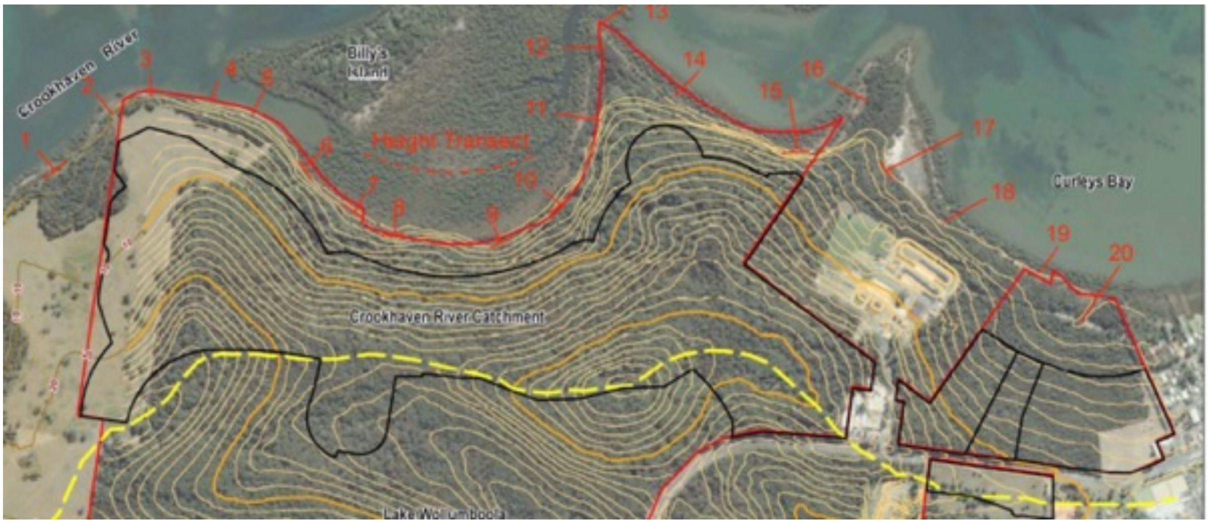


Figure 1 Proposed locations of 20 shore normal transects to ascertain site runoff characteristics and terrestrial to estuarine ecotones.

The Shore- Normal Transect work was undertaken between 4 and 6 September 2019 and completed during a second field survey between 15 and 18 October 2019. In the event 19 transects were surveyed. Targeted searches were also made along the foreshore and riparian zone draining towards the Crookhaven River and Curleys Bay to confirm drainage characteristics and provide evidence of surface flow runoff from the site, as indicated by channel incision, standing water or signs of prolonged water retention (debris lines, silt or mud accumulation or algal growth, surface water expressions from underground or indicative vegetation clusters).

The initial 2019 survey work included a formal aquatic ecology survey of the Downs Creek sub-catchment leading to Lake Wollumboola from the original West Culburra proposal. This field work was completed in October 2019. Further survey work scheduled for Wattle Creek in November/December 2019 was curtailed by the NSW 2019 fire season, and field surveys were delayed through to February 2020. The February 2020 survey then coincided with a flood event.

1.1 Field methods for Freshwater Aquatic Ecology Sampling

Field sampling encompasses overall aquatic and riparian habitat assessment, sampling for aquatic macroinvertebrates and fish and obtaining metered stream water quality data. MPR is licensed to conduct surveys in aquatic ecosystems under NSW Fisheries Scientific Collection Permit (Permit No. P12/0008-3.0).

1.1.1 Macroinvertebrate sampling and analysis

Macroinvertebrate assemblages are sampled using a 250 μm mesh dip net. Reaches for edge sampling within each of the sample locations are selected on the basis of:

(i) being high drought resistant (generally based on pool size, depth and cover of overhanging riparian vegetation),

(ii) having high aquatic habitat diversity; ideally deep pools connected by gentle riffles, abundance of stream bed litter, presence of snags and aquatic vegetation.

For ‘edge’ sampling, the dip net is passed over as many representative aquatic 'edge' habitat types as can be located within each of the pools along the defined stream reach, ensuring that all of the sub-habitat types within a site reach are included. Macrophyte beds are only sampled if there is enough vegetation to provide a representative habitat (i.e., excessively small or sparse portions or inaccessible beds are not targeted).

For ‘riffle’ sampling, the substratum is disturbed with the feet while holding the net downstream with its mouth facing upstream. The substratum is moved vigorously by digging the feet well into the cobbles and boulders. This process is continued until a total of 10 metres of riffle habitat is sampled; including a range of riffle types within a site reach (i.e. variety of flow, depth and substrate types).

Following sampling net samples are then placed into white sorting trays for *in situ* live sorting. Live sorting (picking) is undertaken for up to 1 person-hour (with a minimum of 40 minutes), as per the AusRivAS protocol. Following cessation of live picking, further observations are made of the pool edge sample areas for surface aquatic macroinvertebrate taxa (e.g., water skaters and spiders) and any other taxa (such as freshwater crayfish) not collected by the dip netting process. Where possible (or necessary) representatives of these organisms are collected and added to the dip net samples.

In general, representatives of common and/or easily identified rarer taxa are identified 'in the hand' and then released. Also, for rarer specimens for which positive identification could be made in the field (e.g., water scorpions), these are generally released.
That is, for protection of the pool macroinvertebrate integrity we adopt a 'sampling with replacement' method. Notwithstanding this procedure, for all taxa that could be positively identified in the field, at least one of each of the field-identified taxa is retained as a representative of those taxa for that sampling event. For all other macroinvertebrate taxa where field identifications are not definitive, specimens are retained for later detailed taxonomic analysis in the laboratory. For each survey, tadpoles (which are not macroinvertebrates but chordates) are noted in the results but ae not kept or identified.

All retained specimens are placed in sample jars and preserved in 70% ethanol for subsequent laboratory identification. Sample jars are labelled, with paper laundry tags inserted noting the sample site, sample date and sample collector/picker initials.
In the laboratory, taxonomic identifications are facilitated using Maggy lights or binocular dissecting microscopes. The following taxonomic guides have been found to be the most useful; CSIRO, Land and Water Resources & Environment Australia (1999), Hawking & Smith (1997), Hawking & Theischinger (1999) and Williams (1980).
Organisms are identified (as a minimum) to the appropriate taxa level as per AusRivAS protocols. These are as follows; family level for all insect taxa except Chironomids (which are taken to sub-family). Collembola arthropods (springtails) are classified as a single class and the arachnid arthropods (spiders and mites) are classified as two orders. Mites (Order Acarina) are identified to sub-order classification level where possible. Crustaceans are identified to Family level where suitable keys are available. Ostracoda are left at Class level. The worm-like taxa are shown at Phylum or Class level. For taxa where suitable keys are available, taxa are identified to lower levels of taxonomy.

Sorted specimens are transferred to individual glass vials (one per family/sub-family) and paper laundry tags inserted into each glass vial with the sample site, sample date and initials of taxonomist noted on the tags. Glass vials are then topped up with 70 % alcohol, sealed with plastic lids and placed back into the original field sample jars. For individual specimens that cannot be positively identified, or where the collected material is too indistinct or fragmented to assign a definitive identification, specimens are taken to relevant Australian Museum specialists or other specialists, as recommended by EPA. The following taxonomic QA/QC procedure is followed:

> At least ten percent of the samples/sites are selected at random and the individual retained taxa are identified without reference to the original identifications. A table is then made of the original identifications verses the second identifications, indicating where there were any anomalies in identification (if any). If there are no anomalies, the QA/QC sample protocol is accepted and no further QA/QC checking is undertaken. If there are differences in identifications, all the samples containing the related taxa are re-examined to clear up the anomalies.

Following this procedure, and if there have been anomalies, an additional 10 percent of the remaining samples are chosen and the QA/QC procedure re-applied. This process continues until there are no differences between original identifications and QA/QC identifications.

The aquatic invertebrate assemblage for each sample site is described in terms of the site taxa richness (or **diversity;** number of individual AusRivAS taxa) and in terms of a site **SIGNAL** score. SIGNAL (Stream Invertebrate Grade Number Average Level) is a pollution tolerance index for stream macroinvertebrates derived by correlation analysis of macroinvertebrate occurrence against water chemical analysis (Chessman 1995). The water chemistry attributes generally used are temperature, turbidity, conductivity, alkalinity, pH, dissolved oxygen, total nitrogen and total phosphorus (Chessman 2003a). Each macroinvertebrate Family has been assigned a SIGNAL-2 score (Chessman 2003a) ranging from 10 (very pollution intolerant) to 1 (very pollution tolerant). Taxa with no published SIGNAL score are excluded from the site SIGNAL analysis. Individual site or whole stream SIGNAL indices are then calculated as the mean of all site (or stream) taxa SIGNAL scores.

The **EPT index** is based on the relative number of sensitive Ephemoptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis-flies) families present per site. This index is used to supplement the taxa richness (Diversity) and SIGNAL index as an indicator of stream health.

1.1.2 Fish sampling

At each macroinvertebrate sampling site, up to six baited fish traps (dimensions 250 mm by 250 mm by 400 mm, 4 - 5 mm mesh size and 50 mm diameter entrance) are set at suitable locations. These are either left overnight for retrieval the next day when macroinvertebrate sampling occurs at the site or are left in the stream for the duration of the combined macroinvertebrate sampling and live picking survey (minimum 1 hour).

Captured fish are identified i*n situ* and native fish are released. Any native fish caught as part of the macroinvertebrate dip net sampling are also identified, noted and released. Following completion of the fish and macroinvertebrate sampling, any further observations of fish during the pool condition survey are also noted, with fish species-name only recorded if positively identified. Any fish recorded during aquatic ecology surveys are documented in an MPR Annual Collection Summary Database sent to NSW Fisheries as part of the Scientific Permit conditions.

1.1.3 Field Metered Water quality sampling

A submersible Yeo-Kal 611 water quality data logger is used at all aquatic ecology sampling sites to record depth profiles of water temperature, dissolved oxygen concentration and saturation, pH, conductivity and turbidity. During low flow periods, or in lentic waters and deeper habitats, depth profiles are undertaken to detect the presence of layering within the water column.

Physical observations are also made in the field to highlight indications of recent rain/flood events such as infilling, detritus in water column, flood detritus caught in riparian vegetation, accumulated detritus on shore, scums or flocculates in or on water body etc.).

Physical observations of aquatic habitat variations (e.g., recent rain, subsequent infilling, detritus in water column or on benthos, scum or flocculates in or on water body, etc.) are noted in the field and recorded in the study field notes as are the presence of fresh yabbie burrows and the presence and distribution of aquatic plants.

1.1.4 Field aquatic habitat condition assessment (RCE Index)

A standardised description of site condition is used to compile a stream site condition index, based on a modified version of the Riparian Channel and Environmental (RCE) Inventory developed by Petersen (1992), as reported by Chessman *et al* (1997) for the greater Hunter River catchment. The index is compiled by giving each of the 13 RCE descriptors a score between 0 and 4, then summing the scores to reach a maximum possible score of 52. Scores are then expressed as a percentage.

2 OVERVIEW OF FIELD STUDIES AND WEATHER CONDITIONS

Table 1 below provides a summary of the aquatic ecology assessments undertaken for original and present (2020) West Culburra proposal, including the estuarine habitat assessment and mapping exercises (see **Annexure C** for the estuarine aquatic ecology assessment results). The freshwater aquatic habitats around the project area are shown below in **Figure 1**. **Section 2.1** provides an assessment of Downs Creek and the Wattle Creek freshwater aquatic habitats downstream of the proposed works in the Lake Wollumboola catchment and **Section 2.2** assesses the freshwater habitats bounding the proposal that drain to north to the Crookhaven River.

Table 1 Summary of West Culburra Aquatic Ecological Survey Conducted by MPR

Date	Crookhaven River	Downs Ck	Wattle Ck	Notes
5th July 2019	x	x	x	Initial site inspection of the Crookhaven River and Lake Wollumboola sub-catchment drainages (Wattle Creek and Downs Creek).
4th to 6th Sept 2019	x			Estuarine habitat assessments (seagrass, saltmarsh, mangrove transects and aerial imagery) with preliminary freshwater habitat assessments bounding the foreshore along Cactus Pt to the eastern extent of study area (Rocky Pt east).
15th to 18th Oct 2019	x	x		Continued estuarine surveys along Crookhaven River with freshwater habitat assessments along the length of Downs Creek and in the unnamed drainage line to the south west of Cactus Pt.
11th to 13th Feb 2020	x		x	Freshwater habitat assessment of Wattle Creek catchment plus wet weather water quality assessment of the Crookhaven River and freshwater runoff inspections along the Crookhaven River foreshore.

A preliminary desktop assessment of the sub-catchment drainage lines bounding the proposal that were most likely to contain surface water was undertaken prior to ground-truthing and field investigations. This was done by identifying the largest sub-catchment areas draining to and from the project area using the contour and topography maps and assessing aerial imagery for potential wetland or swamp vegetation communities. It was also noted in the SLR (2013) Ecology & Riparian Issues Report, that "On the Culburra West Project site, areas of "*standing water*" are few and highly ephemeral, and there are no ponds, swamps or permanent freshwater wetlands on the Project site."

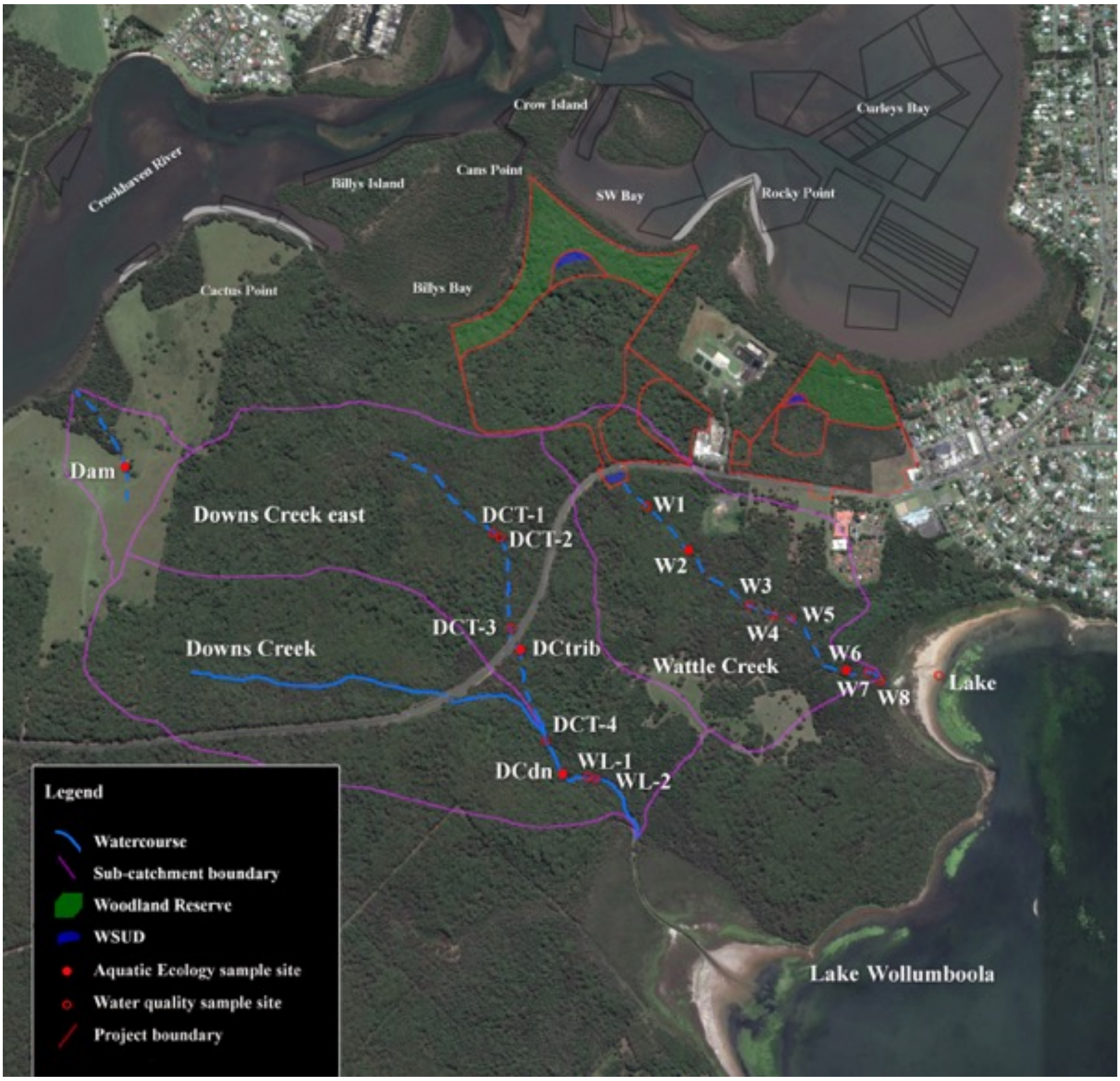


Figure 1: Freshwater habitat assessment sites bounding West Culburra development proposal showing drainage lines in blue (note that dash lines represent unnamed and ephemeral drainages).

After an initial site inspection on the 5th July, field investigations were undertaken by MPR staff over the 4th to 6th September, the 15th to 18th October 2019 and the 11th to 13th February

2020. Targeted searches were undertaken along the foreshore and riparian zone draining north towards the Crookhaven River and to Curleys Bay in the east, and in the sub-catchment tributaries draining to Lake Wollumboola in the south, to confirm drainage characteristics and provide evidence of surface flow runoff from the site, as indicated by channel incision, standing water or signs of prolonged water retention (debris lines, silt or mud accumulation or algal growth, surface water expressions from underground or indicative vegetation clusters).

2.1 Sampling conditions for fieldwork

Rainfall is measured adjacent to the site at the Culburra Treatment Works (Bureau of Meteorology gauge 68083) and rainfall data for the 2019 to 2020 survey period is provided in **Annexure Table B-1**. Overall, the weather patterns leading into the aquatic ecology survey events were generally dry in 2019 with wetter conditions experienced in 2020 and leading into the February survey:

- Only 70% of the average annual rainfall was recorded between the months of January to September 2019 (646mm), and this includes significant rain events recorded in the month of June totalling 219mm.
- Rainfall over the periods leading into the September and October 2019 field investigations were characterised by lengthy dry spells and infrequent low magnitude rainfall events.
- The February 2020 survey period was undertaken following consistent showers in mid-January and a significant wet weather event over the three days prior to the commencement of February survey during which 173mm was recorded, and consistent showers prevailed over the first two sample days.

2.2 Lake Wollumboola Catchment Freshwater Aquatic Habitats

Runoff to the south of the project area is directed towards Lake Wollumboola via an unnamed drainage line (hereafter referred to as Wattle Creek), and Downs Creek, an ephemeral first order creek that drains south-east to Wollumboola Lake (**Figure 1**).

The upper limits of Wattle Creek catchment originate around 220m upslope from Culburra Rd. This area includes a small portion in the southern limits of the proposed western boundary of the development plus road surfaces and the roundabout on Culburra Rd, and the stormwater quality improvement device (WSUD) on the southern side of Culburra Rd that received direct runoff. The upper Wattle Creek catchment area also accommodates small areas of residential, industrial, parkland and associated road infrastructure.

The original Culburra West Development Plan included a proposed sporting field and associated water retention device which was located in the upper limits of an unnamed tributary channel to Downs Creek. While the original development proposal has since been modified (effectively removing any development within the Downs Creek sub-catchment), the aquatic habitat assessment that was previously undertaken for the project was left in and is included below.

2.2.1 Wattle Creek sub-catchment descriptions

The Wattle Creek walkover and aquatic ecological assessment was undertaken by MPR staff over the 12th and 13th February 2020. The fieldwork was undertaken during a wet period that included 197mm of rainfall over the previous week, and consistent showers throughout the day on the 12th February facilitated confirmation of the drainage pathways and means by which runoff is transported downstream to Lake Wollumboola.

The existing Wattle Creek sub-catchment is occupied primarily by bushland with a small amount of industrial area fronting Culburra Rd in between the proposed roundabouts, and there is a retirement village and tip located on the southern side of Culburra Rd which also drain to Lake Wollumboola via Wattle Creek (see **Figure 1**).

The catchment vegetation, with particular reference to the riparian zone (the zone bordering the main drainage channel or valley basin) transitions between open woodland with open understorey occupied primarily by grasses (*Lomandra sp*), shrubs and sedges (*Gahnia sp*) in the upper sub-catchment area and casuarina or paperbark dominated swamp forest with a dense understorey of shrubs, grasses, rushes and tall sedges (*Gahnia clarkei*) in the lower reaches (see **Figures 2** and **3** below).

Figure 2: Wattle Creek looking upstream towards Culburra Rd (left) and downstream through forested area (right).

Figure 3: Downstream locations in Wattle Creek showing Casuarina dominated swamp forest (left) and paperbark swamp forest (right) that was inundated at the time of inspection.

With regard to the aquatic habitat attributes, Wattle Creek is an ephemeral drainage line and the only indication of channel incision capable of supporting at least semi-permanent aquatic habitats are contained within the downstream limits of the sub-catchment just upstream from the lake inlet channel (downstream from W6). Drainage of rainfall runoff through most of the catchment area is distributed downstream via low velocity overland sheet flow through multiple pathways forming swampy conditions across the broad valley floor.

The upper portion of the catchment area bounding Culburra Rd consists of shallow sloped indistinct channel forms that are incapable of retaining water or sustained aquatic habitats (**Figure 2** above). During the field inspection only two small temporary pools were observed in the upper half of the sub-catchment study area (W1 and W2: **Figure 4** below), with the adjoining channel areas up and downstream of W1 and W2 consisting of broad flat basins with indistinct flow paths.

Figure 4: Looking upstream at site W1 (left) and W2 (right), two temporary pools that were filled during the wet conditions. Maximum pool depth (at saturation) reached 0.4m and maximum length was 11m.

Further downstream from W4 to W6 the valley floor broadens and was saturated to a width of at least 140m during the field investigation. Inspection of the track crossings and swamp habitats revealed no distinct flow paths and the downstream movement of water was via sluggish broad sheet flow which was stagnant in parts.

Around 140 downstream from WC5 surface water is directed into a generally continuous incised channel that is maintained downstream to Lake Wollumboola. This section of creek included site WC6 (**Figure 5** below) which was sampled for macroinvertebrates and fish traps were deployed overnight (see **Section 1.2** below for macroinvertebrate and fish results). The property caretaker confirmed that WC6 was an ephemeral drainage channel that had been dry for a period of months prior to the rain event around mid-January and would have supported continuous aquatic habitats since this time (Vic Walker pers. comm 13/2/2020).

Figure 5: Looking downstream in W6 incised channel area with larger pool (left) and meandering narrower channel (right).

The maximum water depth at WC6 reached 1.2m and the average depth was 0.6m, the maximum stream width reached 12m and the average width was around 5m at the time of sampling. There were no filamentous algae observed, nor were there biofilms on submerged surfaces which indicates that most of the aquatic edge habitats had only been recently been submerged.

Downstream from WC7, Wattle Creek discharge overflows into a sunken eroded drainage channel at the upstream-end, off the Wollumboola Lake inlet (**Figure 6**). While this 140m section of channel held mostly of freshwater during the site visit, it would likely contain lake water during periods of no or low discharge from Wattle Creek (assuming lake water levels were high enough).

Figure 6: Wattle Creek downstream overflow point into upper Wollumboola Lake inlet channel (left) and looking downstream through fringing saltmarsh habitats bordering the inlet channel (right).

There is a considerable saltmarsh plant community bordering the inlet channel banks bounding W8 and extending downstream to the lake fringes, which includes large areas of samphire (*Sarcocornia quinqueflora*), *Selliera radicans*, sea rush (*Juncus kraussii*) and Casuarina saplings.

2.2.2 Downs Creek sub-catchment descriptions

An initial walkover of the Downs Creek western (main) tributary arm upstream of Culburra Rd was undertaken on the 5th July 2019. On the 17th and 18th October 2019, MPR staff walked the lengths of the Downs Creek eastern tributary from the upper sub-catchment to the confluence with the main channel of Downs Creek and further downstream to the Downs Creek inlet channel at Wollumboola Lake. Both sections of creek-line upstream of Culburra Road are ephemeral drainages with surface water most likely only present for short periods after rainfall. There was no running water within the tributary or main arm of Downs Creek at the time of sampling and the only surface water observed was mostly contained within infrequently occurring isolated refuge pools.

There were three small pools in the eastern tributary upstream of Culburra Rd (DCT1 to DCT-3) and through this section the tributary is of low relief and occupied by dense native vegetation (see **Figure 7**). On the downstream side of the Culburra Rd culvert there is a large and deep pool (DCtrib), most likely providing permanent aquatic habitat for fish and macroinvertebrates (**Figure 8**).

Figure 7: Downs Creek eastern tributary looking downstream through broad valley floor occupied by saw-sedge with no defined drainage channel (left), and small surface pool at DCT-2 (right).

Figure 8: Looking downstream through main pool at site DCtrib (left) and aquatic edge and charophyte habitats (right).

Channel incision in both Downs Creek and the eastern tributary increases downstream from Culburra Rd, which is maintained downstream to Wollumboola Lake via a deep (2 to 3m depth below bank) and meandering channel with sections of unstable sandy sediment banks. Riparian vegetation is consistent throughout the length. The channel areas through this section are mostly dry with surface water present in the form of very shallow and infrequently occurring pools surrounded by dense tall saw-sedge growths (**Figure 9**), with surface water availability increasing around the upstream limits of Lake Wollumboola inlet channel (from DCdn to WL-1).

Figure 9: Downs Creek channel downstream from Culburra Rd was mostly dry (left) with intermittently occurring shallow refuge pools (site DCT-4 on the right).

In addition to the freshwater aquatic habitat assessments undertaken in Wattle Creek and Downs Creek, a small farm dam located on lands immediately west of the proposal site draining to the Crookhaven River south of Cactus Point (see **Figure 10** below). If water treatment ponds are to be implemented during the construction or operational phases, then this site will provide an indication of the potential freshwater aquatic ecological attributes of such habitats.

Figure 10: Dam site showing floating macrophyte island in middle of pool (left) and looking down channel toward Crookhaven River (right).

2.3 Lake Wollumboola Tributary Aquatic Ecology Survey Results

The field notes and sample site descriptions for all freshwater aquatic ecology study sites are presented in **Annexure Table B-2** and **Table 2** below provides coordinates for the sample site locations**.** Appendix B also includes sampling methodology, site photographs showing site conditions during the aquatic ecology survey, plus macroinvertebrate and fish results.

Aquatic ecology sampling was undertaken at five sites which included macroinvertebrate sampling, water quality logging and overnight fish trapping:

- Two sites were sampled in Wattle Creek; WC2 was sampled 380 downstream from Culburra Rd and WC6 was sampled in the incised channel 200m upstream from Lake Wollumboola entrance channel.
- Two sites were sampled in Downs Creek; one site in Downs Creek eastern tributary on the downstream side of Culburra Rd (site DCtrib) and one site in the receiving waters of Downs Creek below the confluence of the tributary creek and the main arm (DCdn) above Lake Wollumboola.
- One site was sampled in the property dam to the west of the project area (Dam).

Table 2 West Culburra Aquatic Ecology Sample Site Coordinates

Catchment/ site		Coordinates (MGA)	
Wattle Ck		Easting	Northing
	W2	294210	6132036
	W6	294732	6131629
Downs Ck			
	DCtrib	293653	6131705
	DCdn	293849	6131255
Unnamed			
	Dam	292320	6132274

There were nine species of macrophytes (aquatic plants) recorded from the five aquatic ecology sample sites (**Table 3**). Bare twig rush (*Baumea juncea*) and rushes (*Juncus sp*) were prevalent along the channel bank edges at WC6, and tall spike rush (most likely *Eleocharis sp*) was present in small quantities in the main pool basin (no seed heads were present to facilitate identification).

Table 3 West Culburra Aquatic Ecology Site Macrophyte Occurrence

	Ferny Azolla *Azolla pinnata*	Bare Twig Rush *Baumea juncea*	Grass *Carex spp*	Spikerush *Eleocharis spp*	Rush *Juncus sp*	Common Reed *Phragmites australis*	Floating Pondweed *Potamogeton sulcatus*	Water Ribbons *Cycnogeton microtuberosum*	Cumbungi *Typha sp*	Charophytes
WC2										
WC6		x		x	x					
DCtrib		x							x	x
DCdn		x				x		x		x
Dam	x		x	x			x		x	

Site DCtrib supported dense growths of charophyte (a type of branching algae) growing in depths reaching 1.2m, and both bare twig rush and cumbungi were emergent around the fringes of the main pool with the latter choking the downstream outlet of the Culburra Rd culvert.

None of the macrophytes or algal growths at DCdn were present in particularly large quantities given the shallow nature of the pools. Growths of common reed (*Phragmites australis*) which is capable of withstanding high salinity, was present both up and downstream from DCdn and also extending to Wollumboola Lake. Filamentous green algae was present in moderate to abundant amounts at all sites and algal matting (biofilm) was noted on submerged surfaces at both Downs Creek sites. The Dam site supported a considerable stand of cumbungi, grasses and rushes (**Figure 10**).

2.3.1 Water quality

A Yeo-Kal 618 water quality meter was used to measure temperature, dissolved oxygen concentration and saturation, pH, conductivity and turbidity at all aquatic ecology sampling sites plus at selected intermediary sites where possible (see **Figure 1** and **Table 2** for site location and coordinates). Full water quality results (including depth profile readings) are provided in **Annexure Table B-3** and **Table 4** below presents the surface water quality summary results for sites in both of the Lake Wollumboola sub-catchment tributaries.

Depth profiling was undertaken at the deeper sites to detect presence of layering, and site ordering is from upstream to downstream. Note that sequential number within a 100m site length (e.g. DCdn-1 to DCdn-4) represents readings from sequential isolated pools. The Downs Creek water quality was variable among the aquatic ecology survey sites which is expected given the isolated nature of refuge pools. Overall, the following summary is provided for the Downs Creek water quality results:

- Water temperature was lowest in the deepest pool (DCtrib at 14.8°C to 15.1°C) compared to the other refuge pool sites (range of 15.4°C to 19.8°C), and there was no thermal stratification observed within sites where depth profiling was performed. Temperature at downstream site WL-2 (which most likely represents Wollumboola Lake water conditions) was relatively high at 22.7°C and the farm Dam site recorded the overall highest temperature at 25.7°C. This site has no shading from riparian vegetation.
- Conductivity showed considerable variation among sites. The shallower sites in the upper eastern tributary creek plus DCT-4 recorded lower values (range of 166 μS/cm to 216 μS/cm) and were most likely remnant rain runoff pools.

Table 4 Culburra West Summary Water Quality Data

Sub-catchment Site	Date	Time	Depth M	Temp °C	Cond μS/cm	Sal ppt	DO %sat	DO mg/l	pH Units	Turb ntu
Wattle Creek										
WC1	13/02/20	11:38	0.1	22.33	134	0.06	35.3	3.06	4.74	10.5
WC2	13/02/20	11:31	0.1	22.92	132	0.07	47.1	4.05	4.80	8.3
WC3	13/02/20	12:18	0.1	23.91	342	0.17	48.1	4.05	5.51	0.6
WC4	13/02/20	12:22	0.1	26.03	305	0.14	51.2	4.15	4.80	1.0
WC5	13/02/20	12:47	0.1	27.24	331	0.17	60.7	4.81	4.74	5.1
WC6	13/02/20	12:58	0.1	23.97	365	0.19	30.7	2.58	4.78	0.1
WC7	13/02/20	13:03	0.1	23.14	357	0.18	27.1	2.32	4.74	0.2
WC8	13/02/20	13:08	0.1	23.30	363	0.18	62.3	5.31	4.85	0.3
Lake	13/02/20	13:13	0.1	31.03	4512	2.72	97.5	7.13	5.86	37.5
Downs Creek										
DCT-1	17/10/19	16:22	0.3	19.64	166	0.1	25.8	2.37	5.73	118.8
DCT-2	17/10/19	16:19	0.3	17.54	212	0.1	7.0	0.67	5.16	9.1
DCT-3	17/10/19	15:53	0.5	18.72	216	0.1	88.0	8.21	6.66	17.3
DCtrib	18/10/19	09:44	0.1	15.07	1066	0.5	10.5	1.06	7.41	0.5
DCtrib	18/10/19	09:44	0.2	14.98	1347	0.7	9.7	0.98	7.41	0.1
DCtrib	18/10/19	09:45	0.4	14.91	1348	0.7	7.9	0.79	7.41	0.1
DCtrib	18/10/19	09:45	0.7	14.80	1345	0.7	9.1	0.92	7.43	0.1
DCT-4	17/10/19	18:06	0.1	15.41	192	0.1	21.8	2.18	6.67	38.9
DCdn-1	17/10/19	17:57	0.1	18.27	542	0.3	70.5	6.63	6.50	11.2
DCdn-2	17/10/19	17:51	0.1	18.89	972	0.5	35.8	3.32	6.88	0.2
DCdn-3	17/10/19	17:40	0.1	18.24	816	0.4	97.7	9.19	6.83	0.1
DCdn-4	17/10/19	17:32	0.1	19.73	2842	1.6	98.0	8.88	7.42	0.0
DCdn-4	17/10/19	17:33	0.4	19.81	3145	1.8	104.0	9.40	7.08	0.1
WL-1	17/10/19	17:27	0.1	19.62	>8000	31.7	165.6	12.58	8.17	0.1
WL-2	17/10/19	17:17	0.1	22.66	>8000	36.0	200.0	14.39	8.07	0.2
Unnamed Tributary										
Dam	17/10/19	14:26	0.5	25.70	1239	0.7	171.2	13.91	6.14	209.4

- DCtrib showed a higher conductivity (range of 1066 μS/cm to 1348 μS/cm), which suggests that it either receives a contribution from elevated conductivity groundwater sources or is subjected to evaporation over time, increasing salt concentration within the pool.
- The conductivity recorded within the series of isolated pools in DCdn showed considerable variation (from 542 μS/cm at the upstream limits to 3145 μS/cm at the downstream end). It is possible that the pools at the lower end of this site is subjected to saline inputs when Wollumboola Lake levels are high, as indicated by salinity levels at WL-1 and WL-2 - which were close to and above sea water salinities respectively (at 32 ppt and 36ppt).
- Dissolved oxygen (DO) levels also showed considerable fluctuation among sites. Whilst isolated refuge pools often support oxygen depleted environments (through consumption of oxygen by micro-organisms that decompose organic material) they can also be subjected to oxygen saturation through algal blooms and display considerable diurnal fluctuation particularly in the warmer months.

- With the exception of DCT-3, the aquatic habitats upstream of DCdn supported mostly low to very low DO levels (with a range of 7.0% to 25.8% saturation). DCdn recorded moderate to high DO values (between 35.8% and 104.0% saturation) and WL-1, WL-2 and the farm Dam sites recorded super-saturated levels ranging from 165.6% to 200.0% saturation. Filamentous green algae at each of these sites was noted to be high, with the WL site DO levels most likely influenced by the broader DO levels in Wollumboola Lake.
- Water pH readings were mildly acidic at most sites. Interestingly, DCtrib recorded an elevated pH reading (7.41 pH units) compared to other freshwater sites up and downstream (range of 5.16 to 6.88 pH units).
- Water turbidity was low at most sites. DCT-1 and the Dam site recorded elevated readings at 118.8 NTU and 209.4 NTU respectively, however for the most part turbidity levels were less than 10 NTU.

For the most part, Wattle Creek surface waters were well mixed, and the water quality results were generally similar among the Wattle Creek sub-catchment sites, which reflected the prevailing wet weather conditions and flood connectivity between sites up and downstream within the catchment:

- Water temperatures were elevated at the track crossing sites WC4 and WC5 (26.0°C and 27.2°C respectively) when compared to the sites contained in bushland (range of 22.3°C to 24.0°C), and the Lake site (in Lake Wollumboola Lake proper) was the overall highest temperature reading at 31.0°C (**Table 4**).
- Water conductivity readings were lowest in the smaller upstream sites W1 and W2 and were relatively stable for the freshwater sites downstream, with the overall conductivity values ranging between 132 μS/cm (WC2) and 365 μS/cm (WC6). The value at WC8 (363 μS/cm) indicates that at the time of sampling, the downstream channel area leading into Lake Wollumboola was made up of sub-catchment freshwater runoff.
- Lake Wollumboola recorded a salinity value of 2.72 ppt. This value is much less than that recorded in the downstream limits of the Downs Creek – Lake Wollumboola inlet channel (31.7 ppt and 36.0 ppt respectively) during dry weather, and provides an example of short term salinity variation in Lake Wollumboola in response to significant rainfall mediated sub-catchment contributions.
- Dissolved oxygen (DO) levels were low to moderate for the Wattle Creek sites and ranged from 27.1% saturation to 62.3% saturation. Site Lake recorded the overall highest DO reading at 97.5% saturation.
- Water pH values were acidic at all sites and varied between 4.7 pH units and 5.9 pH units over all Wattle Creek sites.

- Water turbidity was generally low at most sites, and the Lake site recorded the highest reading at 37.5 NTU.

2.3.2 Freshwater macroinvertebrate and fish results

Annexure Table B-4 provides the full results of aquatic macroinvertebrate taxonomic identifications to the levels required by AusRivAS, plus occurrence data for all aquatic macroinvertebrates. A total of 27 macroinvertebrate taxa were recorded among the five sample sites including 20 taxa from the Downs Creek study area and only 8 taxa from the Wattle Creek study sites:

- Most of the taxa were insects (20 taxa), with the remainder comprising three crustaceans (two microcrustaceans and on isopod), seed shrimps, water mites, freshwater worms and freshwater limpets. A number of taxa were recorded from the Dam site only; biting midges (family Ceratopogonidae), giant water bugs (family Belostomatidae), lesser water boatmen (family Corixidae), pygmy backswimmers (family Pleidae), small water striders (family Veliidae), dragonfly family Aeshnidae and freshwater limpets (family Ancylidae).
- At the Order level, there were six true bug (Hemiptera) insect taxa), four true flies (Diptera) taxa, then dragonflies (Odonata) and Beetles (Coleoptera) (three taxa), and mayflies (Ephemeroptera) and caddis-flies (Trichoptera) with two taxa each.
- There were very few taxa recorded from the Wattle Creek sites WC2 (4 taxa) and WC6 (8 taxa), and Downs Creek site DCtrib supported a slightly more diverse macroinvertebrate community (12 taxa), with higher numbers recorded at DCdn (16 taxa) and Dam (18 taxa) including more developed and longer-lived specimens.
- The presence of Sphaeromatid isopods (common in estuarine environments) indicates that the water quality in the downstream end of DCdn is to some extent influenced by Lake Wollumboola back-flooding.
- With regards to SIGNAL-2 grades, the most pollution sensitive taxa was mayfly family Leptophlebiidae with a SIGNAL values of 8, which was only recorded from the downstream Downs Creek site DCdn. Overall, the Lake Wollumboola macroinvertebrate community comprised relatively tolerant taxa, as indicated by the low site SIGNAL-2 value range of 3.00 (WC2) to 4.33 (DCtrib).
- Sensitive EPT taxa (Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis-flies)) are mostly restricted to flowing, well oxygenated streams, and there were only four EPT taxa recorded from the Downs Creek sites; two mayflies, two caddis-flies and no stoneflies.
- Whilst the majority of the taxa recorded are capable of dispersing to new aquatic habitats during their adult stages (by flying between aquatic habitats), some of the

taxa (copepods, seed shrimps and water fleas) have life adaptations that enable them to withstand dry periods. These are features that may facilitate the colonisation of isolated pool habitats in Downs Creek following extended dry periods.

With regards to fish species, there were no fish caught or observed from Wattle Creek sites following deployment of several overnight traps, and there were no fish caught or observed from the farm Dam sample site. For Downs Creek, there were five species recorded from the two sample sites, four native species and one introduced pest species:

- Three striped gudgeons *Gobiomorphus australis* were recorded from DCtrib and DCdn, including one large (135mm) specimen recovered from DCtrib.
- Two empire gudgeons *Hypseleotris compressa* were caught at DCtrib, both female that appeared to contain eggs.
- Five Pacific blue-eyes *Pseudomugil signifer* were caught at DCdn. This species is capable of enduring a range of salinities from pure freshwater to sea water and this provides further evidence that the downstream limits of DCdn aquatic habitats are influenced by water quality from Wollumboola Lake.
- Four flathead gudgeons *Philypnodon grandiceps* were also recorded at DCdn.
- The introduced plague minnow *Gambusia holbrooki* was found at DCtrib in both traps and the macroinvertebrate sample net.

Tadpoles were recorded at DCdn and common Toadlet *Crinia signifera* was heard calling during the process of fish trap deployment in Downs Creek. Water skinks *Eulamprus sp* were also noted at both Downs Creek sample sites.

2.4 Crookhaven River Catchment Freshwater Aquatic Habitats

Whilst there were no signs of permanent water observed within the footprint of the original project area (draining north to the Crookhaven River from Cactus Point and east to Curleys Bay), there is vegetation occurring consistently along the riparian zone that is usually associated with freshwater wetlands or swamps (e.g. Swamp Paperbark *Melaleuca ericifolia* and tall saw-sedges *Gahnia clarkei*). There were no formal drainage channel forms identified however there were small sections of sporadically occurring channels in the form of shallow eroded gullies, incised into flat sub-catchment basins to depths of 0.8m to 1.0m and mostly narrow (to 1.2m width) and persisting for only short sections (<20m) before returning into flat indistinct drainage swales. These channels were located around 300m west of the western boundary of the proposal footprint.

While these areas were dry during the 2019 inspection and survey dates, the subsequent wet weather survey in February 2020 sample period enabled an observational assessment of runoff and drainage characteristics which confirmed that rainfall runoff through these flat areas to the north and east of the project footprint was via overland sheet flow to the Crookhaven River and also by shallow infiltration (personal observation by MPR staff on 11th February 2020).

During the February 2020 survey, sections of isolated boggy ground were located in the riparian slopes bordering the Billys Bay saltmarsh and while these slopes were moist there was no surface water observed. These areas support considerable stands of a smaller saw-sedge (*Gahnia sieberiana*) and sparse *Melaleuca sp* (**Figure 11**).

Figure 11: Broad occupation of saw-sedge on riparian slopes upslope from Billys Bay foreshore (left) which were moist but supported no surface water during the wet weather survey in February 2020. Isolated stands of tall saw-sedge (left) which are common in the study area, mostly around the lower riparian zone (behind saltmarsh). There were only small amounts of shallow surface water during the February 2020 field inspection (see **Figure 12** below).

Only small amounts of surface water were present as very shallow puddles at the northern edge of riparian zones (landwards of the upper saltmarsh zones) in areas occupied by tall saw-sedges. The incised channel sections contained deeper pools (to 0.5m) though there was no surface water observed in the vicinity up or down slope from this location (**Figure 12**), nor was there surface water present in this location during previous fieldwork (September and October 2019).

Figure 12: Riparian zone incised channel filled with water during the February 2020 survey (left) and shallow surface water puddle adjacent to tall saw-sedges (right).

Low points throughout the saltmarsh habitats also contained very shallow pooled water in February 2020. In Billys Bay there were seepages discharging to the estuary from the interface between saltmarsh and mangrove zones, in the form of consistently occurring minor trickles, and this phenomenon was also observed throughout much of the steep eroded face of the riparian 'berm' along the Cactus Point foreshore (**Figure 13**).

Figure 13: Seepage discharge from the saltmarsh zone into the estuary in Billy Bay foreshore (left) and from the riparian edge bank face along Cactus Point (right). These observations provide indications of how rainfall infiltration discharge to the estuarine waters.

ANNEXURE B

WEST CULBURRA

FRESHWATER AQUATIC HABITATS

AND ECOLOGY

SUPPLEMENTARY DATA

Annexure Table B-1 Bureau of Meterology Culburra Treatment works Station 68083 Rainfall Data 2019 - 2020 (Note sample dates in yellow)														
	2019												2020	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1st	0.8	1.5	0	0	0	0	0	0	0	0	0	0.1	0	0
2nd	0	11.6	1.8	0.8	0	0	0	0	0	0	0	0	0	0
3rd	3.5	0.8	0	0	0	0.7	0.2	0	0	0	0	0	0	4.5
4th	0	0	0	14.6	0.6	63.6	7.6	0	0	0	12.6	0	0	0
5th	0	0.4	0	0.4	0.8	59.0	5.6	0	0	12.2	0	0	0	0
6th	15.0	10.4	0	0.3	16.0	11.6	1.2	0	0	0	0	0	0	1.4
7th	0	7.2	0	0	0	0	0	0	0.4	0	0	0	2.4	1.4
8th	3.2	0	0	0	0	0	0.5	0	0	0	0	0	0	35.0
9th	16.0	20	0	0	0	0	0	0	0	3.8	0	0	0	33.0
10th	4.2	0	0	1.8	0	0	0	0	0	0	0	0	0.4	105.0
11th	4	0	0	0	3.4	0	0	0	0	0.8	0	0	0.3	4.5
12th	2.4	0	0	0	0.1	0	0	4	0	4.6	0	0	0.5	6.0
13th	0	0	0	0	0	0.1	0	0	0	0	0	1.8	0.6	27.0
14th	0	0	0.6	0.2	0	0	0	0	0	0	0	0.2	0.8	0.2
15th	0	0	4.2	0.6	0	0	0.1	0	0	0	0	0	0	
16th	0	0	25.0	0.1	0	0.4	0	0	0	0	0	0	1.5	
17th	0	0	2	0	0	17.4	0	0	24	0.5	0	0	10.6	
18th	0	0	64.0	0	0	2.2	0	0	18.8	0	0.2	0	43.0	
19th	4.5	0	3.2	1.4	0	0	0	0	30.5	0	0	0	0.8	
20th	0	0	1.5	0	0	0	0	0	0	0	0	0	2.6	
21st	0	10.2	5.0	0	0	0	0	0	0	0	0.4	0	18.0	
22nd	0	0	0.4	0	0	↓	0	0	1.4	0	0	0	0	
23rd	0	0.6	4.0	1.2	0	↓	0	0	0	0	0	0	0	
24th	0	0	0.1	17.2	0	55.0	0	0	0	0	0	0	0.4	
25th	0.6	0.3	0	0	0	6.4	0	0	0	0	0	5	0	
26th	0	0	0.1	0	0	0.6	0	4.2	0	0	0	1	0	
27th	0	0	0	3.1	0	1.6	0	8	0	0	1.4	0	0	
28th	0	0	0	0	0	0.2	0	0.8	0	0.5	0	0	0	
29th	0		0	0	0	0	0	0.5	0	0	0	0	0.2	
30th	8.6		8.8	0	0	0	1.0	8.2	0	0	0	0	0	
31st	0		0.7		0		0.4	0		0		0	0	
Highest Daily	16.0	20.0	64.0	17.2	16.0	63.6	7.6	8.2	30.5	12.2	12.6	5.0	43.0	105
Monthly Total	62.8	63.0	121.4	41.7	20.9	218.8	16.6	25.7	75.1	22.4	14.6	8.1	82.1	-
Mean	96.4	121.7	131.6	111.8	103.3	145.1	73.8	76.5	72.2	83.9	84.3	73.6	96.4	121.7

Annexure Table B-2 Field Comments – Culburra West Site Field Notes		
Date	Site	Comments
WC2	11/2/20	Site sampled in largest pool throughout section downstream from Culburra Rd. Raining heavily during site inspection and generally wet during sample period (saturated catchment), surface water slightly tannin stained and flowing into and downstream from pool via intermittently alternating sheet flows and more concentrated flows in ill-defined drainage channels. Pool banks with gradual slope; no erosion or undercut banks observed. Maximum pool width to 2.5m and length around 9 to 10m, maximum depth to 0.4m. No macrophytes in pool reach and the only aquatic habitat that was available to sample was detritus. The pool channel substrate was firm sandy sediments with sparse pebbles, and small amounts of clay. No filamentous green alga observed, and the submerged surfaces were clean with no build up of silt or biofilms, indicative that the site had only recently been submerged.
WC6	12/2/20	Site sampled in incised creek section adjacent to track with pool forms alternating between larger (broader) open pool areas and meandering narrower channel sections. Water tannin stained; levels raised with sluggish flow downstream through site. Maximum width to 12m and average width 5m, maximum depth 1.2m and average depth 0.6m. Creekline bordered by dense growths of tall saw-sedge (*Gahnia clarkei*) at waterline or marginally submerged, bare twig rush (*Baumea juncea*) and rushes (*Juncus sp*) lining the channel areas throughout site and submerged to depths of 0.5m. Spike rushes (*Eleocharis sp*) were observed but positive identification was unable to be made as no seed heads were present. Detritus prevalent throughout site channel basin, however substrates firm underfoot with no evidence of long-term decomposition processes (as indicated by sulphur odour or blackwater). The aquatic habitats available to sample included macrophytes, detritus and trailing bank vegetation. Very few taxa observed during sorting process. The pool substrates were comprised of firm sandy sediments with small amounts of clay and pebbles. No filamentous green alga observed, nor biofilms on submerged surfaces.

DCtrib	17/10/19	Site sampled in isolated pool 5m d/s of Culburra Rd culvert. No surface flow observed in drainage section, nor was there surface water in adjoining channel areas up or downstream. Pool length around 12m, maximum width 3.5 to 4m, maximum depth around 1.4m and average depth 0.8m. Water clear with slight tannin staining. Channel incised through section with firm sandy banks, occupied by mostly by tall saw-sedge lining the waters' edge and other native trees and shrubs in the riparian. Charophytes present in moderate to abundant quantities in pool, forming dense beds. The emergent cumbungi (*Typha sp*) and bare twig rush present in smaller quantities. Macrophytes and detritus sampled as edge habitats. Substrates firm and clayey with small to moderate amounts of detritus smothering pool basin. Filamentous green algae present in moderate to abundant amounts, particularly in pool areas exposed to sunlight, and green algal matting smothering submerged surfaces in some sections.
DCdn	18/10/19	Site sampled in downstream section of Downs Creek below the confluence of tributary creek section. Site creek channel with intermittently occurring surface water in the form of mostly shallow pools (<10-20cm) intersected by dry sections of channel. Downstream of site the pools are continuous through to Wollumboola Lake. The adjoining section of the channel upstream of the site is very dry with no surface water observed for at least 70m, as indicated by cracked substrates. Maximum pool length around 15m, maximum width 1.4m and average width 0.8m, maximum depth 0.5m and average depth 0.15m. Water mostly clear with slight tannin staining. Charophytes, twig rush, common reed (*Phragmites australis*) and water ribbons (*Cycnogeton microtuberosum*) present in site length. The edge habitats that were sampled included macrophytes, detritus and charophytes. Evidence of scouring flows through section as indicated by debris lines and slanted vegetation. Greeny-blue algal matting smothering some submerged surfaces and filamentous green algae present in moderate to abundant amounts.

Dam	17/10/19	Dam situated in open paddock with cleared pastures upslope and forested channel area downstream of the dam. Minor gully erosion present along the northern and western banks of the pool, water turbid with no surface flow in swale up or downstream of dam. The pool dimensions were approximately 16m in diameter with a maximum depth of 1.4m. A small channel on the north-western edge of the dam allows water to flow through to the Crookhaven River when the dam is at or near capacity, and the water level at the time of sampling was below the overflow point. There was a floating island in the middle of the dam that supported fringing and emergent macrophytes and accumulated detritus. A number of macrophytes were noted in and around the perimeter of the dam pool, including cumbungi (*Typha sp*), sedges (*Carex sp*), spikerush (*Eleocharis sp*), floating pondweed (*Potamogeton sulcatus*) and ferny Azolla (*Azolla pinnata*). The aquatic habitats that were sampled included macrophytes, limited trailing bank vegetation and detritus. The dam channel substrates were soft clayey mud and there was evidence of recent cattle usage. Filamentous green algae was abundant.

Annexure Table B-3 Culburra West Freshwater Aquatic Ecology Water Quality Data													
Sub-catchment		Date	Time	Depth	Temp	Cond	Sal	DO	DO	ORP	pH	Turb	MGA 56	
	Site			M	°C	μS/cm	ppt	%sat	mg/l	mv	Units	ntu	Easting	Northing
Wattle Creek														
	WC1	13/02/20	11:38	0.1	22.33	134	0.06	35.3	3.06	582	4.74	10.5	294073	6132192
	WC2	13/02/20	11:31	0.1	22.92	132	0.07	47.1	4.05	542	4.80	8.3	294210	6132036
	WC3	13/02/20	12:18	0.1	23.91	342	0.17	48.1	4.05	600	5.51	0.6	294455	6131865
	WC4	13/02/20	12:22	0.1	26.03	305	0.14	51.2	4.15	575	4.80	1.0	294511	6131813
	WC5	13/02/20	12:47	0.1	27.24	331	0.17	60.7	4.81	576	4.74	5.1	294572	6131822
	WC6	13/02/20	12:58	0.1	23.97	365	0.19	30.7	2.58	595	4.78	0.1	294732	6131629
	WC7	13/02/20	13:03	0.1	23.14	357	0.18	27.1	2.32	598	4.74	0.2	294836	6131649
	WC8	13/02/20	13:08	0.1	23.30	363	0.18	62.3	5.31	583	4.85	0.3	294885	6131614
	Lake	13/02/20	13:13	0.1	31.03	4512	2.72	97.5	7.13	605	5.86	37.5	295069	6131615
Downs Creek														
	DCT-1	17/10/19	16:22	0.3	19.64	166	0.1	25.8	2.37	550	5.73	118.8	293540	6132074
	DCT-2	17/10/19	16:19	0.3	17.54	212	0.1	7.0	0.67	561	5.16	9.1	293525	6132084
	DCT-3	17/10/19	15:53	0.5	18.72	216	0.1	88.0	8.21	496	6.66	17.3	293639	6131754
	DCtrib	18/10/19	09:44	0.1	15.07	1066	0.5	10.5	1.06	598	7.41	0.5	293653	6131705
	DCtrib	18/10/19	09:44	0.2	14.98	1347	0.7	9.7	0.98	597	7.41	0.1		
	DCtrib	18/10/19	09:45	0.4	14.91	1348	0.7	7.9	0.79	596	7.41	0.1		
	DCtrib	18/10/19	09:45	0.7	14.80	1345	0.7	9.1	0.92	595	7.43	0.1		
	DCT-4	17/10/19	18:06	0.1	15.41	192	0.1	21.8	2.18	507	6.67	38.9	293759	6181375
	DCdn-1	17/10/19	17:57	0.1	18.27	542	0.3	70.5	6.63	504	6.50	11.2	293823	6131279
	DCdn-2	17/10/19	17:51	0.1	18.89	972	0.5	35.8	3.32	496	6.88	0.2	293849	6131255
	DCdn-3	17/10/19	17:40	0.1	18.24	816	0.4	97.7	9.19	472	6.83	0.1	293857	6131252
	DCdn-4	17/10/19	17:32	0.1	19.73	2842	1.6	98.0	8.88	484	7.42	0.0	293877	6131253
	DCdn-4	17/10/19	17:33	0.4	19.81	3145	1.8	104.0	9.40	489	7.08	0.1		
	WL-1	17/10/19	17:27	0.1	19.62	>8000	31.7	165.6	12.58	541	8.17	0.1	293924	6131276
	WL-2	17/10/19	17:17	0.1	22.66	>8000	36.0	200.0	14.39	567	8.07	0.2	293964	6131258
Unnamed Tributary														
	Dam	17/10/19	14:26	0.5	25.70	1239	0.7	171.2	13.91	541	6.14	209.4	292320	6132274

Annexure Table B-4 Culburra West Macroinvertebrate and Fish Survey Results									Life Stage			12/02/20	13/02/20	17/10/19	18/10/19	17/10/19		
Phylum	Class	Sub-Clas	Order	Sub-Order	Family	Sub-Family	Genus/spp	Common name	L	N	A	WC2	WC6	DCtrib	DCdn	Dam	Occurrence	SIGNAL2
Arthropoda	Insecta		Coleoptera		Dytiscidae			Diving Beetles	x		x	1	1		1	1	4	2
Arthropoda	Insecta		Coleoptera		Hydrophilidae			Scavenger Water Beetl	x		x				1	1	2	2
Arthropoda	Insecta		Coleoptera		Scirtidae			Marsh Beetles	x				1	1		1	3	6
Arthropoda	Insecta		Diptera		Ceratopogonidae			Biting Midges	x							1	1	4
Arthropoda	Insecta		Diptera		Chironomidae	Chironominae		Midges	x					1	1	1	3	3
Arthropoda	Insecta		Diptera		Chironomidae	Tanypodinae		Midges	x				1	1	1	1	4	4
Arthropoda	Insecta		Diptera		Culicidae			Mosquitoes	x			1	1		1		3	1
Arthropoda	Insecta		Ephemeroptera		Baetidae			Mayflies		x				1			1	5
Arthropoda	Insecta		Ephemeroptera		Leptophlebiidae			Mayflies		x					1		1	8
Arthropoda	Insecta		Hemiptera		Belostomatidae			Giant Water Bugs								1	1	1
Arthropoda	Insecta		Hemiptera		Corixidae			Lesser Water Boatmen								1	1	2
Arthropoda	Insecta		Hemiptera		Gerridae			Water Striders							1		1	4
Arthropoda	Insecta		Hemiptera		Hydrometridae			Water Measurers							1		1	3
Arthropoda	Insecta		Hemiptera		Pleidae			Pygmy Backswimmers								1	1	2
Arthropoda	Insecta		Hemiptera		Veliidae			Small Water Striders								1	1	3
Arthropoda	Insecta		Odonata	Epiproctophora	Aeshnidae			Dragonflies	x				1			1	2	4
Arthropoda	Insecta		Odonata	Epiproctophora	Corduliidae			Dragonflies	x					1	1	1	3	5
Arthropoda	Insecta		Odonata	Zygoptera	Coenagrionidae			Damselflies	x					1		1	2	2
Arthropoda	Insecta		Trichoptera		Hydroptilidae			Caddis Flies	x						1		1	4
Arthropoda	Insecta		Trichoptera		Leptoceridae			Caddis Flies	x			1	1	1	1		4	6
Arthropoda	Arachnida		Acarina	Hydracarina				Freshwater Mites					1	1	1	1	4	6
Arthropoda	Crustacea	Copepod	Cyclopoida		Cyclopidae			Copepods				1	1	1	1	1	5	*
Arthropoda	Crustacea		Cladocera					Water Fleas						1	1	1	3	*
Arthropoda	Crustacea		Isopoda		Sphaeromatidae			Slaters							1		1	1
Arthropoda	Ostracoda							Seed Shrimps						1	1	1	3	*
Annelida	Oligochaeta							Freshwater Worms						1			1	2
Mollusca	Gastropoda				Ancylidae			Freshwater Limpets								1	1	4
Chordata	Amphibia							Tadpoles							1		1	*
Chordata	Osteichthyes				Eleotridae		*Gobiomorphus australis*	Striped Gudgeon						1	1		2	*
Chordata	Osteichthyes				Eleotridae		*Hypseleotris compressa*	Empire Gudgeon						1			1	*
Chordata	Osteichthyes				Eleotridae		*Philypnodon grandiceps*	Flathead Gudgeon							1		1	*
Chordata	Osteichthyes				Poeciliidae		*Gambusia holbrooki*	Plague Minnow						1			1	*
Chordata	Osteichthyes				Pseudomugilidae		*Pseudomugil signifer*	Pacific Blue-eye							1		1	
							Total number of invertebrate taxa per site:					4	8	12	16	18	27	
								Site SIGNAL2 Scores:				3.00	4.14	4.33	3.77	3.33		
Notes:	* represents those taxa for which SIGNAL-2 scores are not available								EPT taxa:			1	1	2	3	0		

ANNEXURE C

WEST CULBURRA

ESTUARINE AQUATIC HABITATS

AND ECOLOGY

1 INTRODUCTION

After an initial site inspection on the 5th July 2019, and following a preliminary desktop assessment of the available estuarine ecology data it was decided that the initial field work should concentrate on investigating the riparian transition from terrestrial habitats through intertidal to shallow sub-tidal habitats along 20 shore-normal transects for the Crookhaven River catchment as selected from available topographic information (see **Figure 1**). These transects followed the shoreline of the original Concept Plan and subsequently covered the area of the revised (smaller) Concept Plan.

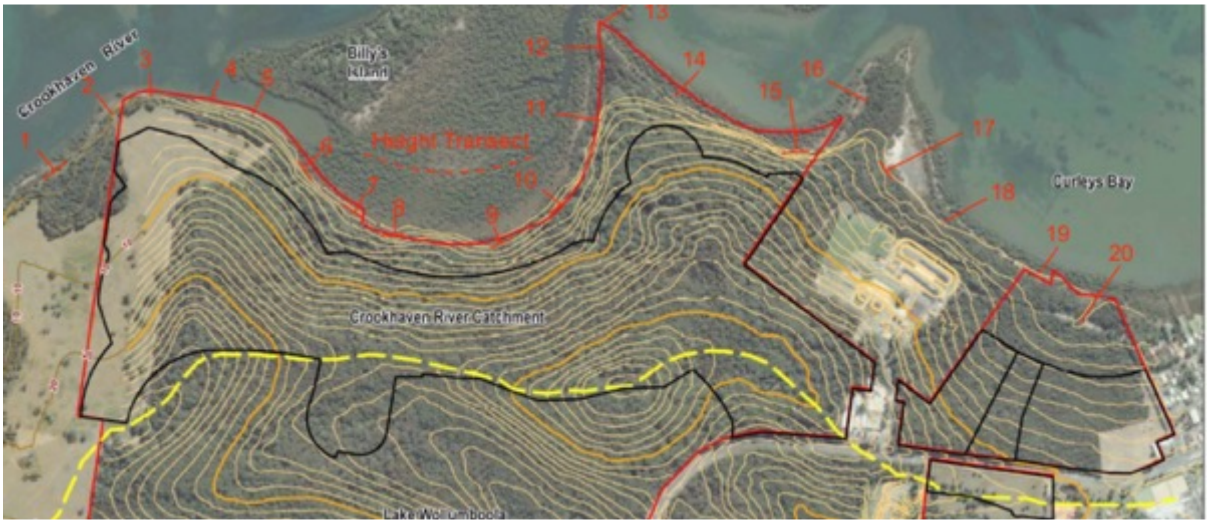


Figure 1 Proposed locations of 20 shore normal transects to ascertain site runoff characteristics and terrestrial to estuarine ecotones.

The shore-normal transect work was undertaken between 4th and 6th September 2019 and completed during a second field survey between 15th and 18th October 2019. In the event 19 transects were surveyed (see **Figure 2 in Section 2** below). These surveys were used to map and describe the riparian edge characteristics, fringing and wide saltmarsh beds plus inshore mangrove edge (see **Section 1.1** for more detailed methodology).

The second field task was to gain a better understanding of the presence, speciation and condition of mangrove forests, and this was achieved by shore-normal surveys into the mangrove forest extending from the riparian foreshore transects. Overall mapping of mangrove forests was also facilitated by aerial photography using a drone. The majority of this field work was completed during the September 2019 survey and completed during the October 2019 survey. A pilot study to ascertain low tide runoff from the Billy's Bay mangrove forest was undertaken on 15th October 2019 prior to commencing shore-normal transect surveys to provide some insight as to where mainland runoff water would drain to during low tides.

Drone aerial photography was also used to detail rocky shore habitats, in-shore plus offshore oyster farm infrastructure, the transitions from mangrove habitats to shallow intertidal sediment and seagrass habitats. This work was generally undertaken during suitable low tides in the late afternoons during the October 2019 surveys.

Initial surveys were also undertaken to describe the seagrass beds, including descriptions of the cryptic and smaller fish plus mobile invertebrate assemblages of the seagrass beds. The initial surveys were undertaken during down time on the main transect work during the September 2019 survey with the intent that the full survey would be undertaken during the next scheduled field survey period.

Further survey work scheduled for late suitable tides during November/December 2019 was curtailed by the NSW 2019 fire season and the next scheduled field surveys were scheduled for February 2020 to take advantage of the king low tides predicted for that period. The February 2020 survey coincided with a flood event in the Crookhaven/ Shoalhaven Estuary for two proposed field surveys - determining the extent of exposed shoreline of Curleys Bay during a king low tide and continuation of the seagrass bed assessments. These surveys could not be undertaken due to turbidity from flood waters and elevated low tides due flood waters. In the event the February 2020 survey period was used to undertake metered water quality profiles at multiple sites within Curleys Bay and the Crookhaven River near Billy's Island to provide tidal water quality change data plus tidal range and lag information.

1.1 Field Methods for Estuarine Aquatic Ecology Sampling and Fieldwork

1.1.1 Riparian shore-normal transects

A total of 19 shore-normal transects were surveyed around the foreshore perimeter of the study area with qualified surveyors from Allen Price & Scarratts Pty Ltd (APS) providing location and height data using Real Time Kinematic GPS survey techniques. GPS survey points were recorded at regular intervals to accurately describe changes in vegetation (riparian, saltmarsh and mangrove species occurrence), shoreline form (substrate height data and undulation) and sequencing of zones (riparian to saltmarsh to mangrove). All height data are reported in Australian Height Datum (AHD).

Start pegs were established within the riparian zone between the riparian terrestrial vegetation and the upper limits of the saltmarsh and transects were surveyed perpendicular to the shoreline, with the outer transect limits recorded at an arbitrary distance in the mangrove zone, so that the saltmarsh to mangrove transition was well represented.

The variation in saltmarsh distribution between areas subjected to historical grazing (Cactus Point) to fenced areas (Bills Bay to Curleys Bay) was identified in the initial site visit on the 5th July 2019 and for this reason, attention was given to bank edges during the GPS survey process to demonstrate the variation in bank edge profiles between cattle affected and cattle excluded areas.

Mangroves surveys were done using a 60m survey tape set in line with the shore transect and as an extension of the shore transect. For each transect, the 0m start of the 60m mangrove survey tape was placed at the riparian zone survey *top of the mangrove zone* point to enable a smooth continuation from the saltmarsh zone. The following mangrove zone measurements were recorded:

- Start and finish distances of grey mangrove (*Avicennia marina*) pneumatophores.
- Start and finish of seagrass beds (if present in transect tape length).
- Distance of water line (and time) with a depth profile using a survey staff.
- Start and finish distances of small and large (>1.5m height) mangroves along mangrove transects.

Mangrove height and density data were recorded for smaller mangroves (seedlings, juveniles or dwarf mangroves <1.5m height) to characterise the assemblage and condition of mangrove stands. Quadrats ($4m^2$) were used to record mangrove height and abundance data for each transect. The location, number of quadrats and number of measurements within quadrats were varied depending on the overall evenness of the mangrove distribution along the transect and on the overall uniformity of plant height along the transect. Photographs were taken to record qualitative mangrove information including mangrove type (seedling, juvenile or stunted adult) and evidence of prior grazing by livestock.

1.1.2 Aerial imagery

Aerial imagery was recorded using a DJI Phantom 3 drone to complement mangrove and seagrass work, and to provide detail for the distribution of hard substratum habitats and other estuarine resources (e.g. oyster farm infrastructure) plus tidal drainage pathways around the Billys Bay and Crow Island channel network. This work was undertaken on the high tide on 4th September 2020 and on the low tide 5th September 2020.

1.1.3 Estimation of Billys Bay Mangrove Stand Drainage Patterns

A pilot study was undertaken to establish whether there were different drainage pathways for the Billys Bay mangrove stand to the two main (East and West) drainage channels, as this would also provide information on site stormwater runoff directions during low tides. Preliminary mangrove stand walk-over surveys indicated that the mangrove trunks and in some cases pneumatophores (peg roots) had a distinct tide/scum line which was 'permanent' rather than an indicator of the last recent high tide. This event tide line was then used as a base line from which the height above the surrounding seabed/sediment could be measured.

Using a survey staff and handheld GPS, MPR staff undertook a random walk survey through the Billys Bay mangroves using a survey staff to measure the uniform tide line height and recording the location with a hand-held GPS. The GPS locations were then plotted onto google earth using the location height measurement as their data tag. The height measurements were rounded to one decimal place, and polygons were drawn around areas of similar height to provide a basic contour map. Whilst is note that site locations provided by hand-held GPS are approximate and that height measurements are only relative to one another and are subject to micro-topography differences around trees, the results at least provided an indication of where the high ridge separating the east and west flowing drainages were located.

1.1.4 Seagrass Sampling

A pilot study was undertaken to estimate the *Zostera* seagrass bed density and condition for locations where seagrass beds occurred offshore from transects:

- At each site, the seagrass bed species and estimations of cover and density were recorded.
- A number of randomly located shallow 100mm diameter core sample was used to determine the total number of shoots (density) and maximum shoot length. Extracted cores were replaced following measurements.
- As this was a pilot study, the number of cores taken depended on how uniform the bed was. Where the *Zostera* bed cover was relativity uniform only one or a few representative cores were taken, with more cores for uneven beds. Cores were randomly taken from either side of the transect line.
- For each core, the overall leaf length of a number of the combined core shoots and the maximum leaf length were measured. The number of shoots measured varied, based on overall evenness of shoot lengths within the core.
- Handheld mesh net sweeps of seagrass beds were undertaken at the three locations (see **Figure 2 below**). At each site 2 x 20m sweeps were performed using a fine mesh (0.9mm) 30cm triangular dip net. The net contents were lightly sieved in clean

estuary water and then placed into a sorting tray to count and identify retained specimens, after which animals were released back to the seagrass bed from where they were taken.

2 OVERVIEW OF FIELD STUDIES AND WEATHER CONDITIONS

Table 1 below provides a summary of the aquatic ecology assessments undertaken for original and present (2020) Culburra West proposal, including the estuarine habitat assessment and mapping exercises (see **Annexure B** for the freshwater aquatic ecology assessment results). The estuarine aquatic habitats and sample site locations are shown below in **Figure 2**.

The sampling conditions leading into the survey periods are presented in **Section 2.1** below. **Section 2.2** provides the results for the intertidal habitat assessments and **Section 2.3** provides the results for the sub-tidal habitat assessment that were undertaken for the Aquatic Ecology Report. **Section 2.4** includes the findings from the Crookhaven River and Curleys Bay tidal water quality work undertaken in February 2020.

Table 1 Summary of Culburra West Aquatic Ecological Survey Conducted by MPR

Date	Crookhaven River	Downs Ck	Wattle Ck	Notes
5th July 2019	x	x	x	Initial site inspection of the Crookhaven River and Lake Wollumboola sub-catchment drainages (Wattle Creek and Downs Creek).
4th to 6th Sept 2019	x			Estuarine habitat assessments (seagrass, saltmarsh, mangrove transects and aerial imagery) with preliminary freshwater habitat assessments bounding the foreshore along Cactus Pt to the eastern extent of study area (Rocky Pt east).
15th to 18th Oct 2019	x	x		Continued estuarine surveys along Crookhaven River with freshwater habitat assessments along the length of Downs Creek and in the unnamed drainage line to the south west of Cactus Pt.
11th to 13th Feb 2020	x		x	Freshwater habitat assessment of Wattle Creek catchment plus wet weather water quality assessment of the Crookhaven River and freshwater runoff inspections along the Crookhaven River foreshore.

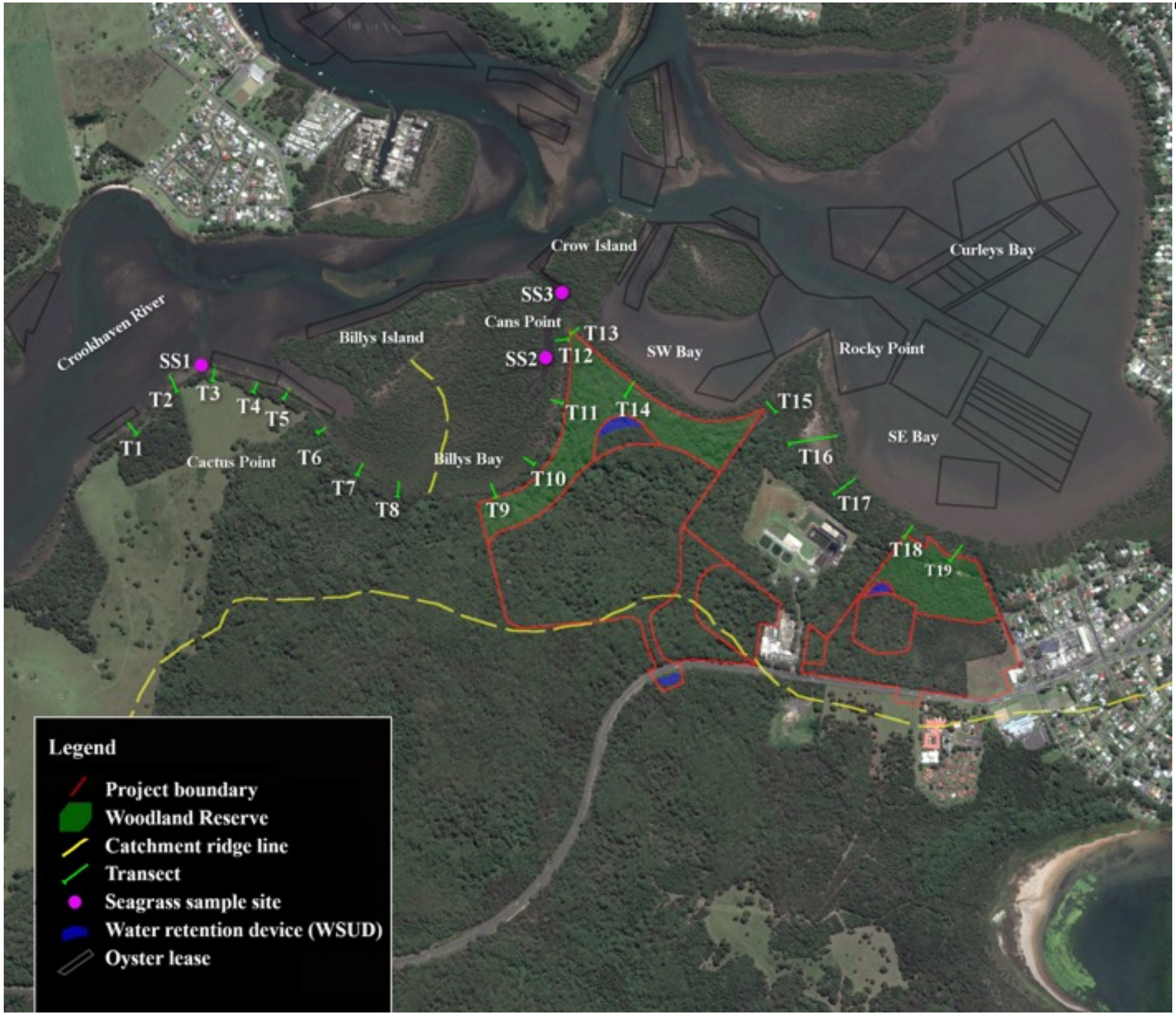


Figure 2: Estuarine aquatic ecology habitat assessment sites bounding the revised Concept Plan. Note the delineation of mangrove drainage areas inshore in Billys Bay (dashed white line).

After the initial site inspection on the 5th July 2019, field investigations were undertaken by MPR staff over the 4th to 6th September, the 15th to 18th October 2019 and the 11th to 13th February 2020.

2.1 Sampling Conditions for Estuarine Ecology Fieldwork

Rainfall is measured adjacent to the site at the Culburra Treatment Works (Bureau of Meteorology gauge 68083). Overall, the weather patterns leading into the aquatic ecology survey events were generally dry in 2019 with wetter conditions experienced in 2020 and leading into the February survey:

- Only 70% of the average annual rainfall was recorded between the months of January to September 2019 (646mm), and this includes significant rain events recorded in the month of June totalling 219mm.
- Rainfall over the periods leading into the September and October 2019 field investigations were characterised by lengthy dry spells and infrequent low magnitude rainfall events.
- The February 2020 survey period was undertaken following consistent showers in mid-January and a significant wet weather event over the three days prior to the commencement of February survey during which 173mm was recorded, and consistent showers prevailed over the first two sample days.

