Ashburton Salt

Projection of Future Habitat Area

Seashore Engineering
October 2022

Technical Note SE099-02-Rev A

Prepared for
K+S Salt

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1. Introduction

This technical note has been prepared as a supplement to Seashore Engineering (Aug 2021) *Ashburton Salt – Response to Sea Level Rise*. Seashore (2021) identified the proposed project layout would have limited direct impact on intertidal habitats, with salt ponds located landward of existing intertidal zone. However, it was noted the salt ponds would block potential migration of the intertidal habitats with sea level rise. By around 2050, presence of salt ponds could reduce potential expansion of mangrove habitat by 40-250ha. Subsequently, accelerating sea level rise is anticipated to reduce capacity for mangroves to be established or recover from disturbance, and in the longer-term, this will substantially constrain mangrove habitat migration with sea level rise, with or without salt ponds.

Following submission of a Draft Environmental Review Document for Ashburton Salt Project, the EPA and other Decision-Making Agencies have requested clarification of relative differences to environmental value of intertidal habitat development, over the short to intermediate term (<100 years), even if longer-term loss is projected.

1.1. SUMMARY OF PREVIOUS ASSESSMENT

The previous evaluation modelled influence of sea level rise on intertidal habitats, comparing change with or without salt ponds proposed for the project. It was assessed that:

- Existing mangrove communities are bounded to landward by hypersaline flats, with a layout characteristic of limitation by porewater salinity. It was consequently inferred that tidal exchange provides a key control to salinity, supporting mangrove habitat where exchange is sufficient to maintain near-marine levels of salinity.
- Construction of salt ponds above the intertidal zone would not directly affect present-day tidal exchange. However, the salt ponds would restrict expansion of tidal exchange with sea level rise, a key mechanism for potential growth of tidal creeks and development of habitat suitable for mangroves. However, it was noted that accelerated rates of sea level rise provide a longer-term limit to mangrove habitat, regardless of changes to tidal exchange.
- Algal mats are located landward of the coastal mangrove fringe, along the western side of the extensive coastal lagoon. This habitat is defined by specific ground levels, indicating the influence of hydroperiod (minimum frequency of tidal wetting).
- The eastern side of the coastal lagoon is separated from the west by a shallow sediment ridge, forming a partly separate basin. Absence of algal mats in the eastern basin, at ground levels where they occur in the west basin, indicates an additional influence on habitat viability – with surface drainage, and corresponding high porewater salinity, considered likely to be a key factor.
- Projected sea level rise will initially increase the area of land with hydroperiod suitable for algal mat habitat. However, once the edge of the algal mat reaches the crest of the low sediment ridge (for approximately +0.25m sea level), continued sea level rise will not create additional viable habitat for algal mats.
- The proposed salt pond layout occupies 450 to 560 ha which might be occupied by algal mats following habitat expansion due to projected sea level rise.

1.2. SCIENTIFIC BASIS TO ESTIMATE FUTURE INTERTIDAL HABITAT

Sea level rise is one of the projected climate impacts associated with warming due to anthropogenic increase of atmospheric greenhouse gases (IPCC 2022). Estimates of potential sea level rise have been derived through climate modelling, interpreting global ocean-atmosphere models through downscaling and regional scale modelling (Zhang *et al*. 2017). Previous synthesis of sea level rise information for Western Australia provided a single forecast curve (Figure 1-1), corresponding to sea level projections for a moderately high emission scenario (Transport 2010). Although there has been substantial additional information developed by the Intergovernmental Panel on Climate Change and other agencies, overall scale and rates of rise remain like those described by Transport (2010), and consequently it continues to be used for regulatory assessment.

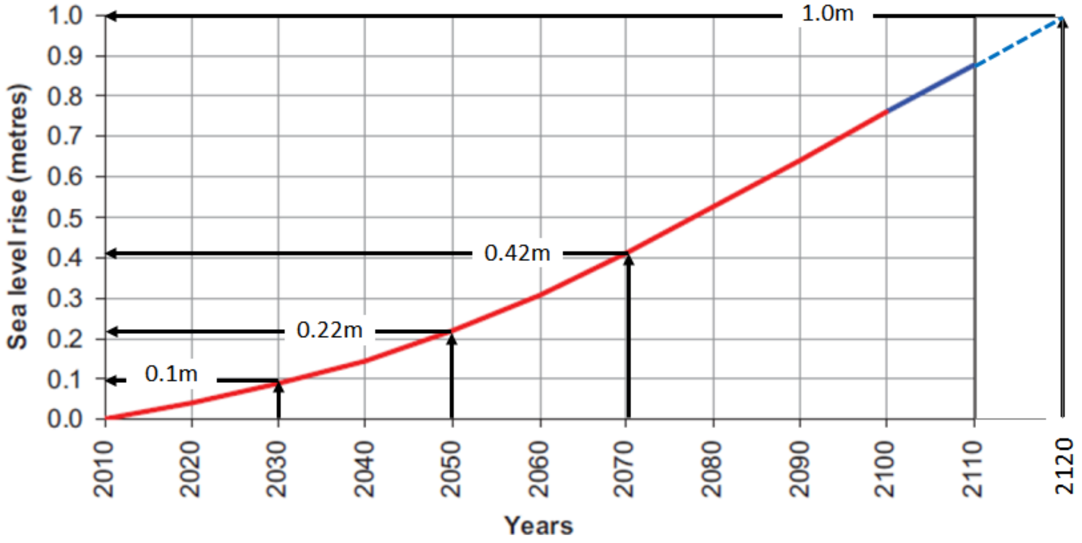


Figure 1-1: Sea Level Forecast Curve Used for WA Coastal Planning (Department of Transport WA 2010)

Overall, projected sea level rise due to climate change is in the order of 1m over the next 100 years, with annual rise of 4mm/yr to 10mm/yr.

