# TNG Darwin Processing Facility: Marine & Coastal Assessment

**Elizabeth River Estuary & surrounds, Darwin Harbour**

TNG Limited

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Advisian
WorleyParsons Group

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TNG Darwin Processing Facility: Marine & Coastal Assessment

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# 1 Introduction

## 1.1 Project Description

TNG Limited (TNG) is seeking the approval of the Northern Territory (NT) and Commonwealth governments to develop the Darwin TIVAN® Processing Facility (the Project) in order to process magnetite concentrate to produce higher value products for export to international customers.

The Project site is contained within Lot 1817, Hundred of Ayers, Wickham within the proposed 1,000 ha Middle Arm Industrial Precinct, a Land Development Corporation initiative that provides access to industrial and commercial land under the Land Development Corporation Act. The Precinct is designed to accommodate large strategic industrial lots for downstream gas processing and gas related industry with access to an extensive corridor network to carry utilities, gas, feedstock and products (DotE, 2015).

In total, Lot 1817 covers 507 ha. The Darwin Processing Facility will be located predominantly in the southern peninsula of the Lot, with support infrastructure located on the northern peninsula. The proposed development envelope is 270.5 ha, which will accommodate the Processing Facility, Water Recycling Plant, rail siding and service and ancillary infrastructure.

No mangroves will be cleared for the Project and no direct impacts are expected on the marine and coastal environment. Indirect impacts on marine environmental quality are considered in this report.

## 1.2 Purpose and Structure

TNG have engaged Advisian to provide a marine and coastal assessment for the proposed Darwin Processing Facility to support the EIS Supplement. The purpose is to provide a conceptual site model of appropriate scale and complexity to illustrate potential environmental risks to sensitive receptors in the marine environment from proposal activities that may influence marine environmental quality.

The structure of the assessment is to:

- Describe the location characteristics from the perspective of marine environmental quality
- Present the existing environment in terms of the quality of the marine environment
- Identify existing sources of pollution to the marine environment and present the expected impact from the Darwin Processing Facility in the context of the existing sources
- Identify sensitive receptors within the marine environment and sensitivities in relation to the expected impacts from the Darwin Processing Facility

## 1.3 Location Characteristics

### 1.3.1 Darwin Harbour

The Darwin Harbour region covers the tributaries, catchment and estuarine areas of Cox Peninsula, Woods Inlet, West Arm, Middle Arm, East Arm and the Howard River. The Harbour is an estuarine system with semi-diurnal tides (two high tides and two low tides) characterised by strong tidal currents, within which water from the Timor Sea mixes with runoff from the northern Australian land surface (Wilson, Padovan & Townsend, 2004). Unlike the estuaries of other large Australian cities (e.g. Perth, Brisbane), which receive most of their catchment inflow from one large river, Darwin Harbour receives inflow from several major rivers (Howard, Elizabeth and Blackmore) and numerous small streams. Darwin Harbour is also distinguished by the small area of its land catchment relative to its estuarine area, particularly in comparison to other major Australian waterways. This means the area that can potentially generate polluted runoff into the Harbour is relatively small (Moritz-Zimmermann, Comley & Lewis, 2002). Water quality in Darwin Harbour and its catchment is generally good to excellent (Fortune, 2016).

Darwin Harbour supports 20,400 hectares of mangrove communities, representing approximately 5 % of the mangrove areas of the N.T. and 0.1 % of remaining world mangrove regions. These mangrove communities are diverse, accounting for 36 of the (approximately) 50 recognised mangrove species throughout the world (Brocklehurst & Edmeades, 1996).

### 1.3.2 Elizabeth River Estuary

River flows reflect the region's wet and dry seasonal rainfall, with flows typically commencing during December and January, and reaching maximum levels between January and March. By June, most rivers have ceased to flow (Drewry, Fortune & Browne, 2010). Under the Northern Territory Government Department of Environment, Parks and Water Security (DEPWS; formerly the Department of Environment and Natural Resources) Water Quality Objectives (WQO) (Fortune, 2010) the aquatic environment immediately surrounding the proposed project site is considered as Upper Estuary (**Figure 1-1**).

Upper estuary environment is described as the most upstream reaches of the estuary, where hypersaline conditions may persist for short periods during the dry season and significant freshwater pulses prevail during the wet season. This zone experiences limited flushing from freshwater inflows or tidal exchange and water here typically has a long residence time in comparison to other parts of the Harbour. Elizabeth River estuary indirectly receives licensed wastewater discharge from Myrmidon Creek, and sediment and nutrient loads from diffuse sources during the wet season (Fortune, 2010).

**Figure 1-2** presents a conceptual diagram from a 2016 study linking the major ecological risks which Elizabeth River faces into the future. These are broadly associated with water quality and mangrove health, which are elaborated upon in greater detail in the sections below.

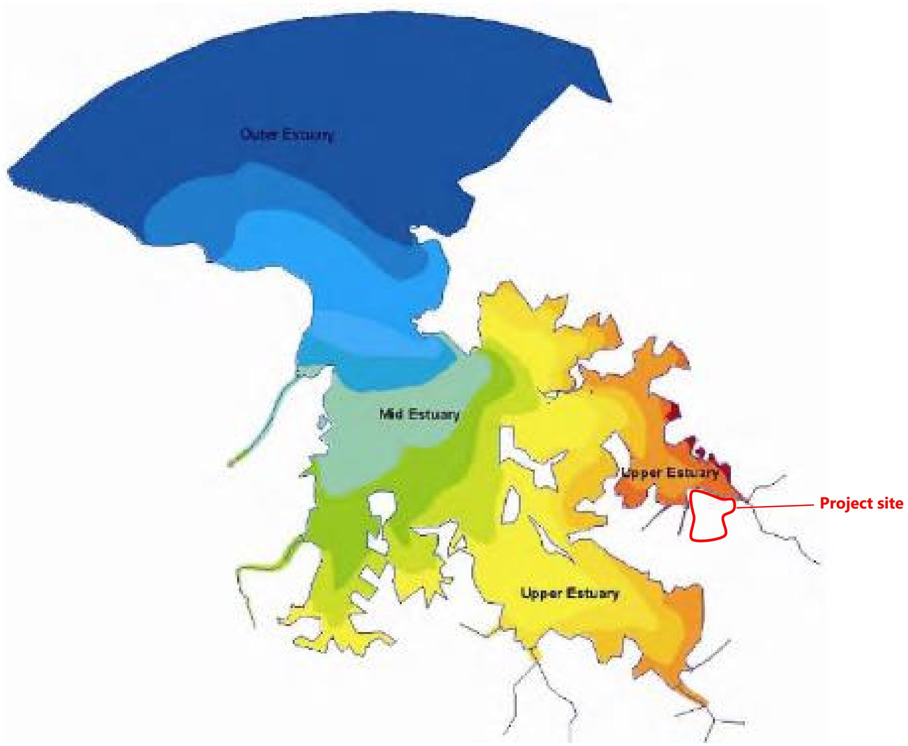



**Figure 1-1 Estuary zonation in Darwin Harbour, with TNG project site indicated in red. Source: Fortune (2010).**

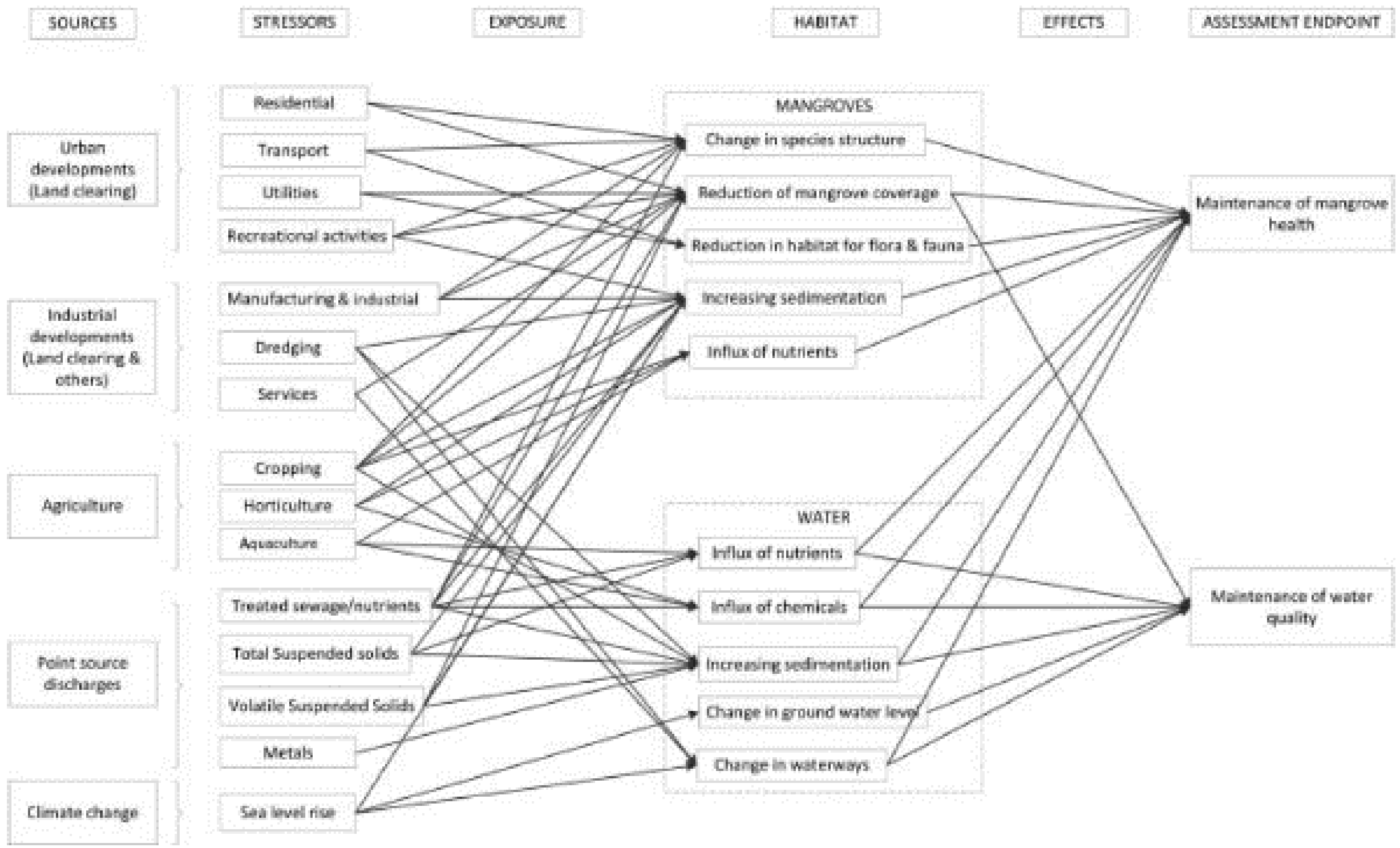


**Figure 1-2. General environmental risk monitoring for Darwin Harbour (Heenkenda & Bartolo, 2016).**

# 2 Water Quality

## 2.1 Darwin Harbour Water Quality Objectives

The Aquatic Health Unit of DEPWS established a set of WQOs for the Darwin Harbour catchment area (Fortune, 2010). The WQOs for Darwin Harbour are designated as Part 7 of the *Water Act 1992 (NT)* as a local guideline level in accordance with the National Water Quality Management Strategy and Australia & New Zealand Environment and Conservation Council (ANZECC) guidelines (Fortune, 2010).

Water quality monitoring has been undertaken in Darwin Harbour by DEPWS (and predecessor organisations) since 1987 and has been summarised annually in a report card format since 2009 (Mauraud, 2013).

### 2.1.1 Water Quality Parameters

A series of indicators and pollutant load targets have been developed and integrated into monitoring programs for Darwin Harbour as performance benchmarks for waterways across the catchment. The following parameters are monitored annually by the DEPWS to assess water quality in the Darwin Harbour region.

**Table 2-1 Water Quality Objectives for the Darwin Harbour region. Source: DLRM, 2009**

| Indicator | | Upper Estuary WQO |
|---|---|---|
| Dissolved Oxygen (DO)% saturation | | 80-100% saturation |
| Chlorophyll-*a* | | <4µg/L |
| Water Clarity | Turbidity (NTU) | NA |
| | Total Suspended Solids (TSS) | <10mg/L |
| Nutrients | Total Nitrogen (TN) | <300µg/L |
| | Nitrogen Oxides (NOx) | <20µg/L |
| | Ammonia (NH3-N) | <20µg/L |
| | Total Phosphorus (TP) | <30µg/L |
| | Filterable Reactive Phosphorus (FRP) | <10µg/L |
| Complimentary | pH | 6.5 - 8.5 |
| | Salinity | NA |
| | Temperature | NA |

Between 2009 to 2012 the results of water quality monitoring were separated for Elizabeth River into freshwater and marine/estuary results, with marine monitoring sites being closer towards the harbour, and freshwater being further up the river into the catchment. From 2013 onwards, all Elizabeth River monitoring sites were combined as Elizabeth River Estuary, after this, all results default to the estuary/marine water quality objectives in **Table 2-1** above. This is reflected in the results tables below.

## 2.2 Elizabeth River Water Quality Monitoring

### 2.2.1.1 *Dissolved Oxygen*

The oxygen in water helps support animals in aquatic systems. Storm water and industrial waste can lower the amount of the oxygen in the water to levels that could be harmful to aquatic animals. Dissolved oxygen (DO) is measured as a concentration (mg/L). Oxygen saturation is the amount of oxygen observed, compared to the amount water naturally holds when in equilibrium with the air (assuming no biological processes), expressed as percentage and varying with temperature and salinity.

The amount of oxygen at 100 % saturation decreases with temperature. The lower holding capacity of warm waters, as well as the higher microbial activity of warm temperatures that use oxygen, makes Darwin Harbour vulnerable to low dissolved oxygen.

The WQO for dissolved oxygen (%) is between 50 to100 % for freshwater and between 80 to100 % for marine/estuarine. After the two were combined from 2013 onwards, the WQO used is the marine level - between 80 to 100 %.

**Table 2-2 Dissolved Oxygen (%) data collected in the Elizabeth River Estuary between 2009 & 2017. Source: DENR (and previous departments), 2009 – 2017)**

| Dissolved Oxygen | | | | | | |
|---|---|---|---|---|---|---|
| Year | | WQO | Min-max | Median | 20th & 80th Percentile | |
| 2009 | Marine | 50/80-100(%) | * | 70-81 | 70 | 81 |
| | Freshwater | | * | 79-92 | 69 | 92 |
| 2010 | Marine | | * | 58-65 | 58 | 65 |
| | Freshwater | | * | 70-82 | 70 | 82 |
| 2011 | Marine | | * | * | * | * |
| | Freshwater | | * | 70-91 | 70 | 91 |
| 2012 | Marine | | * | * | * | * |
| | Freshwater | | * | 87-94.6 | 87 | 94.6 |
| 2013 | | | 51 - 100 | **88** | 81 | 93 |
| 2014 | | | 79.9 – 114.7 | **89** | 82 | 94 |
| 2015 | | | 62 - 110 | **91.2** | 83.3 | 97.8 |
| 2016 | | | * | **>80 - <100** | * | * |
| 2017 | | | * | **>80 - <100** | * | * |

Dissolved Oxygen levels remained between the upper and lower Water Quality Objective thresholds for all monitoring programs undertaken in the Elizabeth Estuary except for 2009, in which the DO (between 70 to 80 %) was found to be slightly below the WQO (>80 %) for marine/estuarine environments. This deviation is minor and thought to be naturally occurring, particularly as DO fell within the WQO in all subsequent years.

### 2.2.1.2 *Water Clarity*

Clear water allows sunlight to reach marine plants to grow, such as seagrass and algae (macroscopic and microscopic) that live on the seabed. Water clarity is affected by the tides, being clearest during neap tides and during the turn of the tides. Water clarity can also be affected by storm water, dredging activity and large amounts of algae.