2.2 Intertidal Habitat Assessments and Ecology

A total of 19 shoreline transects were surveyed along the entire foreshore bounding the proposal's area to characterise the extent of saltmarsh, composition of species and zonation within the tidal column (see **Figure 2** for transect locations) plus mangrove condition and density of seedlings. At each location transects were established from within the riparian zone (generally landward of saltmarsh or wetland plants) offshore through to the edge of mangroves and seagrasses if present. The 19 survey profiles reduced to AHD are provided in **Supplementary Data Figure C-1** and the transect survey species data is provided in **Supplementary Data Table C-2**.

Heading offshore from the riparian zone, the intertidal shoreline supports transitioning of estuarine plant communities from a fringing saltmarsh to grey mangrove (*Avicennia marina*) community around the northern and eastern portion of the propopal's perimeter. *Zostera meulleri* subsp. *capricorni* (*Zostera*) seagrass beds are commonly encountered along the shore length of varying density, and *Zostera* wrack was commonly observed along the study area shoreline during each of the field work investigations.

In general, there are differences in the shape of the shorelines between the more sheltered locations that are protected by islands (Billys Bay) and locations that are exposed to wind induced waves and tidal currents (Crookhaven River at Cactus Point and to Curleys Bay).

There is a distinct difference in condition between unfenced areas where cattle have traditionally had access to waterfront aquatic vegetation communities (saltmarshes and mangroves around Cactus Point) and fenced areas which (mostly) exclude cattle from grazing (to the east of Billys Bay). The Crookhaven River bank edges bounding Cactus Point are distinct, stepped and undercut throughout most of the length due to tidal and wind induced wave erosional activity (**Figure 3**), which restricts the availability of intertidal sediment surface area for saltmarsh species colonisation. She-oak (*Casuarina glauca*) root masses stabilise the edge banks however numerous mature trees were noted to have slumped into the river along this length.

Figure 3: Cactus Point shoreline showing intertidal zone, with very sparse grey mangrove occupation (left) and example of undercut banks forming a distinct, stepped edge (right). This area is heavily grazed (note the cattle hoofprints in the sediments on the left photo).

The intertidal mudflats through this section are heavily grazed with only sparse colonisation by mangrove seedlings and stunted trees around 0.5m to 1.0m in height. In contrast, the fenced areas east of Cactus Point (from Billys Bay and to the east of Rocky Point) have allowed saltmarsh and mangrove habitats to thrive (**Figure 4** below).

Figure 4: Figure showing the immediate difference in grey mangrove seedling occupation in the fenced area between Cactus Point and Billys Bay (left). Shoreline edges around Billys Bay and further east to Rocky Point are less distinct, with gradual sloping bank edges supporting saltmarsh meeting dense mangrove seedlings (right).

2.2.1 Saltmarsh habitat assessment

Upper and lower tidal ranges were calculated for each of the species recorded within the 19 transects surveyed. All ranges are reported in metres Australian Height Datum (AHD). **Table 2** below provides the results of the saltmarsh species zonation from the shore-normal survey transect exercise and **Table 3** provides the occupation of species within individual transects. Note that species were grouped as either saltmarsh or wetland species and are ordered according to their lowest recorded AHD height. Wetland species were those plants not exclusive to saltmarsh habitats (species that also occupy damp or freshwater habitats) and **Table 2** includes characteristic saltmarsh species protected under the *Fisheries Management Act 1994* (FMAct) and listed under the *Fisheries Management* (*General*) *Regulation 2010*; see Table 2 of the NSW Dept of Primary Industries Primefact (2013).

Table 2 Culburra West Saltmarsh Species Tidal Ranges

Spp group	Species	Code	FMA	AHD range (m)		# Transects
			Listed	Upper	Lower	
Mangrove	*Avicennia marina*	AM		0.73	-0.16	19
Saltmarsh	*Sporobolus virginicus*	SV	√	1.18	0.27	14
	Juncus kraussii	JK	√	1.16	0.45	12
	Baumea juncea	BJ	√	1.30	0.54	6
	Sarcocornia quinqueflora	SQ	√	0.97	0.54	3
	Suaeda australis	SA	√	1.01	0.54	6
	Triglochin striata	TS	√	0.84	0.74	1
	Selliera radicans	SR	√	1.20	0.90	5
	Ficinia nodosa	FN	√	1.11	1.02	1
Wetlands	*Tetragonia tetragonoides*	TT		1.18	0.88	4
	Rhagodia candolleana	RC		1.17	1.01	1
	?Enchylaena tomentosa	ET		1.09	1.06	1

A total of eight of the ten FMA listed species were recorded from the study area transects. Sea rush (*Juncus kraussii*) and sea couch (*Sporobolus virginicus*) were the most dominant saltmarsh species throughout the study area, particularly along the shoreline of Billys Bay. Sea couch was the lowest recorded saltmarsh species (at 0.27m AHD) however it occurred over a considerable range within the tidal column (to 1.18m AHD). It was the most commonly occurring species being recorded over 14 of the 19 transects and was also observed on occasion to be growing in isolated tufts below the saltmarsh 'edge' among mangroves.

Sea rush was also widespread throughout the study area being recorded from 12 of the 19 transects and as for sea couch and bare twig rush (*Baumea juncea*), recorded one of the larger tolerance ranges of all saltmarsh species. The upper tidal range limits of samphire (*Sarcocornia quinqueflora*) and streaked arrow grass (*Triglochin striata*) were the overall lowest though these species were less common than sea couch and sea rush.

Whilst many of the species AHD ranges overlapped with the upper limits of grey mangrove (the upper limit mangrove occurrences were of seedlings, not mature established trees), the saltmarsh and mangrove zonation were very distinct in that it was very seldom that saltmarsh species were growing among mangrove stands.

Two of the wetland plants (Seaberry saltbush *Rhagodia candolleana* and ruby saltbush *Enchylaena tomentosa*[1]) recorded somewhat limited ranges however they were very restricted in their distribution, being recorded in one transect only.

The Cactus Point transect data (Transects 1 to 5) reveal there is no established saltmarsh around this section of shoreline as only one small occurrence of salt couch was recorded here (**Table 3**). Heading east from this point, the saltmarshes occupy much of the upper intertidal foreshore which occur underneath a canopy of fringing swamp oak forest for sections of the shoreline in each area. For many of the eastern transects (14 to 19) an outer 'berm' was present, consisting of a raised outer bank supporting saltmarsh species and she-oak (*Casuarina glauca*), bordered inshore by saltmarsh species and often saltpans (bare muddy sediments subject to tidal inundation and evaporation; see **Figure 5**).

[1] This species identification is tentative as there were no fruits or seed heads to aid in identification.

Figure 5: SW Bay saltmarsh showing outer raised berm colonized by saltmarsh species and stabilised by she-oak (to the left) and bordered inshore by saltmarsh and bare saltpans.

Table 3 shows the linear distances measured for each of the saltmarsh and wetland plants within each transect to highlight the dominant species that characterise the Culburra West saltmarshes. Transects have been grouped according to shoreline locations (Billys Bay, Cans Point to Rocky Point, Rocky Point East and Cactus Point) and only transects which supported saltmarsh or wetland species were included. The upper saltmarsh boundaries were generally delineated by occurrences of characteristic saltmarsh forming species (e.g. sea couch, sea rush, seablite (*Suaeda australis*) and swamp weed (*Selliera radicans*)). TL = total length of transect, TL SM = total length of saltmarsh within each transect between innermost and outermost occurrence. All distance values are in metres. The saltmarsh species distance data is summarised as follows:

- The overall highest number saltmarsh species were recorded along the Cans Point to Rocky Point (7 species) and Rocky Point East (7 species) stretches of shoreline, from 3 and 4 transects respectively. In Billys Bay, there were 5 saltmarsh species recorded over the 7 transects and only one small patch of salt couch was recorded among the 5 Cactus Point transects.
- Salt couch and sea rush were the dominant saltmarsh plants recorded across the study area. As a proportion of the linear distance of saltmarsh within each location, salt couch occupied between 41% (in Rocky Point East) and 54% (Cans Point to Rocky Point) of the transect lengths and sea rush occupied between 23% (in Rocky Point East) and 67% (Billys Bay). Note that saltmarsh species recorded considerable overlap in most places, particularly so for salt couch and sea rush which were commonly growing together.

Table 3 Saltmarsh Species Lengths within Transects

Location	Transect	TL	TL SM	Saltmarsh Plants								Wetland Plants		
		m	m	SV	JK	BJ	SQ	SA	TS	SR	FN	TT	RC	ET
Cactus Pt	2	48.1	2.9	2.9										
Billys Bay	6	24.8	6.6	0.3	0.3					2.9		2.9		
	7	33.1	11.5		11.5									
	8	44.1	17.8	10.7	8.6	10.7								
	9	42.7	9.0	7.8	11.3	26.7								
	10	36.3	10.7	10.7	9.4	13.1								
	11	33.9	18.4	10.9	12.2					2.1				
	12	36.9	5.4	1.0				4.4				11.2	4.6	
Billys Bay Total Species Lengths:				41.4	53.3	50.5		4.4		5.0		14.1	4.6	
Cans Pt - Rocky Pt	13	23.5	6.4	6.6										
	14	53.5	41.5	19.4	20.6	14.8	3.2	2.0		3.7				
	15	43.3	37.7	20.5	14.5		3.6	2.3	4.5	5.4				
Cans Pt Rocky Pt Total Species Lengths:				46.5	35.1	14.8	6.8	4.3	4.5	9.1				
Rocky Pt East	16	144.1	119.9	25.1	14.6	30	1.4	1.0		1.7				
	17	71.1	43.2	32.7	16.9	13.4		5.7				3.6		2.6
	18	36.7	11.7	5.6	8.4			3.3				3.9		
	19	44.6	17.4	15.4	3.4						6.8			
Rocky Pt East Total Species Lengths:				78.8	43.3	43.4	1.4	10.0		1.7	6.8	7.5		2.6
Total species Length in study area transects:				169.6	131.7	108.7	8.2	18.7	4.5	15.8	6.8	21.6	4.6	2.6

- Bare twig rush was also relatively dominant being recorded in 17% (Cans Point to Rocky Point East) to 64% (Billys Bay) of transect lengths, however this species was often observed growing further up in the saltmarsh in sparse distribution.
- The other saltmarsh species were recorded in relatively smaller amounts, ranging between 1% and 11% across all locations. Notwithstanding, each of these species which were recorded in smaller quantities were observed to occur as distinct, healthy stands in the broader saltmarsh area within and adjacent transects.

Initial estimations of saltmarsh areas indicate that Rocky Point East support the largest quantity (4.01 Ha), followed by Cans Point to Rocky Point East (2.76 Ha) and Billys Bay (1.37 Ha). The Rocky Point East saltmarsh area includes a large area of saltpan that has been damaged by vehicle use, and while this area contains only a very sparse occupation of saltmarsh species (samphire and seablite) there is potential for saltmarsh recovery in the absence of vehicular access.

2.2.2 Mangrove habitat assessment

The grey mangrove is the dominant species fringing the Crookhaven River intertidal shoreline in the study area and is generally continuous. Only one single river mangrove

Aegiceras corniculatum seedling was observed in Billy bays and several mature river mangroves were observed on the northern side of Crow Island (see **Annexure Plate 18**). Oyster growth on pneumatophores for the most part was confined to the outer limits of the mangrove stands which receive the most inundation, with very sparse growth of oysters on pneumatophores in the upper intertidal range. The Billys Bay eastern channel, Crow Island south and west channels were areas noted to support dense oyster growth on pneumatophores (**Figure 6**). Further to this, epiphytic growth of the red alga *Catenella nipae* were observed in varying quantities growing on grey mangrove pneumatophores in Billys Bay and around SE Bay (**Figure 7**).

Figure 6: Oyster growth on mangrove pneumatophores along the northern edge of Billys Bay eastern channel.

Figure 7: *Catenella nipae* growth on mangrove pneumatophores in SE Bay.

Burrows and abundant individuals of the red-fingered mangrove crab *Parasesarma erythodactyla* were regularly observed in mangrove habitats at low tide around the study area to the east of Billys Bay and throughout Billys Bay saltmarsh areas in the February 2020 wet weather survey (**Figure 6** below), and the only other invertebrate that was commonly observed was a Littorinid estuarine gastropod, observed in similar habitats to the crabs (mostly the upper intertidal range).

Figure 6: The mangrove sesarmid *Parasesarma erythodactyla* was commonly observed around upper intertidal mangrove habitats in Billys Bay.

Results from the mangrove seedling counts and heights are shown below in **Table 4**. Note the measured lengths of mangrove habitats (offshore from outer saltmarsh limits) within Billys Bay transects were continuous across to Billys Island.

Table 4 Mangrove Survey Transect Data

	Transect		Grey Mangrove Juvenile			
	#	Length	Height (m)	SE	Count	SE
Cactus Pt	1	19.5	0.54	0.06	1.3	0.5
	2	28.0	0.31	0.03	1.9	0.2
	3	15.1	0.32	0.06	0.8	0.5
	4	16.6	0.33	0.03	3.3	0.8
	5	10.0	0.25	0.02	1.6	0.6
Billys Bay	6	NA	0.57	0.03	8.3	2.0
	7	NA	0.73	0.16	7.9	1.9
	8	NA	0.94	0.12	6.3	9.0
	9	NA	0.61	0.05	5.0	0.0
	10	NA	0.87	0.15	4.5	0.8
	11	NA	0.28	0.03	12.5	4.4
	12	NA	0.27	0.05	10.8	0.3
SW Bay	13	58.2	0.30	0.04	8.3	3.0
	14	56.4	0.32	0.07	37	
	15	42.3	0.37	0.04	11	
Rocky Pt East	16	32.0	0.47	0.10	9.9	4.1
	17	25.2	0.31	0.04	5.5	3.3
	18	38.3	0.36	0.03	11.2	4.5
	19	53.5	0.36	0.04	37.8	0.3
Note:	The term juvenile includes seedlings and saplings.					

The density of juvenile mangroves in random quadrats were lowest along the Cactus Point intertidal foreshore, with mean (± standard error SE) values ranging between of 0.8 ± 0.5

individuals to 3.3 ± 0.8 individuals per m^2. The other areas supported higher densities of juvenile grey mangroves with highest values recorded between Cans Point and Rocky Point east (reaching 37.8 ± 0.3 individuals per m^2). Whilst this level of seedling recruitment is generally not sustainable (due to high density) it shows that mangroves are successfully establishing in areas devoid of cattle.

2.2.3 Aquatic biota of rock and hard substratum habitats

Overall, most of the rocky substrates bounding the study area are confined to the Crookhaven River fronting Cactus Point and Curleys Bay around Rocky Point in the east, and are comprised of natural bedrock platforms and rocky shores (including both natural and man-made boulder deposits) and shell beds (**Figures 7 to 9** below). While there were small sections of exposed bedrock observed along the shoreline inshore in Billys Bay among mangrove habitat that were more or less covered in a shallow layer of estuarine muddy sand sediment, the majority of the exposed bedrock platforms along Cactus Point shoreline were bare (see **Figure 7** below).

The sandstone boulder configurations at Cactus and Rocky points are used for (and continue to be used for) catching Sydney Rock Oysters in these locations. This is a traditional method for the natural collection of oyster spat and, if unattended can accumulate significant oyster growth rendering the original substrate unrecognisable.

Figure 7: Exposed bedrock platforms along Cactus Point shoreline fronting the Crookhaven River. Rocky substrates meeting undercut riparian banks stabilised by Casuarinas at Transect 5 (left) and bedrock outcrops among shallow sediment intertidal mangrove habitats in Transect 2 (right).

Figure 8: Oyster catching rock deposits along the Crookhaven River fronting Cactus Point at Transect 3 (left) and shoreline boulder rock deposit submerged by high tide (right). This latter example of rocky habitats supported very little encrusting fauna or flora.

These structures can also provide considerable source of oyster larvae during spawning periods. There were no other invertebrates or marine algal growth observed on the rocky substrates with the exception of the small gastropod *Bembicium melanostomum*. Sections of boulder rock along the intertidal shoreline of Cactus Point (**Figure 8**) supported very little growth (only sparse Sydney Rock Oyster observed) and it is unclear as to whether these were recently deposited or are too high in the intertidal range to support encrusting fauna.

Some of the exposed bedrock contained very sparse oyster growths (shell only), and it is likely that wind induced wave along this stretch of shoreline facilitates water movement and the process of smothering and exposure of such platforms by estuarine sediments.

Figure 9: Intertidal rock and shell bed habitats around Rocky Point. This section of shoreline included deposited boulders still used for catching oysters (top and bottom) and natural bedrock outcrops (bottom) with areas of shell beds (not shown).

2.3 Aquatic Habitats of the Sub-tidal Sediments

2.3.1 Seagrass habitat assessment

Detailed aerial images showing the extent and condition (density) of Zostera seagrass beds are provided in **Supplementary Data Plates 13** to **23**. Random seagrass cores were taken using a 100mm diameter shallow sediment core to compliment the aerial imagery. Cores were taken in locations where Zostera beds occurred in a linear direction offshore from the saltmarsh - mangrove transects (Transects 1, 2, 3, 12, 16 and 17) and the seagrass leaf length and shoot density results are presented below in **Table 5**.

Extrapolation of the seagrass core sampling density measurements to standardised 1m^2 units may not be indicative of the broader seagrass beds (due to unevenness of the shoot density observed across many beds), and therefore the seagrass shoot count data were standardised for a 10cm x 10cm area. Note that Transect 16 Zostera bed was generally continuous offshore from the transect so an outer bed measurement was not recorded and Transect 17 core sample as taken from a random isolated patch adjacent to transect as there were no patches within the transect line.

Table 5 Culburra West Transect Zostera Core Sampling Results

Transect	Bed length	Shoot Length (cm)		Shoot Count (per 100cm^2)	
	(m)	Mean	SE	Mean	SE
1	6.3	12.3	1.7	6.7	2.6
2	7.7	28.5	3.1	9.3	2.2
3	23.6	25.0	2.4	5.5	1.1
12	21.9	25.4	2.3	6.8	1.1
16	Cont	16.0	3.1	3.4	1.5
17	NA	20.0		2.0	

Overall, the preliminary seagrass sample results were variable in terms of bed shoot density and leaf length. Transects 2,3 and 12 contained the longest mean shoot lengths (25.0 to 28.5cm) compared to sites 1, 16 and 17, and shoot counts were generally sparse across with the highest density at Transect 2. In addition to the seagrass core sampling and aerial imagery exercises, a pilot study assessment of the aquatic fauna that utilise Zostera seagrass beds was initiated in three locations along the shorelines at Cactus Point, eastern Billys Bay inlet channel and southern boundary of Crows Island (**Figure 2**). Seagrass beds were swept using a handheld dip net and the results are provided below in **Table 6**.

Table 6 Culburra West Preliminary *Zostera* Sweep Sampling Results

Taxa group	Common name	SS1	SS2	SS3
Girella tricuspidata	Luderick	2		2
Centropogon australis	Fortescue			2
Gobiidae	Gobies	1	2	2
Sygnathidae	Pipefish		1	1
Penaeidae	Prawns	1	25	
Palaemonidae	Shrimp			15
Opistobranchia	Sea Slugs	1		
Loliginidae	Squid	2	4	2
Gastropoda	Snails	1	15	30
Bembicium sp	Periwinkle			1
	Area sampled (m^2)	6	12	12

A diverse array of fauna was recorded from the seagrass sweeps including commercially and recreationally important species such as Luderick (juveniles), prawns and squid. Pipefish were recorded at the eastern sites SS2 and SS3.

As a member of the family Sygnathidae, Pipefish are protected under state (FMAct) and federal (*Environmental Protection and Biodiversity Conservation Act 1999*) legislation, and a number of Sygnathid species that are found in NSW are listed in the 2000 IUCN (World Conservation Union) Red List of Threatened Species.

2.4 Key Fish Habitat Assessment

With regard to the sensitivity classification of the specific habitats within these locations (as defined in Table 1 of Fisheries NSW 2013), the following key points are made:

- The patches of *Zostera* along the shoreline fronting the proposal's foreshore area in the Crookhaven River, Crow west channel, south-west and south-east bays are classified as Type 1 "highly sensitive KFH" as bed sizes are greater than $5m^2$.
- Similarly, the coastal saltmarshes identified throughout the study area is classified as Type 1 "highly sensitive KFH" as saltmarsh stands are greater than $5m^2$ in area.
- Mangroves

ANNEXURE C

WEST CULBURRA ESTUARINE

AQUATIC HABITATS AND ECOLOGY

SUPPLEMENTARY DATA

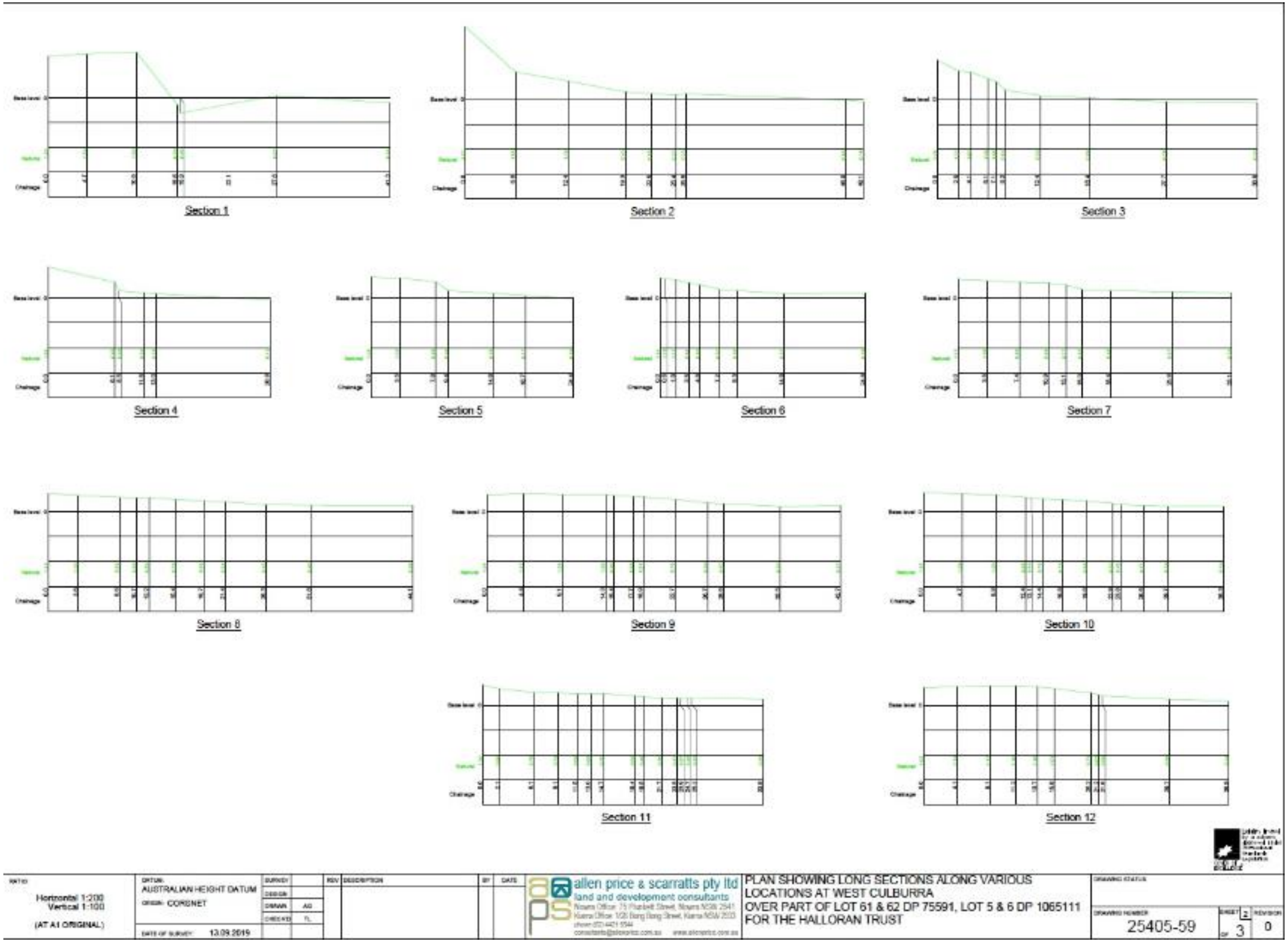
C-1 RIPARIAN TRANSECT SURVEY CROSS SECTIONS

C-2 RIPARIAN TRANSECT SURVEY DATA TABLE

C-3 MANGROVE SURVEY DEPTH PROFILES

C-4 ESTUARINE HABITAT PHOTOS

C-5 OYSTER LEASE STATUS AND PHOTOS


Section 1
Section 2
Section 3
Section 4
Section 5
Section 6
Section 7
Section 8
Section 9
Section 10
Section 11
Section 12
Horizontal 1:200
Vertical 1:100
(AT A1 ORIGINAL)
AUSTRALIAN HEIGHT DATUM
CORSNET
13.09.2019
allen price & scarratts pty ltd
land and development consultants
PLAN SHOWING LONG SECTIONS ALONG VARIOUS
LOCATIONS AT WEST CULBURRA
OVER PART OF LOT 61 & 62 DP 75591, LOT 5 & 6 DP 1065111
FOR THE HALLORAN TRUST
25405-59
2
3
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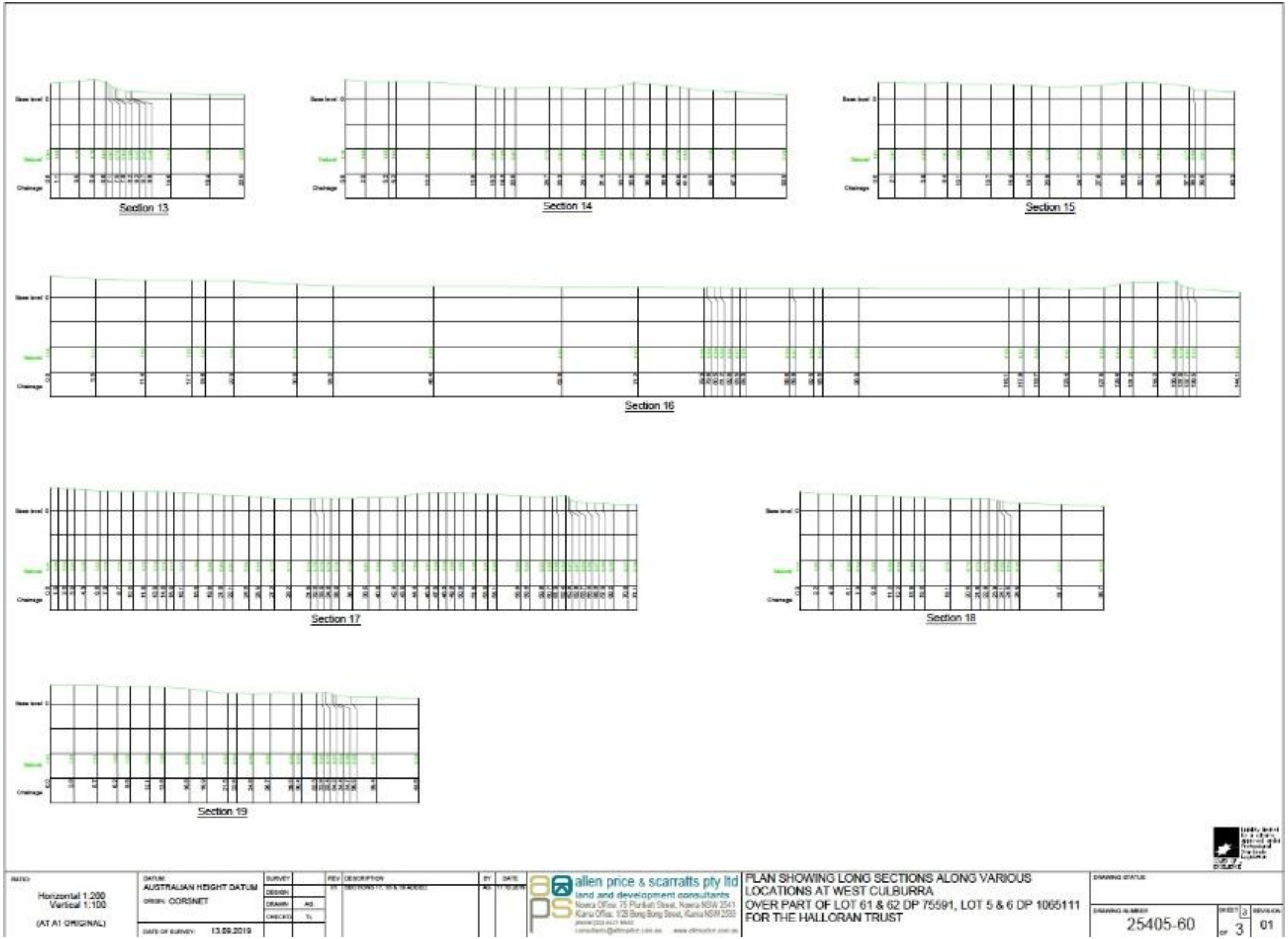

Section 13
Section 14
Section 15
Section 16
Section 17
Section 18
Section 19
Horizontal 1:200
Vertical 1:100
(AT A1 ORIGINAL)
AUSTRALIAN HEIGHT DATUM
CORSNET
13.09.2019
allen price & scarratts pty ltd
land and development consultants
PLAN SHOWING LONG SECTIONS ALONG VARIOUS
LOCATIONS AT WEST CULBURRA
OVER PART OF LOT 61 & 62 DP 75591, LOT 5 & 6 DP 1065111
FOR THE HALLORAN TRUST
25405-60
3
01

ANNEXURE C SUPPLEMENTARY DATA TABLE C-2

Sort	Site	Date	GDA 94 MGA 56		Survey	Distance	RL AHD	Mangrove	Codes	Water	Sed	Start and finish distances																Notes:
			Easting	Northing	Point	m	m	Transect SP	Trans			Tree	Peg	Mang	Zostera	SM	JK	SV	SA	SQ	TS	SR	TT	RC	BJ	ET	FN	
1	1	05/09/19	292427.12	6132959.66	110	0.0	1.25		SP			C-S																Edge of riparian Casuarina, start of open space with terrestrial grass species
2	1		292423.71	6132962.87	111	4.7	1.33																					Terrestrial grass species
3	1		292419.79	6132967.33	112	10.6	1.39																					Terrestrial grass species
4	1		292415.37	6132969.58	113	15.6	-0.20		TB			C-F																Terrestrial grass species, edge Casuarina trees
5	1		292415.23	6132969.91	114	15.9	-0.46	X	BB		BM																	Bare mud
6	1		292412.11	6132975.23	115	21.6							S															Inner edge mangrove pegs
7	1					25.1								S														Mangroves start
8	1		292408.21	6132979.17	116	27.6	0.08																					Mature AM
9	1		292401.77	6132991.24	117	41.3	-0.16						F															Outer edge mangrove pegs (no water in transect @ 9:50am)
10	1					44.6								F														Mangroves Finish
11	1					52.9									S													Zostera Start
12	1					59.2									F													Zostera Finish and oyster lease starts
13	2	05/09/19	292540.74	6133080.37	120	0.0	4.37		SP																			Top of paddock bank, mainly bare ground with layer of Casuarina needles
14	2		292538.41	6133085.92	121	6.0	1.65																					Bottom of slope
15	2		292537.73	6133092.29	124	12.4	1.10	X	TB			C-S																Edge bank lined with Casuarina trees
16	2		292537.33	6133092.73	1001	12.8	0.60		BB																			0.6m out from 124, 0.5m down to BB
17	2					17.1								S														Start of mangroves
18	2		292533.15	6133097.46	125	19.3	0.43							SD-S														Inner edge AM seedlings
19	2		292531.69	6133100.29	126	22.5	0.33									SM-S		S										Start of SV patch
20	2		292530.65	6133103.02	127	25.4	0.27									SM-F		F										Finish of SV patch
21	2		292530.44	6133104.18	128	26.6	0.33				BR-S																	Start of bedrock outcrop
22	2					45.1								F														Finish of mangroves
23	2		292523.23	6133122.12	129	46.0	-0.03				BR-F																	Finish of bedrock outcrop
24	2		292522.35	6133124.04	130	48.1	-0.16							SD-F														Outer edge AM seedlings (no water in transect at 10:25am)
25	2					56.6									S													Start of Zostera
26	2					64.3									F													Finish of Zostera and oyster lease starts
27	3	05/09/19	292643.58	6133112.09	140	0.0	2.35		SP																			Lantana continues downslope
28	3		292644.27	6133114.53	143	2.5	1.71																					In riparian
29	3		292644.57	6133116.05	144	4.1	1.62					LN-F																Edge of lantana, start terrestrial grass
30	3		292644.90	6133118.07	145	6.1	1.25																					In riparian grass
31	3		292645.32	6133118.93	141	7.1	1.06		TB			C-S																Lower edge riparian grass, line of Casuarinas along bank edge
32	3		292645.87	6133119.85	142	8.2	0.54	X	BB																			Start of sandy mud
33	3					12.1		4						S														Mangroves start
34	3		292648.05	6133123.45	150	12.4	0.23						PG-S															Inner edge of AM pegs
35	3		292648.05	6133129.49	147	18.4	0.08							SD-S														Inner edge AM seedlings
36	3		292647.94	6133138.74	148	27.7	-0.16			X			PG-F															Outer edge AM pegs, start of rock clusters with oyster growth, waters edge at 10:40am
37	3					31.2								F														Mangroves finish
38	3		292651.21	6133149.21	149	38.6	-0.23																					End of rock clusters with oyster growth
39	3					38.5									S													Start of zostera
40	3					62.1									F													Finish of zostera
41	4	05/09/19	292761.15	6133080.20	160	0.0	1.88		SP																			No SM within riparian zone above TB or below BB, only Casuarina needle layer in understorey
42	4		292764.78	6133087.38	161	8.1	0.95		TB			C-S																Casuarinas in riparian and along bank edge.
43	4		292765.07	6133087.72	162	8.5	0.44	X	BB																			
44	4		292766.45	6133090.49	163	11.6	0.31							SD-S														Inner edge AM seedlings
45	4					12.0		3.5						S														Start of mangroves
46	4		292767.01	6133091.80	164	13.0	0.26						PG-S															Inner edge mangrove pegs
47	4		292770.40	6133103.04	1002	24.6				X				SD-F														Outer AM seedlings and waters edge 2m inshore from 165 (11:30am)
48	4		292770.97	6133104.95	165	26.8	-0.12						PG-F															Outer edge mangrove pegs
49	4					28.6								F														Finish mangroves
50	4		292771.55	6133106.87	1003	28.6																						add 2m for actual outer edge of outer mangrove pegs (were under water)
51	5	05/09/19	292846.91	6133064.64	180	0.0	1.26		SP			C-S																Only sparse terrestrial grass and Casuarina needle layer in riparian
52	5		292848.67	6133067.62	181	3.5	1.20																					In riparian
53	5		292851.73	6133070.69	182	7.8	0.98																					In riparian
54	5		292849.74	6133072.14	184	8.0	0.96		TB			C-F																Casuarinas forming edge bank
55	5		292850.43	6133072.58	185	8.7	0.59	X	BB		BR-S																	Start bedrock
56	5		292853.38	6133077.36	188	14.3	0.28			X																		Waters edge @ 12:45, inner AM seedlings 1m out from this point
57	5					13.1		4.4						S														Start of mangroves
58	5		292855.76	6133080.48	186	18.7	0.17				BR-F																	Outer edge of rock, inner edge of AM pegs
59	5		292857.98	6133084.70	1004	22.9																						Plus outer AM seedlings 1m inshore from 187
60	5					23.1		14.4						F														Finish mangroves
61	5		292858.45	6133085.58	187	24.4	-0.04						PG-F															Outer edge AM peg roots
62	6	05/09/19	292945.18	6132969.38	190	0.0	1.21		SP			LN-F, C-S																Edge of dense riparian lantana
63	6		292945.74	6132969.61	191	0.6	1.16									SM-S						S	S					Start SM (sparse TT and SR overlying Casuarina needle layer)
64	6		292946.86	6132970.15	192	1.9	1.11																					Mid SM
65	6		292948.35	6132970.84	193	3.5	0.91															F	F					Lower edge of TT and SR SM
66	6		292949.50	6132971.47	194	4.8	0.80																					Bare Casuarina needle layer
67	6		292951.58	6132972.68	195	7.2	0.52	X				C-F				SM-F	1	1										Lower limits SM (sparse line of JK and SV along 'edge')
68	6		292953.44	6132973.55	196	9.3	0.45						PG-S															Inner edge AM pegs
69	6		292953.95	6132973.54	197	9.7	0.45			X				SD-S														Inner edge AM seedling, waters edge @ 13:15
70	6					9.8		2.6						S														Start of mangroves
71	6		292957.74	6132977.27	198	14.9	0.27							AM-S														In AM zone
72	6		292966.18	6132982.34	199	24.8	0.29																					Outer transect point (mangroves continuous across bay to island)

Sort	Site	Date	GDA 94 MGA 56		Survey	Distance	RL AHD	Mangrove	Codes	Water	Sed	Start and finish distances																Notes:
			Easting	Northing	Point	m	m	Transect SP	Trans			Tree	Peg	Mang	Zostera	SM	JK	SV	SA	SQ	TS	SR	TT	RC	BJ	ET	FN	
73	7	05/09/19	293060.93	6132853.26	210	0.0	1.13		SP			C-S																Casuarina and Lomandra at SP, lantana upslope
74	7		293062.54	6132856.37	211	3.5	1.06									SM-S	S											Start JK SM
75	7		293063.79	6132860.05	212	7.4	0.95																					In SM
76	7		293065.49	6132863.11	213	10.9	0.89																					In SM
77	7		293066.45	6132865.05	214	13.1	0.77																					In SM
78	7		293067.42	6132866.76	215	15.0	0.53	X		X		C-F	PG-S	S		SM-F	F											Waters edge @ 14:00, lower edge of SM, start AM pegs
79	7		293069.09	6132869.75	216	18.4	0.45							SD-S														Inner edge AM seedlings (around 1.0m height)
80	7		293072.55	6132876.28	217	25.8	0.37							AM-S														In AM zone
81	7		293076.07	6132882.63	218	33.1	0.33																					Outer transect point (mangroves continuous across bay to island)
82	8	05/09/19	293180.17	6132791.08	230	0.0	1.11		SP			C-S																Kaykuyu and Casuarina needle layer
83	8		293179.93	6132794.70	231	3.6	1.00									SM-S	S											Start JK SM
84	8		293179.96	6132799.65	232	8.6	0.88																					In SM
85	8		293179.88	6132801.73	233	10.7	0.86											S							S			Start SV and BJ in SM
86	8		293179.86	6132803.25	234	12.2	0.85										F											Lower limits of JK
87	8		293180.08	6132806.46	235	15.4	0.75																					In SV and BJ SM
88	8		293180.01	6132809.80	236	18.7	0.65																					In SV and BJ SM
89	8		293180.00	6132812.45	237	21.4	0.61	X				C-F	PG-S	S		SM-F		F							F			Lower limit of SV and BJ SM, start of AM pegs
90	8		293180.14	6132814.45	1005	23.4	0.52							SD-S														Inner edge of AM seedlings 2m out from point 237
91	8		293180.34	6132817.32	238	26.3	0.43			X																		Waters edge @ 15:20
92	8		293180.50	6132822.87	239	31.8	0.40							AM-S														In AM zone
93	8		293179.58	6132835.06	240	44.1	0.38																					Outer transect point (mangroves continue)
94	8					50.8		29.4						A-S														Adults start, outer transect point (mangroves continuous across bay to island)
95	9	05/09/19	293462.19	6132795.13	250	0.0	1.02		SP			C-S													S			Lower edge of Gahnia, start of BJ, Casuarinas generally continuous throughout
96	9		293460.63	6132799.28	251	4.4	1.11																					In BJ SM
97	9		293458.44	6132803.36	252	9.1	1.05																					In BJ SM
98	9		293456.82	6132808.38	253	14.3	1.05																					In BJ SM
99	9		293455.84	6132811.61	254	15.4	0.94					C-F																Lower edge of Casuarinas
100	9		293455.44	6132812.70	255	17.7	0.91									SM-S		S										Start of SV in SM
101	9		293456.63	6132809.39	256	18.9	0.99										S											Start JK
102	9		293453.60	6132816.06	257	22.7	0.75																					In JK/SV/BJ SM
103	9		293452.11	6132819.77	258	26.7	0.54	X						S		SM-F	F	F							F			Lower edge of JK/SV/BJ SM, start AM pegs
104	9		293451.27	6132821.45	259	28.6	0.50																					Inner edge AM seedlings (around 0.8m height)
105	9		293449.97	6132828.22	261	35.5	0.32			X																		Rough estimate of inner waters edge @ 15:50
106	9		293445.49	6132833.90	260	42.7	0.37																					Outer transect point (mangroves continue)
107	9					58.3								A-S														Adults start, outer transect point (mangroves continuous across bay to island)
108	10	05/09/19	293570.88	6132891.02	270	0.0	1.16		SP			LN-F, C-S													S			Lower edge of lantana/ bracken fern, start of BJ
109	10		293566.77	6132893.33	271	4.7	1.09																					In BJ SM
110	10		293563.26	6132895.39	272	8.8	1.01																					In BJ SM
111	10		293560.40	6132897.55	273	12.4	0.88					C-F																Lower edge of Casuarinas,
112	10		293559.78	6132898.01	274	13.1	0.84									SM-S		S							F			Lower edge of BJ, start of SV
113	10		293558.85	6132898.83	275	14.4	0.78										S											Start JK
114	10		293556.73	6132900.05	276	16.8	0.73																					In SV/JK SM
115	10		293554.53	6132902.08	277	19.8	0.66																					In SV/JK SM
116	10		293551.91	6132903.75	278	22.9	0.52							SD-S														Inner edge of AM seedlings (0.1 to 0.2m height)
117	10		293551.12	6132904.13	279	23.8	0.45	X					PG-S	S		SM-F	F	F										Lower edge of SV/JK SM, start of AM pegs
118	10		293548.81	6132905.78	281	26.6	0.37																					Start larger AM seedlings (1.0m in height)
119	10		293546.15	6132907.22	280	29.7	0.34			X																		Waters edge @ 14:37
120	10					36.3	0.34																					Outer transect point
121	10					52.7		29						A-S														Adults start, outer transect point (mangroves continuous across bay to island)
122	11	06/09/19	293649.84	6133063.57	450	0.0	1.20		SP			LN-F, C-S				SM-S						S						Edge of lantana, start of SR and RI (forming dense mat with predonminantly SR)
123	11		293647.94	6133064.47	451	2.1	0.98										S					F						Lower edge of SR/RI, start of JK SM
124	11		293644.12	6133065.78	452	6.1	0.78																					In JK SM
125	11		293641.32	6133066.72	453	9.1	0.74										F	S										Lower edge of JK, start of SV
126	11		293639.14	6133067.70	454	11.5	0.69										S	F										Lower edge of SV, start of JK
127	11		293637.76	6133068.40	455	13.0	0.69					C-F					F	S										Lower edge of JK, start of SV
128	11		293636.20	6133068.83	456	14.7	0.70										S											Start of SV/JK combined
129	11		293632.58	6133069.82	457	18.4	0.55	X								SM-F	F											Lower edge of JK/SV SM, mud substrate
130	11		293631.50	6133070.06	458	19.5	0.49						PG-S	SD-S														Inner edge of AM pegs, AM seedlings (0.1 to 0.4m height) and tufted SV patch
131	11					19.9		1.5						S														Mangroves start
132	11		293629.44	6133070.65	459	21.7	0.45																					Outer edge of isolated SV patch
133	11		293627.61	6133070.94	460	23.5	0.47																					Inner edge of isolated SV patch
134	11		293627.24	6133070.95	461	23.9	0.37																					Outer edge of isolated SV patch
135	11		293626.47	6133071.19	462	24.7	0.43																					Inner edge of isolated SV patch
136	11		293625.95	6133071.26	463	25.2	0.43											F										Outer edge of isolated SV patch
137	11		293617.31	6133071.72	464	33.9	0.35																					Outer transect point (mangroves continue), no water in transect @10:15am
138	12	06/09/19	293661.89	6133244.86	470	0.0	1.03		SP			C-S											S					Upper' edge of sparse TT (very flat transect)
139	12		293658.02	6133243.58	471	4.1	1.14																					In TT zone (sparse growths overlying Casuarina needle layer)
140	12		293654.22	6133242.37	472	8.1	1.17																					In TT zone (sparse growths overlying Casuarina needle layer)
141	12		293651.37	6133241.12	473	11.2	1.18																F	S				Lower edge of TT, start RC
142	12		293648.94	6133240.35	474	13.7	1.10																					In RC (dense growth)
143	12		293646.91	6133239.95	475	15.8	1.01					C-F				SM-S			S					F				Lower edge of RC, start of SA (dense growth)
144	12		293642.82	6133238.32	476	20.2	0.73											S	F									Lower edge of SA, start of SV

Sort	Site	Date	GDA 94 MGA 56		Survey	Distance	RL AHD	Mangrove	Codes	Water	Sed	Start and finish distances																Notes:
			Easting	Northing	Point	m	m	Transect SP	Trans			Tree	Peg	Mang	Zostera	SM	JK	SV	SA	SQ	TS	SR	TT	RC	BJ	ET	FN	
145	12		293641.96	6133237.86	477	21.2	0.63	X					PG-S			SM-F		F										Lower edge of SV, start of mud and AM pegs
146	12		293641.54	6133237.91	478	21.6	0.56							SD-S														Inner edge of AM seedlings
147	12					21.8								S														Start of mangroves
148	12		293633.43	6133237.70	479	29.7	0.35							AM-S														In mangrove zone
149	12		293626.25	6133238.33	480	36.9	0.24																					Outer transect point (mangroves continue)
150	12					56.1								F														Finish mangroves
151	12					79.9								S														Mangroves start and continue
152	13	06/09/19	293667.53	6133260.84	490	0.0	0.94		SP			C-S																In riparian zone with Casuarinas and understorey consisting only of Casuarina needle layer
153	13		293668.32	6133261.59	491	1.1	1.00									SM-S		S										Start of SV
154	13		293670.27	6133263.05	492	3.5	1.10																					In SV SM
155	13		293671.60	6133264.31	493	5.4	1.18																					In SV SM
156	13		293672.64	6133265.25	494	6.8	1.02																					In SV SM
157	13		293672.92	6133265.43	495	7.1	0.91																					In SV SM
158	13		293673.25	6133265.59	496	7.5	0.75	X				C-F				SM-F		F										Lower edge of SV, start of mud
159	13							0.2						S														Start of mangroves
160	13		293673.61	6133265.82	497	7.9	0.64							SD-S														AM seedling start (around 0.1 to 0.3m height)
161	13		293673.79	6133266.03	511	8.2	0.60						PG-S															Inner edge of AM pegs
162	13		293674.72	6133266.56	498	9.2	0.47																					In AM seedlings
163	13		293675.22	6133266.68	499	9.7	0.47											S										Inner edge of isolated SV patch
164	13		293675.39	6133266.77	510	9.9	0.46											F										Outer edge of isolated SV patch
165	13		293679.19	6133269.54	512	14.6	0.34																					In AM zone (mostly pegs, not many seedlings)
166	13		293682.88	6133272.53	514	19.4	0.28			X																		Water line @12:05
167	13		293685.95	6133275.23	513	23.5	0.25																					In AM zone (mostly pegs, not many seedlings), outer transect point (mangroves continue)
168	13					65.6		58.4						F														Mangroves finish
169	13					67.6		60.0																				Sparse Zostera starts past the end of the tape
170	14	06/09/19	293827.40	6133086.78	520	0.0	1.16		SP			LN-F, CS-S				SM-S	S								S			Edge of lantana, start of JK/BJ zone (Casuarinas generally continuous throughout section)
171	14		293828.09	6133089.14	521	2.5	1.06															S						In JK/BJ SM (some sparse SR adjacent to transect)
172	14		293829.42	6133091.53	522	5.2	1.05										F								F			Lower edge of JK/BJ, start of SR patch
173	14		293829.85	6133092.43	523	6.2	1.03										S					F			S			Lower edge of SR, start of JK/BJ SM
174	14		293831.75	6133096.00	524	10.2	1.03																					In JK/BJ SM
175	14		293834.38	6133100.90	525	15.8	0.83										F	S							F			Lower edge of JK/BJ, start of SV patch
176	14		293835.66	6133102.90	526	18.2	0.67				BM-S							F										Lower edge of SV, start of mud basin (with coverage of Casuarina needle layer)
177	14		293836.43	6133103.78	527	19.3	0.65																					In mud basin
178	14		293837.27	6133104.74	528	20.6	0.67				BM-F						S	S										End of mud basin, start of SV/JK SM
179	14		293839.27	6133108.26	529	24.7	0.72					C-F					F											End of JK, SV continues and Casuarina stops
180	14		293839.93	6133109.71	530	26.3	0.67						PG-S															In SV SM zone, start of AM pegs
181	14		293841.50	6133112.09	531	29.1	0.63						PG-F															In SV SM zone, stop of AM pegs
182	14		293842.73	6133114.01	532	31.4	0.65																					In SV SM zone
183	14		293843.91	6133115.96	533	33.7	0.82					C-S								S								In SV SM zone (on berm), SQ and Casuarina start
184	14		293845.16	6133116.37	534	35.0	0.97											F										Stop of SV, SQ continues
185	14		293846.26	6133117.98	535	36.9	0.91												S	F								Lower edge of SQ, SA starts
186	14		293847.06	6133119.74	537	38.9	0.80										S	S	F									Lower edge of SA, start of SV/JK
187	14		293848.04	6133121.21	538	40.6	0.76										F											Lower edge of JK, SV continues
188	14		293848.49	6133121.93	539	41.5	0.63	X				C-F	PG-S	SD-S		SM-F		F										Lower edge of SV, start of AM seedlings and pegs
189	14					41.2		0.2						S														Start of mangroves
190	14					44.0		3						A-S														Adults start
191	14		293849.96	6133124.61	540	44.5	0.49							AM-S														Mature AM
192	14		293849.45	6133127.33	541	47.3	0.45			X																		Waters edge @ 12:55
193	14		293851.23	6133133.21	542	53.5	0.25																					Outer transect point (mangroves continue)
194	14					81.0		40						A-F														Adults finish
195	14					97.6		56.6						F														Finish of mangroves
196	15	06/09/19	294264.08	6133046.13	550	0.0	1.01		SP			C-S				SM-S	S	S										End of Casuarina needle layer (and dense Casuarina forest), start of JK/SV SM (and sparse Casuarina growth)
197	15		294262.63	6133047.60	551	2.1	0.97										F					S						End of JK, SV continues and SR starts
198	15		294260.09	6133050.38	552	5.8	0.95															F						End of SR, SV continues
199	15		294258.34	6133052.23	553	8.4	0.97										S					S						Start of SR and JK, SV continues
200	15		294257.20	6133053.52	554	10.1	0.90										F	F		S		F						End of SR/JK/SV, start of SQ (dense SQ growth)
201	15		294254.86	6133056.29	555	13.7	0.85					C-F						S		F								End of SQ, start of SV (dense SV growth)
202	15		294252.72	6133057.96	556	16.4	0.85											F	S									End of SV, start of SA
203	15		294251.26	6133059.62	557	18.7	0.80												F		S							End of SA, start of TS
204	15		294249.91	6133061.41	558	20.9	0.74				BM-S										F							End of TS, start of bare mud basin
205	15		294247.69	6133064.56	559	24.7	0.77				BM-F										S							End of bare mud basin, start of TS
206	15		294246.14	6133066.26	560	27.0	0.84										S				F							End of TS, start of JK (dense JK growth)
207	15		294244.16	6133068.50	561	30.0	0.99											S										Start of SV, JK continues
208	15		294242.77	6133069.98	562	32.1	1.01					C-S																In SV/JK SM
209	15		294241.39	6133071.74	563	34.3	0.94																					In SV/JK SM
210	15		2942[illegible].67	6133073.77	564	37.7	0.77					C-F				SM-F	F	F										End of SV/JK SM, start of mud
211	15		294238.25	6133074.07	565	38.2	0.59	X		X			PG-S															Waters edge @ 14:15, AM pegs start
212	15					38.4		0.3						S														Start of mangroves
213	15		294237.13	6133074.90	566	39.6	0.51							SD-S														Inner edge of AM seedlings
214	15					41.6		3.5						A-S														Start of adult mangroves
215	15		294233.95	6133076.79	567	43.3	0.44							AM-S														Outer transect point at mature AM (mangroves continue)
216	15					75.7		37.6						A-F														Finish of adult mangroves
217	15					80.7		42.6						F														Mangroves finish. No seagrass just slimy silt over gravel rock

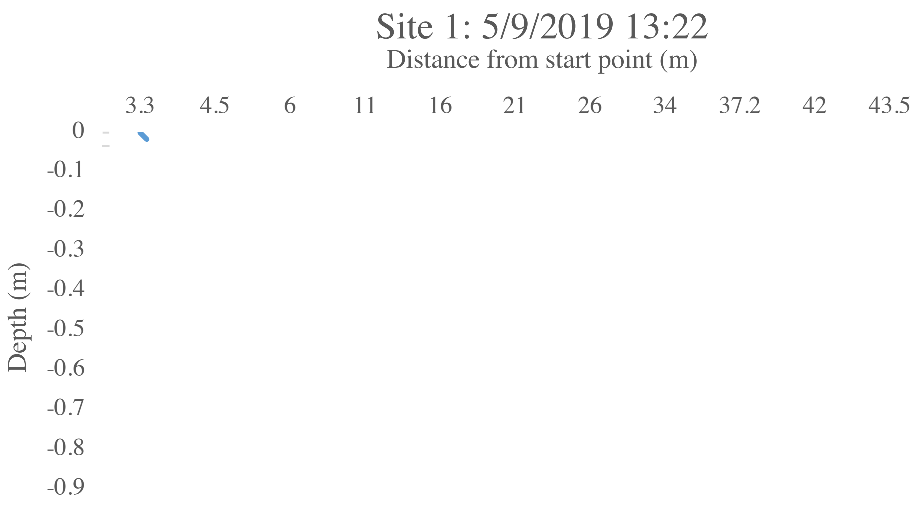
Sort	Site	Date	GDA 94 MGA 56		Survey	Distance	RL AHD	Mangrove	Codes	Water	Sed	Start and finish distances																Notes:
			Easting	Northing	Point	m	m	Transect SP	Trans			Tree	Peg	Mang	Zostera	SM	JK	SV	SA	SQ	TS	SR	TT	RC	BJ	ET	FN	
218	16	06/09/19	294301.58	6132960.00	580	0.0	1.30		SP																S			End of Gahnia and bracken, start of BJ
219	16		294306.84	6132961.43	581	5.5	1.11					C-S																In BJ SM (Casuarina continuous throughout transect section)
220	16		294312.60	6132963.04	582	11.4	1.02																					In BJ SM
221	16		294318.19	6132963.67	583	17.1	1.02									SM-S	S					S						Start sparse JK and SR, BJ continues
222	16		294319.72	6132964.46	584	18.8	1.01															F						End of SR, JK/BJ continue
223	16		294323.10	6132965.38	585	22.3	1.01																					In JK/BJ SM
224	16		294330.55	6132967.22	586	30.0	0.78										F	S							F			Lower edge JK/BJ, start of SV
225	16		294334.63	6132968.53	587	34.2	0.70					C-F						F										Edge of SV, start of exposed mudflat (end of Casuarina)
226	16		294346.33	6132971.77	588	46.4	0.69																					Waters edge @ 15:15
227	16		294361.82	6132974.02	589	62.0	0.63																					Approximate inner edge of SM plants, though none within 10m of transect line
228	16		294370.76	6132976.13	590	71.2	0.61																					Estimated edge of tyre marks
229	16		294377.34	6132980.76	591	79.3	0.58												1									Single 200mm SA
230	16		294377.63	6132980.69	592	79.6	0.60												1									Single 200mm SA
231	16		294378.51	6132980.46	593	80.5	0.59												1									Single 300mm SA
232	16		294379.09	6132980.06	594	81.2	0.60													1								Single 300mm SQ
233	16		294381.15	6132980.52	595	82.6	0.58													S								Start SQ
234	16		294381.91	6132980.60	596	83.5	0.57													F								End of SQ
235	16		294380.45	6132979.90	597	84.3	0.58						PG-S															Inner edge (general line) of AM seedlings and pegs (sparse AM seedling growths, none in direct contact with t
236	16		294387.18	6132981.26	598	89.6	0.54													1								Single 200mm SQ
237	16		294387.46	6132981.06	599	89.9	0.57							1														Single 200mm high AM seedling
238	16		294389.97	6132981.68	600	92.5	0.55							1														Single 300mm high AM seedling
239	16		294391.02	6132981.54	601	93.5	0.54												1									Single 300mm SA
240	16		294395.39	6132982.34	602	98.0	0.54							SD-S														Start of denser AM seedlings (0.2 to 1.0m height)
241	16		294413.51	6132982.48	603	116.1	0.53							AM-F				S										End of AM's, start of SV SM
242	16		294415.20	6132982.64	604	117.8	0.51							1														Single 500mm high AM seedling
243	16		294417.05	6132983.23	605	119.7	0.55						PG-F															Outer edge of AM pegs
244	16		294420.68	6132983.53	606	123.4	0.51																					In SV SM
245	16		294424.89	6132984.06	607	127.6	0.58					C-S					S											Start of berm (mound), JK and Casuarina, SV continues
246	16		294426.77	6132984.52	608	129.6	0.82																					On berm in SV/JK
247	16		294428.35	6132984.91	609	131.2	0.93																					On berm in SV/JK
248	16		294431.25	6132985.48	610	134.2	0.92																					On berm in SV/JK
249	16		294433.48	6132985.24	611	136.4	0.96		TB																			Top of short sloping bank
250	16		294434.01	6132985.44	612	137.0	0.74	X	BB			C-F				SM-F	F	F										Bottom of short sloping bank, end SV/JK and of Casuarinas
251	16		294434.75	6132985.55	613	137.7	0.61			X			PG-S															Waters edge @ 15:45, start of AM pegs
252	16		294435.54	6132985.54	614	138.5	0.52							SD-S														Inner edge of AM seedlings
253	16		294441.07	6132986.12	615	144.1	0.33																					Outer transect point, mangroves continue
254						147.1		3.0						A-S														Adults start
255						169.7		32.0						A-F														Outer mangrove limit
256	17	17/10/19	294438.05	6132815.44	1001	0.0	1.41		SP		LN-F, BB-F, C-S																	Edge of lantana and bitou bush, start of Casuarina needle layer (mature Casuarina canopy overhead)
257	17		294440.88	6132818.71	1002	4.3	1.26																					In Casuarina needle layer.
258	17		294444.03	6132821.69	1003	8.7	1.15																		S			Start of BJ
259	17		294446.13	6132823.79	1004	10.0	1.15																					In BJ
260	17		294449.24	6132827.05	1005	16.1	1.11																					In BJ
261	17		294452.00	6132829.17	1006	19.6	0.98									SM-S		S										In BJ, start SV
262	17		294454.05	6132830.64	1007	22.1	0.91					C-F					S								F			Stop BJ, start of JK and SV continues
263	17		294456.41	6132833.03	1008	25.5	0.86										F											End of JK, SV continues
264	17		294457.51	6132834.29	1009	27.2	0.73				BM-S							F										Abrupt end to SV, start bare mud (inshore or berm muddy patches with mangroves)
265	17		294459.14	6132835.48	1010	29.2	0.73							SD-S														Inner edge of AM seedlings (mostly around 0.8m high with some mature AMs adjacent transect)
266	17		294461.20	6132836.71	1011	31.6	0.74							SD-F														End AM seedlings, mud continues
267	17		294461.57	6132836.88	1012	32.0	0.76				BM-F							S										End mud, start dense SV
268	17		294464.88	6132840.16	1013	33.0	0.76																					In SV
269	17		294466.36	6132841.22	1014	38.5	0.81										S											In SV, start JK
270	17		294469.11	6132843.36	1015	40.0	0.80					C-S																In SV/JK (Casuarina canopy on berm starts)
271	17		294471.15	6132844.77	1016	44.4	1.04																S					In SV/JK, TT starts
272	17		294474.08	6132846.80	1017	48.0	1.10																F					In SV/JK, TT stops
273	17		294474.85	6132847.35	1018	49.0	1.09										F									S		End JK, start sparse Chenopodiaceae (?ET) and SV continues
274	17		294477.25	6132848.46	1019	51.6	1.06																			F		End (?) ET, SV continues
275	17		294477.93	6132850.84	1020	54.1	0.98											F	S									End SV, start SA
276	17		294480.12	6132852.65	1021	56.9	0.90					C-F																In SA (outer edge of Casuarina canopy)
277	17		294482.33	6132854.54	1022	59.8	0.83										S	S	F									End SA, start SV/JK
278	17		294483.16	6132854.94	1023	60.7	0.86																					In SV/JK (on 'berm')
279	17		294483.71	6132855.20	1024	61.3	0.89																					In SV/JK (on 'berm')
280	17		294484.70	6132855.64	1025	62.4	0.90																					In SV/JK (on 'berm')
281	17		294484.97	6132855.87	1026	62.8	0.87		TB							SM-F	F	F										Top of bank, end SV/JK
282	17		294485.08	6132855.89	1027	62.9	0.67	X	BB	X			PG-S															Bottom of bank, inner edge of AM mangrove pegs, waters edge @ 11:05
283	17		294487.82	6132856.11	1028	63.7	0.54							SD-S														Inner edge AM seedlings (mostly small 10-20cm high)
284	17		294489.16	6132859.15	1029	68.2	0.40							A-S														In AM mangrove zone
285	17		294491.64	6132860.71	1030	71.1	0.36																					Outer transect point (mangroves continue)
286						88.1								A-F														Outer mangrove limit

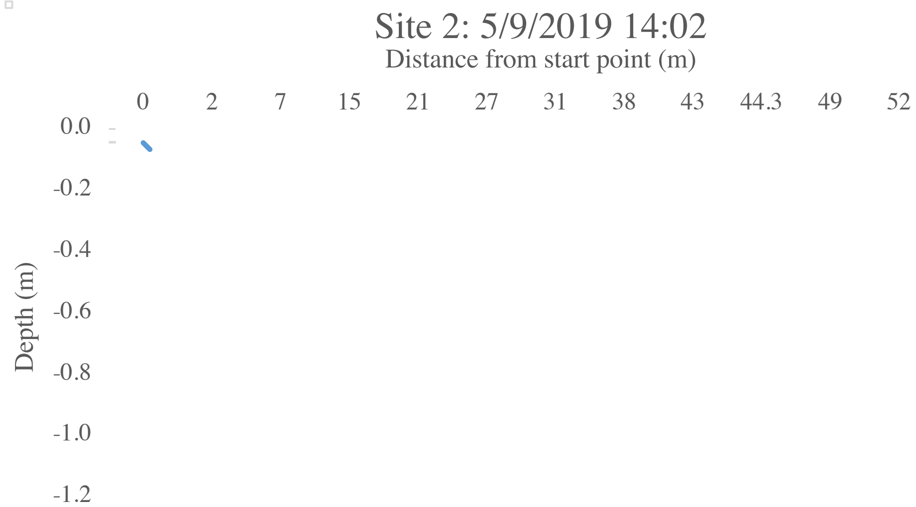
Sort	Site	Date	GDA 94 MGA 56 Easting	Northing	Survey Point	Distance m	RL AHD m	Mangrove Transect SP	Codes Trans	Water	Sed	Tree	Peg	Mang	Zostera	SM	JK	SV	SA	SQ	TS	SR	TT	RC	BJ	ET	FN	Notes:
												Start and finish distances																
287	18	17/10/19	294650.01	6132698.46	1040	0.0	1.13		SP			LN-F, C-S																In Casuarina forest, needle layer covering ground
288	18		294651.10	6132700.37	1041	2.2	1.05																					Start of kaykuyu
289	18		294652.04	6132701.93	1042	4.0	1.02																					In Kaykuyu
290	18		294652.81	6132703.88	1043	6.1	0.94																					In Kaykuyu
291	18		294653.30	6132704.97	1044	7.3	0.94																S					In Kaykuyu, start sparse TT
292	18		294654.76	6132706.12	1045	9.2	0.90																					In Kaykuyu, in TT
293	18		294656.06	6132707.65	1046	11.2	0.88																F					End of Kaykuyu and TT, bare Casurina needle layer continues
294	18		294656.33	6132708.64	1047	12.2	0.86									SM-S	S											End bare Casuarina needle layer, start dense JK
295	18		294657.51	6132709.68	1048	13.8	0.80																					In JK
296	18		294657.99	6132710.82	1049	15.0	0.77					C-F						S										In JK, start SV, end of Casurina canopy
297	18		294659.67	6132713.42	1050	18.1	0.75																					In JK/SV (50/50 density of each)
298	18		294660.77	6132715.66	1051	20.6	0.72										F	F	S									End of JK/SV, start SA
299	18		294661.05	6132716.80	1052	21.8	0.73																					In SA
300	18		294661.73	6132717.50	1053	22.8	0.73																					In SA
301	18		294662.79	6132717.93	1054	23.9	0.63	X		X						SM-F			F									End of SA, waters edge @ 12:00, around 1m of wrack smothering edge banks
302	18		294662.91	6132718.12	1055	24.1	0.58						PG-S															Start AM pegs
303	18		294663.32	6132718.43	1056	24.6	0.54							SD-S														Start of AM seedlings (mostly < 20cm height)
304	18		294664.57	6132719.87	1057	26.5	0.45							A-S							0.45							Adults start
305	18		294667.90	6132723.81	1058	31.7	0.37																					In AM mangrove zone
306	18		294672.10	6132726.60	1059	36.7	0.27																					Outer transect point (mangroves continue)
307						55.1								A-F														Adults finish
308						62.9							PG-F															Peg roots finish
309	19	17/10/19	294782.05	6132633.12	1100	0.0	1.13		SP			C-S																In Casuarina forest, needle layer covering ground
310	19		294783.96	6132635.20	1101	2.8	1.11																				S	Start FN
311	19		294785.57	6132637.60	1102	5.7	1.11																					In FN (generally sparse among Casuarina needle layer)
312	19		294787.39	6132639.24	1103	8.2	1.02																					In FN (generally sparse among Casuarina needle layer)
313	19		294788.49	6132640.23	1104	9.6	1.02																				F	End of sparse FN, Casuarina needle layer continues
314	19		294789.93	6132642.19	1105	12.1	1.02																					Bare Casuarina needle layer
315	19		294791.36	6132643.24	1106	13.8	1.00																					Bare Casuarina needle layer
316	19		294793.40	6132645.43	1107	16.8	0.89					C-F				SM-S	S	S										Start SV/JK
317	19		294794.75	6132646.95	1108	18.9	0.77										F											End JK, SV continues
318	19		294796.41	6132649.01	1109	21.5	0.62																					In SV
319	19		294796.80	6132650.05	1110	22.6	0.62			X								F										End of SV, inshore tidal waters edge @ 13:05 (inshore of 'berm' coming from creek inlet)
320	19		294797.59	6132651.81	1111	24.6	0.59											S										Start SV, in water
321	19		294798.54	6132653.67	1112	26.7	0.62																					In SV
322	19		294800.23	6132655.94	1113	29.5	0.61			X																		In SV, inshore tidal water edge @13:10
323	19		294800.67	6132656.72	1114	30.4	0.64																					In SV
324	19		294802.02	6132658.10	1115	32.3	0.65																					In SV
325	19		294802.38	6132658.59	1116	32.9	0.66										S											In SV, start JK
326	19		294802.66	6132658.93	1117	33.4	0.71																					In SV/JK
327	19		294803.10	6132659.60	1118	34.2	0.57	X		X						SM-F	F	F										Edge SV/JK (some isolated tufts SV continue out adjacent to transect), waters edge @13:15
328	19		294803.14	6132659.79	1119	34.4	0.54						PG-S															Inner edge AM pegs
329	19		294803.28	6132660.05	1120	34.7	0.48							SD-S														Inner edge AM seedlings (around 10cm high and sparse)
330	19		294804.45	6132661.51	1121	36.5	0.39																					Inner edge AM seedlings (around 30 to 100cm high and dense)
331	19		294806.73	6132663.32	1122	39.4	0.37																					In AM mangrove zone
332	19		294809.88	6132667.41	1123	44.6	0.34																					Outer transect point (mangroves continue)
333						45.8								A-S														Adults start
334						88.2								A-F														Adults finish
335						91.2							PG-F															Outer meg limit

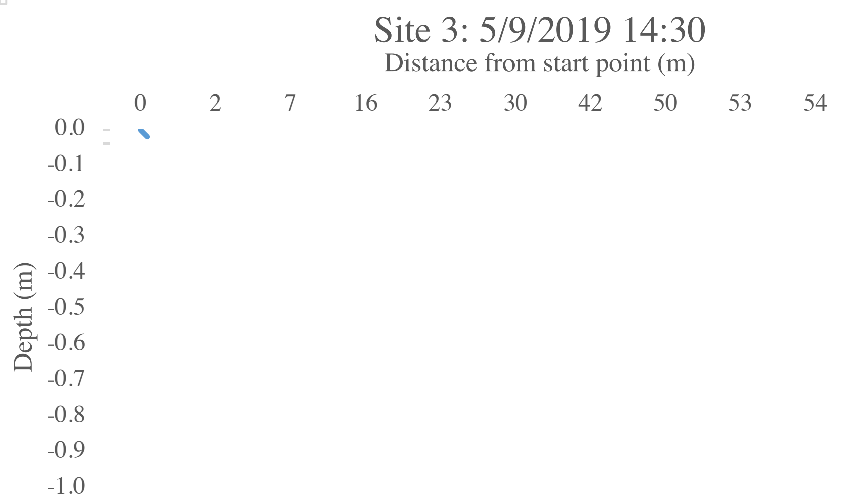
Note: Cells with no RL AHD values or coordinates were not provided by APS either in survey plans or data tables. Distance data for these points were calculated from coordinates.
Sites with no water mark distance values contained no water at the time of survey.

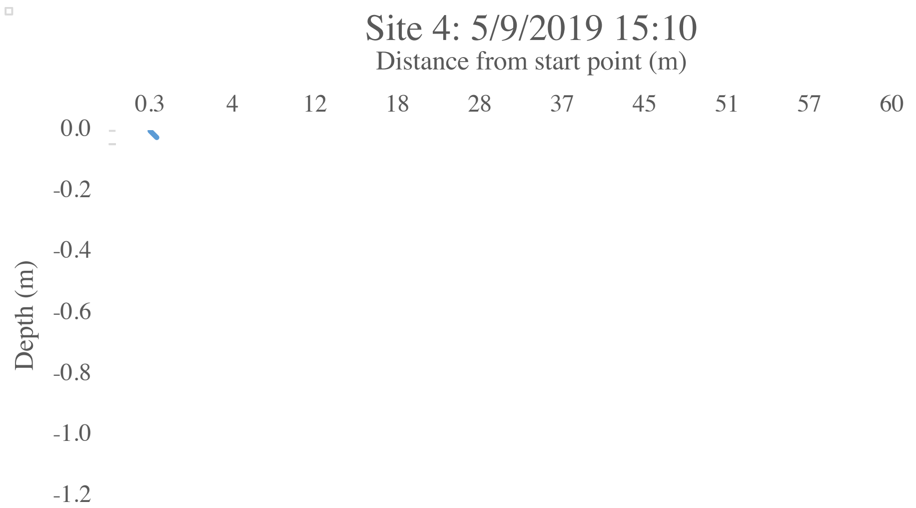
AM	Grey mangrove *Avicennia marina*	BB	Bottom of bank
BJ	*Baumea juncea*	BM	Bare Mud
ET	*?Enchylaena tomentosa*	BR	Bedrock
FN	*Ficinia nodosa*	CS	Casurina
JK	Sea Rush *Juncus kraussii*	LN	Lantana
RC	*Rhagodia candolleana*	S	Start
RI	*Ranunculus sp (inundatus?)*	F	Finish
SA	*Suaeda australis*	PF	Peg Finish
SQ	*Sarcocornia quinqueflora*	PG	Peg Start
SR	*Selliera radicans*	SD	Seedlings
SV	Salt Couch *Sporobolus virginicus*	SM	Saltmarsh
TS	Streaked Arrow Grass *Triglochin striata*	SP	Start point
TT	Native Spinach *Tetragonia tetragonoides*	TB	Top of bank
1	Single plant	TG	Terrestrial Grass

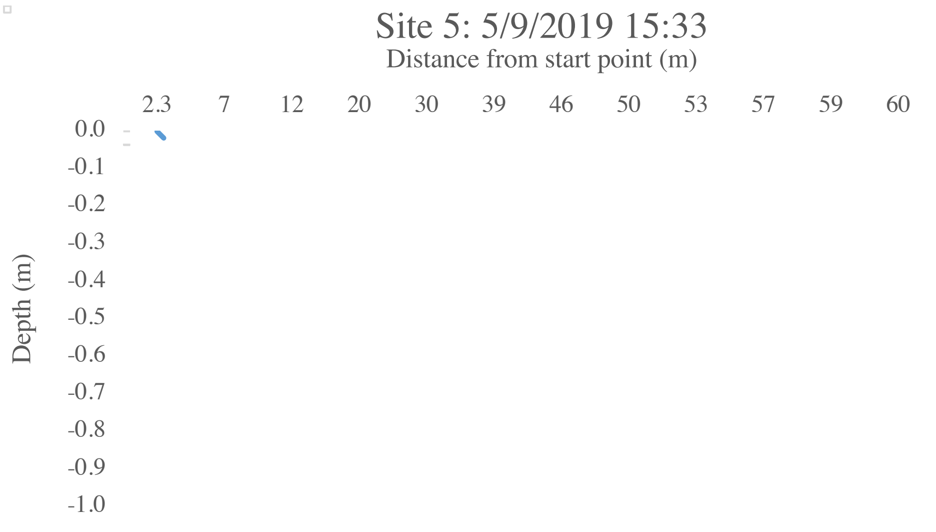
Anneuxure C-3 Depth Profile Figures are provided below for Transects 1 to 7 and 11 to 19. No depth profiling was undertaken at sites which contained no water at the time of inspection (Transects 8 to 10). Profiles begin at the waters edge (0m) with the distance from Mangrove Survey start points shown along the x-axis (see Table C-2 for Mangrove Survey start points).

