Prepared for
K + S Australia Pty Ltd
ABN: 55607033447

Assessment of Benthic Communities and Habitats

Ashburton Salt Project

02-Nov-2022
Ashburton Salt
Doc No. 60692048_4

Assessment of Benthic Communities and Habitats

Ashburton Salt Project

Client: K + S Australia Pty Ltd

ABN: 55607033447

Prepared by

AECOM Australia Pty Ltd
Whadjuk Nyoongar Country, Level 3, 181 Adelaide Terrace, Perth WA 6004, GPO Box B59, Perth WA 6849, Australia
T +61 8 6230 5600 www.aecom.com
ABN 20 093 846 925

02-Nov-2022

Job No.: 60692048

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

Quality Information

Document Assessment of Benthic Communities and Habitats

Ref 60692048

Date 02-Nov-2022

Originator Anthony Bougher, Ian Baxter & Marthin Slabber

Checker/s Ian Baxter

Verifier/s Peter Young

Revision History

Rev	Revision Date	Details	Approved	
			Name/Position	Signature
A	16-Jul-2020	For client review	Peter Young Associate Director	
B	19-Apr-2021	For client review	Peter Young Associate Director	
0	23-Jun-2021	For client review	Peter Young Associate Director	
1	08-Jul-2021	For client review	Peter Young Associate Director	
2	20-Jul-2021	For client review	Peter Young Associate Director	
3	20-Sep-2021	For client use	Peter Young Associate Director	
4	02-Nov-2022	For client use	Peter Young Associate Director	[signature]

Table of Contents

List of Figures

List of Tables

List of Plates

1.0 Introduction

1.1 Project Overview

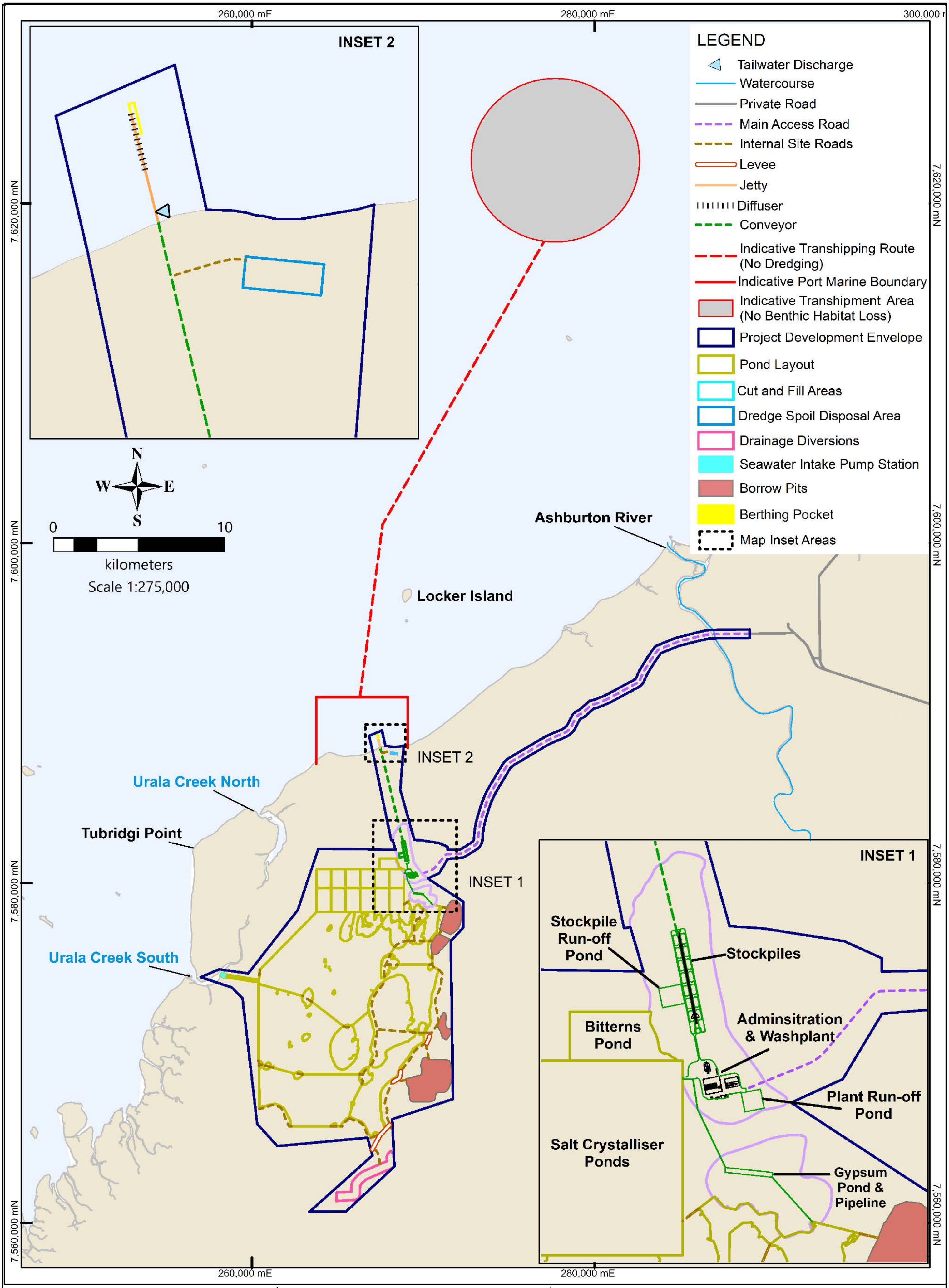
K plus S Salt Australia Pty Ltd (K+S) is proposing to develop a green field solar salt project on the WA coast approximately 40 km south-west of Onslow; inland from Tubridgi Point. The Project, named the Ashburton Salt Project, will include the construction of solar salt concentration and crystallisation ponds and associated infrastructure. A development envelope has been proposed including:

- a seawater intake (comprising an intake sump, pipelines, pumps and channel)
- concentration and crystallisation ponds
- salt wash plant
- stockpiles and conveyors
- bitterns discharge infrastructure (including a dilution pond, pipeline and diffuser)
- jetty and product loading infrastructure
- access road, internal site roads and haul roads (for construction materials and, during operations, for site maintenance and product transfer)
- borrow pits for extraction of clay and other construction materials
- drainage diversions
- dredging and onshore placement of dredged material
- buildings such as offices, storage and workshops
- sewage treatment
- water monitoring bores
- small desalination plant
- service corridors
- electricity and natural gas distribution
- equipment parking and laydown areas
- fuel storage and a refuelling station
- helipad.

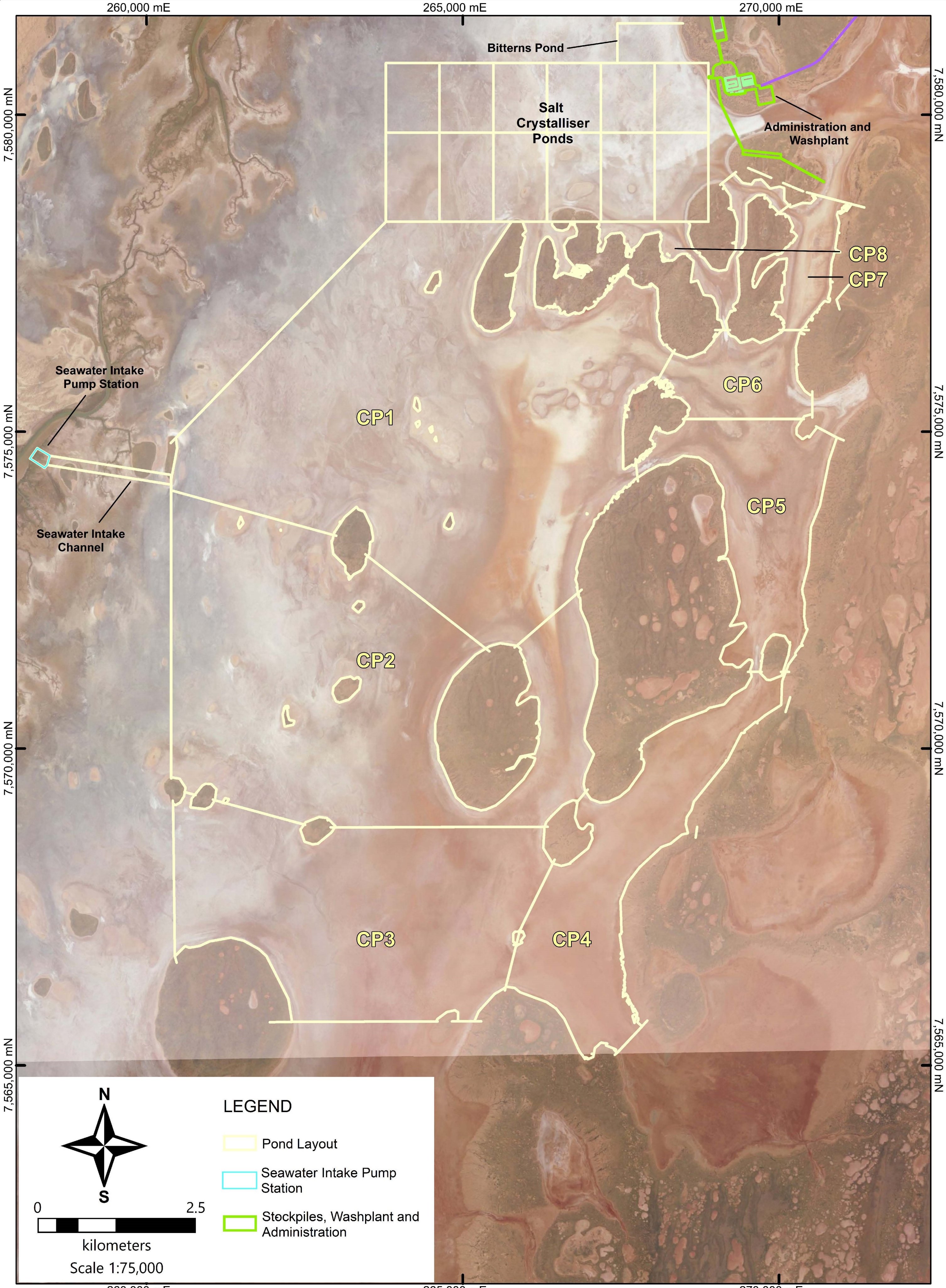
The proposed Project layout is shown in Figure 1.

Seawater will be pumped from Urala Creek South via a channel into a series of eight evaporation (salt concentration) ponds (Figure 2– Ponds CP1 to CP8). As seawater passes through the pond system, water is evaporated via solar energy, thereby producing a progressively denser brine with an increasing concentration of dissolved salts. Saturated brines are transferred to the crystalliser ponds, where water is evaporated by solar energy until salt crystals (predominantly sodium chloride) are precipitated. Under normal operational conditions, it is anticipated that 250-300 mm of harvestable salt will accumulate in the crystalliser ponds over a 12-month period.

At optimum times, the crystalliser ponds will be drained, dried and harvested. After washing and stockpiling the salt is delivered to the jetty via conveyor for loading onto a purpose-built shallow draft, self-propelled transhipment vessel (‘transhipper’), which will carry the salt to a larger oceangoing vessel anchored in deeper water offshore.



K+S	**Figure 1** **Project Layout**	Date: 25/08/2021 Paper: A4 P GDA94, MGA50 Data Source: 4A, 4E, 13D, 17A File Info: S43a_Site_Layout_Detail_20210822.WOR



K+S

Figure 2
Pond Layout

Date: 08/12/2020 Paper: A4 P GDA94, MGA50
Data Source: 4A, 4E, 13D, 17A
File Info: K04_J10_PERF7_Pond_Layout_20201208.WOR

1.2 Environmental Impact Assessment Process

The Project was referred to the WA Environmental Protection Authority (EPA) under Section 38 of the *Environmental Protection Act 1986* (EP Act) in October 2016. The referral and supporting document (EnviroWorks, 2016) identified Benthic Communities and Habitats (BCH) as a key environmental factor that will be directly and indirectly impacted as a result of the Project.

In November 2016, the EPA determined that the Project required a detailed assessment to determine the extent of the Project's direct and indirect impacts, including long-term impacts, and how the environmental issues could be managed, and therefore the Project would require assessment via a Public Environmental Review.

The EPA recognises the ecological importance of BCH, particularly benthic primary producers, and the potential consequences of BCH loss. The EPA's objective for the BCH factor is "to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained".

A BCH assessment study has been undertaken to understand the likely range of possible impacts associated with the Project on this environmental factor as defined in the 2017 Environmental Scoping Document (ESD) (EnviroWorks Consulting 2017). The relevant ESD requirements have been addressed in this report, and accompanying reports, as summarised in Table 1.

The scope of studies has been undertaken in accordance with:

- Environmental Factor Guideline: Benthic Communities and Habitats (EPA 2016a)
- Technical Guidance - Protection of Benthic Communities and Habitats (EPA 2016b)
- Technical Guidance - Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016c)
- Technical Guidance - Protecting the Quality of Western Australia's Marine Environment (EPA 2016d)
- Guidance Statement 1 – Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (EPA 2001).
- Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016e).

1.3 Benthic Habitat Assessment

EPA (2016b) sets out:

a) the EPA's contemporary approach for considering activities which may directly or indirectly cause impact or serious damage to, or irreversible loss of, benthic communities and habitats;

b) considerations for impact mitigation and how they should be applied;

c) a framework for considering cumulative loss of benthic communities and habitats and the potential consequences for marine ecological integrity and biological diversity;

d) the EPA's expectations for information to be supplied by proponents for EIA.

The geographic scope of EPA (2016b) guidance includes all Coastal Waters of Western Australia to the high water mark of the intertidal zone. Therefore this assessment has included BCH located within the following habitats:

- Subtidal zone defined as the zone of ocean close to shore, but constantly submerged by seawater.
- Intertidal zone defined as the area of land where the ocean meets the land between mean high and mean low spring tides. It is submerged by seawater at high tide and exposed to air at low tide.

The supratidal zone is defined as the portion of land which lies above the level of mean high water for spring tides. It is inundated only occasionally by exceptional tides or by tides augmented by a storm surge. The supratidal zone is a transition zone between the intertidal and terrestrial environment. Whilst supratidal habitats have been discussed in this report to provide context, they are not considered specific to the geographic scope of EPA (2016b) which includes habitats up to the high water mark of the intertidal zone.

Each of these zones is depicted in Figure 3 below.