From 2010 to 2014, Total Suspended Solids (TSS) which is a measure of the amount of particulates in the water column, was used by DEPWS as the measure for water clarity. In 2015, DEPWS switched to using turbidity, which is measured in Nephelometric Turbidity Units (NTU). This method is based on measurement of light scatter through the water column. Both units are included in Error! Reference source not found. below.

**Table 2-3 Water clarity data in Total Suspended Solids (TSS) and Turbidity (NTU) collected in the Elizabeth River Estuary between 2009 & 2017. Source: DENR (and previous departments), 2009 – 2017)**

| Water Clarity: TSS & Turbidity (NTU) | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | TSS (marine): <10mg/L Or TSS (freshwater): <5mg/L | * | **1** | * | * |
| | Freshwater | | * | **4** | * | * |
| **2010** | Marine | | * | **17** | * | * |
| | Freshwater | | * | * | * | * |
| **2011** | Marine | | * | * | * | * |
| | Freshwater | | * | **2** | * | * |
| **2012** | Estuarine | | * | * | * | * |
| | Freshwater | | * | **7** | * | * |
| **2013** | | **TSS: <10mg/L** | 1 - 20.7 | **7.5** | 7.1 | 8.5 |
| **2014** | | | 0.66 – 12.84 | **2.09** | * | * |
| **2015** | | **Turbidity: (NTU): <4** | 1.6 - 21 | **3.4** | 2.6 | 5.2 |
| **2016** | | | <2 - >4 | **<4** | * | * |
| **2017** | | | * | **<4** | <4 | >4 |

Water clarity parameters were found to comply with WQO for most years between 2009 & 2017. Turbidity was found to dramatically exceed the WQO for marine environments in 2010, and to exceed the freshwater WQO for 2012. In 2010, the exceedance was not considered by the Department to be a compliance failure as they were in the process of revising the WQO for this parameter. Water clarity is now assessed using Turbidity measured in (NTU), which was recorded in addition to TSS in 2010, and found to be 3.6 (NTU), thus complying with the revised WQO for this parameter (<4).

#### 2.2.1.3 *Algae*

Algae are aquatic plants. Algae are a natural part of the ecosystem and provide food for large (*e.g.* mangrove snails) and small animals (zooplankton). However, when waters become polluted with nutrients, too much algae can adversely affect the marine ecosystem. The types of algae will also be affected by pollution. Sometimes, large amounts of algae can occur naturally, such as the *Trichodesmium* blooms that occur during the "build-up" months.

To assess the quantity of algae at each sample site, Chlorophyll-*a* concentration is measured. Chlorophyll a concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters.

**Table 2-4 Chlorophyll-a (µg/L) data collected in the Elizabeth River Estuary between 2009 & 2017. Source: DENR (and previous departments), 2009 – 2017.**

| Chlorophyll-*a* | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | **Marine: <4**<br><br>**Freshwater: <2** | * | **2** | * | * |
| | Freshwater | | * | **<1** | * | * |
| **2010** | Marine | | * | **2** | * | * |
| | Freshwater | | * | **<1** | * | * |
| **2011** | Marine | | * | **1** | * | * |
| | Freshwater | | * | **0.6** | * | * |
| **2012** | Estuarine | | * | **1.42** | * | * |
| | Freshwater | | * | **2** | * | * |
| **2013** | | | 0.3 – 2.5 | **1** | 0.8 | 1.2 |
| **2014** | | | 0.39 – 2.04 | **0.8** | * | * |
| **2015** | | | 0.6 – 14.7 | **1.5** | 1.0 | 2.8 |
| **2016** | | | <4 | **<4** | * | * |
| **2017** | | | <4 | **<4** | <2 | >4 |

Algae levels have consistently remained under the WQO threshold for all years in the Elizabeth River estuary.

### 2.2.1.4 *Nutrients*

Nutrients exist both as organic and inorganic species, and in dissolved and particulate forms. Total nutrients are the total amount of nutrient present in all its forms (e.g. total nitrogen (TN) is the sum of the nitrogen present in all nitrogen-containing components). Dissolved nutrients occur as dissolved organic and inorganic forms. Dissolved organic nitrogen can be proteins, amino acids, and urea, while dissolved inorganic nitrogen can take the form of nitrate, nitrite (NOx) and ammonia (NH3-N).

Anthropogenic activities produce increasing amounts of nitrogenous material and a significant proportion is in the form of ammonia or compounds which can yield ammonia.). Ammonia ($NH_3$) is a gas which dissolves in water where it ionises to form the ammonium ion $NH_4^+$. Temperature, salinity and pH all have an impact on the proportion of $NH_3$ compared to $NH_4^+$ in an aquatic environment. Toxicity increases at higher pH values since a greater proportion of the total ammonia is present as NH3, the species to which organisms are most permeable (Eddy, 2005). The WQO for Ammonia in Darwin Harbour is below 20 µg/L.

The Phosphorus pool comprises dissolved (FRP – Filterable Reactive Phosphorus) and particulate forms (PP – Particulate Phosphorus). Total phosphorus (TP) is the sum of the phosphorus present. Nutrient concentrations within the water column are important as nutrients are taken up by phytoplankton which may then form blooms if excess nutrients are present. Phosphorus is made biologically available through the weathering of rocks.

Water quality is assessed by measuring the concentrations of Total Nitrogen (TN), Ammonia (NH3-N), NOx, Total Phosphorus (TP), and Filterable Reactive Phosphorus and the results are presented in Table 2-5 below.

**Table 2-5 Nutrients data is presented for Total Nitrogen, Ammonia, NOx, FRP & Total Phosphorus (measured in µg/L) data collected in the Elizabeth River Estuary between 2009 & 2017. Source: DENR (and previous departments), 2009 – 2017.**

| Nutrients | | | | | | |
|---|---|---|---|---|---|---|
| **Total Nitrogen** | | | | | | |
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | Marine/Estuarine: <300(µg/L) Freshwater: <230(µg/L) | * | **255** | * | * |
| | Freshwater | | * | **170** | * | * |
| **2010** | Marine | | * | **255** | * | * |
| | Freshwater | | * | **170** | * | * |
| **2011** | Marine | | * | **250** | * | * |
| | Freshwater | | * | **170** | * | * |
| **2012** | Marine | | * | **180** | * | * |
| | Freshwater | | * | **140** | * | * |
| **2013** | | | 60 - 530 | **220** | 193 | 260 |
| **2014** | | | 120 - 260 | **170** | * | * |
| **2015** | | | 120 - 1010 | **190** | 150 | 250 |
| **2016** | | | * | * | * | * |
| **2017** | | | * | * | * | * |
| **NOx** | | | | | | |
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | Marine/Estuarine: <8(µg/L) Freshwater: <20(µg/L) | * | **2** | * | * |
| | Freshwater | | * | **6** | * | * |
| **2010** | Marine | | * | **4** | * | * |
| | Freshwater | | * | **4** | * | * |
| **2011** | Marine | | * | **7** | * | * |
| | Freshwater | | * | **5** | * | * |
| **2012** | Marine | | * | **4** | * | * |
| | Freshwater | | * | **13** | * | * |
| **2013** | | | 2 - 25 | **7** | 4 | 10 |
| **2014** | | | 3 - 30 | **9.5** | * | * |
| **2015** | | | 3 - 93 | **13** | 6 | 22 |
| **2016** | | | * | **<10** | <20 | <20 |
| **2017** | | | <20 | **<20** | <20 | <20 |
| **Ammonia** | | | | | | |
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | <20(µg/L) | * | **5** | * | * |
| | Freshwater | | * | **10** | * | * |
| **2010** | Marine | | * | **11** | * | * |
| | Freshwater | | * | **13** | * | * |
| **2011** | Marine | | * | **15** | * | * |
| | Freshwater | | * | * | * | * |
| **2012** | Marine | | * | **11** | * | * |
| | Freshwater | | * | * | * | * |
| **2013** | | | 1 - 21 | **8** | 5 | 11 |
| **2014** | | | 1 – 10 | **2.5** | * | * |
| **2015** | | | 1 - 91 | **20.5** | 11.1 | 26 |

| Nutrients | | | | | | |
|---|---|---|---|---|---|---|
| 2016 | | | * | ~20 | * | * |
| 2017 | | | * | ~5 | * | * |
| **Total Phosphorus** | | | | | | |
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | **Marine/Estuarine: <30(µg/L)**<br>**Freshwater: <10(µg/L)** | * | **15** | * | * |
| | Freshwater | | * | **5** | * | * |
| **2010** | Marine | | * | **13** | * | * |
| | Freshwater | | * | **10** | * | * |
| **2011** | Marine | | * | **15** | * | * |
| | Freshwater | | * | **15** | * | * |
| **2012** | Marine | | * | **15** | * | * |
| | Freshwater | | * | **35** | * | * |
| **2013** | | | 5 - 15 | **10** | 5 | 10 |
| **2014** | | | 5 - 15 | **5** | * | * |
| **2015** | | | 5 - 10 | **9** | 5 | 16.9 |
| **2016** | | | * | * | * | * |
| **2017** | | | * | * | * | * |
| **Filterable Reactive Phosphorus** | | | | | | |
| **Year** | | **WQO** | **Min-max** | **Median** | **20th & 80th Percentile** | |
| **2009** | Marine | **Marine/Estuarine: <10(µg/L)**<br>**Freshwater: <5(µg/L)** | * | **4** | * | * |
| | Freshwater | | * | **1** | * | * |
| **2010** | Marine | | * | **4** | * | * |
| | Freshwater | | * | **3** | * | * |
| **2011** | Marine | | * | **4** | * | * |
| | Freshwater | | * | **5** | * | * |
| **2012** | Marine | | * | **0.25** | * | * |
| | Freshwater | | * | **0.5** | * | * |
| **2013** | | | 1 - 7 | **2** | 1 | 4 |
| **2014** | | | 2 - 9 | **4** | * | * |
| **2015** | | | 1 - 13 | **1** | 1 | 2 |
| **2016** | | | >10 | **>10** | * | * |
| **2017** | | | >10 | **>10** | * | * |

Results remained beneath the WQO threshold for the estuary for all years for Total Nitrogen (<300µg/L), NOx (<8/20µg/L) and FRP (<5/10µg/L) for all years.

Minor exceedances of the WQO for Ammonia (<20µg/L) occurred in 2015, this could be due to discharge from terrestrial sources caused by runoff, however it is a minor exceedance (20.5 µg/L) that has not been repeated in subsequent monitoring surveys.

Total Phosphorus exceeded WQO for both marine and freshwater upper estuary environments in 2015. Excess loadings of such Phosphorus may contribute to common water quality problems such as eutrophication and algal blooms and are likely to reduce the habitat quality of in-stream water and receiving estuaries (Drewry *et.al.,* 2009). As these results were not repeated in following years it is likely that these exceedances were the result of exceptional weather events in the respective years, caused by inflows in the upper reaches of the estuary.

#### 2.2.1.5 *Complimentary Parameters*

Data is also collected for pH, water temperature and salinity. These are all known to have an impact on the toxicity of certain nutrients in aquatic environments and are useful for assessing the effect of the WQO parameters on marine biodiversity in the harbour. WQO's have not been established for temperature or salinity, however the objective for pH is between 6.5 and 8.5.

## 2.3 Overall Condition

The general quality of each section of Darwin Harbour is summarized into a report card with a water quality score for each region, depending on their compliance with the Department's WQOs. These are as follows:

**A.** Excellent water quality. All four water quality indicators meet desired levels

**B.** Very good water quality. Three water quality indicators meet desired levels.

**C.** Good water quality. Two water quality indicators meet desired levels.

**D.** Poor water quality. Only one water quality indicator meets desired levels.

**E.** Very poor water quality. No water quality indicators meet desired levels.

The scorecard for results for the Elizabeth River from 2009 to 2017 are listed in Table 2-1Table 2-6.

**Table 2-6 Scorecard results for Elizabeth River sampling 2009 - 2017 (Source: DENR, 2010-2017)**

| Year | Elizabeth River Score | | Number of Sample Sites | Number of Samples |
|---|---|---|---|---|
| | Marine/Estuarine | Freshwater | | |
| 2009 | C | A | 30 | 30 |
| 2010 | A | A | 8 | 15 - 18 |
| 2011 | A | B | 8 | 58 - 63 |
| 2012 | A | C | 27 | 34 |
| 2013 | A | | 18 | 91 |
| 2014 | A | | 17 | 32 |
| 2015 | B | | 18 | 88 |
| 2016 | A | | 9 | 18 |
| 2017 | A | | * | * |

* no available data

The Elizabeth River upper estuary region that surrounds the proposed project site was compliant with water quality objectives for every year between 2009 – 2017 except 2015. In 2015 the median recorded value for Ammonia levels (20.5µg/L) was 0.5µg/L higher than the water quality objective for the upper estuary levels (20µg/L). This small exceedance was not however repeated in the 2016 or 2017 monitoring results, which demonstrate that water quality in the Elizabeth River estuary that surrounds the proposed project site is in excellent condition. This is generally consistent with other zones in Darwin Harbour, with 6 out of 9 water monitoring zones scoring 'A' in 2017, 2 scoring 'B' and only one – Buffalo Creek – scoring an 'E' by failing to comply with all four WQOs.

## 2.4 Myrmidon Creek Water Quality Monitoring

Myrmidon Creek lies to the North of the proposed refinery project site and offers insights into the effects of development and terrestrial discharge on water quality. Myrmidon Creek receives discharge from a sewage treatment plant which services Palmerston and surrounding areas. The influence of the discharge entering the creek appears to be largely confined with no discernible impact to water quality detected downstream at the mouth. Pollutant loads from rural and urban areas during the wet season enter the estuary from the upper reaches where mixed land uses prevail (Fortune & Patterson, 2015).


**Figure 2-1 Myrmidon Creek in relation to the proposed project site (in red). Source: Fortune & Patterson (2015).**

Myrmidon has typically scored C and B (**Table 2-7**) in the water quality report cards, complying with only two or three of the four overall WQOs respectively. Often failing for nutrient levels, as well as water clarity or dissolved oxygen parameters, with highest values of ammonia, total nitrogen and total phosphorus found at sites closest to the Myrmidon Creek outfall. Despite this outfall, Myrmidon Creek water quality remains good and has not deteriorated significantly between 2009 & 17.

**Table 2-7 Myrmidon Creek water quality scores 2009 - 2017.**

| Year | Myrmidon Creek Water Quality Score |
|---|---|
| 2009 | * |
| 2010 | C |
| 2011 | * |
| 2012 | C |
| 2013 | C |
| 2014 | C |
| 2015 | B |
| 2016 | B |
| 2017 | B |

Elizabeth River estuary indirectly receives wastewater discharge from Myrmidon Creek, and sediment and nutrient loads from diffuse sources during the wet season.

# 3 Pollutant Sources

**Figure 3-1** presents a graphical Conceptual site model of the Elizabeth River Estuary major point and diffuse pollutant sources. As shown in **Figure 3-1**, the Elizabeth Estuary receives pollutant loads from both point and diffuse sources. Point sources include the Palmerston wastewater treatment plant and INPEX Ichthys Gas Field Development project, these are discussed in further detail below. A general assessment of load contributions is shown in **Figure 3-2**.