The effect of projected sea level rise on intertidal habitats occurs in conjunction with other dynamic processes, including storms, tidal and sea level variability, sediment dynamics, salinity and nutrient fluxes, geomorphic change and vegetation life cycles. Estimation of future intertidal habitat potentially involves integrating these processes with projected sea level rise over the next 50 to 100 years. However, the overall scientific basis with which to predict longer-term intertidal habitat change is limited. Existing scientific frameworks variously incorporate available (modern) observations, inference from paleo-records, conceptual models for habitat dynamics, and geomorphic models. This information is more strongly available for description of mangroves than algal mats or other intertidal habitats.

- **Modern observations** of intertidal habitat dynamics are mainly available over the last 50 years, with substantially increased knowledge developed in the last 20 years. This time scale describes a period of mild sea level rise, generally <2 mm/yr, with total mean sea level variability of +/-0.2m, over sub-decadal time scales (White *et al*. 2014). Consequently, although periods of accelerated sea level rise (~9mm/yr) have been observed, these have not been sustained for decades or longer.
- Most records of mangrove habitat dynamics relate to the consequences of habitat alteration, generally associated with mangrove loss due to disturbance (Alongi 2008, Winterwerp *et al*. 2013). The capacity for mangrove communities to migrate with projected sea level rise or coastal change is widely acknowledged, although there are few demonstrations of how this occurs (Eliot & Eliot 2016), and in many cases, migration is constrained by structures or incompatible morphology to landward (Gilman 2007; Pontee *et al*. 2022). Satellite based evaluation of mangrove area above a coverage density threshold has provided a tantalising indication of mangrove health response to tidal and mean sea level fluctuations for Australia (Saintilan *et al*. 2022), but this does not directly relate sea level and mangrove habitat area.
- **Paleo-records** of mangrove dynamics extend across a range of geomorphic time scales and settings. Transition from the Last Glacial Maximum provides an initiation point for modern mangrove communities (Woodroffe *et al*. 1993), suggesting their inability to cope with sustained rates of sea level rise (above 5mm/yr) combined with substantial coastal and climate change (Ellison & Stoddart 1991).
- Collation of more modern evidence, including geomorphology, field evidence and laboratory testing, has been used to suggest sea level rise thresholds for Australian mangrove systems. Mangrove loss during phases of rising sea level has been analysed, suggesting that the mangrove capacity to capture sediment becomes limited when relative sea level rise (RSLR) is above 8 mm/yr. Mangrove loss occurs for RSLR above 12 mm/year (Woodroffe *et al*. 2016; Saintilan *et al*. 2020).
- **Conceptual models** for habitat development and persistence are based on matching apparently influential factors (e.g. hydroperiod, nutrient availability, salinity, soil chemistry) to habitat structure and change over time (Semeniuk 1994, 1996). This allows projection of change relevant to settings that are controlled by dynamic factors – in this case mangroves apparently controlled by porewater salinity. However, this does not necessarily allow secondary factors to be identified, that may not presently be influential, but come into play with changing conditions – such as the effect of soil chemistry, where vegetation communities could migrate across the landform unit they occupy, but not into an adjacent unit.
- In many settings, intertidal habitat dynamics are determined by **geomorphic change**, with the influence of vegetation providing a supplementary, albeit sometimes critical, role. Morphodynamics can include coastal erosion or accretion, stream bank collapse, channel migration or avulsion (van Maanen *et al*. 2015, Alizad *et al*. 2018, Gong *et al*. 2018, Anthony & Goichot 2020, Carlson *et al*. 2021, Zhao *et al*. 2022). Models for morphodynamic change are used to extend beyond the observed range of conditions, but with further extension, it becomes increasingly likely that processes will diverge from model representation.

Evaluation of potential future change to intertidal habitats for the Ashburton Salt project has been developed through:

- Historical evidence from aerial imagery indicating minor, local scale changes to mangrove systems, and substantially greater dynamics of algal mat areas, with seasonal and interannual fluctuations.
- A conceptual model for mangrove dynamics, based on structural evidence they are constrained by porewater salinity, specifically hypersaline conditions at the landward fringe. Consequently, the model for response to sea level rise has considered potential expansion of tidal creeks, creating additional area with suitable porewater salinity for mangroves.
- The capacity for mangroves to establish and to have sustained presence is partly dependent on geomorphic stability, requiring sediment supply or production for habitats to survive in conditions of rising sea level, otherwise they ‘drown’ over time. Mangrove habitat destruction can also occur through excessive sediment supply, through smothering, or if barrier development impedes tidal exchange and creates poor water quality. Paleo-records used to characterise broad-brush sea level rise thresholds (Saintilan *et al*. 2020) are comparable to litter production rates (Alongi 2011). However, in practice, their applicability across different settings is not definitive, with coastal instability, bank instability and sediment distribution networks all varying substantially.