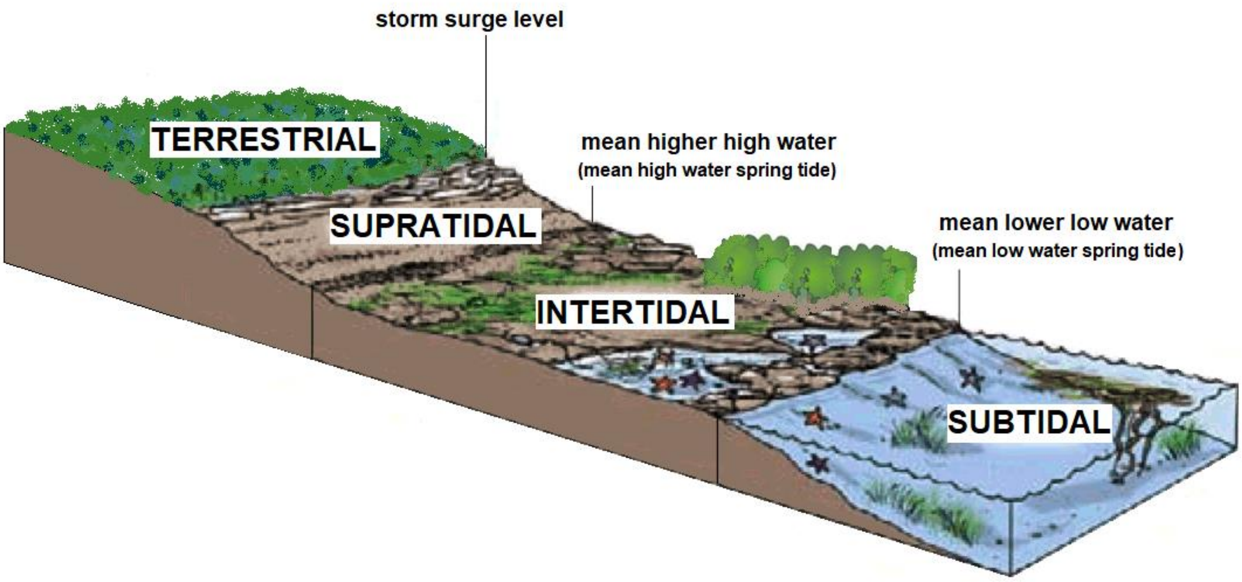


Figure 3 Sub-tidal, intertidal and supratidal zonation

Table 1 ESD Requirements

Task #	Subtask #	Required Work	Report Section	Other Reports
1		Undertake desktop review and ground-truthing of Benthic Communities and Habitats spatial extents and any temporal variations to identify and describe the different types of benthic communities and habitats, and produce comprehensive mapping (at an appropriate scale) of these benthic communities/habitats within an appropriate Local Assessment Unit (LAU).	2.0 3.0 5.2	
2		Determine direct loss of Benthic Communities and Habitats to occur due to project clearing and direct habitat disturbance.	5.5.1	
3		Undertake appropriate impact assessment techniques (including groundwater, hydrodynamic marine, tidal inundation and surface water modelling where relevant) to predict indirect loss of Benthic Communities and Habitats to occur due to:	5.5 0	
	3a	Changes in tidal inundation and/or hydrodynamics caused by project infrastructure.	5.5.2 5.5.3	
	3b	Changes in surface water flows, nutrient movement and sediment movement/deposition caused by project infrastructure.	5.5.5 5.5.6	
	3c	Changes in surface and ground water quality caused by the project.	5.5.4	
	3d	Changes in water flows or depths.	5.5.2 5.5.6	
	3e	Introduction of contaminants.	5.6.3	
	3f	Elevated turbidity due to shipping, boat movements and dredging activities.	5.6.1	
	3g	Introduction of pests in ballast water and on vessel hulls including dredge related vessels.	5.6.4.4	Marine Fauna Rpt
	3h	Hindering the ability to adapt to climate change induced sea level rise (SLR).	8.0	Response to SLR Rpt
	3i	Changes in creek habitat for benthic communities and protected species in relation to the seawater intake points in Urala Creek North and South.		Marine Fauna Rpt
4		Identify any critical associations between important marine fauna (including sea and shore bird) and key benthic communities and habitats that are likely to be impacted (including nursery habitats) and assess, then manage impacts to those marine fauna as described under “Marine Fauna” below.		Marine Fauna Rpt Shorebird Rpt

Task #	Subtask #	Required Work	Report Section	Other Reports
5		Determine the likely toxicity of the bitterns to be discharged and use in combination with bitterns plume modelling to determine the potential impacts of the discharge on benthic communities and habitats. Specifically, undertake a marine biota ecotoxicology assessment of local marine indicator species for proposed marine discharges (bitterns, dredging sediment mobilisation). This assessment will:		See below
	5a	Identify appropriate local indicator species (including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages);		Ecotoxicology Technical Memo Marine Fauna Rpt
	5b	Test the tolerance of indicator species to predicted bitterns discharge and turbidity (under usual operation and extreme events), with consideration given to fertilisation, embryo and larval development, growth, and chronic and acute toxicity.		Ecotoxicology Technical Memo Marine Fauna Rpt
	5c	Establish trigger thresholds, below which discharge concentrations may be considered safe.		Ecotoxicology Technical Memo Marine Fauna Rpt
	5d	Use the results of the biota ecotoxicology assessment to inform the marine hydrodynamic modelling and design process to determine the likely impact of the discharges modelled on marine biota sensitive receptors.	5.6.2.4	Hydrodynamic modelling Report Marine Fauna Rpt
6		Evaluate the combined direct and indirect impacts to Benthic Communities and Habitats, after demonstrating how the mitigation has been considered and applied. Predictions shall:		
	6a	Align with the approaches and standards outlined in Technical Guidance - Protection of Benthic Communities and Habitats (Environmental Protection Authority, 2016) and Technical Guidance - Environmental Impact Assessment of Marine Dredging Proposals (Environmental Protection Authority, 2016);	5.5 0	
	6b	Include a description of the severity and duration of reversible impacts, and the consequences of impacts on, and risks to, biological diversity and ecological integrity at local and regional scales (with specific attention given to prawn nursery habitats);	5.5 0	
	6c	Include an estimate of the level of confidence underpinning predictions of residual impacts; and		
	6d	Give consideration to plausible events with the potential to significantly impact benthic communities and habitats including the introduction of marine pests, breached levee walls, hydrocarbon and other spills, and extreme episodic events (e.g. tropical lows and cyclones).	5.6.3.4 5.6.4.4	Marine Fauna Rpt ERD
7		Assess the biodiversity and functional ecological values and significance of Benthic Communities and Habitats in relation to arid-tropical mangrove communities (Guidance Statement 1 – Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (Environmental Protection Authority, 2001))	9.0	

Task #	Subtask #	Required Work	Report Section	Other Reports
		and in the context of nationally important wetland WA007, Exmouth Gulf East (A Directory of Important Wetlands in Australia (Australian Nature Conservation Agency, 1993)).		
8		Describe the proposed monitoring, management and mitigation measures to be implemented, including an assessment of their effectiveness, at the design and operations stages to demonstrate that all reasonable and practicable avoidance and mitigation measures will be taken to ensure residual impacts and risks are acceptable. Monitoring proposed should include an appropriate baseline and reference sites.	7.1	
9		Document management and monitoring measures proposed for construction, operation and closure, including defined trigger levels and adaptive management responses, to ensure residual impacts are not greater than predicted and achieve predicted outcomes/objectives.	7.1.2.2	
10		Summarise residual impacts, after considering avoidance and minimisation. Analyse these impacts to identify and detail any that are significant. If significant residual impacts remain propose appropriate offsets.	7.2	
11		Create an offsets position following application of the 'mitigation hierarchy' (avoid, minimise, rehabilitate, offset).	7.1.4	
12		Demonstrate and document how the EPA's objective for this factor can be met.	7.2	

Reference for "other reports":

AECOM, 2021a. Marine Fauna Impact Assessment

Biota, 2021. Ashburton Salt Project Migratory Shorebird Assessment

EnviroWorks Consulting, 2021. Ashburton Salt Project: Environmental Review Document (ERD)

Seashore Engineering, 2021, Ashburton Salt Intertidal Habitat Response to Sea Level Rise

2.0 Intertidal Habitats

2.1 Survey and Mapping Methods

A survey of intertidal habitats in the vicinity of the Project was undertaken by experienced AECOM marine and intertidal scientists in May 2019 to:

- Document intertidal habitats at selected localities within the study area.
- Ground truth preliminary mapping of mangrove and algal mat distribution to facilitate an assessment of the extent of potential Project-related impacts as required by EPA Technical Guidance for the Protection of Benthic Communities and Habitats (EPA 2016a, 2016b).
- Collect cores from algal mat and salt flat areas to confirm the presence/absence of algal mats and determine algal mat, structure, species composition and concentration of chlorophyll a and phaeophytin (indicators of photosynthetic activity).

2.1.1 Site selection

A range of sites were accessed to provide both targeted information on areas of potential impact and broader scale information to inform and update the preliminary mapping. The locations of sites were selected with consideration of:

- Areas identified in the preliminary design as being potentially directly impacted (e.g. seawater intake area at Urala Creek South) or immediately adjacent to the disturbance footprint.
- Representativeness of the range of intertidal habitats and major coastal types (including examples of the main mangrove assemblages and algal mat areas).
- Ground truthing data to inform the intertidal mapping required within the Local Assessment Units (LAUs).

The locations of the 63 sites visited during the May 2019 surveys are shown in Figure 4.

2.1.2 Survey methodology

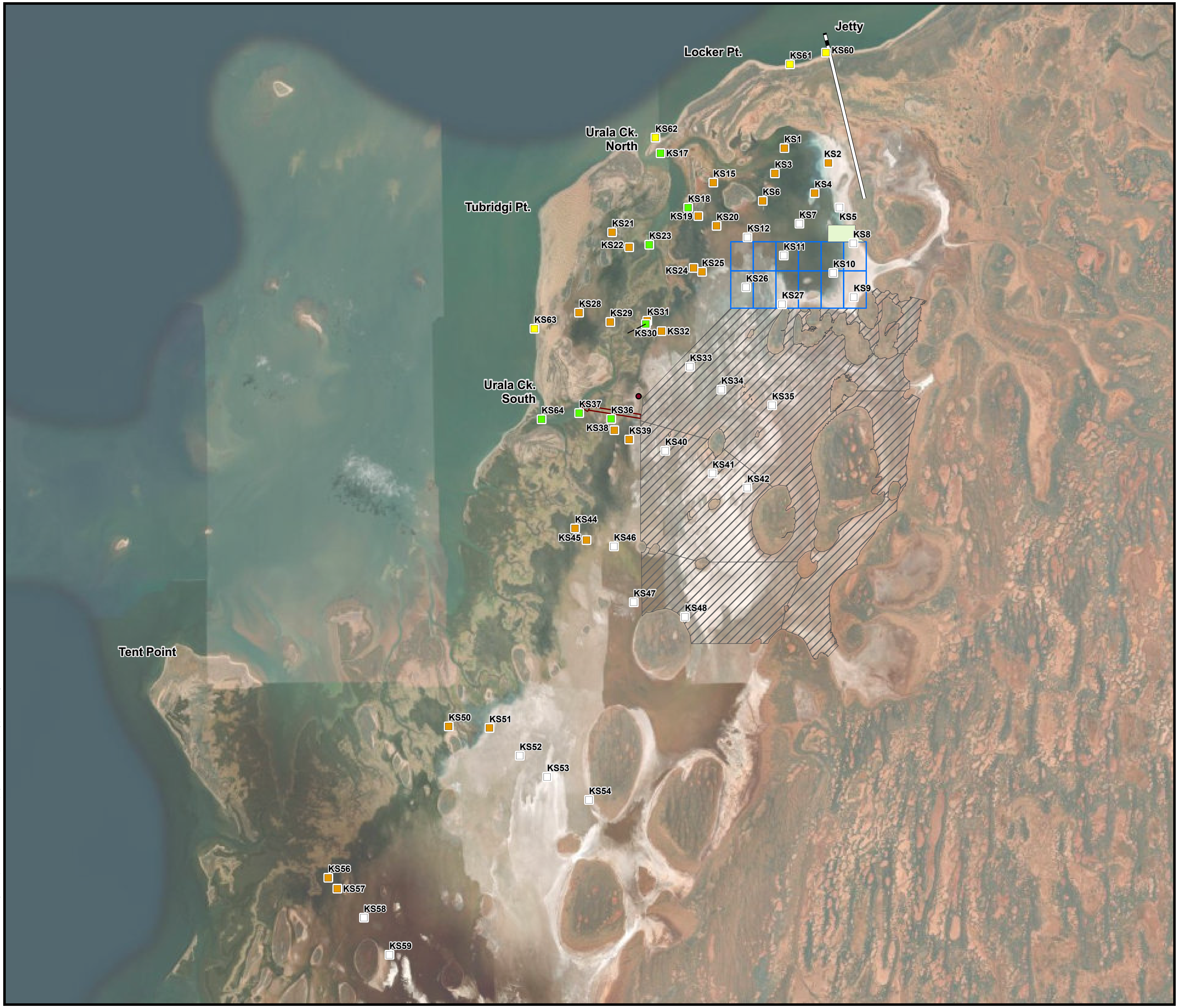
A helicopter was utilised during the survey to provide efficient and safe access to sites. Coastal fly-overs provided by the helicopter were ideal for viewing the type and extent of intertidal habitats and assisted in confirming or modifying the preliminary mapping, including the distribution of mangroves and algal mats.

At each site an area was traversed and information collected on habitat characteristics, vegetation types (if present) and fauna. Data were collected on the range of mangrove associations present at each site and the structure and composition of those associations.

2.1.2.1 Algal mat and salt flat sediment sampling

A total 47 sites in algal mat and salt flat areas were visited to collect information on the algal mat presence/absence, structure, species composition and level of photosynthetic activity. As shown in Figure 1, many of the sites were located along a series of transects in which sampling was included within “core” algal mat habitat and “peripheral” algal mat habitat located at the landward edge of the algal mat zone and salt flat habitat.

At each site, two mini-core samples (diameter 25 mm; depth 30 mm) were collected for laboratory analysis (one to determine species composition and the other for analysis of chlorophyll ‘a’ and phaeophytin as described below). Each mini-core sample was composed of both the surface veneer of algal mat (if present) and the underlying sediment to which the algal mat adheres (see Plate 1 and Plate 2).



PROJECT ID 60597242
CREATED BY KD/RNM
APPROVED BY ABougher
LAST MODIFIED 16 APR 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 2 4 6
Kilometers

1:135,000 (when printed at A3)

LEGEND

- Pond Layout Gates (Option 8)
- Bittens Pond (Option 8)
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Embankment (Option 8)
- Jetty Alignment
- Conveyor

Intertidal Field Survey Locations

Survey Sites Habitat Type

- Algal Mat
- Beach
- Mangrove
- Salt Flat

Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Intertidal Habitat Survey Sites

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
4

Map Document: (\\AUPER1FP001.au.aecomnet.com\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\10_Benthic_Hab_Survey_Feb2020\G60597242_Fig5_Intertidal_Hab_Mapping_Update\G60597242_Figures_Update.aprx) Plotted by: kai.du on 16/04/2021 11:34 AM

A3 size

Plate 1 Sampling in a core algal mat area.

Plate 2 Mini-core sample showing a surface veneer of algal mat, black anoxic layer and the underlying sediment to which the algal mat adheres.

2.1.2.2 Species identification

Mini-core samples cores submitted for identification of blue-green algal/cyanobacterial species were prepared by mounting subsamples on to microscopic slides. Microscopic examination and the identification of species (by comparison with published keys) was then undertaken at progressively higher levels of magnification with objective + ocular lens magnifications of x40, x100 and x400. The resultant image was processed in a digital camera producing a screen image at magnifications in the order of 64, 160 and 640, respectively. It is noted that in some instances the presence of larger sediment particles prevented examination at magnification higher than possible with a x10 objective; however, it was evident in these that no algal filaments or other living biota were present.

Photographs were taken of algae/cyanobacteria and representative physical structures present. The magnification was varied to suit the sample, with low (x64) magnification used to illustrate sediment forms when no algal species were present.

2.1.2.3 Laboratory analysis

One set of core samples were sent to the Marine and Freshwater Research Laboratories (MAFRL) at Murdoch University for laboratory determination of chlorophyll 'a' and phaeophytin.

2.1.3 Habitat mapping

2.1.3.1 Mangroves

Existing mapping from both Biota (2005) and (2016) was overlaid onto recent high-resolution satellite imagery to ascertain the accuracy of the mapping boundaries, in relation to current habitat distribution. Given that the detailed Biota (2005) mapping is over 10 years old it was expected changes to habitat boundaries may have occurred, particularly in some mangrove areas that had been impacted by (and now partly or fully recovered from) Tropical Cyclone (TC) Vance.

The mapping of five main mangrove assemblages or zones within the mangrove habitat type was undertaken to reflect recognisable structural and physiognomic zones, which are identified from particular photo-tones within the imagery and then subsequently updated by ground-truthing. Both Biota (2005) and URS (2010c) have used these same five assemblage types for mangrove mapping in areas immediately south of the study area, and in the Onslow area, so these units were applicable to the mangroves for this study. This consistency in mapping between the studies from adjacent coastal sectors establishes a more detailed level of mangrove mapping for the Project area than was available previously and helps to provide regional context.

The boundaries of habitats identified from the preliminary mapping and any adjustments from post fieldwork (ground-truthing) analysis of imagery were delineated and recorded into an updated spatial dataset using ArcGIS software. Fine-scale adjustments of the resultant 'habitat' polygons were made on-screen in ArcGIS by using the rectified digital imagery as background mapping and correcting any local spatial inaccuracies. The polygons were cross-referenced to the habitat type codes and total areas for each habitat were calculated using ArcGIS.

2.1.3.2 Algal mats

Algal mat communities were mapped using remote sensing methods that exploit the characteristics of multispectral imagery and spectral signatures established for algal mats in the Project area. The multispectral imagery data were used to derive a spectral profile using red and infrared bands across known algal mat areas and then apply this spectral profile or signature to map algal mat areas. This was achieved by first calculating the Normalised Difference Vegetation Index (NDVI) to highlight the difference between the red and near infrared bands and a threshold applied to classify the algal mat using an automated classification method in the ArcGIS software package. The classified image was then further processed to remove artefacts of the image analysis procedures and manually edited to refine the mapping of algal mat areas.

The algal mat mapping by the above methodology was achieved using multispectral imagery captured by Fugro on behalf of K+S Salt Australia in May 2017. The field survey information related to the presence/absence and species composition of algal mats was also used as additional information to help confirm algal mat boundaries.

The above methodology could be re-applied during and post–construction to assess changes to algal mat distribution at local (i.e. Project area) and regional (i.e. eastern side of Exmouth Gulf) scales.