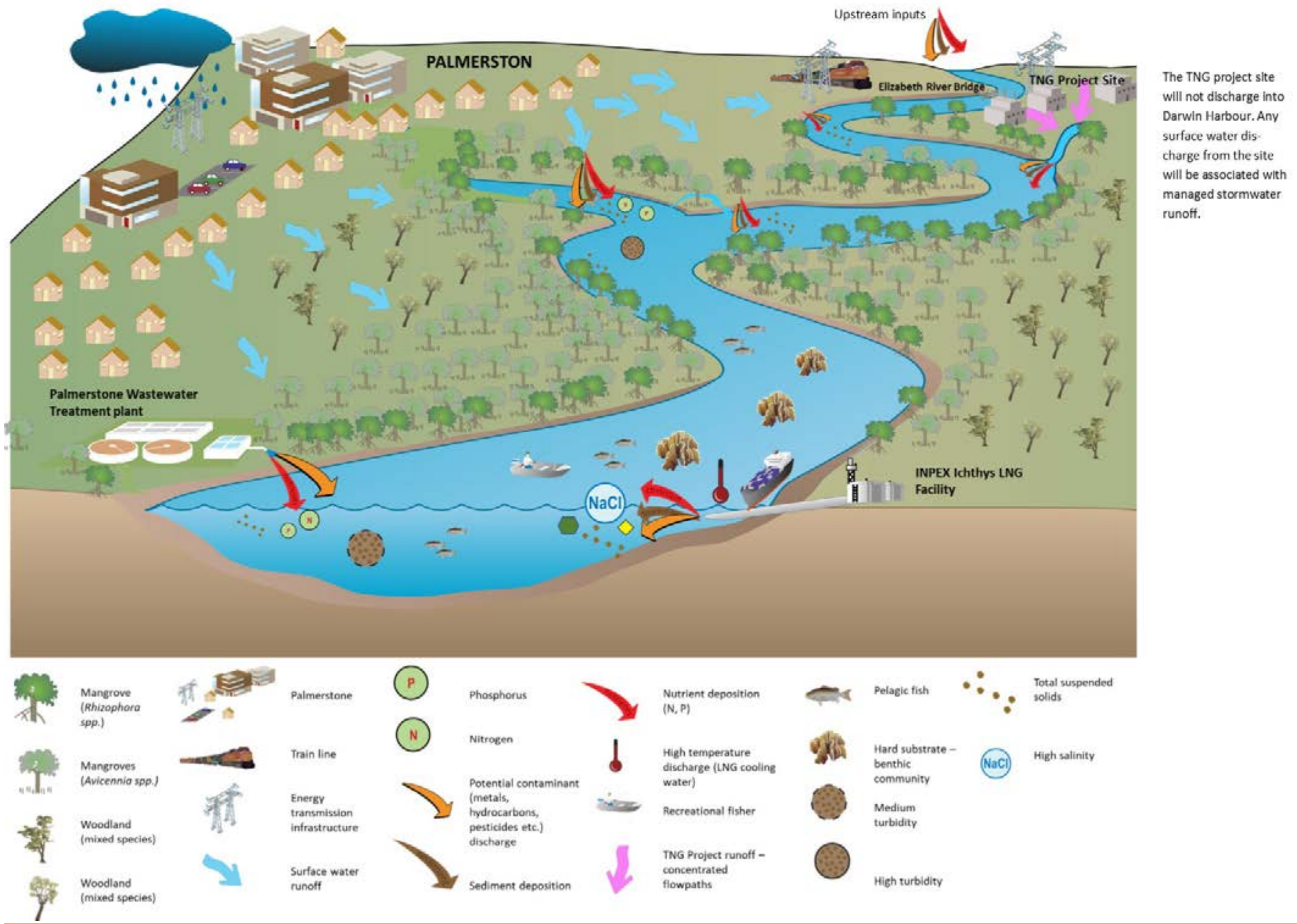


**Figure 3-1 Conceptual site model of the Elizabeth River Estuary major point and diffuse pollutant sources. (Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science [ian.umces.edu/symbols/]).**

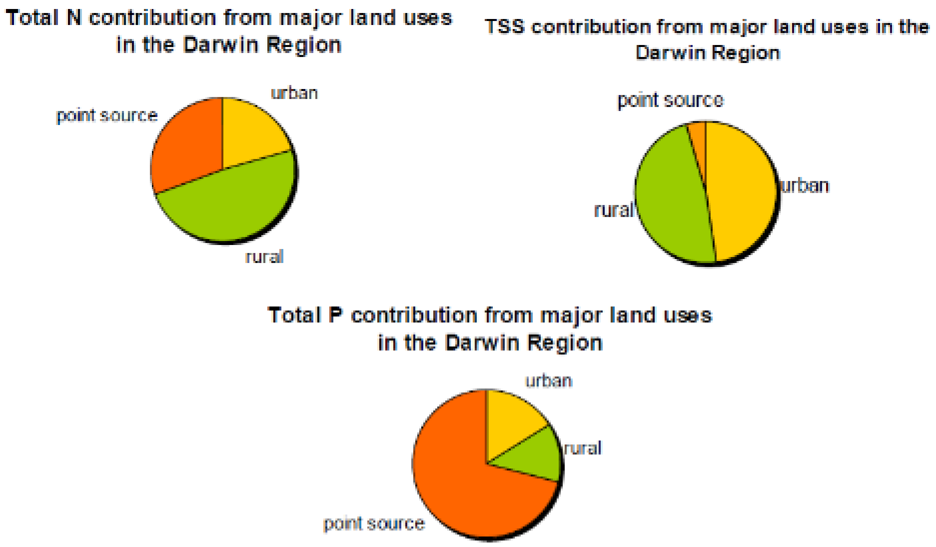


**Figure 3-2 Relative load contributions from major land uses into Darwin Harbour (Skinner, et al., 2009)**

The impacts of pollutants on marine biota are discussed further in **Section 4**.

## 3.1 Diffuse sources

Darwin experiences dry and wet seasons in an annual cycle. Around 80 % of its rainfall occurs between the months of December to March, with an annual rainfall of 1600 mm (Wilson, Padovan & Townsend, 2004). This dramatic seasonal variation in rainfall has water quality impacts on the region, particularly in terms of runoff, discharge and freshwater inflows from the major rivers.

River flows reflect the region's rainfall, with flows typically commencing during December and January, and reaching maximum levels during periods of heavy rainfall between January and March. By June most rivers have ceased to flow with the exception of Darwin and Howard Rivers, and the spring-fed Berry Creek. Correspondingly, diffuse discharge is negligible in the dry season as flows to many of the seasonal creeks which enter the estuary cease to flow by June most years. Diffuse discharge is associated with wet season flows and is typically accompanied by a series of intense pulses of freshwater together with the contaminants it carries (Drewry, Fortune & Browne, 2010).

Diffuse, or non-point, sources such as urban and rural storm-water, leaching through soil, river bank erosion, and roads mainly enter Darwin Harbour during the wet season (**Figure 3-3**).

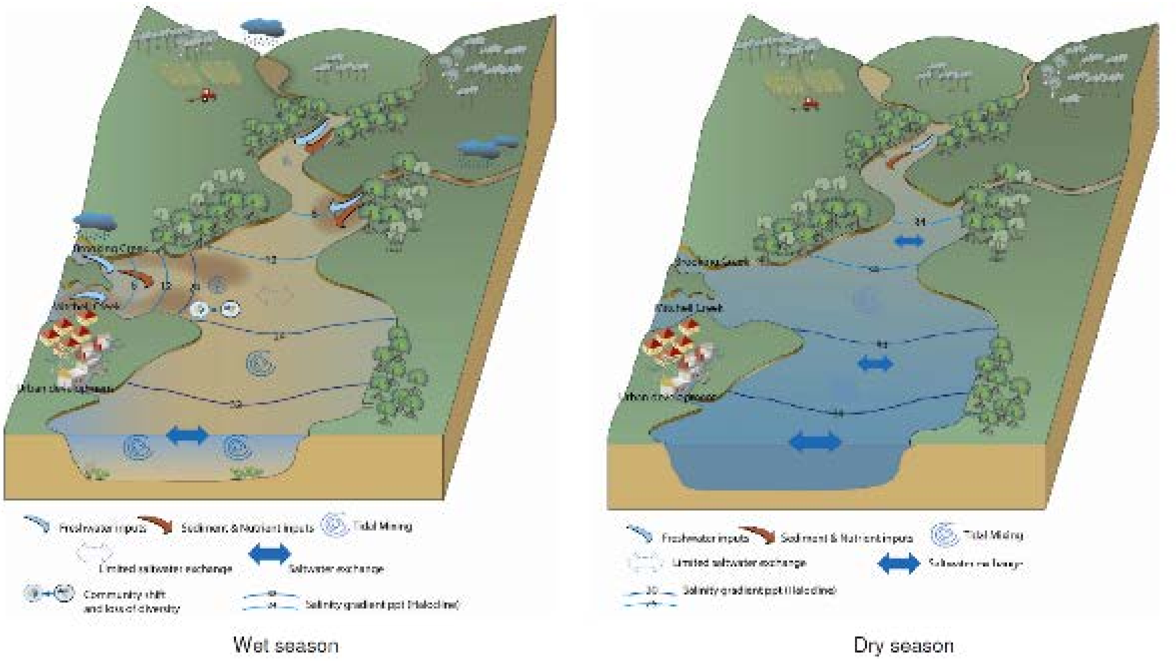


**Figure 3-3 Elizabeth River estuary pollution sources, processes and ecology in the wet and dry seasons. Source: Drewry, Fortune & Browne (2010).**

Urban development such as the city of Palmerston or Weddell approximately doubles the volume of runoff into Darwin Harbour in any given wet season. In addition, pollutant loads increase with rainfall due to the increased runoff volume across all catchment land-uses; hence more runoff results in more pollutant transport (Skinner, et al., 2009). Stormwater is a natural part of the hydrological system, however it can act as a pathway for pollutants to be transferred from terrestrial settings into the marine environment.

## 3.2 Point sources

As shown in **Figure 3-1**, there are two main point sources within the estuary, these are discussed further below.

### 3.2.1 Palmerston Wastewater Treatment Plant

This wastewater treatment facility is location on the southern side on Myrmidon Creek, near to the river bank on the coastal side of Palmerston. The discharge point is approximately 850 meters from the mouth of the creek, where it is around 100 meters wide and six meters deep at high tide.

There is a distinct green sewage plume which enters the creek at the discharge point. The plume, typically restricted to the surface layer, is low in dissolved oxygen and enriched in nutrients, suspended matter and chlorophyll-a. The plume gradually disperses during the ebb tide and is rapidly diluted and mixed, becoming undetectable within a few hours.

The layout of the facility is shown in Figure 3-4, and a diagram of the discharge plume Figure 3-5.

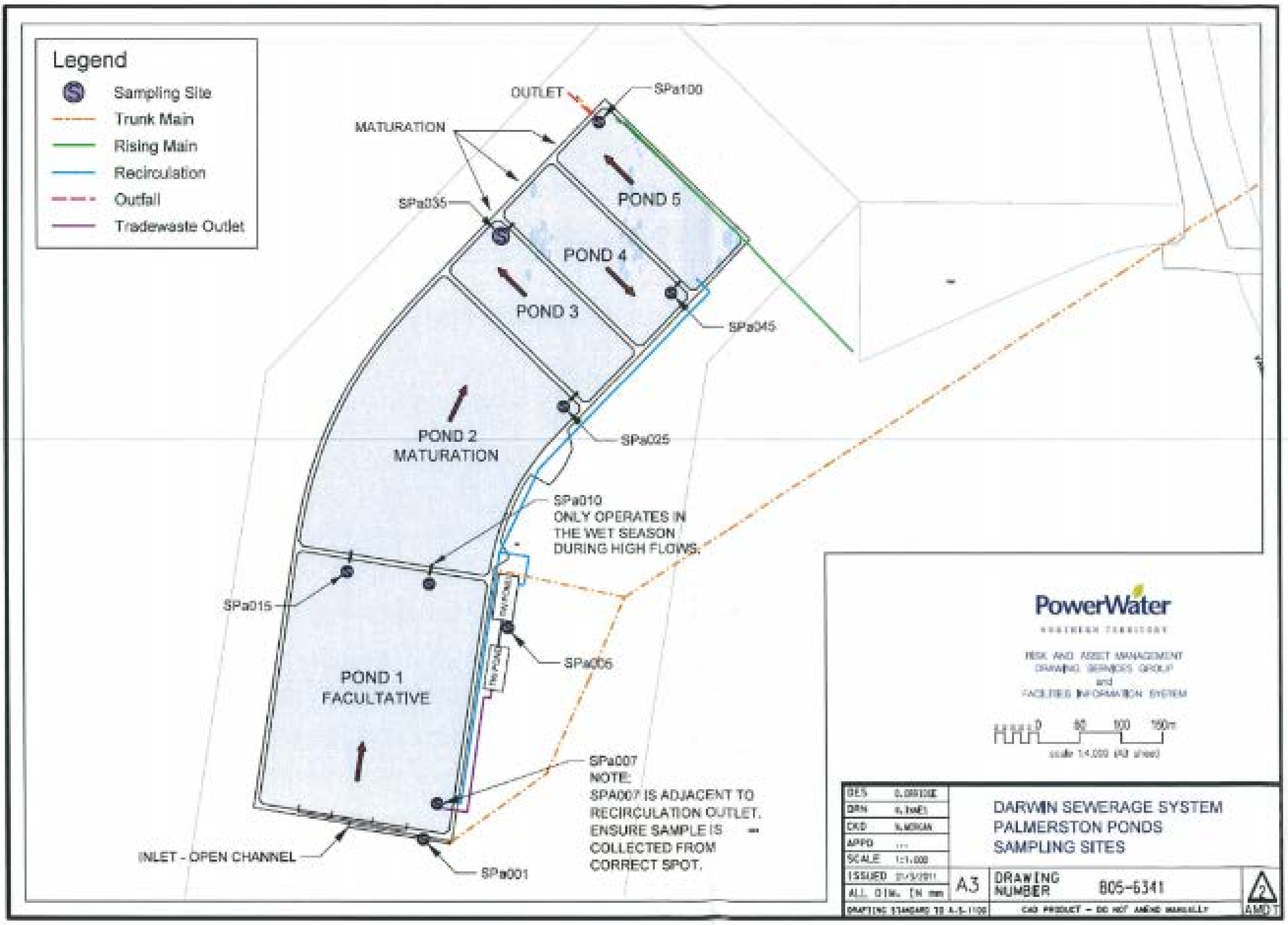


**Figure 3-4 Palmerston wastewater treatment plant site layout.**

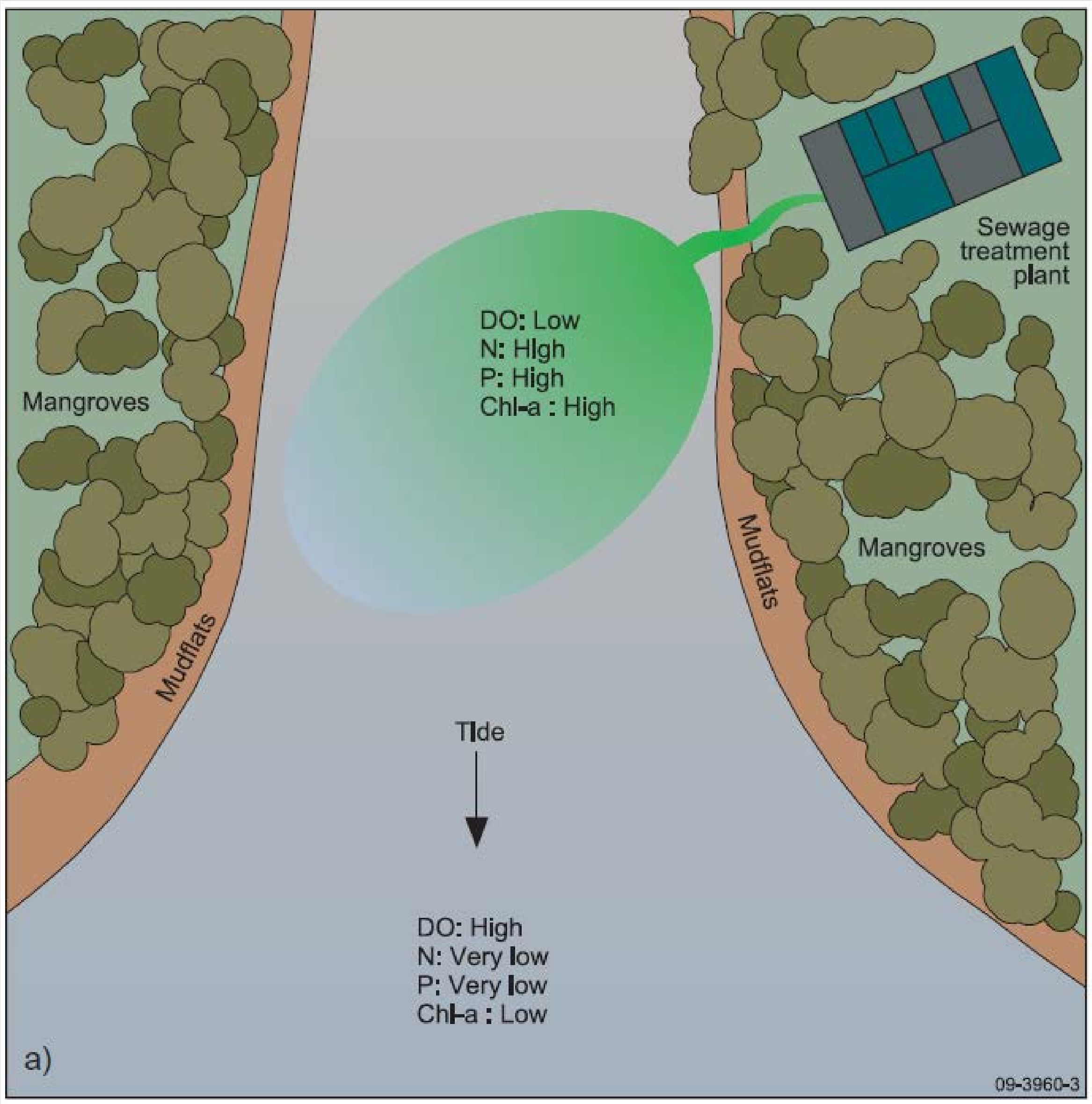


**Figure 3-5 Discharge point at Mymidon Creek with nutrient and oxygen conditions.**

Discharges from this wastewater treatment plant are associated with increased nutrient, toxicant and pollutant loads, which can result in increased algal growth, accumulation of pollutants in sediments. The effects of this discharge are localised, and temporary.