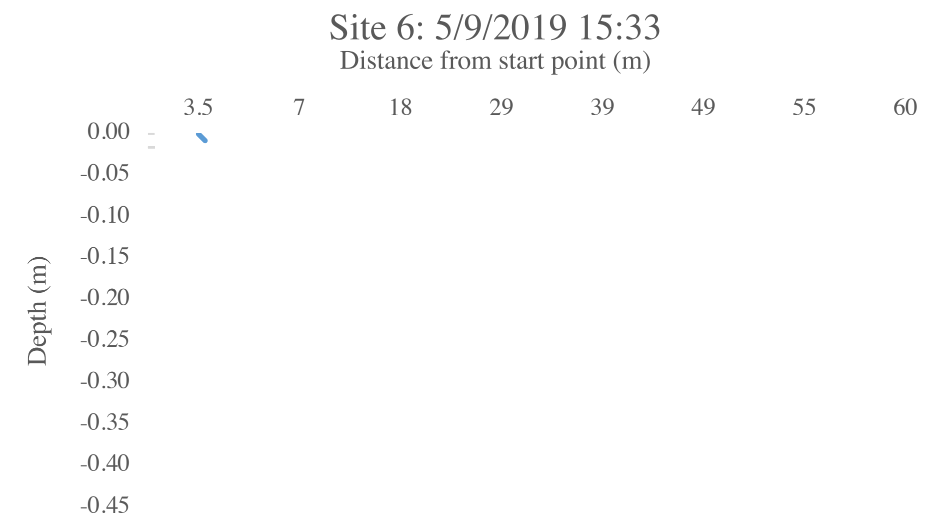


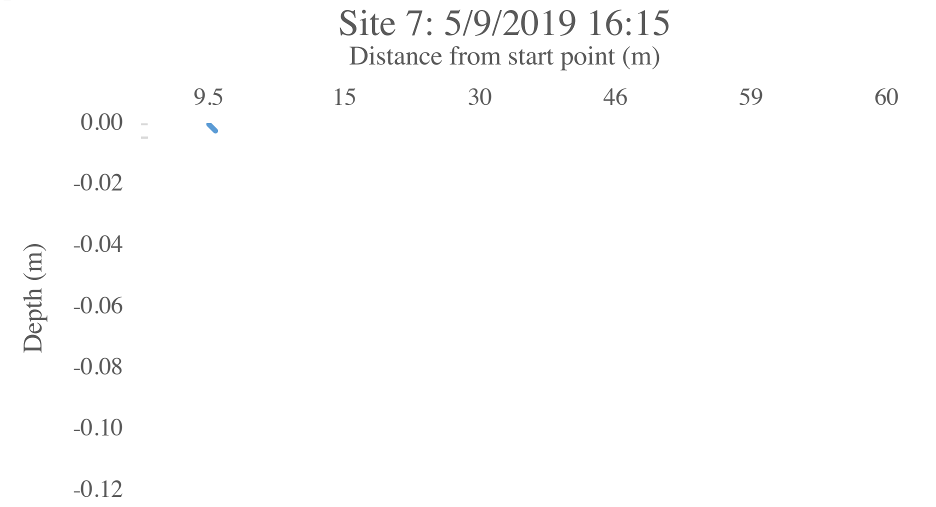


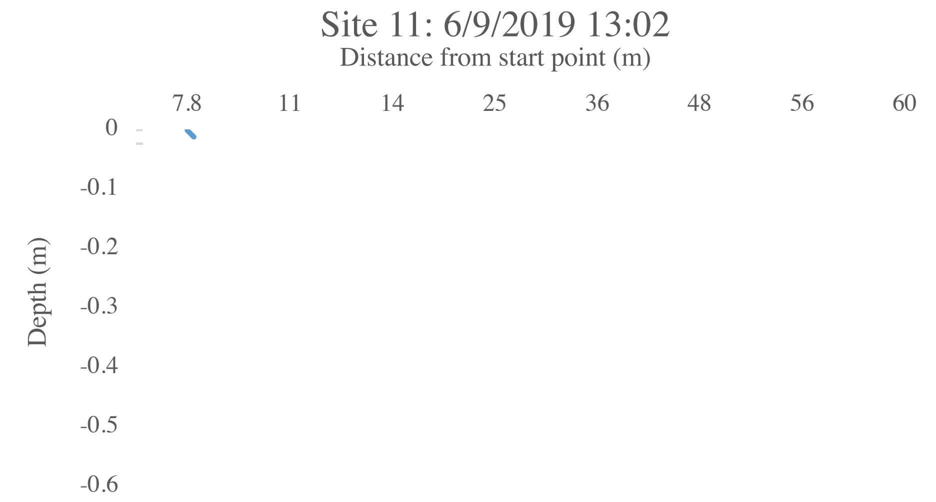


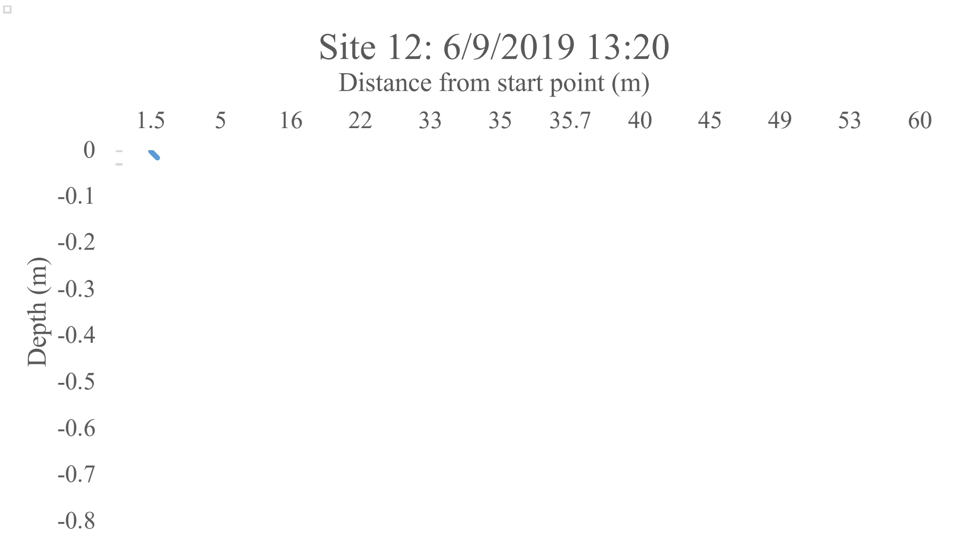


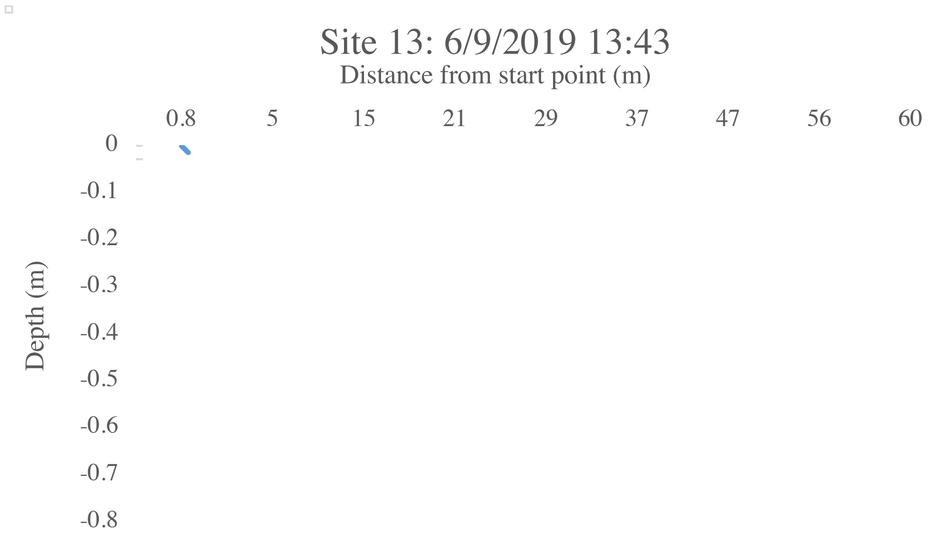

Site 5: 5/9/2019 15:33
Distance from start point (m)
2.3
7
12
20
30
39
46
50
53
57
59
60
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
Depth (m)

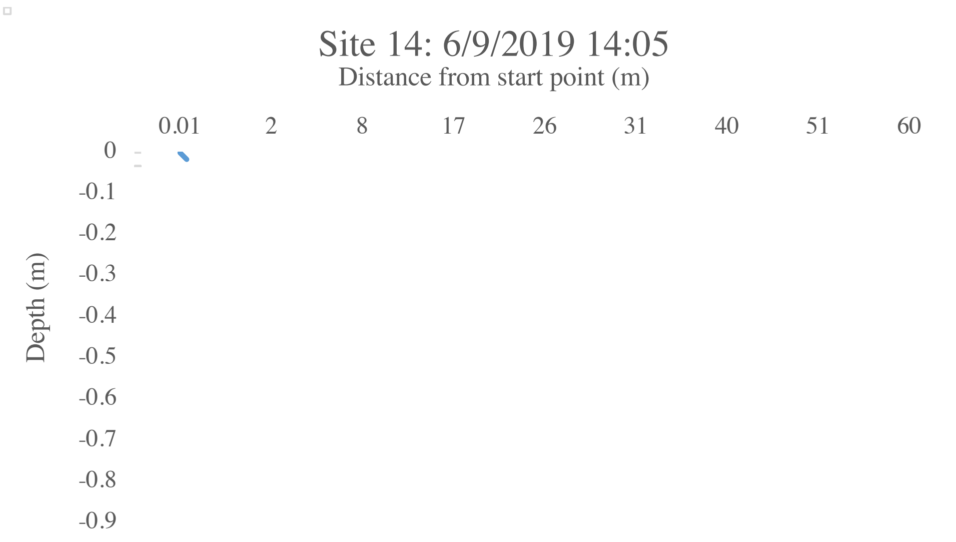

Site 6: 5/9/2019 15:33
Distance from start point (m)
3.5
7
18
29
39
49
55
60
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
Depth (m)

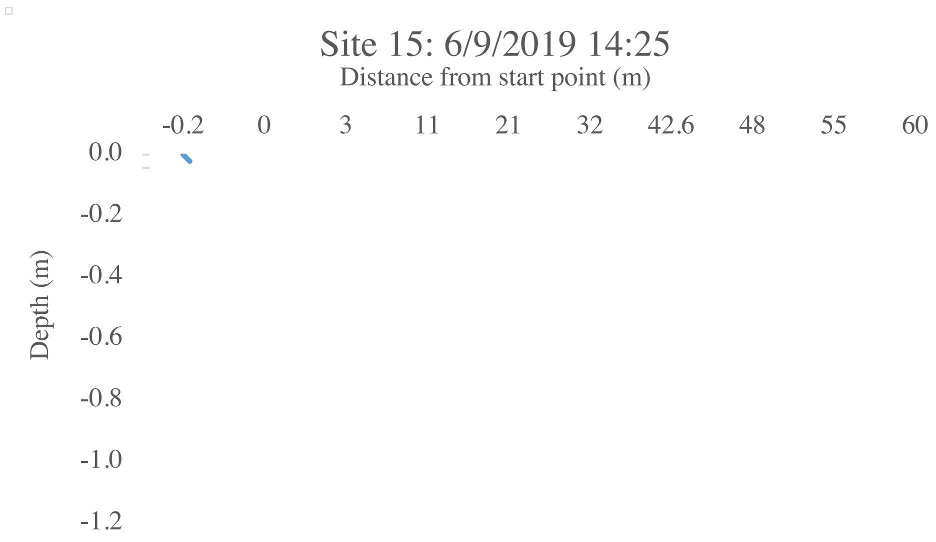

Site 7: 5/9/2019 16:15
Distance from start point (m)
9.5
15
30
46
59
60
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
Depth (m)

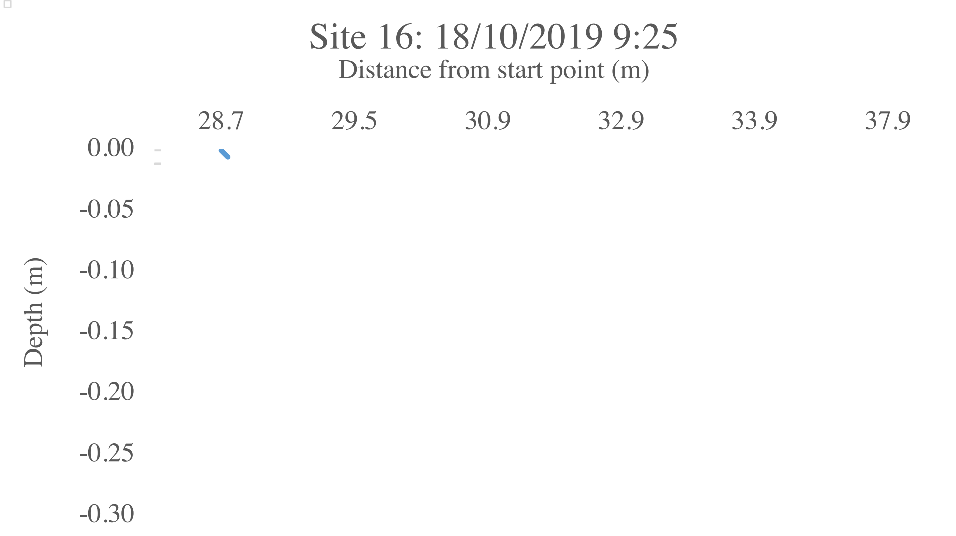

Site 11: 6/9/2019 13:02
Distance from start point (m)
7.8
11
14
25
36
48
56
60
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Depth (m)

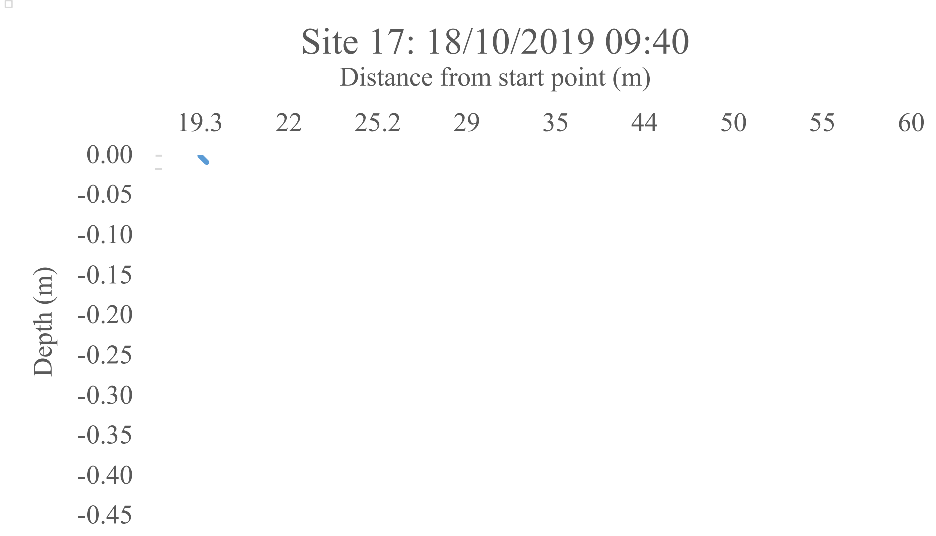

Site 12: 6/9/2019 13:20
Distance from start point (m)
1.5 5 16 22 33 35 35.7 40 45 49 53 60
0 -0.1 -0.2 -0.3 -0.4 -0.5 -0.6 -0.7 -0.8
Depth (m)

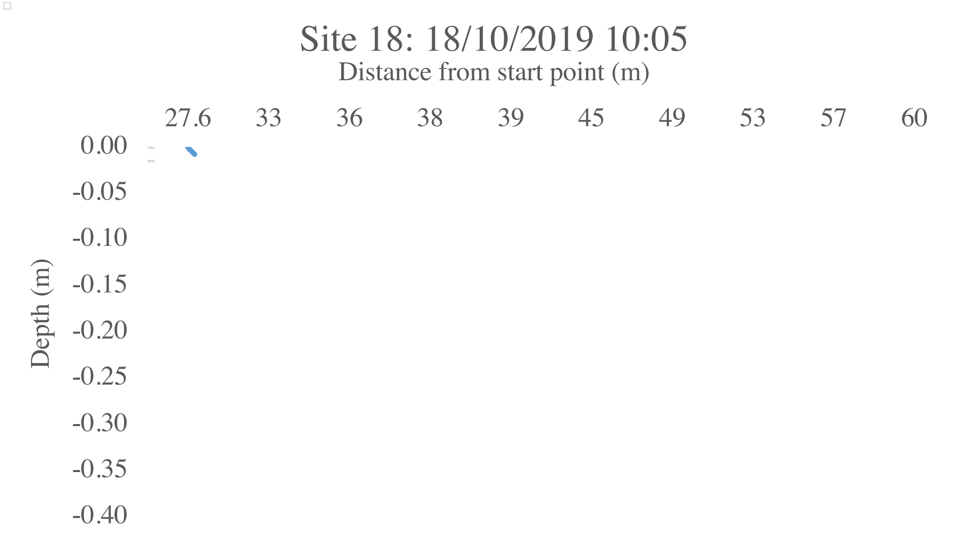

Site 13: 6/9/2019 13:43
Distance from start point (m)
0.8 5 15 21 29 37 47 56 60
0 -0.1 -0.2 -0.3 -0.4 -0.5 -0.6 -0.7 -0.8
Depth (m)


Site 14: 6/9/2019 14:05
Distance from start point (m)
0.01 2 8 17 26 31 40 51 60
0 -0.1 -0.2 -0.3 -0.4 -0.5 -0.6 -0.7 -0.8 -0.9
Depth (m)


Site 15: 6/9/2019 14:25
Distance from start point (m)
-0.2 0 3 11 21 32 42.6 48 55 60
0.0 -0.2 -0.4 -0.6 -0.8 -1.0 -1.2
Depth (m)


Site 16: 18/10/2019 9:25
Distance from start point (m)
28.7
29.5
30.9
32.9
33.9
37.9
Depth (m)
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30


Site 17: 18/10/2019 09:40
Distance from start point (m)
19.3
22
25.2
29
35
44
50
55
60
Depth (m)
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45


Site 18: 18/10/2019 10:05
Distance from start point (m)
27.6
33
36
38
39
45
49
53
57
60
Depth (m)
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40

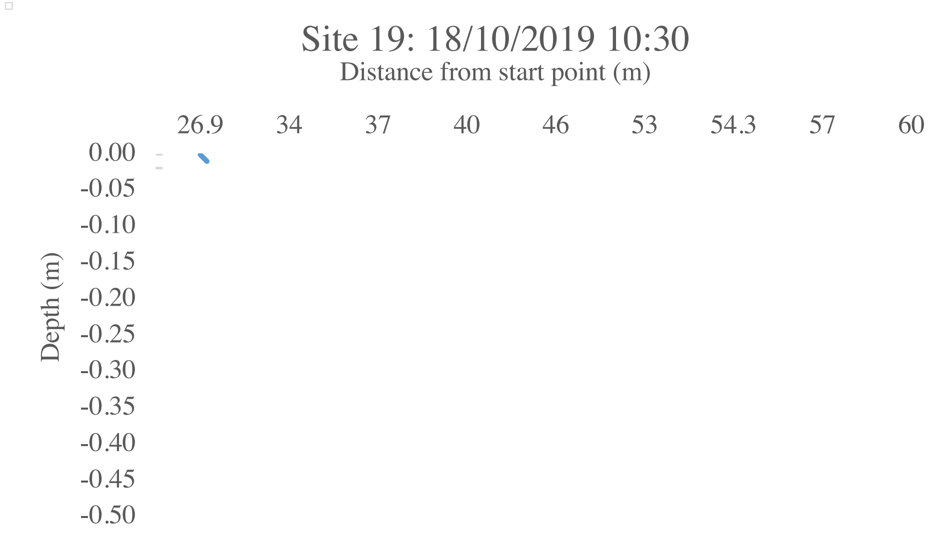

Site 19: 18/10/2019 10:30
Distance from start point (m)
26.9
34
37
40
46
53
54.3
57
60
Depth (m)
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
-0.50

Plate 1: Cactus Point intertidal mudflats showing juvenile and stunted mangroves, bedrock outcrops and sparse sea couch (Transect 2).

Plate 2: Sea rush dominated saltmarsh along the foreshore at Billys Bay.

Plate 3: Sea rush and sea couch saltmarsh with sporadic occurrences of grey mangrove seedlings at the lower limits (Billys Bay eastern end).

Plate 4: Cans Pt to Rocky Point saltmarsh (SW Bay) showing the high density grey mangrove seedling recruitment along the foreshore.

Plate 5: SW Bay saltpan with sea couch and sea rush dominated saltmarsh.

Plate 6: SW Bay mixed occupation saltmarsh (sea blite, streaked arrow grass, sea couch and sea rush).

Plate 7: Samphire at SW Bay.

Plate 8: Streaked arrow grass (foreground) and sea blite (background) in SW Bay.

Plate 9: Swamp weed growth along Billys Bay.

Plate 10: Rocky Point east showing very sparse growths of sea blite, samphire and grey mangrove seedlings.

Plate 11: Rocky Point east sea couch saltmarsh and grey mangroves.

Plate 12: Sea couch dominated saltmarsh behind foreshore berm, showing grey mangrove occupation in saltpan (Rocky Point east).

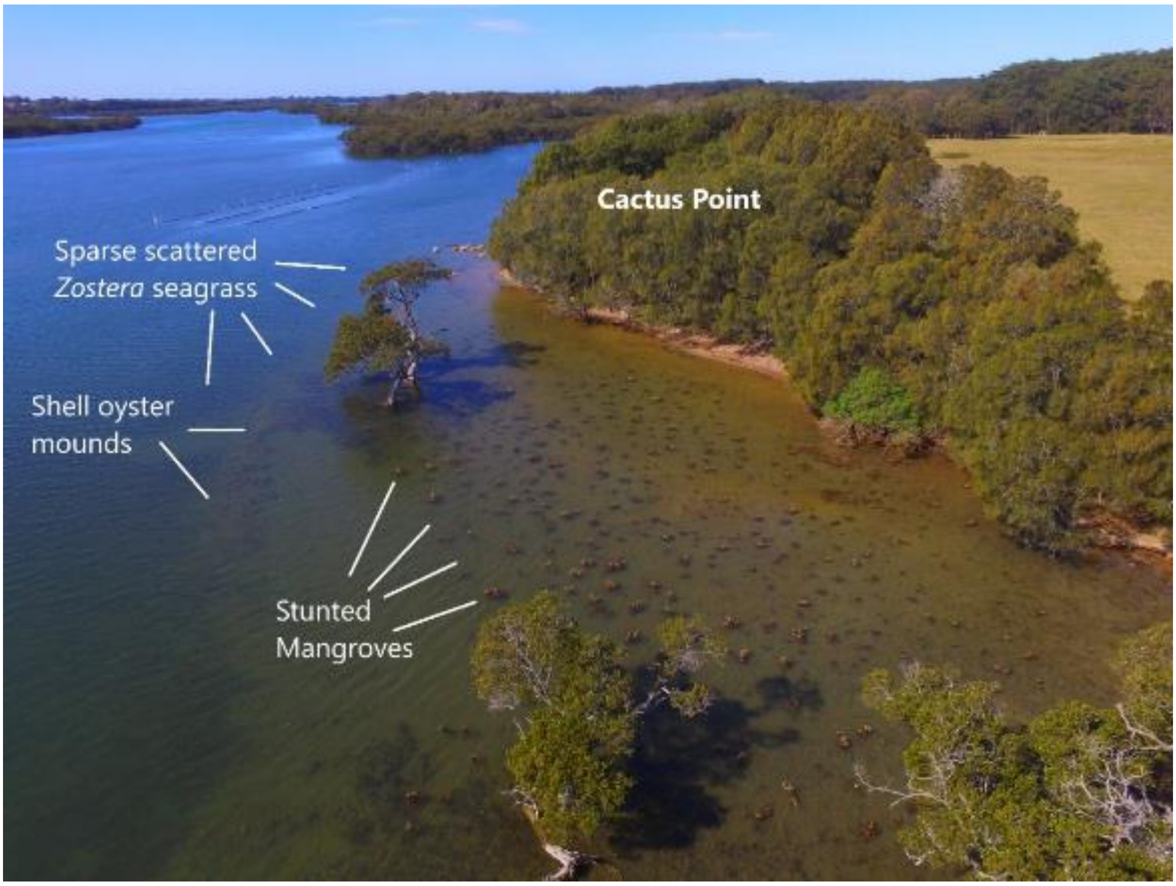


Plate 13: Aerial image of Cactus point looking ENE (4/9/20 high tide).

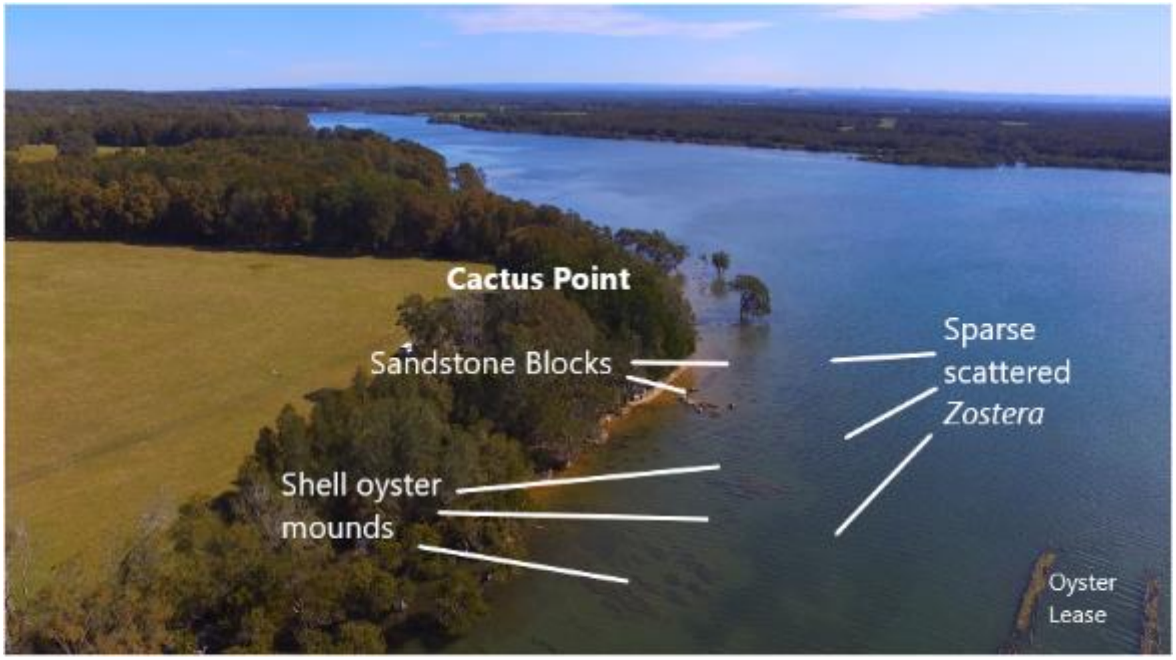


Plate 14: Cactus Point looking WNW (4/9/20 high tide).

Plate 15: Looking east over Billies towards Cans Point and Rocky Point (5/9/20 low tide).

Plate 16: Looking west through Billies Bay from Cans Point to Cactus Point (5/9/20 low tide).

Plate 17: Looking north through Crow Sth channel (5/9/20 low tide).

Plate 18: Looking North through Crow Sth channel to Crow Island, where River mangroves were found on the southern side of the island (5/9/20low tide).

Plate 19: Looking West towards Billies Island, over Crow W channel and the east drainage (5/9/20 low tide).

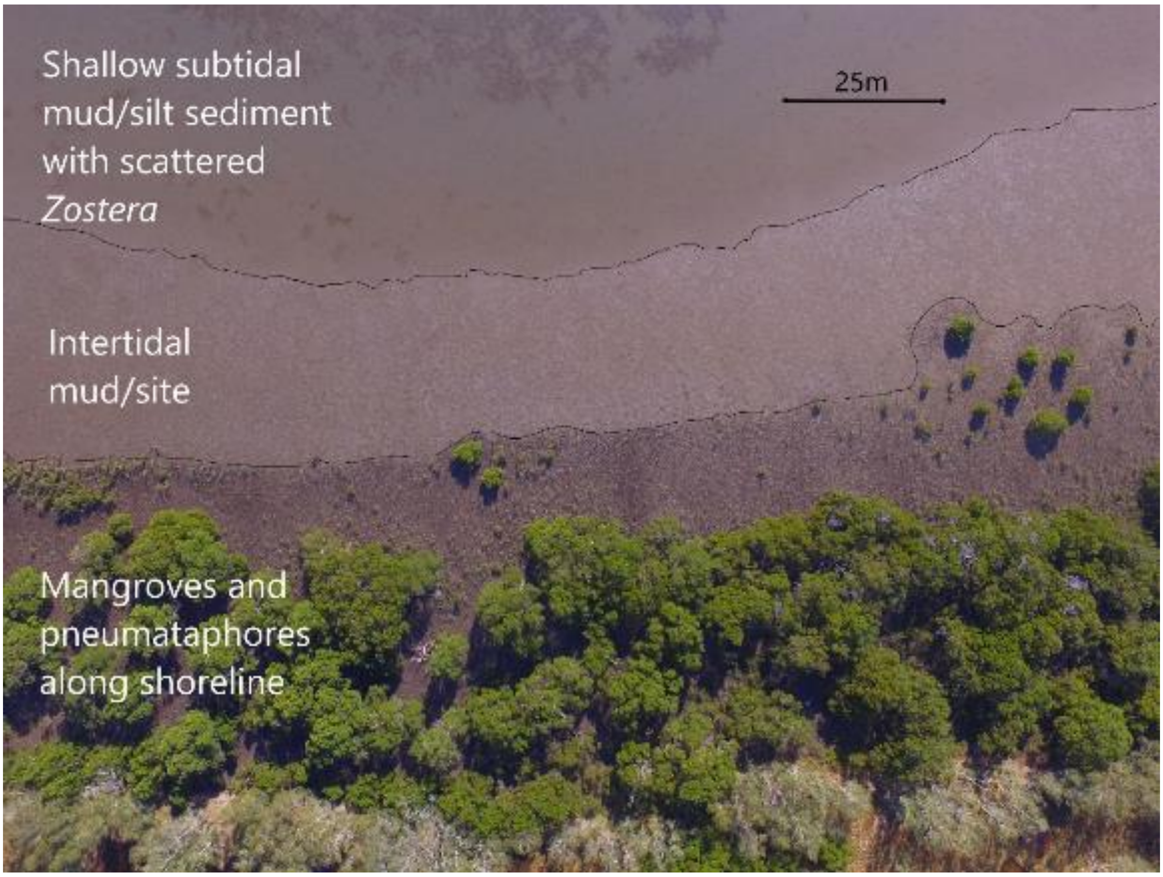


Plate 20: Drone shot of a section of SW bay. Typical intertidal zonation of Culburra West shoreline (5/9/20 low tide).

Plate 21: Looking West over SW bay towards Cans Point (5/9/20 low tide).

Plate 22: Looking SW from Rocky Point across the SW Bay saltmarsh (5/9/20 low tide).

Plate 23: Looking SE from Rocky Point, across the STP saltpan (5/9/20 low tide).

Table C-5 Assessment of Upper Crookhaven River/Curleys Bay Oyster Lease Status 2019-2020						
Oyster Lease	Location	Level of Certainty	Permanent Infrastructure	Farming Method	Observed September 2019 status: Stocking	Comments
1	Cactus Pt	Good	Posts and rails	Trays	1/2 Full	
2	Cactus Pt	Good	White posts	Hanging Baskets	Full	Long ropes
		Good		Boulder rock		Inshore intertidal catching structures
3	Billys Is East	Good	White posts		Empty	
4	Billys Bay	Good	Thin posts	Tumblers	Full	Short ropes
5	Billys Is West	Good	Thin posts	Tumblers	Full*	Short ropes
6	Crow S channel	Good	Posts and rails	Trays and baskets	Full	Short ropes
7	Crow S channel	Good	Posts and rails		Empty*	
8	SW Bay	Good	Posts		Empty	Maybe half to one third with rails attached to posts
		Good		Boulder rock		Inshore intertidal catching structures
9	Rocky Pt	Medium	Posts?		Empty	No infrastructure observed in photos
		Good		Boulder rock		Inshore intertidal catching structures
10	Rocky Pt	Medium	Posts		Empty	
		Good		Boulder rock		Inshore intertidal catching structures
11	SE Bay	Poor	?		?	Not visible, infrastructure or stock
12	SE Bay	Medium	Posts	Baskets or cylinders	1/2 Full	
13	SE Bay	Medium	Posts and rails		Empty	
14	Curleys Bay	Poor	?		?	Not visible, infrastructure or stock
15	Curleys Bay	Medium	Posts	Baskets or cylinders	? Full	
16	Curleys Bay	Poor	Posts	Possibly submerged trays	?	
17	Curleys Bay	Poor	?		?	Not visible, infrastructure or stock
18	Crow Channel	Medium	Posts		Empty	
19	Curleys Chan W	Medium	Posts	Baskets or cylinders	1/2 Full	
20	Greenwell Pt Chan S	Medium	Posts	Baskets or cylinders	Full	
21	Greenwell Pt Chan N	Poor	Posts			Not visible, infrastructure or stock
22	Goodnight Is SW	Poor	Posts	Baskets or cylinders		Not visible, infrastructure or stock
23	Crow Is N	Medium	Posts	Baskets or cylinders	Full	
24	Crook R N side					
Notes:	Certainty Level	Dependent on uncertainty around identifying infrastructure or farming methods or stocking from drones or out of range.				
	Baskets	Pillow shaped baskets				
	Tumblers	Round meshed cylinders with float				
	Short Ropes	Short ropes generally hang individual baskets/ tumblers (posts every 2m or so)				
	Posts	Most posts generally close to one another (maybe 1.5m to 2m apart).				
		Sites 11 to 17 were difficult to assess, with regards to identifying boundaries.				
		Sites shaded in grey are the closest lease areas to the Culburra West development.				
		*Sites confirmed during September 2020 fieldwork.				

Figure 1: Looking North West from Billys Island (Oyster Lease 4).

Figure 2: Looking North from the edge of Billys Island. (Oyster Lease 5)

Figure 3: Looking east over Billys Island (Oyster Leases 2 and 3).

Figure 4: Looking North west across oyster lease (Oyster Lease 1).

Figure 5: Looking East across to Crow island (Oyster Lease 5).

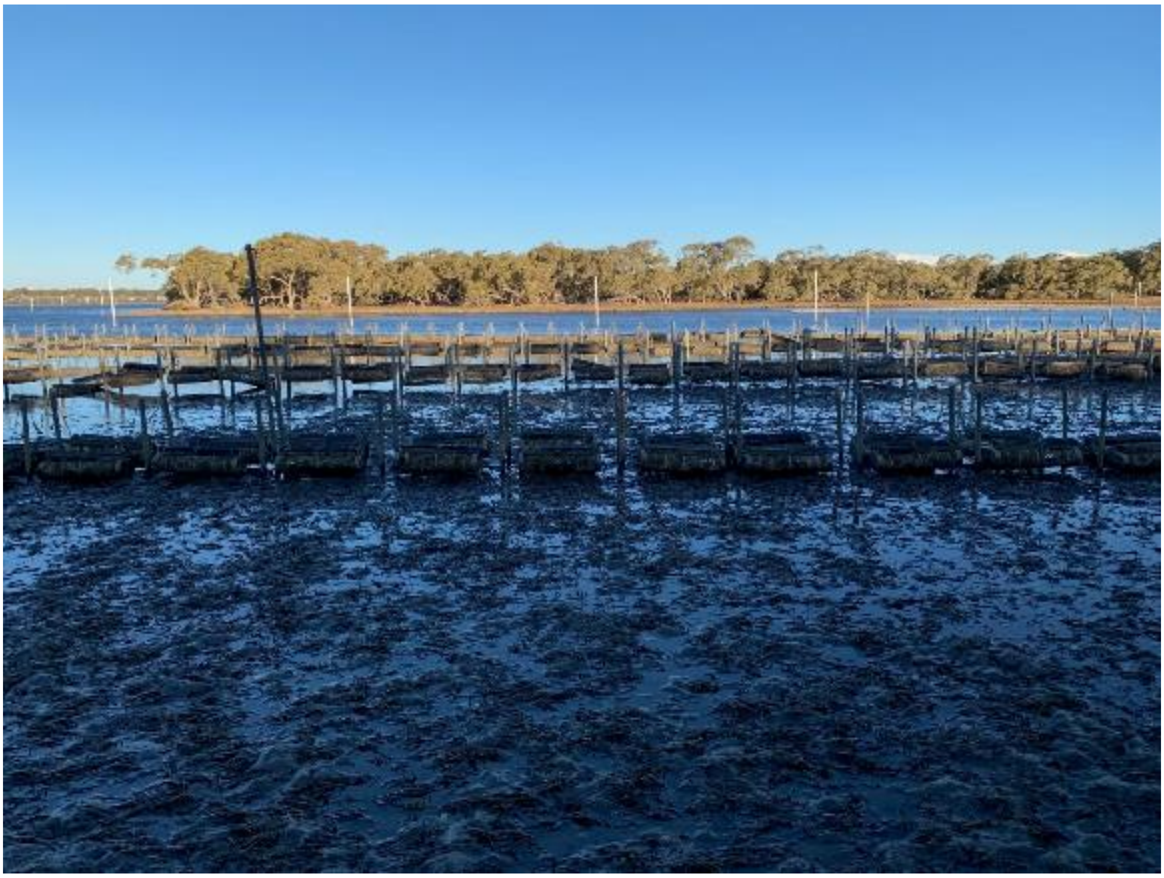


Figure 6: Looking East across Crow Channel (Oyster Lease 6).

Figure 7: Looking East across Crow Channel (Oyster Lease 7).

Figure 8: Looking West across Crow Island (Oyster Leases 6 and 7).

Figure 9: Looking North. (Oyster Lease 8).

Figure 10: Facing North West over Rocky Point (Oyster Lease 9).

Figure 11: Looking East over Rocky Point (Oyster Leases 10 to 15).

Figure 12: Looking East from Rocky Point (Oyster Lease 12).

Figure 13: Looking South East from Rocky Point (Oyster Lease 10-13).

Figure 14: Looking South East across Rocky Point (Oyster Lease 10-15).

Figure 15: Looking North over Crow Channel (Oster Leases 6,7 and 18 to 23).

ANNEXURE D

METERED WATER QUALITY

AND

TIDE MONITORING

IN CROOKHAVEN RIVER AND CURLEYS BAY

FEBRUARY 2020

1 Metered Water Quality and Tidal Movement Sampling Program

There was a flood event in the Crookhaven River in February 2020 following an extended drought period over the whole of 2019 that included extensive bushfire activity in the south coast region of NSW, including fires in the southern portion of the Crookhaven River in January 2020.

During a field excursion to undertake additional estuarine and freshwater ecological surveys scheduled for 11 to 13 February 2020 - to coincide with the lowest low spring tides in the estuary since early 2019, the presence of flood waters provided an opportunity to undertake repeated metered water quality profiles (for Temperature, Conductivity/Salinity, Dissolved Oxygen, Turbidity (as NTU) and pH) at a series of sites in the Crookhaven River and Curleys Bay to provide a better understanding of tidal water exchange between Curleys Bay and the river.

Ten sites were established for the water quality and tide survey, with five of these sites located on fixed oyster lease piles used for both repeat water quality and tide measurements (**Figure 1** and **Table 1).** The other six sites were used for repeat water quality profiles only:

- Site were labelled A to K with the five sites established on fixed oyster infrastructure designated as *Depth Reference Piles* (DRPs). Oyster Industry Representatives were informed of the project and provided permission to establish the DRPs for the survey.
- Repeat metered Submersible Data Logger (SDL) water quality depth profiles were recorded for each site over 3 to 5 times during the period 11 to 13 February 2020. Site I in SW Bay had to be abandoned due to inadequate access problems due to obscured oyster infrastructure.
- Owing to the risk of vessel damage or loss from flood debris, the repeat surveys could only be undertaken in daylight hours, and due to the total opacity of the flood waters there were sever speed limits required to avoid flood debris, submerged oyster lease infrastructure during high tide, and seabed strike during low tide. As a result, each sample run took around 2.5 to 3 hours.
- Water level measurements were taken at each DRP site (d) whilst doing the rounds for the SDL logging. At the five DRP piles, the water level was measured along with the pile height for each sampling period. Following sampling, a differential GPS was used to establish the AHD height of the piles, so the water levels could be reduced to AHD for tide analysis.

Figure 1 Location of 10 water quality monitoring sites in the Crookhaven River and Curleys Bay

2 SURVEY RESULTS FEBRUARY 2020

2.1 Weather and Site Conditions

Rainfall is measured adjacent to the site at the Culburra Treatment Works (Bureau of Meteorology gauge 68083) and the July 2019 – February 2020 rainfall data is provided below in **Table 1**.

Rainfall for late 2019 was very low, accumulating a total of 45.1mm (Oct-Dec 2019). Whist January 2020 had increased rainfall, it was below the long-term monthly average, totaling 82.1mm, with half of this falling with in one day (43mm on the 18th).

February had well above average rainfall totaling 260.3mm, where 173mm of this fell over the three days prior to sampling commencing on the 11th February 2020.

The sampling days themselves were relatively wet and consisted of small intense periods of rainfall. Winds were generally low and oscillated between an Easterly and South direction.

Table 1 Daily Rainfall Records (mm/day) for Culburra treatment works (BoM Station 68083)								
Month and Date	**2019**						**2020**	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
1st	0	0	0	0	0	0.1	0	0
2nd	0	0	0	0	0	0	0	0
3rd	0.2	0	0	0	0	0	0	4.5
4th	7.6	0	0	0	12.6	0	0	0
5th	5.6	0	0	12.2	0	0	0	0
6th	1.2	0	0	0	0	0	0	1.4
7th	0	0	0.4	0	0	0	2.4	1.4
8th	0.5	0	0	0	0	0	0	35
9th	0	0	0	3.8	0	0	0	33
10th	0	0	0	0	0	0	0.4	105
11th	0	0	0	0.8	0	0	0.3	4.5
12th	0	4	0	4.6	0	0	0.5	6
13th	0	0	0	0	0	1.8	0.6	27
14th	0	0	0	0	0	0.2	0.8	0.2
15th	0.1	0	0	0	0	0	0	0
16th	0	0	0	0	0	0	1.5	9.2
17th	0	0	24	0.5	0	0	10.6	8.2
18th	0	0	18.8	0	0.2	0	43	1.2
19th	0	0	30.5	0	0	0	0.8	21.8
20th	0	0	0	0	0	0	2.6	0.5
21st	0	0	0	0	0.4	0	18	0
22nd	0	0	1.4	0	0	0	0	1
23rd	0	0	0	0	0	0	0	0
24th	0	0	0	0	0	0	0.4	0.4
25th	0	0	0	0	0	5	0	0
26th	0	4.2	0	0	0	1	0	0
27th	0	8	0	0	1.4	0	0	0
28th	0	0.8	0	0.5	0	0	0	0
29th	0	0.5	0	0	0	0	0.2	0
30th	1	8.2	0	0	0	0	0	
31st	0.4	0		0		0	0	
Total (mm)	16.6	25.7	75.1	22.4	14.6	8.1	82.1	260.3
Mean	73.8	76.5	72.2	83.9	84.3	73.6	96.4	124.3

Table 1 shows daily rainfall records obtained from BoM station 68083 (Culburra Treatment Works). Survey days are highlighted in yellow.

Figure 1 shows the tide gauge flood response for the Greenwell Point Gauge that indicated the flood plus tide peak was round midday on 10th February. The Greenwell Point tide gauge data for the same period is shown in **Figure 2** which indicates flood behaviour in Crookhaven River, showing the *Residual* when predicted tide levels are removed. The peak flod was

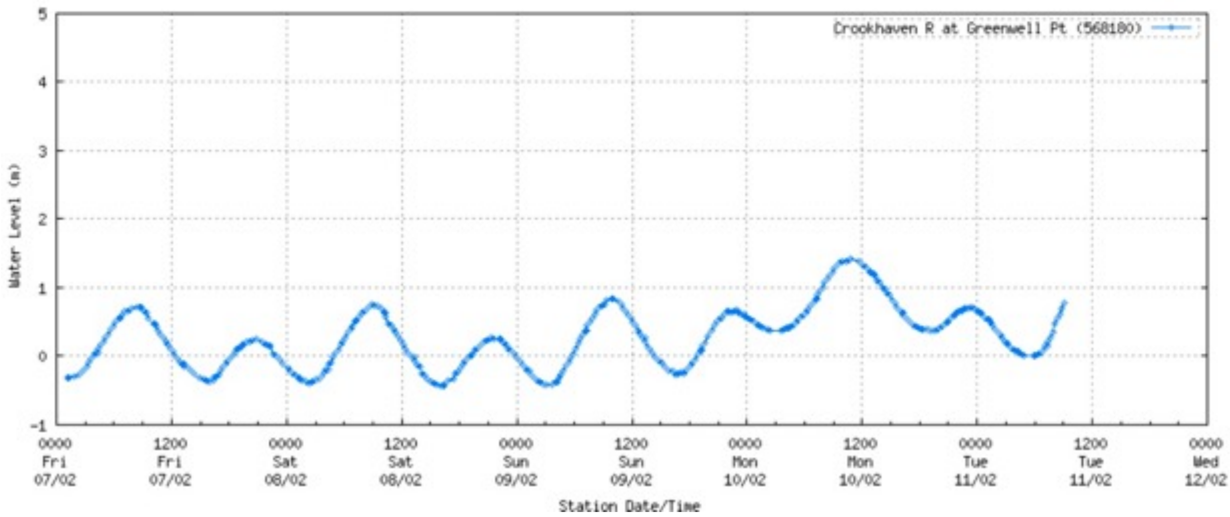


Figure 1 Crookhaven River Tides at Greenwell Point Gauge 9 to 12 February 2020.

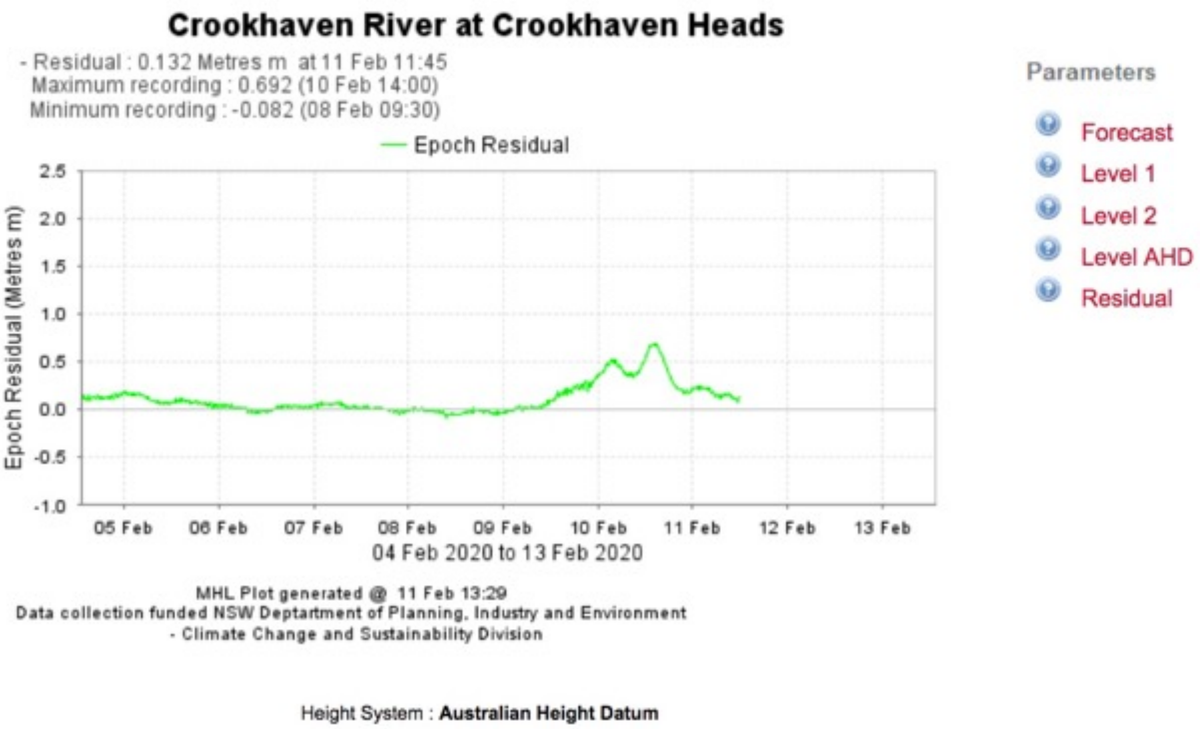


Figure 2 Greenwell Point Gauge 9 to 13 February showing residual flood waters with actual flood peak in the mid afternoon.

2.2 Assessment of Water Quality and Tide Gauging Results

Full metered (SDL) water quality profile results plus Tide measurements and graphs are provided below and **Table 2** provides a summary of water quality data.

Table 2 Site Metered Water Quality Statistics

Site	All sites	A	B	C	D	E	F	G	H	J	K
Bottom Depth (m)		0.98	1.04	1.3	2.53	3.09	1.29	1.05	1.3	0.88	0.7
Temperature (°C)											
Min	21.73	21.74	22.57	21.73	22.06	22.38	22.35	22.74	22.50	22.45	21.98
Median	22.76	22.56	22.84	22.24	22.58	22.83	22.76	22.81	22.80	22.75	22.66
Mean	22.84	22.70	23.08	22.43	22.92	22.70	23.15	22.85	23.08	22.70	22.65
Max	26.29	23.64	23.58	23.22	24.98	22.93	26.29	23.17	25.50	22.78	23.03
Max-Min	4.56	1.90	1.01	1.49	2.92	0.55	3.94	0.43	3.00	0.33	1.05
Salinity (‰)											
Min	3.01	3.32	6.67	5.09	5.14	4.87	3.04	4.51	3.01	3.53	3.81
Median	7.33	6.60	8.81	7.02	9.92	6.35	6.72	6.39	6.61	6.60	7.32
Mean	7.97	7.91	9.03	10.53	10.16	7.48	7.43	6.78	7.11	6.48	7.26
Max	21.67	13.10	12.77	19.31	21.67	10.62	10.52	10.60	11.35	9.24	16.07
Max-Min	18.66	9.78	6.10	14.22	16.53	5.75	7.48	6.09	8.34	5.71	12.26
Dissolved Oxygen (% saturation)											
Min	30.30	30.30	46.50	41.80	52.90	53.50	54.10	64.50	53.50	57.40	55.40
Median	66.30	57.10	59.45	66.90	72.00	71.10	71.10	69.00	66.10	63.75	60.10
Mean	64.95	53.38	57.66	65.54	68.19	67.15	69.13	70.98	66.11	66.11	60.23
Max	83.10	65.20	61.30	74.80	75.70	72.40	83.10	80.20	79.10	78.30	67.50
Max-Min	52.80	34.90	14.80	33.00	22.80	18.90	29.00	15.70	25.60	20.90	12.10
Oxidation Reduction Potential ORP (mV)											
Min	465.00	489.00	500.00	489.00	488.00	471.00	467.00	471.00	470.00	465.00	466.00
Median	495.00	508.00	514.50	493.00	498.00	491.00	479.50	483.50	497.00	493.50	495.00
Mean	499.75	516.54	520.30	507.20	502.82	493.69	491.33	492.11	500.47	491.36	491.14
Max	596.00	596.00	570.00	555.00	540.00	526.00	532.00	518.00	530.00	513.00	507.00
Max-Min	131.00	107.00	70.00	66.00	52.00	55.00	65.00	47.00	60.00	48.00	41.00
Turbidity (NTU)											
Min	1.40	1.40	9.90	3.80	19.50	22.10	29.90	22.10	21.80	32.50	23.90
Median	38.15	38.80	26.85	35.50	37.90	49.20	41.95	40.85	39.70	40.80	34.60
Mean	41.55	39.50	28.85	33.29	42.79	41.68	51.33	39.86	49.66	43.71	40.30
Max	112.60	80.60	45.40	51.70	96.10	55.80	112.60	56.40	102.30	64.10	57.40
Max-Min	111.20	79.20	35.50	47.90	76.60	33.70	82.70	34.30	80.50	31.60	33.50
Water Acidity (pH units)											
Min	5.84	5.97	5.84	6.66	6.79	6.67	5.91	6.53	6.68	6.65	6.47
Median	6.77	6.56	6.63	6.85	6.86	6.77	6.80	6.79	6.79	6.80	6.62
Mean	6.72	6.41	6.39	6.89	6.91	6.76	6.68	6.78	6.78	6.79	6.64
Max	7.27	6.73	6.69	7.27	7.18	6.85	6.96	7.02	6.87	6.87	6.81
Max-Min	1.43	0.08	0.85	0.61	0.39	0.18	1.05	0.49	0.19	0.22	0.34

TABLE A1 - Metered Water Quality Results										
Site	Date	Time	Depth (-m)	Temp (C)	Turb (ntu)	pH (pH)	ORP (mv)	Sal (ppt)	D.O. (%sat)	D.O. (mg/l)
F	11/02/2020	15:59:53	-0.1	26.29	112.6	5.91	520	3.04	83.1	6.59
F	11/02/2020	16:00:07	-0.35	25.87	93.5	5.92	525	4.3	81.6	6.47
F	11/02/2020	16:00:24	-0.36	24.34	97.1	6.25	532	6.38	74.1	5.97
F	11/02/2020	16:00:44	-0.5	22.26	21.6	6.26	548	20.46	65.1	5.03
F	11/02/2020	16:01:11	-0.57	21.9	82.7	6.53	543	22.43	57.9	4.46
F	11/02/2020	16:01:46	-0.56	22.01	31.3	6.43	544	22.67	68.9	5.28
H	11/02/2020	16:10:32	-0.1	25.5	102.3		497	3.01	72.1	5.8
H	11/02/2020	16:11:04	-0.17	24.83	100.2		508	5.31	62.7	5.04
H	11/02/2020	16:11:17	-0.29	23.12	73.1		522	11.35	53.5	4.29
H	11/02/2020	16:11:32	-0.46	21.9	37.3		527	16.26	52.3	4.17
H	11/02/2020	16:11:42	-0.55	21.87	25.9		528	18.32	54.7	4.31
H	11/02/2020	16:11:52	-0.6	21.87	54.2		527	19.76	50.5	3.95
D	11/02/2020	16:35:55	-0.1	24.98	96.1		497	5.14	72.3	5.8
D	11/02/2020	16:36:08	-0.18	24.95	94.5		498	5.27	72	5.78
D	11/02/2020	16:36:17	-0.24	24.95	93.3		498	5.27	71.9	5.77
D	11/02/2020	16:36:26	-0.53	24.92	94		499	5.46	71.7	5.75
D	11/02/2020	16:36:33	-0.63	24.83	91.9		500	5.64	71.5	5.74
D	11/02/2020	16:36:44	-0.77	24.79	92.2		501	5.64	71.1	5.71
D	11/02/2020	16:36:58	-0.86	24.53	91		504	6.52	70.5	5.66
A	12/02/2020	11:27:57	-0.1	21.76	76.2	5.97	489	3.35	65.2	5.62
A	12/02/2020	11:28:11	-0.15	21.74	77.5	6.02	490	3.34	64.7	5.58
A	12/02/2020	11:28:24	-0.22	21.74	77.3	6.06	491	3.33	64.4	5.56
A	12/02/2020	11:28:38	-0.31	21.74	80.6	6.09	491	3.32	64.3	5.54
A	12/02/2020	11:28:46	-0.41	21.73	79.6	6.11	492	3.33	64.2	5.53
A	12/02/2020	11:28:55	-0.48	21.73	79.3	6.12	492	3.34	64	5.52
A	12/02/2020	11:29:04	-0.66	21.73	83.9	6.13	492	3.33	63.9	5.51
A	12/02/2020	11:29:16	-0.77	21.73	80.2	6.14	493	3.33	63.7	5.49
A	12/02/2020	11:29:28	-0.84	21.73	82.3	6.15	493	3.33	63.7	5.49
A	12/02/2020	11:29:41	-0.94	21.73	79.3	6.17	494	3.31	63.5	5.48
A	12/02/2020	11:29:51	-0.98	21.73	80.5	6.18	494	3.32	63.4	5.47
B	12/02/2020	11:45:31	-0.1	22.85	45.4	5.84	514	6.67	60.4	5
B	12/02/2020	11:45:48	-0.19	22.83	43	5.99	515	7.12	59.6	4.92
B	12/02/2020	11:46:01	-0.25	22.83	41.2	6.05	515	7.35	58.9	4.86
B	12/02/2020	11:46:11	-0.33	22.82	34.9	6.09	517	8.01	58.1	4.77
B	12/02/2020	11:46:20	-0.43	22.79	35.1	6.13	519	9.17	57.2	4.67
B	12/02/2020	11:46:29	-0.51	22.74	36.4	6.19	519	9.46	55.9	4.56
B	12/02/2020	11:46:39	-0.66	22.77	30.4	6.22	520	10.34	54.3	4.41
B	12/02/2020	11:46:48	-0.71	22.82	34.5	6.26	521	11.1	53.2	4.29
B	12/02/2020	11:46:57	-0.78	22.88	28	6.28	522	11.75	51.5	4.14
B	12/02/2020	11:47:05	-0.85	22.89	27.9	6.31	522	11.88	50.5	4.05
B	12/02/2020	11:47:16	-0.93	23.04	23.2	6.33	523	13.32	48.5	3.85

B	12/02/2020	11:47:26	-0.97	23.07	24.5	6.36	523	13.87	46.3	3.66
B	12/02/2020	11:47:37	-1.04	23.09	27.1	6.39	523	14.11	45.1	3.56
C	12/02/2020	12:12:03	-0.1	21.89	31.3	7.03	514	15.85	72.8	5.82
C	12/02/2020	12:12:22	-0.14	21.85	30.3	7.04	514	15.91	72.5	5.79
C	12/02/2020	12:12:31	-0.2	21.84	28.8	7.09	514	16.83	72.4	5.75
C	12/02/2020	12:12:41	-0.28	21.83	28.2	7.11	514	16.88	72.8	5.79
C	12/02/2020	12:12:51	-0.35	21.73	25.8	7.27	516	19.31	74.8	5.88
C	12/02/2020	12:13:00	-0.44	21.77	26.5	7.25	515	19.42	75.3	5.91
C	12/02/2020	12:13:12	-0.45	21.69	24.8	7.37	516	21.06	77.5	6.03
C	12/02/2020	12:13:35	-0.56	21.69	23.7	7.39	515	20.92	77.3	6.02
C	12/02/2020	12:13:47	-0.67	21.67	23.7	7.43	515	22.12	78.2	6.05
C	12/02/2020	12:14:01	-0.72	21.66	22.9	7.45	515	22.25	79.2	6.12
C	12/02/2020	12:14:13	-0.82	21.66	23.6	7.46	514	22.36	79.2	6.12
C	12/02/2020	12:14:24	-0.88	21.66	25	7.46	514	22.37	79.3	6.12
C	12/02/2020	12:14:50	-0.86	21.66	25	7.47	513	22.47	79.1	6.11
C	12/02/2020	12:15:01	-0.98	21.66	23.8	7.47	513	22.5	79.2	6.11
C	12/02/2020	12:15:16	-1.12	21.65	23.1	7.48	512	22.53	79.3	6.12
C	12/02/2020	12:15:32	-1.18	21.65	23.1	7.48	512	22.58	79.1	6.1
C	12/02/2020	12:15:44	-1.3	21.66	24.7	7.48	512	22.53	79	6.1
D	12/02/2020	12:26:35	-0.1	22.69	38.9	7.03	488	12.69	74	5.93
D	12/02/2020	12:26:45	-0.16	22.67	35	7.01	489	13.08	73.7	5.9
D	12/02/2020	12:27:04	-0.17	22.66	27.7	7	490	12.88	73.7	5.9
D	12/02/2020	12:27:11	-0.23	22.58	22.4	7.02	491	13.93	73.8	5.88
D	12/02/2020	12:27:22	-0.32	22.06	19.5	7.18	499	21.67	75.7	5.83
D	12/02/2020	12:27:29	-0.39	21.79	17.1	7.32	501	23.8	77.7	5.94
D	12/02/2020	12:27:37	-0.49	21.67	16	7.43	501	24.57	79.2	6.04
D	12/02/2020	12:27:46	-0.58	21.63	14.6	7.5	501	25.11	80.8	6.15
D	12/02/2020	12:27:54	-0.68	21.62	12.7	7.56	502	27	82.6	6.22
D	12/02/2020	12:28:08	-0.79	21.61	12.2	7.6	501	27.42	84.9	6.37
D	12/02/2020	12:28:23	-0.88	21.61	14.6	7.63	500	27.57	85.2	6.39
D	12/02/2020	12:28:33	-1.02	21.61	11.4	7.65	501	28.37	85.6	6.39
D	12/02/2020	12:28:43	-1.15	21.61	11.3	7.66	500	28.78	86.6	6.45
D	12/02/2020	12:28:54	-1.23	21.61	13	7.67	500	28.94	87.1	6.48
D	12/02/2020	12:29:06	-1.31	21.6	10.5	7.68	500	29.1	87.2	6.49
D	12/02/2020	12:29:14	-1.37	21.6	10.5	7.68	500	29.14	87.3	6.49
D	12/02/2020	12:29:24	-1.55	21.6	11.7	7.68	500	29.33	87.4	6.49
D	12/02/2020	12:29:36	-1.72	21.6	11.1	7.69	500	29.71	87.6	6.49
D	12/02/2020	12:29:45	-1.89	21.6	11.2	7.69	500	29.86	87.9	6.51
D	12/02/2020	12:29:52	-2	21.6	12.1	7.7	499	29.9	88	6.51
D	12/02/2020	12:30:01	-2.12	21.6	13.2	7.7	499	30.03	88	6.51
D	12/02/2020	12:30:10	-2.26	21.6	13.2	7.7	499	30.13	87.8	6.49
D	12/02/2020	12:30:18	-2.38	21.6	15.1	7.7	499	30.18	87.8	6.49
D	12/02/2020	12:30:36	-2.53	21.6	10.7	7.71	499	30.17	87.8	6.49
F	12/02/2020	12:43:21	-0.1	22.44	54.9	6.82	467	5.96	71.2	5.97

F	12/02/2020	12:43:30	-0.17	22.42	55.4	6.78	468	6.03	71	5.94
F	12/02/2020	12:43:41	-0.27	22.4	54.9	6.74	469	6.08	70.7	5.92
F	12/02/2020	12:43:52	-0.33	22.37	55.5	6.72	470	6.17	70.4	5.9
F	12/02/2020	12:44:08	-0.38	22.35	54.2	6.68	472	6.41	70.5	5.9
F	12/02/2020	12:44:17	-0.53	22.32	37.3	6.66	473	6.73	70.1	5.86
F	12/02/2020	12:45:12	-0.48	22.3	39.2	6.74	476	6.93	69.5	5.8
F	12/02/2020	12:45:20	-0.63	21.97	33.3	6.67	489	12.88	69.1	5.61
F	12/02/2020	12:45:28	-0.71	21.72	29.8	6.78	494	15.51	64.8	5.21
F	12/02/2020	12:45:41	-0.71	21.68	31	6.87	494	15.64	64.4	5.17
F	12/02/2020	12:45:58	-0.79	21.64	29.3	6.94	493	16.23	63.9	5.12
F	12/02/2020	12:46:13	-0.83	21.63	28.8	6.98	493	16.21	64.8	5.19
F	12/02/2020	12:46:23	-0.91	21.61	27.9	7	493	16.8	64.8	5.18
F	12/02/2020	12:46:31	-1.04	21.62	26.2	6.99	493	17.01	64.6	5.15
F	12/02/2020	12:47:00	-1.15	21.85	25.8	6.87	493	17.7	56.4	4.46
F	12/02/2020	12:47:13	-1.29	22.01	31.1	6.79	494	18.2	43.4	3.41
G	12/02/2020	13:00:34	-0.1	22.82	56.1	6.69	471	4.54	68.3	5.73
G	12/02/2020	13:00:46	-0.17	22.81	55.5	6.66	472	4.51	68.2	5.72
G	12/02/2020	13:00:57	-0.26	22.79	55.2	6.63	473	4.58	68	5.7
G	12/02/2020	13:01:32	-0.21	22.78	56.4	6.58	475	4.58	67.7	5.68
G	12/02/2020	13:01:55	-0.38	22.74	53.1	6.53	478	5.21	67.4	5.63
G	12/02/2020	13:02:06	-0.5	22.4	42.5	6.46	488	9.1	65.3	5.37
G	12/02/2020	13:02:16	-0.59	22.27	38.5	6.54	494	10.78	64.7	5.29
G	12/02/2020	13:02:25	-0.7	22.35	38.4	6.61	495	11.28	65.4	5.32
G	12/02/2020	13:02:33	-0.75	22.37	32.7	6.64	496	11.94	64.4	5.21
G	12/02/2020	13:02:48	-0.88	22.44	24.2	6.68	497	12.89	60.6	4.88
G	12/02/2020	13:02:58	-0.96	22.41	22.8	6.7	497	13.15	57.4	4.62
G	12/02/2020	13:03:05	-1.05	22.47	23	6.71	497	14.03	56.4	4.5
E	12/02/2020	13:15:28	-0.1	22.39	54.4	6.71	493	6.27	72.4	6.06
E	12/02/2020	13:15:37	-0.16	22.38	55.2	6.69	493	6.3	72.2	6.04
E	12/02/2020	13:15:47	-0.23	22.38	55.8	6.67	493	6.35	71.9	6.02
E	12/02/2020	13:15:57	-0.39	22.36	52.9	6.66	494	6.6	71.6	5.99
E	12/02/2020	13:16:09	-0.53	22.36	51.6	6.65	494	6.75	71.4	5.97
E	12/02/2020	13:16:33	-0.67	22.34	51.5	6.65	496	7.25	71.3	5.94
E	12/02/2020	13:16:47	-0.87	21.7	13.2	6.8	514	19.14	72	5.67
E	12/02/2020	13:16:59	-1.03	21.61	13.8	7.29	518	24.94	76.5	5.82
E	12/02/2020	13:17:10	-1.21	21.63	13.9	7.46	516	25.65	80	6.07
E	12/02/2020	13:17:21	-1.41	21.64	11.9	7.55	514	26.42	79.9	6.03
E	12/02/2020	13:17:31	-1.68	21.66	10.8	7.61	514	28.58	81.7	6.08
E	12/02/2020	13:17:42	-1.88	21.68	6.9	7.67	513	29.22	84.5	6.27
E	12/02/2020	13:17:52	-2.13	21.68	6.8	7.7	513	30.31	85.5	6.31
E	12/02/2020	13:18:03	-2.37	21.68	11.6	7.72	512	30.61	86.1	6.34
E	12/02/2020	13:18:17	-2.52	21.68	7.3	7.73	511	30.94	86.7	6.37
E	12/02/2020	13:18:31	-2.66	21.68	7	7.74	510	30.99	87	6.39
E	12/02/2020	13:18:39	-2.79	21.69	9.3	7.74	510	31.02	87	6.38

E	12/02/2020	13:18:50	-2.88	21.68	8.3	7.75	509	31.01	87.1	6.4
E	12/02/2020	13:18:57	-2.98	21.68	5.9	7.75	509	31.01	87.1	6.39
E	12/02/2020	13:19:06	-3.09	21.68	8.7	7.75	509	31.03	87	6.39
H	12/02/2020	13:34:39	-0.1	22.7	55	6.81	470	3.8	66.5	5.61
H	12/02/2020	13:34:50	-0.19	22.7	55.7	6.76	471	3.83	66.4	5.6
H	12/02/2020	13:34:59	-0.27	22.68	56.8	6.73	472	3.92	66.1	5.58
H	12/02/2020	13:35:08	-0.36	22.51	57.3	6.68	479	4.82	65.8	5.54
H	12/02/2020	13:35:16	-0.46	22.24	48.1	6.57	488	7.63	65.7	5.47
H	12/02/2020	13:35:24	-0.56	22.14	43.5	6.61	493	9.49	66.5	5.49
H	12/02/2020	13:35:32	-0.62	22.13	41.5	6.66	495	10.44	66.2	5.43
H	12/02/2020	13:35:40	-0.74	22.18	33.5	6.67	497	11.99	59.9	4.87
H	12/02/2020	13:35:49	-0.88	21.99	31.3	6.78	501	14.43	52.8	4.25
H	12/02/2020	13:35:57	-0.99	21.7	27	6.95	504	17.5	62.2	4.94
H	12/02/2020	13:36:05	-1.15	21.63	20.4	7.13	507	21.44	70.1	5.45
H	12/02/2020	13:36:13	-1.3	21.65	19.8	7.29	507	23.13	73.6	5.66
J	12/02/2020	13:45:07	-0.1	22.53	64.1	6.75	465	3.53	68.1	5.77
J	12/02/2020	13:45:15	-0.2	22.53	62.1	6.72	466	3.54	67.9	5.76
J	12/02/2020	13:45:25	-0.31	22.45	60.2	6.65	469	4.3	67.7	5.73
J	12/02/2020	13:45:33	-0.41	22.22	54.9	6.56	478	6.07	66.3	5.57
J	12/02/2020	13:45:42	-0.53	21.88	47	6.54	491	10	63.5	5.25
J	12/02/2020	13:45:53	-0.64	21.91	34.1	6.66	493	12.22	64.9	5.29
J	12/02/2020	13:46:04	-0.78	22.07	30	6.76	496	14.06	59.9	4.82
J	12/02/2020	13:46:17	-0.88	21.8	29.5	6.94	498	16.39	60.5	4.83
K	12/02/2020	13:52:34	-0.1	22.57	55.2	6.67	466	3.81	66.1	5.59
K	12/02/2020	13:52:42	-0.15	22.57	56.1	6.64	468	4.14	67.5	5.7
K	12/02/2020	13:53:09	-0.21	22.46	54.2	6.58	470	4.22	64.7	5.47
K	12/02/2020	13:54:11	-0.36	22.28	54.3	6.51	475	4.87	63.6	5.37
K	12/02/2020	13:54:20	-0.42	22.22	57.4	6.51	475	4.7	62.2	5.27
K	12/02/2020	13:54:54	-0.44	22.21	55.8	6.51	476	4.76	61.6	5.22
K	12/02/2020	13:55:03	-0.59	22.17	44.7	6.47	480	5.65	61.4	5.18
K	12/02/2020	13:55:12	-0.7	21.98	23.9	6.48	500	16.07	61.4	4.9
A	12/02/2020	14:22:32	-0.1	22.56	38.9	6.58	508	6.44	57.6	4.8
A	12/02/2020	14:22:41	-0.17	22.56	38.8	6.57	508	6.5	57.5	4.79
A	12/02/2020	14:22:49	-0.28	22.55	39	6.56	508	6.64	57.1	4.76
A	12/02/2020	14:22:59	-0.36	22.54	38.7	6.56	508	6.6	56.8	4.73
A	12/02/2020	14:23:06	-0.46	22.54	39.4	6.56	508	6.64	56.9	4.73
A	12/02/2020	14:23:14	-0.54	22.53	40.5	6.56	509	6.72	56.8	4.73
A	12/02/2020	14:23:23	-0.64	22.53	41.4	6.55	509	6.91	56.7	4.72
A	12/02/2020	14:23:32	-0.75	22.52	37.3	6.55	509	6.99	56.7	4.71
A	12/02/2020	14:23:44	-0.81	22.5	34.5	6.55	510	7.2	56.7	4.71
A	12/02/2020	14:23:53	-0.88	22.47	26	6.59	511	7.9	56.7	4.69
A	12/02/2020	14:24:18	-0.93	22.44	27.5	6.66	511	8.77	56.3	4.64
B	12/02/2020	14:31:31	-0.1	23.58	26.7	6.69	500	8.69	61.1	4.93
B	12/02/2020	14:31:39	-0.17	23.57	25.7	6.68	500	8.92	61.3	4.94

B	12/02/2020	14:31:51	-0.24	23.55	27	6.67	501	9.11	59.9	4.82
B	12/02/2020	14:32:00	-0.31	23.54	24.3	6.66	501	9.22	59.3	4.77
B	12/02/2020	14:32:11	-0.43	23.48	19.1	6.61	506	11.83	56.1	4.45
B	12/02/2020	14:32:21	-0.51	22.9	16.4	6.64	510	13.86	51	4.05
B	12/02/2020	14:32:33	-0.63	22.71	17.6	6.69	510	14.25	50.9	4.05
B	12/02/2020	14:32:43	-0.73	22.58	16.6	6.73	510	14.45	52.1	4.14
B	12/02/2020	14:33:03	-0.86	22.72	17.9	6.74	510	14.89	50.4	3.99
C	12/02/2020	14:45:22	-0.1	22.24	51.7	6.71	490	5.09	66.1	5.58
C	12/02/2020	14:45:30	-0.22	22.24	51.7	6.69	491	5.12	65.8	5.56
C	12/02/2020	14:45:41	-0.27	22.24	51.4	6.66	491	5.14	65.2	5.51
C	12/02/2020	14:45:51	-0.46	22.24	48.2	6.6	494	5.8	64.5	5.43
C	12/02/2020	14:45:58	-0.56	22.24	42.7	6.56	499	7.22	63.2	5.27
C	12/02/2020	14:46:06	-0.63	22.23	38	6.58	502	8.21	62	5.15
C	12/02/2020	14:46:15	-0.63	22.23	32.5	6.6	502	8.16	61.7	5.12
C	12/02/2020	14:46:26	-0.73	22.23	47.7	6.63	507	10.64	62	5.07
C	12/02/2020	14:46:36	-0.86	22.22	24.8	6.68	508	11.35	62.6	5.11
C	12/02/2020	14:46:45	-0.89	22.22	20.9	6.73	508	11.63	62.8	5.11
C	12/02/2020	14:46:57	-0.96	22.13	17.5	6.8	510	13.03	61.8	5
D	12/02/2020	14:56:18	-0.1	22.27	38.4	6.81	500	9.62	67.8	5.57
D	12/02/2020	14:56:25	-0.17	22.27	37.9	6.8	500	9.68	66.2	5.44
D	12/02/2020	14:56:32	-0.27	22.26	37.5	6.79	500	9.74	65.5	5.38
D	12/02/2020	14:56:39	-0.35	22.25	38.3	6.79	501	9.92	64.8	5.33
D	12/02/2020	14:56:46	-0.47	22.23	37.7	6.78	501	10.29	64.3	5.27
D	12/02/2020	14:56:55	-0.59	22.22	36.7	6.78	502	10.54	63.7	5.22
D	12/02/2020	14:57:02	-0.6	22.22	36.7	6.8	501	10.38	63.4	5.19
D	12/02/2020	14:57:10	-0.64	22.21	37.5	6.8	501	10.58	63.2	5.17
D	12/02/2020	14:57:17	-0.65	22.21	36.9	6.8	502	10.74	63	5.16
D	12/02/2020	14:57:24	-0.53	22.21	37	6.81	501	10.36	63	5.17
D	12/02/2020	14:57:39	-0.73	22.19	35.6	6.8	502	11.06	63	5.14
D	12/02/2020	14:57:48	-0.81	22.19	35.2	6.81	502	11	62.6	5.12
D	12/02/2020	14:58:01	-0.98	22.15	35.2	6.82	503	11.67	62.1	5.06
D	12/02/2020	14:58:12	-1.15	22.14	29.5	6.81	505	12.83	61.6	4.99
D	12/02/2020	14:58:24	-1.29	22.08	25.5	6.84	507	14.31	58.9	4.73
D	12/02/2020	14:58:34	-1.29	22.07	26.8	6.88	506	14.04	57.8	4.65
D	12/02/2020	14:58:49	-1.42	21.96	9.1	7.04	511	19.16	58.1	4.55
D	12/02/2020	14:59:00	-1.62	21.74	10.4	7.34	517	28.29	63.5	4.73
D	12/02/2020	14:59:11	-1.58	21.65	6.7	7.49	516	28.55	73.8	5.5
D	12/02/2020	14:59:21	-1.81	21.64	7.5	7.58	514	28.74	75.2	5.6
D	12/02/2020	14:59:32	-1.98	21.64	6.5	7.62	513	28.95	76.4	5.68
D	12/02/2020	14:59:42	-2.19	21.63	7.8	7.65	513	29.14	77.2	5.74
E	12/02/2020	15:07:48	-0.1	22.92	49.2	6.77	471	4.88	71.5	5.98
E	12/02/2020	15:07:58	-0.16	22.92	50.2	6.74	472	4.87	71.5	5.97
E	12/02/2020	15:08:09	-0.27	22.92	50.2	6.71	473	4.93	71.2	5.94
E	12/02/2020	15:08:23	-0.38	22.93	50	6.68	475	5	70.7	5.9