2.1.3.3 Samphires

Detailed vegetation mapping conducted by Biota (2020a) has identified and mapped all samphire vegetation in the Project area in accordance with Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016e). The methods used and resulting detailed vegetation mapping is provided in a separate report (Biota, 2020a). The vegetation mapping outputs have been refined further for this report to show the distribution of those samphire areas that are potentially located within the intertidal zone of the defined Local Assessment Units (LAUs) and hence subject to BCH assessment.

2.1.4 Other relevant surveys of intertidal habitats in the region

A desktop review was undertaken, including information from previous BCH mapping and impact assessment studies (including LAU justification and cumulative loss case studies) related to intertidal and subtidal (nearshore) habitats, and the results of previous surveys undertaken in the Onslow area and on the east side of Exmouth Gulf. Key references included:

- Wheatstone LNG Project EIS/ERMP, Appendix N1 - Benthic Primary Producer Habitat Loss Assessment (URS 2010a); Appendix N4 - Ashburton River Delta Mangrove System: Impact Assessment Report (URS 2010b); Appendix N11 - Intertidal Habitats of Onslow coastline (URS 2010c); and Appendix N12 – Survey of subtidal Habitats off Onslow (URS 2010d).
- Yannarie Salt Project ERMP, Appendix 4: Mangrove and Coastal Ecosystem Study. Baseline Ecological Assessment (Biota 2005). Field surveys and mapping of mangroves and algal mats along the entire eastern side of Exmouth Gulf from Giralia Bay to Tubridgi Point where these habitats occupy extensive areas (~11,000 ha).
- Coastal Geomorphology of the Ashburton Delta and adjacent areas (Damara 2010). Assessment of the coastal landforms (including their evolution and development) and related aspects such as coastal processes, historical coastline movements, shoreline stability and longshore transport.
- Onslow Salt ERMP Volume 2: Technical Appendix C Report on the Biological Environments near Onslow, Western Australia (Paling 1990): documents mangrove, algal mat and salt flat habitats from Hooley Creek to Coolgra Point and provides mapping-based area estimates for mangroves and algal mats prior to construction of the salt ponds.

- Roller Oilfield Development CER - Appendix 2: Intertidal Habitats of the Onslow to Tubridgi Point coast and Locker Island (LEC 1991). This report documents the range and distribution of intertidal habitats, describes the major biotic assemblages and identifies some particular areas that should receive priority protection from an oil spill.
- A range of additional scientific journals, papers and publications that included habitat mapping, technical ecological and observational data, and descriptions of BCH in the region.

2.2 Coastal Geomorphology and Habitat Distribution

The Project area is located inshore on supratidal salt flats, adjacent to the northeast shore of Exmouth Gulf and the Onslow Coastal Tract and hence it encompasses geomorphic features from both regional scale units. The area extends from a coastal shoreline comprised of either a tidal mangrove zone (i.e. fringing the northern most extent of Exmouth Gulf) or sandy beaches (i.e. that extend east from Tubridgi Point), across the salt flats of the Onslow Plain to where this plain abuts the terrestrial habitats of the Carnarvon Dunefield on the mainland.

Detailed descriptions of coastal geomorphic units from Locker Point to Tent Point are provided in (Seashore Engineering 2021) - this includes information on stratigraphy, landform stability and elevation profiles across cross sections that extend from coastal limestone/sand barrier areas (such as Tubridgi Point) across the extensive tidal flats of the Project area.

2.2.1 Urala Creek - tidal flat embayment

This geomorphic unit contains the majority of the Project area and comprises a very broad tidal flat that includes narrow tidal creeks with fringing mangroves and extensive mud flats. The extremely flat topography of the coast fringing mangroves and salt flats belies the morphologic complexity of the intertidal zone (Seashore Engineering 2021). The main physical driver is tidal exchange through the channel network, which provides a mechanism for redistribution of fine sediments and affects the viability of vegetation through establishment of salinity gradients (as described in Section 2.3.3).

The unit occupies an area of approximately 200 km^2, protected from the sea by the Tubridgi Point barrier beach/dune system. It is drained to the sea by the north and south arms of Urala Creek. The arrangement of habitat types within the tidal embayment is a pattern typified by the sequence from tidal creek – mangrove vegetated creek margins and adjacent tidal flats – algal mat-covered high tidal flat – extensive salt flat – hinterland margin (i.e. the beginning of the inland dunes). A similar geomorphology and pattern or sequence of intertidal habitats also occurs within the extensive tidal flat embayment systems further south along Exmouth Gulf (Biota 2005) and in the Onslow area (Damara 2010, URS 2010c). Figure 5 and Figure 6 illustrate the main habitat features.

2.2.2 Landward extension of tidal creeks across tidal flats

Tidal creeks play an important role in facilitating the exchange of water, nutrients and sediments between the expansive high tidal flat areas (algal mats, salt flats), mangrove and estuarine habitats and the nearshore waters of Exmouth Gulf. Numerous small tidal creeks (sub-creeks) branch from the main Urala Creek channels and extend landward towards the broad tidal flats in which the Project is located.

The sub-creeks are erosional features that gradually incise and extend small channels into the high tidal flats. At their uppermost reaches they form a dendritic pattern of very small channel and ruts (~1-2 m wide) through which the ebbing tidal waters draining from nearby algal mats areas erode the small channels, thereby gradually extending the small creeks further landward. This is evident by the gullying at the headwaters of the creeks and is consistent with the recognised process of tidal creek formation and development (Robertson & Alongi 1992).

Landward expansion of the channel network, also referred to as channel headcutting, can provide a significant precursor to mangrove colonisation. Channel expansion increases flows and drainage, which reduces porewater salinity of the adjacent mudflats, making them better suited to mangrove growth and sustainability (Seashore Engineering 2021). Apart from the broader areas of mangroves (~50-100 m wide) that fringe the main Urala Creek channel, the main setting in which mangroves occur in the Project area is as narrow bands (~5-20 m wide) fringing the sub-creeks that partly extend across the expansive tidal flats.

Plates 3-8 provide aerial and on-ground views of the uppermost reaches of a typical sub-creek and illustrate how such creeks serve as distributary channels for tidal water flows to/from catchments in the surrounding higher tidal flat areas that include algal mat areas, which typically show as dark areas on aerial photographic imagery.

A: Upper reaches of a tidal creek system with a narrow fringe of mangroves. Algal mat and salt flat areas further landward.

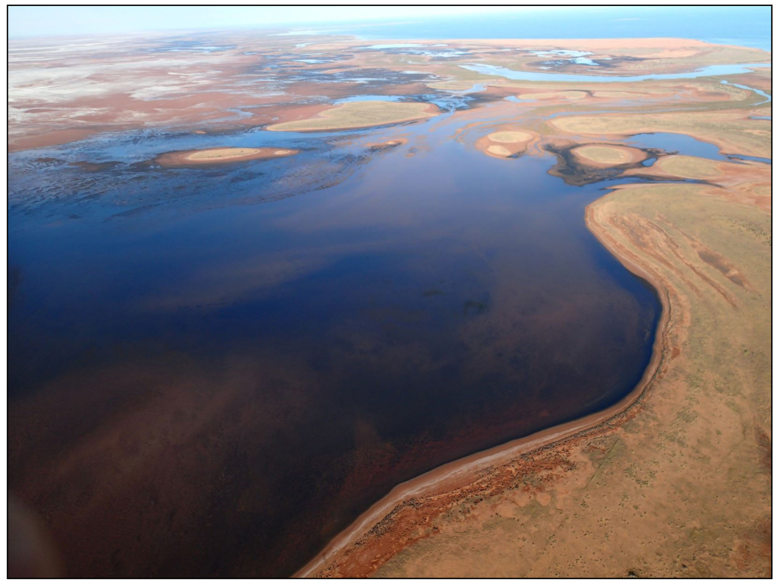
B: Extensive salt flat areas.

C: Broad tidal flat system landward of Urala Creek South. Algal mat areas (dark colour) in foreground.

E: Mixed *Rhizophora*/*Avicennia* low forests near the mouth of Urala Creek South.

D: *Avicennia* dominated mangroves fringing the main channel of Urala Creek South.

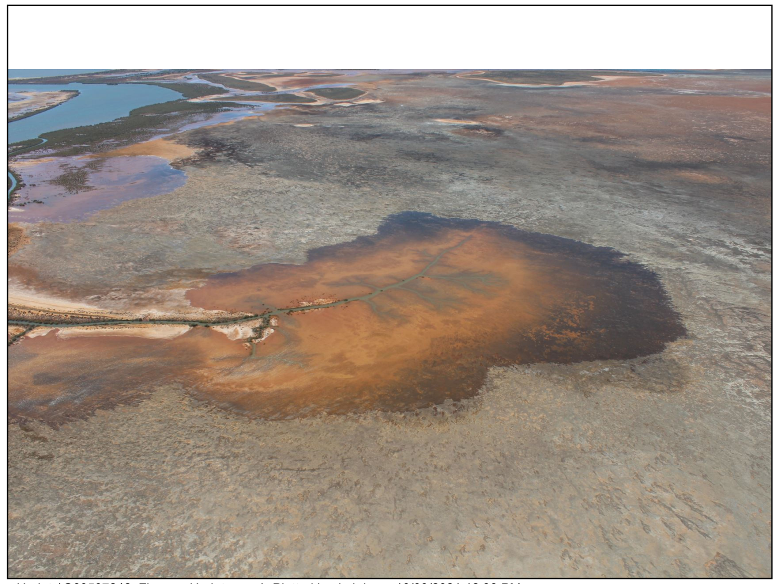
A: Extensive algal mat areas in the broad tidal embayment that receives tidal flows via Urala Creek North.



B: *Avicennia* dominated mangroves near the mouth of Urala Creek North.

E: Mouth of Urala Creek North with sand bars and shoals at entrance.

D: Upper reaches of a narrow sub-creek emanating from the main Urala Creek North channel. Such sub-creeks distribute tidal flows to/from algal mat areas.



C: Extensive salt flat areas.

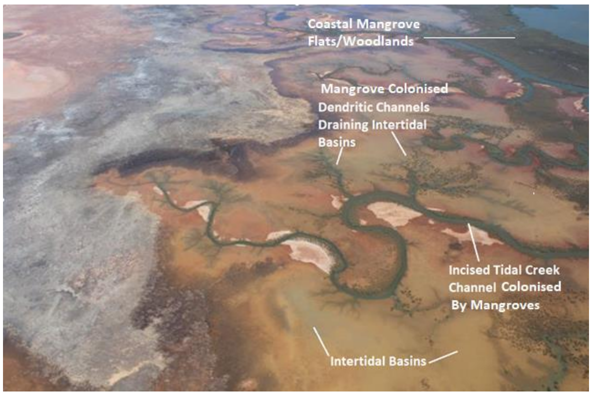


Plate 3 **Coastal area between Urala Creek South and Tent Point showing tidal creek pattern and flood tide.**

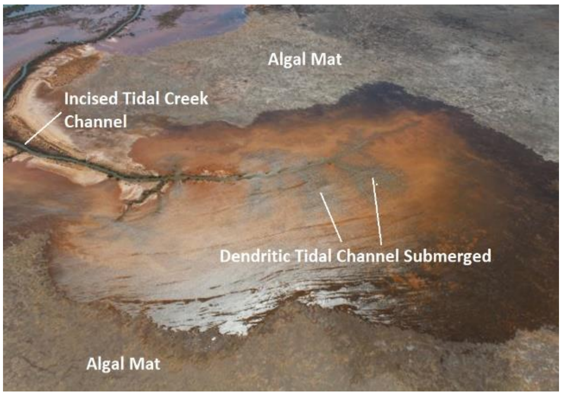


Plate 4 **Upper reaches of a sub-creek showing its function as a distributary channel for tidal flows to/from a catchment located on high tidal flats that support algal mats (dark grey tone).**

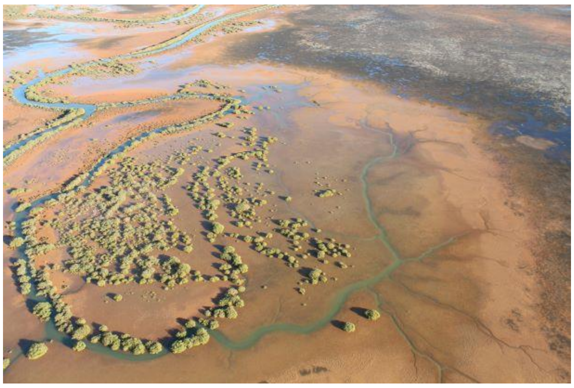


Plate 5 **Upper reaches of a sub-creek showing the transition from mangrove fringed channels to a network of dendritic shaped channels that are eroding into surrounding high tidal flats.**

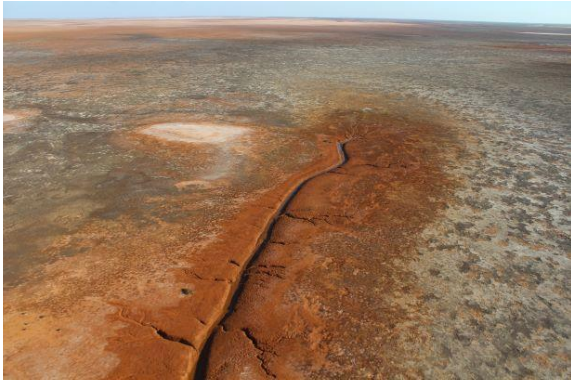


Plate 6 **Upper limit of a sub-creek that is gradually extending landward via erosion of surrounding tidal flats. Algal mat areas can be seen (dark grey tone) and salt flats are further landward in top left of photo.**

Plate 7 **On-ground view of a narrow channel in the upper reaches of a sub-creek. View looking downstream towards the landward limit of mangrove occurrence.**

Plate 8 **Reverse view from Plate 7. Looking landward along a very narrow channel (rut) towards algal mat areas.**

2.2.3 Habitat distribution

The distribution of the mangroves, transitional mud flats, intertidal samphires and algal mats has been mapped and is provided in Figure 7. Expansive areas of salt flats, up to 10 km wide, extend landward from the eastern edge of the algal mat zone to the hinterland. It is within these salt flats that all the proposed concentration ponds would be located. Estimates of the areas (hectares) occupied by intertidal habitats have been calculated from the mapping and are included within the assessment of potential BCH loss (see Section 5.2.1).

Sections 2.3 to 2.9 describe the characteristics of each habitat with respect to their physical and biotic attributes. These habitats are:

- mangroves
- transitional mud flats
- algal mats
- samphires
- salt flats
- sandy beaches

2.3 Mangroves

Mangroves occur within a range of local scale geomorphic settings: either forming the coastal shoreline (i.e. between Urala Creek South and Tent Point), fringing tidal creeks or on tidal flats extending landward from the coastal shoreline and tidal creek areas. Adjacent to the Project area, mangroves form a nearly continuous ribbon of vegetation fringing the creek channels. Mangroves in the Urala Creek North and South system are protected, and partially isolated from the sea, by the large barrier limestone/dune system at Tubridgi Point, through which tidal creeks have breached narrow channels at the southern and northern ends.

Narrow sub-creeks extend from the main Urala Creek channels across the extensive tidal flat system and towards the Project site. In these areas, the mangroves are confined to a narrow fringe adjacent to the creek channel that is typically only 5-20 m wide. Broader areas (~50-100 m wide) of mangrove fringe the lower reaches of Urala Creek South, closer to the ocean.