### 3.2.2 INPEX Ichthys Gas Field Development Project (Blaydin Point)

INPEX's Ichthys gas field development Blaydin Point project is the closest major project to the TNG Project site, located near to the mouth of the Elizabeth River.

A summary of liquid discharges associated with this project is presented in **Table 3-**, though it must be noted that several of these are associated with the offshore gas field development, which is a long distance from Darwin Harbour. Most notable discharges into the harbour include produced water, cooling water and desalination reject water. Most of these discharges are associated with increased salinity and turbidity.

**Table 3-1 Summary of liquid discharges associated with the INPEX Ichthys Gas Field Development Project (INPEX, 2010)**

| Discharge stream | Drilling (intermittently over c.20 years) | Pipelay (c.1 year) | Construction and commissioning (4–5 years) | Operations (c.40 years) | Decommissioning (c.1 year) |
|---|---|---|---|---|---|
| Drilling discharges | ✓ | – | – | – | – |
| Subsea completion and control fluids | – | – | ✓ | ✓ | – |
| Hydrotest water | – | – | ✓ | – | – |
| Produced water | – | – | ✓ | ✓ | – |
| Cooling water | – | – | ✓ | ✓ | – |
| Sewage and grey water | ✓ | ✓ | ✓ | ✓ | ✓ |
| Desalination reject water | ✓ | – | ✓ | ✓ | – |
| Deck drainage | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ballast water | ✓ | ✓ | ✓ | ✓ | ✓ |

Production water is discharged from the facility FPSO directly into the marine environment as well as cooling water and desalination brine all routinely discharged from vessels and facilities into the marine environment.

Production water causes a reduction in water quality associated with elevated concentrations of dispersed oil, metals and production chemicals, as well as increased toxicity to marine biota. Discharge of highly saline desalination brine into the marine environment at the central processing facility and FPSO increases salinity of the surrounding waters.

Large volumes of seawater are used to cool the gas-processing facilities and are then discharged back into the marine environment at around 40-50 degrees Celsius.

## 3.3 TNG Processing Facility Project Site

The TNG Processing Facility will not discharge any wastewater, treated or otherwise, into Darwin Harbour. All Process water and contaminated water will be directed to the WRP for treatment and recycled back into the Process circuit. Process areas will be bunded and potential sources of contamination will have separate drainage systems that direct to the WRP. In the normal course of operations it is not expected that Process chemicals will have a pathway to the marine environment.

Any surface water eventuating into Darwin Harbour will be from stormwater runoff, the management of which is described in the Stormwater Management Plan (SWMP). In brief, stormwater will be collected and treated using infrastructure designed to guideline specifications. Stormwater discharge locations are dispersed around the site and on land in proximity to natural flowpaths.

Increased peak flow of stormwater is expected to occur as a result of the Project due to the increase in impermeable surfaces. This is not a point source in the same way as those described for the Palmerston Sewerage Treatment Plant or INPEX. The flow of runoff is diffuse however, for the purposes of this assessment runoff has been modelled to be mainly concentrated into two specific flow-paths as the diffuse pathways will merge together in the ocean environment due to the topography and geography.

The two concentrated flowpaths have been incorporated into the conceptual site diagram in Figure 3-1. Increased runoff from roads and non-process land uses within the Project Development Envelope, may act as a pathway for pollutants and transport onshore nutrients, incidental hydrocarbons or metals, and increase the concentration of total suspended solids (TSS) in the nearshore marine environment. Stormwater quality objectives have been incorporated into project planning, to ensure that runoff pollutant loads are below the legislative threshold.

Hydrocarbons and heavy metals bioaccumulate in the tissues of living organisms. In some instances, the level of a contaminant in the tissues of one organism does not elicit any toxic effect at all but may constitute a danger to its predators. Heavy metals are poorly soluble in water, tending to adsorb onto suspended particulate matter in the sea, and affect marine organisms. Metals can be subdivided with Mn, Fe, Co, Cu, Zn, and Mo all elements essential for the growth and life cycles of organisms but are toxic at high concentrations, while Pb, Hg, and Cd can be toxic even at low concentrations.

An increase in TSS resulting from sediment resuspension can directly and indirectly impact estuarine ecosystems at all trophic levels due to a reduction in light availability.

As shown in Figure 4-4 the nearshore environment surrounding the project site consists of medium-low density filter feeders (corals, algae, sponges and soft corals), bare sand (mud flats or bars) and mangroves). Filter feeders are sensitive to sedimentation, mangrove/sand-dwelling molluscs and crustaceans are susceptible to penetration by heavy metals and hydrocarbons can deleteriously impact organisms across all trophic levels. Stormwater runoff and minimizing potential pollutant loads have been considered in the early design stages of the project. The design of the stormwater minor and major conveyance systems, minor diversion systems and other stormwater management features (such as Stormwater Quality Improvement Devices (SQUIDs), bioretention basins etc) are expected to be undertaken during the detailed design phases of the project once site layouts and design constraints are finalised. As such, any pollutant loads in surface water runoff from the project are expected to be minor and the impacts on the nearshore marine environment minimal and limited to localized in scale.

# 4 Ecological Characteristics

Figure 4-1 presents a Conceptual site model of the ecological characteristics of the Elizabeth River Estuary and general risks associated with major point and diffuse pollutant sources. This section identifies the sensitive receptors in the marine environment indicating the specific sensitivities in relation to those expected to arise from the Project.

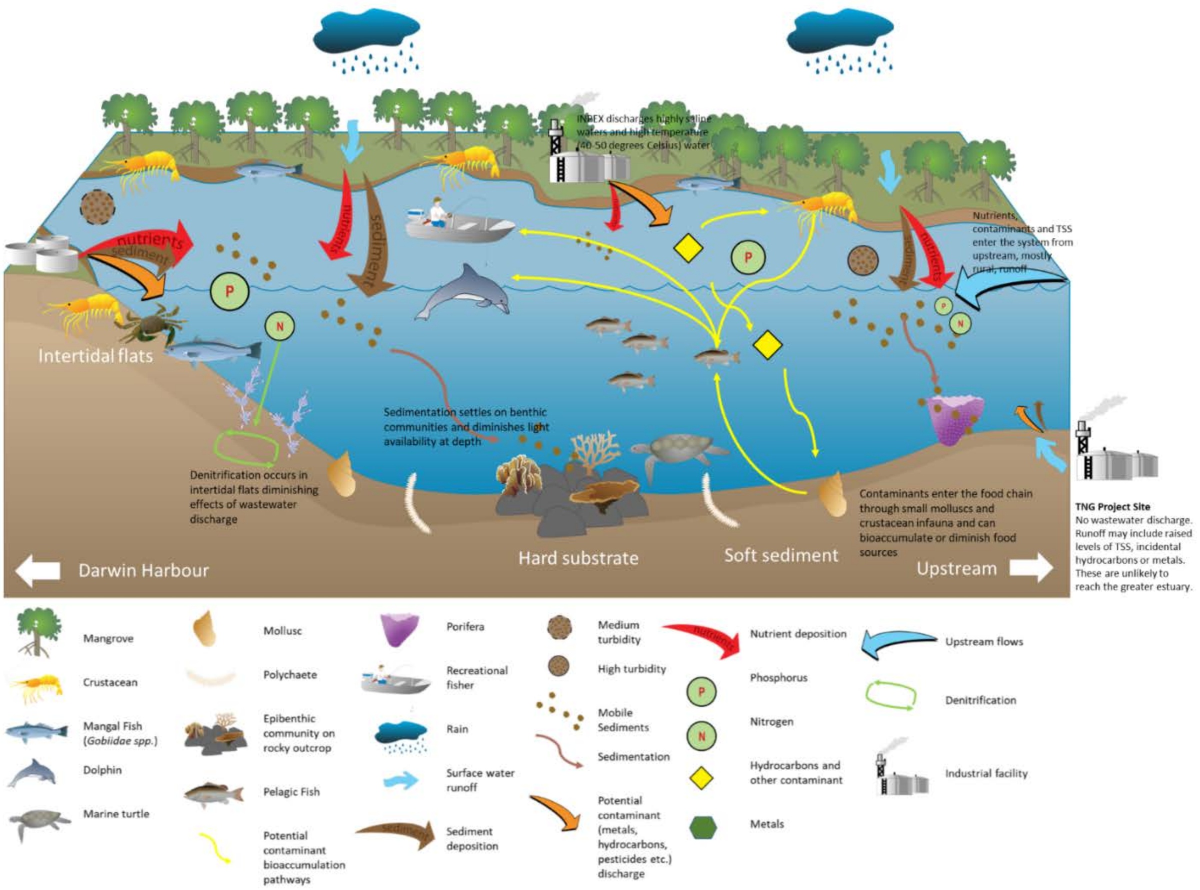


**Figure 4-1 Conceptual site model of the ecological characteristics of the Elizabeth River Estuary and general risks associated with major point and diffuse pollutant sources. (Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science [ian.umces.edu/symbols/]).**

## 4.1 Marine Biota

The Elizabeth River estuary supports a wide variety of marine ecosystems, as well as resident and transient marine organisms. The Estuary is characterised by dense mangrove zones, intertidal mudflats and a seasonal difference in turbidity and salinity. As expected, the harbour end of the river is more saline than upstream, while the turbidity increases in the opposite direction excluding some marine organisms. The entrance to the estuary is characterized by coral and sponge gardens, for example surrounding South Shell Island (SSI), which has high biodiversity.

The organisms and habitats within the estuary are influenced by water quality and composition associated with seasonal or persistent discharge from both point and diffuse sources. This is represented in Figure 4-1 and is discussed in detail below.

### 4.1.1 Invertebrates

Elizabeth River's invertebrate fauna is largely representative of the greater Darwin Harbour region. A significant sampling effort conducted in 2012 found Elizabeth River to have higher species richness for both molluscs and fish (discussed below) than Middle Arm and Blackmore River. During this survey, crustaceans were most abundant (92.5% of all individual organisms recorded).

No marine invertebrates identified in the harbour are listed as threatened or of conservation significance. However, the marine invertebrates in the harbour region are essential for functional ecosystems which support a wide variety of species and provide ecosystem services to the Darwin community, including recreational fisheries.

The major taxonomic invertebrate groups in Darwin Harbour include:

#### 4.1.1.1 *Sponges*

Extremely biodiverse in the Northern Territory, however Darwin Harbour represents around 10% of the known diversity of the greater region. Sponges are found on hard substrates as a transition between reef and subtidal mudflats, as well as on soft-bottom substrates. Sponge gardens play an integral role in the productivity of the ecosystem and provide essential habitat for small fish and many invertebrates.

#### 4.1.1.2 *Corals*

Darwin Harbour has generally low diversity of soft corals, thought to be associated with the higher turbidity in parts of the Harbour. Hard corals are highly biodiverse but restricted to areas with hard substrates and strong currents. Around Elizabeth River, hard corals are restricted in depth (between mean sea-level and 10m deep) by light availability due to the increased turbidity.

#### 4.1.1.3 *Hydroids*

At least 72 species of hydroids have been identified in Darwin Harbour, with seven species found only in this region. They require hard substrate to attach to so are found mostly in these areas of the harbour.

#### 4.1.1.4 *Marine worms*

Polychaetes worms are most diverse and abundant where subtidal reefs are followed by subtidal mud flats and intertidal mud flats. Polychaetes are found over a wide variety of habitats.

#### 4.1.1.5 *Echinoderms*

Several species, many of which are endemic, are found in Darwin Harbour but are potentially at risk of increased human activity including redistribution of sediment or increased river silt from human development.

#### 4.1.1.6 *Molluscs*

Compared to other nearby regions, Darwin Harbour is not as biodiverse for molluscs, however in terms of abundance they are one of the most dominant taxa in the harbour.

#### 4.1.1.7 *Crustaceans*

There are an estimated 1000 crustacean species in the harbour region, with a high abundance of decapods (crabs, prawns, shrimps, lobsters) associated with the harbour's mangrove environments. The Harbour crustacean diversity is dominated by two shrimp species, *Acetes siboga* and *Caridea spp*.

Crustaceans play an import role in the trophic structure in marine ecosystems. Many decapods graze on the substrate for algae and detritus; copepods are an important component of the marine plankton and provide a major food source for many small and juvenile fish; shrimps, prawns and crabs are an important food source for many species of fish; isopods feed in great numbers on dead fish. Consequently, any changes in the marine environment which impact on crustacean abundance will affect those species that use crustaceans as a food source. Conversely, if the fish composition is modified this may have an impact on decapod fauna with a cascading effect on habitat structure and ecosystem function.

### 4.1.2 Fish

Elizabeth River estuary is home to a number of resident and transient pelagic fish species. While commercial fishing is not allowed within Darwin Harbour, many species are the target of recreational fishers. Indigenous fishers most commonly aim for fishes with mangrove habitat as juveniles, such as trevallies (*Caranx spp*.), mackerel (*Scomberomorus semifaciatus)*, salmon, (*Eleutheronema tetradactyilum* and *Polydactus macrochir)*, Spotted Javelinfish (*Pomadasys kaakan*) and barramundi (*Lates calcarifer*). A 2012 hook and line survey of the Elizabeth River (in Smit et al, 2012) found 22 different fish species in the river, with 72% of the total catch consisting of Snapper (*Lutjanus russellii*), Seabream (*Acanthopagrus berda*), Snapper (*Lutjanus johnii*), Spotted Javelinfish (*Pomadadys kaakan*) and Grass Emperor (*Lethrinus laticaudis*) (**Figure 4-2**). Most of these species are target species for recreational fishers.