E	12/02/2020	15:08:32	-0.53	22.97	50.4	6.67	476	5.19	70.5	5.87
E	12/02/2020	15:08:43	-0.67	23	48.8	6.66	478	5.36	70.2	5.83
E	12/02/2020	15:08:54	-0.79	23.02	48.3	6.65	479	5.51	70.2	5.83
E	12/02/2020	15:09:05	-0.78	23.01	48.1	6.66	479	5.49	70.3	5.84
E	12/02/2020	15:09:17	-0.95	22.36	29.7	6.69	498	14.08	69.9	5.59
E	12/02/2020	15:09:29	-1.11	21.84	17	7.02	504	18.94	65.7	5.16
E	12/02/2020	15:09:48	-1.25	21.69	12.6	7.4	503	21.72	66.4	5.15
E	12/02/2020	15:09:56	-1.38	21.66	12.8	7.46	503	22.66	67.5	5.21
E	12/02/2020	15:10:04	-1.5	21.64	12.4	7.51	502	22.77	72.8	5.61
E	12/02/2020	15:10:13	-1.64	21.63	9.3	7.57	503	25.27	74.8	5.69
E	12/02/2020	15:10:20	-1.93	21.65	10.2	7.61	503	26.36	76.7	5.79
E	12/02/2020	15:10:28	-2.19	21.67	11.1	7.64	504	28.6	77.8	5.8
E	12/02/2020	15:10:37	-2.57	21.68	12.8	7.67	503	29.14	79.5	5.9
E	12/02/2020	15:10:46	-2.84	21.68	22	7.68	503	29.11	80.2	5.95
E	12/02/2020	15:10:54	-3	21.68	25.1	7.68	502	29.12	80.1	5.95
F	12/02/2020	15:16:57	-0.1	22.99	42.2	6.81	468	6.68	71.9	5.94
F	12/02/2020	15:17:08	-0.23	22.99	41.7	6.78	469	6.75	71.3	5.88
F	12/02/2020	15:17:15	-0.37	22.98	40.6	6.76	470	6.86	70.9	5.85
F	12/02/2020	15:17:22	-0.53	22.98	40.7	6.76	471	6.85	70.7	5.83
F	12/02/2020	15:17:32	-0.71	22.98	41.2	6.74	472	7.03	70.7	5.82
F	12/02/2020	15:17:42	-0.82	22.57	33.9	6.7	480	10.15	66.6	5.43
G	12/02/2020	15:30:50	-0.1	22.77	44.1	6.89	481	6.34	75.2	6.25
G	12/02/2020	15:30:58	-0.19	22.76	44	6.86	482	6.35	74.9	6.22
G	12/02/2020	15:31:06	-0.24	22.77	41.6	6.84	482	6.35	74.4	6.18
G	12/02/2020	15:31:13	-0.35	22.77	40.1	6.81	483	6.56	74.1	6.14
G	12/02/2020	15:31:20	-0.46	22.78	35.2	6.79	484	6.78	73.2	6.07
G	12/02/2020	15:31:27	-0.57	22.72	26.8	6.64	498	13.14	69.5	5.55
G	12/02/2020	15:31:34	-0.68	22.61	23.6	6.7	502	15.51	58.5	4.62
H	12/02/2020	15:46:03	-0.1	22.89	38.3	6.87	487	5.73	79.1	6.58
H	12/02/2020	15:46:49	-0.17	22.83	39.7	6.77	492	6.61	77.5	6.42
H	12/02/2020	15:46:59	-0.25	22.76	38.3	6.74	494	7.66	74.8	6.17
H	12/02/2020	15:47:06	-0.3	22.5	37.4	6.7	498	9.31	69.3	5.69
H	12/02/2020	15:47:15	-0.44	22.07	27.9	6.67	504	12.54	61.4	4.99
H	12/02/2020	15:47:23	-0.62	21.99	21.9	6.79	509	16.63	55.4	4.4
H	12/02/2020	15:47:33	-0.65	21.83	17.2	6.95	509	17.41	62	4.91
H	12/02/2020	15:47:44	-0.82	21.73	15.5	7.17	514	21.56	67.5	5.24
H	12/02/2020	15:47:57	-0.89	21.75	15.7	7.28	512	22.2	67.3	5.19
J	12/02/2020	15:56:18	-0.1	22.75	47.7	6.87	473	4.02	78.3	6.6
J	12/02/2020	15:56:36	-0.17	22.75	47.6	6.82	474	4.04	78.2	6.59
J	12/02/2020	15:56:46	-0.24	22.75	48.2	6.8	475	4.03	78.2	6.58
J	12/02/2020	15:56:55	-0.3	22.74	49.8	6.78	476	4.11	77.8	6.55
J	12/02/2020	15:57:03	-0.41	22.67	46.6	6.73	478	4.49	76.6	6.45
K	12/02/2020	16:06:58	-0.1	23.02	33.6	6.66	495	7.31	61.7	5.08
K	12/02/2020	16:07:28	-0.21	23.02	32.7	6.62	495	7.32	60.1	4.94

K	12/02/2020	16:07:35	-0.25	23.02	33.2	6.62	495	7.32	60.1	4.94
K	12/02/2020	16:07:43	-0.35	23.02	33.4	6.61	495	7.32	60	4.93
K	12/02/2020	16:08:25	-0.29	23.03	33	6.61	494	7.34	59.8	4.91
K	12/02/2020	16:08:48	-0.38	23.03	34.6	6.61	494	7.35	59.8	4.91
K	12/02/2020	16:08:55	-0.38	23.03	36.7	6.61	494	7.35	59.7	4.91
A	12/02/2020	16:26:24	-0.1	23.52	14.8	6.73	511	13.09	49	3.86
A	12/02/2020	16:26:45	-0.19	23.53	14.4	6.71	511	13.09	48.1	3.79
A	12/02/2020	16:26:55	-0.3	23.53	14	6.71	510	13.1	47.9	3.77
A	12/02/2020	16:27:03	-0.39	23.53	14.6	6.71	510	13.11	47.7	3.76
A	12/02/2020	16:27:14	-0.51	23.53	15.9	6.7	510	13.11	47.5	3.74
C	12/02/2020	16:47:08	-0.1	22.82	41.1	6.94	489	6.48	68.5	5.68
C	12/02/2020	16:47:15	-0.14	22.82	41	6.89	490	6.5	67.5	5.6
C	12/02/2020	16:47:22	-0.22	22.83	35.5	6.85	491	6.58	66.9	5.55
C	12/02/2020	16:47:30	-0.3	22.85	38	6.81	492	6.86	66.5	5.5
C	12/02/2020	16:47:37	-0.37	22.87	35.7	6.79	493	7.02	66.1	5.46
C	12/02/2020	16:47:44	-0.43	22.88	33.7	6.77	493	7.04	65.7	5.42
C	12/02/2020	16:47:51	-0.51	22.89	34	6.75	494	7.36	65.3	5.38
C	12/02/2020	16:48:00	-0.58	22.87	29.5	6.73	496	7.89	64.3	5.28
C	12/02/2020	16:48:08	-0.64	22.79	28.2	6.72	497	8.52	62.2	5.1
D	12/02/2020	16:54:32	-0.1	22.78	42.3	6.89	488	6.74	74.6	6.18
D	12/02/2020	16:54:41	-0.26	22.78	40.9	6.86	489	6.82	72.9	6.04
D	12/02/2020	16:54:50	-0.45	22.78	43.1	6.83	489	6.9	72.5	6
D	12/02/2020	16:54:57	-0.63	22.77	41	6.82	490	7	72.5	6
D	12/02/2020	16:55:04	-0.76	22.77	40.9	6.81	491	7.11	72.3	5.98
D	12/02/2020	16:55:12	-0.85	22.76	40.7	6.8	491	7.26	72.5	5.99
D	12/02/2020	16:55:25	-0.99	22.77	41.7	6.79	492	7.56	72.3	5.96
D	12/02/2020	16:55:37	-1.08	22.77	41.8	6.8	492	7.59	72.5	5.98
D	12/02/2020	16:55:46	-1.23	22.78	40.7	6.8	494	8	72.4	5.96
D	12/02/2020	16:55:55	-1.36	22.78	40.8	6.82	493	7.73	72.6	5.98
D	12/02/2020	16:56:03	-1.47	22.78	40.7	6.81	494	7.99	72.5	5.96
D	12/02/2020	16:56:17	-1.6	22.78	43.1	6.81	495	8.58	72.2	5.92
E	12/02/2020	17:02:55	-0.1	22.87	38	6.85	489	8.82	71.1	5.81
E	12/02/2020	17:03:06	-0.21	22.85	36.7	6.83	490	9.13	69.4	5.66
E	12/02/2020	17:03:13	-0.34	22.83	35.5	6.83	491	9.16	69.4	5.66
E	12/02/2020	17:03:20	-0.47	22.81	34.4	6.83	491	9.29	69.2	5.65
E	12/02/2020	17:03:27	-0.68	22.77	34	6.82	492	9.64	69.4	5.65
E	12/02/2020	17:03:35	-0.77	22.73	33.5	6.82	492	9.98	70	5.69
E	12/02/2020	17:03:44	-0.91	22.76	33.2	6.85	491	9.23	70.2	5.73
E	12/02/2020	17:03:51	-1.06	22.67	33.8	6.83	494	10.74	69.7	5.66
E	12/02/2020	17:03:59	-1.23	22.63	34.7	6.84	496	11.69	69.5	5.61
E	12/02/2020	17:04:07	-1.55	22.63	36	6.86	496	12.07	68.4	5.51
E	12/02/2020	17:04:17	-1.89	22.47	39.7	6.92	499	14.47	67.4	5.37
E	12/02/2020	17:04:28	-2.24	22.25	35.4	7	502	16.75	65.6	5.18
F	12/02/2020	17:11:00	-0.1	23.02	34.6	6.96	479	9	73.8	6

F	12/02/2020	17:11:09	-0.23	23.02	31.3	6.93	480	8.99	73	5.95
F	12/02/2020	17:11:17	-0.36	23.02	31	6.91	480	9	72.7	5.92
F	12/02/2020	17:11:27	-0.54	23.02	32.8	6.89	480	9.01	72.5	5.9
G	12/02/2020	17:26:08	-0.1	23.17	41.6	7.02	484	6.27	80.2	6.62
G	12/02/2020	17:26:17	-0.21	23.17	38.9	6.96	486	6.43	78.4	6.46
G	12/02/2020	17:26:24	-0.3	23.01	22.1	6.79	493	10.6	76.3	6.15
G	12/02/2020	17:26:31	-0.41	22.72	29.8	6.79	504	14.74	63.8	5.05
A	13/02/2020	8:25:37	-0.1	23.64	1.4	6.35	596	11.99	31	2.46
A	13/02/2020	8:25:47	-0.21	23.64	1.9	6.4	594	12	30.3	2.4
B	13/02/2020	8:35:14	-0.1	22.57	10.4	6.64	570	12.43	51.5	4.14
B	13/02/2020	8:35:23	-0.17	22.61	9.9	6.61	570	12.77	46.5	3.73
C	13/02/2020	8:56:29	-0.1	23.19	5	6.74	554	12.11	43.4	3.46
C	13/02/2020	8:56:39	-0.28	23.22	3.8	6.72	555	12.3	41.8	3.33
C	13/02/2020	8:56:48	-0.44	23.21	4.3	6.71	554	12.25	40.5	3.23
D	13/02/2020	9:07:41	-0.1	22.5	22.1	6.85	540	10.09	54.3	4.43
D	13/02/2020	9:07:52	-0.24	22.5	21.1	6.83	540	10.07	53.2	4.35
D	13/02/2020	9:08:02	-0.38	22.5	21.5	6.82	540	10.09	52.9	4.32
D	13/02/2020	9:08:18	-0.46	22.5	21.4	6.8	540	10.08	52.3	4.27
D	13/02/2020	9:08:28	-0.62	22.5	22.5	6.8	541	10.08	52.1	4.26
D	13/02/2020	9:08:38	-0.77	22.5	21.6	6.79	541	10.07	52	4.25
D	13/02/2020	9:08:50	-0.86	22.49	21.6	6.79	541	10.08	51.9	4.24
D	13/02/2020	9:09:15	-0.99	22.49	21.8	6.78	541	10.07	51.8	4.23
D	13/02/2020	9:09:24	-1.13	22.49	21.7	6.78	541	10.08	51.7	4.22
D	13/02/2020	9:09:33	-1.24	22.49	23.2	6.78	541	10.08	51.6	4.22
D	13/02/2020	9:09:42	-1.32	22.5	22.5	6.78	541	10.07	51.5	4.21
D	13/02/2020	9:09:52	-1.46	22.5	22.3	6.78	541	10.08	51.5	4.21
D	13/02/2020	9:10:01	-1.59	22.5	22	6.78	541	10.07	51.5	4.21
E	13/02/2020	9:17:17	-0.1	22.55	22.2	6.79	526	10.47	54.7	4.45
E	13/02/2020	9:17:27	-0.21	22.55	22.4	6.79	526	10.4	53.5	4.36
E	13/02/2020	9:17:36	-0.33	22.58	22.1	6.77	526	10.62	53.5	4.35
E	13/02/2020	9:17:44	-0.42	22.63	22.7	6.76	527	10.69	51.3	4.17
E	13/02/2020	9:17:51	-0.47	22.62	21.7	6.76	527	10.57	50.8	4.13
E	13/02/2020	9:17:58	-0.63	22.57	23.4	6.77	527	10.59	51.8	4.21
E	13/02/2020	9:18:07	-0.71	22.64	25.1	6.76	527	10.75	50.7	4.11
E	13/02/2020	9:18:16	-0.82	22.62	22.7	6.76	527	10.64	49.7	4.04
E	13/02/2020	9:18:25	-0.89	22.64	22.7	6.75	527	10.7	49.4	4.01
E	13/02/2020	9:18:33	-1.02	22.64	25.1	6.75	527	10.72	49.2	4
E	13/02/2020	9:18:43	-1.1	22.65	24.9	6.75	527	10.74	49.3	4
E	13/02/2020	9:18:51	-1.25	22.65	25	6.75	527	10.74	48.9	3.97
E	13/02/2020	9:19:00	-1.43	22.63	24.4	6.75	527	10.73	49.1	3.98
E	13/02/2020	9:19:09	-1.57	22.64	24.3	6.75	527	10.72	49	3.98
E	13/02/2020	9:19:18	-1.72	22.64	24	6.75	527	10.73	48.8	3.96
E	13/02/2020	9:19:46	-1.99	22.63	25.2	6.75	527	10.72	49	3.97
F	13/02/2020	9:28:08	-0.1	22.53	29.9	6.84	518	10.49	55.1	4.48

F	13/02/2020	9:28:25	-0.17	22.54	31	6.82	519	10.51	54.6	4.45
F	13/02/2020	9:28:41	-0.29	22.54	30.8	6.81	519	10.51	54.3	4.42
F	13/02/2020	9:28:52	-0.37	22.54	32.7	6.81	519	10.52	54.1	4.41
F	13/02/2020	9:29:06	-0.58	22.55	36.1	6.8	519	10.53	54	4.39
G	13/02/2020	9:40:22	-0.1	22.87	23.9	6.82	515	7.9	70	5.75
G	13/02/2020	9:40:33	-0.21	22.84	24	6.8	515	8.17	69.7	5.72
G	13/02/2020	9:40:45	-0.23	22.81	25.4	6.78	516	8.47	67.6	5.54
G	13/02/2020	9:41:00	-0.28	22.82	27	6.78	516	8.45	66.8	5.48
G	13/02/2020	9:41:18	-0.32	22.81	29.9	6.77	518	9.37	64.5	5.26
G	13/02/2020	9:42:44	-0.24	22.83	38.5	6.78	518	7.36	65.9	5.43
H	13/02/2020	10:01:09	-0.1	22.82	24.2	6.85	530	10.31	60.7	4.92
H	13/02/2020	10:01:28	-0.22	22.8	21.8	6.83	529	10.32	59.4	4.82
H	13/02/2020	10:01:36	-0.27	22.8	22.6	6.82	529	10.33	59	4.79
H	13/02/2020	10:01:46	-0.33	22.79	22.2	6.82	529	10.35	58.7	4.76
H	13/02/2020	10:01:54	-0.38	22.79	22.8	6.81	529	10.36	58.4	4.74
H	13/02/2020	10:02:04	-0.45	22.76	24.7	6.8	530	10.68	57.1	4.62
H	13/02/2020	10:02:12	-0.52	22.71	25.5	6.78	530	11.09	53.8	4.35
H	13/02/2020	10:02:21	-0.56	22.69	25.5	6.78	530	11.3	50.4	4.08
H	13/02/2020	10:02:30	-0.63	22.64	24.5	6.77	532	11.88	48	3.87
H	13/02/2020	10:02:44	-0.74	22.57	27.6	6.75	534	13.43	37.9	3.03
J	13/02/2020	10:09:51	-0.1	22.75	34	6.84	511	8.99	59.8	4.9
J	13/02/2020	10:10:00	-0.13	22.74	33.3	6.82	511	8.91	59	4.83
J	13/02/2020	10:10:07	-0.19	22.74	32.9	6.81	511	8.9	58.9	4.82
J	13/02/2020	10:10:14	-0.23	22.75	33.4	6.8	511	9.04	58.5	4.79
J	13/02/2020	10:10:21	-0.3	22.76	32.5	6.79	512	9.05	58	4.74
J	13/02/2020	10:10:28	-0.32	22.76	33	6.78	512	9.05	57.8	4.73
J	13/02/2020	10:10:40	-0.35	22.78	33.1	6.78	513	9.24	57.4	4.68
K	13/02/2020	10:19:16	-0.1	22.71	37.1	6.81	507	8.99	56.7	4.64
K	13/02/2020	10:19:25	-0.11	22.69	34.4	6.79	507	8.88	56	4.59
K	13/02/2020	10:19:32	-0.15	22.68	33.9	6.77	507	8.86	55.9	4.58
K	13/02/2020	10:19:39	-0.22	22.66	35.1	6.76	507	8.8	55.6	4.56
K	13/02/2020	10:19:48	-0.31	22.66	32.7	6.75	507	8.79	55.5	4.55
K	13/02/2020	10:19:57	-0.37	22.63	34.3	6.75	507	8.69	55.4	4.55

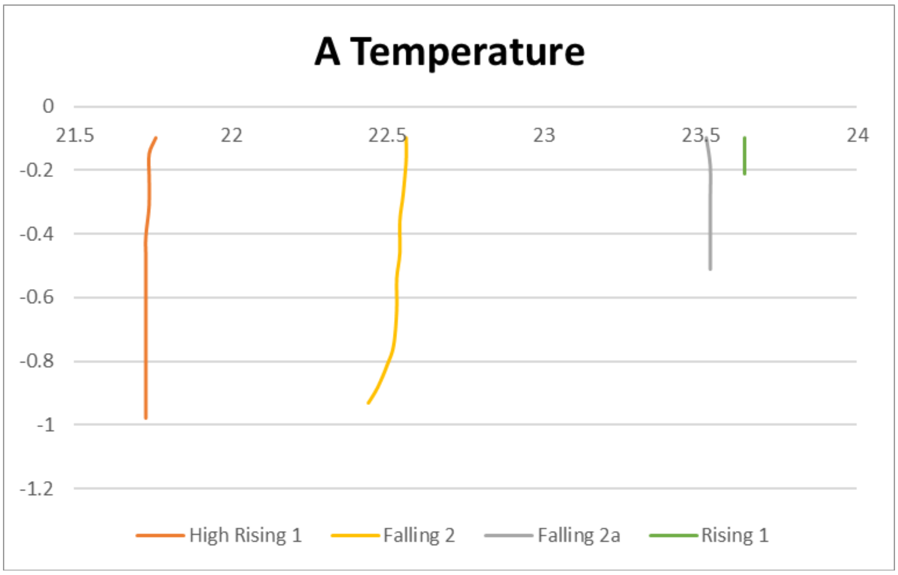
SITE WATER QUALITY PROFILES FOR THE WATER QUALITY DATA PROVIDED IN TABLE A-1 ABOVE.

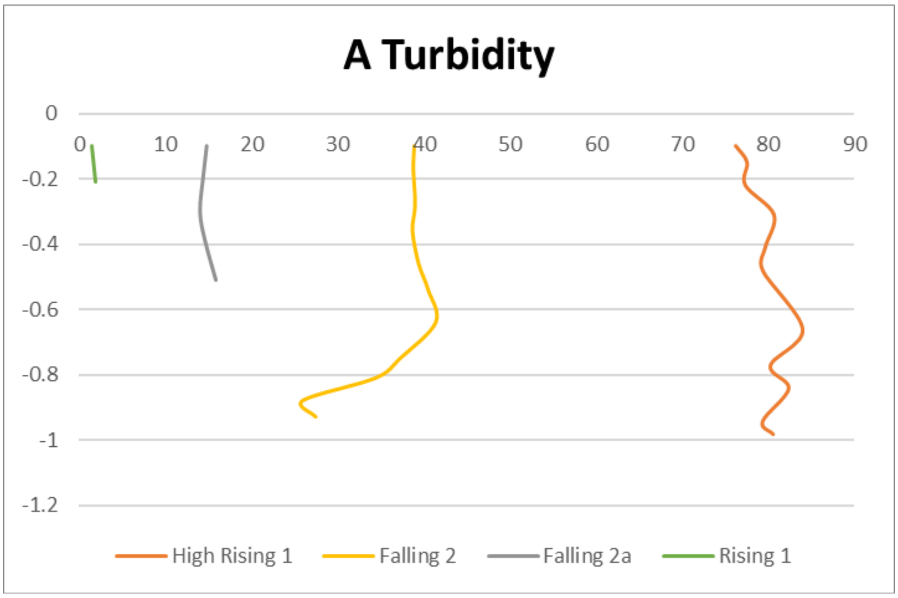
There were between three and four repeat water quality profiles obtained for the 10 sites with tidal data collected on each profile run, and the profile surveys plus tide gauging data are colour coded against the flowing tidal coding scheme:

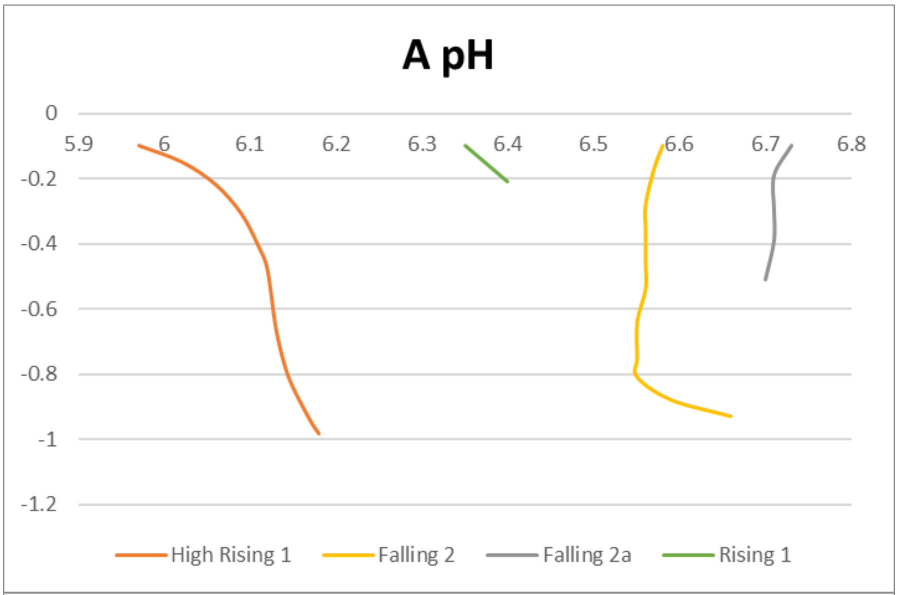
Table A2- Tide Classifications

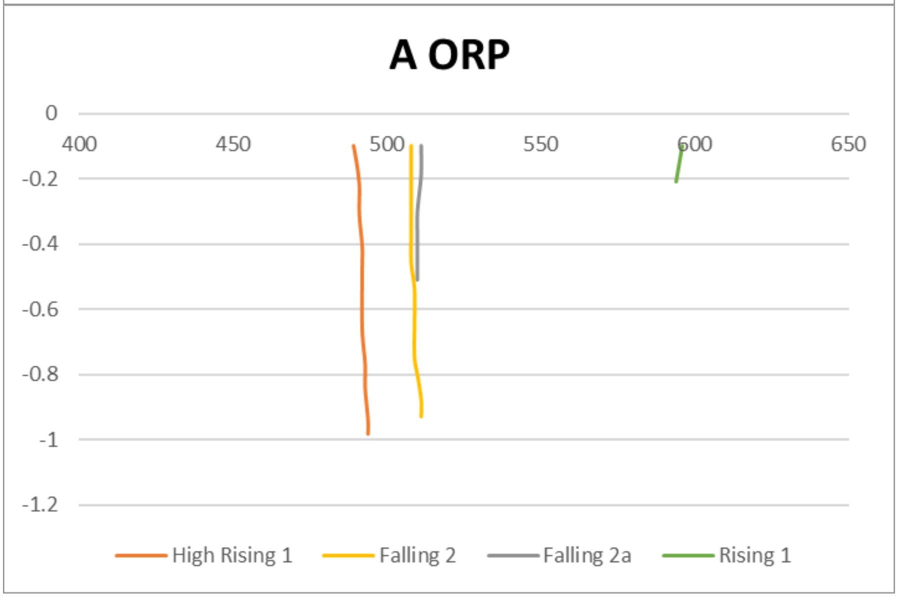
Date	Start	Finish	Classification
11/02/2020	11:41	17:17	Falling 1
11/02/2020	17:17	18:17	Low Falling 1
11/02/2020	18:17	19:17	Low Rising 1
12/02/2020	11:30	12:30	High Rising 1
12/02/2020	12:30	13:30	High Falling 1
12/02/2020	13:30	18:02	Falling 2
13/02/2020	7:04	8:04	Low Rising 2
13/02/2020	8:04	13:13	Rising 1

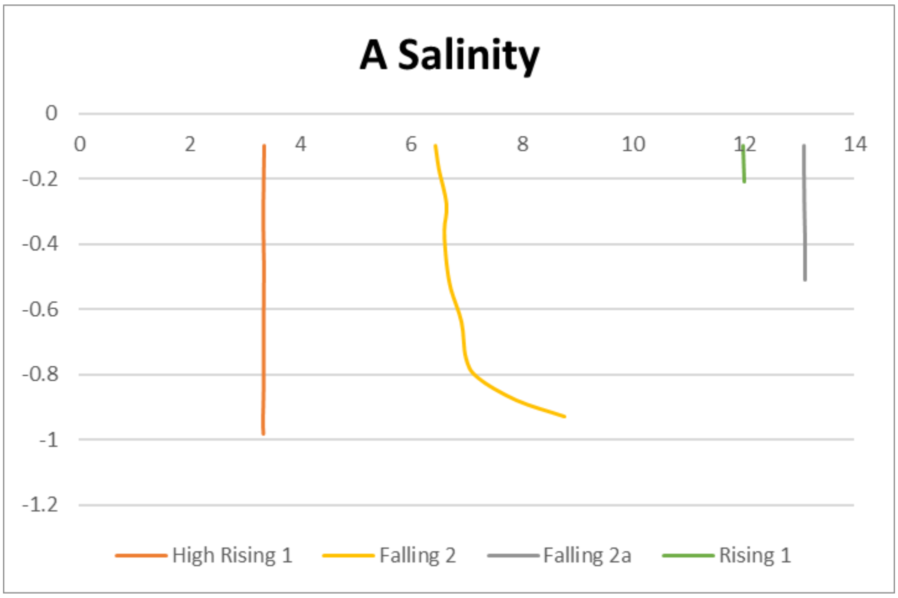
Table A2 classifies each tide over the ampling period. To establish these classifications a one hour tidal lag was factored in for the tide times. The first or last hour of a tide was classified into either a Low Falling, Low Rising, High Falling or a High Rising where the middle of the tides were classed into either Rising or Falling.

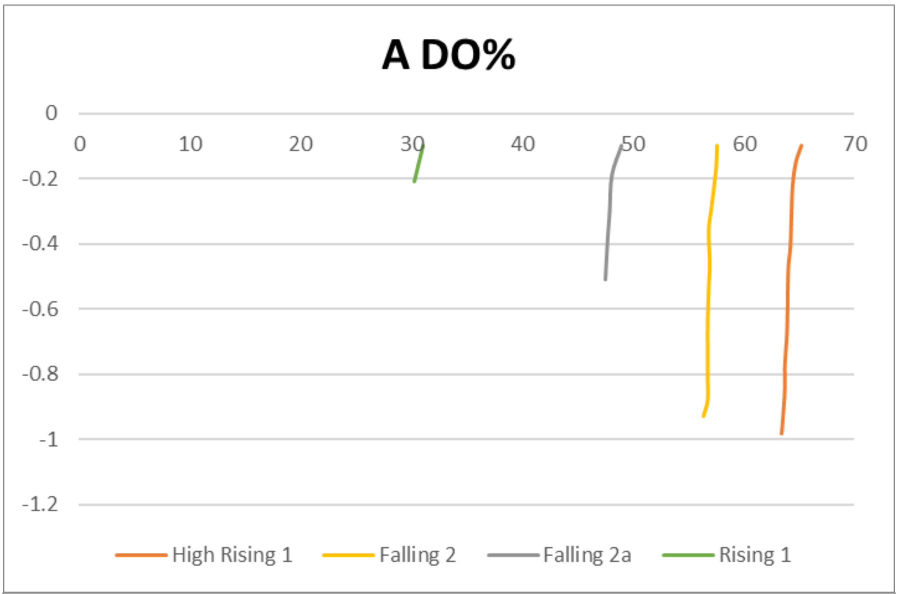

A Temperature
0
21.5
22
22.5
23
23.5
24
-0.2
-0.4
-0.6
-0.8
-1
-1.2
High Rising 1
Falling 2
Falling 2a
Rising 1

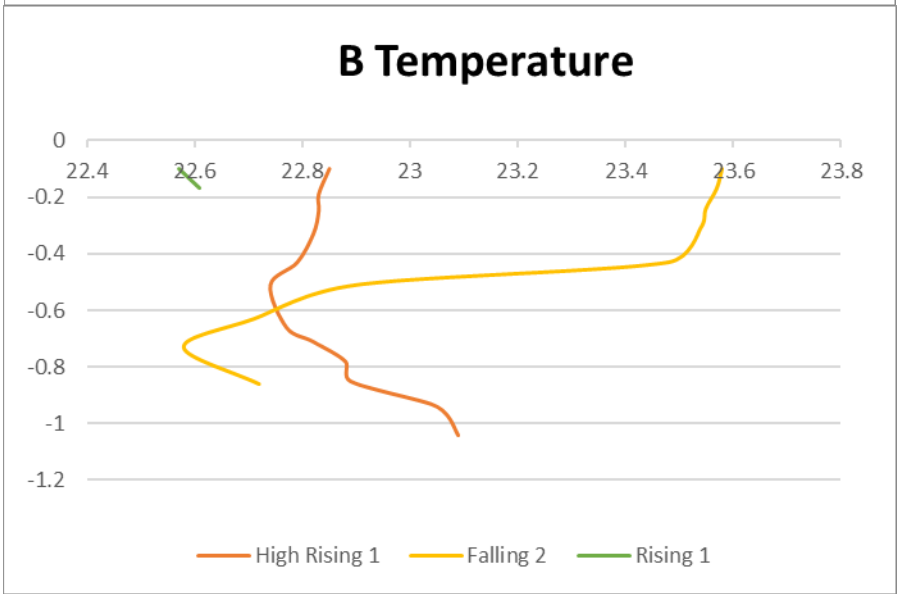

A Turbidity
0
0
10
20
30
40
50
60
70
80
90
-0.2
-0.4
-0.6
-0.8
-1
-1.2
High Rising 1
Falling 2
Falling 2a
Rising 1


A pH
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
5.9
6
6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
High Rising 1
Falling 2
Falling 2a
Rising 1

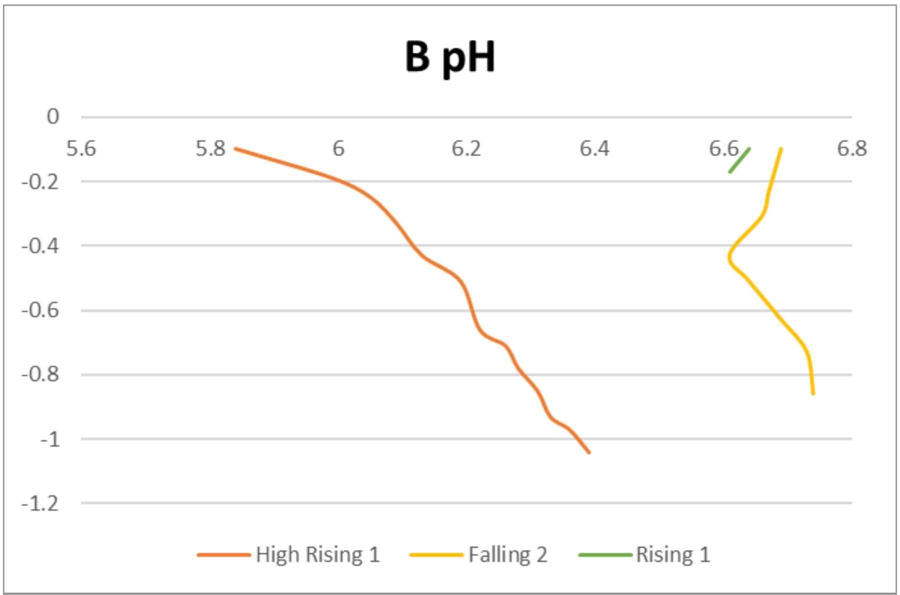

A ORP
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
400
450
500
550
600
650
High Rising 1
Falling 2
Falling 2a
Rising 1

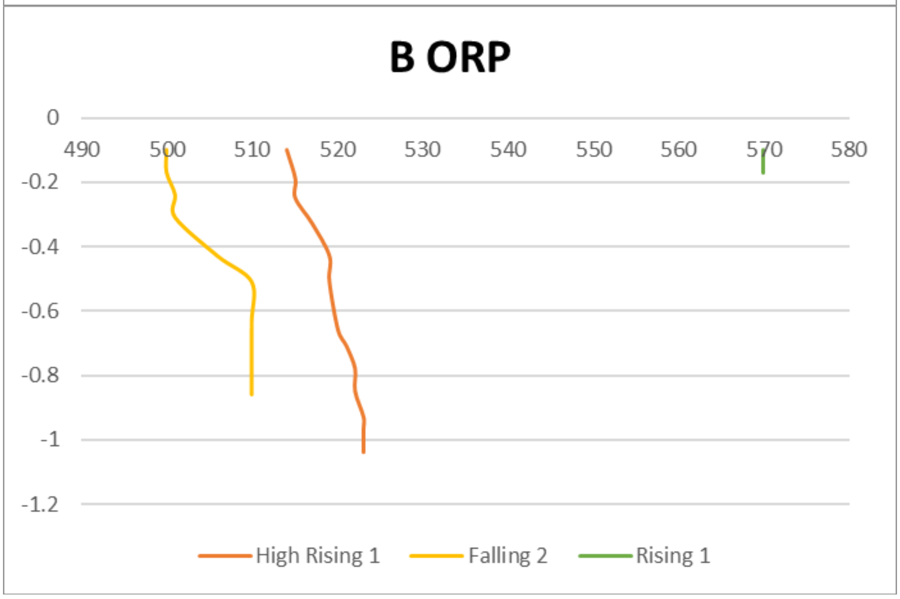

A Salinity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
2
4
6
8
10
12
14
High Rising 1
Falling 2
Falling 2a
Rising 1

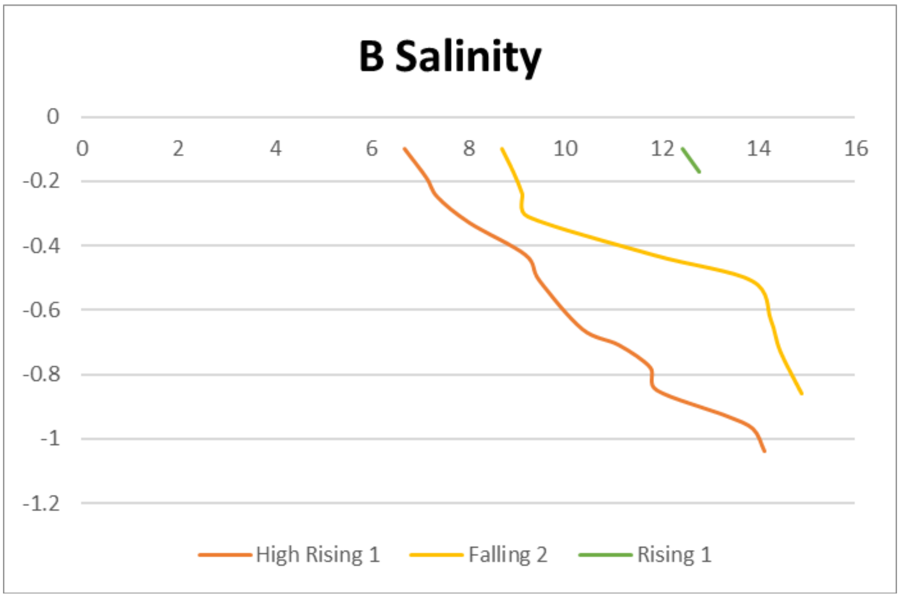

A DO%
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
10
20
30
40
50
60
70
High Rising 1
Falling 2
Falling 2a
Rising 1

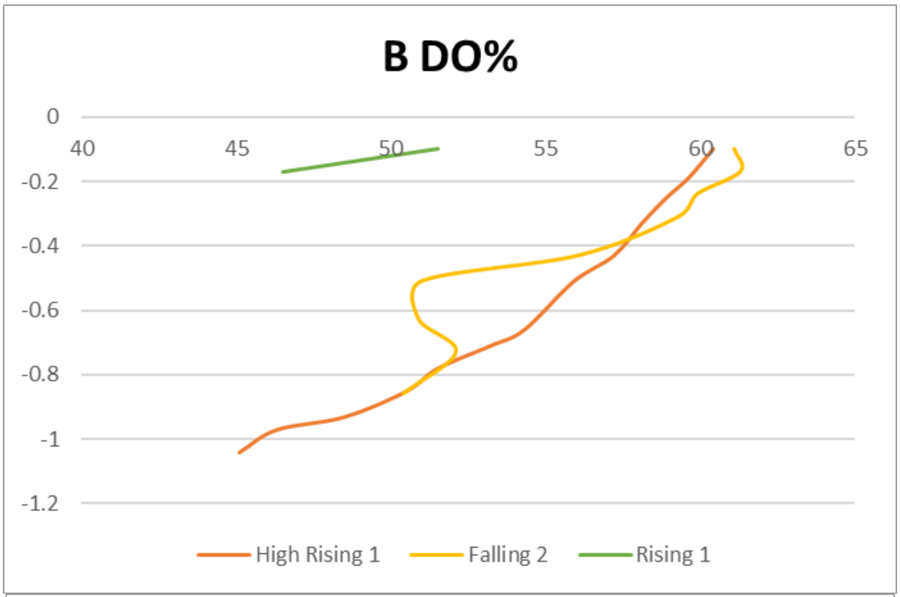

B Temperature
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
22.4
22.6
22.8
23
23.2
23.4
23.6
23.8
High Rising 1
Falling 2
Rising 1

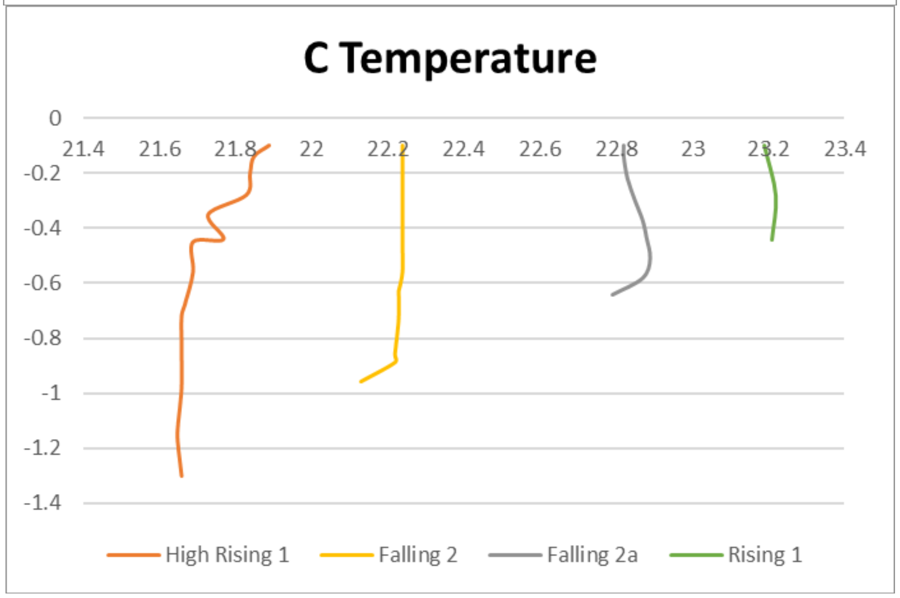

B Turb
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
10
20
30
40
50
High Rising 1
Falling 2
Rising 1

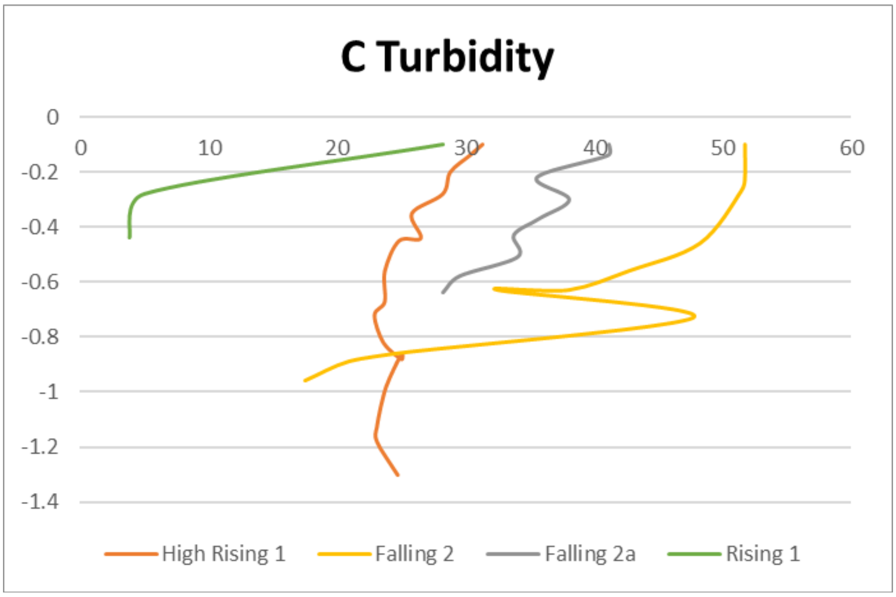

B pH
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
5.6
5.8
6
6.2
6.4
6.6
6.8
High Rising 1
Falling 2
Rising 1

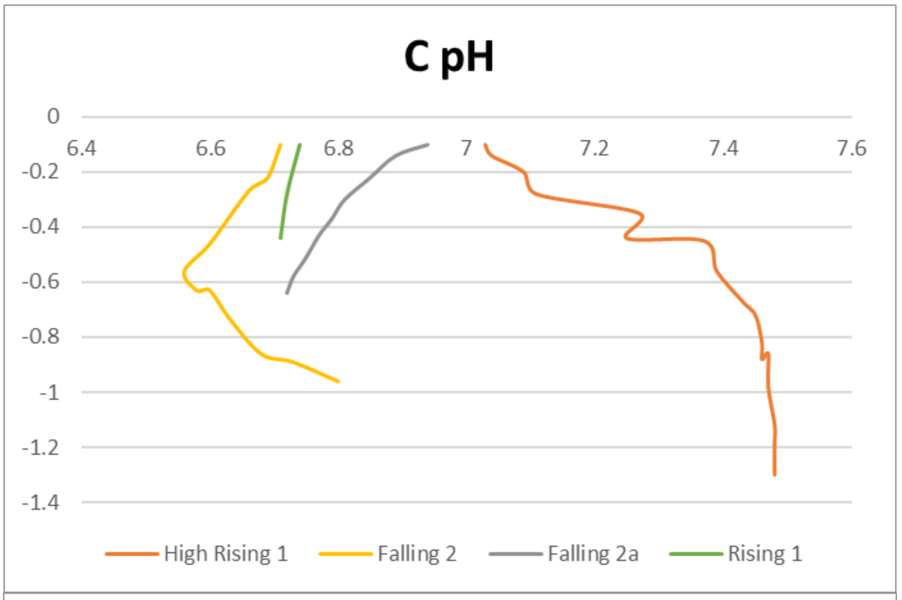

B ORP
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
490
500
510
520
530
540
550
560
570
580
High Rising 1
Falling 2
Rising 1

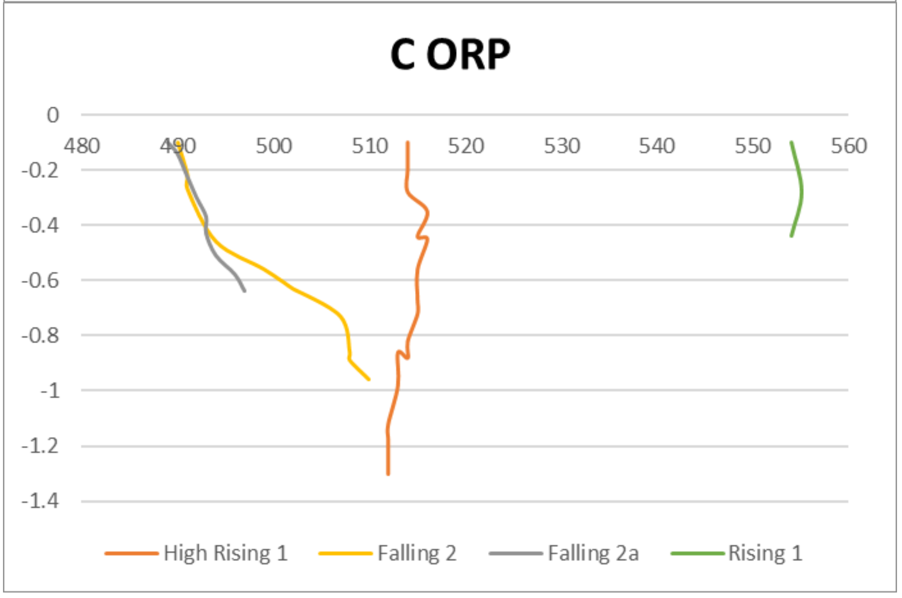

B Salinity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
2
4
6
8
10
12
14
16
High Rising 1
Falling 2
Rising 1

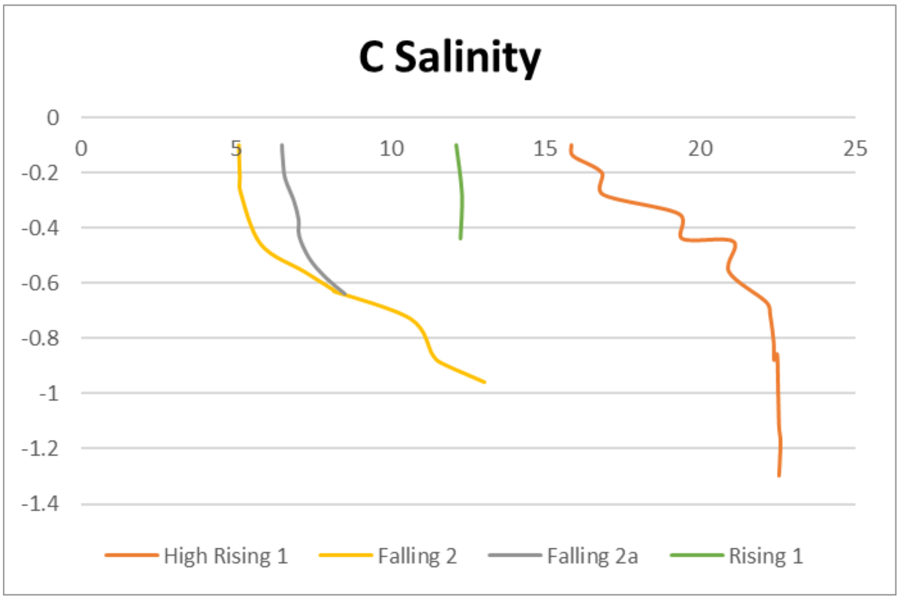

B DO%
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
40
45
50
55
60
65
High Rising 1
Falling 2
Rising 1

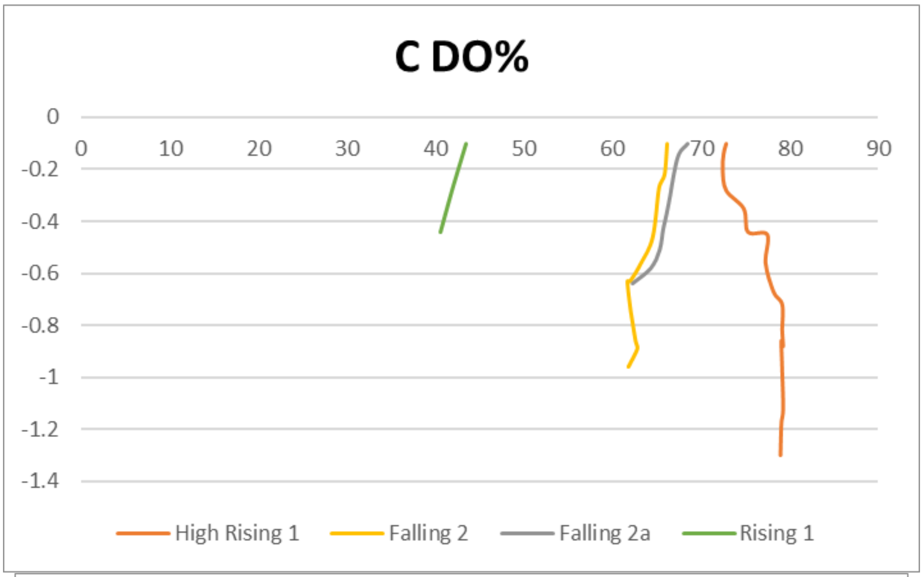

C Temperature
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
21.4
21.6
21.8
22
22.2
22.4
22.6
22.8
23
23.2
23.4
High Rising 1
Falling 2
Falling 2a
Rising 1

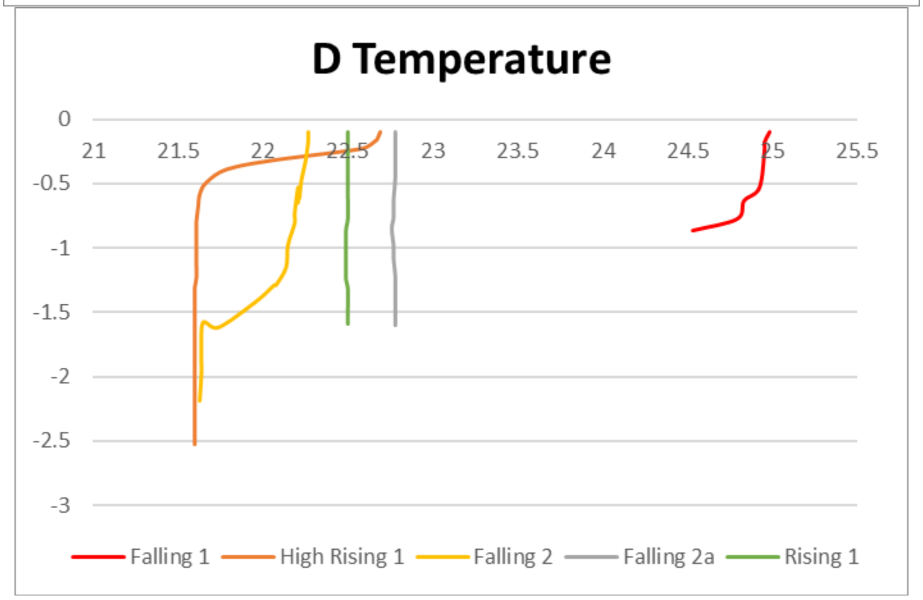

C Turbidity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
10
20
30
40
50
60
High Rising 1
Falling 2
Falling 2a
Rising 1

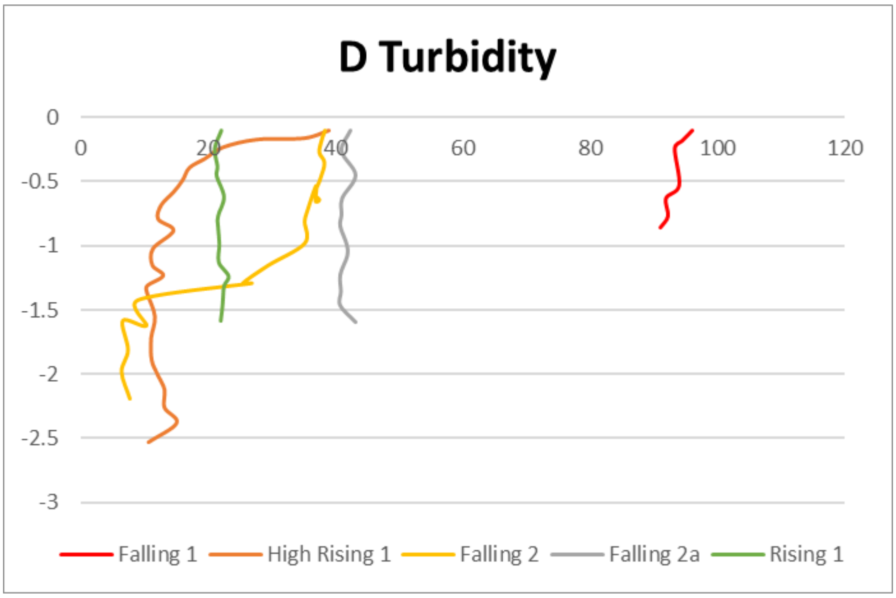

C pH
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
6.4
6.6
6.8
7
7.2
7.4
7.6
High Rising 1
Falling 2
Falling 2a
Rising 1

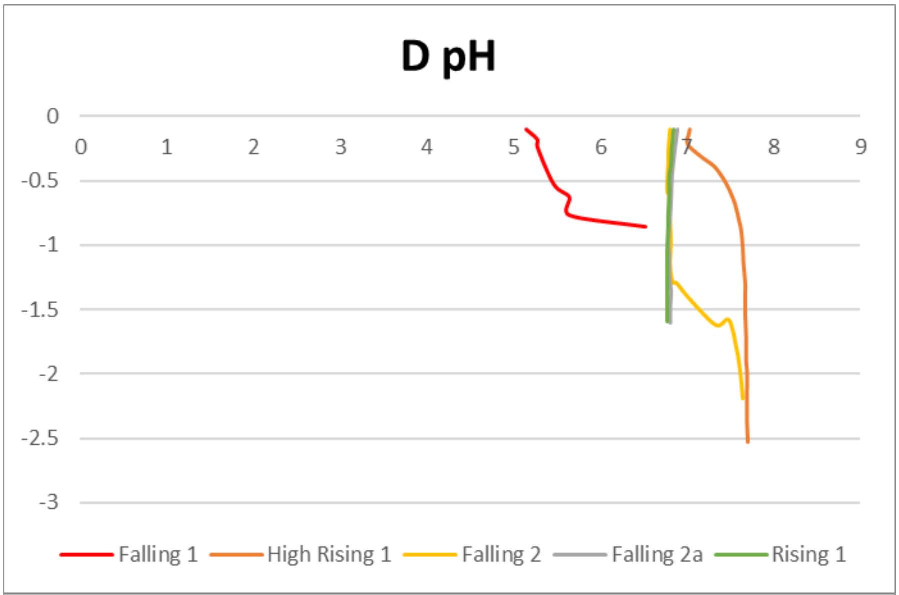

C ORP
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
480
490
500
510
520
530
540
550
560
High Rising 1
Falling 2
Falling 2a
Rising 1

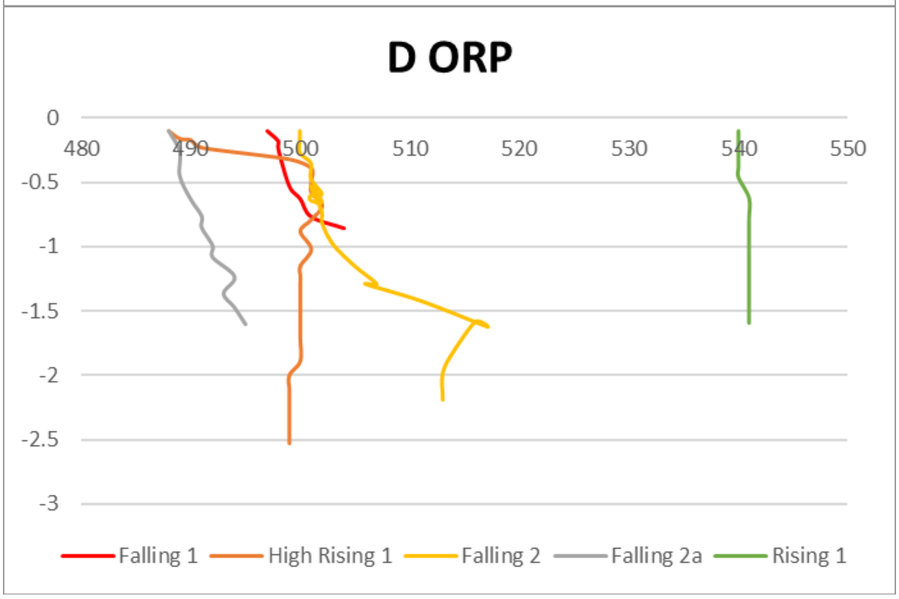

C Salinity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
5
10
15
20
25
High Rising 1
Falling 2
Falling 2a
Rising 1

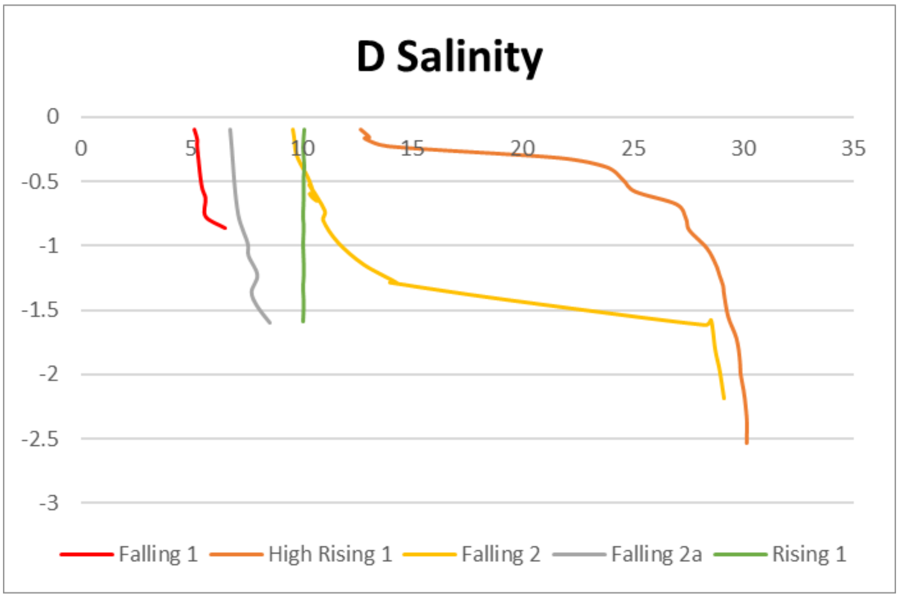

C DO%
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0 10 20 30 40 50 60 70 80 90
High Rising 1
Falling 2
Falling 2a
Rising 1

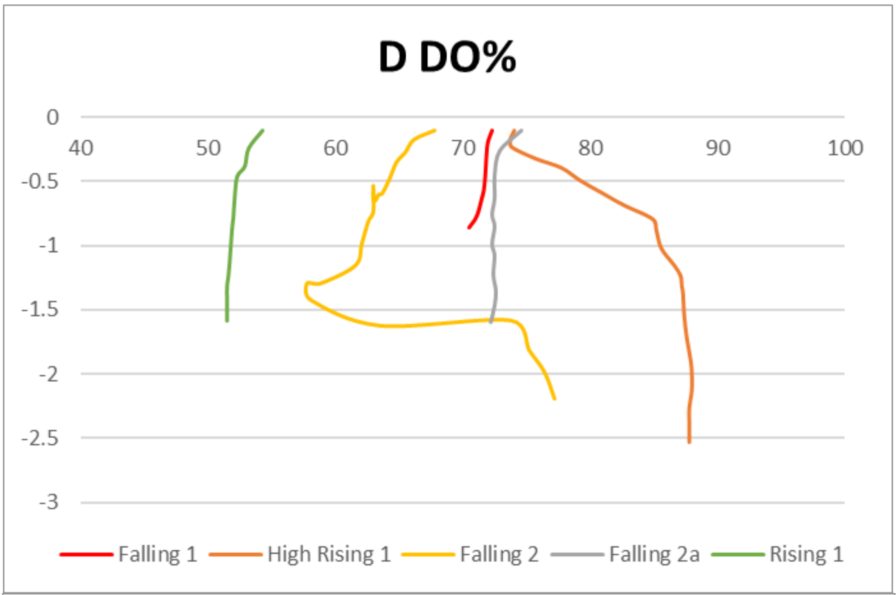

D Temperature
0
-0.5
-1
-1.5
-2
-2.5
-3
21 21.5 22 22.5 23 23.5 24 24.5 25 25.5
Falling 1
High Rising 1
Falling 2
Falling 2a
Rising 1

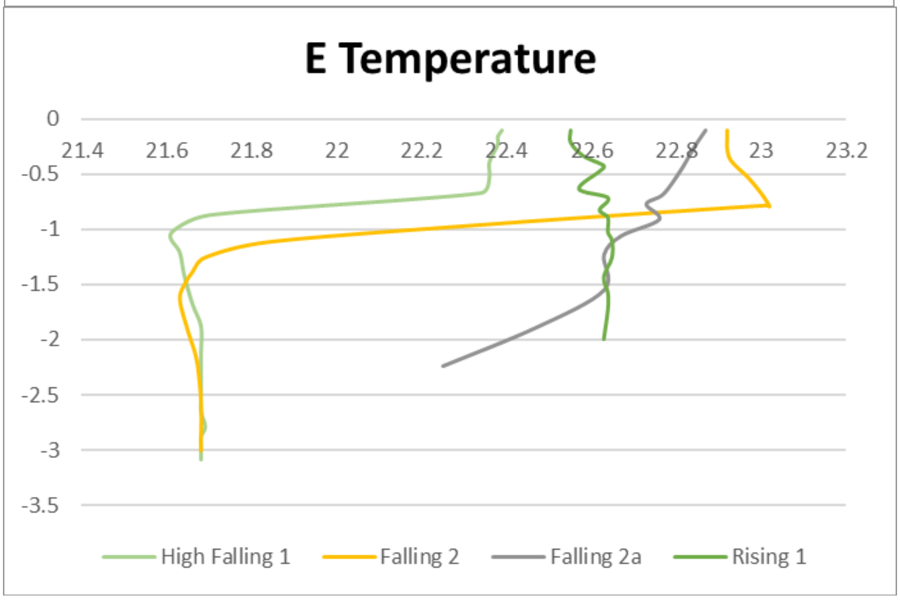

D Turbidity
0
-0.5
-1
-1.5
-2
-2.5
-3
0 20 40 60 80 100 120
Falling 1
High Rising 1
Falling 2
Falling 2a
Rising 1

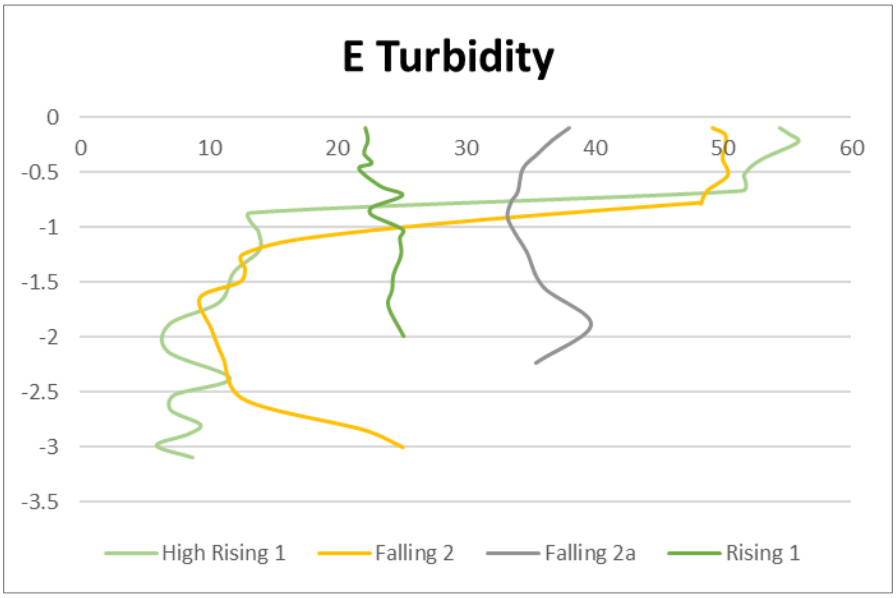

D pH
0
-0.5
-1
-1.5
-2
-2.5
-3
0 1 2 3 4 5 6 7 8 9
Falling 1
High Rising 1
Falling 2
Falling 2a
Rising 1

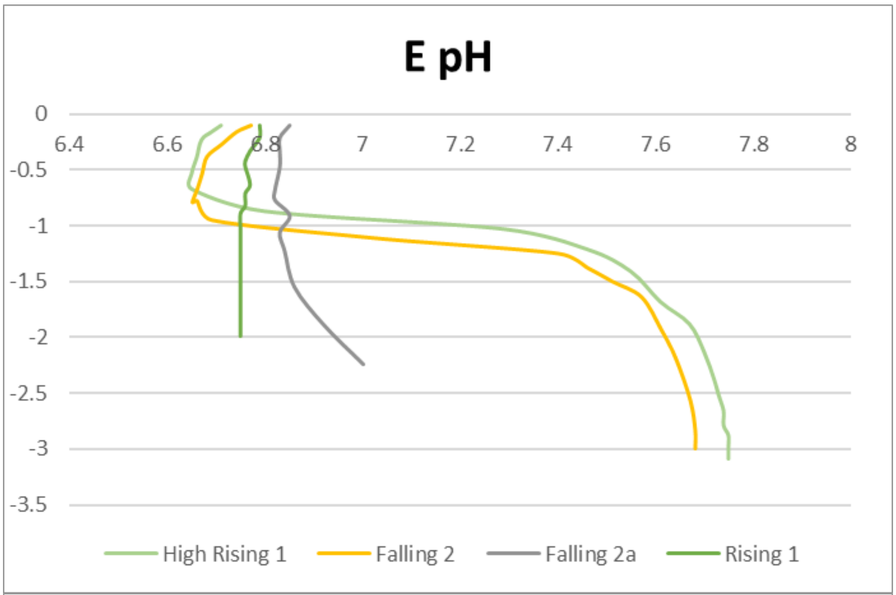

D ORP
0
-0.5
-1
-1.5
-2
-2.5
-3
480 490 500 510 520 530 540 550
Falling 1
High Rising 1
Falling 2
Falling 2a
Rising 1

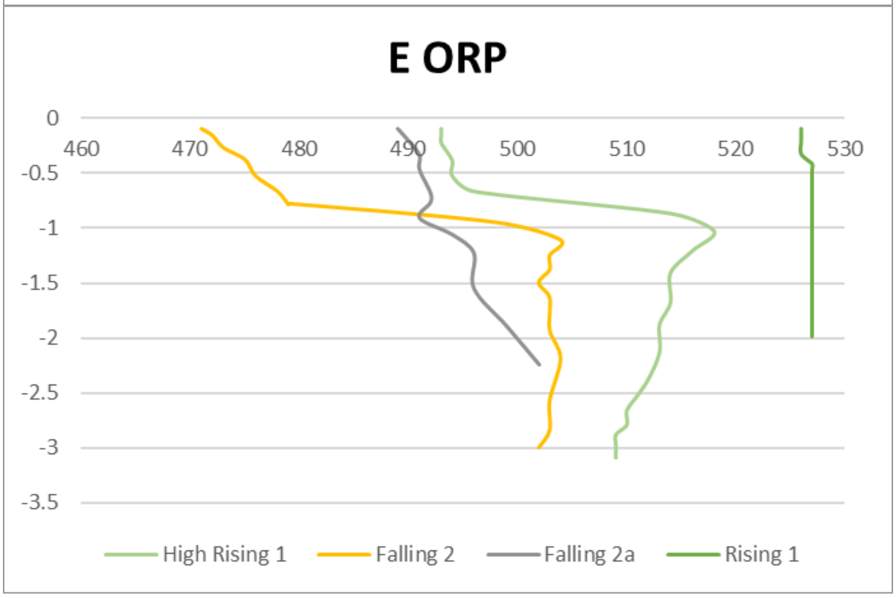

D Salinity
0
-0.5
-1
-1.5
-2
-2.5
-3
0 5 10 15 20 25 30 35
Falling 1
High Rising 1
Falling 2
Falling 2a
Rising 1

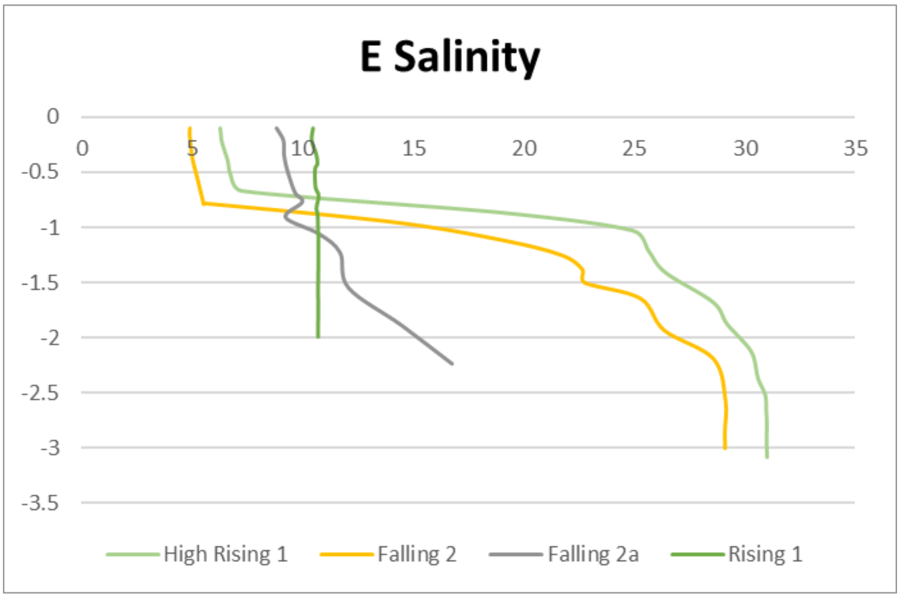

D DO%
0
-0.5
-1
-1.5
-2
-2.5
-3
40 50 60 70 80 90 100
Falling 1
High Rising 1
Falling 2
Falling 2a
Rising 1


E Temperature
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
21.4 21.6 21.8 22 22.2 22.4 22.6 22.8 23 23.2
High Falling 1
Falling 2
Falling 2a
Rising 1


E Turbidity
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0 10 20 30 40 50 60
High Rising 1
Falling 2
Falling 2a
Rising 1


E pH
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
8
High Rising 1
Falling 2
Falling 2a
Rising 1


E ORP
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
460
470
480
490
500
510
520
530
High Rising 1
Falling 2
Falling 2a
Rising 1