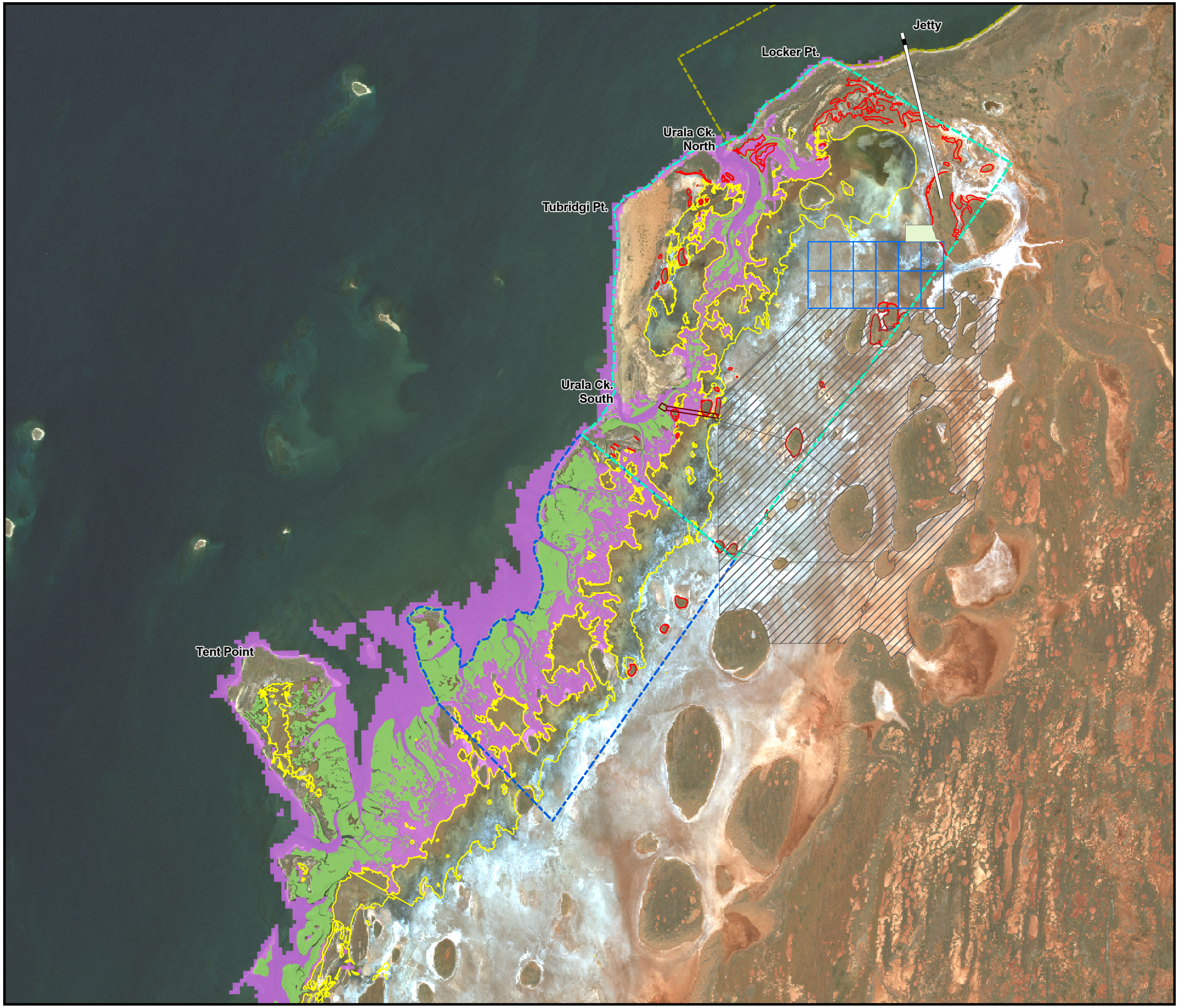
2.3.1 Mangrove flora

Seven species of mangroves are known to occur along the Pilbara coast (EPA 2001). Of these, six species were recorded from the Tubridgi Point to Tent Point area during the Intertidal Habitat Survey or from an earlier study (Biota 2005). The six mangrove species were:

- *Avicennia marina* – grey mangrove
- *Rhizophora stylosa* – spotted-leaved red mangrove
- *Bruguiera exaristata* – ribbed mangrove
- *Ceriops australis* – spurred mangrove
- *Aegialitis annulata* – club mangrove
- *Aegiceras corniculatum* – river mangrove.

The six species represent four families:

- Avicenniaceae (*Avicennia marina*),
- Rhizophoraceae (*Rhizophora stylosa, Bruguiera exaristata, Ceriops australis*),
- Plumbaginaceae (*Aegialitis annulata*)
- Myrsinaceae (*Aegiceras corniculatum*).



PROJECT ID 60597242
CREATED BY SmithS9
APPROVED BY ABougher
LAST MODIFIED 26 OCT 2022

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 2 4 6
Kilometers

1:135,000 (when printed at A3)

LEGEND

- Bittens Pond (Option 8)
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Intake and Channel
- Jetty Alignment
- Conveyor
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires
- Algal Mat Mapping
- Mangrove Mapping
- Transitional Mudflat mapping

Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)

Sentinel Imagery Oct 2022

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Intertidal Habitat Mapping

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

7

Within the Project area, *Avicennia marina* (grey mangrove) was a widespread and dominant species that occurred within the majority of mangrove associations present. It was found growing monospecifically in many areas and in a range of structural forms (e.g. from dense low forests to open shrubland) (Plate 9, Plate 10), but also occurred in association with the other five species in particular locations. The local dominance by *A. marina* reflected the broader regional pattern, with this species being the most widespread and abundant mangrove species in the Pilbara coastal region (Semeniuk 1993a).

Plate 9 Low *Avicennia* mangrove forest fringing Urala Creek South.

Plate 10 Open *Avicennia* shrubland fringing the upper reaches of a tidal creek.

Rhizophora stylosa was the next most common mangrove species and typically formed dense stands (thickets and low forests) in the lower reaches or more seaward sections of the tidal creek systems, which provide a muddy protected environment that is subject to regular tidal inundation (Plate 11). *R*. *stylosa* occurred mostly as monospecific stands, but in some areas was mixed with taller *A. marina*. This species is relatively widespread along the Western Australian coastline, occurring from the Kimberley to the southern end of Exmouth Gulf.

Ceriops australis was less common than the above two species and typically occurred in association with *A. marina* to form open scrub along the landward margin of the mangrove zone:

- In locations where the mangrove zone intergrades with the high tidal mud flat;
- Along the mangrove – hinterland fringe; and
- Along the margins of cheniers (supratidal sand deposits occurring with mangrove and tidal flat areas).

C. australis is considered a minor species in terms of abundance along the Pilbara coast; however, it occurs regularly in the more landward sections of the mangrove creeks. Within Western Australia it is distributed from the Kimberley to Exmouth Gulf, and is common across the north of Australia, extending down the east coast to southern Queensland.

On the basis of Western Australian Herbarium records, the specimen-based distribution for the remaining three species (*Aegialitis annulata*, *Aegiceras corniculatum* and *Bruguiera exaristata*) shows Karratha as the southern limit for these species. However, previous surveys in the Onslow area, on the eastern side of Exmouth Gulf, and along the broader Pilbara coast showed that these species reach their southern range limit at the bottom of Exmouth Gulf (LEC 1991; URS 2010c; Biota 2005; Johnson 1990; and Semeniuk 1993a). The field survey undertaken for the Project study area recorded these three species at Site KS64, located near the mouth of Urala Creek South (Plate 12).

Salt tolerant halophytic shrubs (i.e. non-mangrove species) were a conspicuous component of the vegetation within the mangrove zone at several locations, while they were largely absent in others. Where present, these shrubs were established at varying degrees across the tidal gradient. Close to tidal creeks, they usually comprised a single species such as *Hemichroa diandra* occurring as an understory or heath amongst *A. marina* mangroves. Sometimes *H. diandra* extended beyond the mangrove shrubs and partly down the slope of the tidal creek bank.

Halophytic vegetation within the mangrove zone was common amongst the more landward *A. marina* open shrubland (Plate 13) and consisted of species typical of those found in similar habitats in other mangrove environments on the Pilbara coast (Craig 1983), recorded from the Exmouth Gulf to Onslow area in previous surveys (Biota 2005, Paling 1990, LEC 1991, URS 2010c). With increasing tidal elevation through landward sections of the mangrove zone, the mud flats become devoid of mangrove vegetation and grade into a zone of bioturbated mud flat (Plate 14).

Plate 11 Tidal creek near the mouth of Urala Creek South (Site KS64) that supports a mixture of mangrove species in foreground (*Aegialitis, Aegiceras, Avicennia* and *Ceriops*) and low dense *Rhizophora* forest in background.

Plate 12 *Bruguiera exaristata* mangrove in flower. This species was observed in a few isolated stands near the mouth of Urala Creek South (Site KS64).

Plate 13 Landward edge of the mangrove zone. Low scattered *Avicennia* shrubs amongst *Hemichroa diandra*, a salt tolerant halophytic shrub (non-mangrove species).

Plate 14 Bioturbated mudflat occurring landward of the mangrove zone.

2.3.2 Mangrove associations and their distribution

Tidal exchange and flows are the dominant and prevailing processes that maintain the Pilbara mangroves as they regulate many of the physical, chemical and biological functions. Groundwater and sediment salinity gradients are established across the tidal flats in response to decreasing frequencies of seawater (tidal) recharge with increasing tidal flat elevation, and these gradients have produced recognisable structural and physiognomic zones or associations within the mangroves. The five mangrove associations used for the detailed mangrove mapping of the Urala Creek North to Tent Point area were consistent with those mapped along the eastern side of Exmouth Gulf by Biota (2005) and in Ashburton Delta to Onslow area by URS (2010b, URS2010c). This similarity in mangrove associations reflects the similar mangrove habitats occurring along concurrent sections of the coast that are subject to the same factors that influence or determine the type and distribution of mangroves (e.g. very similar or identical tidal regime).

This consistency in mapping between these studies from adjacent coastal sectors provide regional context and establish a more detailed level of mangrove mapping over a larger area of coast than was available previously.

The mangrove associations and the area they occupy within the coastal sector from Urala Creek North to Tent Point are shown in Table 2. Codes used to denote the various associations reflect the dominant mangrove species. Detailed mapping of mangrove associations is provided in Appendix A.

Table 2 Areas of mangrove associations recorded from the Tubridgi Point – Tent Point area and comparison with the overall Exmouth Gulf area

Code	Mangrove Associations	Tubridgi Pt to Tent Pt	Exmouth Gulf
Am1	Tall dense *Avicennia marina* fringing major tidal creeks and seaward margins	137 ha	226 ha
Am2	Low to moderate, dense *Avicennia marina* shrubland	2266 ha	8234 ha
Am3	Low, open to very open *Avicennia marina* on landward margins	1174 ha	2327 ha
AmRs	Mixed, tall *Avicennia marina/Rhizophora stylosa* low forests and thickets	94 ha	291 ha
Rs	Mixed, dense *Rhizophora stylosa* low forests and thickets	53 ha	126 ha
	Total	**3724 ha**	**11,204 ha**

The two associations that dominate the Urala Creek systems are:

Low to moderate height, dense *Avicennia marina* shrubland (Am2)

This association occurs as a fringe along the lower-mid reaches of the main channels of Urala Creek North and Urala Creek South. Near the Urala Creek South mouth it also extended landward across tidal flats from behind a taller association (units AmRs). This association was predominantly monospecific *A. marina*, approximately to 2 m in height and with a variable moderate to dense canopy cover. This unit was often backed by, and intergraded with, the open scrub unit (Am3) described below.

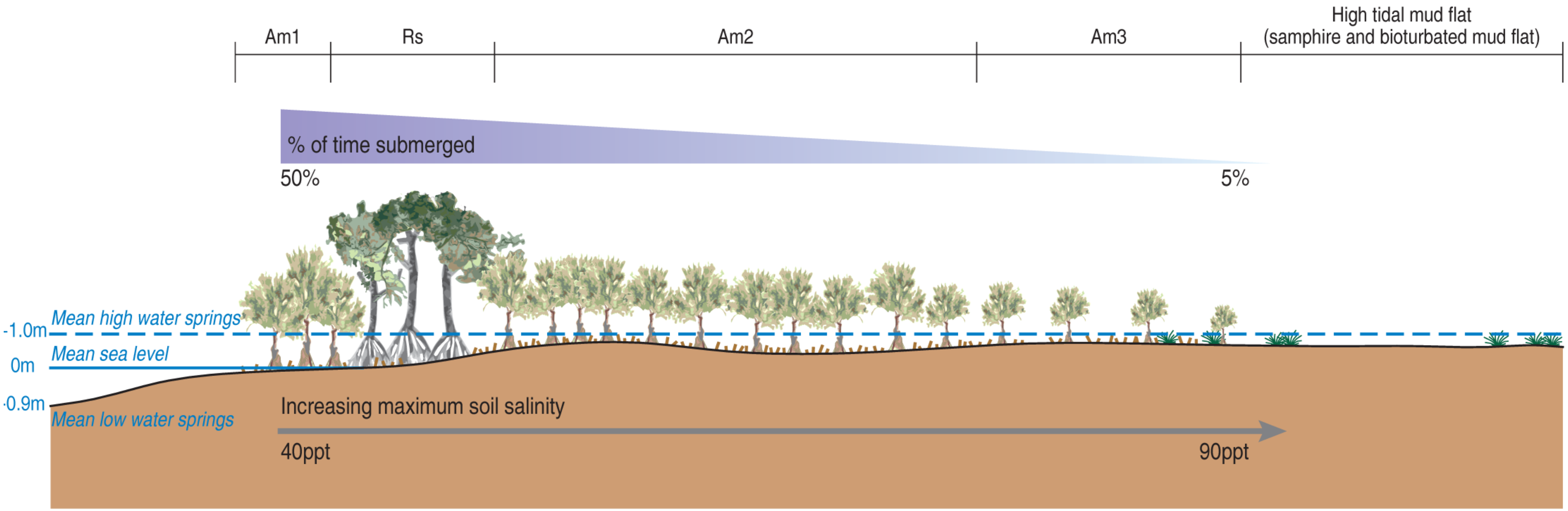
Low, open to very open *Avicennia marina* scrub on the landward margins (Am3)

Extensive areas of this unit occurred along the uppermost reaches of the tidal creeks and at the landward extent of the mangrove zone on tidal flat areas. As tidal elevation increased and the frequency of inundation decreased, the density of trees within these areas became generally low to scattered and they grew in a stunted, recumbent form due to high soil salinities that were approaching (or at) the threshold level tolerated by mangroves. In these areas, patches of salt tolerant halophytic species (i.e. non-mangrove species) were often interspersed amongst the *A. marina* scrub mangroves.

2.3.3 Factors controlling mangrove distribution

Mangroves in the study area occupied the section of the intertidal gradient that was approximately between Mean Sea Level (0 m AHD) and an elevation of approximately (0.7 m AHD), a level between Mean High Water Neaps (0.3 m AHD) and Mean High Water Springs (0.9 m AHD) (Seashore Engineering 2021).

The relationship between tidal elevation and frequency of tidal inundation plays a central role in controlling the distribution of mangrove species and assemblages by developing salinity gradients across the tidal zone. Inundation by seawater during flood tides is the main recharge mechanism that regulates the intertidal zone with lower salinities occurring in mangrove areas of lower tidal elevation (e.g. lower reaches of tidal creeks and more seaward locations). The salinity gradients influence both the occurrence of the different mangrove species (due to differing salinity tolerance limits) and the mangrove community structure. This factor largely determines the zonation of mangrove associations shown in the schematic profile below (Figure 8) and as shown in the detailed mangrove association mapping provided in Appendix A.



Mangrove Associations

Am1 Tall, dense *Avicennia marina* on seaward margins
Am2 Low, dense *Avicennia marina* shrubland
Am3 Low, open to very open *Avicennia marina* scrub on landward margins
Rs Tall, dense *Rhizophora stylosa* on seaward margins and lower reaches of tidal creeks

Figure 8 Distribution of mangrove associations in relation to the salinity gradient

Data obtained from similar mangrove habitats on the Pilbara coast show that salinities increase from approximately 40-55 parts per thousand (ppt) at the more seaward areas (e.g. seaward and taller *Avicennia* zone and *Rhizophora* zone) to approximately 70-90 ppt in the more landward sections of the mangrove zone where low open *Avicennia* shrubland occurs (Semeniuk 1983; LDM 1998, Biota 2005). The dominant species in the study area (*Avicennia* marina) has the greatest salinity tolerance of the Pilbara mangrove species and occurs in areas where groundwater salinity reaches up to 90 ppt (approximately 2.5 times seawater) (Gordon 1988). With increasing tidal elevation through landward sections of the mangrove zone, the reduction in tidal inundation in combination with high evaporation rates results in groundwater and soilwater conditions (including salinity) that are beyond the threshold tolerated by mangroves. In these areas the mud flats become devoid of mangrove vegetation and grade into a zone of bioturbated mud flat (Plate 14) or algal mat habitat. Plate 15 and Plate 16 show aerial views of the mangrove zonation described above and represented schematically in Figure 8.

Plate 15 Aerial view of mangrove zonation

Plate 16 Aerial view of the main Urala Creek North channel showing mangrove zonation and subtidal creek habitat

2.3.3.1 Lack of freshwater input to Pilbara mangroves

In northern tropical parts of Australia, freshwater flows or freshwater seepage from the hinterland into the intertidal zone are substantial and have resulted in some mangrove zones being partly dependent on freshwater input for their survival. Regular wet season rainfall provides freshwater seepage to the landward section of the intertidal zone. Consistent freshwater input over several months each year dilutes potentially high salinity groundwater to levels where mangroves can grow in a zone of mangroves referred to as the hinterland fringe (typically a narrow band of mangroves occurring where tidal flats abut the hinterland) (Semeniuk 1983).