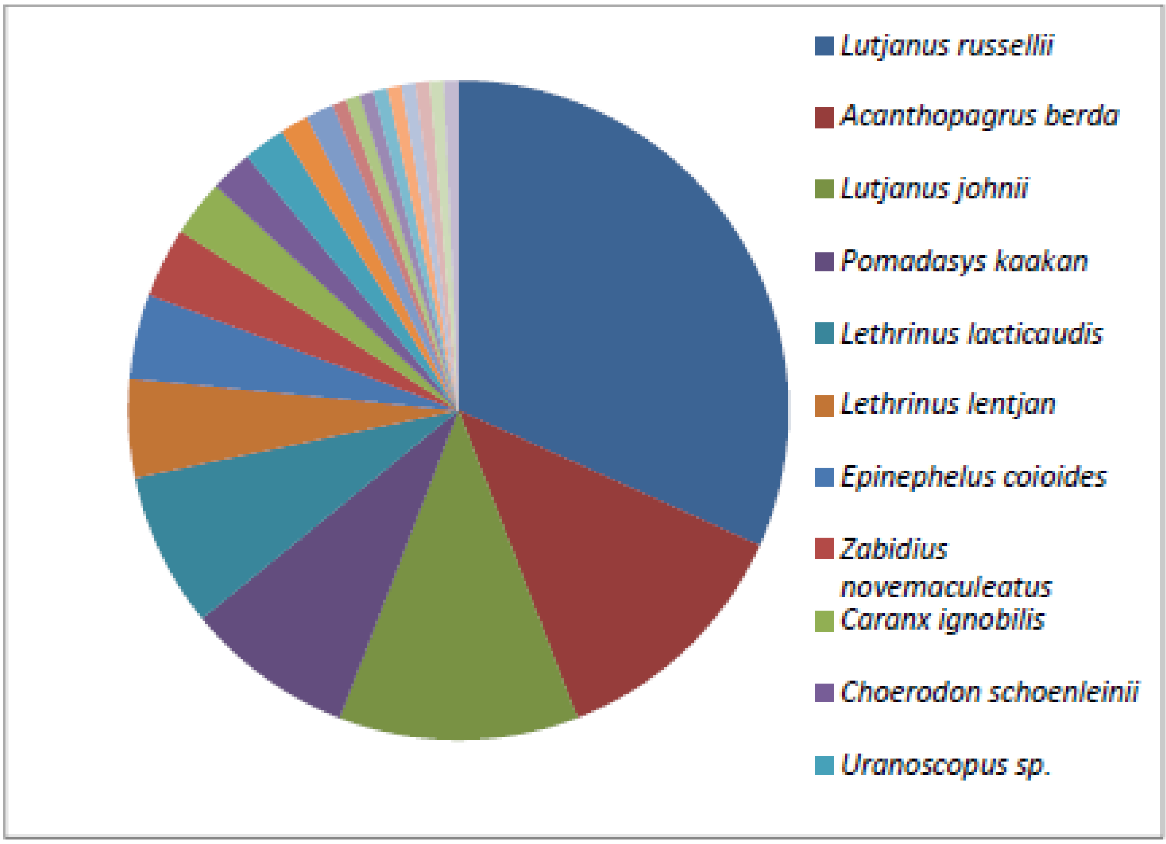


**Figure 4-2 Fish collected during 2011 hook and line surveys in Elizabeth River (Smit et al., 2011)**

This hook and line survey very likely under-represents fish diversity and abundance in the Elizabeth River Estuary as the method does not account for mangrove fish assemblages. Further grab and beam trawl surveys (Smit et al., 2012) represented 61 species, mostly small bottom-dwelling species due to the nature of the sampling method. The most abundant (40 %) were Gobies (family *Gobiidae)*, followed by gudgeons (famly *Eliotridae*).

Estuaries have an important role as the nursery for many species of marine fish. Coastal wetlands, such as mangrove forests, are important nursery sites for juvenile fish and crustaceans. For example Moses' Snapper - an important commercial and recreational fish - spend their early life stages in estuarine waters.

Virtually all habitats, including shallow intertidal areas play an important role in the ecological functioning of the Harbour. At high tide all habitats in all locations became available for fish and appeared to be important feeding areas for them. All abundant species are important prey species for recreationally harvested species. Depending on their location in the Harbour, different habitats appear to be important for different species and groups of fish. The conservation role of Elizabeth River Estuary is important for supporting Darwin Harbour fish biodiversity.

### 4.1.3 Seabirds

Darwin Harbour offers habitat for a number of resident and migratory seabird species. Frigatebirds, boobies, terns, noddies, tropicbirds, petrels, shearwaters and gulls all found in the Elizabeth River Estuary. Of these, several migratory species are listed under the EPBC Act, such as the Streaked Shearwater (*Calonectris leucomelas*), Masked booby (*Sula dactylatra*), lesser frigatebird (*Fregata ariel*), lesser crested tern (*Thalasseus bengalensis*) and little tern (*Sternula albifrons*).

Mangroves in Darwin Harbour provide important habitat for resident and refuge for migratory bird species.

### 4.1.4 Marine mammals & other vertebrates

Darwin Harbour provides resident or transient habitat for dolphins, dugongs, marine turtles, marine snakes and saltwater crocodiles.

#### 4.1.4.1 *Dolphins and Dugongs*

Three species of coastal dolphin, Australian snubfin (*Orcaella heinsohni*), Indo-Pacific humpback (*Sousa chinensis)* and Indo-Pacific bottlenose (*Tursiops aduncus*), are resident in the harbour and one offshore false killer whale (*Pseudorca crassidens*) is an irregular visitor. Dugongs are also known to occur in the harbour, mostly associated with seagrass meadows.

The most commonly sighted is the Indo-Pacific Humbpack, then the Indo-Pacific bottlenose. All three resident species use the area for breeding. Bottlenose dolphins are rarely seen on the western side of the harbour, or in turbid, muddy waters. East Arm is important foraging habitat.

Dolphins have been found to travel long distances (20 to 50 km) upstream in other locations, however monitoring shows that sightings of all three species further up the Elizabeth Estuary than Blaydin Point are rare. It is also rare for dugongs to be seen past Blaydin Point, although potential foraging habitat can be found almost throughout the estuary. Dugongs could be found anywhere that supports seagrass or algae, which is all areas with hard-substrate bottom less than 10m in depth, and areas of rocky reef such as South Shell Island.

#### 4.1.4.2 *Marine Turtles*

Of the six species of marine turtles found in the Northern Territory, the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) turtles regularly utilize Darwin Harbour.

Turtle occurrence in the harbour is likely to be associated with foraging, as the harbour is largely fringed with mangrove forests, there is little habitat for nesting within the harbour. All three of these species have been observed on the reefs around the islands in the Elizabeth River (Catalina Island). While all three travel upstream in the estuary the herbivorous Green Turtle is observed most frequently upstream, likely due to its ability to feed on mangroves. All three species are listed as vulnerable under Commonwealth legislation.

#### 4.1.4.3 *Marine Snakes*

The harbour is home to several marine snake species, including species of file snake (*Acrochordidae*), mud snakes (*Homalopsinae*) and true sea snakes (*Hydrophiidae*). While marine snake monitoring is difficult, and largely opportunistic, there have been several recorded observations in the Elizabeth River, as far as the Elizabeth River Bridge. There is suitable habitat throughout the Elizabeth River Estuary so marine snake occurrence upstream is likely.

### 4.1.5 Benthic communities

The majority of Elizabeth River consists of soft-bottom habitat, characterized by mobile sediments. These sediments are typically inhabited by molluscs, polychaetes and crustaceans. Epibenthic communities are generally associated with hard substrates, Generally, these areas are found in seafloor depressions Elizabeth River or rocky outcrops at the mouth of the river. The deeper depressions are characterised by soft sediments and may have large amounts of organic matter.

Only 9 % of the hard substrates found in Elizabeth River were found to be bare (Smit, et al., 2012). Hard substrate communities within the phototrophic zone (below mean sea-level height), such as the northern part of Elizabeth River, are best described as mixed communities with varying degrees of cover of corals, alga, sponges, gorgonians, hydroids, with no species group having more than 40 % cover. Geomorphology for the Elizabeth River is presented below in **Figure 4-3**, and the benthic community composition for the river in **Figure 4-4**.

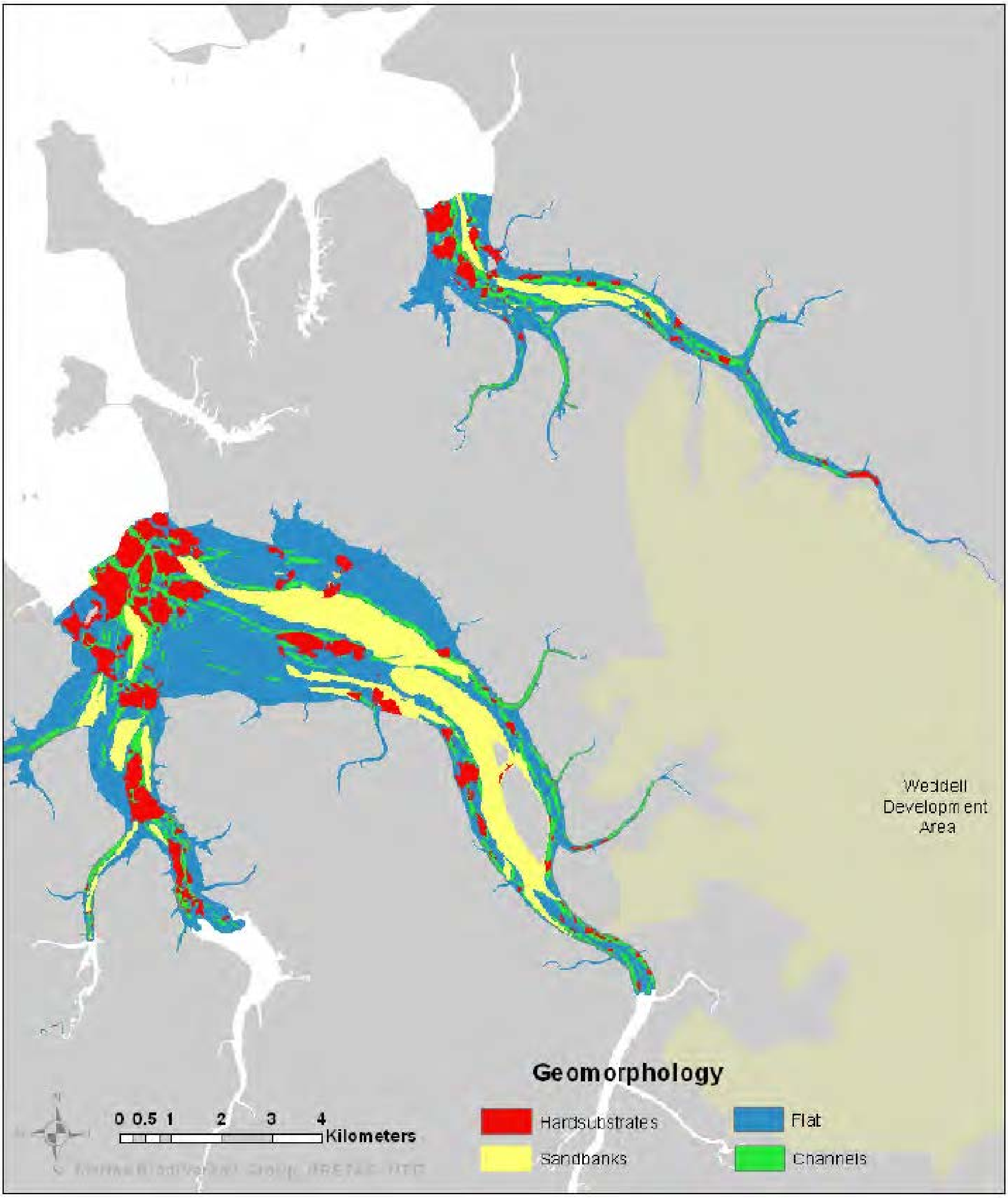


**Figure 4-3 seascape attributes of inner Darwin Harbour, with Elizabeth River at the top of the map (Smit et al., 2012)**

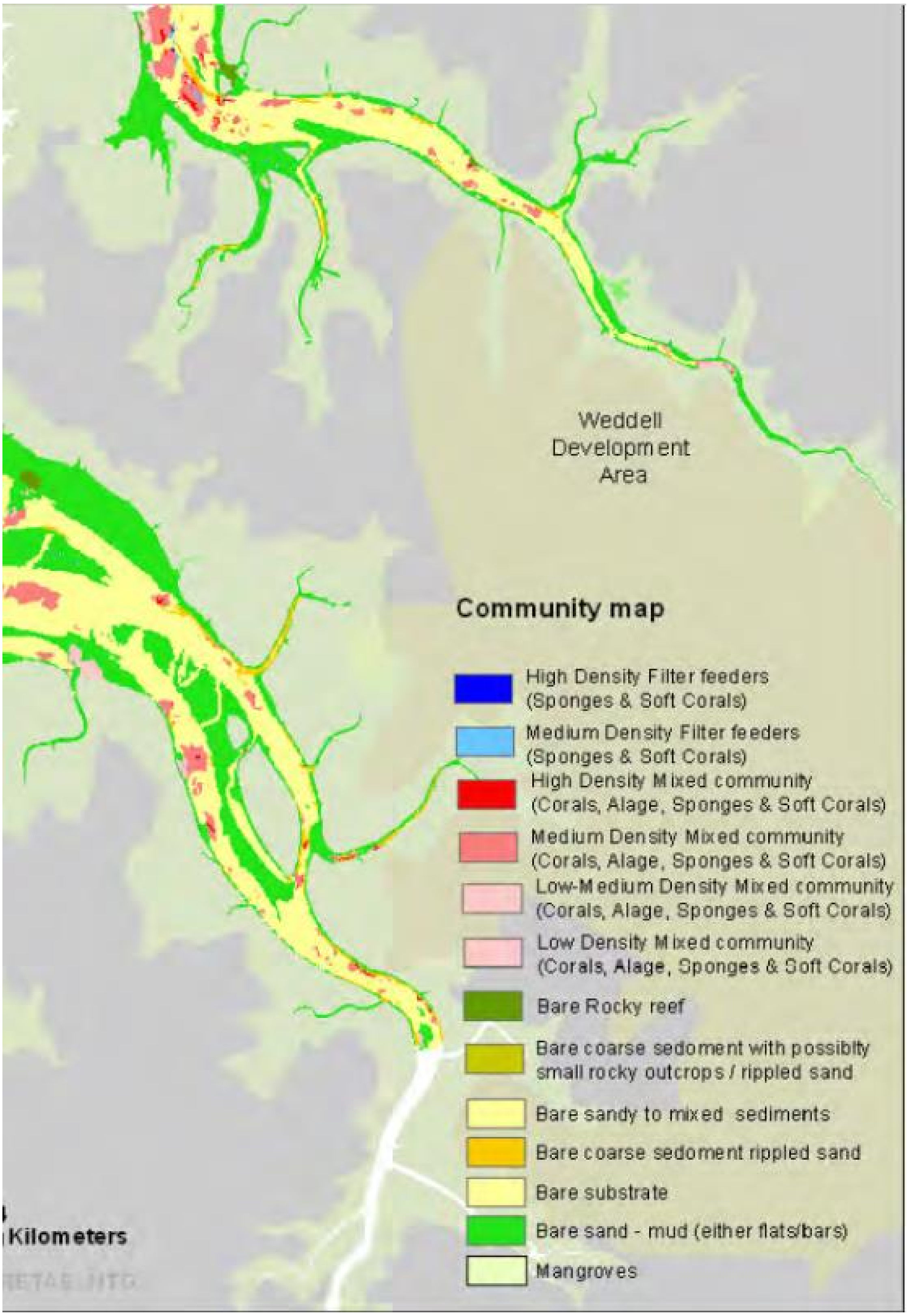


**Figure 4-4 Benthic community composition for Elizaebeth River (top). (Smit, et al., 2012).**

## 4.2 Mangrove Communities in the Darwin Harbour

Mangroves are taxonomically diverse, salt-tolerant, mostly woody plants commonly found in the intertidal zone, fringing tropical and subtropical coastlines (Polidoro et.al., 2010). Mangroves in Darwin Harbour constitute one of the largest tracts of mangrove forest throughout the Northern Territory and Australia and are largely regarded as pristine and intact (Moritz-Zimmermann, Comley & Lewis, 2002). Darwin Harbour's mangrove forests cover around 20,400 hectares, constituting around 5 % of the Northern Territory's entire mangrove area (Brocklehurst & Edmeades, 1996). In addition to being one of the largest discrete blocks, Darwin Harbour is recognised for its diversity, containing 36 mangrove species, 6 of which are most common, *Rhizophora stylosa, Ceriops tagal, Sonneratia alba, Bruguiera exaristata, Avicennia marina and Camptostemon schultzii* (Brocklehurst & Edmeades, 1996).