E Salinity
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
5
10
15
20
25
30
35
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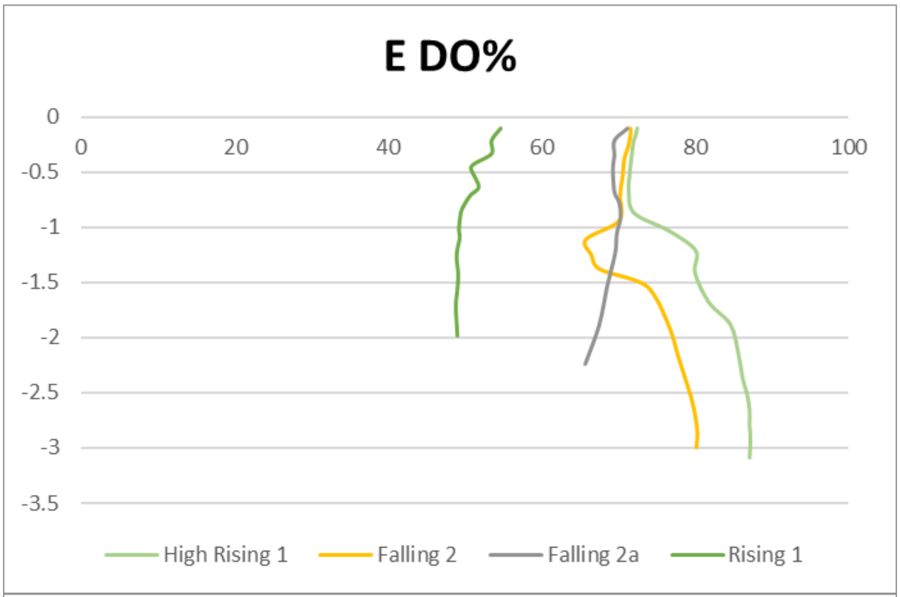
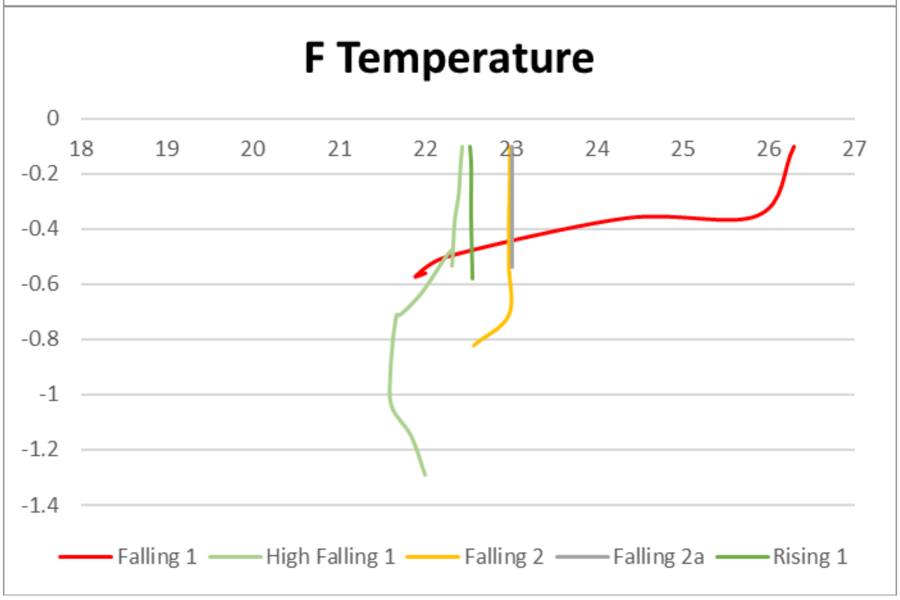
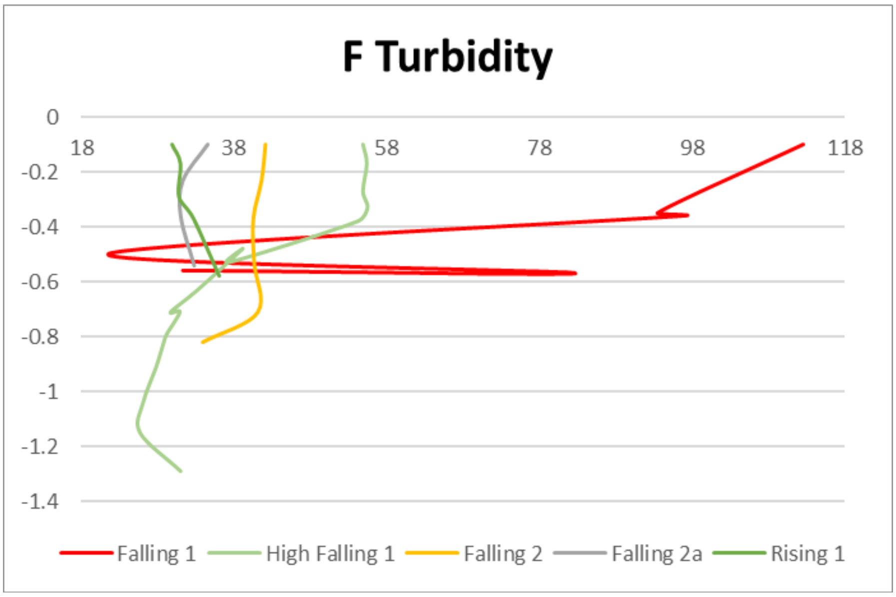
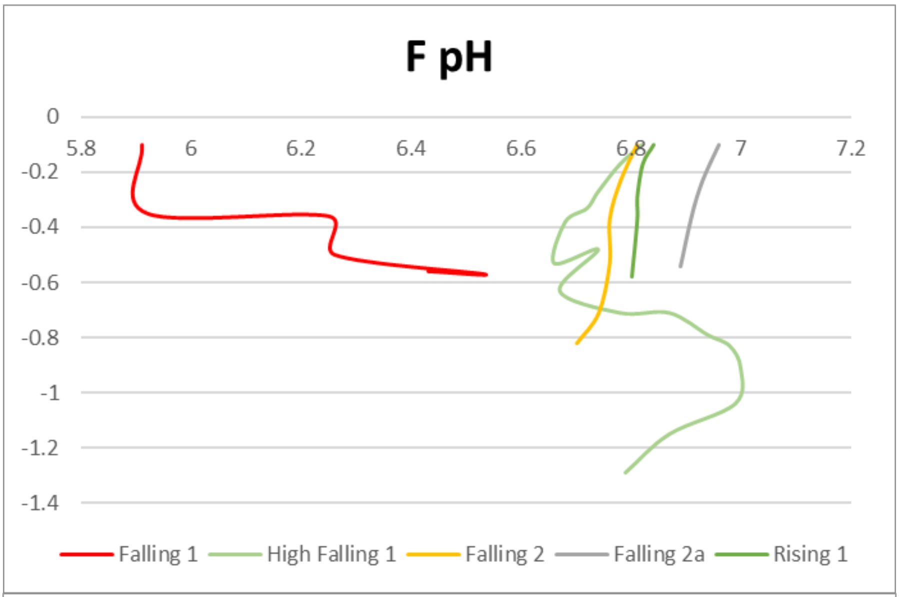
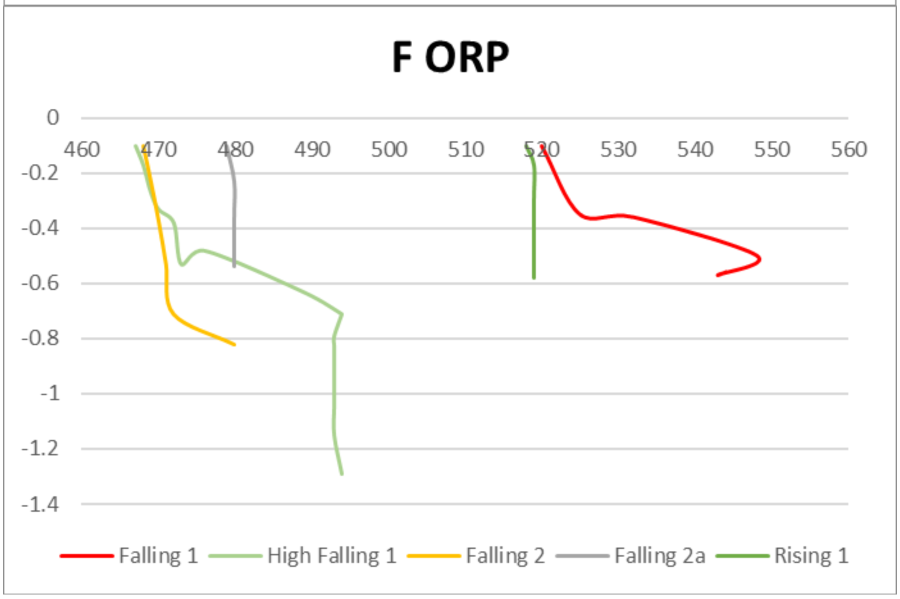
Falling 2
Falling 2a
Rising 1

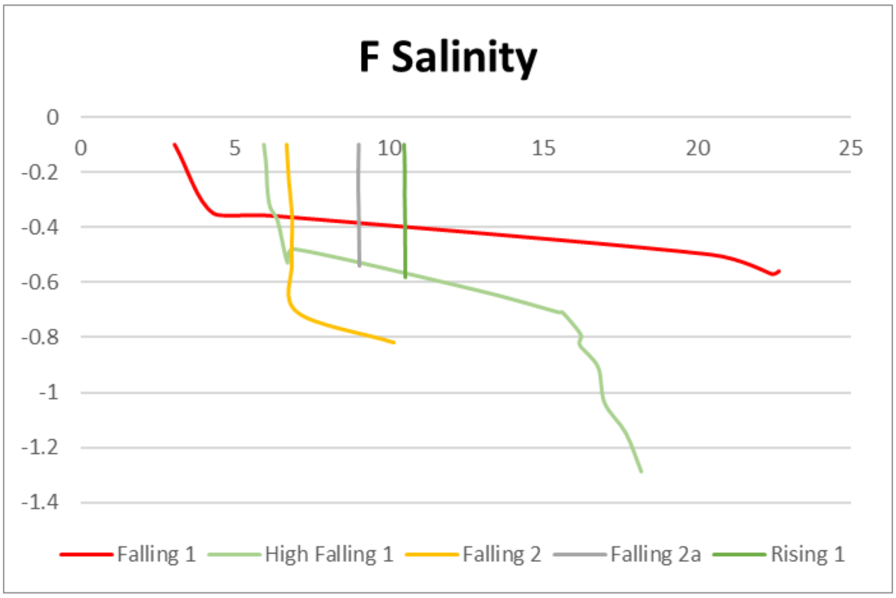

E DO%
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
20
40
60
80
100
High Rising 1
Falling 2
Falling 2a
Rising 1

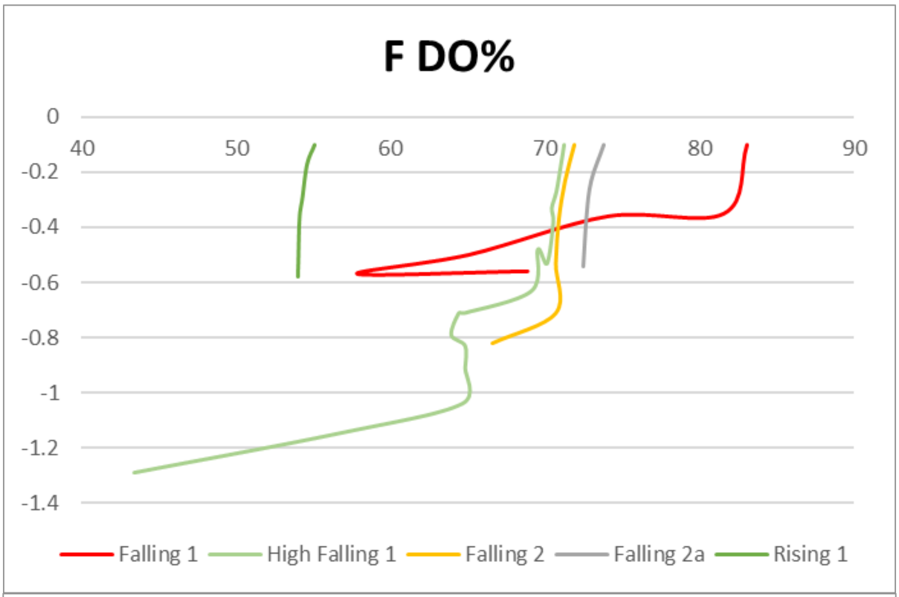

F Temperature
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
18
19
20
21
22
23
24
25
26
27
Falling 1
High Falling 1
Falling 2
Falling 2a
Rising 1

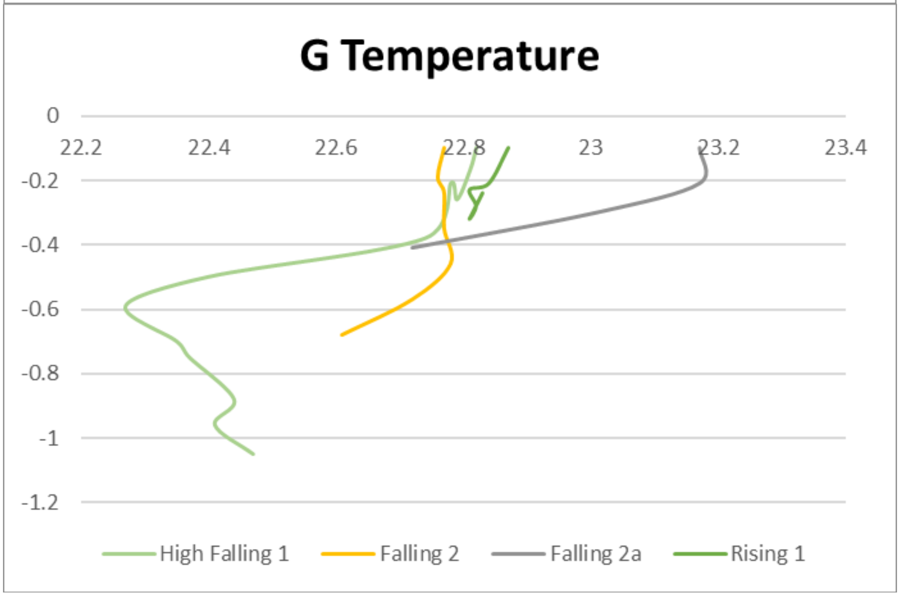

F Turbidity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
18
38
58
78
98
118
Falling 1
High Falling 1
Falling 2
Falling 2a
Rising 1

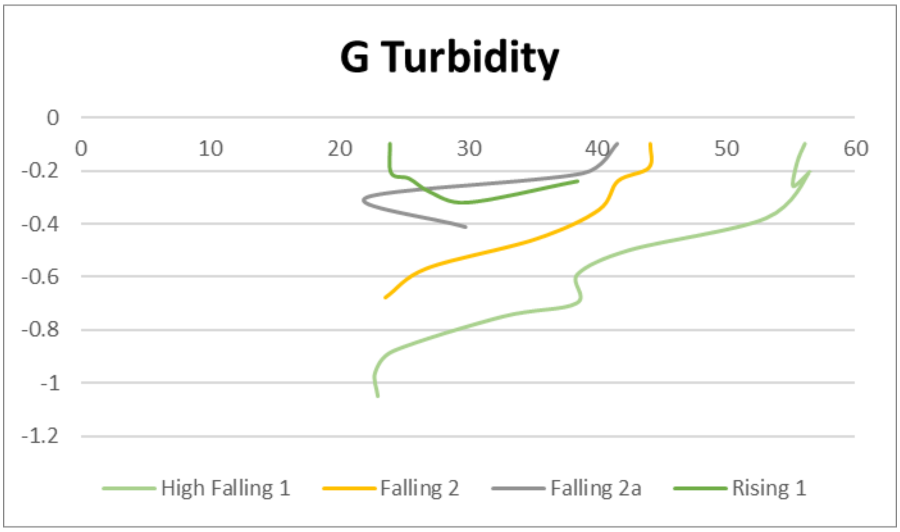

F pH
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
5.8
6
6.2
6.4
6.6
6.8
7
7.2
Falling 1
High Falling 1
Falling 2
Falling 2a
Rising 1

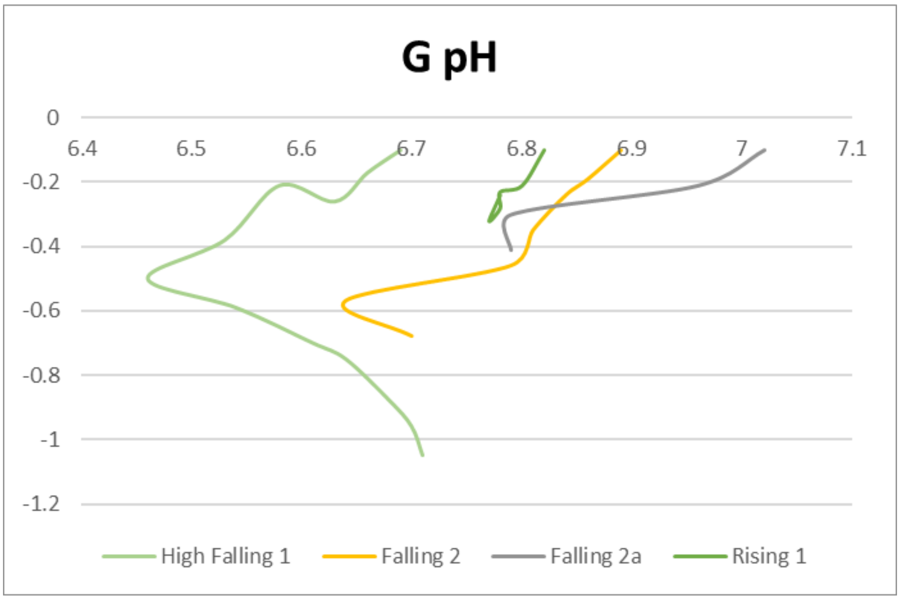

F ORP
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
460
470
480
490
500
510
520
530
540
550
560
Falling 1
High Falling 1
Falling 2
Falling 2a
Rising 1

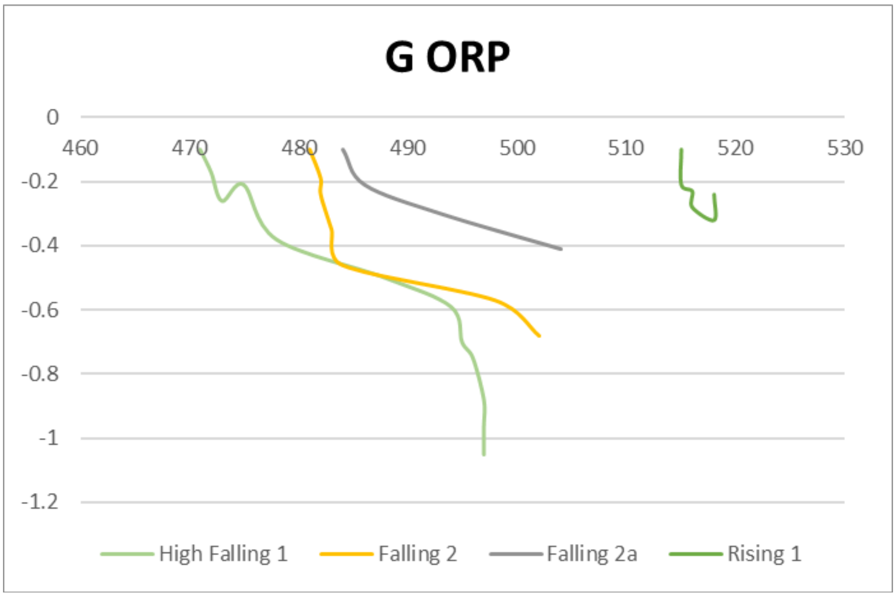

F Salinity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
5
10
15
20
25
Falling 1
High Falling 1
Falling 2
Falling 2a
Rising 1

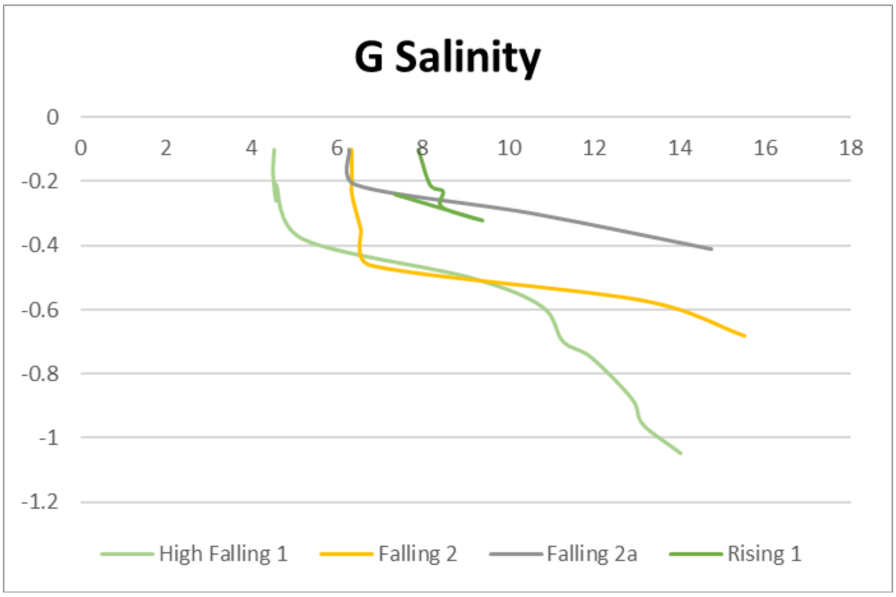

F DO%
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
40
50
60
70
80
90
Falling 1
High Falling 1
Falling 2
Falling 2a
Rising 1

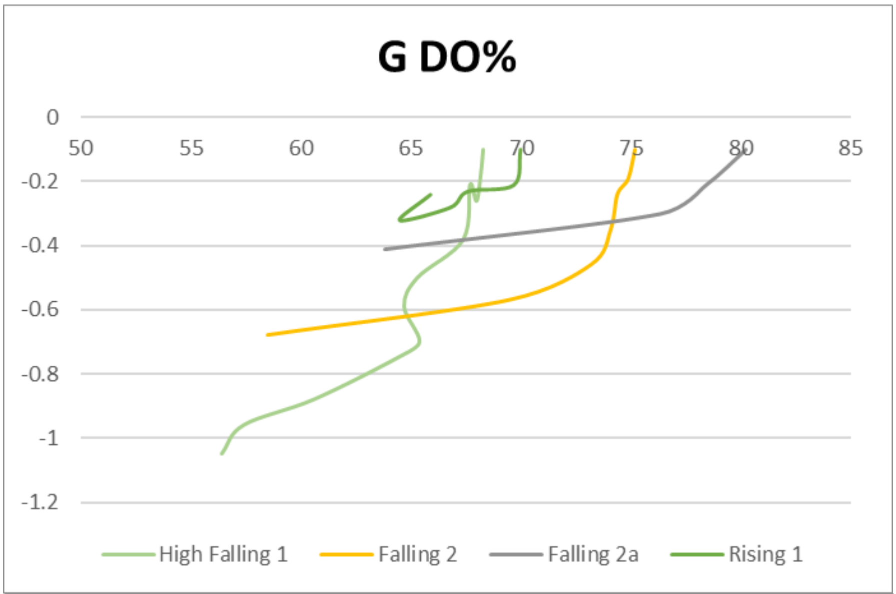

G Temperature
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
22.2
22.4
22.6
22.8
23
23.2
23.4
High Falling 1
Falling 2
Falling 2a
Rising 1

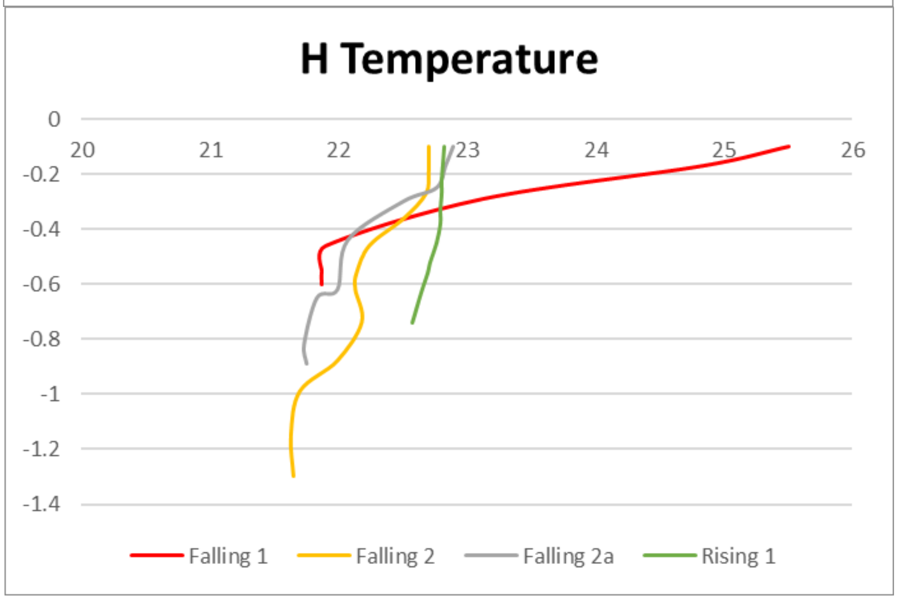

G Turbidity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
10
20
30
40
50
60
High Falling 1
Falling 2
Falling 2a
Rising 1

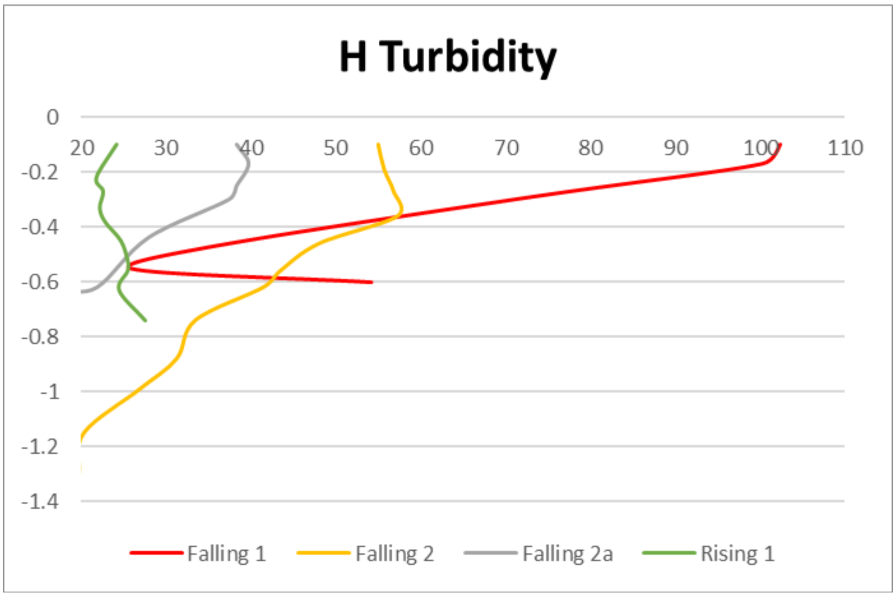

G pH
0
6.4
6.5
6.6
6.7
6.8
6.9
7
7.1
-0.2
-0.4
-0.6
-0.8
-1
-1.2
High Falling 1
Falling 2
Falling 2a
Rising 1

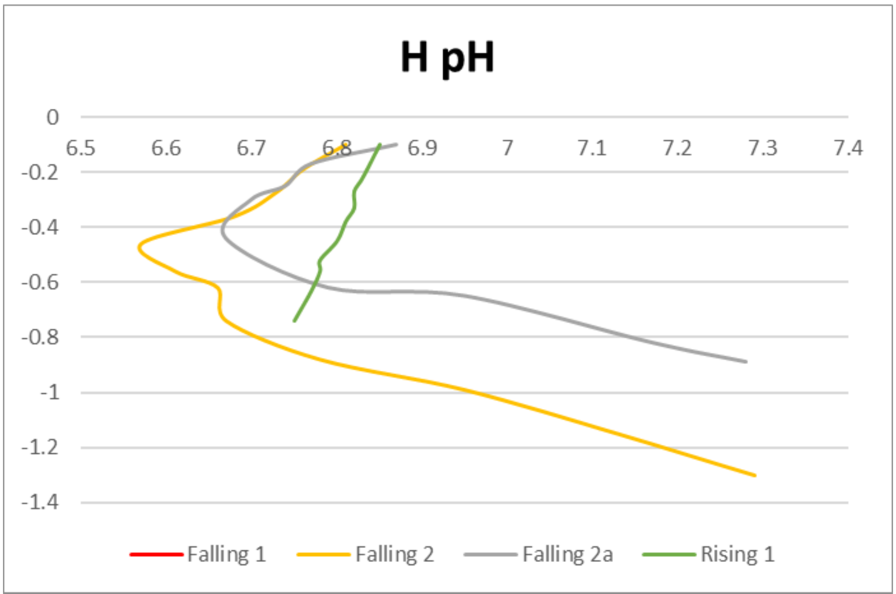

G ORP
0
460
470
480
490
500
510
520
530
-0.2
-0.4
-0.6
-0.8
-1
-1.2
High Falling 1
Falling 2
Falling 2a
Rising 1

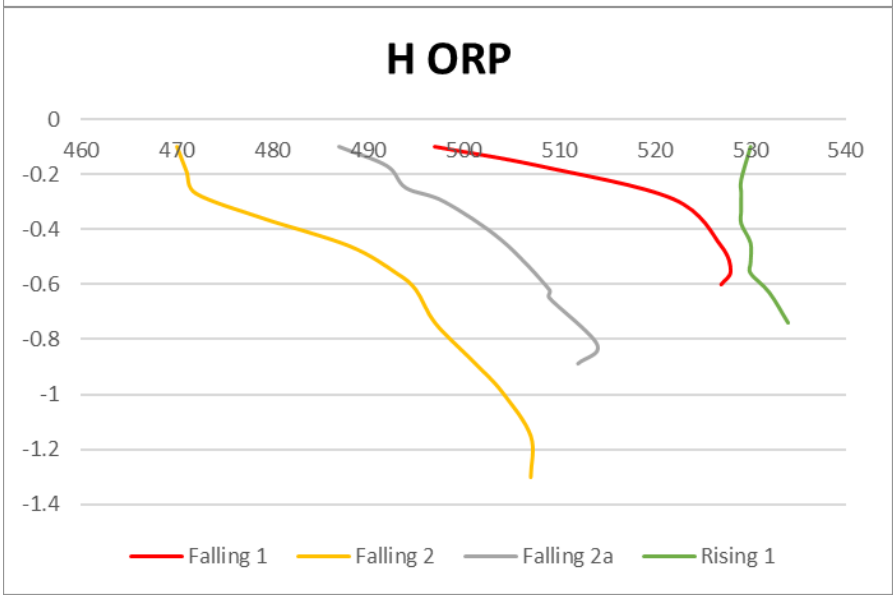

G Salinity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0 2 4 6 8 10 12 14 16 18
High Falling 1
Falling 2
Falling 2a
Rising 1

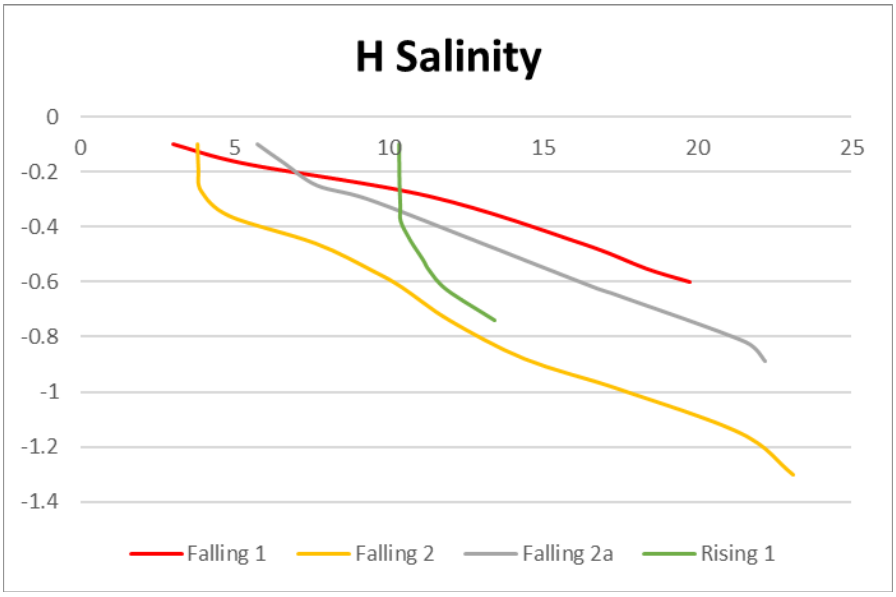

G DO%
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
50 55 60 65 70 75 80 85
High Falling 1
Falling 2
Falling 2a
Rising 1

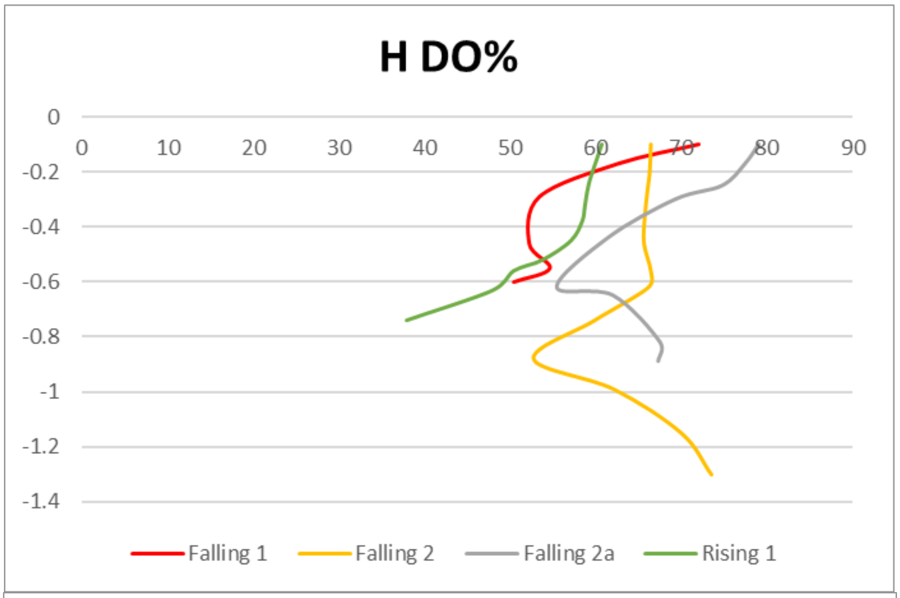

H Temperature
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
20 21 22 23 24 25 26
Falling 1
Falling 2
Falling 2a
Rising 1

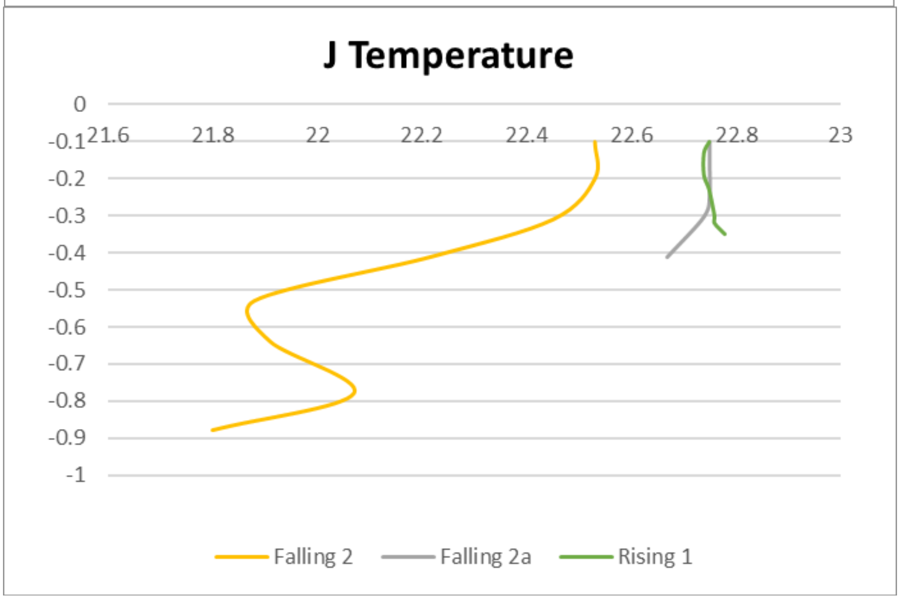

H Turbidity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
20 30 40 50 60 70 80 90 100 110
Falling 1
Falling 2
Falling 2a
Rising 1

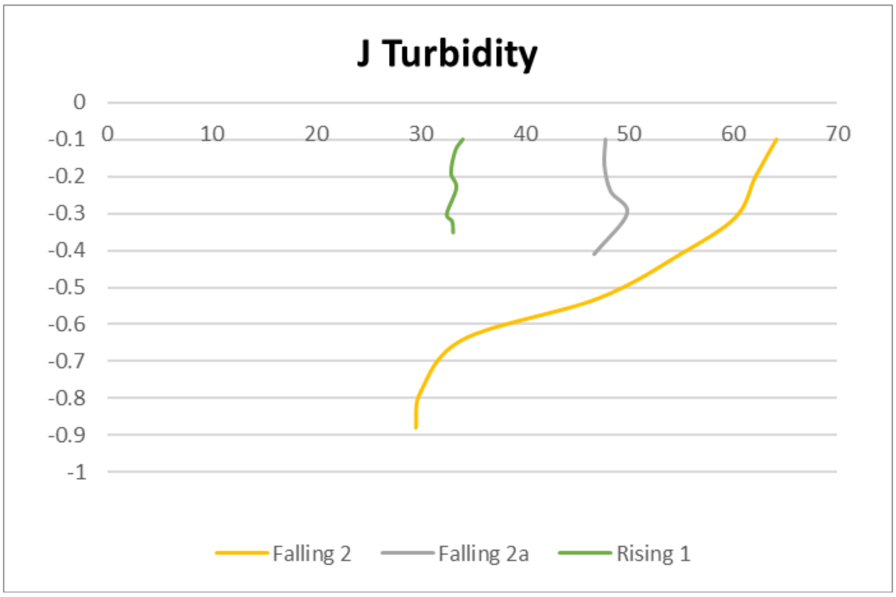

H pH
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
6.5 6.6 6.7 6.8 6.9 7 7.1 7.2 7.3 7.4
Falling 1
Falling 2
Falling 2a
Rising 1

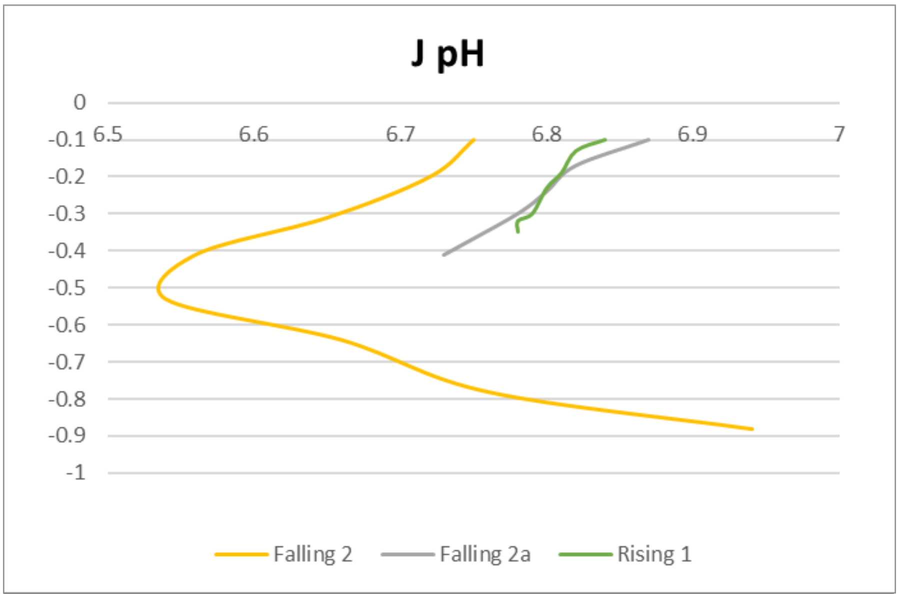

H ORP
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
460 470 480 490 500 510 520 530 540
Falling 1
Falling 2
Falling 2a
Rising 1

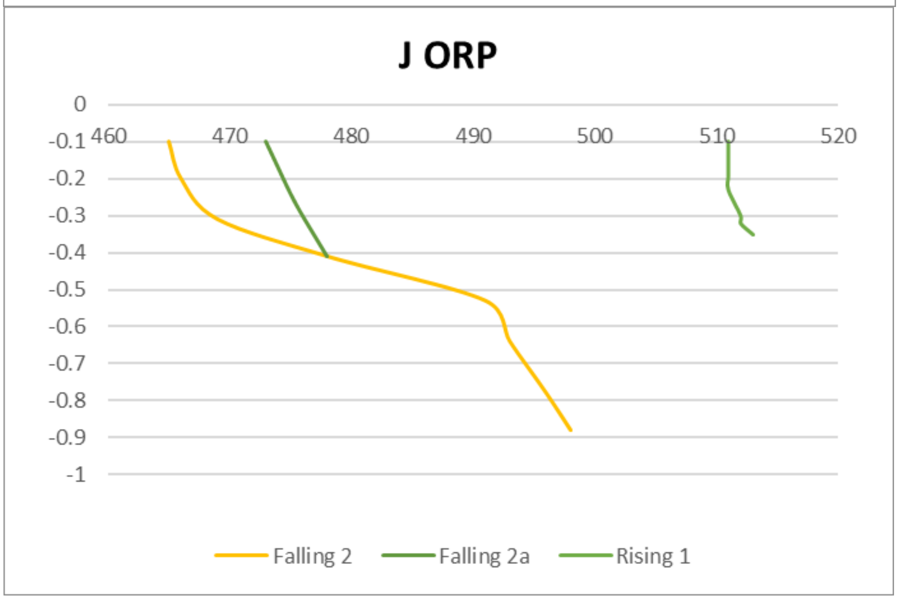

H Salinity
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
5
10
15
20
25
Falling 1
Falling 2
Falling 2a
Rising 1

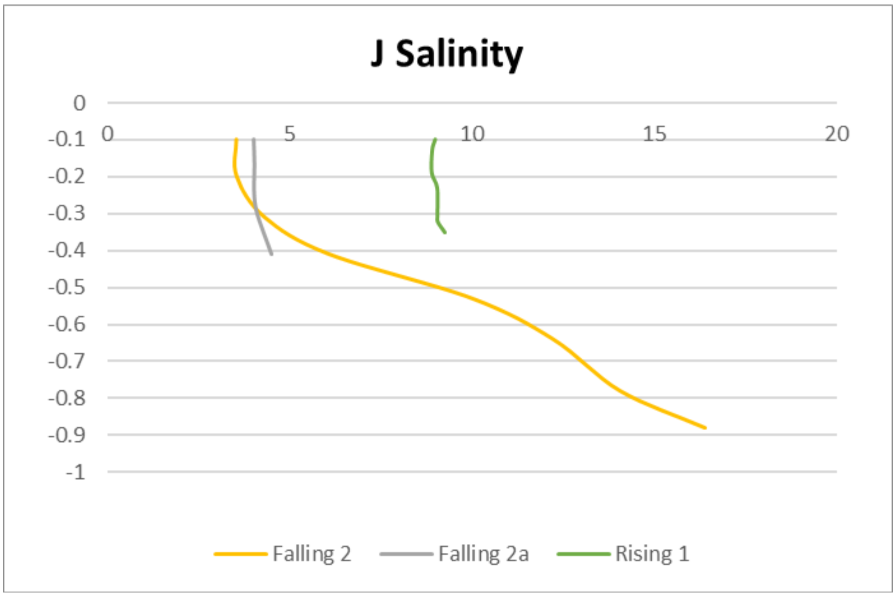

H DO%
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
10
20
30
40
50
60
70
80
90
Falling 1
Falling 2
Falling 2a
Rising 1

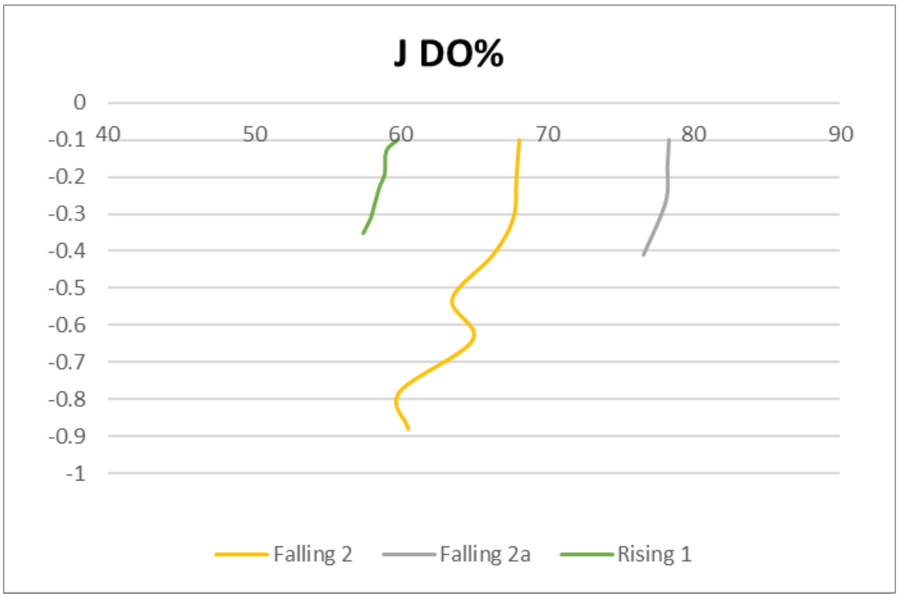

J Temperature
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
21.6
21.8
22
22.2
22.4
22.6
22.8
23
Falling 2
Falling 2a
Rising 1

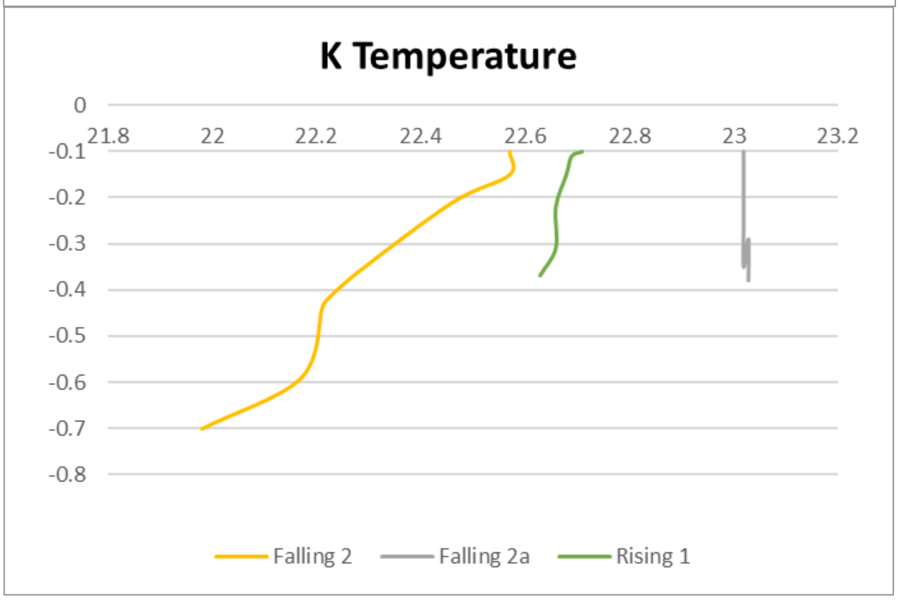

J Turbidity
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
0
10
20
30
40
50
60
70
Falling 2
Falling 2a
Rising 1

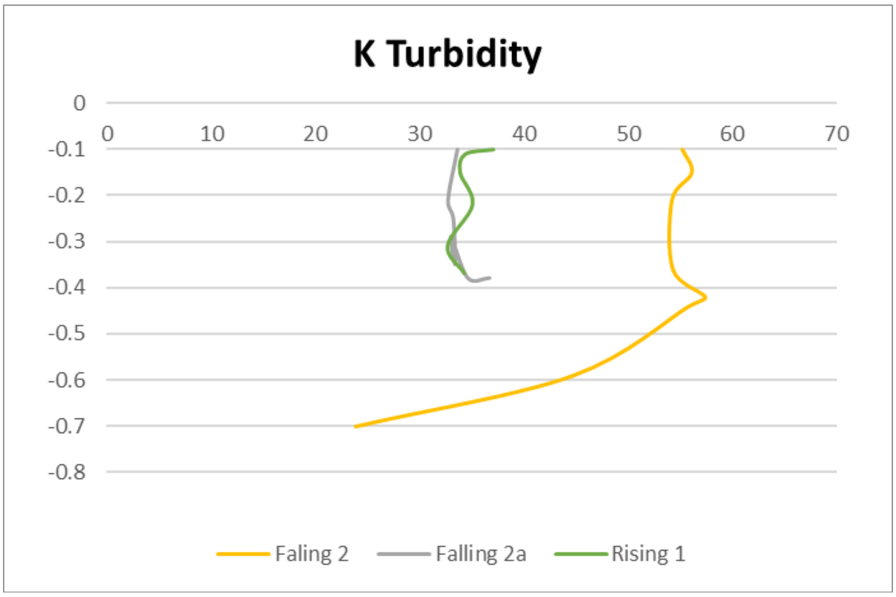

J pH
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
6.5
6.6
6.7
6.8
6.9
7
Falling 2
Falling 2a
Rising 1

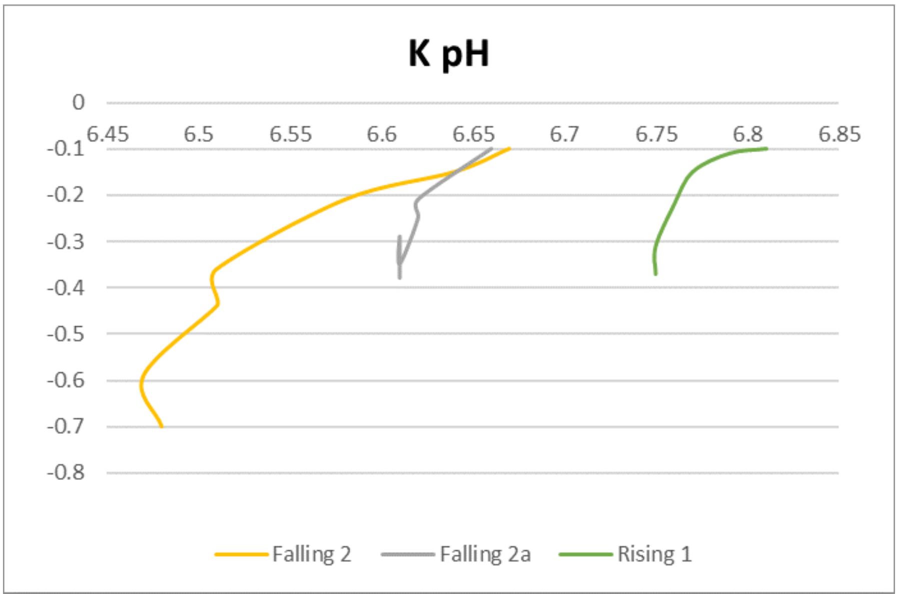

J ORP
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
460
470
480
490
500
510
520
Falling 2
Falling 2a
Rising 1

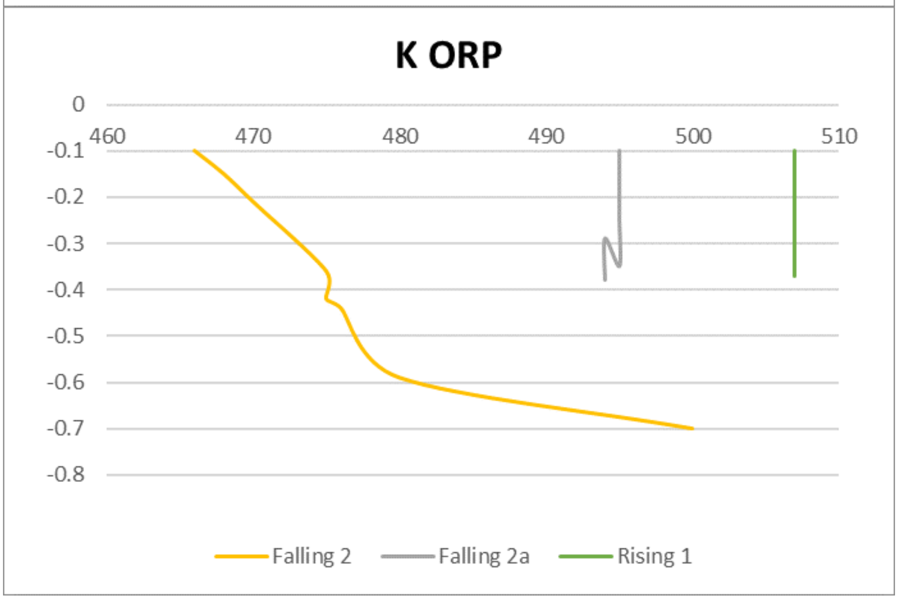

J Salinity
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
0
5
10
15
20
Falling 2
Falling 2a
Rising 1

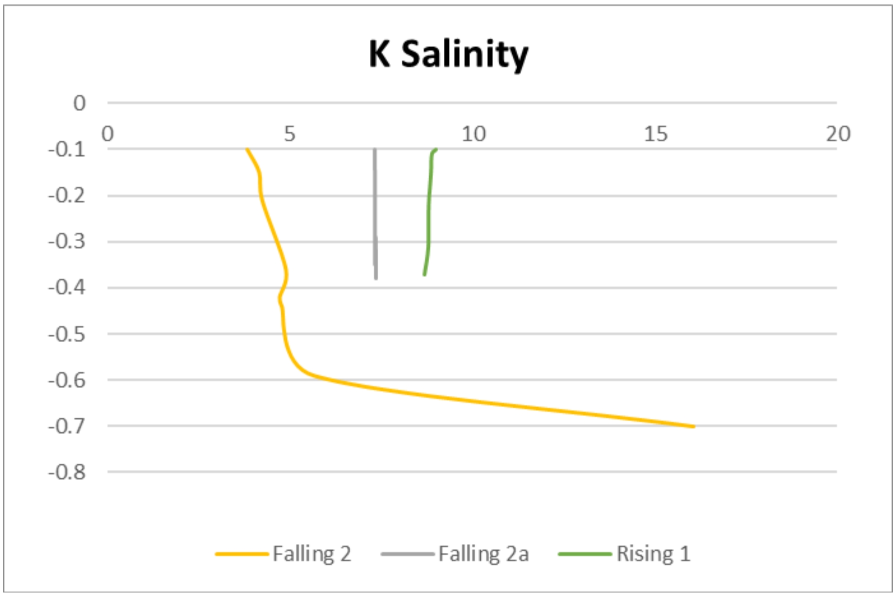

J DO%
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
40
50
60
70
80
90
Falling 2
Falling 2a
Rising 1

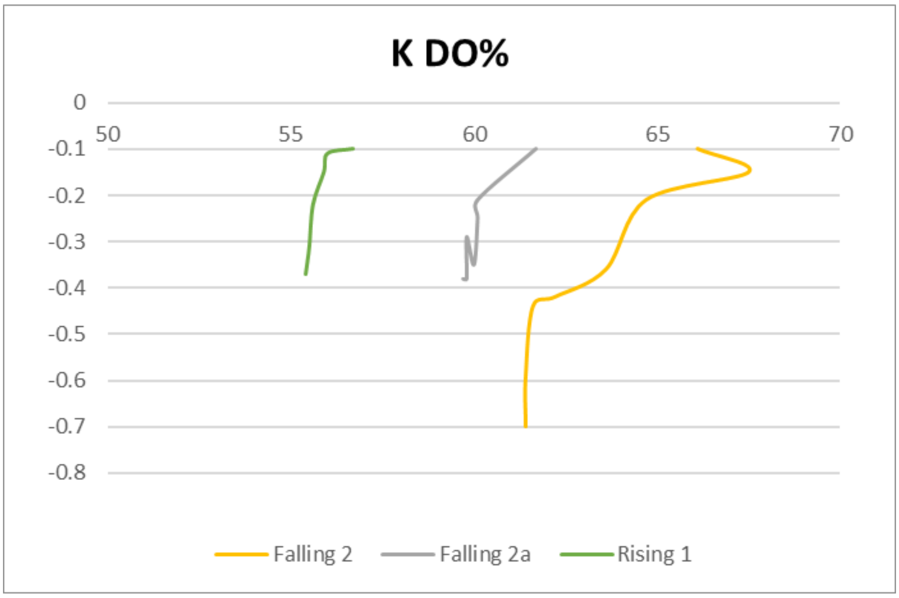

K Temperature
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
21.8
22
22.2
22.4
22.6
22.8
23
23.2
Falling 2
Falling 2a
Rising 1


K Turbidity
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
0
10
20
30
40
50
60
70
Faling 2
Falling 2a
Rising 1


K pH
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
6.45
6.5
6.55
6.6
6.65
6.7
6.75
6.8
6.85
Falling 2
Falling 2a
Rising 1


K ORP
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
460
470
480
490
500
510
Falling 2
Falling 2a
Rising 1





Tide Measurements (Table A3) + Tide Survey Graph

Table A3 - Tide measurements below AHD

Site	Date	Time	Graph Date / Time	WL below AHD	Seabed Below AHD
DRP 1	11/02/2020	14:35	43872.61	0.57	-0.52
DRP 2	11/02/2020	14:50	43872.62	0.46	-0.71
DRP 5	11/02/2020	15:25	43872.64	0.34	-0.415
DRP 4	11/02/2020	15:35	43872.65	0.34	-0.79
DRP 3	11/02/2020	15:45	43872.66	0.295	-0.645
DRP 4	11/02/2020	16:13	43872.68	0.23	-0.79
DRP 3	11/02/2020	16:18	43872.68	0.175	-0.645
DRP 1	12/02/2020	11:25	43873.48	0.715	-0.445
DRP 2	12/02/2020	12:08	43873.51	0.87	-0.7
DRP 3	12/02/2020	12:40	43873.53	0.875	-0.635

DRP 4	12/02/2020	13:30	43873.56	0.77	-0.78
DRP 5	12/02/2020	13:50	43873.58	0.68	-0.39
DRP 1	12/02/2020	14:18	43873.60	0.655	-0.445
DRP 2	12/02/2020	14:40	43873.61	0.535	-0.66
DRP 3	12/02/2020	3:15	43873.64	0.43	-0.63
DRP 4	12/02/2020	3:43	43873.65	0.35	-0.79
DRP 5	12/02/2020	4:02	43873.67	0.25	-0.37
DRP 1	12/02/2020	4:23	43873.68	0.3	-0.48
DRP 2	12/02/2020	4:45	43873.70	0.11	-0.69
DRP 3	12/02/2020	5:10	43873.72	0.09	-0.65
DRP 1	13/02/2020	8:20	43874.35	-0.05	-0.45
DRP 2	13/02/2020	8:53	43874.37	-0.01	-0.7
DRP 3	13/02/2020	9:25	43874.39	0.01	-0.64
DRP 4	13/02/2020	9:58	43874.42	0.15	-0.79
DRP 5	13/02/2020	10:15	43874.43	0.225	-0.37

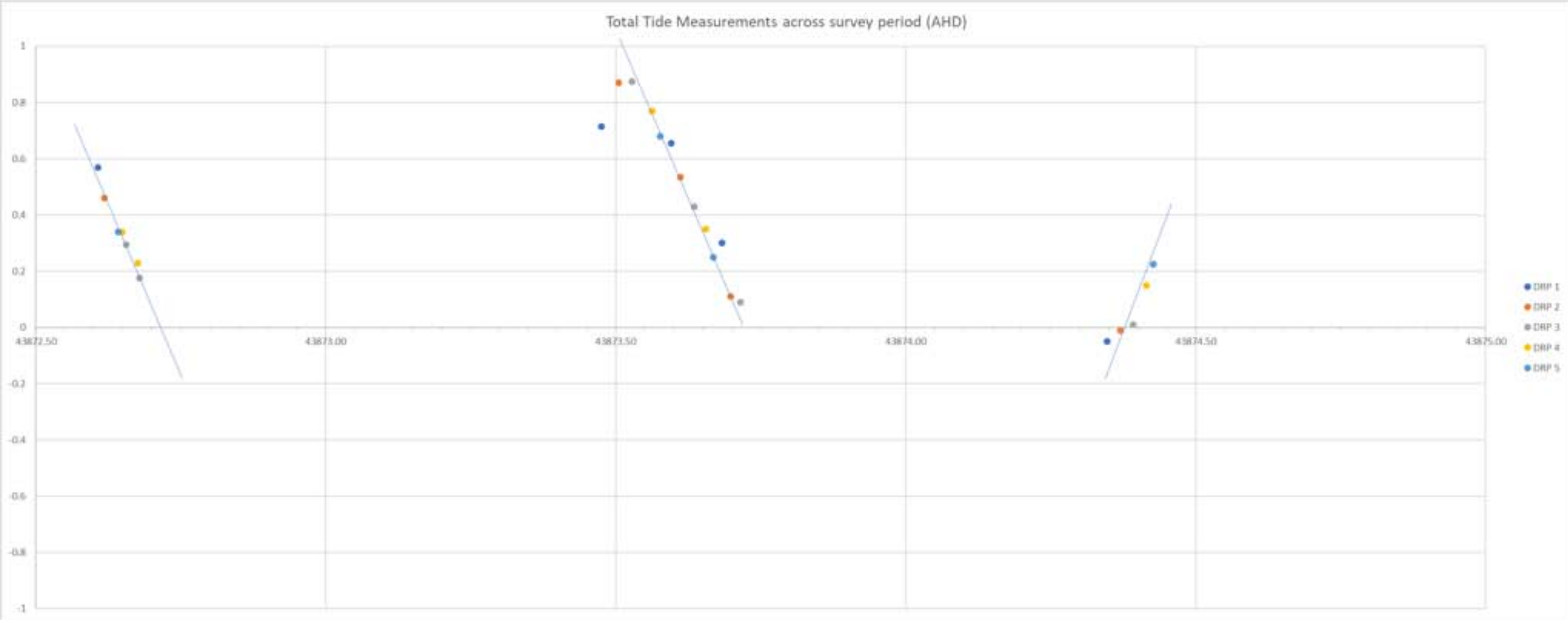


Figure A-1 Tide Data for the Five Tide gauge Sites 11 Feb (day 43852) to 13 Feb (day 43854)

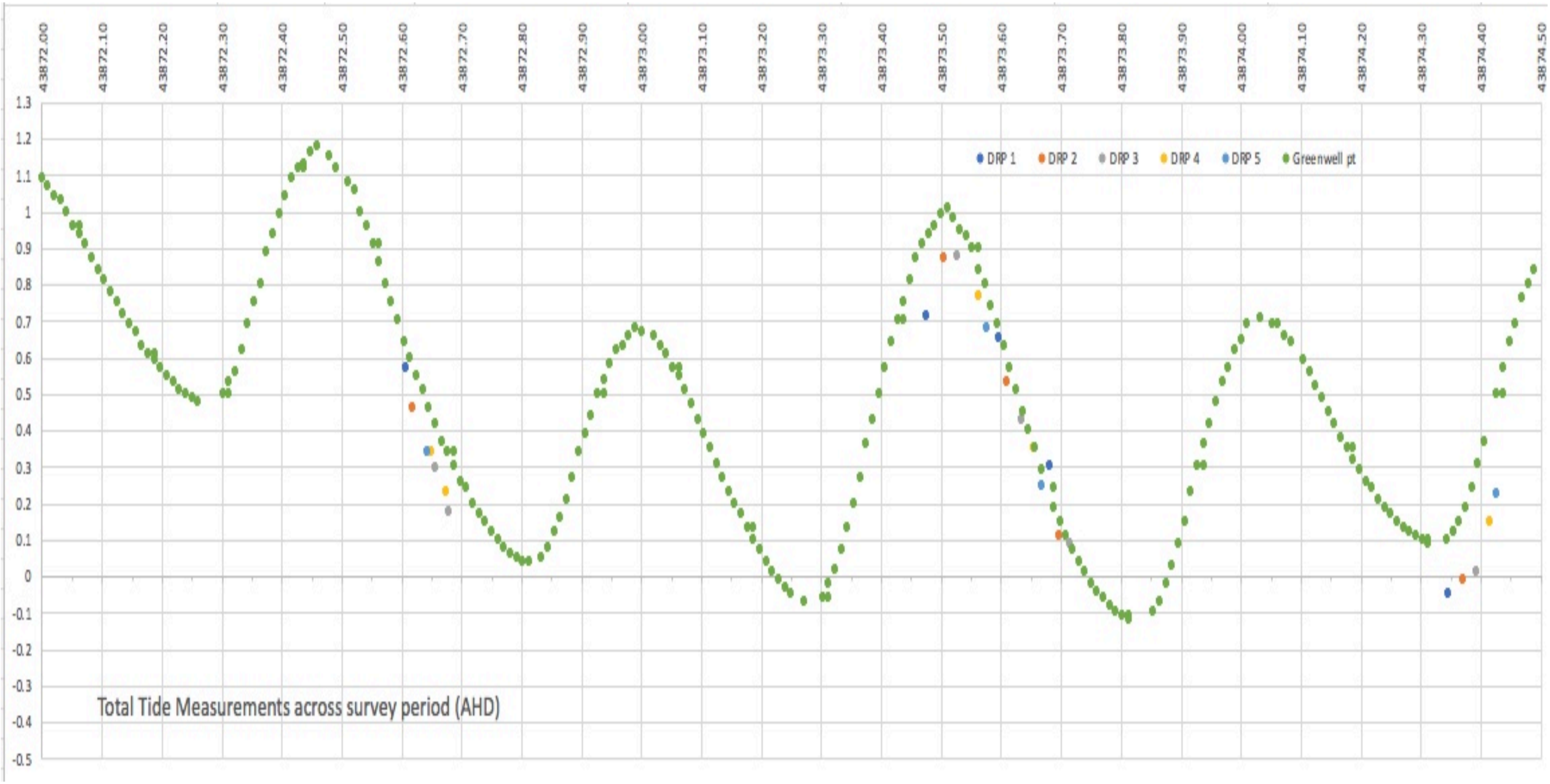


Figure A-2 Tide Data for the Five Tide Gauge Sites 11 Feb (day 43852) to 13 Feb (day 43854) superimposed over Greenwell Point Tide Gauge data

DRP Site photographs (Figures 1-5)

Figure 1: DRP 1

Figure 1: DRP 2

Figure 3: DRP 3

Figure 4: DRP 4

Figure 5: DRP 5

ANNEXURE E

WEST CULBURRA

CROOKHAVEN AND SHOALHAVEN RIVERS

WATER QUALITY REVIEW

1 INTRODUCTION

Review of existing water quality data for the previous Concept Plan indicated that there were a number of public and government data bases of water quality for the Shoalhaven/Crookhaven River system with some of these data sources utilised to provide overall river water quality statistics for estuarine modelling purposes. For the present revised proposal MPR was requested to provide a more comprehensive account of the available water quality data and how these data can be used for devising the related Estuarine Ecology and Shellfish Habitat Health Monitoring Program.

2 Water Quality Data Review Sources

Water quality data for the study area and the receiving waters of the Crookhaven River and Curleys Bay have been accessed through the Shoalhaven City Council (SCC) *Aquadata* web site, and Oyster Industry NSW Shellfish Monitoring Program data for Crookhaven River including both logged water temperature and salinity data collected by Shellfish Program and water quality data collected by oyster farmers under their license conditions. These data have been provided by NSW Food Authority Shellfish Program with permission from the relevant oyster farmers.

There have also been several water quality sampling programs undertaken for the previous and current Concept Plan including stormwater runoff analysis data collected by Allen Price & Scarratts Pty Ltd (APS) and estuary surface water sample analysis by Martens & Associates Pty Ltd (Martens). Sampling locations for the four water quality data sets are shown in **Figure 1** below.

2.1 APS & Martens Water Quality Monitoring Program

As part of the West Culburra Concept Plan, APS and Martens conducted water sampling from freshwater runoff sites within and adjacent to the West Culburra development proposal boundary and from estuarine sites in the Crookhaven River.

APS (2020) collected wet weather surface runoff samples from five sites between November 2018 and August 2020. The sample frequency varied between sites; site G is located near the Crookhaven River foreshore upstream of Cactus Point and was sampled on seven occasions (November 2018 to July 2020), site F is located in Billys Bay foreshore near the western boundary of the development proposal and was sampled once (August 2020).

Sites I, J and H are located within the development proposal boundary and were sampled between three and five occasions between February 2020 and July 2020, and site D is located on the eastern shore of Curleys Bay and was sampled on eight occasions between November 2018 and August 2020 Site D is located on the eastern shore of Curleys Bay and was sampled on eight occasions between November 2018 and August 2020. Between November 2018 and June 2019, the sample analysis included pH, EC, suspended solids and nutrients, and this was extended for subsequent sample events to include metals, faecal coliforms and enterococci.

Martens sampled five estuary sites in total, including three sample sites in the Crookhaven River that extends from the upstream limits at WQ-201 (2.5km upstream of Billys Island) to the downstream limits at WQ-205 (opposite Goodnight Island), plus two sites in Curleys Bay, over eight monthly events between October 2019 and May 2020. Data have been collected. A broad suite of analytes were tested including nutrients, dissolved metals, electrical conductivity (EC), pH, major ions and ionic balance, alkalinity, *E. coli* and faecal coliforms, however total suspended solids were not analysed.

2.2 SCC Aquadata Water Quality Monitoring Program

Aquadata is a purpose-built web-portal that facilitates community access to water quality analysis which is conducted by ALS on behalf of Shoalhaven City Council (SCC), for a wide range of stakeholders including recreational fishers and oyster farmers. The SCC Aquadata website can be found at https://webreports.esdat.net/SCC#results-map.

A total of eight *Aquadata* water quality monitoring sites (shown in **Figure 1** and **Table 1**) were used to review water quality parameters including temperature, dissolved oxygen (DO), pH, salinity, turbidity, faecal coliforms (FC), enterococci (Ent), chlorophyll-a (Chl-a), total nitrogen (TN) and total phosphorous (TP).

Table 1 Shoalhaven City Council Aquadata Total Number of Water Samples 1992 to 2020

Location	Site	Temp	Sal	DO	Ph	Turb	FC	Ent	TN	TP	Chl-a
CR	E-452	50	50	49	48	40	50	19	1	1	2
CR	E-453	56	56	55	55	47	58	20	51	51	49
CR	E-454	116	116	112	114	104	84	74	20	20	57
CU	E-455	58	57	56	56	46	58	20	1	1	2
CU	E-456	58	57	56	56	46	56	20	1	1	2
CU	E-457	57	56	55	55	46	56	20	1	1	2
CRE	E-776	64	64	62	64	63	28	59			115
CRE	E-777	64	64	62	64	63	27	61			115

Note: CR = Crookhaven River harvest area, CU = Curleys Bay harvest area, CRE = Crookhaven Rive entrance.

Whilst considerable inter-annual temporal variation exists in sample frequency, the overall sample data sets extends between 1992 and 2020 providing a long-term basis for characterisation of water quality from the most relevant sites. See **Appendix Table E-X** for the full Aquadata sample dataset.

2.3 NSW Shellfish Monitoring Program

The production of oysters in NSW requires water quality that supports healthy oyster growth and results in a product that is safe to eat following harvest under the NSW Shellfish Program (NSW DPI 2016), which includes location specific water quality trigger levels which determine closure and reopening of harvest areas for sale to the public.

Water quality data from 17 NSW Shellfish Program monitoring sites situated over three harvest areas in the Crookhaven River system were utilised to review background water quality conditions (**Table 2**).

Table 2 NSP Total Number of Water Samples 2003 to 2020

Location	Site	Temp	Salinity	*E. coli*	Phyto
CR	1	208	208	209	
CR	7	205	205	206	
CR	8	208	208	209	
CR	9	207	207	208	
CR	23	184	188		
CR	24	188	192		
CU	2	180	180	181	
CU	10	179	179	181	
CU	11	179	179	181	
CU	25	165	167		
CU	26	153	155		
GI	3	211	211	211	
GI	12	228	228	229	
GI	13	229	229	230	
GI	27	195	195		
GI	28	217	217		
GI	35				155

Note: CR = Crookhaven River, CU = Curleys Bay and GI = Goodnight Island harvest areas. Phyto = phytoplankton samples.

The NSP dataset extends between 2003 and 2020 and while it contains fewer water quality parameters than the *Aquadata* dataset (temperature, salinity, *Escherichia coli* (*E. coli*) and phytoplankton), the sample frequency is more consistent with a larger number of sites surrounding the study area. See **Appendix Table E-X** for the full NSP sample dataset.

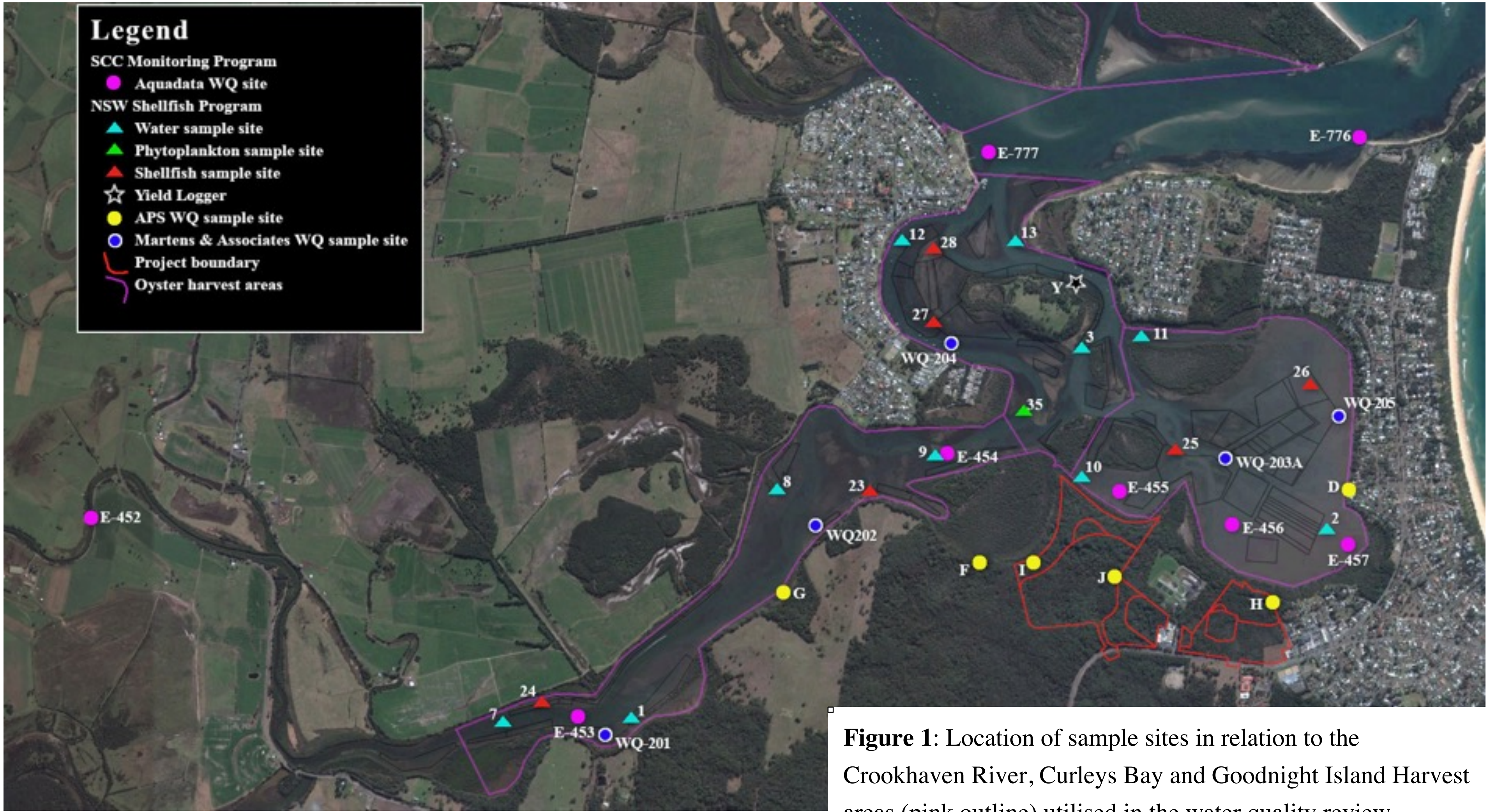


Figure 1: Location of sample sites in relation to the Crookhaven River, Curleys Bay and Goodnight Island Harvest areas (pink outline) utilised in the water quality review.

3 WEST CULBURRA WATER QUALITY REVIEW

Sections 3.1 to **3.4** provide the summary water quality results for the data sources introduced in **Section 2.**

3.1 APS Monitoring Program Water Quality Summary

The complete APS water quality data are provided in **Annex Tables E-1** to **E-5. Tables 3** to **9** below provide the summary results for the main water quality parameters and include the detection limits (LOR) values plus ANZECC 2018 trigger values where applicable. See **Figure 1** in **Section 2** for site locations.

Table 3 APS WQ Site pH Results Summary

Analyte	pH				
LOR	-				
ANZG 2018	7 - 8.5				
Site	D	G	H	I	J
N	8	7	5	5	3
N>DL	8	7	5	5	3
Min	2.1	2.2	7.0	5.2	4.6
Median	6.8	6.1	7.2	5.5	5.2
Mean	5.5	4.8	7.2	5.5	5.2
80%ile	7.2	6.4	7.4	5.6	5.5
Max	7.2	6.5	7.5	5.7	5.7

Table 4 APS WQ Site Ammonia Results Summary

Analyte	Ammonia mg/L				
LOR	0.01				
ANZG 2018	0.91				
Site	D	G	H	I	J
N	8	7	5	5	3
N>DL	8	7	5	5	3
Min	0.005	0.005	0.005	0.005	0.005
Median	0.010	0.005	0.030	0.020	0.020
Mean	0.024	0.097	0.029	0.016	0.022
80%ile	0.042	0.100	0.042	0.022	0.032
Max	0.080	0.460	0.050	0.030	0.040

Table 5 APS WQ Site TN Results Summary					
Analyte	Total Nitrogen mg/L				
LOR	0.1				
ANZG 2018	0.3				
Site	D	G	H	I	J
N	8	7	5	5	3
N>DL	8	7	5	5	3
Min	0.7	1.3	0.7	0.5	1.0
Median	1.7	1.9	1.4	1.1	1.1
Mean	2.2	1.9	1.7	0.9	1.2
80%ile	2.8	2.3	2.6	1.1	1.4
Max	5.8	2.3	2.7	1.1	1.6

Table 6 APS WQ Site TP Results Summary					
Analyte	Total Phosphorous mg/L				
LOR	0.01				
ANZG 2018	0.03				
Site	D	G	H	I	J
N	8	7	5	5	3
N>DL	8	7	5	4	3
Min	0.04	0.0	0.1	0.0	0.02
Median	0.10	0.0	0.1	0.0	0.02
Mean	0.10	0.1	0.1	0.1	0.04
80%ile	0.15	0.2	0.1	0.1	0.05
Max	0.16	0.2	0.2	0.22	0.07

Table 8 APS WQ Site TSS Results Summary					
Analyte	Total Suspended Solids mg/L				
LOR	5				
ANZG 2018	-				
Site	D	G	H	I	J
N	8	7	5	5	3
N>DL	8	7	5	5	3
Min	8	2.5	8	2.5	11
Median	10.5	19	15	33	32
Mean	11.3	23.8	13.4	34.1	37.7
80%ile	12.6	34.2	18	55.6	54.8
Max	18	60	18	74	70

Table 8 APS WQ Site *Enterococci* Results Summary					
Analyte	Enterococci cfu/100mL				
LOR	1				
ANZG 2018	70[a]	70[a]	70[a]	14[a]	70[a]
Site	D	G	H	I	J
N	5	4	5	5	3
N>DL	5	4	5	5	3
Min	80	4200	1000	1	1
Median	8600	5250	6500	10	2
Mean	3900	5400	4734	10	2.7
80%ile	12960	6600	7520	130	7
Max	26000	7500	9200	570	10
Note: Mean values are geometric mean values					

Table 9 APS WQ Site Faecal Coliforms Results Summary					
Analyte	Faecal Coliforms cfu/100mL				
LOR	1				
Site	D	G	H	I	J
N	5	4	5	5	3
N>DL	5	4	5	5	3
Min	1600	60	870	50	2
Median	8500	2450	4600	1000	200
Mean	5500	1034	4603	886	132
80%ile	9240	3320	10000	3560	3560
Max	11000	3500	14000	7800	5800
Note: Mean values are geometric mean values.					