By comparison, freshwater input to Pilbara mangroves is very irregular due to the arid climate and would only usually occur after significant rainfall events associated with cyclones. Hence, groundwater salinities become very high at the landward edge of a mangrove zone which is backed by extensive salt flats devoid of vegetation. There is no sustained dilution of the hypersaline groundwater conditions by freshwater input (as occurs elsewhere in the tropics) and hence no hinterland fringe mangrove zone has developed within the Pilbara intertidal zone that is dependent on freshwater input. In summary, the salinity conditions required for the survival of mangroves along the Pilbara coast are maintained by tidal inundation and not by freshwater sources such as the fluvial input from the hinterland.

2.4 Transitional Mud Flats

Seaward and landward of the mangrove zone exists a mosaic of "transitional mud flats" or mud flats which form a transition zone between the mangroves and other habitats. These have been termed "low tidal mud flats" and "high tidal mud flats" as described below.

2.4.1 Low tidal mudflats

Seaward of the mangrove zone and fringing some tidal creeks, is a zone of mostly bare or bioturbated mudflats which are submerged during higher tides and exposed a lower tides. These low tidal mudflats contain high densities of crabs, molluscs and polychaetes which provide a food source for shorebirds when the mudflats are exposed at lower tides. The high density of crab holes which occur in the bioturbated zone acts as a conduit for recharging shallow groundwater with tidal water flows.

2.4.2 High tidal mud flats

Landward of the mangrove zone, large areas of mud flats extend approximately to the algal mat zone. These mud flat areas occur in the upper or higher sections of the intertidal zone and hence this habitat type is mapped as "high tidal mud flats". They are not regularly inundated by tides and often consist of a complex zonation or "mosaic" of the following sub-habitats:

- Bioturbated mud flats - areas devoid of macro-vegetation but heavily worked-over by burrowing crabs (Plate 14).
- Patches of sparse halophytic shrubs but with some crab burrows.
- Bare mud flats.

2.5 Algal Mats

Algal mats are comprised of a dense mass of individual filaments of cyanobacteria (formerly known as blue green algae and hence the term algal mat) occurring on the surface of mud flats which are only infrequently tidally inundated. Cyanobacterial mats have been demonstrated to fill an important ecological function in coastal arid zone systems, fixing atmospheric nitrogen into biologically available forms (Paling, McComb & Pate 1989).

In the Project area, algal mats occur on mudflats landward of the mangrove and typically at elevations approximating Mean High Water Springs and slightly higher. Hence only on greater tides will the algal mats normally be inundated and it is estimated that they are tidally submerged for an average of 3% per month or less (Biota 2005). While algal mats extend over large spatial areas (~6,000 ha in the Tubridgi Point – Tent Point area), the elevation range over which they occur is very small (~10-20 cm) due to flatness of the tidal flat terrain that extends landward from mangroves, through both algal mat and salt flat areas. Wind may be a significant factor in determining if inundation will occur; onshore winds increasing the likelihood of inundation and offshore winds decreasing the likelihood. Factors that are likely to influence the distribution of algal mats are:

- Grazing pressure by invertebrates and too frequent tidal inundation (causing less stable substrates and destabilising tidal currents) likely contribute to maintaining the lower elevation limit of algal mat occurrence. Studies in the Onslow and Exmouth Gulf area document an area of high bioturbation activity (mostly from fiddler crabs, *Uca* spp.) on predominantly bare mud flat areas between the landward edge of the mangrove zone and algal mat areas (URS 2010c, Lovelock et al. 2010).
- Very low frequencies of tidal inundation and flushing at the upper elevation limits of mat occurrence would impose extreme salinities and dehydration.

Tidal submergence curves generated by hydrodynamic modelling of the Project area, and surveyed elevation data, can be used to quantify the tidal inundation regime experienced by algal mats and mangroves. The application of the hydrodynamic model is used in Section 5.5 to assess the potential for Project-related changes to tidal flushing in mangroves and algal mats.

2.5.1 Mat characteristics and composition

Sampling of algal mats was undertaken along a series of transects in which sites were included in both "core" algal mat areas (i.e. where contiguous algal mats were extensive and mats were thicker) and "peripheral" areas along the landward edge of the algal mat zone (where mats were more fragmented and thinner). Examples of core algal mats are shown in Plate 17 and Plate 18. Cyanobacteria typically formed a crenulate or pustular mat structure that was underlain by a dark anoxic later and the base tidal flat sediment material (clays and fine-grained sands). Table 3 summarises the cyanobacterial taxa recorded from the algal mat cores.

Table 3 Summary of taxa recorded from algal mats

Algal Taxa	Core Mat Area	Peripheral Mat Area
Anabaena sp.	Common	Not detected
Calothrix sp.	Rare	Not detected
Cyanothece sp.	Not detected	Rare
Lyngbya sp.	Abundant	Rare
Microcoleus sp.	Abundant	Common
Oscillatoria sp.	Abundant	Common
Schizothrix sp.	Common	Not detected
Diversity	**6**	**4**
Mat thickness	**2-5 mm**	**1-3 mm**

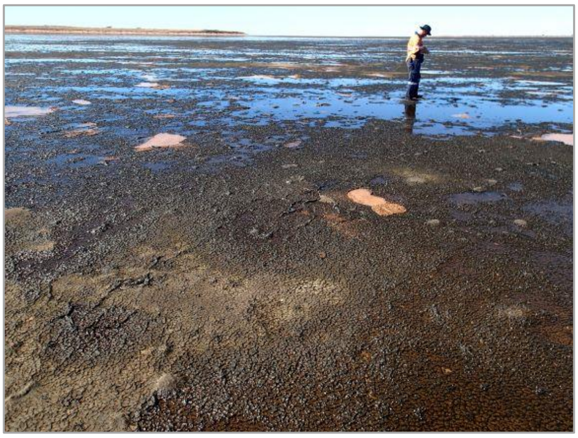


Plate 17 Core algal mat showing the crenulate mat structure that was most prevalent in the Project area

Plate 18 Close up view of the crenulate algal mat structure

A summary of the microscope assessments of the 46 algal mat cores is provided below:

- The major species present in the algal mats clearly defined by their dark green colour were *Microcoleus* sp. and *Lyngbya* sp. and *Oscillatoria* sp. (Plate 19, Plate 20). Also present in the mats were a number of additional blue green algal species including *Schizothrix* sp., *Calothrix* sp. and *Cyanothece* sp., and the diatom, *Navicula* sp.
- As the presence of a distinct mat became less apparent, *Oscillatoria* sp. and *Lyngbya* sp. became more dominant and the number of blue green algal species and other biotic activity became less common.
- Algal mat species assemblages were similar along the length of the coastal tidal flat areas sampled.

- No algal mat species or other biotic activity could be discerned in cores collected from salt flats areas and these sediments were without an apparent mat or algal crust present.
- The composition of the algal mats was generally consistent with the dominant taxa recorded from similar intertidal areas in Western Australia (Penrose 2011; John *et al*, 2009; Paling 1989) and the results of previous studies in the Exmouth Gulf-Onslow-Mardie section of the Pilbara coast (Biota 2005; Stantec 2018).

Plate 19 View of cyanobacteria under microscope (*Lyngbya* sp.)

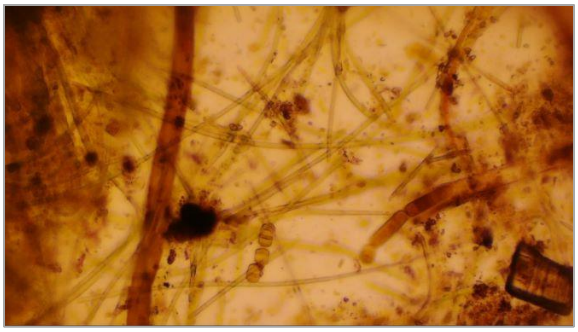


Plate 20 View of cyanobacteria under microscope (*Oscillatoria* sp.)

2.5.2 Indicators of photosynthetic activity

Surface sediment samples (mini-cores) collected from algal mat and salt flat areas were analysed for concentration of chlorophyll-a and phaeophytin for indication of the level of photosynthetic activity. The results are summarised on an areal basis (mg/m^2) in Table 4, with the values presented to highlight differences in photosynthetic activity between algal mats (core and peripheral areas) and salt flats, together with a summary of algae recorded from microscopic analysis.

Table 4 Chlorophyll-a and phaeophytin values (Mean ± SE) and species from algal mat and salt flat areas

	Chlorophyll-a (mg/m^2)	Phaeophytin (mg/m^2)	Algal Mat Species Present
Algal mat (core)	414 ± 77	166 ± 29	Distinct dark green mat structure present. Main species were *Microcoleus* sp., *Lyngbya* sp. and Oscillatoria sp. as noted from other Pilbara algal mat areas. Also present were some additional blue green algal species including *Schizothrix* sp. *Calothrix* and *Cyanothece* sp., and the diatom *Navicula* sp.
Algal mat (peripheral)	137 ± 22	133 ± 27	The presence of a distinct mat became less apparent in peripheral areas and the diversity of algal mat species was reduced with *Oscillatoria* sp. and *Lyngbya* sp. being dominant.
Salt flats	29 ± 5	25 ± 5	No algae/cyanobacteria observed.

The chlorophyll-a concentrations recorded from core algal mat areas are higher than those from the southern section of Exmouth Gulf (312 ± 22 mg/m^2, range 224-416 mg/m^2, Lovelock et al. 2010) and significantly higher than those recorded from Dampier (50-150 mg/m^2, Paling et al. 1989).

By comparison with core algal mat areas, chlorophyll-a concentrations were lower in peripheral algal mat areas located along the landward edge of the algal mat zone where conditions become more difficult for cyanobacteria to develop dense and contiguous mat structures. Both chlorophyll-a and phaeophytin concentrations in salt flat areas dropped close to detection limits, this highlighting the lack of biological activity in salt flats due to prevailing extreme conditions (i.e. dehydration and very high salinities).

The very low levels of chlorophyll-a and lack of algae observed by microscope in the salt flat samples makes it difficult to ascertain the source of the minor amounts of chlorophyll-a present.

One possibility is the presence of ephemeral fresh or brackish water species which grow in profusion but for a relatively short period in the brackish floodwater of the salt flats following inland rainfall events.

The ratio of chlorophyll-a to phaeophytin (a degradation product of chlorophyll) has been used to provide information on the health of the microalgal population in water bodies. During rapid growth, the proportion of phaeophytin is low and during periods of decline, the proportion of phaeophytin increases. The ratios between chlorophyll and phaeophytin recorded from cores (Table 4) show a strong bias towards chlorophyll in the core mat samples, which is consistent with the active growth resulting from more frequent inundation. The ratios are approximately equal in peripheral algal mat areas where conditions would be close to the threshold for mat survival.

There is no established norm for the ratio between chlorophyll-a and phaeophytin in algal mats; however, these data could form part of the further investigations and be useful as a guide to the status of the rehabilitated mat.

2.6 Sandy Beaches

Sandy beaches occur along the western and northern shorelines of Tubridgi Point and extend east along the coast from Urala Creek South, including the Locker Point area and the proposed location of the export jetty (Plate 21).

The beaches are comprised of fine, well sorted sand with a near-horizontal supratidal ramp and a steep intertidal beach slope. The surface of the beach slope was very smooth, without bioturbation except for occasional crab burrows. There was no mid-lower littoral sand flat, the beach simply sloping into the sublittoral zone. Sandy beaches, composed of medium to coarse-grained calcareous sands and shelly sands, are widespread along the coastline. The beaches are backed by low foredunes (vegetated by coastal species, e.g. *Spinifex longifolius*, *Rhagodia preissii* and *Ipomea brasiliensis*) which front parabolic dune blowouts or vegetated parallel dune systems (Plate 22).

Plate 21 Sandy beach in the Locker Point area near the proposed jetty location (Site KS60)

Plate 22 Sandy beach habitat backed by low foredunes

2.7 Tidal Creeks

Tidal creeks form a dendritic channel system through the intertidal environment. Their key role is to provide import and export of tidal water flows, nutrients and biota which form the intertidal environment. They range in size from large estuary like waterways (such as Urala Creek North and South) to much smaller dendritic channels branching off the main channels. Tidal creeks are interspersed throughout the mangrove, mudflat and algal mat systems.

Tidal creeks are a major part of the intertidal system, with parts of the creeks becoming exposed mudflats at low tide (therefore being intertidal), although the deeper parts of the creeks are predominantly subtidal (always submerged by water). It is therefore subjective whether the tidal creeks are included as intertidal or subtidal habitat.

2.8 Samphires

Samphires are halophytic succulent herbs and small shrubs from the genus *Tecticornia* within the family Chenopodiaceae. Samphires are able to tolerate both prolonged waterlogging and drought. They are also highly salt-tolerant once established. Samphire species are physiologically adapted to live in very dry conditions, or areas that are "physiologically dry" because the water present is predominantly saline. Many samphire species occur in areas that only receive occasional or no tidal inundation and infrequent freshwater inputs, due to their ability to tolerate both saline conditions and prolonged drought (DPIRD, 2021), (Coleman, 2016). Samphire vegetation communities mapped by Biota (2020a) occur in various settings including within intertidal areas, at the base of supratidal slopes such as those fringing mainland remnant islands, and in claypans and drainage lines where water emanating from the hinterland debouches.

The Biota (2020a) mapping identified large areas of samphire vegetation adjacent to the eastern and north-eastern sections of the project area that are not subject to tidal influences but would receive infrequent inundation from terrestrial sources via ephemeral drainage lines. As a result, the Biota (2020a) vegetation mapping outputs have been refined further for this report to only show the distribution of those samphire areas that are potentially located within the intertidal zone of the defined Local Assessment Units (LAUs) and hence, subject to BCH assessment (see Appendix B).This mapping unit shown is referred to as "intertidal samphires" in Figure 7 and combines the three samphire vegetation communities (Units S1 – S3) described below. Examples are shown in Plate 23 to Plate 28:

- Unit S1 - *Tecticornia doliiformis*, (*T. indica, T. halocnemoides, Frankenia ambita*) low shrubland over *Sporobolus mitchellii, Eragrostis falcata* very open grassland.
- Unit S2 - *Tecticornia doliiformis*, (*T. indica, T. halocnemoides, Frankenia ambita*) low shrubland over *Sporobolus mitchellii, Eragrostis falcata* very open grassland.
- Unit S3 -*Tecticornia auriculata*, (*T. indica, T. halocnemoides*) low shrubland over *Eragrostis falcata* scattered grasses.

Plate 23 Unit S1 (ASHC04, Phase 1)

Plate 24 Unit S1 (ASH55, Phase 2)

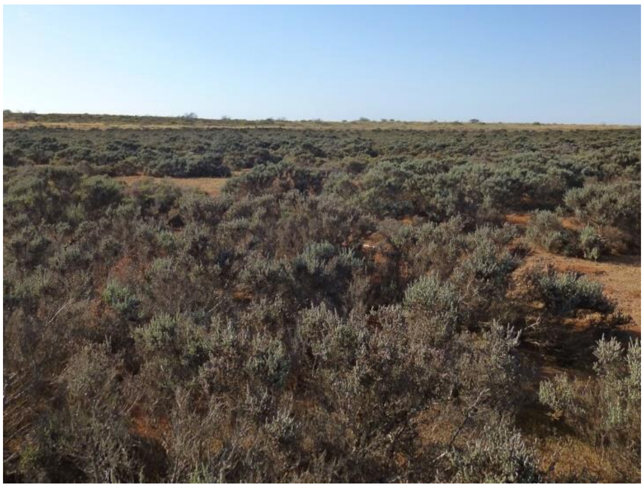


Plate 25 Unit S2 (ASH21, Phase 1)

Plate 26 Unit S2 (ASH35, Phase 1)

Plate 27 Unit S3 (ASH09, Phase 2)

Plate 28 Unit S3 (ASH54, Phase 2)

2.9 Salt flats

Where expansive and wide mud flats extended landward from algal mat habitats, the tidal flats graded into supratidal salt flats, often without clear demarcation between them. These salt flats are inundated only on rare occasions by extreme spring high tides, cyclone-induced storm surges or by freshwater during heavy rainfall and flood events. Extensive areas, up to 10 km wide, of salt flats occur in the Project area and the majority of the proposed solar salt pond system would be located within the salt flats.

Supratidal mud flats in the Pilbara bioregion are highly saline and are referred to here as salt flats. High surface temperatures and evaporation rates lead to hypersaline groundwater and the crystallisation of salt in surface sediments (Plate 29, Plate 30). The extreme conditions result in salt flats being devoid of marine or intertidal biota (no vegetation, algae or invertebrate fauna) and hence this habitat is not considered to support any benthic communities.