This information provides a reasonable level of confidence for projecting a growth phase for mangroves under initial sea level rise, but there is less confidence in the switch to mangrove loss with higher rates of sea level rise, and subsequent rate of mangrove loss (Table 1-1). For small sea level rise, mangrove communities display ‘buffered’ sensitivity to sea level due to the nature of fringing morphology (e.g. banks built during high water conditions may remain until a higher event, if not subject to migration).

Table 1-1: Confidence Associated with Modelled Behaviour

Behavioural Models	Confidence
Mangrove presence controlled by porewater salinity	**High** for mean sea level +/- 0.2m **Moderate-High** subsequently, as other (unidentified) factors may gain influence
Tidal creek extension, including channels inside mangrove flats, is related to tidal exchange	**Moderate-High** Relationship is not evenly distributed, with increased tidal exchange more strongly affecting longer channels.
Mangrove area increase with greater potential habitat (relating creek expansion to area with suitable porewater salinity)	**Moderate** Limited indication of historic expansion with mild sea level rise.
Mangrove area reduction resulting from excessive sea level rise, impeding establishment / resilience, or causing geomorphic instability.	**Low-Moderate** Behavioural thresholds not strongly defined and may be subject to diverse local factors.

Observationally, morphodynamic stability is nearly a pre-requisite for mangrove growth, with establishment phases usually when sea levels are moving downward or rising slowly, over inter-annual time scales. This is particularly relevant over time scales for mangrove establishment, typically in the range of 3-8 years.

Opportunity for establishment phases is developed through the superposition of sea level rise with sea level variability (Figure 1-2). To estimate the relative balance of growth and disturbance phases, historic sea level variability has been described using the distribution of 5-yearly mean sea level trends (Figure 1-3).

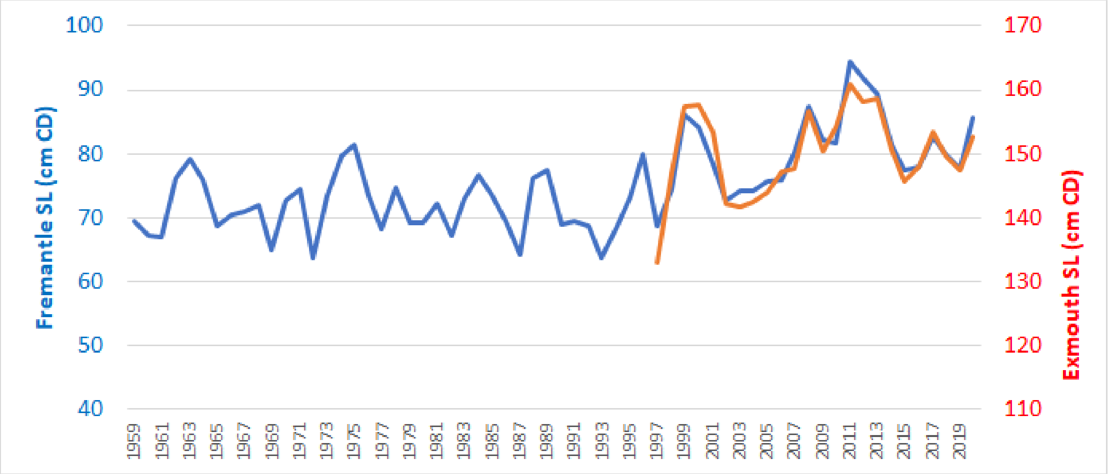


Figure 1-2: Fremantle and Exmouth Annual Mean Sea Level Record

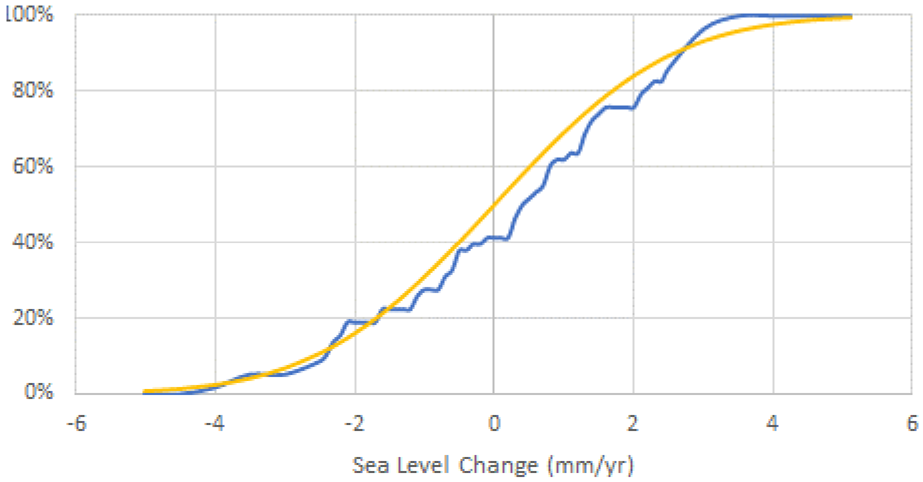


Figure 1-3: Cumulative Distribution of 5-Yearly Mean Sea Level Trends

2. Models For Projection of Intertidal Habitat Change

Projections of intertidal habitats change related to the Ashburton Salt project have been developed for mangrove and algal mat habitats. This has been undertaken using two models:

Model 1: Mangrove Response to Sea Level Rise
Model 2: Algal Mat Response to Sea Level Rise

2.1. MANGROVE HABITAT RESPONSE TO SEA LEVEL RISE

Mangrove habitat change has been estimated using the conceptual framework developed in Seashore (2021), summarised in Section 1.2, and illustrated schematically by Figure 2-1.

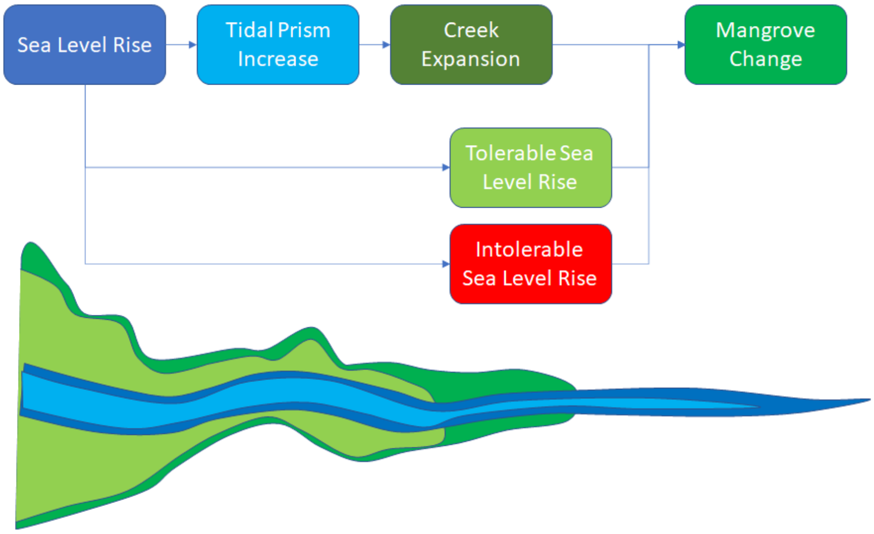


Figure 2-1: Model Schematic for Mangrove Response to Sea Level Rise

Potential for creek expansion was previously reported in Seashore Engineering (2021) as a function of tidal exchange. Without the proposed salt ponds, sea level rise is projected to increase tidal exchange, resulting in creek expansion, for both the discrete creeks which extend into the coastal lagoon, and those smaller channels which are distributed throughout coastal fringing mangrove ‘woodland’. For low rates of sea level rise, channel expansion provides opportunity for increased habitat suitable for mangroves, by reducing porewater salinity. However, the relative distribution of potential habitat expansion is unequal:

- Larger channels are connected to areas that are not presently subject to inundation – these will experience a greater proportional increase to tidal exchange.
- Discrete areas of mangroves can expand in two dimensions. This gives greater proportional expansion than for mangroves fringing creek channels, or those occupying a ‘continuous’ coastal band, where potential expansion can only be landward.

Inclusion of ‘intolerable’ sea level rise thresholds was undertaken through consideration of thresholds for impeded mangrove growth and anticipated instability (Figure 2-2), incorporating the additional factor of sea level variability.