In the *Darwin Regional Land Use Structure Plan 1990* (DLH, 1990), the (previously) Northern Territory Department of Lands and Housing (DLH) proposed to leave more than 80 % of mangrove area in the Darwin Harbour untouched (page 18). This commitment was not reaffirmed in the *Darwin Regional Land Use Plan 2015* (DLPE, 2015), however the importance of mangrove communities in the Harbour is acknowledged.

### 4.2.1 Functional Importance of Mangroves

Mangroves play an integral role in Darwin Harbour's marine ecosystem and protect the coastline from erosion and storm surge (Moritz-Zimmermann, Comley & Lewis, 2002). Mangrove forests form effective, self-repairing barriers against severe storms, storm surge and tropical cyclones. Trees act as windbreaks, and their extensive root systems trap and stabilise sediments (Montgomery, et.al., 2019 &, 2018; Moritz-Zimmermann, Comley & Lewis, 2002).

Mangroves are effective sediment sinks, and reduce the siltation of waterways and estuaries, improving water quality and protecting coral reefs from upstream sediment loads, particularly after heavy rain (Saenger et al., 1983).

Mangroves are also highly productive forests, among the most carbon-rich ecosystems in the tropics and account for a high proportion of carbon sequestration in tropical coastal environments (Alongi, 2012) such as Darwin Harbour.

The diverse mangrove ecosystem provides habitat for a wide array of animals (Moritz-Zimmermann, Comley, and Lewis, 2002). Mangrove fauna, such as crustaceans and fish, migrate out of the mangrove ecosystem and contribute significantly to the marine food chain. Estuarine and near-shore fisheries harvest the products of this complex food chain. Their yields are strongly linked to mangrove productivity (Saenger et al., 1983). They produce large amounts of organic matter and nutrients (Metcalfe, 1999), which support not only the fauna and flora of the mangrove ecosystem itself, but also adjacent habitats (Moritz-Zimmermann, Comley, and Lewis, 2002).

### 4.2.2 Diversity

The diversity of mangrove species in Darwin Harbour is high in comparison to the rest of the Northern Territory coastline. Of the 48 plant species recognized as regular inhabitants of Northern Territory mangrove communities, 36 have been identified in Darwin Harbour (DIPE, 2002).

Towards the seaward shores of the harbour, in zones largely shaped by marine processes including inundation by high-tides twice daily as well as wave action and currents, *Sonneratia alba* is found to be the dominant species. While nearer to land and fringing tidal creeks, *Rhizophora stylosa* is the dominant species, covering approximately 33% of the total area of Darwin Harbour's mangroves (Metcalfe, 2007).

The species identified by Brocklehurst & Edmeades (1996) in their major surveys of Darwin Harbour mangrove distribution and diversity are included in Table 4-1 below, along with percentage occurrence.

**Table 4-1 Species found in major Darwin Harbour mangrove survey, including frequency and percentage occurrence (Brocklehurst & Edmeades, 1996).**

| Species | Frequency | Occurrence (%) |
|---|---|---|
| *Acacia auriculiformis* | 1 | 1.28 |
| *Acrostichum speciosum* | 1 | 1.28 |
| *Aegialitis annulata* | 19 | 24.36 |
| *Aegiceras corniculatum* | 12 | 15.382 |
| *Avicennia marina* | 38 | 48.72 |
| *Bruguiera exaristata* | 24 | 30.77 |
| *Bruguiera gymnorrhiza* | 1 | 1.28 |
| *Bruguiera parviflora* | 19 | 24.36 |
| *Calopogonium spp.* | 1 | 1.28 |
| *Camptostemon schultzii* | 18 | 23.08 |
| *Carpentaria acuminata* | 1 | 1.28 |
| *Ceriops tagal* | 38 | 48.72 |
| *Cynanchum carnosum* | 2 | 2.56 |
| *Cyperus spp.* | 1 | 1.28 |
| *Diospyros compacta* | 1 | 1.28 |
| *Excoecaria ovalis* | 12 | 15.38 |
| *Fimbristylis cymosa* | 2 | 2.56 |
| *Fimbristylis polytrichoides* | 2 | 2.56 |
| *Fimbristylis rara* | 1 | 1.28 |
| *Gymnanthera oblonga* | 1 | 1.28 |
| *Halosarcia halonemoides* | 1 | 1.28 |
| *Halosarcia indica* | 1 | 1.28 |
| *Lumnitzera racemosa* | 13 | 16.67 |
| *Melaleuca cajuputi* | 1 | 1.28 |
| *Osbornia octodonta* | 4 | 5.13 |
| *Pandanus spiralis* | 1 | 1.28 |
| *Rhizophora lamarckii* | 1 | 1.28 |
| *Rhizophora stylosa* | 46 | 58.97 |
| *Scyphiphora hydrophylacea* | 4 | 5.13 |
| *Sonneratia alba* | 10 | 12.82 |

| Species | Frequency | Occurrence (%) |
|---|---|---|
| *Sporobolus virginicus* | 3 | 3.85 |
| *Stylidium fissilobium* | 1 | 1.28 |
| *Tecticornia australasica* | 2 | 2.56 |
| *Thespesia populneoides* | 1 | 1.28 |
| *Xylocarpus mekongensis* | 6 | 7.69 |

### 4.2.3 Distribution

The structural features of mangrove communities in Darwin Harbour demonstrate clear shoreline zonation, with single species often arranged in monospecific, or homogenous, bands parallel to the coastline. Different mangrove communities or assemblages tend to grow at different topographic elevations or levels of tidal inundation (**Figure 4-5**), but this can vary with localised discrepancies or disturbances, meaning that assemblages along these coastlines will often resemble patches rather than strips (Metcalfe, 2007).

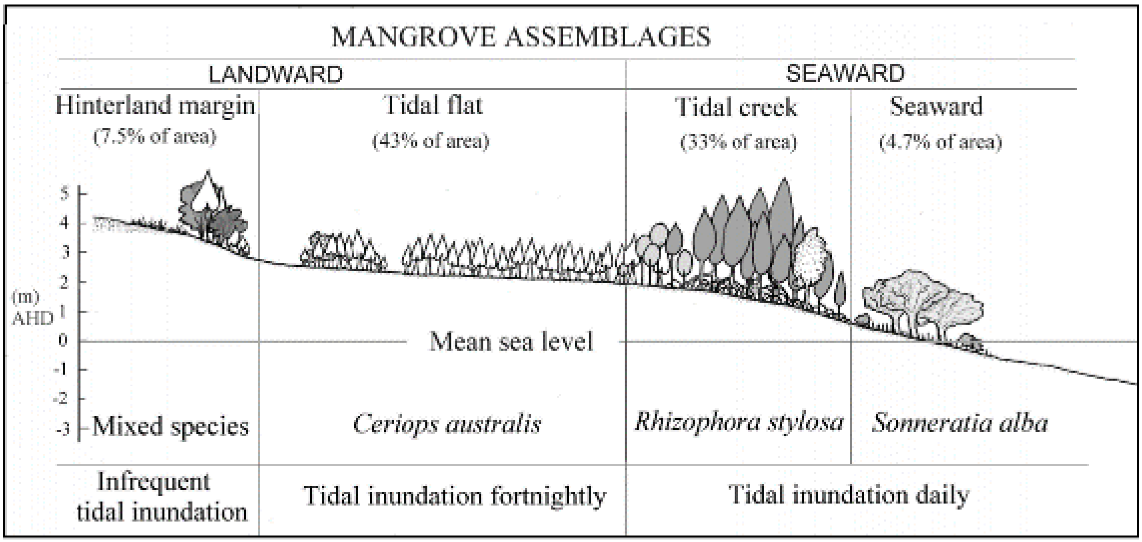


**Figure 4-5 Schematic profile diagram of the typical pattern of mangrove zonation from landward (L) to seaward (R) in Darwin Harbour. Source: Metcalfe (2007).**

In addition to complex physico-chemical and biological interactions, distribution of mangrove assemblages in the Darwin Harbour are likely to be influenced by seasonality of climate and tidal regimes, freshwater inflows from point and diffuse sources, topography and substrate type. Landward mangrove habitats are also likely to be more influenced by terrestrial, rather than marine, processes including freshwater seepage, seasonal deposition of terrestrial sediments, infrequent tidal inundation and desiccation (Metcalfe, 2007).

The mangrove communities of Darwin Harbour have been previously mapped by Brocklehurst & Edmeades (1996), who summarize the mangroves into 12 distinct ‘map units’, with 10 identified mangrove communities (excluding beach and salt flats). These communities are shown in Table 4-2, along with the proportion of the total mangrove area for each community. Community 4, the *Ceriops* *tagal* low closed forest, or mid-tidal flat, assemblage is the most commonly found community in Darwin Harbour, comprising around 39% of the total mangrove area.

**Table 4-2 Map units, or mangrove community classifications, and area/cover from Brocklehurst & Edmeades (1996).**

| Map Unit | Mangrove Community (Brocklehurst and Edmeades, 1996) | Area of Darwin Harbour (1996) (ha) | Percentage cover |
|---|---|---|---|
| 1 | *Rhizophora stylosa* closed forest (shoreline forest) | 668 | 3.3% |
| 2 | *Rhizophora stylosa/Camptostemon schultzii* closed forest (tidal creek) | 5,965 | 29.2% |
| 3 | *Rhizophora/Bruguiera/Ceriops* closed-forests (transition) | 734 | 3.6% |
| 4 | *Ceriops tagal* low closed forest (mid-tidal flat) | 7,959 | 39.0% |
| 5 | *Ceriops tagal/Avicennia marina* low closed forest (high tidal flat) | 892 | 4.4% |
| 6 | Mixed species low closed forest (hinterland margin) | 1,525 | 7.5% |
| 7 | Mixed species low woodland (low woodland) | 288 | 1.4% |
| 8 | *Sonneratia alba* woodland (seaward) | 968 | 4.7% |
| 9 | *Rhizophora stylosa* low woodland (islands, rocky shores) | 2.8 | 0.01% |
| 10 | Low open woodland (low tidal mudflat) | 24.2 | 0.1% |
| 11 | Samphire/Salt flat | 1,377 | 6.7% |
| 12 | Beach | 28 | 0.1% |

## 4.3 Elizabeth River Estuary Mangrove Composition

**Figure 4-6** presents a conceptual diagram showing estuarine activities and their effect on mangroves, water bodies.

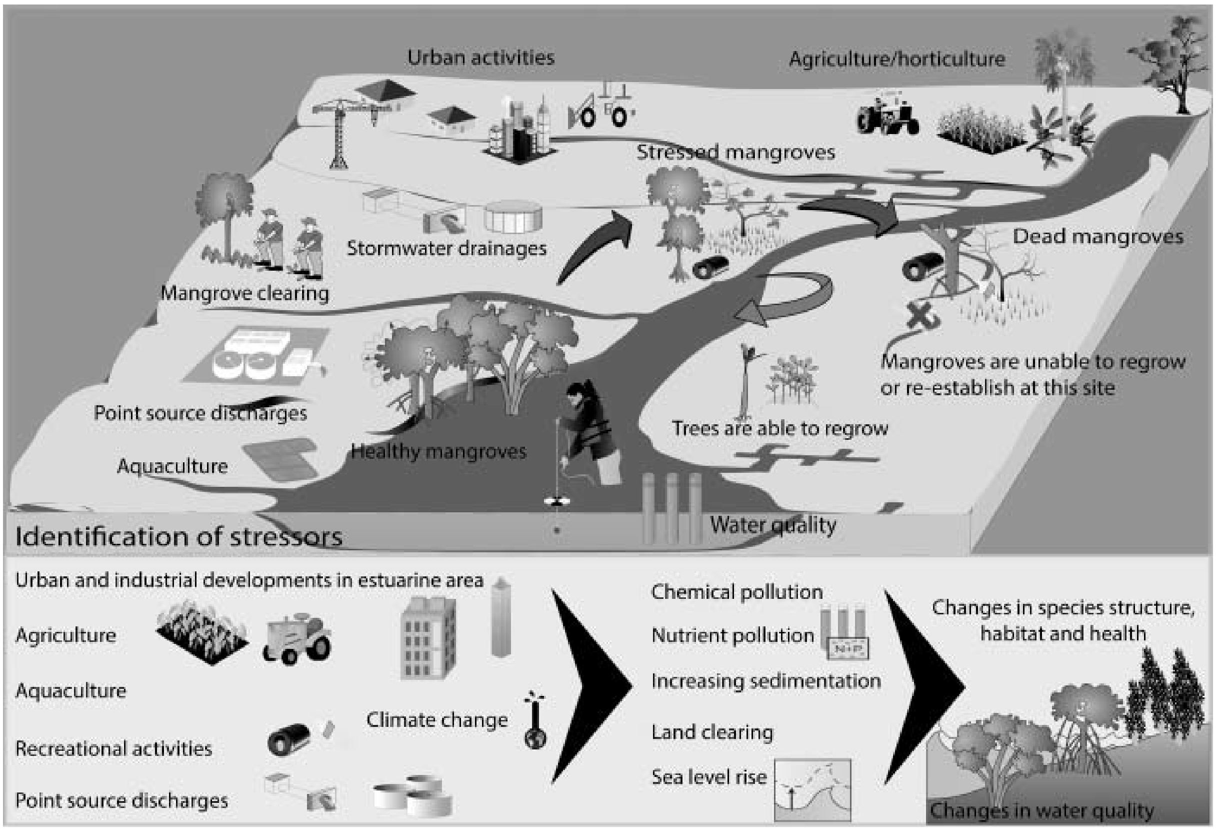


**Figure 4-6 A conceptual diagram showing estuarine activities and their effect on mangroves, water bodies,**

A Mangrove Monitoring Plan (MMP) was established by the Department of Infrastructure, Planning and the Environment (DIPE) for Darwin Harbour in 2002 (Moritz-Zimmermann, Comley, and Lewis, 2002). The monitoring sites proposed in the MMP can be seen in **Figure 4-7**.

Study site (E2) within the Elizabeth River Estuary is most relevant for the purposes of this report. The site is approximately 1km upstream of the Elizabeth River Bridge, which forms the border of the proposed project site (Metcalfe, 2007). Refer to **Figure 4-7** below for the location of this study site.