The hydrogeology within salt flat areas is characterised by the presence of hypersaline groundwater that is thought to have formed over time from combined actions of seawater submersion, evaporitic concentration of salts supplied periodically by tidal inundation and storm surge, and contribution from the regional groundwater throughflow from east to west. These create a dense hypersaline waterbody underneath the salt flats which is more dense than incoming groundwater from inland areas to the east or groundwater from tidal (ocean) influences to the west (GHD 2021a).

Salt flat is not considered to be a BCH type, given it is bare salt crust with no living benthic communities detected within or on it (Table 4).

Plate 29 Salt flat area on the landward section of the Project area

Plate 30 Surface salt crust overlaying the brown mudflat sediments

3.0 Subtidal Habitats

3.1 Survey and Mapping Methods

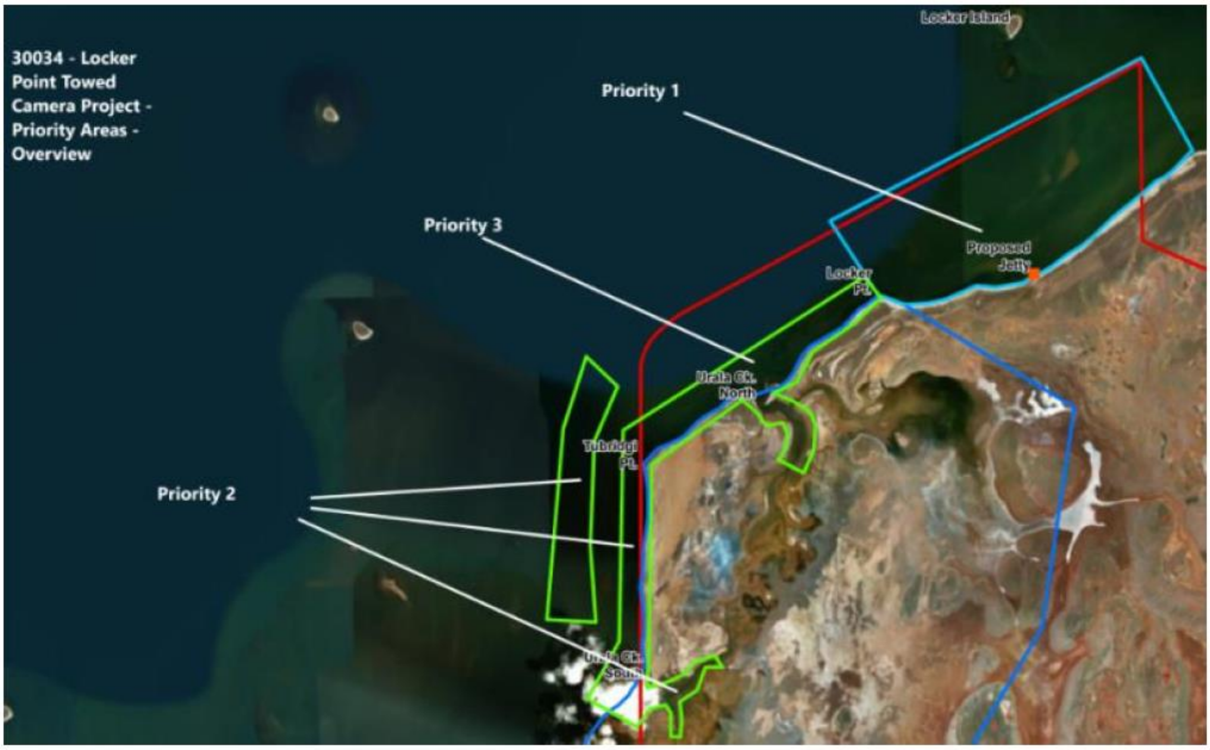
A survey of subtidal habitats in the vicinity of the Project area was undertaken by Geo Oceans in February 2019 to:

- Document subtidal habitats at selected localities within the study area.
- Ground truth to confirm preliminary mapping of subtidal habitat distribution and facilitate an assessment of the extent of potential Project-related impacts as required by EPA Technical Guidance for the Protection of Benthic Communities and Habitats (EPA 2016b).

3.1.1 Site selection

Based upon the proposed Project design and existing habitat data from previous surveys, three priority areas were identified for survey of subtidal habitats, as shown in Figure 9:

- The area surrounding the proposed export jetty and bitterns discharge zone (Priority 1).
- The nearshore and offshore habitats from Tubridgi Point to Urala Creek South, including within the creek (Priority 2).
- The nearshore habitats from Tubridgi Point to Locker Point, including within Urala Creek North (Priority 3).



Source: Geo Oceans 2019

Figure 9 Priority survey areas of subtidal habitats in the Project area

Priority area 1 is a 50 km^2 area which extends approximately 5 km offshore and was designated to form the LAU for the Project's nearshore BCH habitat assessment as per EPA guidance (EPA 2016b). However, the area was centrally based around the initial jetty location as proposed during early Project designs. Subsequent changes to the Project design included relocation of the proposed jetty westwards from the location shown in Figure 9, to approximately 2 km east of Locker Point, though still inside the Priority 1 area.

3.1.2 Survey methodology

A review of existing subtidal habitat data of relevance to the Project area (primarily that from the Yannarie Solar Salt proposal and the Wheatstone project, refer Section 3.2.1), along with recent satellite imagery and LiDAR data, was undertaken by Geo Oceans to validate the existing data and maps in the survey area. Initial ground truthing survey locations were based upon the review of existing data and maps. Additional locations were added in response to on-site habitat assessments. Transects across target areas were completed using a high definition towed video camera integrated with Geo Ocean's Go Visions software which enabled real time benthic habitat classification and geocoding of all survey points. In total, 73 transects spanning 5.9 km of seafloor were completed across the survey areas (Figure 10).

3.1.3 Data analysis and validation

Habitat data (point data) were recorded digitally through the Go Visions integrated software and analysed in real time according to a defined habitat classification scheme. Substrate type and characteristics (e.g. sand, small particle size), benthic biota type (e.g. macroalgae), abundance, percent cover and community composition were used to classify distinct habitat community classes. Notable benthic fauna and flora such as hard corals, seagrass and macroalgae, as well as any mobile fauna encountered, were taxonomically identified wherever possible.

Data points and GPS coordinates were error checked in a Microsoft Access database before being converted to a GIS shapefile in ArcGIS. Habitat data were evaluated for consistency with point data and satellite imagery, with any discrepancies addressed by reanalysing video imagery against the habitat classification scheme and methodologies used in the field.

3.1.4 Subtidal habitat mapping

Subtidal habitat boundaries were delineated by AECOM using a combination of towed video data, aerial imagery and satellite imagery, with additional cross referencing against LiDAR and sonar data acquired specifically for the Project. Available LiDAR data were only viable in shallow intertidal areas due to the natural very high sediment loads in the water. Where required, additional sonar transects were undertaken to assist in finalising habitat mapping.

Where consolidated substrate ('reef') habitat boundaries in shallow coastal waters were visible in satellite imagery, they were delineated and classified as such by checking against towed video data. In the nearshore areas, consolidated substrate habitat boundaries were delineated as darker patches relative to surrounding sand habitats, with checks against towed video data for accuracy. In deeper waters, where reef habitats were more difficult to discern from satellite imagery due to the homogeneity of colour, towed video and sonar data were primarily used to guide the delineation and classification of those habitats.

The revision of the jetty location (as per Section 3.1.1) necessitated extension of the nearshore LAU westwards to retain the central location of the proposed jetty and bitterns discharge zone within the LAU. Therefore, the habitats mapped beyond 2 km offshore to west of Priority area 1 are inferred from high quality satellite imagery and single-beam sounder records, but are not supported by ground truthing data from the Geo Oceans survey.

The habitats mapped by AECOM using a combination of data from the Geo Oceans 2019 survey, available bathymetry data, satellite imagery and sonar transect data within the subtidal LAU, are presented in Figure 11.

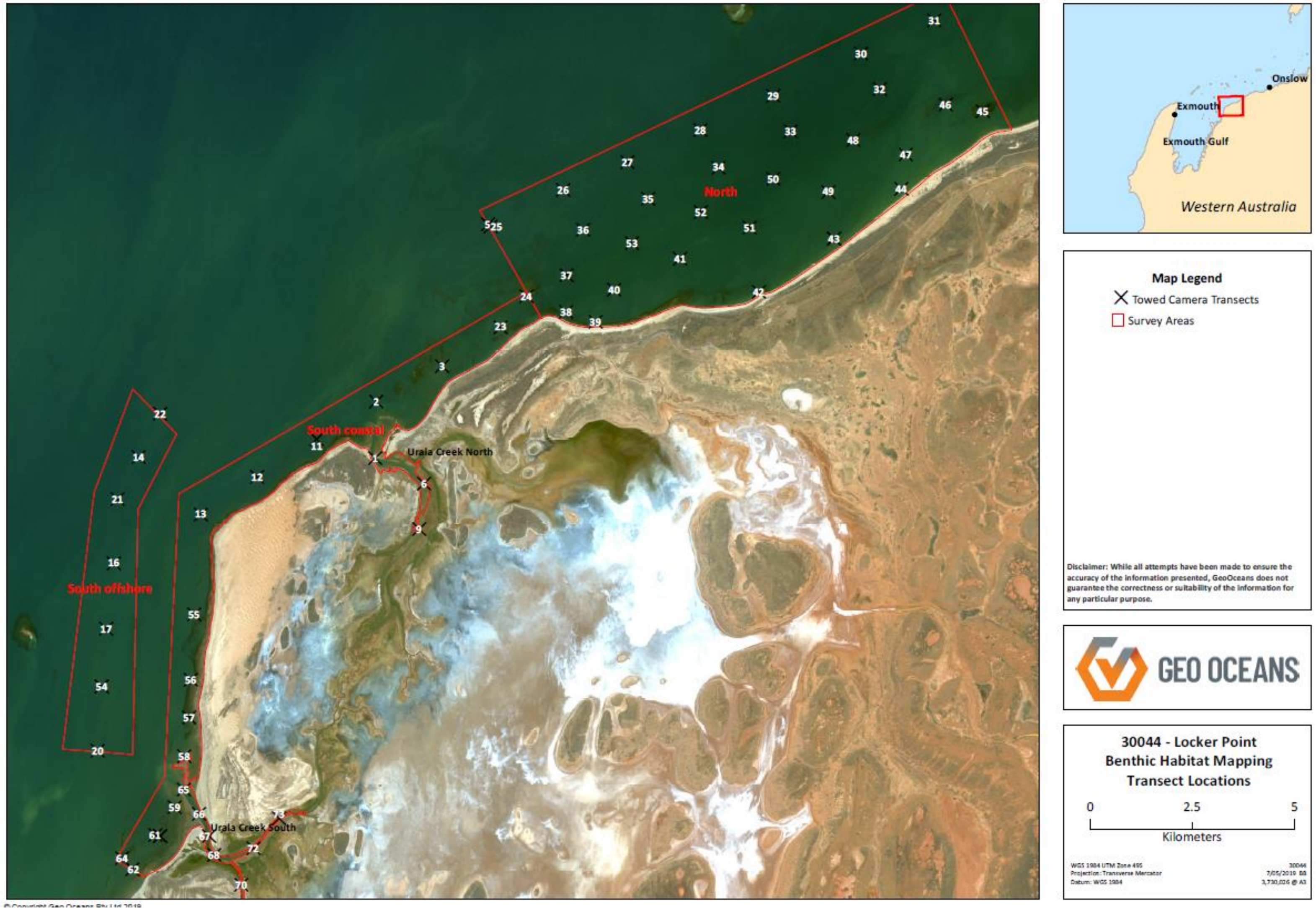


Figure 10 Towed video transect locations during the 2019 benthic habitat survey (Geo Oceans 2019)

PROJECT ID 60597242
CREATED BY ROB.MCGREGOR
APPROVED BY ABougher
LAST MODIFIED 29 SEP 2022

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometers

1:45,000 (when printed at A3)

LEGEND

- Jetty Alignment
- Conveyor
- Nearshore LAU
- Seagrass Observation Locations

Habitat

- Macroalgae
- Macroalgae and Sparse Coral
- Soft Sediment
- Assumed Seagrass (Feb. 2019)

Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Map of Benthic Habitats within the Revised Nearshore LAU

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
11

3.2 Subtidal Habitats

3.2.1 Previous relevant surveys of subtidal habitats in the region

A desktop review was undertaken which included information from previous BCH mapping and impact assessment studies related to intertidal and subtidal (nearshore) habitats, and the results of previous surveys undertaken in the Onslow area and on the eastern side of Exmouth Gulf. These included studies undertaken as part of the Yannarie Salt proposal, the Wheatstone ERMP, BCH mapping for the Learmonth Pipeline Bundle Fabrication Facility and Tow Route, studies by the Western Australian Department of Fisheries and CSIRO, as well as recent studies conducted by the Western Australian Marine Science Institution as part of its Dredging Science Node suite of studies.

3.2.2 Regional subtidal habitat types

The subtidal benthic habitats of the north eastern side of the Exmouth Gulf, and the area further north east towards Onslow, is characterised by predominantly soft and often silty sediment habitats which extend for kilometres offshore to the 10 m isobath (Oceanica 2006, URS 2010d). Waters in the area are typically turbid owing to their shallow depth (<5 m), the silty substrate, complex tidal movements and dominant west, south westerly and southerly winds which achieve considerable fetch across the Exmouth Gulf, resulting in raised sea state, thus causing resuspension of the silty substrate in shallow sandy habitats (DHI 2010).

Subtidal habitats that support complex epibenthic faunal biota are often limited to the fringes of nearby islands, shoals and shallow limestone pavement reef (URS 2010d). The benthic subtidal biota are typical of the shallow Pilbara coastal areas and the communities are generally dominated by macroalgal genera in areas of harder substrate, with mixed assemblages of sponges, soft corals, hydroids, bryozoans and ascidians, as well as the occasional hard coral. The area also supports several tropical ephemeral seagrass species which colonise the shallow unconsolidated (often described as ‘soft’) sediment habitats; however, meadows are generally transitionary with significant variation in temporal and spatial biomass (Vanderklift et al. 2017).

3.2.2.1 Soft sediment habitats (potential seagrass and macroalgae habitat)

Soft sediment habitats account for the majority of subtidal benthic habitats recorded during habitat surveys in the Exmouth Gulf and Onslow coast region (Oceanica 2006, Waddington & Kendrick 2009, URS 2010c, MBS 2018). While the vast majority of such habitats observed contained little to no epibenthic vegetation, some areas did support seagrass meadows and mixed seagrass and macroalgae assemblages. Of the seagrass species which occur in the region, all are ephemeral tropical species which have been found to display significant spatial and temporal variation in biomass between winter and summer (Vanderklift et al. 2017), including rapid recolonisation of unconsolidated sediments following impact events such as cyclones (Loneragan 2013). Furthermore, species composition within an area may also vary between seasons and years and (Loneragan 2013) but the ecological drivers for such variability, especially in the Pilbara, is still poorly understood (Vanderklift et al. 2017). Consequently, although the vast majority of soft sediment habitats observed across the region have featured little or no epibenthic vegetation, all such unvegetated unconsolidated sediments within the photic zone have the potential to support seagrass and macroalgae, and therefore should be viewed as potential seagrass and macroalgae habitats.

Unconsolidated and largely unvegetated sediments are the most common subtidal benthic habitats in the eastern Exmouth Gulf and Onslow area. Subtidal benthic habitat surveys to inform the Yannarie solar salt proposal impact assessment reported expansive areas of mud-dominated soft sediment devoid of any vegetation in areas offshore from Hope Point in the eastern side of Exmouth Gulf. Habitats north and seaward of Hope Point contained greater areas of bare sand or mud compared to such areas to the south of Hope Point (Oceanica 2006). Benthic surveys of areas in the Onslow and Ashburton area as part of the Wheatstone EIA found habitats of unvegetated soft sediment in 70% of the area surveyed shoreward of the 10 m isobath, and over 90% of the area seaward of the 10 m isobath (URS 2010d). Similar results were reported further afield in Exmouth Gulf during the benthic habitat surveys for the Subsea 7 pipeline bundle facility, where unvegetated sediment habitats accounted for 88% of the nearshore area and over 95% percent of the deeper habitat seaward of the 10 m isobath. It is worth noting that the majority of the Subsea 7 survey area lies within the current designated Exmouth prawn trawl fishery area (MBS 2018).