3.2 Martens Monitoring Program Estuarine Water Quality Summary

The complete Martens water quality monitoring data are provided in **Annex Tables E-6** to **E-10. Tables 10** to **15** below provide the summary results for the main water quality parameters and include the detection limits (LOR) values plus ANZECC 2018 trigger values where applicable. See **Figure 1** in **Section 2** for site locations.

Table 10 Martens WQ Site pH Results Summary					
Analyte	pH				
LOR	-				
ANZG 2018	7 - 8.5				
Site	WQ201	WQ202	WQ203	WQ204	WQ205
N	8	8	8	8	8
N>DL	8	8	8	8	8
Min	6.9	7.1	7.5	7.2	7.5
Median	7.8	7.8	7.9	8.1	7.8
Mean	7.7	7.7	7.8	7.9	7.8
80%ile	7.9	7.9	8.0	8.1	7.9
Max	8.0	7.9	8.0	8.4	8.0

Table 11 Martens WQ Site Ammonia Results Summary					
Analyte	Ammonia mg/L				
LOR	0.005				
ANZG 2018	0.91				
Site	WQ201	WQ202	WQ203	WQ204	WQ205
N	8	8	8	8	8
N>DL	8	8	8	8	8
Min	0.008	0.006	0.014	0.011	0.005
Median	0.032	0.032	0.033	0.055	0.034
Mean	0.162	0.146	0.099	0.138	0.091
80%ile	0.239	0.160	0.142	0.129	0.108
Max	0.780	0.770	0.400	0.720	0.430

Table 12 Martens WQ Site TN Results Summary					
Analyte	Total Nitrogen mg/L				
LOR	0.1				
ANZG 2018	0.3				
Site	WQ201	WQ202	WQ203	WQ204	WQ205
N	8	8	8	8	8
N>DL	8	8	8	7	8
Min	0.2	0.1	0.1	0.1	0.1
Median	0.4	0.3	0.2	0.3	0.2
Mean	0.8	0.6	0.3	0.5	0.3
80%ile	0.7	0.5	0.3	0.5	0.3
Max	3.6	2.4	1.2	2.1	1.2

Table 13 Martens WQ Site TP Results Summary					
Analyte	Total Phosphorous mg/L				
LOR	0.05				
ANZG 2018	0.03				
Site	WQ201	WQ202	WQ203	WQ204	WQ205
N	8	8	8	8	8
N>DL	5	1	1	1	2
Min	0.03				0.03
Median	0.05				
Mean	0.13				
80%ile	0.07				
Max	0.70	0.3	0.1	0.30	0.09

Table 14 Martens WQ Site *E. coli* Results Summary					
Analyte	*E. Coli* cfu/100mL				
LOR	1				
ANZG 2018	70[a]	70[a]	70[a]	14[a]	70[a]
Site	WQ201	WQ202	WQ203	WQ204	WQ205
N	7	7	7	7	7
N>DL	6	5	3	4	4
Min	1.0	0.5	0.5	0.5	0.5
Median	5.0	7.0	1.0	4.0	5.0
Mean	10.0	5.9	1.7	3.1	3.3
80%ile	42.0	18.0	5.8	5.0	6.8
Max	2000	100.0	12.0	100.0	150.0

Note: Mean values are geometric mean values.

Table 15 Martens WQ Site Faecal Coliforms Results Summary					
Analyte	Faecal Coliforms cfu/100mL				
LOR	0.005				
ANZG 2018	-				
Site	WQ201	WQ202	WQ203	WQ204	WQ205
N	6	6	6	6	6
N>DL	5	4	4	4	3
Min	1.0	0.5	0.5	0.5	0.5
Median	7.5	7.0	3.5	4.5	2.8
Mean	14.7	6.0	3.0	4.1	2.9
80%ile	50.0	20.0	12.0	5.0	7.0
Max	2000	200.0	40.0	100.0	150.0
Note: Mean values are geometric mean values.					

3.3 Aquadata Summary

The complete SCC water quality monitoring dataset is provided in **Annex Tables E-11** to **E-15** and **Tables 16** to **15** below provide the summary results for the main water quality parameters. The grey shaded sites represent the sites in closest proximity to the Concept Plan area; see **Figure 1** in **Section 2** for site locations.

Table 16 SCC WQ Site Salinity Results Summary									
Council Salinity Crookhaven River									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		50	56	116	57	57	56	64	64
Min	14-Apr-92	0	0.98	0.61	5.15	9.49	1	4.3	0.4
Mean		19.0	25.0	28.0	29.0	28.0	27.0	29.6	27.8
Median		23.1	26.6	30.4	31	29.4	28.0	32.9	30.6
80%ile		31.1	32.2	33.3	32.8	32.0	32.6	35.3	35.0
Max	18-Mar-20	39.1	39.2	38.7	37.4	37.2	37.9	36.3	36.3

Table 17 SCC WQ Site Temperature Results Summary									
Council Temperature Crookhaven River (°C)									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		50	56	116	58	58	57	64	64
Min	14-Apr-92	9.1	10.1	10.6	9.1	0.9	8.2	10.9	13.3
Mean		18.3	19.3	19.7	19.1	18.6	18.9	19.1	19.5
Median		19.1	20.6	20.0	19.9	20.1	19.7	19.5	19.8
80%ile		23.3	23.2	23.4	22.7	22.9	23.0	22.2	22.5
Max	18-Mar-20	26.0	28.0	28.8	29.5	27.0	26.7	25.2	26.0

Table 18 SCC WQ Site Dissolved Oxygen Results Summary									
Council DO% sat Crookhaven River									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		49	55	112	56	56	55	62	62
Min	01-Sep-92	23.7	25.2	5.41	37.7	6.78	37.6	21.7	24.7
Mean		62	83	87	94	90	92	86.6	83.9
Median		60.4	83.2	86.4	95.4	89.7	92	86.8	85.1
80%ile		84.4	97.264	102.74	110	109	107.2	99.0	96.3
Max	18-Mar-20	116.69	125	171.2	130	137.23	134.94	153.9	151.8

Table 19 SCC WQ Site pH Results Summary									
Council pH Crookhaven River									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		48	55	114	56	56	55	64	64
Min	14-Apr-92	5.00	6.00	5.99	5.99	4.00	5.99	6.84	6.53
Mean		7.43	7.70	8.00	7.99	7.88	7.96	7.95	7.99
Median		7.51	7.78	8.03	8.00	8.00	8.04	7.97	7.99
80%ile		7.95	8.00	8.36	8.45	8.46	8.42	8.29	8.26
Max	18-Mar-20	8.57	8.95	9.34	9.21	9.24	9.26	9.08	8.96

Table 20 SCC WQ Site Turbidity Results Summary									
Council Turbidity Crookhaven River (NTU)									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		40	47	104	46	46	46	63	63
Min	01-Sep-92	1.9	0.0	0.0	0.0	2.2	1.5	0	0
Mean		65	43	19	27	48	40	17	10
Median		32.35	17.9	6.75	11.7	18.95	16.2	4.4	5.3
80%ile		96.44	70.98	26.4	35.5	51.2	59.5	14.2	19.7
Max	18-Mar-20	441.7	349.4	225.4	142.7	764.1	217.1	327.5	58.2

Table 21 SCC WQ Site Faecal Coliforms Results Summary									
Council Faecal Crookhaven River (cfu/100ml)									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		50	58	84	58	56	56	28	27
Min	14-Apr-92	0	0	-1	-1	0	0	0	0
Mean		114	136	11	17	49	58	6.5	34.1
Median		75.5	25	1	1	3	2	0.5	0.5
80%ile		165.2	107.6	7.4	9.2	16	16	6.2	4.4
Max	18-Mar-20	530	4000	260	520	1600	2000	47.0	700.0

Table 22 SCC WQ Site Enterococci Results Summary									
Council Enterococci Crookhaven River (cfu/100ml)									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		19	20	74	20	20	20	59	61
Min	20-Apr-05	28	0	0	0	0	0	0	0
Mean		679	148	5	6	59	91	7.6	9.6
Median		75	11	2	1	1	1	1.0	1.0
80%ile		198	55.6	5	5.4	10.2	17.2	5.4	6.0
Max	18-Mar-20	10000	1700	85	40	880	1500	120.0	140.0

Table 23 SCC WQ Site Chlorophyll-a Results Summary									
Council Chlorophyll-a Crookhaven River (mg/m3)									
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457	E-776	E-777
Count		2	49	57	2	2	2	115	115
Min	10-Mar-94	0	0	0	0	0	0	0	0
Mean		21	17.2	2.3	1.7	2.8	4.05	2.3	2.8
Median		21	3	1	1.7	2.8	4.05	0.0	2.0
80%ile		33.6	9.52	2	2.72	4.48	6.48	2.0	3.0
Max	18-Mar-20	42	220	38.3	3.4	5.6	8.1	40.0	38.0

Table 24 SCC WQ Site Total Phosphorous Results Summary							
Council TP Crookhaven River (mg/L)							
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457
Count		1	51	20	1	1	1
Min	10-Mar-94	0.21	0.002	0	0.05	0.05	0.06
Mean			0.046	0.039			
Median			0.031	0.05			
80%ile			0.07	0.05			
Max	18-Mar-20		0.32	0.07			

Table 24 SCC WQ Site Total Nitrogen Results Summary							
Council TN Crookhaven River (mg/L)							
Sites	Dates	E-452	E-453	E-454	E-455	E-456	E-457
Count		1	51	20	1	1	1
Min	10-Mar-94	2.1	0.09	0	0.5	0.6	0.5
Mean			0.596	0.324			
Median			0.42	0.275			
80%ile			0.62	0.50			
Max	18-Mar-20		4.10	1.00			

3.4 NSW Shellfish Program Summary

Tables 25 to **27** below present the summary data from the NSW Shellfish Monitoring Program for the Crookhaven River, Curleys Bay, Goodnight Island and Comerong Bay harvest areas and the complete dataset is available in **Annex Tables E-16** to **E-18**. Sites in red indicate the closest sites to the West Culburra Concept Plan area, see **Figure 1** in **Section 2** for site locations.

Table 25 NSW Shellfish Program Salinity (ppt) Water Quality Results Summary

	Crookhaven River						Goodnight Island					Curleys Bay					Co Bay
Site	07	24	01	08	23	09	03	27	28	12	13	02	26	25	10	11	18
Count	205	192	208	208	188	207	211	195	217	228	229	180	155	167	179	179	248
Min	2.1	10.3	2.1	2.1	17.2	5.0	6.4	3.0	22.0	3.8	9.2	6.3	20.0	18.0	7.6	7.6	10.0
Median	28.8	28.8	28.9	29.4	30.1	30.1	31.4	32.0	32.0	32.0	32.0	30.6	30.5	30.5	30.9	30.9	33.0
mean	27.3	27.7	27.8	28.9	29.6	29.7	30.8	31.1	31.3	31.1	31.0	29.2	29.5	29.5	29.6	29.7	32.1
80%ile	32.0	32.0	32.1	32.6	33.0	32.8	33.6	34.0	34.0	34.0	34.0	32.2	32.6	32.6	32.6	33.0	34.6
Max	36.7	36.0	39.9	39.9	36.6	36.6	39.8	38.4	38.4	39.0	38.0	37.0	37.0	37.0	36.3	36.3	38.0

Table 26 NSW Shellfish Program Temperature (°C) Water Quality Results Summary

	Crookhaven River						Goodnight Island					Curleys Bay					Co Bay
Site	07	24	01	08	23	09	03	27	28	12	13	02	26	25	10	11	18
Count	205	188	208	208	184	207	211	195	217	228	229	180	153	165	179	179	248
Min	2.5	0.0	2.5	9.0	9.0	2.5	10.0	6.0	6.0	10.0	10.0	10.0	10.0	2.5	10.0	10.0	10.0
Median	20.0	19.8	19.0	19.0	19.5	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
mean	18.9	19.0	18.8	18.8	19.0	18.6	18.8	19.1	19.1	18.8	18.7	18.7	19.1	18.8	18.9	18.8	18.9
80%ile	23.0	23.0	23.0	23.0	23.0	22.0	22.5	22.8	23.0	22.2	22.2	22.6	22.8	22.6	22.7	22.2	22.0
Max	28.0	28.0	28.0	27.0	27.0	27.0	27.7	27.6	27.1	27.6	30.0	28.0	28.0	28.0	27.1	27.1	28.1

Table 27 NSW Shellfish Program *Escherichia coli* (cfu/100ml) Water Quality Results Summary

	Crookhaven River						Goodnight Island					Curleys Bay					Co Bay
Site	07	24	01	08	23	09	03	27	28	12	13	02	26	25	10	11	18
Count	206		209	209		208	211			229	230	181			181	181	251
Min	1		0	1		1	1			1	1	1			1	1	1.0
Median	7.5		5.0	3.0		4.0	3.0			3.0	4.0	2.0			3.0	3.0	2.0
mean	26.2		23.2	13.1		12.1	11.0			33.8	14.4	19.3			16.7	41.3	9.6
80%ile	28.0		33.4	13.0		16.0	13.0			14.0	14.0	17.0			15.0	21.0	7.0
Max	240		240	201		201	201			5300	210	470			240	4000	730.0

ANNEXURE E

WEST CULBURRA

WATER QUALITY REVIEW

SUPPLEMENTARY DATA

TABLES E-1 TO E-5

APS LAB WATER QUALITY RESULTS

TABLES E-6 TO E-10

MARTENS LAB WATER QUALITY RESULTS

TABLES E-11 TO E-15

SCC AQUADATA WATER QUALITY RESULTS

TABLES E-16 TO E-19

NSW SHELLFISH PROGRAM

WATER QUALITY RESULTS

Annex Table E-1 APS Wet Culburra Site D Water Quality Monitoring Results 2018-2020

Analyte	Units	LOR	ANZG 2018*		29/11/18	5/06/19	24/06/19	9/02/20	5/03/20	22/05/20	14/07/20	10/08/20	N	N>DL	Min	Median	Mean	80%ile	Max
				Date Sampled:	29/11/18	5/06/19	24/06/19	9/02/20	5/03/20	22/05/20	14/07/20	10/08/20							
				Site:	D	D	D	D	D	D	D	D							
				Prev 7 days rain (mm):	40.4	64.3	19.6	2.4	9.2	21.8	16.5	175.8							
				Prev 2 days rain (mm):	40	64.3		2.4	9.2	0.4	7.4	173.2							
Physical and Chemical			Marine	Freshwater															
pH	pH Units		7.0-8.5	6.5-8.0	4.3	2.2	2.1	7.1	7.2	6.5	7.2	7.0	8	8	2.1	6.8	5.5	7.2	7.2
EC	µS/cm	1			4300	3060	4040	356	174	442	346	308	8	8	174	399	1628	3648	4300
TSS	mg/L	5			11	13	18	8	10	8	10	12	8	8	8	11	11	13	18
Hardness	mgCaCO3/L	3						66	33	114	86	76	5	5	33	76	75	92	114
Ammonia	mg/L	0.01	0.91	0.9	0.01	0.005	0.01	0.08	0.03	0.05	0.005	0.005	8	8	0.005	0.010	0.024	0.042	0.080
Nitrite	mg/L	0.01			<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	8	1					0.1
Nitrate	mg/L	0.01			0.44	0.86	0.72	1.51	0.11	3.64	1.55	0.54	8	8	0.11	0.79	1.17	1.53	3.64
NOx	mg/L	0.01	0.015	0.04	0.44	0.86	0.72	1.51	0.11	3.65	1.55	0.54	8	8	0.11	0.79	1.17	1.53	3.65
TKN	mg/L	0.1			0.6	0.8	0.9	1.4	0.6	2.1	1.1	0.9	8	8	0.6	0.9	1.1	1.3	2.1
TN	mg/L	0.1	0.3	0.5	1	1.7	1.6	2.9	0.7	5.8	2.6	1.4	8	8	0.7	1.7	2.2	2.8	5.8
TP	mg/L	0.01	0.03	0.05	0.04	0.08	0.07	0.15	0.05	0.16	0.14	0.11	8	8	0.04	0.10	0.10	0.15	0.16
FRP	mg/L	0.01	0.005	0.02				0.1	0.005	0.05	0.01	0.03	5	5	0.01	0.03	0.04	0.06	0.10
Dissolved Metals																			
Aluminium	µg/L	10						380	600	1620	1080	1630	5	5	380	1080	1062	1622	1630
Arsenic	µg/L	1						2	1	2	2	2	5	5	1	2	2	2	2
Cadmium	µg/L	0.1	5.5	0.2				<0.1	<0.1	<0.1	<0.1	<0.1	5	0					
Chromium	µg/L	1	4.4	1				2	1	3	2	3	5	5	1.0	2.0	2.2	3.0	3.0
Copper	µg/L	1	1.3	1.4				9	6	13	11	10	5	5	6.0	10.0	9.8	11.4	13.0
Lead	µg/L	1	4.4	3.4				0.5	0.5	3	2	2	5	5	0.5	2.0	1.6	2.2	3.0
Nickel	µg/L	1	7**	11				1	0.5	2	1	1	5	5	0.5	1.0	1.1	1.2	2.0
Zinc	µg/L	5	15	8				25	18	45	39	36	5	5	18.0	36.0	32.6	40.2	45.0
Iron	µg/L	50						220	370	970	800	990	5	5	220	800	670	974	990
Mercury	µg/L	0.1	0.1**	0.6				<0.1	<0.1	<0.1	<0.1	<0.1	5	0					<0.1
Biological																			
Faecal Coliforms	CFU/100mL	1	70[a]					8500	8800	11000	4000	1600	5	5	1600	8500	5550	9240	11000
Enterococci	CFU/100mL	1						26000	5200	8600	9700	80	5	5	80	8600	3900	12960	26000

Annex Table E-2 APS West Culburra Site G Water Quality Monitoring Results 2018-2020

				Date Sampled:	29/11/18	5/06/19	24/06/19	9/02/20	5/03/20	22/05/20	14/07/20							
				Site:	G	G	G	G	G	G	G							
				Prev 7 days rain (mm):	40.4	64.3	19.6	2.4	9.2	21.8	16.5							
				Prev 2 days rain (mm):	40	64.3		2.4	9.2	0.4	7.4							
Analyte	Units	LOR	ANZG 2018*									N	N>DL	Min	Median	Mean	80%ile	Max
Physical and Chemical			Marine	Freshwater														
pH	pH Units		7.0-8.5	6.5-8.0	4.0	2.2	2.3	6.2	6.5	6.5	6.1	7	7	2.2	6.1	4.8	6.4	6.5
EC	µS/cm	1			2940	3330	2820	295	925	353	811	7	7	295	925	1639	2916	3330
TSS	mg/L	5			2.5	27	19	36	14	8	60	7	7	3	19	24	34	60
Hardness	mgCaCO3/L	3						24	104	32	73	4	4	24	53	58	85	104
Ammonia	mg/L	0.01	0.91	0.9	0.1	0.005	0.005	0.005	0.46	0.005	0.1	7	7	0.005	0.005	0.097	0.100	0.460
Nitrite	mg/L	0.01			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	7	0					
Nitrate	mg/L	0.01			0.44	0.64	0.3	1.03	0.03	0.17	0.5	7	7	0.03	0.44	0.44	0.61	1.03
NOx	mg/L	0.01	0.015	0.04	0.44	0.64	0.3	1.03	0.03	0.17	0.5	7	7	0.03	0.44	0.44	0.61	1.03
TKN	mg/L	0.1			0.9	1.3	1.2	1.3	2.3	1.5	1.6	7	7	0.9	1.3	1.4	1.6	2.3
TN	mg/L	0.1	0.3	0.5	1.3	1.9	1.5	2.3	2.3	1.7	2.1	7	7	1.3	1.9	1.9	2.3	2.3
TP	mg/L	0.01	0.03	0.05	0.02	0.04	0.03	0.005	0.06	0.19	0.19	7	7	0.0	0.0	0.1	0.2	0.2
FRP	mg/L	0.01	0.005	0.02				<0.01	<0.01	<0.01	<0.01	4	0					<0.1
Dissolved Metals																		
Aluminium	µg/L	10						1130	620	860	5390	4	4	620	995	2000	2834	5390
Arsenic	µg/L	1						0.5	3	0.5	1	4	4	0.5	0.8	1.3	1.8	3.0
Cadmium	µg/L	0.1	5.5	0.2				<0.1	0.1	<0.1	<0.1	4	1					1.0
Chromium	µg/L	1	4.4	1				2	4	2	7	4	4	2.0	3.0	3.8	5.2	7.0
Copper	µg/L	1	1.3	1.4				3	6	2	5	4	4	2.0	4.0	4.0	5.4	6.0
Lead	µg/L	1	4.4	3.4				1	2	0.5	3	4	4	0.5	1.5	1.6	2.4	3.0
Nickel	µg/L	1	7**	11				1	6	2	4	4	4	1.0	3.0	3.3	4.8	6.0
Zinc	µg/L	5	15	8				45	108	25	57	4	4	25	51	59	77	108
Iron	µg/L	50						1010	6750	840	6510	4	4	840	3760	3778	6606	6750
Mercury	µg/L	0.1	0.1**	0.6				<0.1	<0.1	<0.1	<0.1	4	0					<0.1
Biological																		
Faecal Coliforms	CFU/100mL	1	70[a]					3200	60	1700	3500	4	4	60	2450	1034	3320	3500
Enterococci	CFU/100mL	1						4200	6000	7500	4500	4	4	4200	5250	5400	6600	7500

Annex Table E-3 APS West Culburra Site H Water Quality Monitoring Results 2020

				Date Sampled:	9/02/2020	5/03/2020	22/05/2020	14/07/2020	10/08/2020							
				Site:	H	H	H	H	H							
				Prev 7 days rain (mm):	2.4	9.2	21.8	16.5	175.8							
				Prev 2 days rain (mm):	2.4	9.2	0.4	7.4	173.2							
Analyte	Units	LOR	ANZG 2018*							N	N>DL	Min	Median	Mean	80%ile	Max
Physical and Chemical			Marine	Freshwater												
pH	pH Units		7.0-8.5	6.5-8.0	7.1	7.3	7.2	7.5	7.0	5	5	7.0	7.2	7.2	7.4	7.5
EC	µS/cm	1			296	135	394	287	327	5	5	135	296	288	340	394
TSS	mg/L	5			8	18	18	15	8	5	5	8.0	15.0	13.4	18.0	18.0
Hardness	mgCaCO3/L	3			54	31	94	61	82	5	5	31.0	61.0	64.4	84.4	94.0
Ammonia as N	mg/L	0.01	0.91	0.9	0.005	0.05	0.02	0.04	0.03	5	5	0.005	0.030	0.029	0.042	0.050
Nitrite as N	mg/L	0.01			<0.01	<0.01	<0.01	<0.01	<0.01	5	0					<0.01
Nitrate as N	mg/L	0.01			1.73	0.29	1.65	0.38	0.38	5	5	0.3	0.4	0.9	1.7	1.7
NOx	mg/L	0.01	0.015	0.04	1.73	0.29	1.65	0.38	0.38	5	5	0.3	0.4	0.9	1.7	1.7
TKN	mg/L	0.1			1	0.4	1	1	0.6	5	5	0.4	1.0	0.8	1.0	1.0
TN	mg/L	0.1	0.3	0.5	2.7	0.7	2.6	1.4	1	5	5	0.7	1.4	1.7	2.6	2.7
TP	mg/L	0.01	0.03	0.05	0.12	0.1	0.11	0.2	0.07	5	5	0.07	0.11	0.12	0.14	0.20
FRP	mg/L	0.01	0.005	0.02	0.06	0.005	0.04	0.02	0.03	5	5	0.005	0.030	0.031	0.044	0.060
Dissolved Metals																
Aluminium	µg/L	10			370	480	620	1840	800	5	5	370	620	822	1008	1840
Arsenic	µg/L	1			1	1	1	1	1	5	5	1.0	1.0	1.0	1.0	1.0
Cadmium	µg/L	0.1	5.5	0.2	<0.1	<0.1	<0.1	0.1	<0.1	5	1					0.1
Chromium	µg/L	1	4.4	1	2	2	2	3	2	5	5	2.0	2.0	2.2	2.2	3.0
Copper	µg/L	1	1.3	1.4	15	5	15	30	10	5	5	5.0	15.0	15.0	18.0	30.0
Lead	µg/L	1	4.4	3.4	0.5	0.5	1	3	0.5	5	5	0.5	0.5	1.1	1.4	3.0
Nickel	µg/L	1	7**	11	0.5	0.5	2	6	2	5	5	0.5	2.0	2.2	2.8	6.0
Zinc	µg/L	5	15	8	24	44	30	253	32	5	5	24	32	77	86	253
Iron	µg/L	50			320	460	760	2130	790	5	5	320	760	892	1058	2130
Mercury	µg/L	0.1	0.1**	0.6	0.1	<0.1	<0.1	<0.1	<0.1	5	1					0.1
Biological																
Faecal Coliforms	CFU/100mL	1	70[a]		14000	9000	4600	4100	870	5	5	870	4600	4603	10000	14000
Enterococci	CFU/100mL	1			7100	6500	5600	9200	1000	5	5	1000	6500	4734	7520	9200

Annex Table E-4 APS West Culburra Site I + F Water Quality Monitoring Results 2020

Analyte	Units	LOR	ANZG 2018*			10/02/2020	5/03/2020	22/05/2020	14/07/2020	10/08/2020	10/08/2020	For Site I						
					Site:	I	I	I	I	I	F							
					Prev 7 days rain (mm):	2.4	9.2	21.8	16.5	175.8	175.8							
					Prev 2 days rain (mm):	2.4	9.2	0.4	7.4	173.2	173.2							
			Marine	Freshwater								N	N>DL	Min	Median	Mean	80%ile	Max
Physical and Chemical																		
pH	pH Units		7.0-8.5	6.5-8.0		5.2	5.5	5.5	5.7	5.5	6.5	5	5	5.2	5.5	5.5	5.6	5.7
EC	µS/cm	1				78	87	38	54	96	168	5	5	38.0	78.0	70.6	88.8	96.0
TSS	mg/L	5				10	51	33	74	2.5	2.5	5	5	2.5	33.0	34.1	55.6	74.0
Hardness	mgCaCO3/L	1				4.0	11.0	0.5	0.5	13.0	17.0	5	5	0.5	4.0	5.8	11.4	13.0
Ammonia as N	mg/L	0.01	0.91	0.9		0.005	0.02	0.02	0.03	0.005	0.005	5	5	0.005	0.020	0.016	0.022	0.030
Nitrite as N	mg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5	0					
Nitrate as N	mg/L	0.01				0.08	0.005	0.005	0.12	0.04	0.18	5	5	0.01	0.04	0.05	0.09	0.12
NOx	mg/L	0.01	0.015	0.04		0.08	0.005	0.005	0.12	0.04	0.18	5	5	0.01	0.04	0.05	0.09	0.12
TKN	mg/L	0.1				0.5	1.1	0.5	1	1.1	0.9	5	5	0.50	1.00	0.84	1.10	1.10
TN	mg/L	0.1	0.3	0.5		0.6	1.1	0.5	1.1	1.1	1.1	5	5	0.50	1.10	0.88	1.10	1.10
TP	mg/L	0.01	0.03	0.05		0.02	0.06	0.03	0.22	<0.01	0.02	5	4	0.02	0.05	0.08	0.12	0.22
FRP	mg/L	0.01	0.005	0.02		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5	0					
Dissolved Metals																		
Aluminium	µg/L	10				1060	3700	1530	10900	1750	970	5	5	1060	1750	3788	5140	10900
Arsenic	µg/L	1				0.5	1	0.5	2	0.5	0.5	5	5	0.5	0.5	0.9	1.2	2.0
Cadmium	µg/L	0.1	5.5	0.2		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	5	0					<0.1
Chromium	µg/L	1	4.4	1		0.5	6	1	10	3	2	5	5	0.5	3.0	4.1	6.8	10.0
Copper	µg/L	1	1.3	1.4		0.5	2	0.5	10	1	2	5	5	0.5	1.0	2.8	3.6	10.0
Lead	µg/L	1	4.4	3.4		0.5	2	0.5	4	0.5	0.5	5	5	0.5	0.5	1.5	2.4	4.0
Nickel	µg/L	1	7**	11		0.5	2	0.5	2	0.5	1	5	5	0.5	0.5	1.1	2.0	2.0
Zinc	µg/L	5	15	8		2.5	27	2.5	11	8	25	5	5	2.5	8.0	10.2	14.2	27.0
Iron	µg/L	50				530	1750	770	6090	840	1000	5	5	530	840	1996	2618	6090
Mercury	µg/L	0.1	0.1**	0.6		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	5	0					<0.1
Biological																		
Faecal Coliforms	CFU/100mL	1	70[a]			1000	7800	560	2500	50	40	5	5	50	1000	886	3560	7800
Enterococci	CFU/100mL	2				1	1	10	570	20	190	5	5	1	10	10	130	570

Annex Table E-5 APS West Culburra Site J Water Quality Monitoring Results 2020

Analyte	Units	LOR	ANZG 2018*					N	N>DL	Min	Median	Mean	80%ile	Max
				Date Sampled:	10/02/2020	5/03/2020	10/08/2020							
				Site:	J	J	J							
				Prev 7 days rain (mm):	2.4	9.2	175.8							
				Prev 2 days rain (mm):	2.4	9.2	173.2							
Physical and Chemical			Marine	Freshwater										
pH	pH Units		7.0-8.5	6.5-8.0	4.6	5.7	5.2	3	3	4.6	5.2	5.2	5.5	5.7
EC	μS/cm	1			153	78	83	3	3	78.0	83.0	104.7	125.0	153.0
TSS	mg/L	5			11	70	32	3	3	11.0	32.0	37.7	54.8	70.0
Hardness	mgCaCO3/L	3			13	7	11	3	3	7.0	11.0	10.3	12.2	13.0
Ammonia as N	mg/L	0.01	0.91	0.9	0.02	0.04	0.005	3	3	0.005	0.020	0.022	0.032	0.040
Nitrite as N	mg/L	0.01			<0.01	<0.01	<0.01	3	0					<0.01
Nitrate as N	mg/L	0.01			0.02	0.005	0.005	3	3	0.005	0.005	0.010	0.014	0.020
NOx	mg/L	0.01	0.015	0.04	0.02	0.005	0.005	3	3	0.005	0.005	0.010	0.014	0.020
TKN	mg/L	0.1			1	1.6	1.1	3	3	1.0	1.1	1.2	1.4	1.6
TN	mg/L	0.1	0.3	0.5	1	1.6	1.1	3	3	1.0	1.1	1.2	1.4	1.6
TP	mg/L	0.01	0.03	0.05	0.02	0.07	0.02	3	3	0.0	0.0	0.0	0.1	0.1
FRP	mg/L	0.01	0.005	0.02	<0.01	<0.01	<0.01	3	0					<0.01
Dissolved Metals														
Aluminium	μg/L	10			880	1310	2400	3	3	880	1310	1530	1964	2400
Arsenic	μg/L	1			<1	<1	<1	3	0	0.0				<1
Cadmium	μg/L	0.1	5.5	0.2	<0.1	<0.1	<0.1	3	0	0.0				<0.1
Chromium	μg/L	1	4.4	1	1	1	6	3	3	1.0	1.0	2.7	4.0	6.0
Copper	μg/L	1	1.3	1.4	<1	<1	<1	3	0	0.0				<1
Lead	μg/L	1	4.4	3.4	<1	<1	<1	3	0	0.0				<1
Nickel	μg/L	1	7**	11	<1	<1	<1	3	0	0.0				<1
Zinc	μg/L	5	15	8	11	24	9	3	3	9.0	11.0	14.7	18.8	24.0
Iron	μg/L	50			610	930	1290	3	3	610	930	943	1146	1290
Mercury	μg/L	0.1	0.1**	0.6	<0.1	<0.1	<0.1	3	0	0.0				<0.1
Biological														
Faecal Coliforms	CFU/100mL	1	70[a]		200	5800	2	3	3	2.0	200.0	132.4	3560.0	5800
Enterococci	CFU/100mL	1			2	1	10	3	3	1.0	2.0	2.7	6.8	10

Notes for Annex Tables E-1 to E-5

Note: *ANZECC 2018 Default Guideline Values for 95% species protection levels in marine waters.

**Represent 99% DGVs as recommended by ANZG (2018)

The more conservative DGV for hexavalent Chromium IV was used for Cr.

Mercury DGV is Inorganic Hg.

a = Faecal coliform values taken from respective Shellfish Harvest Area Management Plans for water samples.

Faecal coliform and Enterococci mean values are geometric means.

Values in red represent half the detection limits.

Annex Table E-6 Martens and Associates West Culburra Site WQ 201 (Crookhaven River) Water Quality monitoring Results 2019-2020

Analyte	Units	LOR	ANZG 2018*	02/10/2019	24/10/2019	29/11/2019	09/01/2020	19/02/2020	19/03/2020	29/04/2020	27/05/2020	N	N>DL	Min	Median	Mean	80%ile	Max
			Site:	WQ201	WQ201	WQ201	WQ201	WQ201	WQ201	WQ201	WQ201							
			Prev 7 days rain (mm):	0	0	1.4	2.4	67.6	10.6	0.2	99.5							
			Prev 2 days rain (mm):	0	0	0	0	23.0	0	0	16							
Physical and Chemical																		
Temperature	°C		-							25.0	19.0	2	2	19.0				25.0
pH	pH Units		7 - 8.5	7.7	7.8	7.9	7.7	6.9	8.0	7.8	7.6	8	8	6.9	7.8	7.7	7.9	8.0
Electrical Conductivity	µS/cm	1		50000	52000	53000	53000	3600	31000	45000	39000	8	8	3600	47500	40825	52600	53000
Total Dissolved Solids	mg/L	5		39000	38000	3600	42000	1900	25000	35500	29000	8	8	1900	32250	26750	38600	42000
NOx	mg/L	0.005	0.015	0.010	0.013	0.003	0.003	0.050	0.003	0.003	0.350	8	3	0.003	0.006	0.054	0.035	0.350
Ammonia	mg/L	0.005	0.91	0.019	0.042	0.037	0.008	0.78	0.026	0.016	0.37	8	8	0.008	0.032	0.162	0.239	0.780
Total Nitrogen	mg/L	0.1	0.3	0.3	0.3	0.2	0.8	3.6	0.55	0.2	0.6	8	8	0.2	0.4	0.8	0.7	3.6
Phosphate	mg/L	0.005		0.0025	0.0125	0.005	0.01	0.091	0.015	0.01	0.032	8	6	0.003	0.011	0.022	0.025	0.091
Nitrate	mg/L	0.005		0.006	0.0125	0.0025	0.0025	0.051	0.0025	0.0025	0.03	8	3	0.003	0.004	0.014	0.023	0.051
Calcium	mg/L	0.5		360	340	460	410	42	255	360	270	8	8	42.0	350.0	312.1	390.0	460.0
Potassium	mg/L	0.5		405	380	495	430	30	255	350	320	8	8	30.0	365.0	333.1	420.0	495.0
Sodium	mg/L	0.5		11000	11000	15500	11000	650	8000	10000	9800	8	8	650.0	10500.0	9618.8	11000.0	15500.0
Magnesium	mg/L	0.5		1300	1200	1500	1400	74	855	1200	810	8	8	74.0	1200.0	1042.4	1360.0	1500.0
Hardness	mgCaCO3/L	3		6350	5900	7200	6800	410	4200	5900	4000	8	8	410.0	5900.0	5095.0	6620.0	7200.0
Hydroxide Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Bicarbonate Alkalinity	mg/L	5		120	120	130	130	59	110	120	100	8	8	59.0	120.0	111.1	126.0	130.0
Carbonate Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Total Alkalinity	mg/L	5		120	120	130	130	59	110	120	100	8	8	59	120	111	126	130
Sulphate	mg/L	1		2500	2400	2900	2900	180	1700	2200	1950	8	8	180	2300	2091	2740	2900
Chloride	mg/L	1		18000	19000	22000	21500	1100	13000	17000	15000	8	8	1100	17500	15825	20500	22000
Ionic Balance	%			5	1	10	-2.5	3	4.5	3	5	8	8	-2.5	3.8	3.6	5.0	10.0
Total Phosphorous	mg/L	0.05	0.03	0.0375	0.025	0.07	0.0375	0.7	0.06	0.05	0.05	8	5	0.03	0.05	0.13	0.07	0.70
Dissolved Metals																		
Aluminium	µg/L	10		10	5	5	5	180	5	7.5	10	8	4	5.0	6.3	28.4	10.0	180.0
Arsenic	µg/L	1		1	1	2	1.5	2	2	2	1	8	8	1.0	1.8	1.6	2.0	2.0
Boron	µg/L	20		4600	4400	5050	4650	310	2900	3300	2450	8	8	310.0	3850.0	3457.5	4630.0	5050.0
Barium	µg/L	1		8	8	9	13	6	12	14	13.5	8	8	6.0	10.5	10.4	13.3	14.0
Beryllium	µg/L	0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8	0					
Cadmium	µg/L	0.1	5.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	8	0					
Cobalt	µg/L	1	1	<1	<1	<1	<1	5	<1	<1	<1	8	1					5.0
Chromium	µg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Copper	µg/L	1	1.3	0.5	0.5	0.5	0.5	1	0.5	0.5	2	8	3	0.5	0.5	0.8	0.8	2.0
Iron	µg/L	10		<10	<10	<10	<10	1300	<10	<10	17	8	2	17.0				1300.0
Mercury	µg/L	0.05	0.1**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8	0					
Manganese	µg/L	5	80	24	9	11.5	7	560	26	22.5	38.5	8	8	7.0	23.3	87.3	33.5	560.0
Molybdenum	µg/L	1		12	12	12	13	1	8	10	8	8	8	1.0	11.0	9.5	12.0	13.0
Nickel	µg/L	1	7**	<1	<1	<1	<1	5	<1	<1	1.5	8	2	1.5				5.0
Lead	µg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Selenium	µg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Strontium	µg/L	1		7800	7400	8350	7800	470	5400	6350	6100	8	8	470.0	6875.0	6208.8	7800.0	8350.0
Titanium	µg/L	1		<1	<1	<1	<1	1.8	<1	<1	<1	8	1					1.8
Vanadium	µg/L	1	100	<1	1	1	<1	<1	<1	<1	<1	8	2	1.0				1.0
Zinc	µg/L	1	15	1	3	2	0.5	7	0.5	0.75	4.5	8	6	0.5	1.5	2.4	3.9	7.0
Silicon	mg/L	0.2		0.6	0.6	0.1	0.5	3.1	0.5	0.5	0.4	8	7	0.1	0.5	0.8	0.6	3.1
Biological																		
E. coli	cfu/100mL	1	70[a]	1	1	5		2000	10	2	50	7	6	1.0	5.0	10.0	42.0	2000
Faecal Coliforms	cfu/100mL	0.005		1		5		2000	10	2	50	6	5	1.0	7.5	14.7	50.0	2000

Annex Table E-7 Martens and Associates West Culburra Site WQ 202 (Crookhaven River) Water Quality monitoring Results 2019-2020

Analyte	Units	LOR	ANZG 2018*	02/10/19	24/10/19	29/11/19	09/01/20	19/02/20	19/03/20	29/04/20	27/05/20	N	N>DL	Min	Median	Mean	80%ile	Max
			Site:	WQ202	WQ202	WQ202	WQ202B	WQ202B	WQ202B	WQ202B	WQ202B							
			Prev 7 days rain (mm):	0	0	1.4	2.4	67.6	10.6	0.2	99.5							
			Prev 2 days rain (mm):	0	0	0	0	23.0	0	0	16							
Physical and Chemical																		
Temperature	°C		-							25.0	19.3	2	2	19.3				25.0
pH	pH Units		7 - 8.5	7.9	7.8	7.9	7.9	7.1	7.8	7.6	7.8	8	8	7.1	7.8	7.7	7.9	7.9
Electrical Conductivity	µS/cm	1		47000	52000	52000	52000	8300	33000	46000	41000	8	8	8300	46500	41413	52000	52000
Total Dissolved Solids	mg/L	5		40000	38000	32000	41000	5500	26000	36000	31000	8	8	5500	34000	31188	39200	41000
NOx	mg/L	0.005	0.015	0.003	0.013	0.003	0.003	0.040	0.007	0.003	0.020	8	3	0.003	0.005	0.011	0.017	0.040
Ammonia	mg/L	0.005	0.91	0.015	0.038	0.1	0.006	0.77	0.014	0.025	0.2	8	8	0.006	0.032	0.146	0.160	0.770
Total Nitrogen	mg/L	0.1	0.3	0.1	0.5	0.1	0.5	2.4	0.3	0.2	0.3	8	8	0.1	0.3	0.6	0.5	2.4
Phosphate	mg/L	0.005		0.0025	0.0125	0.0025	0.0025	0.073	0.008	0.01	0.016	8	4	0.003	0.009	0.016	0.015	0.073
Nitrate	mg/L	0.005		0.0025	0.0125	0.0025	0.0025	0.04	0.005	0.0025	0.02	8	3	0.003	0.004	0.011	0.017	0.040
Calcium	mg/L	0.5		370	340	450	400	67	270	390	280	8	8	67.0	355.0	320.9	396.0	450.0
Potassium	mg/L	0.5		410	380	480	420	56	290	350	370	8	8	56.0	375.0	344.5	416.0	480.0
Sodium	mg/L	0.5		12000	10000	15000	11000	1800	8300	10000	11000	8	8	1800	10500	9887.5	11600	15000
Magnesium	mg/L	0.5		1300	1200	1400	1400	170	930	1200	860	8	8	170.0	1200.0	1057.5	1360.0	1400.0
Hardness	mgCaCO3/L	3		6400	5700	6900	6800	880	4500	6000	4200	8	8	880.0	5850.0	5172.5	6640.0	6900.0
Hydroxide Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Bicarbonate Alkalinity	mg/L	5		130	120	130	120	65	100	110	100	8	8	65.0	115.0	109.4	126.0	130.0
Carbonate Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Total Alkalinity	mg/L	5		130	120	130	120	65	100	110	100	8	8	65.0	115.0	109.4	126.0	130.0
Sulphate	mg/L	1		2500	2300	2900	2800	410	1900	2300	2000	8	8	410.0	2300.0	2138.8	2680.0	2900.0
Chloride	mg/L	1		19000	18000	22000	21000	2800	14000	18000	16000	8	8	2800	18000	16350	20200	22000
Ionic Balance	%			5	0	8	-2	3	2	1	6	8	8	-2.0	2.5	2.9	5.6	8.0
Total Phosphorous	mg/L	0.05	0.03	0.05	0.05	0.05	0.05	0.3	0.025	0.05	0.05	8	1					0.3
Dissolved Metals																		
Aluminium	µg/L	10		5	5	5	5	80	5	5	5	8	1					80.0
Arsenic	µg/L	1		2	2	2	2	2	2	2	1	8	8	1.0	2.0	1.9	2.0	2.0
Boron	µg/L	20		4600	4300	4700	4400	780	3200	3200	2600	8	8	780.0	3750.0	3472.5	4520.0	4700.0
Barium	µg/L	1		8	8	8	11	8	13	14	14	8	8	8.0	9.5	10.5	13.6	14.0
Beryllium	µg/L	0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8	0					
Cadmium	µg/L	0.1	5.5	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	8	2	0.1				0.1
Cobalt	µg/L	1	1	<1	<1	<1	<1	3	<1	<1	<1	8	1					3.0
Chromium	µg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Copper	µg/L	1	1.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	8	1					2.0
Iron	µg/L	10		<10	<10	<10	<10	610	<10	<10	<10	8	1					610.0
Mercury	µg/L	0.05	0.1**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8	0					
Manganese	µg/L	5	80	11	10	7	2.5	410	27	21	20	8	7	2.5	15.5	63.6	24.6	410.0
Molybdenum	µg/L	1		12	12	12	13	3	8	9	9	8	8	3.0	10.5	9.8	12.0	13.0
Nickel	µg/L	1	7**	<1	<1	<1	<1	3	<1	<1	<1	8	1					3.0
Lead	µg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Selenium	µg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Strontium	µg/L	1		7900	7300	8200	7800	1200	5600	6400	6600	8	8	1200	6950	6375	7860	8200.0
Titanium	µg/L	1		<1	<1	<1	<1	1.7	<1	<1	<1	8	1					1.7
Vanadium	µg/L	1	100	<1	1	<1	<1	<1	<1	<1	<1	8	1					1.0
Zinc	µg/L	1	15	0.5	2	2	2	4	1	0.5	2	8	6	0.5	2.0	1.8	2.0	4.0
Silicon	mg/L	0.2		0.4	0.4	0.1	0.1	3	0.5	0.3	0.4	8	6	0.1	0.4	0.7	0.5	3.0
Biological																		
E. coli	cfu/100mL	1	70[a]	0.5	10	0.5		100	20	7	7	7	5	0.5	7.0	5.9	18.0	100.0
Faecal Coliforms	cfu/100mL	0.005		0.5		0.5		200	20	7	7	6	4	0.5	7.0	6.0	20.0	200.0

Annex Table E-8 Martens and Associates West Culburra Site WQ 203 (Curleys Bay) Water Quality monitoring Results 2019-2020

Analyte	Units	LOR	ANZG 2018*	02/10/19	24/10/19	29/11/19	09/01/20	19/02/020	19/03/20	29/04/20	27/05/20	N	N>DL	Min	Median	Mean	80%ile	Max
			Site:	WQ203	WQ203	WQ203	WQ203	WQ203	WQ203	WQ203	WQ203							
			Prev 7 days rain (mm):	0	0	1.4	2.4	67.6	10.6	0.2	99.5							
			Prev 2 days rain (mm):	0	0	0	0	23.0	0	0	16							
Physical and Chemical																		
Temperature	°C									25.0	19.0	2	**2**	19.0				25.0
pH	pH Units		7 - 8.5	7.9	7.8	8.0	8.0	7.5	7.9	7.8	7.7	8	**8**	7.5	7.9	7.8	8.0	8.0
Electrical Conductivity	µS/cm	1		47000	51000	51000	51000	15000	33000	45000	42000	8	**8**	15000	46000	41875	51000	51000
Total Dissolved Solids	mg/L	5		39000	37000	35000	40000	11000	30000	36000	32000	8	**8**	11000	35500	32500	38200	40000
NOx	mg/L	0.005	0.015	0.003	0.013	0.003	0.003	0.200	0.010	0.020	0.020	8	**4**	0.003	0.011	0.034	0.020	0.200
Ammonia	mg/L	0.005	0.91	0.014	0.034	0.13	0.018	0.4	0.016	0.032	0.15	8	**8**	0.014	0.033	0.099	0.142	0.400
Total Nitrogen	mg/L	0.1	0.3	0.1	0.3	0.1	0.2	1.2	0.3	0.2	0.2	8	**8**	0.1	0.2	0.3	0.3	1.2
Phosphate	mg/L	0.005		0.0025	0.0125	0.0025	0.010	0.032	0.0025	0.009	0.012	8	**4**	0.003	0.010	0.010	0.012	0.032
Nitrate	mg/L	0.005		0.0025	0.0125	0.0025	0.0025	0.21	0.01	0.02	0.02	8	**4**	0.003	0.011	0.035	0.020	0.210
Calcium	mg/L	0.5		370	340	450	390	120	270	360	280	8	**8**	120.0	350.0	322.5	382.0	450.0
Potassium	mg/L	0.5		390	380	480	400	130	280	340	360	8	**8**	130.0	370.0	345.0	396.0	480.0
Sodium	mg/L	0.5		11000	11000	15000	11000	3500	9100	10000	9600	8	**8**	3500.0	10500	10025	11000	15000
Magnesium	mg/L	0.5		1200	1200	1400	1300	350	910	1200	880	8	**8**	350.0	1200.0	1055.0	1260.0	1400.0
Hardness	mgCaCO3/L	3		6000	6000	7000	6500	1700	4400	5700	4300	8	**8**	1700.0	5850.0	5200.0	6300.0	7000.0
Hydroxide Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	**0**					
Bicarbonate Alkalinity	mg/L	5		120	190	120	120	66	97	110	100	8	**8**	66.0	115.0	115.4	120.0	190.0
Carbonate Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	**0**					
Total Alkalinity	mg/L	5		120	190	120	120	66	97	110	100	8	**8**	66.0	115.0	115.4	120.0	190.0
Sulphate	mg/L	1		2400	2400	2800	2800	790	2000	2300	2100	8	**8**	790.0	2350.0	2198.8	2640.0	2800.0
Chloride	mg/L	1		18000	19000	21000	21000	5600	15000	18000	16000	8	**8**	5600.0	18000	16700	20200	21000
Ionic Balance	%			4	1	11	-3	4	4	1	1	8	**8**	-3.0	2.5	2.9	4.0	11.0
Total Phosphorous	mg/L	0.05	0.03	0.025	0.025	0.025	0.025	0.10	0.025	0.05	0.05	8	**1**					0.1
Dissolved Metals																		
Aluminium	µg/L	10		5	5	5	5	70	10	5	5	8	**2**	5.0				70.0
Arsenic	µg/L	1		2	1	2	2	2	2	2	1	8	**8**	1.0	2.0	1.8	2.0	2.0
Boron	µg/L	20		4700	4400	4200	4300	1500	3200	3300	2500	8	**8**	1500.0	3750.0	3512.5	4360.0	4700.0
Barium	µg/L	1		8	7	6	7	13	13	15	13	8	**8**	6.0	10.5	10.3	13.0	15.0
Beryllium	µg/L	0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8	**0**					
Cadmium	µg/L	0.1	5.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	8	**0**					
Cobalt	µg/L	1	1	<1	<1	<1	<1	<1	<1	<1	<1	8	**0**					
Chromium	µg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	**0**					
Copper	µg/L	1	1.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	8	0	0.5				0.5
Iron	µg/L	10		<10	<10	<10	<10	170	<10	<10	<10	8	**1**					170.0
Mercury	µg/L	0.05	0.1**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8	**0**					
Manganese	µg/L	5	80	6	2.5	2.5	2.5	94	11	10	8	8	**5**	2.5	7.0	17.1	10.6	94.0
Molybdenum	µg/L	1		12	12	11	13	4	8	10	9	8	**8**	4.0	10.5	9.9	12.0	13.0
Nickel	µg/L	1	7**	<1	<1	<1	<1	<1	<1	<1	<1	8	**0**					
Lead	µg/L	1	4.4	<1	<1	<1	2	<1	<1	<1	<1	8	**1**					2.0
Selenium	µg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	8	**0**					
Strontium	µg/L	1		7700	7300	7600	7600	2100	5600	6400	6700	8	**8**	2100.0	7000.0	6375.0	7600.0	7700.0
Titanium	µg/L	1		<1	<1	<1	<1	1.4	<1	<1	<1	8	**1**					1.4
Vanadium	µg/L	1	100	<1	<1	1	<1	<1	<1	<1	<1	8	**1**					1.0
Zinc	µg/L	1	15	1	0.5	2	2	1	0.5	0.5	5	8	**5**	0.5	1.0	1.6	2.0	5.0
Silicon	mg/L	0.2		0.3	0.4	0.1	0.1	2.9	0.9	0.4	0.4	8	**6**	0.1	0.4	0.7	0.7	2.9
Biological																		
E. coli	cfu/100mL	1	70[a]	1	0.5	0.5		5	12	0.5	6	7	**3**	0.5	1.0	1.7	5.8	12.0
Faecal Coliforms	cfu/100mL	0.005		1		0.5		40	12	0.5	6	6	**4**	0.5	3.5	3.0	12.0	40.0

Annex Table E-9 Martens and Associates West Culburra Site WQ 204 (Goodnight Island) Water Quality monitoring Results 2019-2020

Analyte	Units	LOR	ANZG 2018*	02/10/19	24/10/19	29/11/19	09/01/20	19/02/20	19/03/20	29/04/20	27/05/20	N	N>DL	Min	Median	Mean	80%ile	Max
			Site:	WQ204	WQ204	WQ204	WQ204	WQ204	WQ204	WQ204	WQ204							
			Prev 7 days rain (mm):	0	0	1.4	2.4	67.6	10.6	0.2	99.5							
			Prev 2 days rain (mm):	0	0	0	0	23.0	0	0	16							
Physical and Chemical																		
Temperature	°C		-							25.0	18.8	2	2	18.8				25.0
pH	pH Units		7 - 8.5	8.0	8.1	8.1	8.1	7.2	8.4	7.8	7.7	8	8	7.2	8.1	7.9	8.1	8.4
Electrical Conductivity	μS/cm	1		48000	51000	52000	51000	10000	39000	47000	42000	8	8	10000	47500	42500	51000	52000
Total Dissolved Solids	mg/L	5		40000	37000	33000	41000	7300	31000	38000	33000	8	8	7300.0	35000	32537	39200	41000
NOx	mg/L	0.005	0.015	0.003	0.013	0.003	0.003	0.070	0.003	0.003	0.030	8	2	0.003				0.070
Ammonia	mg/L	0.005	0.91	0.011	0.081	0.082	0.013	0.72	0.011	0.029	0.16	8	8	0.011	0.055	0.138	0.129	0.720
Total Nitrogen	mg/L	0.1	0.3	0.5	0.4	0.05	0.4	2.1	0.2	0.1	0.2	8	7	0.1	0.3	0.5	0.5	2.1
Phosphate	mg/L	0.005		0.0025	0.0125	0.0025	0.008	0.066	0.0025	0.008	0.017	8	4	0.003	0.008	0.015	0.015	0.066
Nitrate	mg/L	0.005		0.0025	0.0125	0.0025	0.0025	0.062	0.0025	0.0025	0.02	8	2	0.003				0.062
Calcium	mg/L	0.5		380	330	450	390	84	320	380	270	8	8	84.0	355.0	325.5	386.0	450.0
Potassium	mg/L	0.5		410	380	480	410	62	350	360	380	8	8	62.0	380.0	354.0	410.0	480.0
Sodium	mg/L	0.5		12000	11000	15000	11000	2000	10000	11000	11000	8	8	2000.0	11000	10375	11600	15000
Magnesium	mg/L	0.5		1400	1200	1400	1300	230	1100	1200	860	8	8	230.0	1200.0	1086.3	1360.0	1400.0
Hardness	mgCaCO3/L	3		6600	5800	7000	6400	1200	5200	6100	4200	8	8	1200.0	5950.0	5312.5	6520.0	7000.0
Hydroxide Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Bicarbonate Alkalinity	mg/L	5		120	120	120	120	66	96	110	110	8	8	66.0	115.0	107.8	120.0	120.0
Carbonate Alkalinity	mg/L	5		<5	<5	<5	<5	<5	15	<5	<5	8	1					15.0
Total Alkalinity	mg/L	5		120	120	120	120	66	110	110	110	8	8	66.0	115.0	109.5	120.0	120.0
Sulphate	mg/L	1		2500	2400	2800	2800	520	2400	2400	2050	8	8	520.0	2400.0	2233.8	2680.0	2800.0
Chloride	mg/L	1		19000	19000	21000	21000	3600	18000	19000	15500	8	8	3600.0	19000	17012	20200	21000
Ionic Balance	%			6	0	11	-3	-2	0	3	8	8	8	-3.0	1.5	2.9	7.2	11.0
Total Phosphorous	mg/L	0.05	0.03	0.025	0.025	0.025	0.025	0.300	0.025	0.05	0.05	8	1					0.30
Dissolved Metals																		
Aluminium	μg/L	10		5	5	5	5	80	10	5	5	8	2	5.0				80.0
Arsenic	μg/L	1		2	2	2	2	2	2	2	<1	7	7	2.0	2.0	2.0	2.0	2.0
Boron	μg/L	20		4700	4300	4600	4200	970	3900	3300	2400	8	8	970.0	4050.0	3546.3	4480.0	4700.0
Barium	μg/L	1		7	7	5	7	10	11	11	14	8	8	5.0	8.5	9.0	11.0	14.0
Beryllium	μg/L	0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8	0					
Cadmium	μg/L	0.1	5.5	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	8	1					0.1
Cobalt	μg/L	1	1	<1	<1	<1	<1	2	<1	<1	<1	8	1					2.0
Chromium	μg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Copper	μg/L	1	1.3	0.5	0.5	0.5	0.5	0.5	0.5	2	0.5	8	1					2.0
Iron	μg/L	10		<10	<10	<10	<10	530	<10	<10	<10	8	1					530.0
Mercury	μg/L	0.05	0.1**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8	0					
Manganese	μg/L	5	80	10	7	2.5	2.5	370	17	8	16	8	6	2.5	9.0	54.1	16.6	370.0
Molybdenum	μg/L	1		12	12	12	13	3	9	11	9	8	8	3.0	11.5	10.1	12.0	13.0
Nickel	μg/L	1	7**	<1	<1	<1	<1	3	<1	<1	<1	8	1					3.0
Lead	μg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Selenium	μg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Strontium	μg/L	1		7400	7500	8000	7600	1500	6800	6300	6600	8	8	1500.0	7100.0	6462.5	7560.0	8000.0
Titanium	μg/L	1		<1	<1	<1	<1	2	<1	<1	<1	8	1					2.0
Vanadium	μg/L	1	100	<1	2	1	<1	<1	<1	<1	<1	8	2	1.0				2.0
Zinc	μg/L	1	15	1	1	0.5	1	2	1	0.5	1	8	6	0.5	1.0	1.0	1.0	2.0
Silicon	mg/L	0.2		0.3	0.1	0.1	0.1	3.1	0.1	0.6	0.4	8	4	0.1	0.2	0.6	0.5	3.1
Biological																		
E. coli	cfu/100mL	1	14[a]	5	0.5	0.5		100	4	1	5	7	4	0.5	4.0	3.1	5.0	100.0
Faecal Coliforms	cfu/100mL	0.005		5		0.5		100	4	1	5	6	4	0.5	4.5	4.1	5.0	100.0

Annex Table E-10 Martens and Associates West Culburra Site WQ 205 (Curleys Bay) Water Quality monitoring Results 2019-2020

Analyte	Units	LOR	ANZG 2018*	02/10/19	24/10/19	29/11/19	09/01/20	19/02/20	19/03/20	29/04/20	27/05/20	N	N>DL	Min	Median	Mean	80%ile	Max
			Site:	WQ205	WQ205	WQ205	WQ205	WQ205	WQ205	WQ205	WQ205							
			Prev 7 days rain (mm):	0	0	1.4	2.4	67.6	0.2	99.5	99.5							
			Prev 2 days rain (mm):	0	0	0	0	23.0	0	16	16							
Physical and Chemical																		
Temperature	℃		-							25.0	18.8	2	2	18.8				25.0
pH	pH Units		7 - 8.5	7.9	7.8	8.0	7.9	7.5	7.8	7.8	7.8	8	8	7.5	7.8	7.8	7.9	8.0
Electrical Conductivity	μS/cm	1		46500	52000	52000	52000	14000	32000	46000	41000	8	8	14000	46250	41938	52000	52000
Total Dissolved Solids	mg/L	5		40000	37000	34000	42000	9550	27000	37000	32000	8	8	9550	35500	32319	38800	42000
NOx	mg/L	0.005	0.015	0.010	0.013	0.003	0.003	0.200	0.020	0.003	0.003	8	3	0.003	0.006	0.032	0.017	0.200
Ammonia	mg/L	0.005	0.91	0.016	0.074	0.051	0.005	0.43	0.014	0.011	0.13	8	8	0.005	0.034	0.091	0.108	0.430
Total Nitrogen	mg/L	0.1	0.3	0.1	0.3	0.1	0.2	1.2	0.3	0.1	0.1	8	8	0.1	0.2	0.3	0.3	1.2
Phosphate	mg/L	0.005		0.0025	0.0125	0.0025	0.0025	0.022	0.0025	0.007	0.0025	8	2	0.003				0.022
Nitrate	mg/L	0.005		0.007	0.0125	0.0025	0.0025	0.16	0.01	0.0025	0.0025	8	3	0.003	0.005	0.025	0.012	0.160
Calcium	mg/L	0.5		380	350	450	400	100	270	370	280	8	8	100.0	360.0	325.0	392.0	450.0
Potassium	mg/L	0.5		410	380	480	420	120	280	350	350	8	8	120.0	365.0	348.8	416.0	480.0
Sodium	mg/L	0.5		12000	10000	15000	10000	3100	8500	11000	11000	8	8	3100	10500	10075	11600	15000
Magnesium	mg/L	0.5		1300	1200	1400	1300	310	920	1200	850	8	8	310.0	1200.0	1060.0	1300.0	1400.0
Hardness	mgCaCO3/L	3		6400	5700	7000	6500	1600	4400	5900	4200	8	8	1600	5800.0	5212.5	6460.0	7000.0
Hydroxide Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Bicarbonate Alkalinity	mg/L	5		125	120	120	120	65.5	99	110	100	8	8	65.5	115.0	107.4	120.0	125.0
Carbonate Alkalinity	mg/L	5		<5	<5	<5	<5	<5	<5	<5	<5	8	0					
Total Alkalinity	mg/L	5		125	120	120	120	65.5	99	110	100	8	8	65.5	115.0	107.4	120.0	125.0
Sulphate	mg/L	1		2500	2300	2900	2800	710	1900	2300	2100	8	8	710.0	2300.0	2188.8	2680.0	2900.0
Chloride	mg/L	1		19000	18000	22000	21000	5100	15000	18000	16000	8	8	5100	18000	16762	20200	22000
Ionic Balance	%			6	1	9	-6	2	2	4	5	8	8	-6.0	3.0	2.9	5.6	9.0
Total Phosphorous	mg/L	0.05	0.03	0.025	0.025	0.09	0.025	0.09	0.025	0.05	0.05	8	2	0.03				0.09
Dissolved Metals																		
Aluminium	μg/L	10		5	5	5	5	60	10	5	5	8	2	5.0				60.0
Arsenic	μg/L	1		1	1	2	1	2	2	1	0.5	8	7	0.5	1.0	1.3	2.0	2.0
Boron	μg/L	20		4700	4300	4600	4300	1500	3300	3000	2400	8	8	1500	3800	3512	4480	4700
Barium	μg/L	1		9	8	8	12	12	13	14	13	8	8	8.0	12.0	11.1	13.0	14.0
Beryllium	μg/L	0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8	0					
Cadmium	μg/L	0.1	5.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	8	0					
Cobalt	μg/L	1	1	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Chromium	μg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Copper	μg/L	1	1.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	8	1					1.0
Iron	μg/L	10		<10	<10	<10	<10	160	<10	<10	<10	8	1					160.0
Mercury	μg/L	0.05	0.1**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8	0					
Manganese	μg/L	5	80	10	2.5	7	2.5	88	14	2.5	7	8	5	2.5	7.0	16.7	12.4	88.0
Molybdenum	μg/L	1		12	12	13	13	4	9	9	9	8	8	4.0	10.5	10.1	12.6	13.0
Nickel	μg/L	1	7**	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Lead	μg/L	1	4.4	<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Selenium	μg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	8	0					
Strontium	μg/L	1		7400	7400	8400	7700	1900	5600	6500	6700	8	8	1900	7050	6450	7580	8400
Titanium	μg/L	1		<1	<1	<1	<1	1.5	<1	<1	<1	8	1					1.5
Vanadium	μg/L	1	100	<1	<1	<1	<1	<1	<1	1	<1	8	1					1.0
Zinc	μg/L	1	15	1	1	0.5	0.5	1	2	0.5	0.5	8	4	0.5	0.8	0.9	1.0	2.0
Silicon	mg/L	0.2		0.4	0.4	0.1	0.3	2.7	0.8	1.1	0.5	8	7	0.1	0.5	0.8	1.0	2.7
Biological																		
E. coli	cfu/100mL	1	70[a]	0.5	6	0.5		150	5	0.5	7	7	4	0.5	5.0	3.3	6.8	150.0
Faecal Coliforms	cfu/100mL	0.005		0.5		0.5		150	5	0.5	7	6	3	0.5	2.8	2.9	7.0	150.0

Notes For Annex Tables E-6 to E-10
Note: *ANZECC 2018 Default Guideline Values for 95% species protection levels in marine waters. **Represent 99% DGVs as recommended by ANZG (2018) a = Faecal coliform values taken from respective Shellfish Harvest Area Management Plans for water samples. E. coli and Faecal Coliforms mean values are geometric means. Values in red represent half the detection limits. Values shaded yellow represent exceedances of ANZECC DGV or NSW Shellfish Monitoring trigger values.