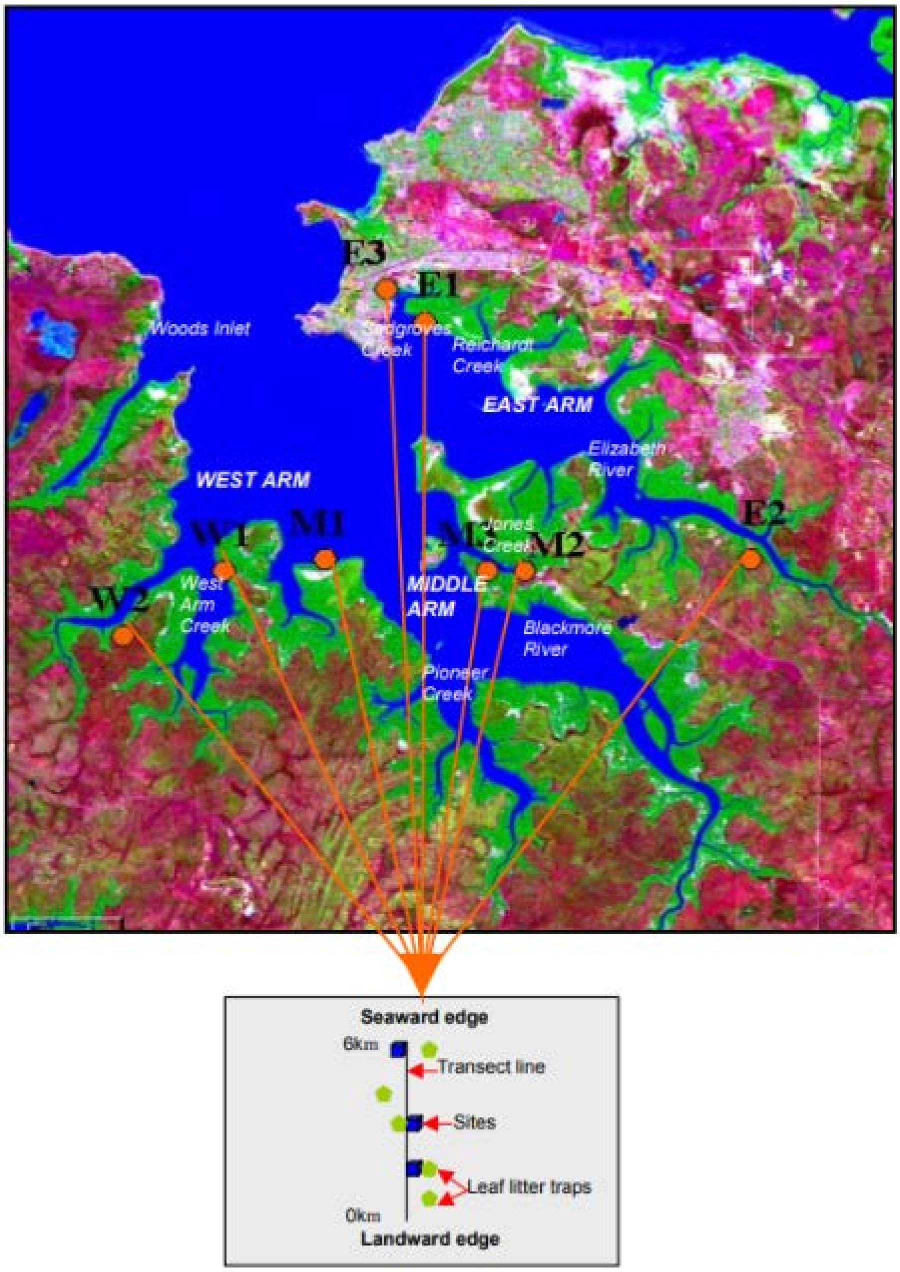


**Figure 4-7 DMMP Monitoring Sites. Source: DIPE (2002)**

The tidal flat community in this region is characterised by low *C. australis* and scattered *A. marina* on well-consolidated mud. The tidal creek assemblage was relatively low-growing, multi-stemmed and dense, as is characteristic of upstream areas of East Arm. *S. alba* trees in the seaward zone were interspersed with lowgrowing *Aegiceras corniculatum* and *Aegialitis annulata* (Metcalfe, 2007).

## 4.4 Mangrove Community Health

INPEX's Ichthys LNG Project, located on Blaydin Point approximately 5km the north-west of the proposed refinery site, is the nearest major project to the study area. As part of their Environmental

Monitoring Program, INPEX conducted several baseline mangrove health surveys (Cardno, 2013a). Baseline monitoring was conducted at several potential impact sites throughout Darwin Harbour (**Figure 4-8**), sites I4, I5 and I6 are of most relevance to this report, given their proximity to the proposed refinery site. I5 is of specific interest as it is located on the shoreline of the proposed refinery site.

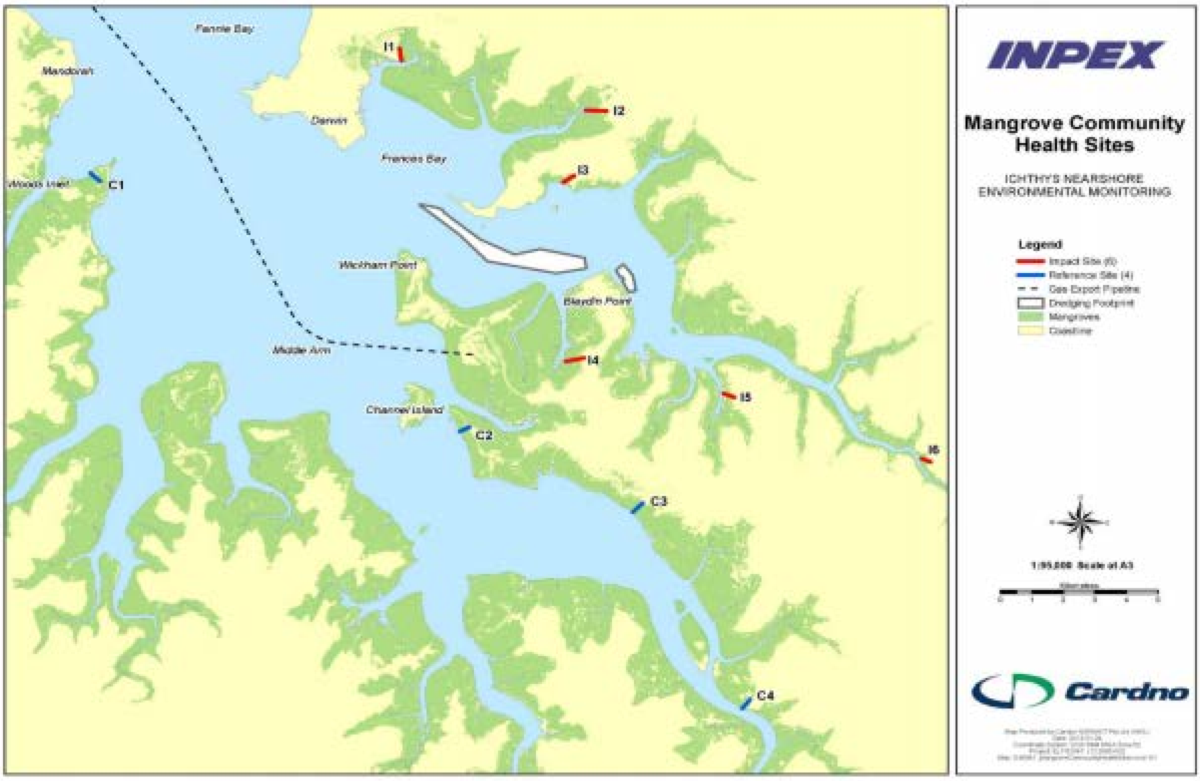


*Figure 4-8 Location of Mangrove Community Health monitoring sites. Source: Cardno (2013a)*

Each transect was assessed across four assemblages, from Hinterland Margin (landward), Tidal Flat (Ceriops), Tidal Creek (Rhizophora), to Seaward (Sonneratia), as shown in **Figure 4-9**. The parameters used to assess Mangrove Community Health were, canopy cover, seedling & sapling parameters and fauna composition. Two baseline surveys were conducted in 2012 two months apart (June & August). There is very little seasonal difference between these results given the short amount of time and time of year the separate surveys were conducted. Quarterly monitoring surveys have been undertaken since the baseline surveys to assess any trends or impacts caused by their development and associated activities. The results of this monitoring demonstrate very little impact on the health parameters of mangrove trees in the region, for both control and potential impact sites, between 2012 and 2018.


*Figure 4-9 Typical layout of transect from landward to seaward with mangrove health monitoring plots (20 m x 20 m) in each of the four main assemblages. Source: INPEX, 2013.*

### 4.4.1 Canopy Cover

Since leaf shedding and leaf growth are sensitive to a wide range of environmental factors, a reduction in canopy cover over time may indicate ecosystem stress or disturbance. Mangrove canopy cover, or the density of mangrove tree canopy, was assessed as part of INPEX Ichthys environmental monitoring program using a densiometer (Stickler 1959), which measured the combined leaf and branch cover at each site. This monitoring has been conducted quarterly since 2012, with the most recent results (2018) demonstrating consistently similar canopy cover across all sites in comparison to baseline (2012) results **Figure 4-10.**

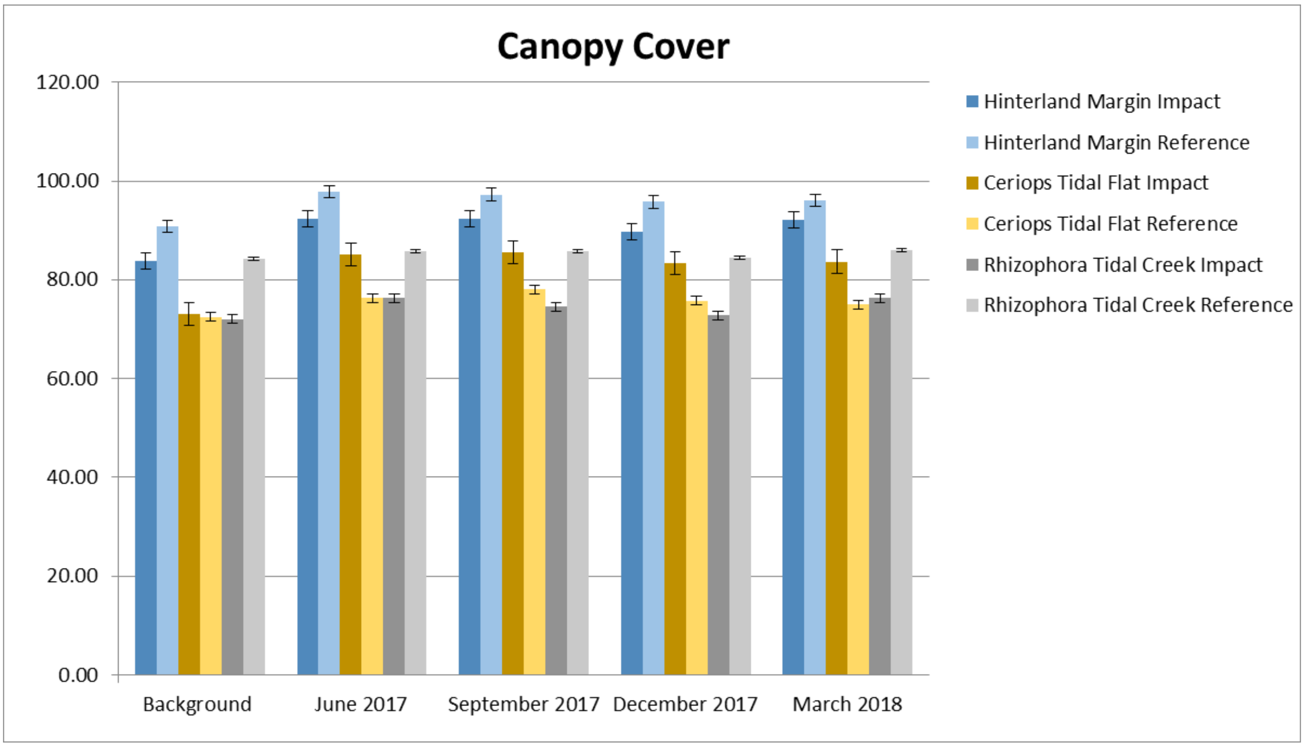


**Figure 4-10 Comparison between canopy cover baseline data (2012) and data from 2017-18,. Source: Cardno, 2018).**

Canopy cover is relatively consistent over time across the three sites of particular interest (I4-6) and their respective mangrove communities with a greater overall cover observed in the *Rhizophora*-dominated Tidal Creek assemblage and mixed species Hinterland Margin.

Canopy cover is distinctly low (~60 %) for the Tidal Flat community at site I5 when compared to results from other impact sites and the control sites (82.2 % to 95.8 %). I5 is the closest site to the proposed refinery site, however low canopy cover is consistent across the years and is attributed to the naturally patchy nature of *C. australis* in low-open forest in the Tidal Flat that is characteristic of this site in contrast to others. Baseline data and quarterly monitoring data collected between 2013-14 is presented for the three sites of interest in **Table 4-3** below. Trendlines for each of the four communities are presented in **Figure 4-11**, demonstrate relative consistency in canopy cover fluctuations across seasons for each assemblage at each site. A general drop for the two most seaward assemblages can be observed around January, this could be attributed to increased storm action during the heart of the wet season.

**Table 4-3 Mean (%) Mangrove Canopy Cover for relevant sites (I4-6) sites during INPEX Baseline Survey 1 (2nd June 2012) and Baseline survey 2 (11 August 2012), and INPEX Quarterly Surveys (January 2013 - June 2014).**

| Site | Assemblage Type | B1 | B2 | Jan-13 | May-13 | Jul-13 | Nov-13 | Jan-14 | Mar-14 | Jun-14 |
|---|---|---|---|---|---|---|---|---|---|---|
| I4 | Hinterland Margin | 98.7 | 96.9 | 95.8 | 96.2 | 97.4 | 96.6 | 96.2 | 97.4 | 96.3 |
| | Tidal Flat | 90.3 | 89.6 | 89 | 87.5 | 89.7 | 91.3 | 90.8 | 89.8 | 89.2 |
| | Tidal Creek | 97.2 | 97.3 | 95.8 | 96.2 | 96.7 | 96.8 | 97.3 | 98.2 | 95.5 |
| | Seaward | 87.4 | 82.2 | 83.6 | 82.8 | 83.1 | 83.3 | 82.7 | 85.5 | 82.8 |
| I5 | Hinterland Margin | 84.1 | 93.6 | 93.3 | 93.6 | 91.9 | 92.9 | 89.3 | 93.8 | 91.1 |
| | Tidal Flat | 61.3 | 71 | 66.7 | 65.1 | 62.8 | 63.5 | 59.3 | 62.4 | 52 |
| | Tidal Creek | 95.2 | 92.4 | 90.9 | 94.7 | 91.2 | 93.5 | 95.7 | 94.1 | 86.8 |
| | Seaward | 79.1 | 82.2 | 73.4 | 79.4 | 81.7 | 78.7 | 74.1 | 78.1 | 75.9 |
| I6 | Hinterland Margin | 89.3 | 87.5 | 97.8 | 84.7 | 86.8 | 83.3 | 82.4 | 85.5 | 75.4 |
| | Tidal Flat | 91.1 | 91.3 | 90.9 | 85.3 | 89.3 | 89.5 | 89.6 | 90 | 88.6 |
| | Tidal Creek | 98.8 | 98 | 86.4 | 97.6 | 98.5 | 98.8 | 98 | 99 | 98.3 |
| | Seaward | * | * | * | * | * | * | * | * | * |

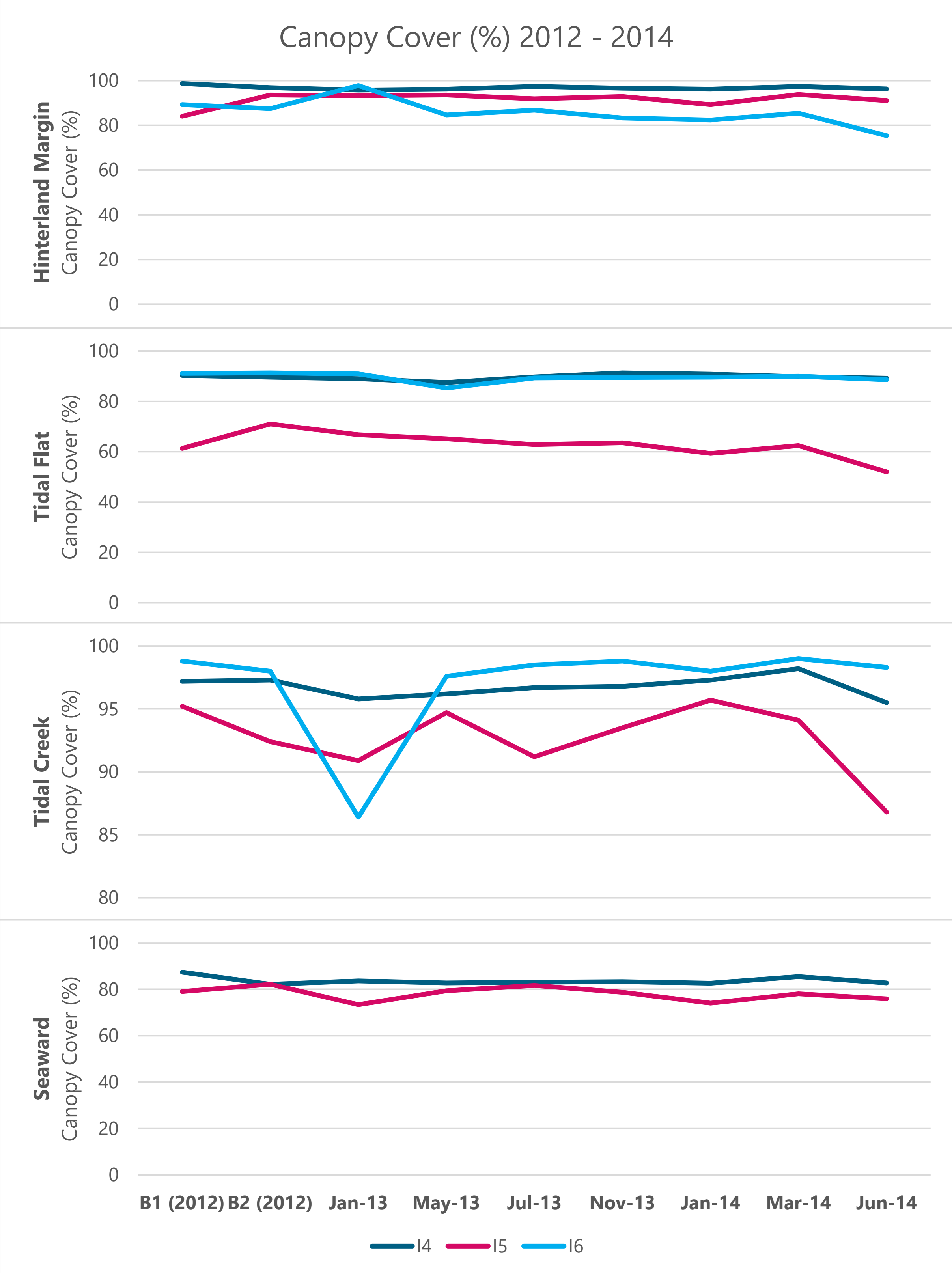


**Figure 4-11 Mean mangrove canopy cover (%) for four mangrove assemblages (Hinterland Margins, Tidal Flat, Tidal Creek & Seaward) for three monitoring sites (I4-6) between 2012 and 2014, data gathered for INPEX Ichthys LNG Project**

### 4.4.2 Seedling and Sapling Health

#### 4.4.2.1 *Density and Recruitment*

Mean seedling & sapling densities were calculated for each mangrove assemblage across all sites as part of environmental monitoring (Inpex 2012). Only results for impact sites are included in Table 4-4due to their relative proximity to the proposed refinery site.