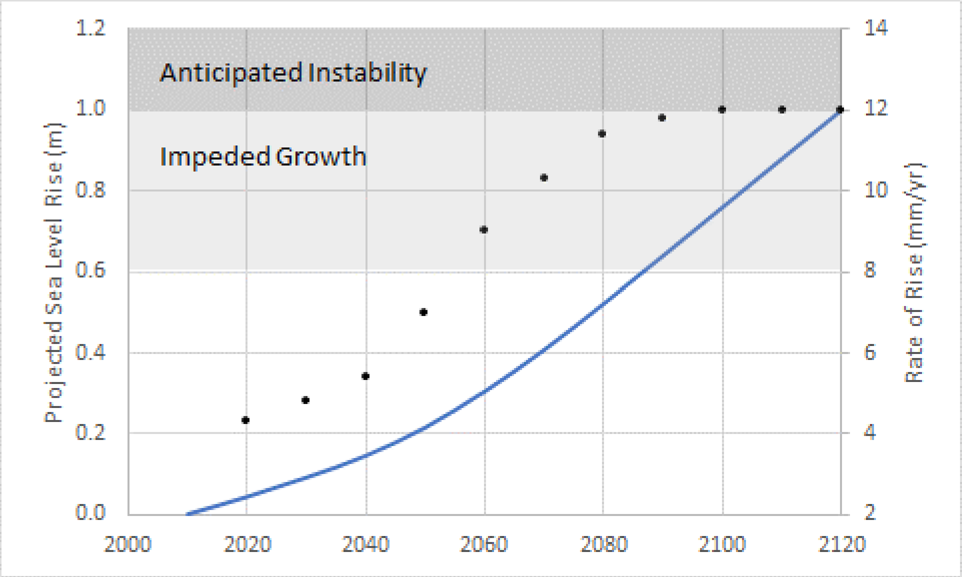


Figure 2-2: Projected Sea Level Rise and Relationship to Mangrove Thresholds

The rate of response to sea level rise, switching from mangrove growth to loss, was estimated using the estimated relative occurrence of growth and disturbance phases, by superimposing sea level rise and sea level variability (Figure 2-3). Using a threshold of 8mm/yr as a distinction between conditions conducive to loss or growth, the relative balance of these phases was used to estimate the overall direction of response to sea level rise. For the example shown (Figure 2-3), at 4mm/yr mean sea level rise, approximately 3% of the time there would be a rate of rise expected to cause mangrove disturbance. Application of this transitional model, where net behaviour is related to occurrence rather than severity, gives a ‘balance’ at 8 mm/yr mean sea level rise and 98% occurrence of loss conditions if mean sea level rise of 12 mm/yr occurs.

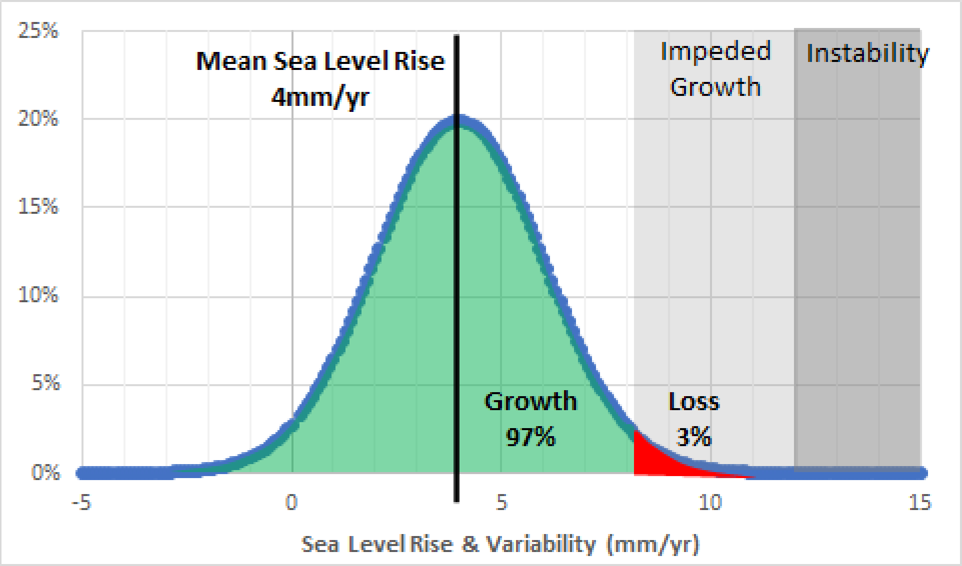


Figure 2-3: Model for Transitional Response to Sea Level Rise

Application of this model to local assessment units (LAU1 and LAU2) has been undertaken to estimate the time sequence of mangrove habitat. Definition of these areas and estimates of existing mangrove habitat have been taken from AECOM (2021). Influence of proposed salt ponds is shown in Figure 2-4, where the ponds can prevent increase of tidal exchange with sea level rise. The difference between the two curves is based on 100% transfer from increased tidal exchange to habitat expansion. As noted previously, this distribution is not equal, with the larger 'woodland' areas of mangroves likely to experience a smaller proportional increase than the smaller areas along creek channels.

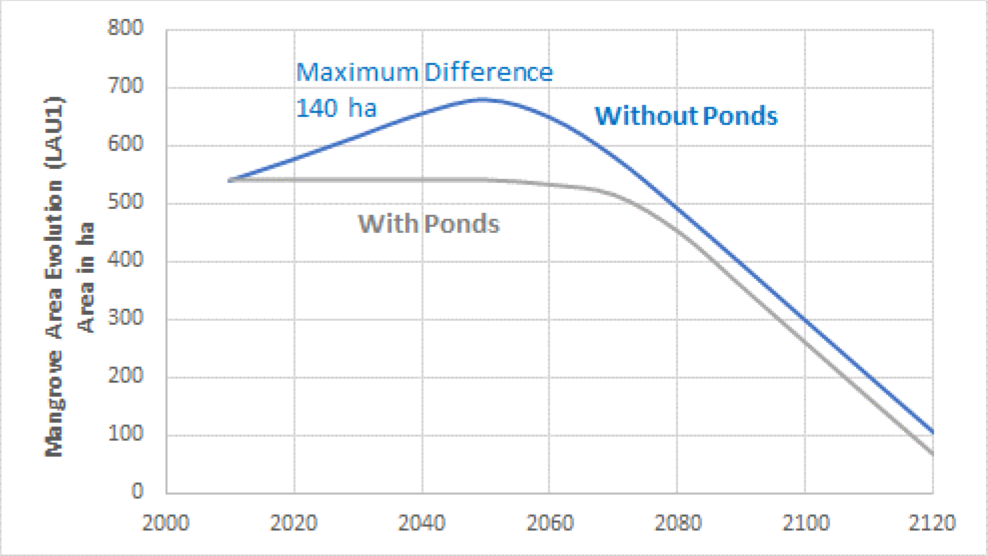


Figure 2-4: Projection of Mangrove Habitat for LAU1 (North)

The salt ponds do not occupy areas potentially contributing to future tidal exchange for the area of LAU2 (South). Consequently, projected mangrove behaviour is solely a response to sea level rise (Figure 2-5).