Annex Table E-11 SCC Aquadata Salinity Electrical Conductivity and Dissolved Oxygen Concentrations 1992 to 2020

Sample	Salinity (ppt)						Conductivity (μs/cm)						DO (% saturation)					
Date	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457
14-Apr-92			27.0	28.0	26.0				40000	40000	38000							
01-Sep-92			35.4						43.78						102.3			
01-Sep-92			35.2						43.66						97			
31-Mar-93	5.0	20.0	22.0	22.0	18.0	19.0	8000	28000	30000	30000	25000	25000	73	85	100	100	75	93
15-Jul-93	5.0	21.0	21.0	22.0	22.0	22.0	15000	28000	28000	29000	29000	30000	72	125	105	118	112	107
30-Sep-93	2.0	15.0	24.0	25.0	23.0	23.0	3600	32400	35000	33000	35200	35000	50	81	99	93	92	103
30-Dec-93	31.0	30.0	32.0	32.0	32.0	32.0	47000	46000	48000	47000	47000	47000	65	93	95	97	100	100
10-Mar-94	6.0	7.0	15.0	17.0	15.0	15.0	10000	18000	31000	35000	32000	31000	45	66	100	102	94	102
28-Mar-94	27.0				27.0	27.0	39000				39000	39000	84				107	108
06-Jun-94	4.0	21.0	29.0	24.0	26.0	27.0	6000	27000	36000	33500	37000	37000	49	90	121	110	123	123
13-Oct-94	27.5	35.0	34.0	31.0	31.5	33.0	37000	44000	43000	41500	41000	43000	79	80	83	94	93	92
05-Dec-94	38.5	33.0	32.0	30.0	32.5	33.0	47000	46000	46000	44000	47000	47000	85	107	137	130	120	117
28-Mar-95		26.0	28.0	30.0				48500	41000	42000				99	105	128		
24-Jul-95	5.0	20.0	24.5	22.0	25.0	25.0	15000	25000	30500	31000	31000	31000	76	78.3	93	96.7	89	89.8
30-Jan-96		20.0	22.0	24.0	21.0	21.0		31500	34000	37000	32500	32000		47	64	90	99	92
25-Jun-96	7.0	22.0	24.0	23.0	24.0	24.0	5000	9000	10000	11000	10000	10000	90	86	93	100	93	93
22-Oct-96					31.6						48394.7						94.12	
18-Feb-97		20.0	16.0	15.0	15.0	18.0		34000	27000	25000	25000	29000		86	91	78	81	83
22-Jul-97																		
29-Sep-97		1.0	8.0	10.2	9.5	9.1		1919.08	13844.4	17177.9	16134.9	15507.9		96.93	139.27	129.08	128.62	131.26
10-Dec-97	6.2	21.2	20.8	19.6	20.4	21.7	10000	35500	35000	34000	34500	36000	70.2	96.6	101.28	109.7	103	107
31-Mar-98	39.0	38.8	38.7	37.0	37.2	37.9	58360	58000	57970	55600	55970	56850	75.3	90.7	107.8	112	115	117.5
11-Jun-98	9.5	22.0	27.4	31.9	27.3	27.0	16194.9	34906.2	42524.2	48803.6	42410.5	41993.1	83.99	98.47	104.49	96.78	104.53	106.78
03-Aug-98	2.7	9.5	21.6	25.0	24.4	24.3	5030.69	16158.7	34383.9	39394.9	38437.8	38398.1	116.69	122.54	146.6	128.64	137.23	134.94
22-Oct-98	23.0	31.0	32.1	32.5	31.6	31.4	36237.5	47469.1	49034.7	49511	48395	47998.4	63.83	97.08	104.12	95.83	94.12	100.58
11-Jan-99	27.5	30.2	29.7	29.5	29.4	29.5	42770	46555	8.25	7.58	7.65	45515	87.36	112	118	107	109	103
15-Apr-99	26.0	24.0	26.0	24.0	22.5	23.0	35000	35000	35000	34000	33000	34000	55	76.3	87.5	79	80	83
12-Aug-99	11.0												59	77.9	83.2	80.3	78.8	80.6
11-Jan-00	27.6	28.1	31.9	30.4	27.4	27.8	42900	43600	48900	46900	42700	43200	37.9	86	121.9	127.9	104.8	104.6
12-Jul-00	7.9	26.7	20.5	27.5	26.9	26.7	13700	41600	32900	42800	42000	41700	36.8	86.4	75	72.7	77.4	78.6
27-Sep-00	28.3	26.4	31.0	30.8	30.5	26.6	43900	41300	47700	47400	47000	41600	39.8	76	84	80	79.6	79.2
21-Feb-01	25.6	23.4	24.8	28.9	25.4	26.9	40200	36900	38.9	44700	39900	41900	30.1	80.1	83.9	95.6	74.8	93
03-Apr-01																		
04-Jun-01	31.8	32.1	32.6	32.2	32.1	32.2	48800	49100	49800	49300	49100	49.3	50.3	67.1	66.5	66.9	65.8	66

12-Dec-01	0.4	33.3	35.3	33.4	33.1	33.0	610	50800	53400	50900	50600	50400	30.4	77.2	94.7	84.4	81.7	84.4
16-May-02	18.5	27.5	30.1	30.3	30.3	29.1	29800	42800	46400	46600	46700	45100	30.03	61.8	75.1	73.8	76.1	77.2
27-Jun-02	9.3	27.2	31.6	31.2	32.0	32.1	15900	42400	48400	47900	49000	49200	60.4	78.8	75.8	79.3	78.8	76.4
16-Dec-02	35.3	35.2	34.7	34.8	35.1	34.9	53500	53400	52700	52800	53200	52900	42.8	60.4	76.2	76.7	56.4	62.6
17-Jun-03	6.5	20.1	27.6	28.5	26.7	28.2	11400	32200	42900	44200	44400	43700	70.7	105.6	123.3	124	120.1	116.1
05-Nov-03	31.3	35.1	34.0	33.6		34.7	48100	53200	51800	51200		52600		95.2		95.2		
11-Dec-03	10.1	24.9	30.4	32.6	30.4	30.1	17100	39100	46800	49900	46800	46300	46.9	81	90.3	97.8	83.2	86.7
02-Jun-04	33.7	34.1	33.3	33.2	33.3	33.2	51300	51900	50800	50700	50800	50700	93.1	113.3	121.1	122.5	131.5	129.1
20-Apr-05	28.6	31.5	31.5	32.3	31.5	32.0	44300	48300	48400	49300	48300	49100	103.9	100.6	102.8	105.5	103.8	103.5
29-Jun-05	6.4	20.0	30.3	34.3	31.6	31.8	5768	32100	46600	52100	48500	48700	51.4	79.6	91.8	87.1	95	94.3
15-Dec-05	28.1	31.4	31.9	31.6	31.7	32.6	43600	48100	48800	48500	48500	49800	66.6	80.6	85.3	86.7	85.4	93
20-Mar-06		36.9	35.3	35.3	35.1	35.5		55700	53500	53500	53100	53700						
21-Mar-06		36.9						55700										
11-Dec-07	23.2	22.8	32.6	31.4	25.4	24.4	36700	36100	49900	48200	39800	38400	67.8	84.3	101.4	94.7	90	85
18-Feb-08	1.0	3.4	31.4	31.6	26.1	22.5	1924	6051	48200	48400	40800	35600	56.1	57.1	77.4	83.9	81.4	84.1
18-Feb-08		1.4	21.9	25.1	18.8	19.0		2596	34800	39400	31800	30700		25.2	76.3	79.1	81.1	79.4
04-May-09	32.0	32.2	31.7	31.8	31.4	31.6	49100	49300	48600	48700	48200	48400	88.5	85.2	101.9	103.8	110.5	109
07-Sep-09			36.0						54400						92.8			
28-Sep-09	38.4	37.8	36.6	36.1	36.7	36.5	57600	56800	55300	54600	55300	55100	86.5	101.3	99.8	105	112.4	103.3
13-Oct-09			33.4						50890						85.5			
01-Dec-09			34.8						52870						80.8			
14-Dec-09			35.3						53440						76.3			
14-Dec-09			35.0						53130						75.6			
11-Jan-10			33.9						51640						73.3			
25-Jan-10			34.5						52400						84.8			
08-Feb-10			22.3						35360						86.2			
22-Feb-10			14.6						24020						86.1			
08-Mar-10			27.0						42050						107.7			
23-Mar-10			25.8						40440						68.3			
19-Apr-10			31.4						48230						106.8			
12-May-10			33.0						50310						90.7			
07-Jun-10			19.0						30680						93.3			
13-Sep-10			31.6						48450						103.4			
20-Oct-10			28.4						44020						92.2			
16-Nov-10			18.4						29790						78			
11-Jan-11			24.9						39170						97.8			
19-Jan-11			26.9						41980						96.1			
14-Feb-11			27.3						42450						103.1			
11-Apr-11			5.4						9700						74.1			

21-Sep-11			28.2						43800						43.9			
17-Oct-11			33.8						51500						58.2			
07-Nov-11			33.2						50690						75.5			
21-Nov-11			32.6						49830						76.7			
05-Dec-11			29.9						46190						80.2			
06-Dec-11			23.5						37100						81.8			
03-Jan-12			28.2						43710						72.7			
16-Jan-12			31.3						48030						64.4			
13-Feb-12			25.5						39920						67.3			
27-Feb-12			19.7						31660						65.2			
28-Mar-12			14.8						24410						54.8			
16-Apr-12			26.1						40870						82			
18-Apr-12	4.5	18.3		5.2	24.5	25.3	7252	29630		39490	38520	39740	31.1	70.7		76	6.78	80.8
14-May-12			32.6						49790									
13-Jun-12			13.9						23000						171.2			
24-Jul-12			32.8						50080						70.7			
15-Aug-12			30.5						46900						104.8			
25-Sep-12			32.7						49910						100			
10-Dec-12			34.9												102.5			
06-Mar-13			0.6												50.7			
12-Feb-14	39.1	39.2	38.2	37.4	35.8	36.7							97	98	106.3	117.5	119.5	119.1
16-Jun-14			35.6												64.9			
27-Oct-14			32.7												91.8			
17-Nov-14	2.0	29.0	37.0	31.0	31.0	31.0							93.8	93.8	84	84.3	89.4	84.4
17-Feb-15																		
17-May-15			13.4												79.1			
18-May-15																		
14-Sep-15	0.0	1.0	15.8	32.8	25.7	1.0							25.7	83.2	73.8	76.6	77.1	73.4
16-Sep-15	1.4	16.7	25.9	32.8	25.7	23.0							25.7	83.2	70.6	76.6	77.1	73.4
02-Feb-16																		
07-Feb-16	20.0		32.2	33.6	29.9	23.6							58.4		84.4	83.8	80.5	73.7
08-Feb-16																		
18-Apr-16			31.8						48780						84			
15-Jun-16																		
27-Sep-16			30.4						46830						86.6			
15-Nov-16	29.7	30.5	33.0	32.3	30.8	29.9	45800	47000	50390	49390	47370	46140	73.9	76	96	97.5	87.7	85
10-Jan-17			32.1						49130						100.2			
27-Feb-17	24.7	28.0	31.6	30.7	28.6	27.1	38790	43510	48490	47230	44360	42290	46	66.5	82.3	75.3	71.8	76.4
27-Mar-17			18.8						30330						5.41			

26-Jun-17			30.4						46800						51.3			
21-Sep-17			32.0						49070						51.8			
01-Nov-17	31.3	32.1	31.8	31.8	31.8	31.9	48.02	490160	48690	48790	48740	48890	23.7	34.1	39.2	37.7	38.5	37.6
22-Jan-18			32.9						50170						56.2			
14-Feb-18		31.9	32.7	32.5	32.3	32.4		48860	49950	49660	49360	49520		35.1	49.3	48.3	42.5	41.7
12-Apr-18			29.1						45000						22.6			
27-Jun-18			32.5						49720									
10-Oct-18	30.8	30.8	32.1	31.1	31.0	30.2	47410	47390	49100	47760	47610	46470	57.5	53.2	61.7	64.1	59	60.3
18-Oct-18			30.1						46360						76.5			
28-Feb-19			34.3						52170						91.3			
21-May-19		4.2	34.1	33.8	33.8	33.9		51930	51910	51460	51390	51590		96.6	101.6	111.7	104.3	114.2
25-Nov-19			23.5						37180						113.6			
26-Nov-19	24.8	23.9	23.8	23.8	23.8	23.6	39050	37770	37530	37550	37510	37260	59.3	75.8	105.6	99	88.8	87
09-Dec-19			24.1						38.01						96.5			
07-Jan-20			20.8						33230						47.7			
18-Mar-20			25.2						39540						91.5			

Annex Table E-12 SCC Aquadata Water pH, Temperature amd Faecal Coliform Concentrations 1992 to 2020																		
Sample	pH (Units)						Temp ºC						Faecal Coliforms (cfu/100ml)					
Date	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457
14-Apr-92			8	7.9	8				20	20	21				0	0	4	
01-Sep-92			7.99						15.48						0			
01-Sep-92			7.96						15.5									
31-Mar-93	6.6	7	6.8	6.7	6.8	6.8	21	21	21	21	21	20	155	160	18	14	20	25
15-Jul-93	7.1	7.8	8	8.2	8.1	8.1	17	16	15.5	16	16	17	16	68	0	0	4	8
30-Sep-93	8.2	7.8	8.3	8.2	8	7.6	20	22	21	21	21	21	140	16	64	0	4	0
30-Dec-93	7.2	7.6	7.6	7.7	7.8	7.7	23	23	23	24	23	22	80	172	56	16	24	50
10-Mar-94	6.4	6.7		7.5	7.2	7.6	23	23	23	23	24	23	240	800	260	520	1600	304
28-Mar-94							20				19	19	60				0	0
06-Jun-94	7.3	7.7	7.7	8	7.7	8	16	16.5	15.5	16	15.5	15.5	280	104	4	16	4	24
13-Oct-94	7.4	7.7	7.7	8	8	8	17	17	17	16	16	17	12	24	4	0	0	0
05-Dec-94	7.6	7.9	8.1	8	8	7.8	23.5	24	21	21.5	23	23.5	112	20	0	0	0	0
28-Mar-95								19	21	21				60	0	0		
24-Jul-95	7.92	7.42	7.25	6.82	7.01	7.08	12.5	12.5	12.5	13	13	13	4	12	0	0	0	0
30-Jan-96		7.24	7.6	7.77	7.76	7.77		24	23	23	22	22		68	16	0		
25-Jun-96	7.8	7.4	7.5	7.1	7.4	7.1	13	13	13	13	13	13	0	8	0	0	9	0
22-Oct-96					7.29						18.4						0	
18-Feb-97		6.8	6.8	7.4	7.6	7.7		28	27	25	25	24		134	12	20	16	12
22-Jul-97															4	0	0	
29-Sep-97		7.04	7.37	7.31	7.32	7.26		16.05	16.07	15.25	15.1	15.2		160	120	160	132	100
10-Dec-97	6.84	7.12	7.36	7.28	7.46	7.22	23.5	23.2	22.9	23	22.5	22.7	100	8	0	0	16	0
31-Mar-98	7.9	7.75	7.77	7.6	7.73	7.7	21.04	20.6	19.55	21	20.45	19.7	340	55	1	20	5	8
11-Jun-98	7.61	7.47	7.54	7.58	4	7.61	13.39	13.43	14.99	15.23	14.14	13.93	116	132	4	12		12
03-Aug-98	5	6.4	8.3	8.3	8.3	8.3	10.01	11.05	11.28	10.31	10.35	10.8	10	8	0	0	0	0
22-Oct-98	6.12	6.98	7.65	7.3	7.29	7.35	18.5	19.68	18.54	19.04	18.4	18.74	95	9	0	0	0	2
11-Jan-99	8.57	8.95	9.34	9.21	9.24	9.26	26	25.5	25	29.5	24.5	24.5	125	51	2	0	5	1
15-Apr-99	7.4	7.9	8.2	8.1	8.1	8.1	20.1	20.8	20.8	21	20.7	20.7	30	4	0	4	4	0
12-Aug-99	7.9	8.1	8.2	8.4	8.4	8.4	13.3	14.9	14.9	14.9	14.6	14.4	160	36	12	4	0	4
11-Jan-00	7.7	8.4	8.5	8.5	8.4	8.3	23.34	25.42	23.62	24.15	24.77	25.34	12	0	2	2	13	11
12-Jul-00	7.14	8.62	8.36	8.57	8.65	8.69	9.05	10.5	10.6	9.06	9.09	8.2	9	8	1	5	1	1
27-Sep-00	6	6	5.99	5.99	5.99	5.99	14.78	15.24	15.39	15.21	15.11	15.23	215	58	1	3	9	3
21-Feb-01	6.47	7.31	7.35	7.32	7.41	7.4	23.9	25.4	25.23	25.77	25.27	25.35	81	267	5	5	19	24

03-Apr-01														110				
04-Jun-01	8.5	7.99	8.31	8.37	8.65	8.76	12.42	13.52	15.41	14.06	13.53	14.05	24	25	3	8	5	4
12-Dec-01	7.3	7.93	8.25	8.12	8.08	8.1	18.31	20.83	19.84	19.82	20.02	19.88	0	1	0	0	0	0
16-May-02	7.5	7.92	8.3	8.29	8.26	8.23	15.45	16.4	17.83	17.84	17.29	16.69	164	36	12	0	4	8
27-Jun-02	8.05	8.72	8.8	8.8	8.85	8.87	9.31	10.05	12.33	12.17	10.79	10.59	68	11	6	1	1	2
16-Dec-02	7.1	7.53	7.88	7.9	7.6	7.68	23.9	25.08	23	22.73	23.82	24.29	48	28	4	4	0	0
17-Jun-03	6.67	7.76	8.22	7.94	8.11	8.08	11	12.7	14.17	14.47	13.68	12.79	530	130	4	0	0	16
05-Nov-03	7.31	7.66	7.98	7.98		8.03	18.5	20.57	20.02	18.47		18.73	12	0	0	0		0
11-Dec-03	7	7.77	8.04	8.14	7.91	7.96	23.97	24.47	24.01	22.62	22.3	23.88	320	304	1	0	0	0
02-Jun-04	8.15	8.48	8.69	8.63	8.65	8.68	11.79	12.19	14.45	13.59	12.78	13.09	76	28	2	2	1	1
20-Apr-05	7.34	7.81	7.93	7.91	7.95	8.05	20.23	21.23	20.55	19.78	20.27	20.36	33	22	4	1	54	2
29-Jun-05	6.99	7.42	7.89	7.93	7.97	7.97	12.35	13.97	14.06	14.63	13.68	13.73	248	80	8	4	0	0
15-Dec-05	7.2	7.41	7.56	7.74	7.73	7.58	25.56	27.26	27.31	27.19	27	26.74	56	38	-1	3	8	2
20-Mar-06		7.89	8.7	8.73	8.75	8.65		21.84	22.28	22.27	22.33	21.65		36	2	-1	1	12
21-Mar-06		7.89												36				
11-Dec-07	7.19	7.54	7.76	7.64	7.55	7.75	19.85	21.26	19.86	20.08	20.8	20.55	130	3	7	2	3	2
18-Feb-08	8.46	7.91	8.34	8.55	8.56	8.48	21.61	22.5	22.37	22.53	22.77	23.02	520	400	24	24	56	40
18-Feb-08		7.78	8.17	8.5	8.49	8.45		22.95	22.82	22.72	23.13	23.2						
04-May-09	7.97	7.99	8.45	8.3	8.46	8.41	14.56	17.46	17.01	17.72	17.3	17.59	140	7	0	0	2	0
07-Sep-09			8.76						15.4						8			
28-Sep-09	8.36	8.82	8.91	8.71	8.8	8.88	13.29	11.52	11.7	11.42	10.4	10.71	65	2	1	1	0	0
13-Oct-09			8.15						18.35						0			
01-Dec-09			8.11						19.56						0			
14-Dec-09			8.03						21.71						0			
14-Dec-09			7.97						22.41									
11-Jan-10			7.93						25.59									
25-Jan-10			7.69						23.37									
08-Feb-10			7.6						23.7									
22-Feb-10			7.43						24.57									
08-Mar-10			7.88						24.32									
23-Mar-10			8.37						24.55									
19-Apr-10			7.94						21.91									
12-May-10			7.72						16.59									
07-Jun-10			8.39						14.12									
13-Sep-10			7.43						16.07						0			
20-Oct-10			7.71						18.4									
16-Nov-10			7.54						21.78									

11-Jan-11			7.96						25.34									
19-Jan-11			8.1						21.48									
14-Feb-11			7.88						23.53									
11-Apr-11			6.86						20.53						17			
21-Sep-11			7.77						16.63									
17-Oct-11			7.61						17.71									
07-Nov-11			8.02						19.22									
21-Nov-11			7.65						19.92									
05-Dec-11			8						17.65									
06-Dec-11			8.46						18.33									
03-Jan-12			7.78						23.4									
16-Jan-12			7.82						21.16									
13-Feb-12			7.83						22.36									
27-Feb-12			7.64						23.61									
28-Mar-12			7.3						21.54									
16-Apr-12			7.88						20.33						10			
18-Apr-12	7.19	7.43		7.79	5.99	7.97	18.9	20.6		20.22	20.51	20.91		4000	0	48	500	408
14-May-12			8.47						17.34									
13-Jun-12			8.04						14.26									
24-Jul-12			8.3						16.22									
15-Aug-12			8.23						13.73									
25-Sep-12			8.17						17.34						1			
10-Dec-12			8.21						19.5									
06-Mar-13			7.18						20.19						12			
12-Feb-14							24.18	24.19	24.61	22.58	20.58	23.02	75	25	10	10	25	5
16-Jun-14			8.24						17.92						0			
27-Oct-14			7.87						19.46						0.5			
17-Nov-14	8.21	7.65	7.33	7.55	7.36	6.44	21.52	21.67	21.66	21.17	20.86	20.34	36	4	0.5	0.5	0.5	0.5
17-Feb-15													170	24	1	0.5	0.5	0.5
17-May-15			7.73						14.93									
18-May-15															2			
14-Sep-15	7.9	7.8	8.22	7.88	8.34	8.21	14.43	17.32	17.3	16.77	17.12	17.61			0.5			
16-Sep-15	7.9	7.23	8.22	8.34	8.28	8.15	14.43	17.32	17.3	16.77	17.12	17.61	30	74	4	4	6	1
02-Feb-16																		
07-Feb-16	7.66		8.37	8.38	8.36	8.2	23.6		28.83	23.44	23.71	24.27						
08-Feb-16													22	1	5	6	3	5
18-Apr-16			8.15						20.63						1			

15-Jun-16																		48
27-Sep-16			8.36						17.9									
15-Nov-16	7.7	8.1	8.43	8.42	8.31	8.2	19.32	19.19	18.2	17.93	0.87	18.34	150	1	1	1	1	3
10-Jan-17			8.21						24.27						0.5			
27-Feb-17	7.52	7.85	8.25	8.21	8.11	8.08	21.67	22.02	20.55	20.4	20.89	20.92	220	8	6	42	190	2000
27-Mar-17			8.1						23.88						190			
26-Jun-17			8.61						16.09						2			
21-Sep-17			8.74						18.6						0.5			
01-Nov-17	7.76	8.05	8.48	8.45	8.49	8.48	19.29	18.73	18.52	17.73	17.75	16.93	56	7	2	2	1	2
22-Jan-18			8.58						23.18						0.5			
14-Feb-18		8.09	8.51	8.29	8.18	8.16		25.9	24.29	24.61	25.37	25.76	56	2	1	1	2	1
12-Apr-18			8.9						24.42						0.5			
27-Jun-18			8.79						15.76						0.5			
10-Oct-18	8.05	8.26	8.69	8.63	8.59	8.56	17.49	18.03	17.64	17.3	17.59	17.32	63	1	4	1	10	71
18-Oct-18			8.4												0.5			
28-Feb-19			8.24						23.61						0.5			
21-May-19		7.82	8.06	8.48	8.02	8.04		17.29	19.06	18.98	18.82	18.4		9	2	0.5	0.5	0.5
25-Nov-19			8.08						22.12									
26-Nov-19	7.58	7.83	8.21	7.93	7.94	7.96	23.32	23.07	19.46	20.45	21.86	22.13	13	1	1	0.5	1	0.5
09-Dec-19			7.88						24.13									
07-Jan-20			7.2						25.57									
18-Mar-20			7.7						21.51						3			

Annex Table E-13 SCC Aquadata Chlorophyll-a, Total Phosphorous and Total Nitrogen Concentrations 1994 to 2020																		
Sample	Chl-A (mg/m^3)						TP (mg/L)						TN (mg/L)					
Date	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457
10-Mar-94		0.4						0.06						0.56				
06-Jun-94		2.54						0.04						0.61				
13-Oct-94								0.035						0.34				
05-Dec-94		5.1						0.036						0.45				
28-Mar-95		5.9						0.15						0.58				
24-Jul-95		1.3						0.004						0.26				
30-Jan-96		10.3						0.029						0.78				
25-Jun-96								0.006						0.25				
18-Feb-97		30.7						0.032						0.55				
29-Sep-97		7.6						0.108						0.88				
10-Dec-97		19.9						0.043						0.4				
31-Mar-98		6.5						0.063						0.64				
11-Jun-98		3.1						0.02						0.51				
03-Aug-98		0.8						0.011						0.62				
22-Oct-98		2.6						0.02						0.34				
11-Jan-99		11.3						0.029						0.48				
15-Apr-99		5.6						0.022						0.23				
11-Jan-00		2.7						0.011						0.27				
12-Jul-00		2.7						0.017						0.43				
27-Sep-00		3.8	0.3					0.02						0.27				
21-Feb-01		6						0.028						0.42				
03-Apr-01		4.9						0.078						0.54				
04-Jun-01		1.1						0.011						0.31				
12-Dec-01		1.7						0.031						0.29				
16-May-02		75						0.035						0.26				
27-Jun-02		1						0.011						0.29				
16-Dec-02		198.7						0.07						0.51				
17-Jun-03		2.4						0.01						0.43				
05-Nov-03		1.2						0.002						0.09				
11-Dec-03		1						0.002						0.6				
02-Jun-04		0						0.002						4.1				

20-Apr-05		9						0.053						0.32				
29-Jun-05		37						0.034						0.77				
15-Dec-05		1.3						0.024						0.48				
20-Mar-06		0						0.013						0.23				
21-Mar-06		0						0.013						0.23				
11-Dec-07		3.2						0.042						0.25				
18-Feb-08	42	220	12	3.4	5.6	8.1	0.21	0.32	0.05	0.05	0.05	0.06	2.1	2.9	1	0.5	0.6	0.5
04-May-09		1.1						0.02						0.34				
07-Sep-09			2.1					0.02						0.24				
28-Sep-09	0	0	0	0	0	0												
13-Oct-09			0.61															
01-Dec-09			0.33															
14-Dec-09			0															
11-Jan-10			1.4															
25-Jan-10			11															
08-Feb-10			4															
22-Feb-10			38.3															
08-Mar-10			2															
23-Mar-10			2															
19-Apr-10			3															
12-May-10			2															
07-Jun-10			0															
13-Sep-10			1						0						0			
20-Oct-10			2															
16-Nov-10			2															
11-Jan-11			3															
19-Jan-11			0															
14-Feb-11			1															
11-Apr-11			0															
21-Sep-11			2															
17-Oct-11			2															
07-Nov-11			1															
21-Nov-11			2															
05-Dec-11			1															
06-Dec-11			1						0						0.6			
03-Jan-12			1															
16-Jan-12			1															

13-Feb-12		2					
23-Feb-12		3					
27-Feb-12		1					
28-Mar-12		0					
16-Apr-12		3			0.07		0.3
18-Apr-12			0	0.1		0.9	
14-May-12		1					
13-Jun-12		2					
24-Jul-12		4					
15-Aug-12		0					
25-Sep-12		5					
10-Dec-12		0			0		0
06-Mar-13		0			0.07		0.5
12-Feb-14	4			0.09		0.3	
16-Jun-14		1			0		0
27-Oct-14		2			0.07		0.25
17-Nov-14	3			0.07		0.4	
17-Feb-15	11			0.07		0.4	
18-May-15		0.5			0.04		0.3
14-Sep-15		0.5			0.04		0.5
16-Sep-15	123			0.18		1.5	
08-Feb-16	5			0.06		0.6	
18-Apr-16		2			0.04		0.1
15-Nov-16	2			0.05		0.3	
10-Jan-17		0.5			0.05		0.5
27-Feb-17	3			0.05		0.25	
27-Mar-17		1			0.05		0.25
21-Sep-17		0.5			0.05		0.5
01-Nov-17	1			0.1		0.9	
22-Jan-18		0.5			0.05		0.5
14-Feb-18	3			0.01		1.6	
12-Apr-18		0.5			0.05		0.25
27-Jun-18		0.5			0.05		0.5
10-Oct-18	2			0.015		0.179	
18-Oct-18		0.5			0.014		0.158
28-Feb-19		1			0.026		0.172
21-May-19	0.5			0.01		0.243	

11-Sep-19	0.5	0.05	0.109
26-Nov-19	2	0.007	0.198
09-Dec-19	1		
07-Jan-20	1		
18-Mar-20	1	0.00025	0.449
15-Sep-20	1		

Annex Table E-14 SCC Aquadata Turbidity and Total Dissolved Solids Concentrations 1992 to 2020												
Sample	Turbidity (NTU)						TDS (mg/L)					
Date	E-452	E-453	E-454	E-455	E-456	E-457	E-452	E-453	E-454	E-455	E-456	E-457
01-Sep-92			12.8									
01-Sep-92			1.4									
24-Jul-95	1.85	2.3	1.73	3.27	3.63	3.72						
30-Jan-96		10.5	8.9	6.3	22.5	19.6						
25-Jun-96	2.1	1.9	1.8	3	3	3						
22-Oct-96					19.4							
29-Sep-97		27.48	4.67	6.48	3.34	18.74						
10-Dec-97	11.96	2.64	3.21	2.84	2.23	3.07						
31-Mar-98	24.6	34.1	8.2	11.9	28.1	18.7						
11-Jun-98	12.97	17.9	5.28	33.98	9.43	10.58						
03-Aug-98	15.65	8.16	5.77	6.91	8.04	6.25						
22-Oct-98	11.13	14.35	10.61	10.65	19.4	12.38						
11-Jan-99	18.72	19.8	8.05	8.62	16.82	32.95						
15-Apr-99	4.36	5.32	2.75	3.35	3.31	4.75						
11-Jan-00	7.3	15.1	0.4	1	6.1	3.3						
12-Jul-00	85.6	82.3	83.4	82.3	82.7	86.7						
27-Sep-00	6.4	10.1	0.3	1.2	2.6	2.3						
21-Feb-01	7.9	0	0	0	7.2	14						
03-Apr-01		5.82										
04-Jun-01	12.8	14.7	8.6	10.7	10.9	11.9						
12-Dec-01	9.9	25.8	11.2	14.4	19.6	16.1						
16-May-02	30.5	29.5	18.5	24.1	22.2	26.2						
27-Jun-02	157.8	55.1	26	26	51.2	29.9						
16-Dec-02	87.9	37.2	6.3	8.8	31.7	14.5						
17-Jun-03	59.5	7.5	2.8	3.1	4.9	9.4						
05-Nov-03	441.7	14.6	6.6	8.5		18.4						
11-Dec-03	65.2	8.5	1.2	2.3	9.4	1.5						
02-Jun-04	8.5	2.8	0.4	11.5	10.5	4.3						
20-Apr-05	221.2	14	4.8	13.4	75.4	38.1						
29-Jun-05	2.7	20.4	3.7	14.1	10.2	170.1						
15-Dec-05	74.9	125.1	126.7	140.1	128.7	130.8						
20-Mar-06		24.3	1.4	4.1	3	9.5						

21-Mar-06		24.3					
11-Dec-07	14.4	20.7	6.7	12	15	15.2	
18-Feb-08	70.2	349.4	37	142.7	90.9	204.3	
18-Feb-08		42.5	12.2	33.6	18.5	16.3	
04-May-09	37.6	14.5	9.7	16.7	9.9	14.5	
07-Sep-09			0.6				
28-Sep-09	4	4.6	0.9	2.1	58.2	33.5	
13-Oct-09			7.4				33000
01-Dec-09			3.3				34000
14-Dec-09			27.2				34000
14-Dec-09			0.3				
11-Jan-10			4				33000
25-Jan-10			4.1				34000
08-Feb-10			3.4				22000
22-Feb-10			7.5				15000
08-Mar-10			4.7				27000
23-Mar-10			21				26000
19-Apr-10			3				31000
12-May-10			3.6				32000
07-Jun-10			2.8				19000
13-Sep-10			4.2				31000
20-Oct-10			4.3				28000
16-Nov-10			2.8				19000
11-Jan-11			0.4				25000
19-Jan-11			2				27000
14-Feb-11			3				27000
11-Apr-11			1.5				
21-Sep-11			0.5				
17-Oct-11			0.7				
07-Nov-11			11.8				32000
21-Nov-11			28.7				
05-Dec-11			6.8				30000
06-Dec-11			0				
03-Jan-12			13.3				28000
16-Jan-12			21.3				31000
13-Feb-12			23.7				25000
27-Feb-12			27				20000
28-Mar-12			32.1				15000
16-Apr-12			28.3				26000

18-Apr-12	289.3	93.4		51.3	**3.17**	71.4	5000	19000		25000	25000	
14-May-12			42.5						32000			
13-Jun-12			18.6						14000			
24-Jul-12			159.9						32000			
15-Aug-12			15						30000			
25-Sep-12			16.7						32000			
10-Dec-12			6.3									
06-Mar-13			1.4									
12-Feb-14	98.5	99.1	82	52.6	27.1	36.9						
16-Jun-14			11.6						35000			
27-Oct-14			29.1									
17-Nov-14	96	114.1	38	135.2	764.1	172.1						
17-May-15			2.8									
14-Sep-15	48.9	17.3	7.2	35.5	20.9	9.6						
16-Sep-15	48.9	17.3	6.1	35.5	20.9	9.6						
07-Feb-16	25.6		12.4	7.8	18	22.9						
18-Apr-16			8.1									
27-Sep-16			1.9									
15-Nov-16	34.2	61.3	12.8	12.1	27.4	69						
10-Jan-17			183									
27-Feb-17	159.1	232.1	225.4	30.6	40.9	59.5						
27-Mar-17			53.8									
26-Jun-17			27.4									
21-Sep-17			33.5									
01-Nov-17	66	73.4	58.5	55.2	66.3	217.1						
22-Jan-18			23.7									
14-Feb-18		96.1	21.5	3.1	43.4	52.6						
12-Apr-18			33.3									
27-Jun-18			22.6									
10-Oct-18	110.1	112.3	31	96.2	83.6	112.3						
28-Feb-19			2.8									
21-May-19		13.2	13.2	60.4	298.9	6						
25-Nov-19			2.4									
26-Nov-19	98.2	13.6	1	3.9	6.6	9						
09-Dec-19			3.2									
07-Jan-20			5.5									
18-Mar-20			3.4									

Annex Table E-15 SCC Enterococci Concentrations 2005 to 2020						
Sample Date	Enterococci (cfu/100ml)					
	E-452	E-453	E-454	E-455	E-456	E-457
20-Apr-05	60	52	3	4	45	5
15-Dec-05	75	70	7	11	0	0
20-Mar-06	74	0	0	0	5	
11-Dec-07	120	6	2	0	1	2
18-Feb-08	1000	600	8	26	10	30
04-May-09	160	5	1	0	1	0
07-Sep-09			0			
28-Sep-09	40	4	0	1	0	3
13-Oct-09			0			
01-Dec-09			0			
14-Dec-09			1			
11-Jan-10			1			
25-Jan-10			3			
08-Feb-10			58			
22-Feb-10			2			
08-Mar-10			5			
23-Mar-10			4			
19-Apr-10			1			
12-May-10			2			
07-Jun-10			15			
13-Sep-10			3			
20-Oct-10			0			
16-Nov-10			7			
11-Jan-11			4			
19-Jan-11			2			
14-Feb-11			1			
11-Apr-11			15			
21-Sep-11			0			
17-Oct-11			0			
07-Nov-11			0			

21-Nov-11			0			
05-Dec-11			1			
06-Dec-11			1			
03-Jan-12			1			
16-Jan-12			0			
13-Feb-12			2			
27-Feb-12			1			
28-Mar-12			18			
16-Apr-12			4			
18-Apr-12	10000	1700	26	21	880	220
14-May-12			5			
13-Jun-12			85			
24-Jul-12			2			
15-Aug-12			1			
25-Sep-12			2			
10-Dec-12			2			
06-Mar-13			4			
12-Feb-14	500	400	2	0	0	0
16-Jun-14			11			
27-Oct-14			1			
17-Nov-14	51	21	0.5	1	0.5	0.5
17-Feb-15	64	14	5	0.5	1	1
18-May-15			2			
14-Sep-15			26			
16-Sep-15	28	26	5	1	1	1
02-Feb-16	120	4	4	0.5	0.5	0.5
18-Apr-16			4			
15-Jun-16						14
15-Nov-16	190	6	8	2	1	1
10-Jan-17			0.5			
27-Feb-17	210	22	8	40	210	1500
27-Mar-17			6			
26-Jun-17			1			
21-Sep-17			0.5			
01-Nov-17	80	3	2	2	2	4
22-Jan-18			0.5			
14-Feb-18	46	8	1	1	1	1

12-Mar-18			0.5			
27-Jun-18			1			
10-Oct-18	38	2	1	0.5	11	36
18-Oct-18			0.5			
28-Feb-19			0.5			
21-May-19		18	3	1	2	1
26-Nov-19	36	6	0.5	1	1	1
18-Mar-20			0.5			

Annex Table E-16 NSW Shellfish Program Crookhaven River Site Water Quality Data 2003 to 2020

Analyte	Ecoli (cfu/100ml)				Salinity (ppt)						Temp °C					
Site	01	07	08	09	01	07	08	09	23	24	01	07	08	09	23	24
09/05/2003	10	20	4	4	28.1	26.8	28.1	29.6		28.1	17	17	17	18		17
29/05/2003	150	90	160	140	2.1	2.1	2.1	5			14	14	14.5	15		
10/06/2003				12				20.4						14		
17/06/2003	40	100	28	10	22.6	18.7	26.7	26.9		20	12	12	12	13		12
23/06/2003	15	38	16	4	21.2	20	22.6	28	23.8	21.2	12	12	12	12	11.5	12
09/07/2003	98	67	32	21	9.4	7.1	14.8	18.9			12	12	12	13		
16/07/2003	21	20	1	1	20.2	19.1	28.5	28.5	27.2	19.1	13	14	14	14	14	14
31/07/2003	1	6	1	3	29	26.1	29	29.3	29	26.1	11	10.5	11	12	11.5	10.5
13/08/2003	3	6	9	16	29.9	29.9	31.2	31.5			14	14	14	15		
27/08/2003	6	1	1	0.99	29.9	29.9	31.2	31.2	30.9	29.9	14	14	14	14	13.5	14
10/09/2003	1	3	1	1	31.8	31.8	31.8	31.8			16	16.5	16.5	16		
24/09/2003	27	17	4	4	32.6	34.1	32.6	32.3	32.6	34.1	19.5	20	19	18.5	19	20
09/10/2003	6	0.99	12	2	32.1	32.1	33	33			17	17	16.5	16		
22/10/2003	2	20	2	0.99	34.1	34.1	34.1	35.1	33.8	34.5	20.5	20.5	20	19.5	19.5	21
06/11/2003	1	0.99	0.99	6	34.1	34.1	33.8	34.8			20	20	19	18		
19/11/2003	1	3	2	0.99	34.8	34.8	34.8	34.5	34.8	35.2	22	22.5	22	21.5	22	23
24/11/2003	200	160	53	24	24.8	22	27.8	30.4			15	16	16	16		
02/12/2003	28	19	9	7	20.8	19.6	27.5	27.5	27.5	20.8	20	20	20	19	19	20
04/12/2003	67	120	14	9	23.3	21.8	28.4	29.8			23	23	22	22		
08/12/2003	49	22	55	33	23.4	21.9	26.3	29.1	29.1	21.9	20	20	20	19	20	20
17/12/2003	13	28	1	7	30.1	27.8	30.1	31.7	31.3	27.4	23.5	24	23.5	24	23.5	23.5
15/01/2004	0.99	12	4	4	31.8	32.2	31.8	21.8	31.8	31.8	21.5	22	21.5	21.5	21	21.5
29/01/2004	14	24	0.99	6	31.7	33.4	33	33			24.5	25	24	24		
09/02/2004	7	25	28	30	33.8	33.8	33.8	33.4	33.4	33.8	26	26.5	26	25	25	26.5

23/02/2004	0.99	9	2	6	34.3	34	34	34			24	23.5	23	23.5		
08/03/2004	5	7	1	3	32.1	32.1	33	33	33	32.1	25	25	24	24	24	25
22/03/2004	0.99	10	1	1	32.2	33.6	31.8	31.8			22	22	21.5	21.5		
05/04/2004	70	76	80	86	27.9	27.9	27.9	27.9	27.9	27.9	20	20	20	20	20	20
13/04/2004	60	21	0.99	1	28.8	28.8	29.9	29.9	28.8	28.8	19	19	19.5	19	19	19
15/04/2004	3	0.99	0.99	8	29.4	29.4	29.4	29.4			21.5	21	21.5	21.5		
03/05/2004	1	10	0.99	0.99	32.7	32.4	31.5	31.5	31.5	32.4	15	14	15	15.5	15	14.5
05/05/2004	10	25	6	0.99	31.2	31.5	28.7	29.9			14	15	15	14		
06/05/2004	4	3	7	5	31.2	31.5	28.7	29.9	31.5	28.7	14	15	15	14	15	15
12/05/2004	19	9	5	0.99	32.4	32.4	32.4	32.4	31.2	32.1	14	14	14	14	14	13.5
13/05/2004	6	60	18	20	32.1	30.9	32.4	32.4			13	13.5	14	14.5		
31/05/2004	0.99	9	0.99	1	32.1	31.8	32.1	32.1	32.1	31.8	13	12	13	13	13	12
28/06/2004	4	7	2	2	32.5	32.5	32.8	32.8	32.8	32.5	10.5	10	11	11	11	10.5
20/07/2004	210	180	13	4	28.7	28.7	31.5	31.5			10	10	11	11		
26/07/2004	10	4	8	4	30.6	30.6	30.6	30.6	30.6	30.6	12	12	12	12	12	12
29/07/2004	4	5	1	1	31.5	30.6	31.8	31.8	31.8	30.6	11.5	12	12	12	12	12
26/08/2004	1	16	2	4	30.7	29	32.1	31.8		29	17	16.5	17	16.5		16.5
30/08/2004									33.3						17	
23/09/2004	4	10	2	7	30.9	30.9	30.9	32.1		30.9	18	18	18	17		18
07/10/2004	6	11	13	1	18.6	19.3	22.4	28.5	28.1	18.6	17	19	17	18	17	17
21/10/2004	120	110	7	14	25.4	21.1	26.8	28.1		21.1	17	17	17	17		17
25/10/2004	240	150	75	56	10.3	10.3	19	17.2	17.2	10.3	22	22	22	21	21	22
04/11/2004	3	140	120	3	27.2	14.2	16.8	27.2	21.6	14.2	18	20	20	18	19.5	20
18/11/2004	4	9	9	3	26.7	23.4	30.6	30.6	30.6	24.9	21	20.5	21	21	21	20
22/12/2004									36.3	35.1					26	26
23/12/2004	0.99	0.99	9	4	31.3	31.3	31	31.8			23	23	22	21		
01/02/2005	2	8	1	1	30.8	30.8	30.8	30.8	31.1	30.8	25	25	25	25	26	25
10/02/2005	0.99	2	0.99	3	31.3	31.3	31.3	32.2	31.3	31.3	23.5	23	23	22.5	23	23.5
21/02/2005	40	28	85	36	39.8	29.8	29.4	29.8	29.4	29.8	22	22	21	22	21	22
28/02/2005	10	2	6	13	28.7	30.1	30.1	30.1	30.1	30.5	23	23	23	23	23	24
02/03/2005									29.8						22	

10/03/2005	10	5	3	0.99	30.6	31	29	31		31	22	22	22	22		22
29/03/2005	0.99	0.99	0.99	1	31.2	31.2	32.6	32.6	32.6	31.2	19	19	19	19	19	19
14/04/2005	30	17	3	8	30.6	30.6	29.6	30.6	30.3	31.3	21	21	21.5	20.5	20.5	21.5
05/05/2005	7	1	99	5	32.6	32.6	31.2	31.2	31.2	32.6	19	19	18.9	19	19.5	19
09/05/2005	33	18	3	30	33.5	33.8	33.5	33.5	33.5	33.6	18	18	18	18	18	18
11/05/2005	0				33						16.5					
12/05/2005									33.8	35.8					19	17
19/05/2005	14		8		25.9		25.9				14		14			
23/05/2005	6	60	1	50	23.5	21.7	29.3	29.6	29.3	23.5	17	16	17	18	17	0
01/06/2005	0.99	4	1	20	28.2	26.9	29.6	30.9			16.5	13.5	13.5	13.5		
02/06/2005			8				28.5		30.9	26.9			14		13	13
25/07/2005	58	42	9	6					27.5	14.1					15	14
16/08/2005	3	2	45	16	29.6	26.7	33.1	33.1	33.1	29.6	13	12	12	12	13	13
02/11/2005	5	5	3	4	30.1	30.1	33.2	33.2	30.1	30.1	23	23	21	21	23	23
17/01/2006	6	1	8	30	30.5	30.5	29.1	29.1	29.1	30.5	24	24	20	20	20	24
05/06/2006	68	70	58	120	20.2	20.2	29.6	29.6	25.9	20.2	13	13	13	13	14	13
13/06/2006	60	70	12	13	24	21.1	29.3	32.1	33.5	23.8	11.5	11	12	13	13	11.5
19/06/2006	9	6	1	2	24.3	24.3	28.2	26.9	26.9	24.3	13	13	13	13	13	13
18/07/2006	56	65	58	43	20	20	25.6	24.3	24.3	20	12	12	13	13	13	12
20/08/2006	3	6	0.99	0.99	24.3	24.3	27.2	29.9	29.9	25.6	13	13	14	14	14	13
07/11/2006	4	8	1	1	34.1	34.1	34.1	34.1	34.1	34.1	20	20	20	20	20	20
30/01/2007	1	12	0.99	0.99	35.4	35.4	36.6	36.6	36.6	35.4	27	27	27	27	27	27
18/02/2007	1	3	1	0.99	27.2	31.1	29.3	33	33	31.1	26	26	25	24	24	26
26/02/2007	11	6	16	28	30.5	30.5	31.3	30.1	30.5	31.3	24	24	23	23	24	23
06/03/2007	0.99	1	10	8	23.7	25.1	22.2	23.7	23.7	25.1	24	24	24	24	24	24
14/03/2007	3	2	0.99	0.99	22.8	22.8	25.7	25.7	25.7	22.8	22	22	22	22	22	22
21/03/2007	12	15	12	6	26.1	26.1	28.7	30.1	28.7	26.1	23	23	23	23	23	23
30/04/2007	2	5	15	5	28.8	28.8	28.8	29.9	28.5	28.8	19	19	19	19	18	19
31/07/2007	9	5	1	2	21.4	21.4	25.6	27.2	27.2	21.4	13	13	13	14	14	13
13/08/2007	5		1	20	27.2		28.7	28.7	28.7	27.2	14		15	15	15	14
20/08/2007	7	17	8	3	23.2	15.5	27.5	28.7	27.8	16.8	15	15	15	15	16	15

29/08/2007	6	25	1	1	24.6	24.6	28.8	28.5	28.5	24.6	19	19	19	18	18	19
07/09/2007	1	19	2	3	25.1	31.7	27.5	27.5	27.5	20.6	16	15	15	15	15	15
11/09/2007	3	3	1	0.99	27.5	27.5	29.6	30.9	29.6	27.5	19	19	18	18	18	19
25/09/2007	2	0.99	6	4	29.6	29.9	32.6	30.9	30.9	29.9	18	19	19	18	18	19
06/11/2007	0.99	0.99	0.99	0.99	32.3	32.6	32.3	31.2	32.3	32.3	18	19	18	19	18	18
26/11/2007	17	15	6	10	30.1	31	30.1	31	29.8	31	23	22	23	22	22	22
05/12/2007	3	7	15	28	25.1	27.8	23.3	25.7	21.8	26.4	24	24	23	22	23	24
10/12/2007	150	120	50	21	21.8	20.6	21.8	25.7	23.3	20.6	23	23	23	22	23	23
13/12/2007	31	13	6	1	20.8	19.6	21.9	24.9	23.9	19.6	20	20	20	20	20	20
20/01/2008	3	6	3	0.99	30.1	31.3	31.3	32.6	31.3	30.1	23	23	23	23	23	23
29/01/2008	0.99	3	0.99	0.99	33.4	33.4	33	33	33	33.4	25	25	24	24	24	25
03/02/2008	60	3	3	2	31.1	31.5	29.6	30.8	31.1	31.1	26	27	26	25	26	26
25/02/2008	3	12	4	1	16.8	14.1	21	28.7	25.1	14.1	24	25	24	23	24	25
10/03/2008	4	10	5	3	19	10.8	24.7	29.8			22	23	23	22		
14/04/2008	39	62	37	9	29.1	30.2	29.9	31.2	31.2	30.2	20	20	19	19	19	20
30/07/2008	240	200	90	40	23.8	19.6	26.1	27.7	26.1	19.6	11	10	10	11	10	10
05/08/2008	24	0.99	1	59	28	28.6	29.6	30.9	30.9	28	12	12	13	13	13	12
27/10/2008	54	4	0.99	0.99	29.3	27.8	30.5	30.1	30.1	29	25	24	24	23	23	24
15/12/2008	37	6	0.99	0.99	32.9	31.4	33.8	32.6	32.6	31.4	20	20	19	19	19	20
28/01/2009	0.99	8	0.99	0.99	35.4	36.7	34.7	35.1	35.1	35.4	27	28	25	26	26	27
18/02/2009	60	60	12	32	33.2	31.8	31.4	34.1	32.9	31.4	21	21	20	20	20	20
02/04/2009	76	140	28	12	33.6	32.6	32.6	33.6	32.6	33	22	23	23	22	23	24
06/04/2009	55	40	10	15	33.2	33.6	34.1	33.2	34	33.2	21	22	20	21	23	21
14/04/2009	50	13	1	3	31	31.3	31.7	32.2	31.7	31.3	22	23	24	22	24	23
19/08/2009	5	2	0.99	0.99	34.6	34.1	33	34.3	34.8	34.3	17	15	16	16	18	16
13/10/2009	2	9	1	1	33.3	32.1	32.1	32.1	33	32.1	17	17	17	17	16	17
26/10/2009	64	62	60	47	30.7	30.9	32.1	33.5	32.3	30.9	17	18	17	18	18	18
04/01/2010	3	2	0.99	18	32.6	32.6	32.6	33.2	33.6	35.8	23	23	23	21	22	28
01/02/2010	0.99	28	0.99	0.99	34.2	35.4	35.1	33.8	35.4	34.2	27	27	26	26	27	27
09/03/2010	55	78	0.99	4	19.4	12.6	24.7	26.1	23.3	18.1	23	23	23	23	23	23
15/03/2010	3	87	3	0.99	22.8	22.5	25.1	26.8	28.2	22.5	26	25	24	25	25	25

17/03/2010	1	3	0.99	30	26.8	24.2	28.2	27.8	27.8	25.5	25	25	25	24	24	25
16/06/2010	1	12	0.99	0.99	19.3	19.1	23.2	26.5	25.1	20.6	15	14	15	16	16	15
29/07/2010	190	240	58	2	26.5	23.2	27.8	28.7	27.8	25.1	16	15	16	15	16	16
01/09/2010	1	0.99	15	0.99	28.1	29.6	29.3	30.7	29.3	29.6	17	18	17	17	17	18
06/10/2010	29	26	8	0.99	24.2	22.8	24.7	29.1	24.7	24.2	22	22	23	20	23	22
25/10/2010	7	1	2	2	28.5	27.5	28.5	29.3	29.3	28.5	18	19	18	17	17	18
31/01/2011	3	1	9	1	26.8	26.8	27.8	31.7	31.7	26.8	25	25	24	24	24	25
13/04/2011	56	62	13	26	20.2	20.2	19	22.7	22.7	20.2	18	18	18	18	18	18
18/04/2011	42	60	30	45	23.1	21.6	26.3	26.3	26.3	23.1	19	19	20	20	20	19
27/04/2011	33	120	7	24	23.1	21.6	28.8	29.9	29.9	21.6	19	19	19	19	19	19
02/05/2011	36	62	13	21	21.6	20.5	24.6	27.2	27.2	20.5	19	19	19	18	18	19
15/05/2011	2	4	0.99	6	26.9	26.9	26.9	29.6	29.6	26.9	13	13	13	13	13	13
11/07/2011	1	6	0.99	0.99	23.4	23.4	23.4	23.4	23.4	23.4	9	9	9	9	9	9
30/08/2011	35	18	14	13	19.9	18.6	25.1	26.8	26.8	19.9	17	17	16	17	17	17
17/10/2011	0.99	0.99	2	1	26.3	26.3	27.9	32.9	32.9	26.3	20	20	20	20	20	20
03/11/2011	2	1.99	8	10	27.9	27.9	28.8	28.5	27.9	28.8	20	20	19	18	20	19
05/12/2011	2	2	1.99	3	22.4	22.4	21.9	21.9	21.9	22.4	21	21	20	20	20	21
20/01/2012	1.99	1.99	1.99	1.99	31.1	31.1	31.1	32.5	32.5	32.5	26	26	26	26	26	26
22/02/2012	8	4	79	98	24.2	24.2	24.2	28.2	24.2	28.2	25	25	25	25	25	25
28/02/2012	26	25	7	7	20.1	20.1	21	21	21	20.1	25	25	24	24	24	25
17/04/2012	6	18	4	2	23.4	23.4	24.9	28.8	28.8	24.7	20	20	20	19	19	23
19/04/2012	201	201	110	40	14.2	14.2	21.9	23.4	29.1	14.2	20	20	20	20	20	20
15/05/2012	4	2	12	2	27.2	27.2	27.2	28.7	27.2	28.7	14	14	14	15	14	15
17/07/2012	3	2	3	4	26.7	24	26.7	26.7	26.7	24.1	12	12	12	12	12	12
02/10/2012	6	1.99	1.99	1.99	24	24	24	24	33.5	33.8	18	18	18	18	18	19
17/10/2012	1	2	2	5	26.3	26.3	23.4	26.3	26.3	26.3	20	20	20	21	21	20
04/02/2013	14	1.99	17	6	29.1	29.1	30.2	30.2	29	30.2	20	20	20	20	20	20
19/03/2013	2	1.99	1.99	2	26.4	22.2	26.4	27.4	27.4	22.4	24	24	24	23		
25/03/2013	2	1.99	4	2	26.1	26.1	29.8	29.8	29	26	23	23	22	22	22	23
02/04/2013	2	2	6	1.99	29	27.9	27.9	29.7	29.1	27.9	20	20	20	20	20	20
06/05/2013	6	6	4	6	25	25	26	29	29	25	17	17	17	19	19	17

18/06/2013	8	16	1.99	6	24.8	24.8	26.9	29	24.8	29	15	15	15	16	15	16
19/08/2013	6	14	1.99	1.99	22	23	23	22	23	22	14	15	15	14	15	14
23/08/2013									23	23					15	15
01/10/2013	6	1.99	1.99	2	23.1	23.1	22.7	28.5	28.5	23.1	19	19	18	18	18	19
03/12/2013	1.99	1.99	2	1.99	29.8	29.8	30.6	30.6	30.6	29.8	22	22	21	21	21	22
26/03/2014	87	91	46	80	23	23	26	24	23	24	23.3	23.3	23.1	23.7	23	23
28/04/2014	9	10	2	1	21.5	27.5	39.9	30.6	30.6	27.5	19	19	19	21	21	19
30/06/2014	0.99	6	1	2	24	24	24	24	24	24	10	10	11	12	12	10
13/08/2014	1	0.99	0.99	0.99	31.1	31.1	36.1	33.8	36.1	35.1	12	12	14	14	14	12
29/09/2014	8	13	3	6	28	28	25	28	28	28	24.6	24.5	24.6	24.6	24.6	24.5
14/10/2014	1	5	3	1	28.5	27.2	38.5	32.1	32.1	27.2	18	18	18	17	17	18
30/10/2014	7	6	1	2	25.7	22.7	27	30	30.9	22.7	18	18	18	18	22	18
18/11/2014	2	0.99	0.99	1	29	29.1	29.1	30.6	29.1	30.6	21	21	21	21	21	21
03/12/2014	0.99	3	4	2	30	30	31	32	33	32	25	25	24	22	23	23
05/01/2015	0.99	0.99	0.99	1	26.4	26.4	27.8	24.8	20	17	24	24	24	22	22	24
11/01/2015	25	10	31	23	26	25.1	27	26.9	25	28.7	24	24	23	23	24	23
27/01/2015	3	3	5	16	25.3	25.3	28.2	29.4	29.4	25.3	21	21	21	21	21	21
29/01/2015	3	0.99	2	21	24.9	24.9	27.09	29.1	29.1	24.9	20	20	20	20	20	20
17/03/2015	1	8	1	1	30.6	30.6	31.8	31.8	31.8	30.6	21	21	21	21	21	21
25/03/2015	0.99	4	1	3	31	31	31	32	32	32	22	22	22	22	22	22
15/04/2015	12	3	1	4	28	28	28	27	28	28	28	20	20.3	20.3	19.8	20
20/04/2015	48	53	14	25	21	20	20	20			16	16	16	16		
15/06/2015	34	33	6	1	24	24	28.5	28.7	28.7	24	12	12	14	16	15	12
07/07/2015	1	0.99	0.99	0.99	19	19	20	24	24	19	12	12	13	12	12	13
11/08/2015	7	3	0.99	3	26.7	26.7	28	28	28	26.7	12	12	12	12	12	12
13/10/2015	4	7	3	3	27.5	28	28	28	28	28	19	19	20	19	19	19
17/12/2015	13	17	1	29	29	29	29	30	30	29	22	22	22	21	21	22
06/01/2016	1	0.99	6	12	22	22	21	23	23	21	21	21	21	20	21	21
17/03/2016	88	52	84	72	27.4	27.4	29.4	29.4	29.4	27.4	25	23	21	21	21	23
04/04/2016	23	22	11	9	27	27	27	31	31.4	27.9	20	20	20	20	20	20
02/06/2016	5	8	4	1	24	24	24	24	24	24	14	14	14	14		

16/11/2016	0.99	0.99	0.99	0.99	39.9	32.9	32.6	36	36	32	20	20	19	19	19	20
20/02/2017	0.99	11	10	0.99	32.2	31	30	32	32	31	22	21	21	20	20	21
10/05/2017	0.99	3	3	1	22	22	23	23	23	22	16	16	17	18	18	16
22/08/2017	0.99	1	0.99	0.99	33	33	33	33	33	33	16	16	16	16	16	16
03/10/2017	0.99	0.99	3	2	35	35	34	34	35	34	19	19	19	18	18	19
11/10/2017	0.99	0.99	0.99	8	36	35	35	35	35	35	20	21	21	21	21	21
01/11/2017	5	14	2	8	31	31	31	31	31	31	19	17	18	19	17	19
07/11/2017	0.99	5	0.99	0.99	34	33	35	36	35	36	19.5	19.5	19.6	19.6	19.5	19.5
10/01/2018	15	10	4	20	35.9	35.9	35.9	33.6	33	35	25	25	23	22	22	25
27/02/2018	120	110	22	16	31	32	33	32	33	31	22	22	22	22	22	22
05/03/2018	1	1	0.99	9	32	32	34	35	32	32	21	23	22	23	22	22
26/03/2018	12	10	0.99	7	30	31	30	29	30	30	20	20	20	20	20	20
30/04/2018	12	11	13	10	30	30	30	32	32	30	17	17	17	18	18	17
04/06/2018	1	2	3	2	29.9	29.9	29.9	31.2	32.2	29.9	14	14	14	14	14	14
08/10/2018	11	10	0.99	2	32	32	32	32	32	32	18	18	18	18	18	18
08/11/2018	0.99	0.99	2	0.99	31	31	31	31	30	31	19	19	19	19	19	19
03/12/2018	0.99	0.99	0.99	2	22	22	22	22	22	22	21	22	21	21		
09/01/2019	5	4	9	6	29.3	29.3	30	31	31.7	29.3	25.4	25.4	25.4	25.4	25	25
06/02/2019	1	4	0.99	7	32	31	32	31	32	31	26	26	26	26	26	26
19/02/2019	1	5	2	0.99	33	33	33	33	33	33	23	23	23	23	23.9	23.9
18/03/2019	87	190	62	16	29	29	29	29	33	29	23.4	23.4	23.4	23.4	23	23
25/03/2019	2	21	1	2	37	33	34	35	35	32	23	23	23	23	23	23
04/04/2019	56	48	14	26	29	29	28	30	29	28	21.3	21.3	21.3	21.4	21.3	21.3
29/04/2019	3	1	1	9	33	33	33	34	34	33	17.1	17.1	17.1	17.1	17	18
30/05/2019	1.99	10	2	1.99	35	35	35	35	35	35	10	10	10	10	14	14
11/06/2019	16	6	4	4	30.2	30.2	31.5	33	33	30	15	15	15	16	15	15
25/06/2019	201	201	201	201	23	26	25	24	25	25	13	13	13	13	13	13
15/07/2019	4	4	1.99	1.99	32	32	34	34	32	34	10	10	10	10	11	10
17/09/2019	2	2	1.99	30	30	30	30	30	30	30	16	16	16	16	16	16
18/09/2019	4	1.99	4	2	32	32	32	32	33	33	16	16	16	16	16	16
20/01/2020	2	2	2	6	35	35	34	34	34	34	22.4	22.4	22.4	22.4	22.5	22.5

21/01/2020	2	4	6	4	33	33	33	33			2.5	2.5	22.5	2.5		
22/01/2020									33	33					22.5	22.5
17/03/2020	1.99	4	2	2	26	26	26	28	28	26	19	19	19	19	19	19
27/05/2020	26	170	4	2	30.4	30	32	32	32	30	17	17	17	17	17	17
02/06/2020	22	14	12	1.99	20.3	19.9	21.6	21.6	21.8	19.9	13	13	14	14	14	13
09/06/2020	2	2	1.99	1.99	22	22	31	31	31	23	15	15	16	16	16	16
23/06/2020	6	1.99	2	4	32	33	31	33	34	31	16	16	16	16		

Annex Table E-17 NSW Shellfish Program Curleys Bay Site Water Quality Data 2003 to 2020

Analyte	Ecoli (cfu/100ml)			Salinity (ppt)					Temp °C				
Site	02	10	11	02	10	11	25	26	02	10	11	25	26
09/05/2003	1.99	2	20	29.3	28.1	28.1	28.3		17	17	17.5	17.5	
29/05/2003	148	156	144	6.3	7.6	7.6			15	15	15		
05/06/2003							22					16	
10/06/2003	2	14	6	21.4	21.4	21.5	23.2		13	13	14	15	
23/06/2003	2	1	1	26.4	26.7	26.7	26.7		11	12	12	12.5	
09/07/2003	28	9	28	21.4	22.8	22.8			13	13	13		
31/07/2003	0.99	0.99	0.99	28.7	30.6	30.6	30.6	30	10.5	12.5	12.5	12	10
13/08/2003	4	3	1	31.2	31.5	31.5			14.5	15	15		
27/08/2003	13	0.99	2	30.6	31.2	32.4	32.1	30.6	12	14	14	13	12
10/09/2003	0.99	0.99	0.99	31.5	31.8	31.8			15.5	16	16		
24/09/2003	0.99	2	1	32.3	32.3	32.3	32.6	33.8	18	18	18.5	19	19
09/10/2003	14	0.99	6	33	33	33			16.5	16.5	16.5		
22/10/2003	1	7	0.99	34.1	33.8	34.1	34.1	33.8	20	19.5	20	20.5	19.5
06/11/2003	3	2	22	33.8	34.8	33.5			19	18.5	18.5		
19/11/2003	0.99	1	1	33.6	34	34		33.6	22	23	23		22
24/11/2003	48	7	50	24.8	33	30.4			15	16	16		
02/12/2003	12	9	62	27.5	27.5	27.5	28.5		19	19	19	18	
04/12/2003	38	2	4	28.4	29.8	29.4			22	22	21		
17/12/2003	2	2	0.99	31.3	31.3	30.5	31.3		23	23.5	24	23.5	
15/01/2004	16	1	0.99	31.4	31.8	31.8	31.8	31.2	20	21	21	21	19
29/01/2004	19	4	3	32.6	32.6	32.6			23.5	23.5	23.5		
09/02/2004	2	20	25	33.8	33.4	34.7	34.7	34.7	26	25	25	25.5	25

23/02/2004	2	0.99	1	34	32.6	34			23	23.5	23		
08/03/2004	0.99	1	4	31.7	33	33	33	31.7	24.5	24	24	24	24
22/03/2004	2	1	2	31.4	32.2	32.2			20.5	22	22		
05/04/2004	140	180	200	27.9	26.3	21.6	23.1	21.6	20	20	19	19.5	19.5
13/04/2004	0.99	50	14	29.9	31.2	29.9	31.2	29.9	19	19	19	19	19
15/04/2004	0.99	3	10	29.4	29.4	29.8			21	21.5	22		
19/04/2004							32.3	32.3				18	18
03/05/2004	1	0.99	0.99	32.1	31.8	31.5	31.5	32.4	13.5	16.5	15.5	15	14
05/05/2004	0.99	1	1	31.5	31.5	34.1			15	15	15		
06/05/2004	0.99	0.99	6	31.5	31.5	34.1	31.5	31.5	15	15	15	15	15
12/05/2004	8	6	9	32.4	32.7	32.4	30.9	32.4	14	15	14	13.5	14.5
13/05/2004	8	29	24	31.8	32.7	32.1			12.4	15	13.5		
31/05/2004	17	3	13	31.5	32.1	31.8	31.8	31.8	11.5	13.5	12.5	12.5	12
28/06/2004	1	21	6	32.5	32.5	32.5	32.5	32.5	10	11.5	10.5	10	10
20/07/2004	130	180	180	30.3	30.6	33.1			11	12	12		
26/07/2004	2	4	0.99	30.9	30.9	30.9	30.9	30.9	13	13	13	13	13
29/07/2004	0.99	2	0.99	32.5	31.8	31.8	31.5		10.5	12	12	11.5	
26/08/2004	2	3	5	31.8	31.8	31.8			16.5	16	16		
30/08/2004							33	33				16	16
23/09/2004	0.99	2	12	32.1	31.8	32.1	32.1		17.5	16.5	17	17	
07/10/2004	4	2	1	27.2	29.3	30.7	29.6	30.7	18	17	17	18	17
21/10/2004	30	15	120	28.1	25.4	26.5	22.4		17	16	16.5	17	
25/10/2004	21	15	12	22.4	21.1	20.8	21.9	21.5	21	21	20	20	22
18/11/2004	5	5	6	30.2	30.6	31.4	30.2	30.2	20.5	21	20	20	20
22/12/2004							36.3	36.3				26	26
23/12/2004	2	1	3	31	31.8	32.9			22	21	20.5		
01/02/2005	0.99	0.99	2	30.8	30.8	30.8	30.5	30.8	25	25	25	24	25
10/02/2005	0.99		23	31.3		32.2	32.2	31	23		22	22	22
21/02/2005	100		41	28.4		28.4	29.8	28.4	22		22	22	22
28/02/2005	6	2	3	32.2	29.5	31	34.1	31	22	22	22	20	22

10/03/2005	30	0.99	0.99	30.6	32.2	30.6		30.6	21.5	22	21.5		21
14/04/2005		8	4		30.2	30.6	30.2	30.2		20	20	20	20
05/05/2005	2	0.99	7	30.9	31.2	30.9	31.2	32.6	18.5	19	18.5	19	19
09/05/2005		10			22.8					19			
19/05/2005	39	50	17	27.2	27.5	27.5	27.2	27.5	14	15	15	14	15
01/06/2005	0.99			30.6					12				
02/06/2005		12	2		30.9	30.9	30.6	30.6		13	13	12.5	12
25/07/2005	2	0.99	3				30.1	31.8				16	16
17/01/2006	10	6	20	31.3	30.1	34	30.1		23	23	23	23	
05/06/2006	60	12	24	25.9	26.1	27.2	26.1		14	15	14	15	
13/06/2006	6	9	8	31.8	33.8	32.4	33.5		12	14	14	13.5	
19/06/2006	0.99	3	4	30.6	31.8	31.8	30.6		12	12	12	12	
10/07/2006	0.99	0.99	3	27.2	26.9	26.9	26.9		14	13	13	13	
09/08/2006	22	5	5	24.3	22.8	24.5	24.3	24.3	13	13	14	13	13
07/11/2006	20	3	7	32.6	34.1	34.1	34.5	32.6	19	20	20	21	19
09/11/2006	55	2	14	33	33.8	33.8	32.3	33.3	16	19	19	18	17
30/01/2007	0.99	2	2	37	36.3	36.3	37	37	28	26	26	28	28
18/02/2007	0.99	4	4	28.6	32.1	32.1	28.6	32.1	26	25	25	26	25
26/02/2007	26	62	85	28.7	28.7	27.4	28.7	27.4	23	23	23	23	23
11/03/2007	470	240	4000	24.7	24.7	23.3	24.7	25.1	23	23	23	23	24
14/03/2007	0.99	2	0.99	24.2	26.1	24.2	26.1	24.2	22	23	22	23	22
21/03/2007	6	8	4	28.7	30.1	30.1	31.3	30.1	23	23	23	23	23
30/04/2007	2	5	11	28.5	29.9	29.9	30.2	28.5	18	19	19	20	18
23/07/2007	7	29	29	20.4	21.5	21.5	21.5	20.4	14	14	14	14	14
13/08/2007	0.99	26	5	27.2	27.2	27.2	27.2	28.7	14	14	14	14	15
20/08/2007	1	0.99	0.99	28.7	21.5	29.9	28.7	27.2	15	15	14	15	14
29/08/2007	1	3	0.99	28.5	29.9	30.7	29.9	29.6	18	19	17	19	18
07/09/2007	17	55	2	28.7	28.7	28.7	28.7	28.5	15	15	15	15	14
11/09/2007	0.99	0.99	0.99	30.9	30.9	30.9	30.9	30.9	18	18	18	18	18
25/09/2007	0.99	1	2	30.7	30.9	33	30.9	30.7	17	18	16	18	17

06/11/2007	0.99	0.99	7	30.9	32.9	31.2	30.9	30.9	18	20	19	18	18
26/11/2007	1	19	5	30.1	30.1	28.7	30.1	30.1	23	23	23	23	23
10/12/2007	11	22	21	23.3	27.7	23.3	24.5	22.8	23	22	23	22	22
15/01/2008	8	9	32	30.6	31.4	31.4	30.6	31.4	21	20	20	21	20
20/01/2008	1	1	1	31.3	31.7	30.5	31.3	31.3	23	24	24	23	23
29/01/2008	0.99	4	1	33	32.6	32.6	34	33	24	23	23	23	24
03/02/2008	0.99	80	95	29.6	31.1	28.6	31.1	29.6	26	26	26	26	26
25/02/2008	2	4	0.99	27.4	28.7	27.2	27.4	27.4	23	23	24	23	23
14/04/2008	120	29	50	29.9	31.2	29.9	32.6	29.9	19	19	19	19	19
23/04/2008	54	7	10	29.6	29.6	29.6	29.6	29.3	18	18	18	18	17
30/07/2008	32	22	34	27.5	29	27.7	28.7	27.5	10	11	11	10	10
05/08/2008	1	1	95	30.9	30.9	30.9	30.9	30.6	13	13	13	13	12
17/08/2008	2	0.99	2	30.6	30.9	30.6	30.6	30.3	12	13	12	12	11
27/10/2008	0.99	0.99	2	30.5	31.1	31.5	32.1	30.5	24	26	27	25	24
15/12/2008	0.99	13	0.99	31.2	33.8	32.6	32.6	32.6	19	19	19	19	19
28/01/2009	0.99	0.99	1	34.7	33.8	34.7	35.1	34.7	25	26	25	26	25
18/02/2009	49	3	44	32.9	31.4	31.4	32.9	31.4	20	20	20	20	20
02/04/2009	65	66	57	33	34	33.6	34	33	24	23	22	23	24
06/04/2009	2	7	3	33.8	33.2	32.6	33.2	33.8	19	21	19	21	19
14/04/2009	8	2	12	31	32.2	32.2	32.2	31.7	22	22	22	22	24
20/04/2009	4	1	11	32.3	31.2	32.3	32.3	32.3	18	19	18	18	18
19/08/2009	0.99	5	15	34.1	34.3	34.1	34.3	34.1	15	16	15	16	15
13/10/2009	0.99	10	0.99	33.3	30.9	33.3	33.3	33.3	17	18	17	17	17
26/10/2009	120	9	75	32.1	32.1	33.5	32.1	32.1	17	17	18	17	17
04/11/2009	2	1	1	32.9	33.8	33.8	33.8	32.9	20	19	19	19	20
04/01/2010	6	2		33.6	34.5		33.6	34.5	22	21		22	21
01/02/2010	0.99	1	1	35.4	33.8	35.4	33.8	34.2	27	26	27	26	27
09/03/2010	10	8	16	26.1	27.4	27.1	27.4	26.1	23	23	22	23	23
16/06/2010	0.99	0.99	0.99	23.5	28.5	30.9	25.1	26.8	16	18	18	16	17
29/07/2010	2	1.99	1.99	27.5	28.7	30.2	27.5	28.7	15	15	15	15	15

06/10/2010	0.99	2	1	28.2	29.4	29.8	28.2	29.8	21	21	22	21	22
25/10/2010	18	0.99	3	28.5	32.1	33.3	33.3	28.5	18	17	17	17	18
19/01/2011	6	12	10	25.7	25.7	25.7	25.7	25.7	22	22	22	22	22
31/01/2011	0.99	2	1	30.5	35.2	29	35.8	30.5	24	23	24	28	24
04/04/2011	7	20	20	22.4	22.8	22.4	22.8	22.4	21	22	21	22	21
18/04/2011	18	15	48	27.2	29.1	29.1	29.1	27.2	18	20	19	20	18
27/04/2011	10	17	2	24.7	28.8	28.5	28.8	26.3	19	19	18	19	18
30/08/2011	13	10	6	23.5	30.4	26.5	25.1	23.5	16	16	16	16	16
17/10/2011	2	1	1	29.9	31.4	29.1	30.2	29.9	19	20	20	20	19
03/11/2011	14	14	4	27.2	28.5	28.8	28.5	28.8	18	18	19	18	19
05/12/2011	0.99	0.99	6	20.8	21.9	20.5	21.9	21.9	20	20	19	20	20
05/04/2012	56	38	44	25.7	24.2	28.4	24.2	25.7	22	22	22	22	22
19/04/2012	201	120	201	21.9	21.9	21.9	21.9	21.9	20	20	20	20	20
08/05/2012	2	1.99	2	27.5	29.9	28.8	28.8	27.5	19	19	19	19	19
26/06/2012	1.99	1.99	1.99	22.4	22.4	22.4	22.6	22.6	12	12	12	12	12
02/10/2012	1.99	1.99	1.99	32	33	33	33.5	32.3	18	18	18	18	18
17/10/2012	1	1	0.99	22.4	22.4	23.8	22.4	22.4	21	21	21	21	21
22/10/2012	1.99	1.99	1.99				26.5	26.5				18.5	18.5
04/02/2013	9	1.99	1.99	31.4	31.8	31.4	31.4	31.8	20	21	20	20	21
25/03/2013	14	6	1.99	25	28	32	25	28	21	21	21	21	21
02/04/2013	2	34	4	28	29	29	30	29	20	20	20	20.2	20.2
06/05/2013	2	1.99	2	27	28	28	28	28	18	19	19	19	19
04/06/2013	26	18	14	25	25	25	25	25	14	14	14	14.4	14.4
19/08/2013	1.99	1.99	2	24	24	24	24	24	15	15	15	15	15
14/10/2013	9	43	32	29	29	31	29	29	18	18	19	18	18
03/12/2013	1.99	16	1.99	32.6	33.6	33.6	30.6	30.6	22	22	22	21	22
26/03/2014	92	200	98	23	18	24	18	24	23	23	23	23	23
30/06/2014	1	2	0.99	35	35	34	34	35	13.9	13.9	13.9	13.9	13.9
14/10/2014	3	0.99	0.99	30	33	33	30	33	19	18	17	18	19
30/10/2014	3	1	1	31	31	31	31	31	18	18	18	18	18

03/12/2014	0.99	0.99	1	32	31	30	30	32	23	23	23	23	23
05/01/2015	0.99	1	0.99	31.5	31.4	31.4			21	20	20		
11/01/2015	4	1	0.99	20	21	23	23	22	23	23	23	22	22
21/01/2015	3	0.99	1	28	29	32	28	28	27.1	27.1	27.1	27.1	27.1
29/01/2015	11	19	6	23	22	23	23	22	20	20	20	20	20
25/03/2015	0.99	0.99	0.99	32	31	34	32	32	22	21	21	22	22
15/04/2015	1	2	1	28	28	26	28	28	20.4	20.5	20.5	20.4	20.5
20/04/2015	34	37	35	22	22	24	22	22	19.1	19.2	18.9	19.1	19.2
16/06/2015	14	8	1	27	28	29	28	26	16.9	17.1	16.9	16.8	16.8
07/07/2015	0.99	0.99	0.99	26.5	28	32	28	29	16	16	17	16	17
30/09/2015	0.99	0.99	2	22	21	20	18	20	18.2	18.2	18.9	18.2	18
13/10/2015	2	2	4	30	29	31	30	30	17.5	17.4	17.5	17.4	17.5
17/12/2015	13	26	13	24	24	27	31	27	20	20	20	19.8	20
06/01/2016	1	0.99	1	32	32	33	33	32	19.7	20	20.1	20.1	19.1
17/03/2016	280	64	160	24.7	27.4	27.4	24.7	27.4	23	23	23	23	23
02/06/2016	3	7	280	20	20	20	20	20	14	15	15	15	14
22/08/2017	2	1	1	33	33	33	33	33	16	16	16	16	16
31/10/2017	1	1	3	31	31	31	31	31	19	19	19	19	19
07/11/2017	0.99	0.99	3	21	21	23	21	21	17	18	20	17	18
10/01/2018	4	3	9	33	33	33	33	33	23	23	23	23	23
27/02/2018	15	12	17	32	32	32	32	32	22	22	22	22	22
26/03/2018	1	1	2	30	29	30	30	29	20	20	20	20	20
30/04/2018	3	6	23	30	31	30	30	30	18	18	18	18	18
04/06/2018	4	5	3	32.5	32.5	32	32	32	15	15	15	15	15
08/10/2018	1	5	14	34	34	34	34	34	18	18	18	18	18
08/11/2018	1	0.99	0.99	32	32	32	32	32	19	19	19	19	19
03/12/2018	0.99	0.99	0.99	30	29	28	28	29	21	21	21		
09/01/2019	1	9	0.99	30	30	30	30	30	25.4	25.4	25.4	25.4	25.4
06/02/2019	1	2	0.99	31	31	31	31	31	26	26	26	26	26
19/02/2019	1	1	2	31	31	31	31	31	23.9	23.9	23.9	23.9	23.9

18/03/2019	110	110	120	31	30	30	30	30	23.1	23.1	23.1	23	23
25/03/2019	0.99	8	2	32	33	22	33	33	23	23	23	23	23
04/04/2019	14	100	12	30	28	30	30	28	21.4	21.4	21.4	21.4	21.4
09/04/2019	3	2	2	33	32	33	33	33	22	22	22	22	22
29/04/2019		8	0.99	32	32	33	32	33	17.1	17.1	17.1	17	17
30/04/2019	1			32					17.1				
30/05/2019	2	2	6	33	33	33	33	33	14	14	14	14	14
11/06/2019	22	4	10	28	27	29	27	29	15	15	15	15	15
25/06/2019	201	201	201	25	24	23	22	26	13	13	13	13	13
15/07/2019	1.99	4	1.99	31	31	31	31	31	10	10	10	11	11
17/09/2019	2	1.99	2	33	33	33	33	33	16	16	16	16	16
18/09/2019	2	1.99	1.99	34	33	33	33	33	16	16	16	16	16
20/01/2020	42	94	50	32	32	32	32	32	22.5	22.5	22.5	2.5	22.5
21/01/2020	4	4	2	31	31	31			22.5	22.5	22.5		
22/01/2020							31	31				22.5	22.5
04/03/2020	2	4	6	26	26	26	26	26	22	22	22	22	22
27/05/2020	1.99	2	1.99	29	27	27	27	27	17	17	17	17	17
09/06/2020							25	25				16	16
23/06/2020	1.99	2	1.99	33	34	34	33	34	16	16	16		

Annex Table E-18 NSW Shellfish Program Goodnight Island Site Water Quality Data 2003 to 2020

Analyte	Ecoli (cfu/100ml)			Salinity (ppt)					Temp °C				
Site	03	12	13	03	12	13	27	28	03	12	13	27	28
09/05/2003	6	8	6	29.3	28.5	29.6	28.5	28.5	17.5	18	18	18	18
29/05/2003	170	150	152	6.4	3.8	9.2			16	16	16		
05/06/2003								22					16
10/06/2003	4	1	7	21.5	21.5	20.4	21.5	23	14	14	14	14	14
23/06/2003	1	1	9	26.7	26.7	26.7	28.5	26.7	12	12.5	12	14	12
09/07/2003	13	22	24	21.4	22.8	22.8			13	13.5	13		
31/07/2003	1	2	0.99	30.6	30.6	32.1	30.6	30.6	12.5	12	13.5	12	12
13/08/2003	1	6	0.99	32.7	31.5	32.7			15	15	15.5		
27/08/2003	1	1	0.99	32.4	31.2	32.4	31.2	31.2	14	14	14	14	14
10/09/2003	3	0.99	3	31.8	31.8	33			16	16.5	16		
24/09/2003	3	1	3	32.3	33.8	33.3	33.5	32.6	18	19	17.5	18	19
09/10/2003	1	2	4	33	33.3	33			16.5	17	16		
22/10/2003	6	0.99	3	33.8	34.1	33.8	34.1	34.5	19.5	20.5	19	20.5	21
06/11/2003	1	2	1	34.8	33.5	34.8			18	18.5	18		
19/11/2003	0.99	1	2	33.6	34.5	33.6	34.5	34.8	22	21	22	21.5	22
24/11/2003	3	110	6	34.3	28.1	30.4			16	17	16		
02/12/2003	10	22	1	29.3	30.7	30.4	29	33.3	17	17	16	19	16
04/12/2003	0.99	1	1	30.6	31.4	32.9			21	22	20		
17/12/2003	3	0.99	0.99	30.1	31.3	31.3	32.1	31.3	23.5	23	23	25	23
15/01/2004	12	6	3	31.4	33.2	33.2	33.2	33.2	20.5	21	21	21	21
29/01/2004	6	4	4	32.6	34	34			23.5	23.5	23.5		
09/02/2004	0.99	0.99	22	34.3	33.4	34	34.3	34	24	25	23	24	23.5
23/02/2004	1	0.99	1	34	33.6	34.8			23	22	22		
08/03/2004	6	1	1	33	33	34	3	33.4	24	24.5	23	24.5	25

22/03/2004	2	1	1	33.2	33.6	33.6			21	22	22		
05/04/2004	200	76	200	26.3	29.1	27.9	29.1	29.1	20	20.5	20	20.5	20.5
13/04/2004	16	9	14	29.9	31.2	28.8	31.2	29.9	19	19	19	19	19
15/04/2004	0.99	0.99	2	30.6	30.6	29.4			21.5	21	21		
19/04/2004							32.3	30.9				18	18.5
03/05/2004	0.99	1	4	32.7	33	32.7	32.1	31.8	15.5	16	15.5	17	16.5
05/05/2004	4	10	2	34.1	31.5	34.1			15	15	15		
06/05/2004	3	5	1	34.1	34.1	34.1	34.1	31.5	15	15	15	15	15
10/05/2004	1	5	1	30.2	30.4	30.4	30.2	30.2	15	16	16	15	15
12/05/2004	2	9	31	32.7	32.7	32.7	32.7	32.7	15	15.5	15	15.5	15
13/05/2004	15	12	27	32.4	32.7	32.4			14.5	15	14.5		
17/05/2004	0.99	1	1	31.5	31.5	31.5	31.5	32.1	15	15	15	15	17
31/05/2004	13	5	42	32.1	32.4	33.5	32.4	32.4	13.5	14	13.5	14.5	14.5
03/06/2004	3	1	0.99	35.5	34.3	34.3			16	16	16		
28/06/2004	1	1	8	32.8	33.1	32.8	33.1	33.1	11	12	11	12.5	12
20/07/2004	20	40	150	33.1	30.9	31.1			12	13	12		
26/07/2004	5	9	15	30.9	32.1	32.1	32.1	32.1	13	13	13	13	13
29/07/2004	0.99	1	2	31.8	33.1	33.1	33.1	33.1	12	12	12	12.5	12
26/08/2004	3	3	4	32.7	34.3	32.7	34.3	34.3	15.5	16	15.5	16	16
23/09/2004	2	3	7	32.1	33.8	32.1	33.8	33	17	17	17	17	16.5
07/10/2004	1	0.99	0.99	30.7	33.5	33.3	33.5	33.5	17	18	17	18	18
21/10/2004	22	11	120	30.7	32.1	32.1	30.7	30.7	17	17	17	17	17
25/10/2004	32	70	9	21.9	22.8	24.9	21.5	24.9	20	22	20	22	20
18/11/2004	0.99	2	5	31	31.8	31.4	31.8	31.8	22	21	20	21.5	21
22/12/2004							38.4	38.4				25	25
23/12/2004	0.99	0.99	0.99	33.2	33.2	32.9			21	21	20.5		
01/02/2005	1	3	9	30.5	31.7	30.8	31.7	30.5	24	24	25	24	24
10/02/2005	0.99	22	2	31	32.2	31.8	31	30.1	22.5	22	21.5	22.5	23
21/02/2005	13			39.8			29.8	29.8	22			22	22
10/03/2005	3	12	1	29.4	29.8	31	30.6	31	21.5	22	22	21.5	22
14/04/2005	5	8	8	30.2	29	29	30.2	29.1	20	19.5	19.5	20	20