A variety of different types of vegetated subtidal unconsolidated sediment habitats across the eastern Exmouth Gulf and Onslow have been reported in previous surveys for both the Yannarie (Oceanica 2006) and Wheatstone impact assessments and other studies (Vanderklift et al. 2017, MBS 2018). Observed soft sediment habitats with some level of vegetative benthic biota have included patchy areas of low cover seagrass on muddy substrate (containing one or multiple species of seagrass); moderate single species seagrass meadows on fine sediment substrate or sand; mixed assemblages of various seagrass species and macroalgae species; and thin red microalgal mats on sand in deeper waters (Waddington & Kendrick 2009).

The most abundant vegetated habitats on soft sediment in the region have been observed in shallow waters generally less than 5 m deep (Oceanica 2006, URS 2010d). This is likely due to the naturally elevated turbidity in the region which limits light penetration, thus restricting photosynthetic biota such as seagrasses and algae to shallower habitats.

Vegetated soft sediment habitats, such as seagrass meadows and macroalgae beds, are an integral contributor to overall primary producer biomass and ecosystem productivity. Macroalgae, and to a far lesser degree the tropical seagrass species found in the area, can also provide stabilisation of the sediment against tidal and wave forces.

3.2.2.2 Seagrass

The Exmouth Gulf and Onslow region supports several species of seagrasses, which occur in areas of unconsolidated sediment or mixed sediment habitats in shallow waters. Seagrasses, along with macroalgae, are considered key food habitats for dugongs (*Dugong dugon*) and green turtles (*Chelonia mydas*) as well as providing critical nursery habitats for juvenile fish and many macroinvertebrates, including commercially valuable prawn species (Coles et al.1993). Prawn post-larvae settle into shallow seagrass areas which provide shelter and food sources such as epiphytic algae and detritus. Although not to the extent of substantial temperate meadows, seagrass meadows in the Pilbara also contribute to minimising erosion through stabilising sediment through their rhizomes (Kirkman 1997).

Several species of *Halophila* (*H. spinulosa, H. decipiens* and *H. ovalis*) have been documented in the region, as have *Halodule uninervis*, two species of *Cymodocea* (*C. angustata* and *C. serrulata*) as well as the species *Syringodium isoetifolium* and *Thalassia hemprichii* (URS 2010f, Vanderklift et al. 2017). All seagrass species(with the exception of *Thalassia hemprichii*) are considered to be ephemeral or opportunistic species with tropical affinities (McMahon et al. 2017). *Cymodocea angustata* is the only endemic species in Western Australia, while across the Pilbara *Halophila ovalis* and *Halodule uninervis* appear to be the most widespread species in shallow waters (Vanderklift et al. 2017).

While overall percent cover and biomass of seagrass in the Pilbara is substantially lower in comparison to southern more temperate regions, substantial variation exists in species colonisation of certain areas and in temporal biomass trends. Seagrass biomass in Exmouth Gulf, especially in the case of *H. uninervis* and *H. ovalis,* varies considerably between winter and summer, with up to four-fold biomass increases recorded between August and November through to January (Loneragan 2013). Surveys by Vanderklift et al (2017) at various locations across the Pilbara indicated there is no consistent pattern in the species composition of seagrass through the Pilbara or in the temporal patterns of abundance, with the exception of a location in the south eastern portion of Exmouth Gulf where a regular pattern was observed with total seagrass cover highest in summer and lowest in winter.

Significant temporal and spatial variation in biomass can also occur amongst different species, while differences in phenology of a single species have also been observed within meadows in close proximity (hundreds of meters) (Vanderklift et al. 2017). The species composition of specific meadows across one to two years can also vary and the drivers for such change are poorly understood; however, Vanderklift et al, (2017) suggest that consumption of seagrass leaves and rhizomes by herbivores may be a key influence.

The establishment of new seagrass beds is achieved through two main mechanisms: colonisation of bare soft substrate through extension of rhizomes from existing plants, and recruitment of new individuals through the germination of seeds or reattachment of dispersed fragments (McMahon et el. 2017). Light intensities were measured by Vanderklift et al (2017) for 18 months across eight locations in the Pilbara (including Exmouth Gulf) and compared to results against laboratory-defined thresholds for light intensities under which sub-lethal impacts started to occur in three species (*H. uninervis, H. ovalis and Cymodocea serrulata*). The study reported light intensities at the survey locations rarely dropped below thresholds, including during winter months.

3.2.2.3 Macroalgae

A review of existing knowledge (URS 2010f) conducted as part of the Wheatstone project EIA indicated macroalgae in the region form part of the broader Pilbara flora which is a subset of the Indo-West Pacific flora. All the known species in the Pilbara have tropical affinities and wide geographical ranges.

Macroalgae in the region can be found on both soft sediments and harder substrates such as rubble and pavement or reef areas. Shallow subtidal surveys for the Wheatstone project found macroalgae were present at low to medium density at most sites where there was an underlying hard bottom to provide attachment. Dense macroalgae tended to only occur on the shallow subtidal pavements that surrounded most islands. The dominant algae were brown algae of the genera *Sargassum, Padina* and *Dictyopteris,* and red algae of the genera *Gracilaria* and *Laurencia* (URS 2010d)*.* Green algal genera such as *Caulerpa* and *Halimeda* occured on sandy substrates and were often mixed with seagrass, although abundance and density were generally low. Data from studies across the tropics indicate macroalgae do not form conspicuous beds in the tropical regions with the exception of *Sargassum* which tends to be common on intertidal and subtidal platforms (URS 2010f).

As with seagrass, macroalgae are dependent on light and are, therefore, restricted to habitats which receive sufficient light, which in the case of the Pilbara coastal areas are generally in shallow water (<5 m deep). Offshore, less turbid areas have been observed to support macroalgae and seagrass at deeper depths. Very limited information exists on seasonal variation in tropical macroalgae in the region, although some observations of intertidal algae at Barrow Island suggest peak growth and fertility of *Sargassum* occurs over summer (URS 2010f).

Ecologically, macroalgae perform a similar role to seagrasses and they are important contributors to primary productivity. Following observations of minimal seagrass biomass in Exmouth Gulf, McCook (1995) suggested macroalgae are also an important secondary food source for dugongs. Macroalgae, especially *Sargassum spp.,* provide shelter and habitat for larvae and juveniles of various organisms, while crustose coralline algae play a significant role in reef stability through cementing and binding reef materials through the fixing of calcite crusts. *Halimeda*, which is a very common calcified green alga in the North West region, is a significant contributor to reef sediment. Decomposing macroalgae also provide a food source for detritivores (URS 2010f).

3.2.2.4 Sand veneered pavement and reef

Consolidated substrate, including sand veneered pavement and reefs, in the north-eastern part of Exmouth Gulf, and towards Onslow, occur as parallel bands close to shore and around low-lying islands, generally along the 5 m isobath (URS 2010d). Dominant biota on pavements and reefs are typically various macroalgae and microalgal species, with sub-dominant filter feeder communities such as sponges, ascidians, bryozoans, gorgonians and various other soft corals. Some pavement and reef areas also support scleractinian (‘hard’) corals; however, these are usually limited to small individuals of turbidity-tolerant genera such as *Porites*, *Turbinaria* and *Montipora.* Some distinct areas of pavement reef support larger coral colonies (URS 2010d). Despite supporting the most diverse range of epibenthic faunal biota, overall biota cover is usually low (<10%) with cover generally thinning out with increasing depth as less light reaches the bottom and photosynthetic taxa become less prevalent (URS 2010d).

During subtidal surveys for the Wheatstone project, coral cover inshore of the 10 m isobath was limited to reef and pavement areas, with greatest cover in shallow waters of around 4 m depth. With the exception of Ward Reef, which supported high coral cover (>50%), overall cover on nearly all other inshore survey sites was low (<10%). Overall coral species diversity was also low, with *Montipora, Acropora, Turbinaria* and *Porites* the most dominant genera observed (URS 2010d).

Further south along the eastern shore of the Exmouth Gulf, surveys for the Yannarie project reported even less diversity on the shallow subtidal reefs, with macroalgae and sponges becoming more common but hard coral occurrence falling to near zero. The observance of sponges, although more common, appeared to be limited to waters 3 m and shallower (Oceanica 2006). Recent studies on sponges in the Pilbara have reported the region is a biodiversity hotspot for sponges with, 406 species reported in the IMCRA-defined Pilbara Nearshore bioregion (Fromont et al. 2016). A study by Amzi Abdul Wahad et al. (2017) of sponges in the Onslow and Wheatstone project area prior to, during and following the Wheatstone dredging program found there were no marked effects on sponge abundance, morphology and mode of nutrition. The study also reviewed the water quality data prior to and during the dredging campaign and noted that, despite there being pronounced acute and chronic changes in the water quality across large areas, sponge biology showed no marked effects. The study suggested that sponges are well adapted to high turbidity events and sediment loads, which is most likely due to regular sediment loads from flood events and episodic cyclone activity.

3.2.3 Sub-regional subtidal habitats

The following sub-sections provide a summary of the habitat types identified by the Geo Oceans (2019) survey across all survey areas shown in Figure 10. Approximately half of the survey areas were outside the subtidal LAU, therefore it should be noted that some of these habitat types represent the wider ‘sub-regional’ survey area, outside of the subtidal LAU.

3.2.3.1 Sand – unconsolidated sediment (sand/silt), no epibenthic fauna

The Geo Oceans survey found unconsolidated sediment consisting of predominantly sand and silt (supporting no epibenthic faunal communities) as the dominant habitat type within the survey area, accounting for 96% of the area surveyed. This habitat is typical of the Pilbara region where a combination of unconsolidated sediment in shallow depths and high energy water movement impedes the establishment of epibenthic faunal communities. It is worth noting, however, that due to the ephemeral nature of seagrass species which inhabit Exmouth Gulf and the Onslow coastal area, those unconsolidated sediment habitats which did not support seagrass during the current survey do have the potential to do so in the future. As a result, all unconsolidated sediment habitats in the Project area must viewed as potential seagrass habitats.

3.2.3.2 Seagrass, sand - unconsolidated sediment (sand/silt) with seagrass

Seagrass beds on unconsolidated sand were the second most dominant habitat type encountered during the Geo Oceans survey, accounting for an estimated 19% of the sand habitat area surveyed. This type of habitat was encountered close to shore in most areas, and in front of both Urala Creek North and Urala Creek South. *Halodule* was the most common seagrass genus encountered, while more sparse cover of *Halodule* and various macroalgae (*Halimeda* sp. and *Caulerpa* sp.) mixed assemblages were also commonly observed. *Halophila* spp. were recorded mixed with *Halodule* near Urala Creek South.

3.2.3.3 Macroalgae, reef – macroalgae-dominated reef habitat

Reefs, which are defined as hard, consolidated substrate interspersed with gravel and pebble substrates, made up 3.6% of the total survey area during the Geo Oceans survey. Macroalgae inhabited reef was the most common reef community and accounted for 86% of reef observed, it was recorded nearshore and offshore. Mixed assemblages of macroalgae were prominent with *Sargassum* the most dominant genus; lobed brown algae, *Caulerpa* and *Halimeda* species also observed. Other benthic species observed in this habitat included scattered corals, sponges, hydroids and ascidians.

3.2.3.4 Coral, reef – consolidated substrate with corals present

Two small distinct patches were observed, one patch each in the north and south areas outside of the LAU. These contained consolidated substrate with hard coral cover in excess of 10%. *Porites,* faviid*, Turbinaria, Goniopora, Acropora* and *Pectinia* genera were recorded, while massive, encrusting and plating corals were the most common growth forms. The two patches were both in approximately 5 m of water and 1 to 2 km offshore. These habitats also supported macroalgae, sponges, sea fans and ascidians.

3.2.3.5 Subtidal creek habitats

Benthic habitats within Urala Creek North and Urala Creek South were observed to be predominantly sandy and silty substrate at all the survey points across both creeks. Sparse patches of brown and green algal growth were observed in the lower reaches of Urala Creek South, while none were observed in Urala Creek North.

Tidal creeks are a major part of the intertidal system, with parts of the creeks becoming exposed mudflats at low tide (therefore being intertidal), although the deeper parts of the creeks are predominantly subtidal (always submerged by water). It is therefore subjective whether the tidal creeks are included as intertidal or subtidal habitat.

3.2.4 Subtidal habitats of the Nearshore Local Assessment Unit (LAU)

Benthic habitats of the Nearshore LAU were mapped by AECOM using a combination of:

- Towed video transect data from the Geo Oceans (2019) survey.
- Aerial imagery and satellite imagery.
- LiDAR bathymetry data acquired specifically for the Project.
- Sonar transects acquired specifically for the Project.

It was found that the Nearshore LAU consisted of three habitat types as described below, depicted in Plate 31 to Plate 33 (images from the Geo Oceans 2019 survey) and mapped in Figure 11.

3.2.4.1 Soft Sediment (potential seagrass habitat)

The majority of the Nearshore LAU was found to be unconsolidated sediment consisting of predominantly sand and silt (supporting no epibenthic faunal communities). This habitat is typical of the Pilbara region where a combination of unconsolidated sediment in shallow depths and high energy water movement impedes the establishment of epibenthic faunal communities. However, soft sediment does have the potential to support ephemeral seagrasses in the future. As a result, all unconsolidated sediment habitats in the Nearshore LAU are viewed as potential seagrass habitats. Of the soft sediment habitats observed and subsequently mapped by surveys undertaken by Geo Oceans (2019), seagrasses were observed at a number of locations, typically in densities of less than 5% cover, making remote sensing methods unreliable for mapping these habitats over large areas. Due to this, seagrass cover was extrapolated to regions surrounding actual observations to produce estimated seagrass presence based on the available ground truthing data.

Areas of seagrass were observed at two locations offshore (to the east and west) of the proposed jetty location and at a number of locations in shallow waters, extending offshore at the western end of the Nearshore LAU. Small areas of seagrass were identified in similarly low densities along single transects between the proposed jetty and mouth of Urala creek North. Benthic habitat comprising greater than 10% seagrass was only mapped along a section of one transect outside the mouth of Urala Creek South.

3.2.4.2 Macroalgae

Macroalgae inhabited reef was found to occur nearshore on the reef pavement extending from the beach along the coast. In this habitat type, mixed assemblages of macroalgae were prominent with *Sargassum* the most dominant genus; lobed brown algae, *Caulerpa* and *Halimeda* species also occur in this habitat type.

3.2.4.3 Macroalgae and sparse coral

Reef dominated by macroalgae, interspersed with sparse scattered coral was found to occur on the seaward edge on the reef pavement extending offshore along the coast and within a patchy area approximately 2 km offshore in the south western portion of the LAU . Mixed assemblages of macroalgae are dominant in this habitat type with *Sargassum* the most dominant genus; lobed brown algae, *Caulerpa* and *Halimeda* species also occur in this habitat type. Other benthic species observed in this habitat include scattered corals, sponges, hydroids and ascidians.

Plate 31 Habitat 1: Soft sediment.

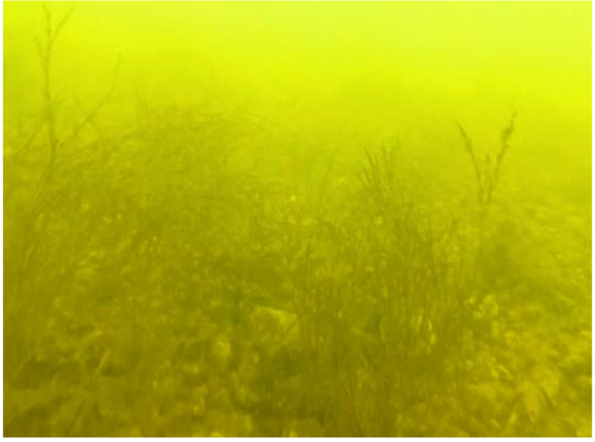


Plate 32 Habitat 2: Macroalgae (sparse brown algae).

Plate 33 Habitat 2: Macroalgae (reef with Sargassum sp., Halimeda sp., Caulerpa racemosa).

Plate 34 Habitat 3: Macroalgae and sparse coral (reef with Sargassum sp. sparse coral & sponges.).

4.0 Productivity and Nutrient Cycles

Mangrove habitats play a major role in supporting coastal food webs and nutrient cycles in the coastal zone and they are an efficient sink of dissolved nitrogen, phosphorus and silicon (Alongi 1996). The ecological roles of mangroves on arid coasts are less well understood than those of the wet tropics but a significant role in primary and secondary production and nutrient recycling is evident there also.