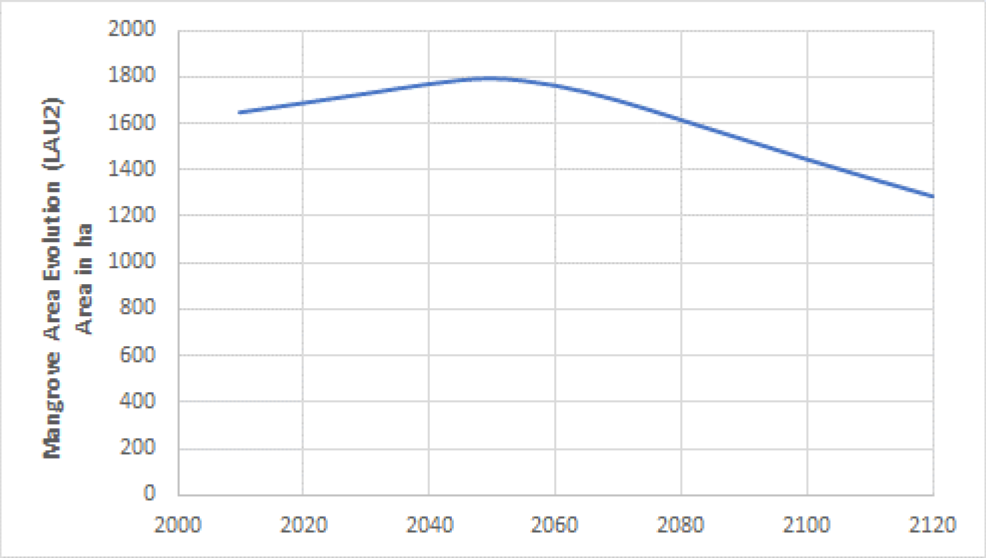


Figure 2-5: Projection of Mangrove Habitat for LAU2 (South)

2.2. ALGAL HABITAT RESPONSE TO SEA LEVEL RISE

Algal mat habitat change has been estimated using the conceptual framework developed in Seashore (2021), illustrated schematically by Figure 2-6. This represents a far simpler physical basis than mangrove dynamics, with algal mat expansion related to increasing area of tidal inundation, until the western part of the coastal lagoon is fully occupied. The low sediment ridge near the centre of the coastal lagoon is expected to cause a physical constraint to further expansion.