05/05/2005	5	5	6	32.6	31.2	32.6	33.2	33.8	19	19.5	19	21	19
19/05/2005	25	30	43	27.5	28.7	28.7	28.7	28.7	15	15	15	15	15
23/05/2005	48	3	5	30.9	32.3	32.3	32.3	32.3	18	18	18	18	18
01/06/2005	3			30.9					13				
02/06/2005		2	6		31.2	31.2	29.9	32.7		14	14	14.5	15
25/07/2005	2	0.99	0.99				30.2	33				15	16
17/01/2006	10	16	15	34	36.4	36.4	36.4	36.4	23	23	23	23	23
05/06/2006		58	31		23.8	24.5		24.5		11	14		14
13/06/2006		14	4		34.1	34.1		35.5		15	15		16
19/06/2006		3	10		29.9	29.9		29.9		14	14		14
10/07/2006		3	0.99		26.9	26.9		26.9		13	13		13
09/08/2006		14	0.99		27.5	29.9		27.1		15	14		14
07/11/2006		1	9		34.1	34.1		34.1		20	20		20
09/11/2006		1	3		33.5	33.5		33.8		18	18		19
30/01/2007		0.99	1		36.7	36.3		35.9		24	26		25
18/02/2007		0.99	21		33	33		33		24	24		24
26/02/2007		6	11		28.7	30.1		29.3		23	23		25
11/03/2007		5300	210		27.4	24.7		25.1		23	23		24
14/03/2007		2	8		24.7	25.7		26.1		23	22		23
21/03/2007		4	9		29.8	30.1		33		22	23		24
30/04/2007		2	9		29.9	29.9		29.9		19	19		19
23/07/2007		40	22		24.8	24.8		24.8		15	15		15
13/08/2007		3	28		27.2	28.7		27.2		14	15		14
20/08/2007		1	1		32.7	32.4		32.7		15	14		15
29/08/2007		0.99	8		31.8	32.1		33.3		16	17		17
07/09/2007		3	1		27.8	28.7		28.1		16	15		17
11/09/2007		2	1		30.7	30.7		30.9		17	18		18
25/09/2007		0.99	0.99		34.3	34.3		33.3		16	16		17
06/11/2007	0.99	29	1	32.3	32.3	32.6	32.3	32.3	18	18	19	18	18
26/11/2007	1	4	2	29.8	29.8	29.8	31	33.2	22	22	22	22	21
10/12/2007	27	30	17	25.7	27.1	25.7	25.7	30.6	22	22	22	22	21

20/01/2008	2	0.99	0.99	32.6	31.7	32.6	33.4	34.4	23	24	23	25	24
29/01/2008	0.99	0.99	0.99	32.6	32.6	32.6	33	32.6	23	23	23	24	23
03/02/2008	12	4	1	30.8	31.1	30.8	32.5	33.8	25	26	25	26	26
19/02/2008	1	15	10	26.4	21	25.1	22.2	32.1	24	24	24	24	25
14/04/2008	17	16	12	31.2	31.2	30.9	31.2	31.2	19	19	18	19	19
30/07/2008	16	28	26	29.3	29.3	29.3	29.3	30.9	12	12	12	12	13
27/10/2008	8	1	0.99	30.1	30.1	31.3	32.6	32.6	23	23	23	23	23
15/12/2008	3	8	4	32.6	33.8	32.6	33.5	34.8	19	19	19	18	18
28/01/2009	0.99	3		34.3	34.8		34.8	34.8	24	22		22	22
18/02/2009	20	30	14	34.1	32.9	34.1	32.9	32.9	20	20	20	20	20
02/04/2009	48	32	80	33.6	34.5	33.6	34.5	33.6	22	21	22	21	22
06/04/2009	44	47	38	32.9	33.8	35.1	33.8	35.1	20	19	19	19	19
14/04/2009	3	2	5	32.2	31.8	32.2	31.8	33.6	22	21	22	21	22
19/08/2009	0.99	1	0.99	32.5	34.1	34.1	37	34.1	10	15	15	17	15
26/10/2009	55	10	120	33.5	33.5	32.3	32.1	33.5	18	18	18	17	18
02/11/2009	15	2	0.99	33.5	34.3	34.6	34.6	34.6	18	16	17	17	17
28/12/2009	10	40	40	34	33.2	32.2	33.2	34.8	23	21	22	21	22
01/02/2010	0.99	0.99	0.99	33.8	34.7	35.1	34.7	34.7	26	25	26	25	25
09/02/2010	28	39	40	21	30.1	22.2	34.3	31.7	24	23	24	24	24
01/03/2010	12	5	13	31.4	32.9	31.4	33.8	33.8	20	20	20	19	19
01/06/2010	40	50	20	26.8	28.1	28.1	28.1	28.5	17	17	17	17	18
14/06/2010	3	0.99	4	27.8	27.8	28.1	26.8	30.9	16	16	17	17	18
29/07/2010	1.99	1.99	4	32.7	34.3	34.3	33	33	15	16	16	16	16
11/08/2010	4	0.99	0.99	30.4	34.3	31.8	34.3	31.8	16	16	16	16	16
20/09/2010	0.99	0.99	1	25.4	26.5	26.5	26.5	26.5	17	16	16	16	16
20/10/2010	1	0.99	1	30.2	33.3	33	30.2	33.3	15	17	16	15	17
25/10/2010	0.99	9	1	31.2	32.6	32.6	32.6	32.6	19	19	19	19	19
07/11/2010	13	12	31	30.6	34.5	30.6	31.8	34.5	21	21	21	21	21
19/12/2010	2	8	5	22.8	30.6	25.7	30.6	25.7	22	21	22	21	22
12/01/2011	50	30	33	25.5	29	27.8	24.2	29.1	25	24	24	25	24
31/01/2011	6	4	4	28.6	28.2	31.1	28.2	31.1	26	25	26	24	26

04/04/2011	42	20	26	24.2	25.7	24.2	24.2	24.2	22	22	22	22	22
18/04/2011	25	6	14	30.6	30.6	30.6	30.6	30.6	21	21	21	21	21
27/04/2011	13	18	23	28.8	28.8	28.8	28.8	28.8	19	19	19	19	19
13/06/2011	28	24	40	25.9	27.2	27.5			14	14	15		
03/08/2011	0.99	0.99	4	28.7	30.2	30.2	28.7	30.2	15	15	15	15	15
12/08/2011	56	22	50	24.5	27.2	24.5	24.5	24.5	14	14	14	14	14
29/08/2011	7	9	7	22.7	25.4	25.4	22.4	22.8	18	17	17	17	22
03/11/2011	6	20	1.99	28.8	28.8	28.8	28.8	28.8	19	19	19	19	19
09/01/2012	1.99	1.99	1.99	29.4	35.6	33.2	29	29	21	21	21	21	21
29/03/2012	2	4	4	23.3	23.3	23.3	23.3	23.3	23	23	23	23	23
19/04/2012	60	4	190	24.9	31.4	26.3	24.9	24.9	20	20	20	20	20
01/05/2012	16	14	24	22.4	25.4	22.4	25.4	25.4	17	17	17	17	17
02/10/2012	1.99	1.99	1.99	33	33	33	33	33	19.6	19.3	19.4	19.3	19.3
22/10/2012	2	2	4	23.9	23.9	23.9	23.9	23.9	17	17	17	17	17
04/02/2013	46	81	1.99	30	30	30	30	30	20.4	20.4	20.3	20.1	20.4
12/02/2013	1.99	1.99	6	32	34	33	34	33	21.6	21.5	21.6	21.5	21.6
11/03/2013	4	1.99	4	28	33	33	33	33	24.9	24.7	24.6	24	24
13/03/2013							33	33				24.8	24.8
02/04/2013	2	12	8	30	28	29	30	30	18	18	18	17.9	17.9
25/04/2013	6	6	2	25	26	29	28	28	19.9	19.9	19.9	19.8	19.9
04/06/2013	32	26	36	28	27	26	28	28	14	14	14	14.4	14.4
13/08/2013	1.99	1.99	1.99	32	36	26	36	32	18	18	18	18	18
01/10/2013	4	1.99	1.99	32	33	33	33	33	22.6	22.3	22.1	22.2	22.2
12/11/2013	6	1.99	1.99	31	31	31	31	31	19.3	19.4	19.6	19.6	19.6
26/03/2014	79	70	97	25	24	25	25	24	23.3	23.3	23.3	23	23
22/04/2014	2	1	11	32.1	31.2	31.5	31.2	31.2	17	17	17	17	17
11/06/2014	1	3	7	34.1	34.1	33.9	33.1	34.1	15	15	15	15.4	15.4
30/06/2014	1	4	0.99	33	34	34	33	34	13.4	13.2	13.2	13.3	13.4
16/07/2014	1	1	0.99	36	36	36	36	36	14.2	14.2	14.2	14.2	14.2
07/08/2014	3	0.99	6	34.1	34	34	34	34.1	13.9	14.1	14	13.9	14.1
13/08/2014	0.99	0.99	0.99	33.4	33.6	34.1	33.4	33.4	14	14	14	14	14

17/08/2014	1	1	1	34	34.1	34	34	34	14.5	14.5	14.5	14.1	14.5
12/09/2014	2	1	0.99	28	36	35			16.7	16.7	16.7		
02/10/2014	0.99	0.99	0.99	28	30	30	28	30	20	19.9	19.6	20.2	19.9
14/10/2014	1	0.99	0.99	31	31	32	31	32	18	18	18	18	18
30/10/2014	0.99	2	3	29	28	28	28	28	18	18	17.9	18	18.1
18/11/2014	1	0.99	1	35	39	35	36	35	23.4	21.4	21	23	21
04/12/2014	22	12	7	30	35	36	34	36	23	23	23	23	23
05/01/2015	1	6	0.99	34	30	28	30	30	22.5	22.5	22.5	23	23.1
11/01/2015	9	2	3	34	34	34	34	34	26	26	26	26	26
21/01/2015	3	0.99	0.99	29	34	34	34	34	27.7	27.6	27.6	27.6	27.1
29/01/2015	13	14	12	30	29	30	29	30	20	20	30	20	20
16/03/2015	5	5	1	30	30	31	30	30	20.6	20.6	21.6	20.6	20.6
25/03/2015	0.99	2	0.99	33	33	33	33	33	22.7	22.5	22.5	22.7	22.7
15/04/2015	6	14	2	30	30	31	30	30	20.8	20.9	20.9	20.1	20.9
20/04/2015	20	22	6	29	28	28	29	28	16.2	16.3	16.3	15.1	15
18/05/2015	1	2	5	30	29	30	30	29	20	19.9	19	19	20
16/06/2015	7	0.99	2	33	32	32	33	32	17	16	17	17	17
19/06/2015	11	11	11	31	29	30			11.7	12	11		
30/06/2015	0.99	3	0.99	26	25	26	25	26	12.8	13	13.2	13	13.1
05/08/2015	0.99	0.99	1	30	31	31	30	31	14	14	14	14	14
16/09/2015	0.99	0.99	0.99	35	34	34	35	35	18.2	18.2	18.2	18.2	18.2
12/10/2015	1	0.99	2	31	31	31	31	31	24	23.9	24	23.9	23.9
17/12/2015	12	6	1	31	31	32	31	31	18.8	18.9	19.1	19.2	19.9
06/01/2016	9	12	12	35	36	33	36	35	20.4	20.1	20.3	20.4	20.4
11/01/2016	1	0.99	0.99	38	37	38			27.4	27.2	21.1	26	27.1
26/01/2016	2	0.99	1	31	33	34	31	33	25.5	25.5	25.5	25.5	25.5
01/02/2016	5	7	5	23	23	22	22	22	23	24	23.9	23.9	23.4
17/03/2016	110	84	100	30	30	30	30	30	22.3	22.3	22.3	22.3	22.3
21/03/2016	0.99	3	1	35	34	32	34	34	20.7	20.7	20.7	20	20
04/04/2016	0.99	11	8	35	36	35	36	35	19.4	19.4	19.5	19.5	19.6
02/06/2016	5	4	7	34	34	34	34	33	14.3	14.4	14.5	14.2	14

01/08/2016	3	4	2	31	36	35	31	35	14	14	14	13	13
30/08/2016	1	1	3	31	30	31	29	31	14	14	14	14	14
07/02/2017	1	8	4	35	35	34	35	35	23.2	23.2	23.2	23.2	23.2
10/04/2017	1	6	5	33	35	33	33	35	20.5	20.5	20.5	20.05	20.05
19/04/2017	14	36	7	26	26	26	25	26	20	21	21	21	21
26/04/2017	0.99	1	4	34	33	34	34	34	20.5	20.5	20.5	20.5	20.5
03/05/2017	15	11	7	31	31	29	31	31	16.4	16.3	16.3	16.3	16.3
09/05/2017	1	1	2	32	34	33	33	32	15	15.1	14.6	14.6	15
22/05/2017	21	50	35	28	28	28	28	28	17	17	17	17	17
29/05/2017	2	1	9	31	31	31	31	31	18.1	18.1	18.1	18	18.1
07/06/2017	6	5	16	38	38	38	38	38	17	17	17	17	17
21/06/2017	14	7	56	26	27	26	26	26	16	16	16	16	16
06/07/2017	4	1	1	31	31	31	31	31	16	16	16	16	16
18/07/2017	1	8	33	31	31	31	31	31	15	15	15	6	6
01/08/2017	0.99	0.99	1	33	34	33	33	34	15.5	15.5	15.5	15	15
08/08/2017	0.99	0.99	0.99	35	35	35	35	35	10	10	10	16	16
31/10/2017	1	2	1	32	32	32	32	31	19	19	19	19	19
07/11/2017	0.99	0.99	0.99	37	23	37	37	37	19.5	20	19.5	19.5	19.5
10/01/2018	5	4	9	32	32	32	32	32	25	25	25	24	24
27/02/2018	2	0.99	6	32	32	32	32	32	22	22	22	22	22
05/03/2018	9	7	15	30	29	30	30	30	22	22	22	22	22
26/03/2018	2	3	3	29	30	29	30	29	20	20	20	20	20
30/04/2018	3	2	2	31	32	32	31	30	18	18	18	18	18
04/06/2018	3	0.99	2	32	32	32	32	32	15	15	15	15	15
12/06/2018	2	1	1	32	32	32	32	32	16	16	16	16.6	16.6
08/10/2018	2	1	14	33	33	33	33	33	18	18	18	18	18
08/11/2018	0.99	0.99	0.99	34	34	34	34	34	19	19	19	19	19
03/12/2018	0.99	2	0.99	29	30	30	29	30	21	21	21		
17/12/2018	1	3	6	27	26	28	26	26	22	22	22	22	22
09/01/2019			1			32	32	32			25.4	25.4	25.4
06/02/2019	3	3	1	32.1	32	32	33	33.8	26	26	26	26	26

09/02/2019	1	37		32	32				25.4	25.4			
19/02/2019	3	2	1	32	32	32	32	32	23.9	23.9	23.9	23.9	23.9
18/03/2019	22	14	95	31	31	31	32	31	23.1	23	23.1	23	23
25/03/2019	4	5	8	34	33	33	33	33	23	23	23	23	23
01/04/2019	3	2	4	32.1	32	32.4	32	32.4	18.5	18.5	18.4	18.5	18.5
04/04/2019	12	30	18	32	32	32	32	32	21.5	21.4	21.4	21.4	21.4
09/04/2019	0.99	0.99	0.99	33	33	33	33	33	22	22	22	22	22
11/04/2019	1.99	1.99	2	34	34	34	34	34	20	20	20	20	20
29/04/2019		5	4	32	32	32	32	32	17.1	17.1	17.1	17.1	17.1
30/04/2019	3			34					17.1				
06/05/2019	2	0.99	1	35	35	35	35	35	17	17	17	17	17
30/05/2019	2	4	2	33	33	33	33	33	14	14	14	14	14
11/06/2019	2	1.99	4	32	32	32	32	32	15	15	15	15	15
25/06/2019	201	150	130	26	26	26	28	28	13	13	13	13	13
02/07/2019	1.99	1.99	8	33	33	33	33	33	13	13	13	13	13
17/09/2019	4	1.99	6	33	33	33	33	33	16	16	16	16	16
18/09/2019	1.99	1.99	1.99	34	34	34	34	34	16	16	16	16	16
20/01/2020	2	8	4	32	32	32	32	32	22.5	22.5	22.5	22.5	22.5
21/01/2020	6	2	2	32	32	32	32	32	22.5	22.5	22.5	22.5	22.5
23/01/2020							33	33				22.5	22.5
03/02/2020	2	1.99	1.99	32	32	32	32	32	24	24	24	24	24
05/02/2020							35	35				21.5	21.5
02/03/2020	8		10	28		28	28	28	23.1		23.1	23.1	23.1
04/03/2020	12	16	18	26	26	26	26	26	22	22	22	22	22
09/03/2020	2	14	6	26	26	26	26	26	23	23	23	23	23
12/03/2020	2	6	1.99	28	29	28	29	29	23	23	23	23	23
23/03/2020	2	1.99	1.99	35	36	35	37	37	20.1	20.1	20.1	20.1	20.1
27/05/2020	1.99	1.99	2	29	29	29	29	29	17	17	17	17	17
09/06/2020	1.99		1.99	29		29	29	29	16		16	16	16
23/06/2020	14	1.99	1.99	34	34	34.1	34	34	16	16	16	16	16

Annex Table E-19 NSW Shellfish Program Comerong Bay Harvest Area Site 18 (River) Water Quality Data 2003 to 2020			
Analyte	**Ecoli (cfu/100ml)**	**Salinity (ppt)**	**Temp °C**
09/05/2003	8	28.5	18.5
29/05/2003	170	14.5	16.5
10/06/2003	20	23.2	15
23/06/2003	14	25.6	13.5
09/07/2003	33	27.2	14.5
31/07/2003	0.99	33.8	14.5
13/08/2003	1	34.1	15.5
27/08/2003	0.99	33.8	14.5
10/09/2003	0.99	33	16
24/09/2003	2	33.3	17
09/10/2003	0.99	34.3	16
22/10/2003	4	34.8	18.5
06/11/2003	14	34.6	17.5
19/11/2003	0.99	35.3	20
24/11/2003	56	20.9	16
02/12/2003	0.99	36.6	16
04/12/2003	0.99	33.8	19
17/12/2003	0.99	33.6	22.5
15/01/2004	1	33.2	21
29/01/2004	1	34	23
09/02/2004	4	34.8	22
23/02/2004	0.99	34.5	21.5
08/03/2004	3	33.6	22.5
22/03/2004	0.99	34.8	22

05/04/2004	14	33.2	21
13/04/2004	7	29.4	21
15/04/2004	0.99	30.6	21.5
03/05/2004	2	34.8	15
05/05/2004	1	34.3	16
06/05/2004	2	34.3	16
12/05/2004	6	34.6	17
13/05/2004	14	34.8	18
31/05/2004	5	34.3	16
03/06/2004	3	34.6	17
28/06/2004	4	33.5	13.5
20/07/2004	1	32.4	14
29/07/2004	4	33.5	13
26/08/2004	1	34.3	16
01/09/2004	0.99	34.6	17
23/09/2004	0.99	33	16.5
07/10/2004	11	35.3	17
21/10/2004	3	32.1	17
25/10/2004	15	29.1	20
18/11/2004	2	31.4	20
23/12/2004	0.99	32.9	20.5
01/02/2005	1	28.2	25
10/02/2005	18	33.2	21
21/02/2005	57	29.8	22
28/02/2005	0.99	34.8	22
10/03/2005	5	31.8	21.5
14/04/2005	4	31.4	19.5
05/05/2005	4	33.8	19.5
09/05/2005	2	33.8	19
19/05/2005	34	30.4	16
02/06/2005	2	33	16

25/07/2005	3		
17/01/2006	3	36.4	23
05/06/2006	17	29.3	12
13/06/2006	9	33	16
10/07/2006	2	29.9	14
09/08/2006	0.99	28.5	14
07/11/2006	2	36.4	19
30/01/2007	0.99	34	23
18/02/2007	1	33.5	18
26/02/2007	15	27.4	23
06/03/2007	18	25.1	24
14/03/2007	1	25.7	22
21/03/2007	3	34	23
30/04/2007	1	31.4	20
23/07/2007	4		
13/08/2007	0.99	32.7	15
20/08/2007	0.99	34	15
29/08/2007	3	33.3	17
07/09/2007	3	29	16
11/09/2007	3	30.7	17
26/09/2007	1	33.3	17
06/11/2007	3	32.3	18
26/11/2007	22	26.7	21
10/12/2007	3	29.4	21
20/01/2008	0.99	32.6	23
23/01/2008	1	34	23
29/01/2008	1	33.2	21
03/02/2008	14	31.7	24
19/02/2008	4	30.1	23
14/04/2008	16	31.2	19
30/07/2008	58	30.9	13

30/08/2008	0.99	34.1	15
08/09/2008	150	27.2	14
15/09/2008	0.99	34.6	17
27/10/2008	0.99	32.9	20
03/12/2008	0.99	35.1	19
15/12/2008	0.99	34.8	18
07/01/2009	1	36.4	23
13/01/2009	0.99	35.2	23
19/01/2009	0.99	34.1	20
28/01/2009	0.99	35.2	23
18/02/2009	7	34.1	20
24/02/2009	5	34	23
03/03/2009	1	35.2	23
09/03/2009	10	34.5	21
02/04/2009	6	33.2	21
06/04/2009	3	33.8	19
14/04/2009	2	33.2	21
20/04/2009	0.99	32.3	18
19/08/2009	0.99	35.5	16
07/10/2009	15	36.1	18
13/10/2009	0.99	34.6	17
26/10/2009	40	34.8	18
02/11/2009	0.99	34.6	17
28/12/2009	20	33.2	21
04/01/2010	75	34.5	21
07/01/2010	1	34.1	20
01/02/2010	1	34.7	25
01/03/2010	2	33.8	19
15/03/2010	3	28.4	22
01/06/2010	38	28.1	17
14/06/2010	1	28.1	17

12/07/2010	0.99	33.3	17
29/07/2010	1.99	34.3	16
09/08/2010	0.99	27.2	14
11/08/2010	0.99	35.2	15
20/09/2010	0.99	31.5	15
06/10/2010	3	29.9	19
20/10/2010	1	30.7	17
25/10/2010	1	33.3	17
11/11/2010	0.99	36.7	20
22/11/2010	1	29.8	22
19/12/2010	15	29.8	22
03/01/2011	18	28.2	21
12/01/2011	1	30.5	24
31/01/2011	0.99	34.3	24
04/04/2011	1	31	22
18/04/2011	30	31.8	21
27/04/2011	18	30.2	28
18/05/2011	0.99	30.7	17
13/06/2011	27	31.5	15
03/08/2011	2	33	16
12/08/2011	12	30.2	15
29/08/2011	22	28.1	17
19/10/2011	0.99	33.3	17
03/11/2011	1.99	32.3	18
28/11/2011	2		
14/12/2011	1.99	33.5	18
21/12/2011	2	33.8	19
09/01/2012	1.99	29.4	21
29/03/2012	2	29.3	28
02/04/2012	60	25.1	24
17/04/2012	1.99	29.1	20

19/04/2012	1.99	31.4	20
01/05/2012	5	27.2	18
26/06/2012	1.99	33.1	12
02/10/2012	1.99	34	20
22/10/2012	4	24.2	18
04/02/2013	81	30	20.1
12/02/2013	1.99	35	21.6
11/03/2013	1.99	34	24.9
02/04/2013	4	29	17.8
25/04/2013	16	30	19.8
06/05/2013	1.99	29.3	17.3
04/06/2013	22	28	14
18/06/2013	2	28	15.1
13/08/2013	1.99	36	18
01/10/2013	2	33	21.5
12/11/2013	2	34	19.3
09/01/2014	0.99	33	23
26/03/2014	730	10	23.3
22/04/2014	0.99	27.8	17
11/06/2014	10	34.1	15
30/06/2014	0.99	37	13.4
17/09/2014	1	37	19
22/09/2014	1	32	17.7
24/09/2014	0.99	38	19.8
14/10/2014	0.99	35	18
30/10/2014	2	31	17.8
03/12/2014	1	37	23
04/12/2014	1	38	23
05/01/2015	0.99	33	22.5
11/01/2015	0.99	35	25.1
21/01/2015	1	35	28.1

29/01/2015	1	31	20
25/03/2015	0.99	35	22.7
15/04/2015	0.99	32	20.7
20/04/2015	3	27	16.1
18/05/2015	0.99	28	20
16/06/2015	4	33	17
30/06/2015	1	29	13.1
28/07/2015	1	23	12.8
16/09/2015	2	29.1	18.2
30/09/2015	0.99	35	18.9
17/12/2015	8	31	19.5
06/01/2016	4	35	20.1
11/01/2016	0.99	38	27.6
26/01/2016	0.99	34	25.5
01/02/2016	7	22	22
02/03/2016	0.99	33	22.4
17/03/2016	16	28	22.2
21/03/2016	0.99	36	20.7
04/04/2016	0.99	35	19.3
02/06/2016	3	34	13.9
01/08/2016	1	37	13
11/08/2016	1	29	14
15/08/2016	0.99	36	11.3
30/08/2016	6	26	14
03/01/2017	0.99	31	22
07/02/2017	0.99	34	23.2
16/02/2017	0.99	34	24.5
10/04/2017	25	36	20.5
19/04/2017	4	26	21
26/04/2017	3	35	20.5
03/05/2017	2	33	16.4

09/05/2017	7	32	15.2
22/05/2017	4	28	17.5
29/05/2017	7	33	18.1
07/06/2017	9	35	17
21/06/2017	5	26	16
01/08/2017	0.99	35	15.5
08/08/2017	0.99	33	10
15/08/2017	0.99	36	16
31/10/2017	1	33	19
07/11/2017	0.99	37	19.5
10/01/2018	1	33	24
27/02/2018	4	32	22
30/04/2018	1	33	18
04/06/2018	0.99	32	15
12/06/2018	2	35	16
28/06/2018	3	32	15.4
11/07/2018	0.99	34	14
08/10/2018	4	33	18
08/11/2018	1	34	19
03/12/2018	2	30	21
17/12/2018	10	26	22
06/02/2019	0.99	34.5	26
09/02/2019	0.99	32	25.4
11/02/2019	0.99	32	24
19/02/2019	0.99	32	23.9
18/03/2019	16	30	23
25/03/2019	0.99	33	23
04/04/2019	1.99	33	21.3
29/04/2019	1	34	17.1
30/05/2019	1.99	33	14
11/06/2019	2	31	15.4

25/06/2019	6	28	13
02/07/2019	10	34	13
17/09/2019	1.99	33	16
18/09/2019	1.99	32	16
20/01/2020	36	32	22.5
21/01/2020	4	33	22.5
02/03/2020	4	28	23
04/03/2020	6	28	22
27/05/2020	1.99	27	17
09/06/2020	2	29	16
23/06/2020	2	34	16
29/06/2020	2	26	14

ANNEXURE F

WEST CULBURRA

BILLYS BAY AND CURLEYS BAY

SEDIMENT PILOT STUDY SAMPLE RESULTS

1 INTRODUCTION

The revised Concept Plan for forested lands west of Culburra Beach township draining north to the Crookhaven River estuary has been developed to include a stormwater collection, treatment and re-use scheme to result in a nil or beneficial effect (NorBE) on the water quality of the receiving waters of Curleys Bay in the Crookhaven River.

Whilst the stormwater control scheme will have no direct piped drainages to Curleys Bay, the scheme includes shallow infiltration of treated waters to maintain flow to the terrestrial forest in the buffer zone between the development and the Bay. Accordingly, the receiving aquatic environments for discharge waters from the proposed developments will be the tidally zoned aquatic communities downstream of the 100m wide buffer forest, namely riparian fringing *Casuarina* and saltmarsh communities, mangrove stands/forest (foreshore reserve) and associated mudflats, the overlaying tidal waters and the seagrass beds in the shallow sub-tidal waters of the bay.

In terms of available plant nutrients (mainly Nitrogen and Phosphorus) transported to Curleys Bay via stormwater, these are mainly delivered to the aquatic environments of Curleys Bay via natural runoff, shallow groundwater discharge and constructed stormwater infrastructure. The nutrient loads are delivered as particulate and dissolved phases and these are either transported out of Curleys Bay via tidal exchange, taken up and assimilated into biota directly as food or taken up by submerged vegetation (algae, microalgae, seagrass and mangroves), or deposited into the sediments where they are worked into the sediments under both physical and biological mechanisms (bioturbation). Given that all the above zoned vegetated communities are rooted plants they all take up nutrients from the soils in varying proportions.

Accordingly, studies of the water quality of the receiving waters provide a partial understanding of where and how water borne nutrients become available for plant growth. The present sediment study has as its aim the provision of base-line sediment character and nutrient status data for the various zoned vegetated estuarine habitats around Curleys Bay, in order to provide some guidance as to the resilience of the various rooted plant communities to variations in sediment character in the riparian and bay shallows.

1.1 Study Design

The overall design for this pilot study was to select replicate cored sediment *samples* at random from various vegetated estuarine habitats from two different *locations*:
For the intertidal habitats the two *locations* are defined as (a) the section of shoreline with generally forested runoff (i.e., the forested areas draining to Billys Bay and SW Bay), and (b) the section of shoreline receiving urban runoff into Curleys Bay generally east then north from Canal Street drain towards Orient Point (NW Bay).

- Possible sample sites were located in defined drainage sub-catchments and two sample sites were selected at random for each location. For the *urban* location, most possible sites were confined to stormwater easement leading to the bay.
- The zoned vegetation habitats selected for sampling were (a) riparian edge Casuarina habitat, (b) inshore saltmarsh habitat, (c) inshore mangrove habitat (generally dominated by seedlings), (d) dwarf mangrove habitat, (e) mid zone mangrove habitat, generally dominated by mature trees. All these habitats with the exception of dwarf mangroves were found at the two selected *locations*. Dwarf mangroves were only found at the 'forested' location.

For the seagrass beds the two Curleys Bay *locations* were defined as (a) generally inshore seagrass habitats adjacent to shoreline mangrove forests and (b) seagrass beds at active oyster leases.

As indicated in **Table 1**, MPR collected cored sediment samples at all replicate sites to determine a range of sediment characteristics (particle size distribution, total organic carbon and a range of nutrients) for the selected vegetated habitat classes (edge Casuarina RC, saltmarsh SU, inner mangroves MJ, dwarf mangroves MD, mid tidal range mangroves MM plus *Zostera* seagrass. **Figure 1** shows the sample sites.

Table 1 Culburra West Sediment Sampling Pilot Study Program

I/T Site	Date	RC	SU	MJ	MD	MM	SG
1 Forest	10/09/20	S	S	S	S	S + B	
2 Forest	10/09/20	S	S	S	S	S + B	
4 Urban	11/09/20	S	S	S		S + B	
6 Urban	10/09/20	S	S	S		S + B	
Seagrass sites							
SG6 Inshore	10/09/20						S
BBEch Inshore	10/09/20						S
L5 Lease	10/09/20						S
L7 Lease	10/09/20						S

Note: S – Surface sediment samples, B – Bottom sediment samples.
RC: Riparian Casuarina site — MD: Dwarf zone mangrove site
SU: Saltmarsh upper limit site — MM: Mid zone mangrove site
MJ: Inner zone (Juvenile) mangrove

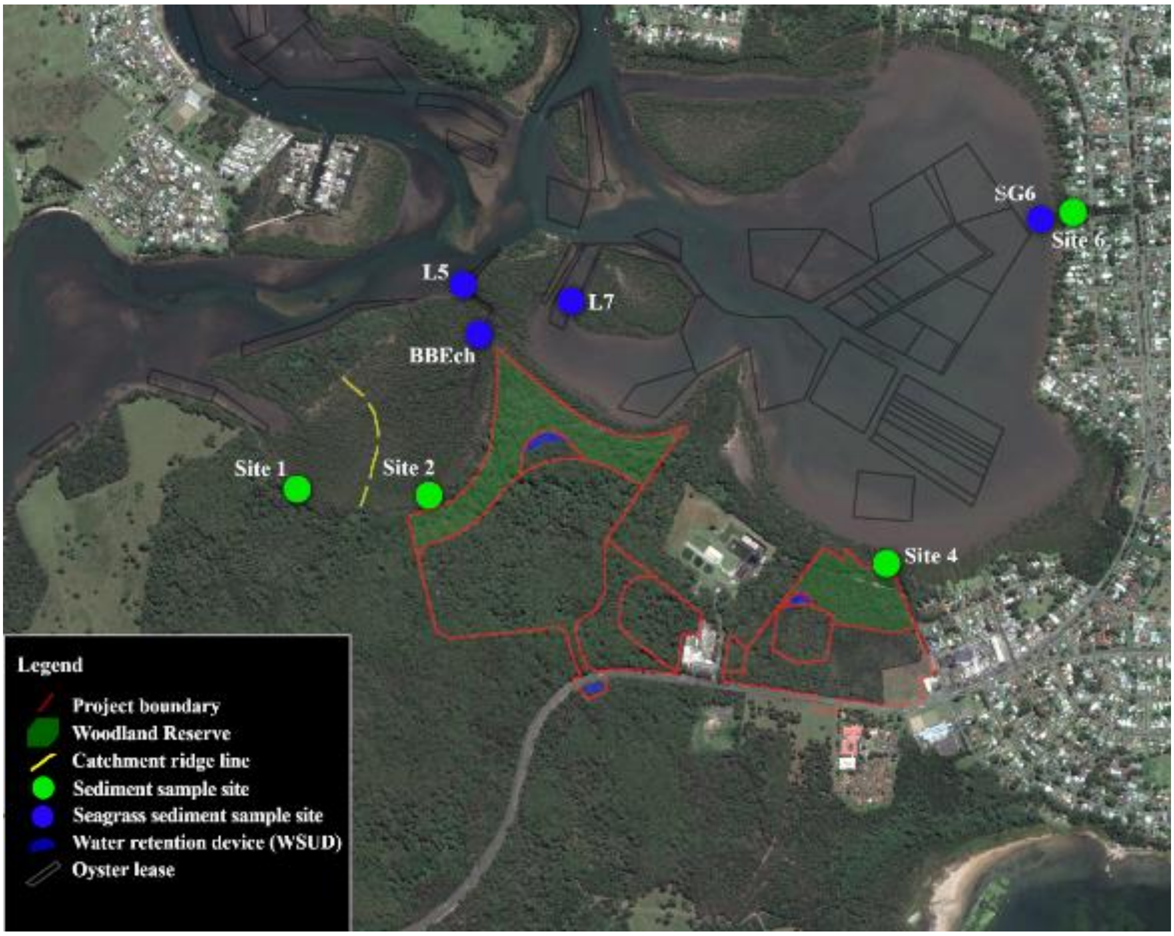


Figure 1: Curleys Bay Sediment Study sample site locations

1.1.1 Sediment Sampling

Soil and sediment samples were collected using a 100mm PVC pipe corer or by hand digging in locations where cores were not retrievable. As per the site sample schedule in **Table 1**, composite samples comprising the upper 200mm of sediments were labelled as *surface samples* and core profile depths of 200mm to 400mm were labelled as *bottom samples* (Mid Zone Mangrove MM samples only). GPS coordinates were recorded at all sample locations within each Site. Composite sample material was transferred into sterilised 250ml jars for chemical analysis and plastic zip-lock bags for particle size analysis.

After each core sample, the sample equipment was thoroughly cleaned of any remaining sample sediments with clean estuary water to minimise potential for cross-contamination between sites. All samples were delivered to a NATA accredited laboratory (ALS Labs Wollongong) within 24 hours. Soil and sediment samples were tested for particle size analysis, nitrate plus nitrite, total nitrogen (TN), total phosphorous (TP), reactive phosphorous, ammonium and total organic carbon (TOC).

2 WEST CULBURRA SEDIMENT STUDY SAMPLE RESULTS

Field notes and site coordinates are provided in **Appendix Table F-1,** the complete sediment nutrient chemical analysis results are provided in **Appendix Table F-2** and **Appendix F** includes the site photographs. Study sites are shown on **Figure 1**, **Figures 2** to **6** below with habitat and location means summarised in **Tables 2** to **4** below in **Section 2.1**.

Fieldwork was undertaken over the 10th and 11th September 2020. Despite some below average rainfall conditions over isolated months (April, June, September), the study area over year to August had already received well above the annual precipitation due large rain events in February, July and August. Rainfall conditions leading into the fieldwork were characterised by a large magnitude rain event over the 7th to 11th August which recorded 256mm, and this was followed by generally dry conditions for the three-week period prior to sampling. There was 1mm rain recorded at the Bureau of meteorology (BOM) Culburra Treatment Works rain gauge on the 10th September, however there was no rain observed on either sample date.

2.1 Sediment Sample Results

Particle size analysis reveals that the study site substrates are dominated by silt and sands, and there were no cobble sized rocks observed for any of the samples (**Figure 2 and Tables 2** and **4**):

- There were spatial variations in sediment composition for the riparian Casuarina sites. From forested to urban catchments the proportion of sand generally increased whilst silt (fines) proportions decreased, and the urban sites (4 and 6) contained generally similar compositions of sediment proportions. Riparian Casuarina site sediments were made up mostly of silts (20% to 81%) and sand (18% to 70%), and small amounts of gravels at all sites (1% to 10%). Overall, the greatest ranges of % silt fractions were found at Casuarina and mangrove habitats (**Table 4**).
- Saltmarsh habitat sediments were dominated by silts (range of 54% to 78%; **Table 4**) and smaller amounts of sand (19% to 45%) and gravel (1% to 5), showing a slight increase) from forested to urban catchments.
- Site sediment compositions were generally similar between forested sites (sites 1 and 2) MJ and MD samples and were comprised mostly of sandy sediments and lesser amounts of silts and gravels. Urban sites 4 and 6 contained higher proportions of silt (40% and 45% respectively) and site 6 contained 23% gravel fragments.
- While the Mid Zone mangrove (MM sites) surface and bottom samples showed spatial variation in sediment compositions, there were within site consistencies

between surface and bottom samples. Forested sites 1 and 2 surface samples supported generally higher proportions of silt (64% to 71%) compared to sand fractions (28% to 34%), and variable for the two urban sites.
- The seagrass site sediments contained the highest proportions of sands which ranged between 61% and 88%, and to a lesser extent, silty sediments at 12% to 22%. Site SG6 was the only seagrass site to contain gravels (17%).

The sediment TOC and NOx and ammonia nutrient results are provided in **Figures 3** to **6** and **Tables 2** to **3** below provide the study mean values which are summarised as follows:

- Percent TOC was low for MD sites, the forested MJ sites, two urban MM surface cores and site 6MM bottom core (**Figure 3**; **Table 2**). Most other samples had elevated TOC ranging between 6% and 9 % with two high sample results for 1SU (15%) and 6MJ (18.4%).
- Nitrous Oxide (NOx) concentrations were generally less than 0.5 mg/kg for 18 of 26 sites with slightly elevated values (± 1mg/kg) for four mangrove sites and higher values to 6.5 mg/kg for four Casuarina and saltmarsh sites (**Figure 4**; **Table 3**).

- Sediment ammonium concentration was analysed for saltmarsh and mangrove sites only (**Figure 4**). Ammonium concentrations were negligible (less than 0.2 mg/kg) for all surface and bottom samples at Mid Zone Mangrove sites (**Table 3**) with the exception of surface samples at urban site 4MM (6.1 mg/kg) and the forested sites which produced the overall highest ammonium concentrations values (13.2 mg/kg and 14.4 mg/kg).
- Dwarf mangrove, forested juvenile mangrove, 2SU and 6SU ammonium concentrations were low (below 3 mg/kg) and there were elevated ammonium concentrations at 1SU, 4SU saltmarsh sites plus both urban juvenile mangrove sites.

The total nitrogen and phosphorous concentrations provide an indication of overall sediment nutrient status of the most commonly available forms, and the results show that there are differences between the study estuarine vegetation zones:

- Sediment TP values were highest in the uppermost estuarine riparian Casuarina and saltmarsh habitat zones, with the mean habitat value of 649 mg/kg and 781 mg/kg respectively (**Figure 5**; **Table 3**). Within each of these habitats, the TP concentrations were higher at the urban sites than the forested sites.
- While the forested dwarf mangrove and juvenile mangrove habitats contained relatively low concentrations, the urban juvenile mangrove site 6 reported an

elevated value (1030 mg/kg; **Figure 5**). This site was located at the end of an urban stormwater drain where it enters the estuary in Curleys Bay.

- Surface and bottom mid zone mangrove sediment TP values varied across sites (**Figure 5**) however the overall combined mean values were lower than other vegetation zones further inshore, with the exception of dwarf mangrove (forested sites). Interestingly, while the urban site 6 TP sample values were the overall lowest values recorded (6MM-S 101 mg/kg and 6MM-B 75 mg/kg), the other site 6 estuarine values were the highest in their respective habitats (saltmarsh and juvenile mangrove).
- Seagrass sediments TP concentrations were mostly low however site SG6 contained an elevated TP concentration (462 mg/kg) compared to the other seagrass locations (177 to 2020 mg/kg).
- As for TP, the sediment TN concentrations were highest in the riparian Casuarina and saltmarsh habitat zones with mean concentrations of 11638 mg/kg and 6193 mg/kg respectively. The urban riparian Casuarina sites contained the overall highest TN values (mean of 15650 mg/kg) and there was a marked difference between forested sites 1 (4450 mg/kg) and 2 (10800 mg/kg).
- The TN concentrations for the different mangrove habitats followed the same pattern as noted for TP; the forested dwarf mangrove and juvenile mangrove habitats plus urban site 4 contained relatively similar, and low concentrations compared to the urban juvenile mangrove site 6 which reported an elevated value (10500 mg/kg), and the forested mid zone (MM) samples had higher TN values than the urban samples for both surface and bottom cores (**Figure 5; Table 3**).
- The seagrass TN sediment values were the overall lowest across the different habitats, ranging between 440 mg/kg and 660 mg/kg.

The relative abundance of the main essential limiting nutrients are represented as TN:TP ratios which are provided in **Figure 6**, the specific habitat and location means are provided in **Table 3** and the concentration ranges are in **Table 4**:

- The highest ratios were noted for the riparian Casuarina sites with no difference between mean TN:TP values for the urban and forested sites.
- Mean forested saltmarsh sediment TN:TP (11.5) was double that noted for urban saltmarsh value (5.7), owing mostly to the excessive TP values recorded at 6SU.
- Despite the range of individual nutrient concentrations recorded across the study area, most of the other site TN:TP values were <10, indicating a relative consistency in combined nutrient concentrations within each site.
- The seagrass sites had the overall lowest TN:TP ratios due to the relatively low concentrations of sediment bound TN.

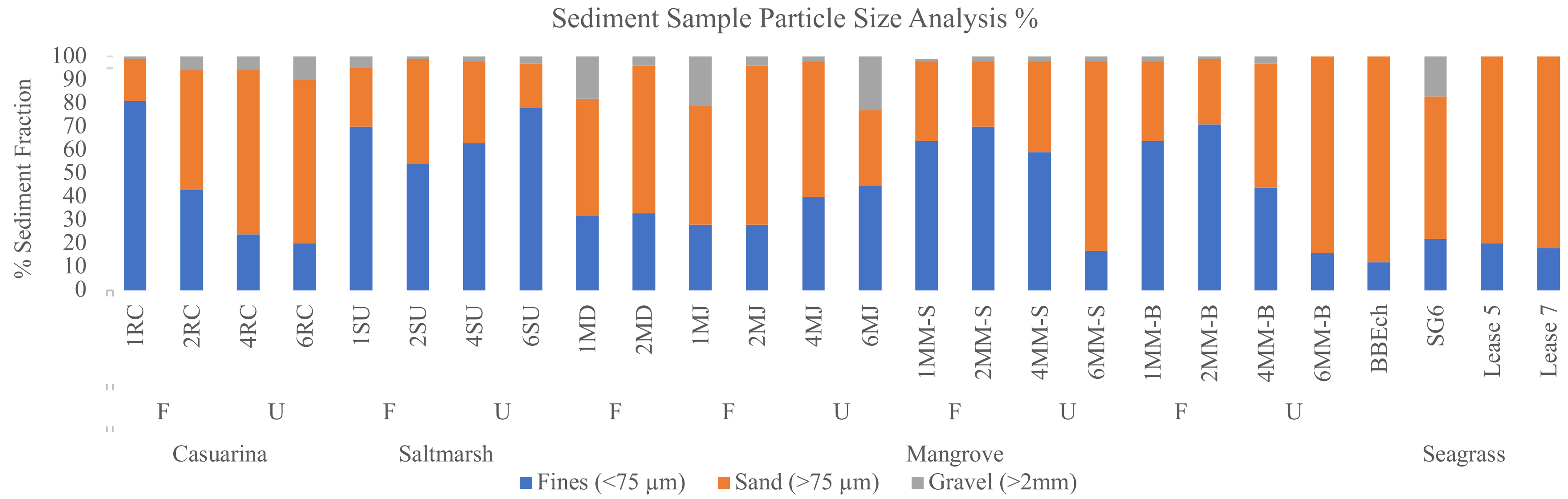


Figure 2: Sediment sample particle size distribution (% total).

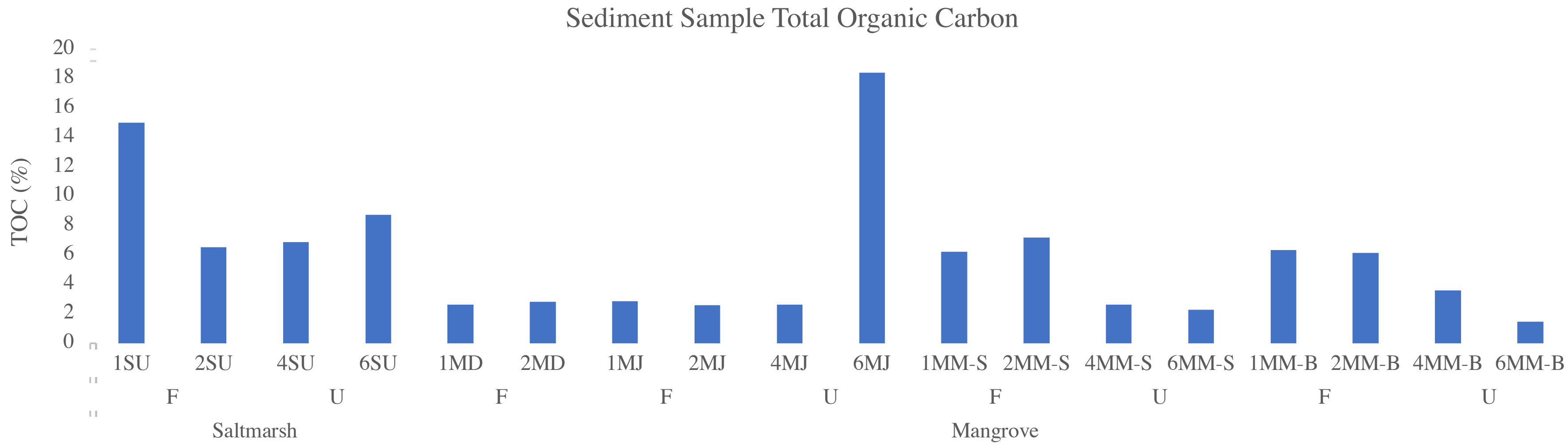


Figure 3: Sediment sample Total Organic Carbon distribution (%TOC) for saltmarsh and mangrove habitats.

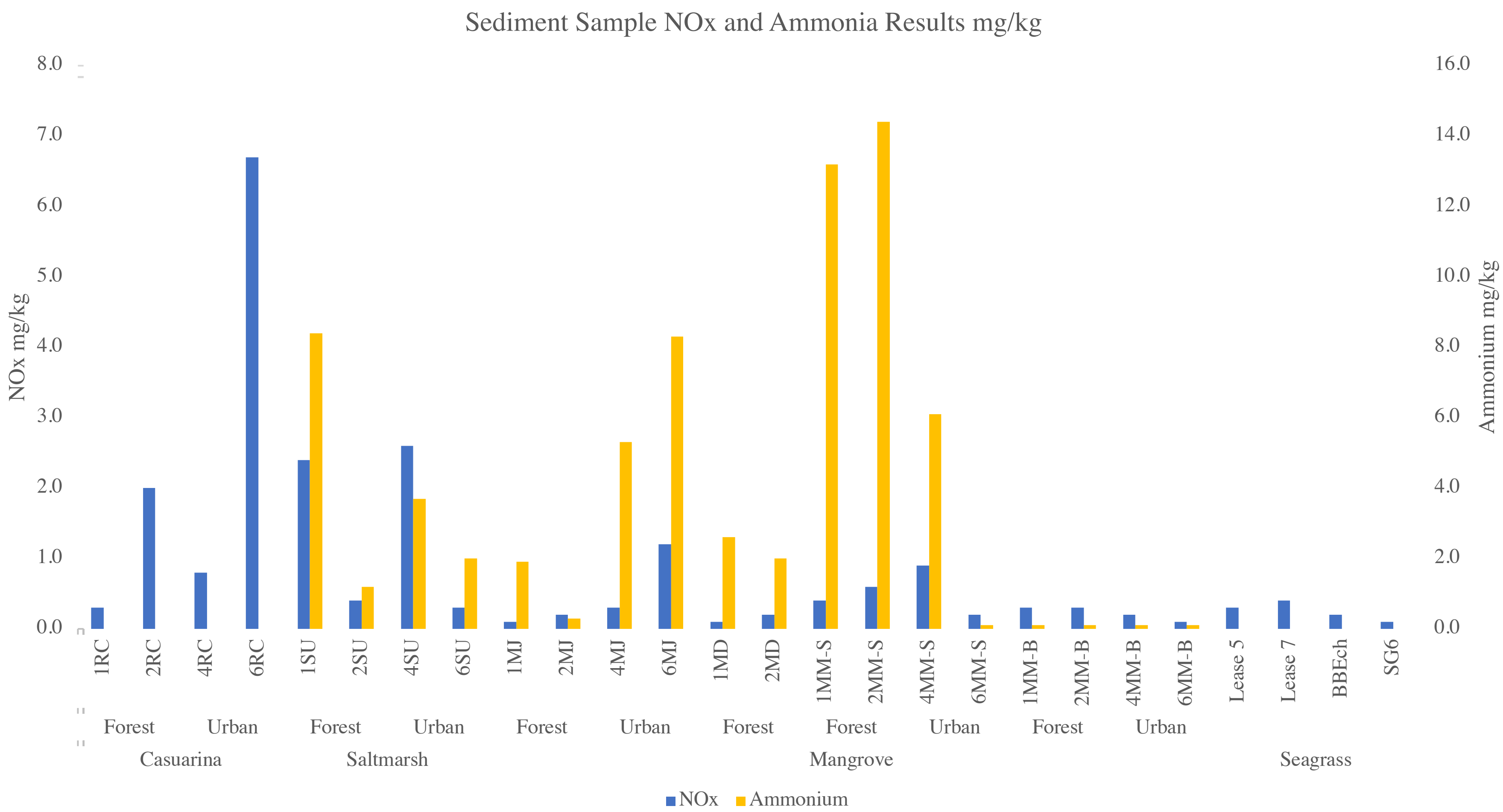


Figure 4: Sediment sample Nitrous Oxides (NOx) and Ammonium concentrations across site groupings.

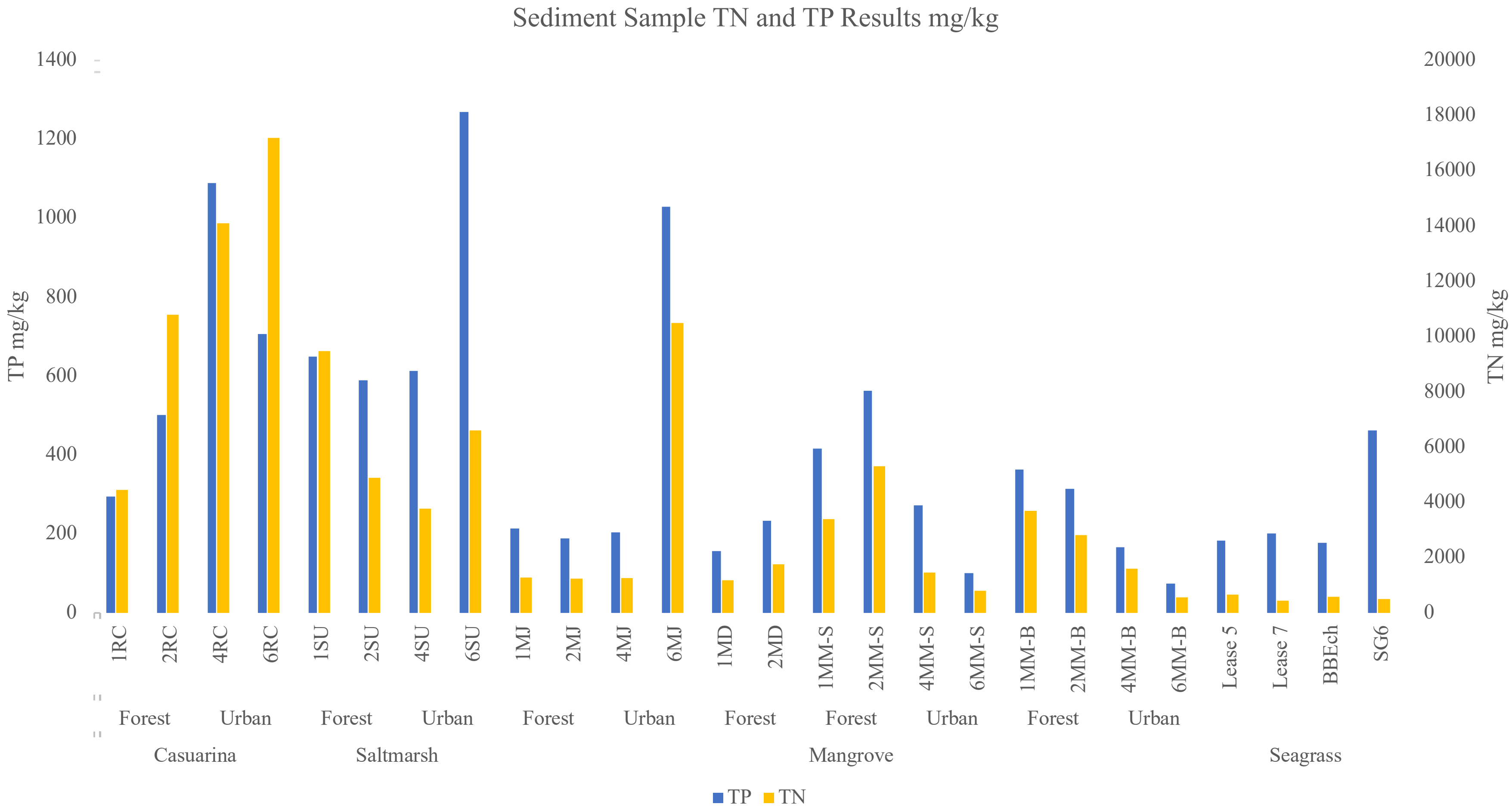


Figure 5: Sediment sample Total Nitrogen (TN) and Total Phosphorous (TP) concentrations across site groupings.

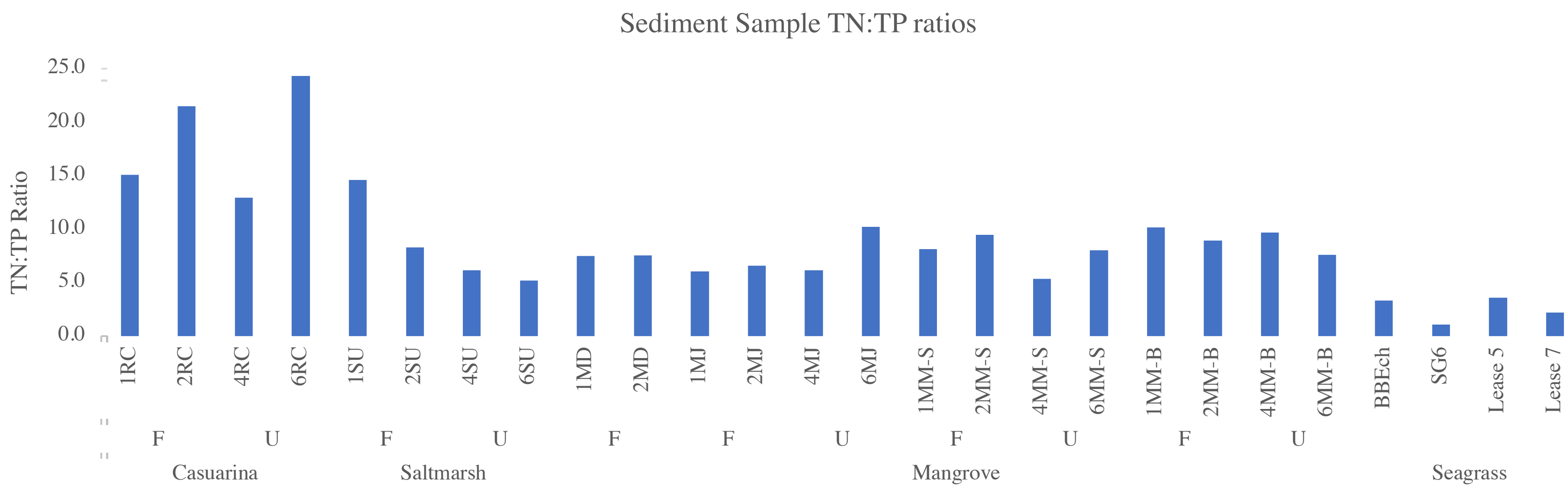


Figure 6: Sediment sample TN:TP ratios across site groupings.

Table 2 Habitat Sediment Study Means (Particle Size + TOC) for Locations and Habitats

Habitat	Location	Fines	Sand	Gravel	TOC
RC	For	62.00	34.5	4	
	Urb	22.00	70.0	8	
	Total	42.00	52.3	6	
SU	For	62.00	35.00	3	11
	Urb	70.50	27.00	3	8
	Total	66.25	31.00	3	9
MD	For	32.50	56.50	11	3
MJ	For	28.00	59.50	13	3
	Urb	42.50	45.00	13	11
	Total	35.25	52.25	13	7
MM-S	For	67.00	31.00	2	7
	Urb	38.00	60.00	2	2
	Total	52.50	45.50	2	5
MM-B	For	67.50	31.00	2	6
	Urb	30.00	68.50	2	3
	Total	48.75	49.75	2	4
Seagrass	Shallow	17.00	74.5	9	
	Oysters	19.00	81.0	1	
	Total	18.00	77.8	5	
Total Study	Min	12.0	18	1	1
	Mean	42.92	51.81	5	6
	Max	81.00	88.00	23	18

Table 3 Habitat Sediment Study Means for Locations and Habitats						
Habitat	Location	NOx	NH3N	TN	TP	TN:TP
RC	For	1.15		7625	399	18.3
	Urb	3.75		15650	899	18.6
	Total	2.45		11638	649	18.5
SU	For	1.40	4.80	7190	619	11.5
	Urb	1.45	2.85	5195	942	5.7
	Total	1.43	3.83	6193	781	8.6
MD	For	0.15	2.30	1470	195	7.5
MJ	For	0.15	1.10	1265	202	6.3
	Urb	0.75	6.80	5880	617	8.2
	Total	0.45	3.95	3573	409	7.2
MM-S	For	0.50	13.80	4355	490	8.8
	Urb	0.55	3.10	1135	187	6.7
	Total	0.53	8.45	2745	338	7.7
MM-B	For	0.30	0.10	3255	340	9.5
	Urb	0.15	0.10	1090	121	8.6
	Total	0.23	0.10	2173	230	9.1
Seagrass	Shallow	0.13		545	320	2.2
	Oysters	0.35		550	193	2.9
	Total	0.24		548	256	2.6
Total Study	Min	0.1	<0.1	440	75	1.1
	Mean	0.83	3.88	4247	425	8.8
	Max	6.70	14.40	17200	1270	24.3

Table 4 Concentration Ranges for Estuarine Sediments						
Analyte	Range	Cas	Salt Marsh	Mangroves	Seagrass	All
% silt	Min	20	54	16	12	12
	Max	81	78	71	22	81
	Range	4.1	1.4	4.4	1.8	6.8
TOC %	Min		6.5	1.5		1.5
	Max		15.0	18.4		18.4
	Range		2.3	12.5		12.5
NOx mg/kg	Min	0.3	0.3	0.1	0.1	0.1
	Max	6.7	2.6	1.2	0.4	6.7
	Range	22.3	8.7	12.0	8.0	134.0
NH3-N mg/kg	Min		1.2	0.1		0.1
	Max		8.4	14.4		14.4
	Range		7.0	144.0		144.0
TN mg/kg	Min	4450	3780	570	440	440
	Max	17200	9490	10500	660	17200
	Range	3.9	2.5	18.4	1.5	39.1
ReactP mg/kg	Min		<0.1	<0.1		<0.1
	Max		<0.1	0.2		0.2
TP mg/kg	Min	295	589	75	177	75.0
	Max	1090	1270	1030	462	1270.0
	Range	3.7	2.2	13.7	2.6	16.9
TN:TP	Min	12.9	5.2	5.4	1.1	1.1
	Max	24.3	14.6	10.2	3.6	24.3
	Range	1.9	2.8	1.9	3.3	22.5
Note: Range = Absolute ranges.						

ANNEXURE F

SUPPLEMENTARY DATA

F-1 FIELD NOTES AND SITE DATA

F-2 SEDIMENT NUTRIENT AND CHEMICAL LAB RESULTS

PLATES 1-22 SITE PHOTOS

Annexure Table F-1 Culburra West Sediment Sampling Notes September 10 & 11 2020

Site	Sample Type	Location	Coordinates MGA E	N	Date	Sample Time	Depth m Water	Core/Hole	Sampled	Notes
1	RC	F	293066	6132849	10/09/20	15:10	-	0.4	0.25	Sampled among Casuarinas above saltmarsh. Soil profile very similar to other riparian Casuarina sites, removed Casuarina needle layer before sampling. Soil consists of a uniform coloured rich brown organic humus layer with dense fibrous and larger roots (5-10mm diameter) in top 400mm of sediment, no distinct clay layer observed (as observed at Site 6). Took composite sample of top 200 to 300mm of soil, most of the fibrous root material taken out. No rock layer detected at depth of 1m.
2	RC	F	293450	6132802	10/09/20	16:35	-	0.3	0.3	Sampled among Casuarinas above saltmarsh zone. Soil profile very similar to other riparian Casuarina sites, removed Casuarina needle layer before sampling. Soil consists of a uniform coloured rich brown organic humus layer with dense fibrous and larger roots (5-10mm diameter) in top 400mm of sediment, no distinct clay layer observed (as observed at Site 6). Took composite sample of top 300mm of soil, most of the fibrous root material taken out. No rock layer detected at depth of 1m.
4	RC	U	294832	6132638	11/09/20	06:50	-	0.4	0.3	Sampled among Casuarinas above saltmarsh zone. Soil profile very similar to other riparian Casuarina sites, removed the dense Casuarina needle layer before sampling. Soil consists of a uniform coloured rich brown organic humus layer with dense fibrous and larger roots (5-10mm diameter) in top 400mm of sediment, no distinct clay layer observed (as observed at Site 6). Composite sample of top 300mm of soil taken with most of the fibrous root material taken out.
6	RC	U	295368	6133719	10/09/20	11:45	-	-	0.1	Sample taken from riparian Casuarina stand adjacent stormwater drain, removed Casuarina needle layer before sampling. Soil consists of a rich brown organic humus layer with dense fibrous and larger roots (5-10mm diameter) in top 100mm of sediment, with brown to light brown clay layer underneath. Sampled top 100mm of sediment.
1	SU	F	293074	6132857	10/09/20	15:20	-	0.3	0.2	Site sampled in saltmarsh among *Juncus kraussii* and *Sporobolus virginicus*. Soil profile is uniform dark brown in top 200mm then distinct change to red then lighter brown clay layer underneath. No rock layer detected at depth of 800mm. Fibrous root material present throughout most of sample.

2	SU	F	293439	6132814	10/09/20	16:40	-	0.3	0.2	Site sampled in distinct saltmarsh zone, with the dominant species similar to the broader Billys Bay shoreline and Site 1 (*Juncus kraussii* and *Sporobolus virginicus*). Soil profile consisting of muddy clay with some sandy sediments, brown grey in top 50mm, tending light brown to black at around 150 to 200mm depth. Fibrous root material present throughout depth profile.
4	SU	U	294834	6132649	11/09/20	07:10	-	0.2	0.2	Site sampled in distinct saltmarsh zone occupied by *Sporobolus virginicus* (*Juncus kraussii* also present close by). Soil profile consisting of muddy clay with some sandy sediments, top 100mm light brown to grey with some red clay patches, tending light grey to black underneath. Fibrous root material present throughout depth profile.
6	SU	U	295424	6133736	10/09/20	13:20	-	0.25	0.2	Sample taken from saltmarsh patch at the end of Addison Rd culdesac (northern side of stormwater drain). *Sarcocornia quinqueflora* and *Sporobolus virginicus* present, and grey mangroves adjacent. Sediment core consists of sticky dark brown sediments.
1	MJ	F	293080	6132863	10/09/20	16:00	-	0.3	0.2	Site sampled in inshore mangrove habitat around 3 to 4m out from saltmarsh lower edge. Pneumatophores and seedlings present in location. Core dark brown throughout with obvious streaks of red clay throughout length, sandy pebble material present. Fibrous root material present throughout depth of core.
2	MJ	F	293437	6132820	10/09/20	16:50	-	0.2	0.2	Site sampled in mangrove habitat, around 3m offshore from the lower limits of the saltmarsh. Sediment profile consisting of brown sandy layer on top with increasing grey content with depth (to 200mm), pneumatophores present throughout area. Consolidated fibrous root material present throughout sediment sample.
4	MJ	U	294831	6132655	11/09/20	07:20	-	0.2	0.2	Sample taken from inner boundary of mangrove habitat, around 3m out from saltmarsh edge. Mangrove seedlings and pneumatophores present throughout area. Sediment profile consists of uniform grey sandy mud sediments, consolidated fibrous root material throughout sample.
6	MJ	U	295354	6133724	10/09/20	12:35	-	0.3	0.2	Site sampled in mangrove zone at drain entrance to estuary, mature mangrove pneumatophores and seedlings present in location. Very fibrous root material throughout sample, sample generally taken from top layer of estuary sediments and among root masses. Sediment profile consisting of brown muddy sand with some light brown clay patches.

1	MD	F	293085	6132875	10/09/20	15:45	0.02	0.3	0.2	Site sampled in mangrove habitat, among distinct zone of dwarf mangroves plus scattered seedlings (overall 50 to 80cm height), pneumatophores present throughout area. Core generally uniform dark brown with streaks of red clay in lower half (below 100 to 150mm depth), some pebbly sand material present in lower core section. Fibrous root material present in core and sample. Top 200mm taken for sample.
2	MD	F	293435	6132830	10/09/20	16:55	-	0.3	0.2	Site sediment profile generally consistent through sample depth (to 300mm), consisting of brown to grey sandy sediments, pneumatophores and dwarf mangroves present, supporting growth of epiphytic marine algae *Catenella nipae*. Consolidated fibrous root material present throughout sample.
1	MM	F	293094	6132923	10/09/20	15:35	0.1	0.35	2 x 0.175	Taken from mangrove habitat among mature mangroves, scattered sparse seedlings and pneumatophores present in location. Core generally unform darkish brown in colour with slight increase in darkness with depth, sandy mud sediments with some clumps of red clay. Fibrous root material present throughout core. Sample split into upper 175mm and bottom 175mm.
2	MM	F	293417	6132872	10/09/20	17:05	-	0.4	2 x 0.2	Sampled among mature mangroves with sparsely scattered dwarf mangroves and sparse seedlings present. Pneumatophores present in location, supporting growth of epiphytic marine algae *Catenella nipae*. Sediment profile consisting of sandy mud sediments, light grey and generally uniform in colour and consistency throughout depth. Sample split into upper 200mm and bottom 200mm.
4	MM	U	294836	6132672	11/09/20	07:40	-	0.4	2 x 0.2	Sampled among mature mangroves with small quantities of dwarf mangroves or seedlings present. Pneumatophores present throughout location, supporting prolific growth of epiphytic *Catenella nipae*. Sediment profile consisting of sandy mud sediments, light brown grey at surface (100mm) tending grey (100mm and deeper). Sample split into upper 200mm and bottom 200mm.
6	MM	U	295339	6133719	10/09/20	12:50	-	0.4	2 x 0.2	Core split into 2 parts (upper 200mm and bottom 150 to 200mm). Sandier looking sediments than MJ, unform brown colour throughout sample core, pneumatophores present throughout area supporting localised dense growth of epiphytic marine algae *Catenella nipae*. Dense fibrous root material present, particularly in upper 100mm.

BBEch	Seagrass	293606	6133319	10/09/20	09:50	0.15	0.35	0.2	Core went down to around 350mm and hit shell layer (sample above shell layer retrieved). Around 50-60 estimated holes in substrate per 30cm x 30cm. Yabbies and amphipods in sample core sediments. Uniform colour and grain size throughout core length. Zostera leaves taken out of sample.
6	Seagrass	295287	6133678	10/09/20	08:40	0.3	0.35	0.2	A lot of shell material in bottom 150-200mm. Most of the seagrass leaves taken out of sample, but still some remaining in sample. Core generally uniform grey colour throughout. Around 30 yabby holes per 30cm x 30cm in surrounding substrates.
L5	Seagrass	293546	6133472	10/09/20	09:30	0.4	0.35	0.2	Site sampled in oyster lease. Generally uniform colour throughout core length. Around 25 to 30 yabby holes per 30cm x 30cm. Not really any shell material observed in core, consistent Zostera bed at location. Water slowly moving south up channel from L5 and into BBEch channel. Zostera leaves taken out of sample.
L7	Seagrass	293880	6133416	10/09/20	10:20	0.6	0.35	0.2	No shell material observed in sample, uniform sediment grain size and colour throughout core depth. Zostera seagrass shoots taken out of sample. Seagrass density generally consistent with other sample sites; generally long leaves (20 to 40cm), occurring in clumps (~2-3 clumps per 30cm x 30cm) consisting of 5 to 15 shoots per clump and bare sediment in between. Unable to observe number of holes in sediment due to depth. Polychaete worm in sample.
Note:	For location, F = forested and U = Urban.								

Appendix Table F-2 Culburra West Sediment Pilot Study Sample Results

		Sample Date:	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	11/9/20	11/9/20	11/9/20	11/9/20	11/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20	10/9/20
		Site:	1RC	1SU	1MD	1MJ	1MM-S	1MM-B	2RC	2SU	2MD	2MJ	2MM-S	2MM-B	4RC	4SU	4MJ	4MM-S	4MM-B	6RC	6SU	6MJ	6MM-S	6MM-B	BBEch	Lease 5	Lease 7	SG6
Soil Particle size	Units	DL																										
+75μm	%	1	19	30	68	72	36	36	57	46	67	72	30	29	76	37	60	41	56	80	22	55	83	84	88	80	82	78
+150μm	%	1	14	26	57	64	27	29	52	42	57	64	24	22	69	32	52	33	43	75	20	53	57	42	67	70	52	57
+300μm	%	1	8	21	43	51	18	20	43	33	38	46	17	13	58	22	36	22	29	67	15	51	21	10	34	48	21	32
+425μm	%	1	6	19	35	44	12	15	35	24	27	32	12	9	50	16	23	15	20	61	13	48	12	5	18	27	11	26
+600μm	%	1	4	16	29	38	8	11	27	16	18	21	8	6	41	11	14	10	13	53	11	45	7	3	6	9	3	22
+1180μm	%	1	2	9	21	28	3	4	14	4	7	7	3	2	17	4	4	4	5	28	6	36	3	<1	1	<1	<1	18
+2.36mm	%	1	<1	3	16	18	<1	<1	3	<1	3	3	<1	<1	2	<1	1	1	2	2	2	17	2	<1	<1	<1	<1	16
+4.75mm	%	1	<1	1	11	9	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	12
+9.5mm	%	1	<1	<1	6	3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2
+19.0mm	%	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
+37.5mm	%	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
+75.0mm	%	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Soil Classification based on Particle Size																												
Fines (<75 μm)	%	1	81	70	32	28	64	64	43	54	33	28	70	71	24	63	40	59	44	20	78	45	17	16	12	20	18	22
Sand (>75 μm)	%	1	18	25	50	51	34	34	51	45	63	68	28	28	70	35	58	39	53	70	19	32	81	84	88	80	82	61
Gravel (>2mm)	%	1	1	5	18	21	1	2	6	1	4	4	2	1	6	2	2	2	3	10	3	23	2	<1	<1	<1	<1	17
Cobbles (>6cm)	%	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nitrite + Nitrate	mg/kg	0.1	0.3	2.4	0.1	0.1	0.4	0.3	2.0	0.4	0.2	0.2	0.6	0.3	0.8	2.6	0.3	0.9	0.2	6.7	0.3	1.2	0.2	0.1	0.2	0.3	0.4	<0.1
Total Kjeldahl Nitrogen	mg/kg	20	4450	9490	1180	1290	3390	3700	10800	4890	1760	1240	5320	2810	14100	3780	1260	1460	1610	17200	6610	10500	810	570	590	660	440	500
Total Nitrogen	mg/kg	20	4450	9490	1180	1290	3390	3700	10800	4890	1760	1240	5320	2810	14100	3780	1260	1460	1610	17200	6610	10500	810	570	590	660	440	500
Total Phosphorus	mg/kg	2	295	649	157	214	417	364	502	589	233	189	563	315	1090	614	204	272	166	707	1270	1030	101	75	177	183	202	462
Reactive Phosphorus	mg/kg	0.1	----	<0.1	0.1	<0.1	0.2	<0.1	----	<0.1	0.1	<0.1	<0.1	0.2	----	<0.1	0.1	<0.1	<0.1	----	<0.1	<0.2	<0.1	<0.1	----	----	----	----
Ammonium	mg/kg	0.2	----	8.4	2.6	1.9	13.2	<0.2	----	1.2	2.0	0.3	14.4	<0.2	----	3.7	5.3	6.1	<0.2	----	2.0	8.3	<0.2	<0.2	----	----	----	----
Total Organic Carbon	%	0.02	----	15.0	2.64	2.86	6.22	6.33	----	6.54	2.82	2.58	7.21	6.16	----	6.87	2.64	2.64	3.61	----	8.74	18.4	2.28	1.47	----	----	----	----

Plate 1: Site 1RC among the riparian Casuarina forest fronting Billys Bay.

Plate 2: Saltmarsh site 1SU among the mixed *Juncus kraussii* and *Sporobolus virginicus*.

Plate 3: Site 1MJ collected from the inshore edge of the mangrove zone.

Plate 4: Site 1MD among dwarf mangroves in Billys Bay.

Plate 5: Site 1MM among mature mangroves.

Plate 6: Site 2RC among Casuarinas in the eastern portion of Billys Bay.

Plate 7: *Sporobolus virginicus* saltmarsh sample site 2SU.

Plate 8: Inner mangrove sample site 2MJ.

Plate 9: Site 2MD collected among dwarf mangroves.

Plate 10: Site 2MM. Note the presence of *Catenella nipae* algae on pneumatophores.

Plate 11: Riparian Casuarina site 4RC along the southern shoreline of Curleys Bay.

Plate 12: Site 4SU in *Sprorobolus virginicus* saltmarsh.

Plate 13: Inner mangrove sample location at site 4MJ.

Plate 14: Mid mature mangrove sample location 4MM.

Plate 15: Eastern Curleys Bay shoreline riparian Casuarina sample site 6RC.

Plate 16: Site 6 saltmarsh sample location 6SU.

Plate 17: Looking downstream from stormwater drainage channel at 6MJ.

Plate 18: Mature mangrove sample site 6MM.

Plate 19: Billys Bay *inshore* eastern channel seagrass sample site BBEch.

Plate 20: Crookhaven River *oyster lease* seagrass sample site location L5.

Plate 21: Crow South Channel *oyster lease* seagrass sample site location L7.

Plate 22: Eastern Curleys Bay *inshore* seagrass sample location SG6.