**Table 4-4 Mean Seedling and Sapling density at all Impact sites. Source: Cardno (2013a – 2014c).**

| | Assemblage | B1 & B2 Combined | Jan-13 | May-13 | Jul-13 | Nov-13 | Jan-14 | Mar-14 | Jun-14 |
|---|---|---|---|---|---|---|---|---|---|
| **Seedling** | **Hinterland Margin** | 2.1 | 1.7 | 2.1 | 3.4 | 3.0 | 1.8 | 1.9 | 1.5 |
| | **Tidal Flat** | 12.1 | 9.5 | 11.9 | 11.5 | 15.8 | 11.1 | 10.2 | 14.5 |
| | **Tidal Creek** | 1.7 | 1.2 | 1.8 | 7.7 | 1.1 | 1.0 | 1.6 | 2.7 |
| | **Seaward** | 15.0 | 7.2 | 4.2 | 11.6 | 6.8 | 0.3 | 7.0 | 10.9 |
| **Sapling** | **Hinterland Margin** | 0.1 | 0.2 | 0.5 | * | 0.5 | 0.5 | 0.3 | 0.4 |
| | **Tidal Flat** | 0.6 | 0.6 | 0.8 | * | 1.0 | 0.9 | 1.0 | 0.8 |
| | **Tidal Creek** | 0.1 | 0.1 | 0.2 | * | 0.1 | 0.1 | 0.1 | 0.1 |
| | **Seaward** | 0.0 | 0.1 | 0.1 | * | 0.2 | 0.1 | 0.2 | 0.3 |

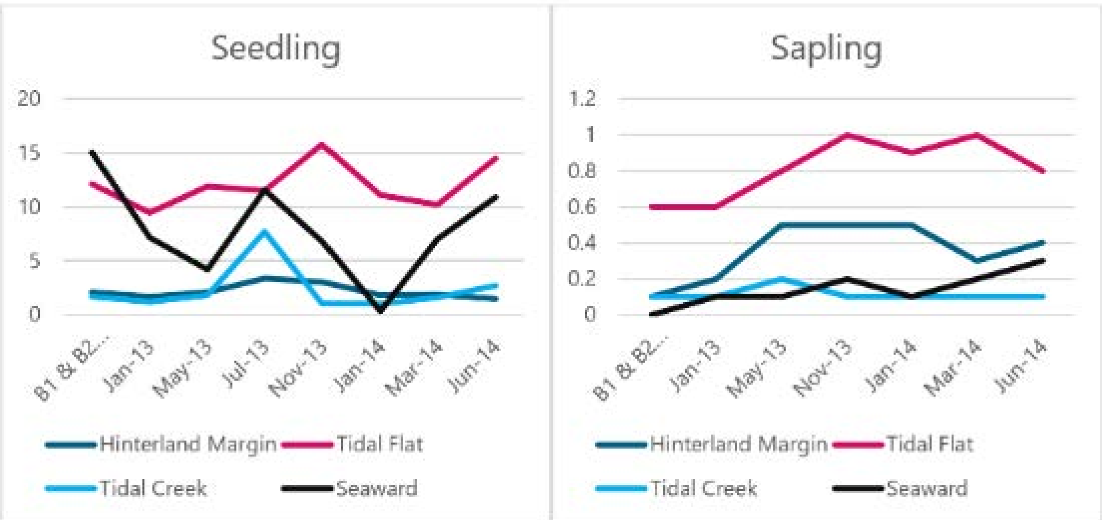


**Figure 4-12 Mean Seedling and Sapling densities between 2012 & 2014 across all impact sites**

Changes in seedling density over time were relatively minor for the Hinterland Margin and Tidal Creek assemblages, while there was greater variation observed at the Seaward and Tidal Flat assemblages.

Sapling density was relatively low at all sites and assemblages **Figure 4-12**. Overall, changes in sapling density among surveys during this period was minimal.

### 4.4.2.2 *Seedling Survival*

**Figure 4-13** demonstrates a steady decline in the percentage of seedlings surviving in all sites and assemblages at quarterly surveys between Baseline survey 2 (B2) (July/August 2012) and Mangrove Community Health – Dredging Report 7 (April 2014).

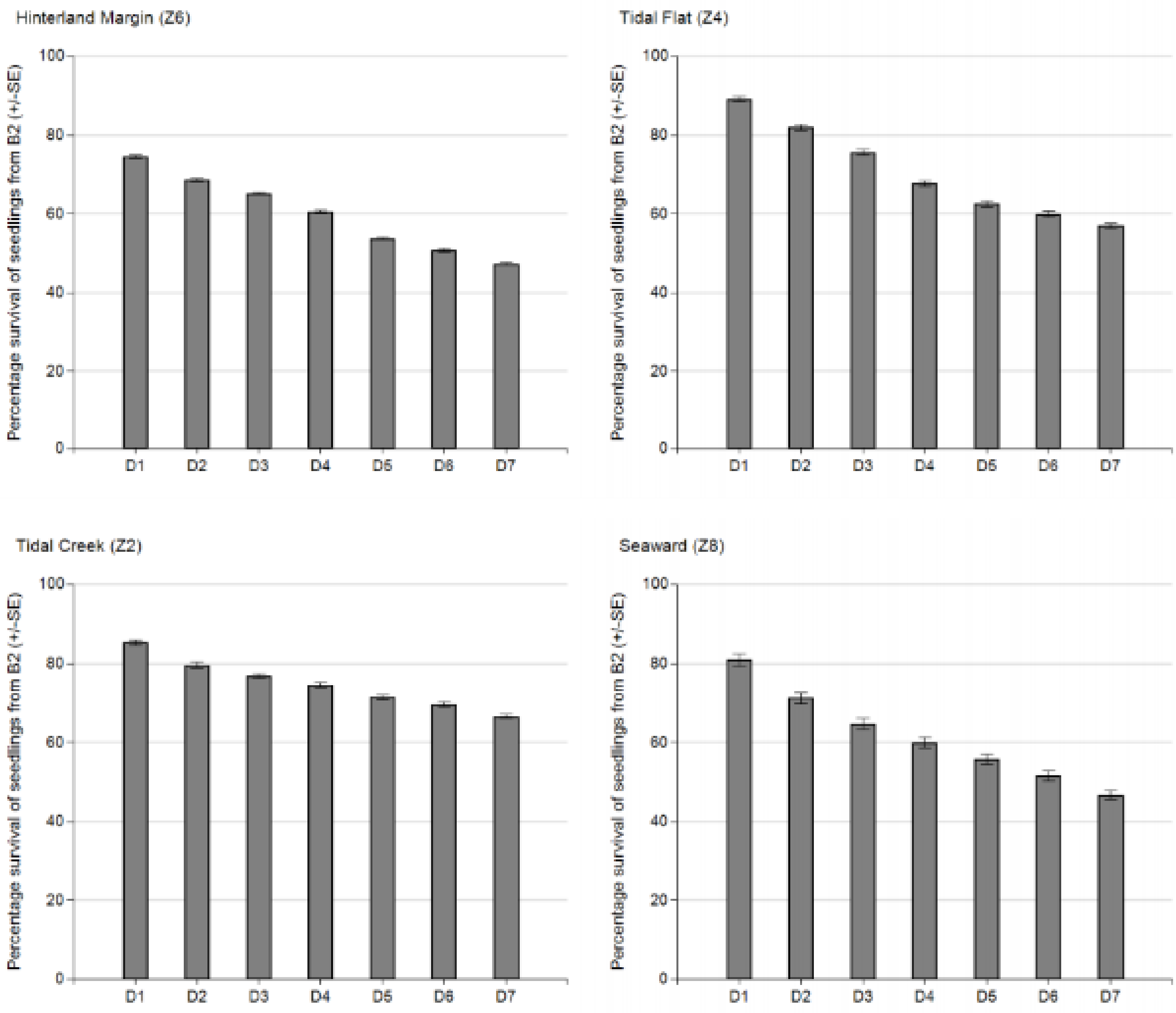


**Figure 4-13 Mean percentage survival of individual seedlings in the four assemblages from landward to seaward recorded during the INPEX Ichthys Dredging Phase (D1 to D7), in comparison with the Baseline Phase (B2=100%). Source: Cardno (2014c)**

In sites I5 and I4 only 5.2% (± 2.3 SE) and 29.9% (± 7.1 SE) seedlings survived since the baseline survey in the seaward assemblage. The decline in I5 survival was sharp, with a large loss in numbers during D1 (October/November 2012). The decline at I4 was more gradual over time. This was not attributed to the effects of sedimentation, although relatively high at these sites by D7 (April 2014), sedimentation was low during the rapid decline at I5 in 2013 D1 survey.

### 4.4.3 Overall Condition

No significant decline in mangrove community health was detected across the annually surveyed impact sites during the 2017-18 monitoring period. Any changes that were found were assessed to represent natural variation. Mangrove communities in Darwin Harbour located close to the INPEX Ichthys project have remained in a healthy condition since the beginning of the Ichthys Environmental Monitoring Program (Greencap, 2018).

# 5 Conclusion

The purpose of the report is to provide a conceptual site model of appropriate scale and complexity to illustrate potential environmental risks to sensitive receptors in the marine environment from proposal activities that may influence marine environmental quality.

Sensitive receptors and their specific sensitivities in relation to expected impacts from the Darwin Processing Facility are listed in Table 5-1.

**Table 5-1. Sensitive Environmental Receptors and known sensitivities**

| Sensitive Environmental Receptors | Known sensitivities |
|---|---|
| Molluscs and Crustaceans | Contaminants enter the food chain through small molluscs and crustacean infauna and can bioaccumulate or diminish food sources |
| Hydroids, Marine Worms, Echinoderms | Loss of habitat for many invertebrates if sponges are diminished due to sedimentation.<br><br>Echinoderms are sensitive to redistribution of sediments or increased sedimentation. |
| Fish | Sensitive to bioaccumulation of contaminants in food sources and/or diminished food sources<br><br>Possible disruption to breeding cycles if estuary becomes unsuitable habitat for early life stages for species that require estuary as nursery habitat. |
| Seabirds | Bioaccumulation of contaminants in food sources and/or diminished food sources<br><br>Sensitive to loss of specific habitats required for feeding or roosting such as mudflats, saltpans and mangroves. |
| Marine mammals and other vertebrates | Bioaccumulation of contaminants in food sources and/or diminished food sources<br><br>Dugongs are sensitive to loss of seagrass and algae from sedimentation<br><br>Bottlenose dolphins are sensitive to turbidity |
| Turtles | Diminished food sources from effects of sedimentation |
| Benthic Communities (including sponges and corals) | Sedimentation settles on benthic communities and diminishes light availability at depth.<br><br>Corals are sensitive to turbidity.<br><br>Benthic communities require hard substrates that may be buried by sediments. |
| Mangrove Communities | Complex physico-chemical and biological interaction influence the distribution of mangrove assemblages in the Darwin Harbour. Assemblages are likely to also be influenced by seasonality of climate and tidal regimes, freshwater inflows from point and diffuse sources, topography and substrate type. Landward mangrove habitats are likely to be more influenced by terrestrial, rather than marine, processes including freshwater seepage, seasonal deposition of terrestrial sediments, infrequent tidal inundation and desiccation (Metcalfe, 2007). |

## 5.1 Existing marine and coastal environment

Water quality in the Elizabeth River estuary has remained good to excellent since monitoring began. Large parts of the estuary are still lined with mangroves but industrial development along the foreshore has reduced mangrove cover in recent years. The estuary receives urban stormwater runoff from the city of Palmerston during the wet season, dispersed discharge from the Palmerston wastewater treatment plant that enters the harbour in Myrmidon Creek and more recently the discharges associated with INPEX Ichthys project site at Blaydin Point. It has scored 'A' (being the highest quality) in annual water quality reporting for all years except 2010.

There has been no significant decline in the health of mangrove communities in the Elizabeth River estuary in recent monitoring years, with any changes representing natural variation. Mangrove communities in Darwin Harbour located close to the INPEX Ichthys project have remained in a healthy condition since the beginning of their monitoring program. The Elizabeth River estuary supports a wide variety of marine ecosystems, as well as resident and transient marine organisms.

## 5.2 Risks to sensitive environmental receptors

Most of the site has a low to moderate erosion risk during the project's construction phase, but erosion and sediment controls will be implemented to reduce the amount of TSS entering the estuary. Erosion and sediment control measures will ensure that any discharge associated with construction are based on the criteria in Table B40 in Best Practice Erosion and Sediment Control (BPESC) document, 90 percentile TSS concentrations not exceeding 50mg/L and pH in the range of 6.5 to 8.5. This pH range sits within the water quality objectives for the Upper Estuary, while the WQO for TSS is to maintain <10mg/L. Given the short duration of the construction phase and the seasonal nature of rainfall at the project site, and with appropriate erosion and sediment controls it is not anticipated that the discharge of TSS into the estuary associated with construction will negatively impact the WQO's in the estuary.

There will be no direct discharge of wastewater into Darwin Harbour associated with the operational phase of the TNG Project. Any potential surface water discharge will be associated with stormwater runoff, increased due to the changes in topography and non-permeable surfaces. Stormwater runoff at the project site will be managed to minimise any risk of contamination reaching Darwin Harbour, as detailed in the SWMP. As such, there will be very low impact on the water quality both throughout the estuary, or in the local estuarine environment nearby the project boundaries.

As the TNG project will not be discharging wastewater into the harbour there is no need for the construction of a discharge pipeline. As such there will be no clearing or impact on the mangrove belt surrounding the project, other than low risk of stormwater discharge potentially containing small amounts of contaminants.

As discussed, any pollutant loads in surface water runoff from the project are expected to be minor and the impacts on the nearshore marine environment and ecosystems minimal and localized.

With proposed stormwater management incorporated into the detailed design phase, it is not expected that there will be any significant impacts on the coastal environment or ecosystems of the Elizabeth River as a result of surface water discharges associated with the TNG Project.

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