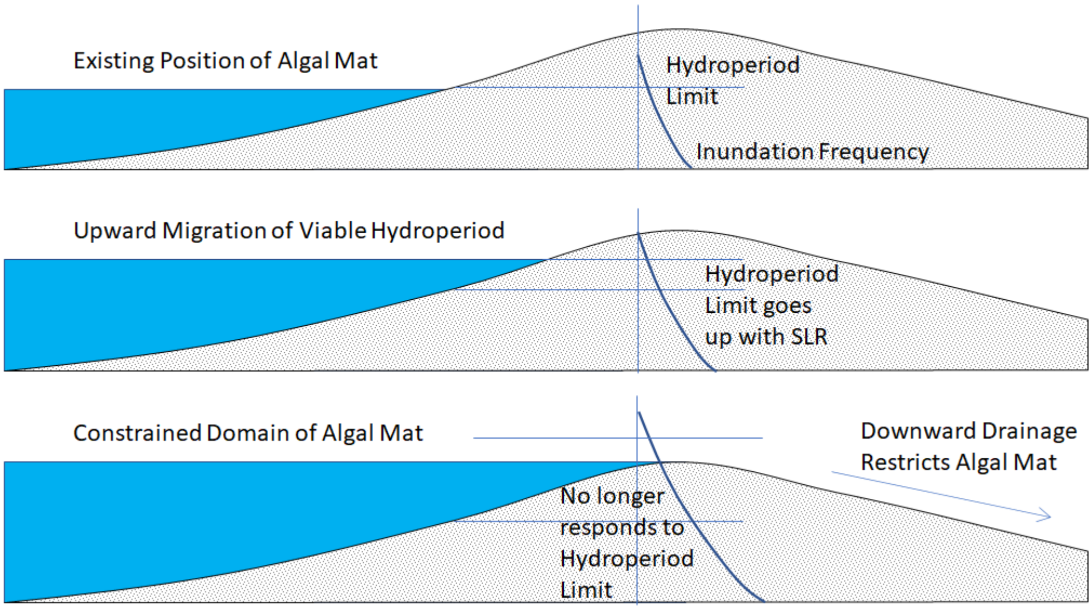


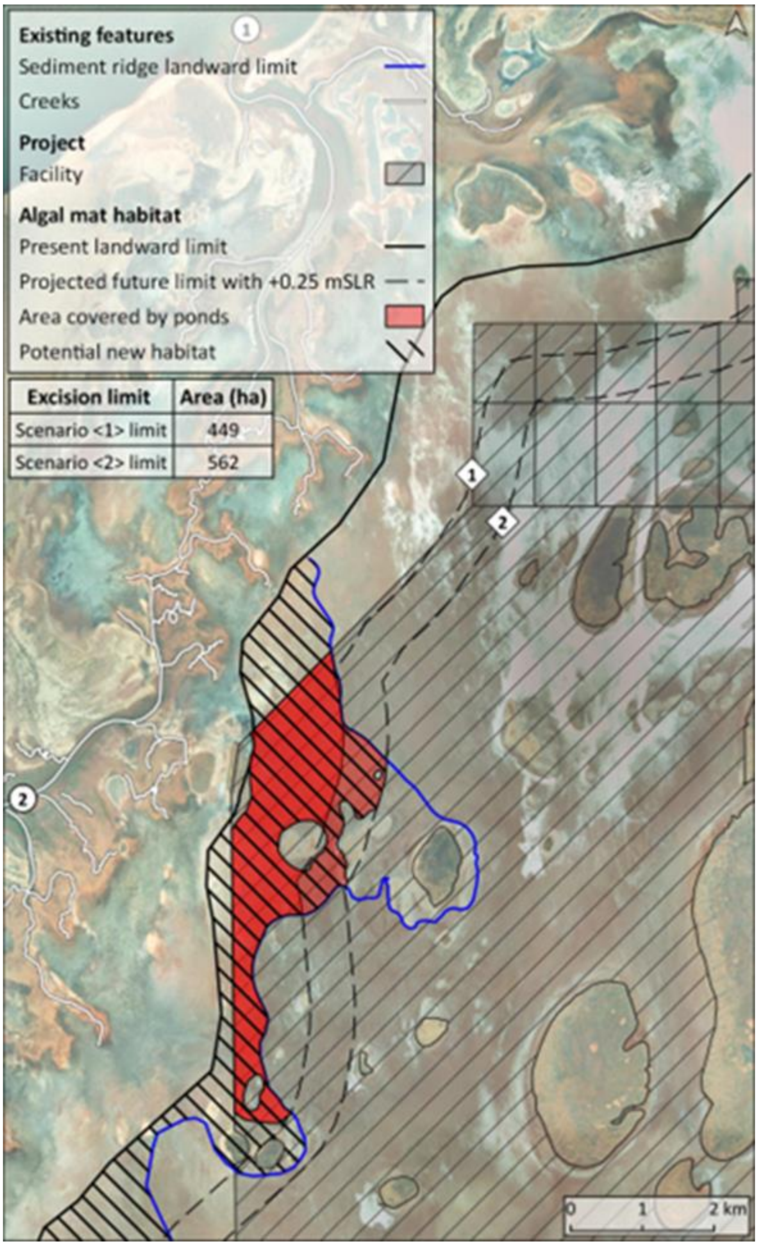
Figure 2-6: Model Schematic for Algal Mat Response to Sea Level Rise

Expected expansion is 500-750 m per 0.1 m sea level rise, based on existing LiDAR DEM contours, reaching the shallow sediment ridge with 0.1-0.3m rise from the existing landward limit of algal mat. To project algal mat habitat with sea level rise, the horizontal rate of expansion has simply been related to approximate length, assuming the ridge will provide constraint following sea level rise of 0.25m.

The proposed salt ponds overlay a part of the western coastal lagoon, to which algal mat could otherwise expand with sea level rise. This area was estimated to be up to 560 ha, which is effectively excised from potential growth (Figure 2-7).

Application of the algal mat response model to local assessment units (LAU1 and LAU2) has been undertaken to estimate the time sequence of algal mat habitat. Definition of these areas and estimates of existing mangrove habitat have been taken from AECOM (2021).

Influence of proposed salt ponds in LAU1 (North) is shown in Figure 2-8. The salt ponds do not occupy areas potentially occupied by algal mat expansion in LAU2 (South). Consequently, projected algal mat behaviour in LAU2 is solely a response to sea level rise (Figure 2-9).



Excision limit	Area (ha)
Scenario <1> limit	449
Scenario <2> limit	562

Figure 2-7: Area where Salt Ponds Interact with Potential Algal Mat Habitat

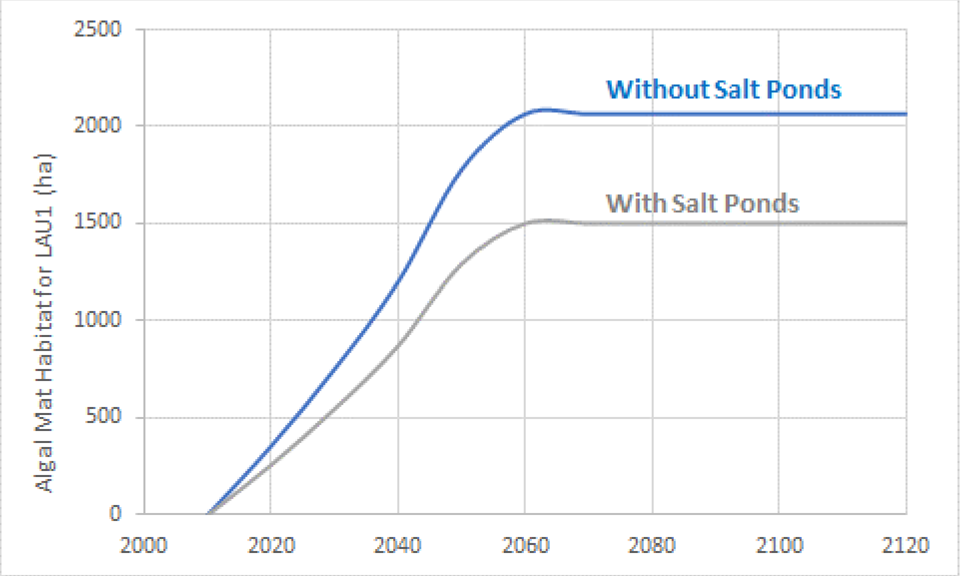


Figure 2-8: Projection of Algal Mat Habitat for LAU1 (North)

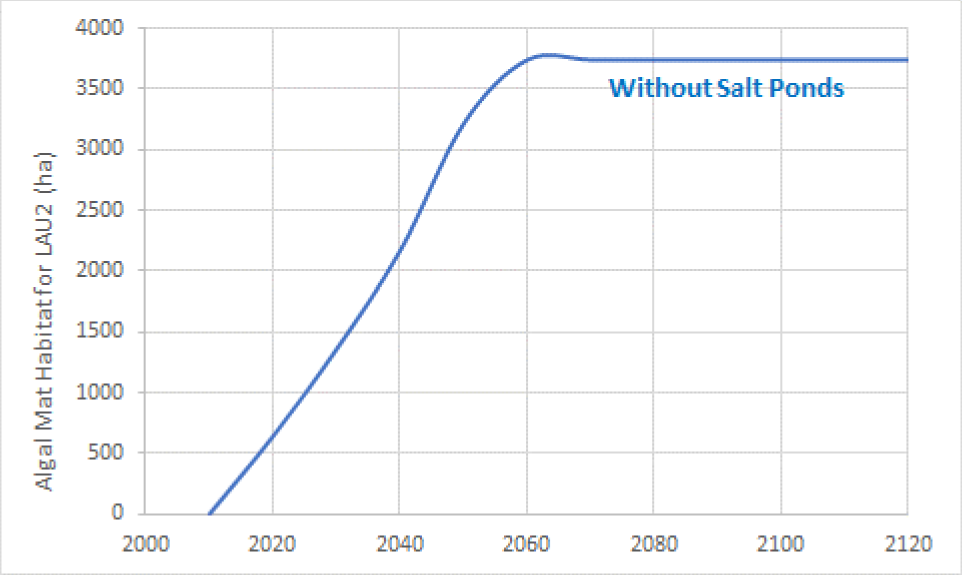


Figure 2-9: Projection of Algal Mat Habitat for LAU2 (South)

3. Model Outcomes

Model outcomes are presented in tabular from in Table 3-1 for mangrove habitat and Table 3-2 for algal mat habitat. It is reiterated that these estimates have been developed using a combination of observational and conceptual models, incorporating behavioural patterns that although based on best available knowledge identified, have limited scientific support, and should be applied correspondingly. The most significant limitation is associated with reduction of mangrove habitat resulting from excessive rates of sea level rise – although there is geomorphic evidence of this process, it has not been experienced in the modern period.

Table 3-1: Projected Time Series of Mangrove Habitat

Year	Sea level rise (m)	Mangrove area (ha) without project		Mangrove area (ha) with project	
		LAU1	LAU2	LAU1	LAU2
2010	0.00	540	1645	540	1645
2020	0.04	577	1684	540	1684
2030	0.09	616	1725	540	1725
2040	0.15	655	1765	540	1765
2050	0.22	679	1789	540	1789
2060	0.31	649	1759	532	1759
2070	0.41	581	1696	514	1696
2080	0.52	491	1613	451	1613
2090	0.64	395	1529	355	1529
2100	0.76	298	1446	258	1446
2110	0.88	202	1365	162	1365
2120	1.00	106	1288	66	1288

Table 3-2: Projected Time Series of Algal Mat Habitat

Year	Sea level rise (m)	Algal mat area (ha) without project		Algal mat area (ha) with project	
		LAU1	LAU2	LAU1	LAU2
2010	0.00	3350	2034	3350	2034
2020	0.04	3705	2679	3608	2679
2030	0.09	4101	3399	3896	3399
2040	0.15	4546	4209	4220	4209
2050	0.22	5124	5259	4640	5259
2060	0.31	5413	5784	4850	5784
2070	0.41	5413	5784	4850	5784
2080	0.52	5413	5784	4850	5784
2090	0.64	5413	5784	4850	5784
2100	0.76	5413	5784	4850	5784
2110	0.88	5413	5784	4850	5784
2120	1.00	5413	5784	4850	5784

Projections are sensitive to assumptions, including the forecast sea level curve.

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