The diversity of mangrove plants, fish and invertebrates that mangrove habitats support is not high (compared to other tropical ecosystems) and biodiversity is moderate. However, the density of fauna therein can be very high. As a direct result of the high primary and secondary productivity in mangrove ecosystems, the standing stock of commercial species may be many times higher than that of adjacent coastal marine habitats (Morton 1990; Robertson & Duke 1990; Rönnbäck 1999). There is a variety of terrestrial and marine vertebrates and invertebrates that utilise the food resources of mangroves on a temporary basis (Milward 1979; Hutchings & Recher 1982). Many coastal species, including many that have commercial importance, use mangroves and adjacent tidal creeks as breeding and nursery areas, taking advantage of the protection and rich food resources available there (Dall et al. 1990; Robertson & Blaber 1992).

4.1 Primary and Secondary Production

Alongi et al. (2000) studied biogeochemical processes in mangrove forests (*Avicennia* and *Rhizophora*) at localities on the arid Pilbara coast. Paling et al. (1989) examined the important role of cyanobacteria in nitrogen fixation on algal mats in the region.

There are several sources of primary production in Pilbara mangroves (including the extensive mud and salt flats along their landward margins):

- Mangrove plants produce large quantities of detrital material, derived from fallen leaves and decaying wood.
- Microphytobenthos (e.g. cyanobacterial layers) of high-tidal mud flats produce and fix significant amounts of nitrogen in the substrate (Paling et al. 1989).
- Micro-epiflora and bacteria on the mangrove vegetation and planktonic micro-flora imported from the coastal waters by tidal flux also play various primary and secondary productivity roles.

Consequently, the substrate of mangroves and associated mud flats has a high organic content and supports high microbial activity and large densities of grazing and detrital-feeding fishes and invertebrates (Odum & Heald 1972; Sutherland 1980; Alongi 1989a, 1989b; Alongi & Sasekumar 1992; Ray et al. 2000). While there are some predatory species, and some suspensory-feeding invertebrates that live in the seaward margins of mangroves, the majority of a mangrove biomass comprises surface-dwelling and burrowing grazers and detritivores that perform the critical role of breaking down organic materials, aerating the soil and providing conduits (i.e. burrows) for inundating tidal waters to flush out salts and maintain the soil and groundwater salinities required for mangrove survival.

Mangrove surface-dwelling and burrowing invertebrates are essential secondary producers that convert organic material created by the primary producers to forms that are made available to mangrove ecosystems and beyond. The Ocypodids (fiddler crabs - genus *Uca*) feed mainly on the micro-epibenthos on the substrate surface while the sesarmids (marsh crabs – genera *Neosarmatium*, *Perisesarma*, *Parasesarma*) feed on detrital material they gather from the mud flat surface. The sesarmids play a particularly important role as they drag the plant material into their burrows where they shred it, thereby resizing and redistributing organic material throughout the soil profile.

4.2 Nutrient Cycles and Pathways

Recognising that nutrient cycles and pathways are key processes functioning within intertidal areas and the connectivity to nearshore areas and Exmouth Gulf, K+S commissioned a study to develop a nutrient pathway model (Figure 12) and quantify a nutrient budget for the Project site and the broader area of the eastern Exmouth Gulf. The full findings of the study are presented within a separate report and the key nutrient pathways are outlined in Figure 11 below (Water Technology 2021b).

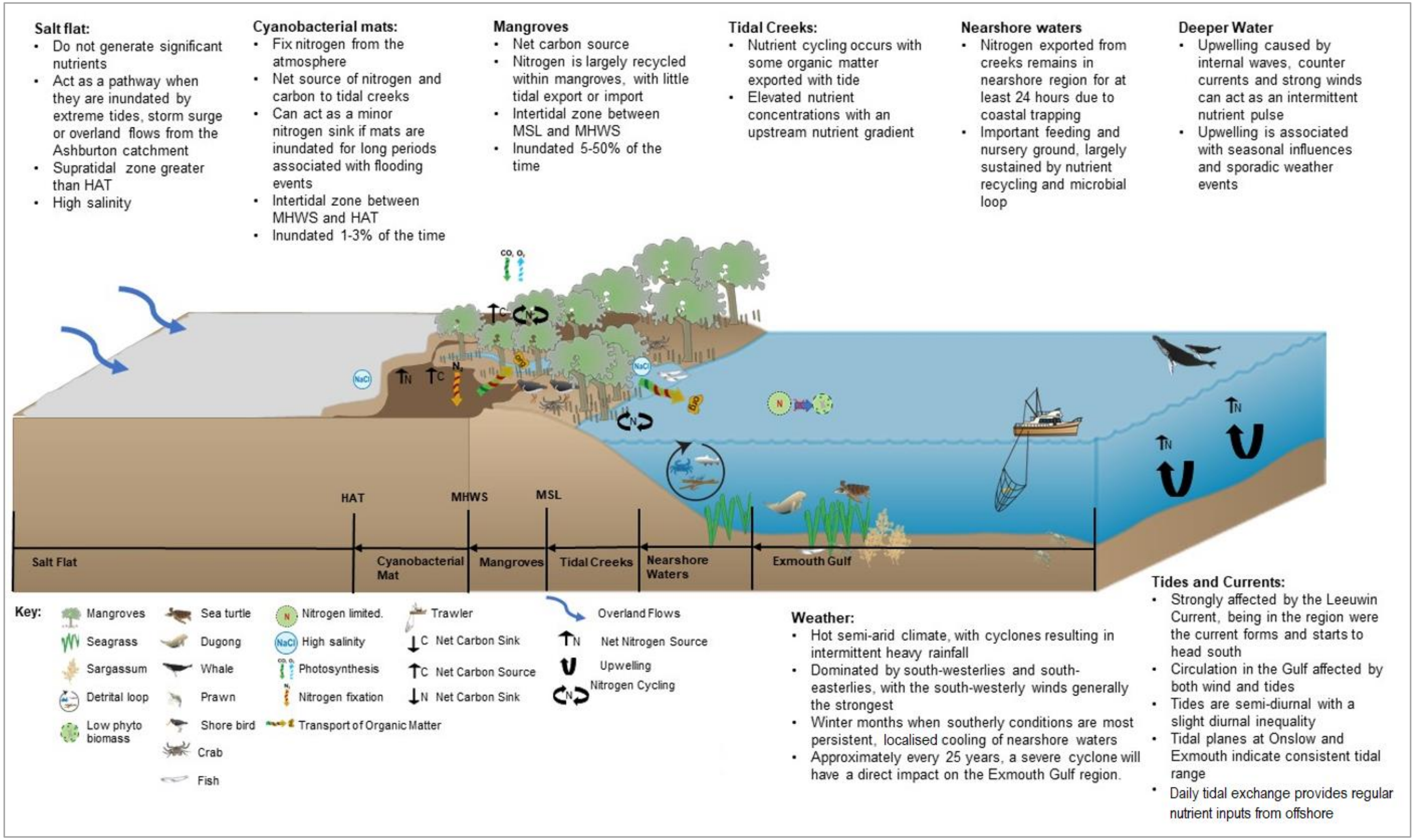


Figure 12 Conceptual nutrient pathway model (from Water Technology 2021b)

5.0 Benthic Community Habitat Loss Assessment

5.1 EPA Guidance for Assessments of BCH Loss

The EPA recognises the important roles that benthic communities play in maintaining the integrity of marine ecosystems and the supply of ecological services. Accordingly, the EPA provides technical guidance based on BCH as a key environmental factor and with the objective to *protect benthic communities and habitats so that biological diversity and ecological integrity are maintained* (EPA 2016a).

The EPA Technical Guidance Protection of Benthic Communities and Habitats (EPA 2016b) was prepared to *explain how impacts on benthic communities and habitats (BCH) are considered during Environmental Impact Assessment (EIA) and to set out the type and form of information that should be presented to facilitate the assessment of impact on BCH in Western Australia's marine environment*.

5.2 Local Assessment Units (LAUs)

The approach outlined in the technical guidance (EPA 2016b) is for proponents to present cumulative residual loss, or serious damage to, BCH in the context of spatially based and defined areas referred to as LAUs. Proponents are required to determine of areas of BCH which have been lost historically or are currently present and proposed to be lost or impacted and calculate cumulative losses within the defined LAUs.

EPA (2016) provides the following advice regarding the definition of LAU boundaries:

- There is no standard LAU size or shape – they need to be clearly defined on a case-by-case basis.
- In WA's marine environment LAUs would typically be approximately 50 km^2 (e.g. a rectangular area defined buy a 10 km stretch of coastline extending 5 km offshore [or to the limit of State Waters]). Larger or smaller LAUs will be considered if well justified.
- Proponents should seek advice of relevant Government agencies on the appropriateness of the proposed LAU boundaries and, where necessary, discuss compatibility of proposals with marine reserve management objectives as early as possible in the design of proposals.

In the context of the above guidance, the assessment below considers the following factors in defining LAU boundaries appropriate for the Ashburton Salt Project:

- Coastal geomorphology
- Coastal sectors
- Broad ecosystem units
- The distribution of intertidal and subtidal habitats with respect to the Project layout
- Conservation, planning and tenure boundaries
- LAUs used for previous assessments with similar BCH.

Both Intertidal and Nearshore LAUs are proposed to reflect the proposed Project layout adjacent to intertidal BCH, mangroves and algal mats and the proposed jetty located in nearshore waters near Locker Point within subtidal BCH. The proposed LAUs are shown in Figure 13. Consultation occurred with DWER Marine Ecosystems Branch in order to designate these proposed LAUs.

PROJECT ID 60597242
CREATED BY SmithS9
APPROVED BY ABougher
LAST MODIFIED 26 OCT 2022

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50
0 2 4 6
Kilometers

1:140,000 (when printed at A3)

LEGEND

- Jetty Alignment
- Conveyor
- Pond Layout Gates (Option 8)
- Bittens Pond (Option 8)
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Intake and Channel
- Embankment (Option 8)
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Algal Mat Mapping
- Mangrove Mapping
- Intertidal Samphires

Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016) , Sentinel Imagery Oct 2022

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Proposed LAUs for the Ashburton Salt Project

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
13

5.2.1 Intertidal LAUs

Guidance for an appropriate Intertidal LAU was sought from previous EPA assessments on projects located within similar coastal settings - limestone barrier islands sheltering tidal embayments with mangrove fringed creek systems backed by extensive mudflats.

Assessment of the Yannarie Salt project divided the east Exmouth Gulf (i.e. Giralia Bay to Tubridgi Point) into four LAUs using the geomorphic features (e.g. major headlands) that *may indicate local connectivity in mangrove populations, tidal hydrodynamics and other relevant aspects* (Biota 2005). The northernmost of these LAUs extended from Tent Island in the south to Tubridgi Point in the north and it is partly within this LAU that the proposed Ashburton Salt Project is located.

During development of the EIA for the Ashburton Salt Project, a provisional Intertidal LAU was proposed using similar boundaries to the Tent Island to Tubridgi Point LAU adopted previously for the Yannarie project, with the following modifications to make it appropriate for the Ashburton Salt Project layout and to give consideration of the updated EPA guidance (EPA 2016b) and relevant regional conservation management boundaries:

- The northernmost boundary of the LAU be extended north-east from Tubridgi Point for a further 4 km to include the mouth of Urala Creek North. This extension recognises the tidal connectivity between Urala Creek South and Urala Creek North and enables the complete tidal embayment that is maintained by tidal flows through both Urala Creek South and Urala Creek North to be included within the LAU.
- The proposed extension of the northern boundary of the LAU is also consistent with the northern boundary defined in the Commonwealth's *A Directory of Important Wetlands in Australia* (Environment Australia 2001) for the Exmouth Gulf East site (wetland site WA007).

Advice on the provisional Intertidal LAU was sought from the DWER Marine Ecosystems Branch (MEB) and subsequently modifications were made to separate the LAU into two areas (Figure 13).

Rationale for the proposed boundaries of the two Intertidal LAUs are:

- Intertidal LAU North recognises the tidal connectivity between Urala Creek South and Urala Creek North and includes within the LAU the complete tidal embayment that is maintained by tidal flows through both Urala Creek South and Urala Creek North.
- Intertidal LAU South includes mangrove and algal mat areas that extend south from Urala Creek South and extends far enough to capture any potential impacts of the project on the tidal regime to the south.
- The eastern boundary of the proposed Intertidal LAU is approximately aligned with the landward limit of algal mat (or BCH) occurrence. Large areas of salt flats occur between the algal mats and the hinterland (i.e. east of the LAU) and it is within these areas that the majority of the salt pond infrastructure would be located. Due to the extreme conditions (hypersalinity, high surface temperatures and evaporation rates) experienced in salt flats, these areas do not support any intertidal or marine benthic communities (i.e. they are devoid of vegetation and intertidal invertebrate fauna - see Section 2.9) and hence they are not considered as BCH in this assessment. It should be noted that while salt flats are not included in the LAU cumulative loss assessments due to the absence of BCH, their role as pathways for nutrients and freshwater emanating from the hinterland is discussed in Section 5.5.6.
- As mentioned above, the northern boundary of the LAU is consistent with the northern boundary of wetland site WA007, as defined in Environment Australia (2001).
- The alignment and size of the proposed LAUs are sufficient to capture both direct and potential indirect impacts from the Project on intertidal BCH given consideration of the scale of the Project and salt pond layout.

While the EPA technical guidance statement indicates that WA's marine environment LAUs would typically be approximately 50 km^2 (e.g. a rectangular area of ocean defined by a 10 km stretch of coastline extending 5 km offshore) it also recognises that larger or smaller LAUs will be considered if well justified. It should be noted that many previous BCH assessments of Pilbara projects located within intertidal areas have used LAUs much larger than 50 km^2 as the LAU boundaries, based predominantly on coastal geomorphology, have incorporated large areas of non BCH (e.g. terrestrial and supratidal areas within, and adjacent to, areas of intertidal BCH). This reduces the proportion of BCH within many Intertidal LAUs by comparison with typical marine or Subtidal LAUs. In the case of the proposed Intertidal LAUs for the Ashburton Salt Project, both LAUs are larger than 50 km^2; however, the combined area of intertidal BCH ranges from 62.9 km^2 (Intertidal LAU North) to 59.3 km^2 (Intertidal LAU South) which represents proportions of 39% and 76% respectively, covered by BCH within each LAU (Table 5).

Table 5 Estimates of Intertidal BCH areas (ha or km^2) within proposed LAUs

	Area of Intertidal BCH	LAU Area	Proportion (%) of LAU Occupied by Intertidal BCH
Intertidal LAU North	6,295 ha or 62.9 km^2	160 km^2	39%
Intertidal LAU South	5,930 ha or 59.3 km^2	78 km^2	76%

Examples of the use of LAUs on the Pilbara coast that are of similar size, or larger, than those proposed are: 154 km^2 – Fortescue Metals Group port proposal at Port Hedland (FMG 2005, EPA 2005); 154 km^2 - Dampier Port Expansion (URS 2005); 47-161 km^2 - Yannarie Salt Intertidal LAUs (Biota 2005); and 50-196 km^2 - Wheatstone Intertidal LAUs (URS 2010a).

5.2.2 Nearshore LAU

To enable the BCH loss assessment of the construction of the proposed jetty and bitterns discharge outfall, as well as the dredging works for the berthing pocket, a Nearshore LAU is proposed that forms an approximately 50 km^2 (5,000 ha) rectangular area encompassing approximately 10 km of coastline and extending offshore for 5 km to approximately the 5 m depth contour. The Nearshore LAU is centrally located around the proposed location of the jetty and bitterns discharge outfall (Figure 13).

The results from the Geo Oceans survey and mapping works (Geo Oceans 2019), and from subsequent interpretation of satellite imagery and sounder recordings, indicate that the Nearshore LAU consists of a patchy complex of habitats that extends seaward from the sandy intertidal beaches (Figure 10). The estimated areal extents of various BCH classes are presented in Table 6.

Table 6 Estimates of Nearshore BCH areas (ha) within proposed LAU

Habitat/Dominant Biota	Substrate	Other Biota	Habitat Area (ha)	Proportion (%) of LAU Occupied by Subtidal BCH
Macroalgae	Reef	Filter feeders	82	2%
Macroalgae, sparse coral	Reef	Filter feeders, sparse coral	244	5%
Soft sediment	Sand	Potential seagrass habitat	4,674	93%

5.3 Environmental Aspects and Potential Impacts

The following potential direct and indirect impacts on BCH were identified and assessed:

- Site preparation and clearing activities, including the removal or impoundment (i.e. within pond system) of BCH.
- Location and alignment of Project infrastructure that could result in hydrodynamic changes, either to prevailing tidal flows or to the infrequent freshwater flows across the Project area from terrestrial or hinterland sources.
- Operation of a pump station that may modify tidal flows and sediment dynamics within adjacent BCH.
- Impoundment of seawater and concentrates (brines) at higher than natural ground levels, potentially leading to seepage and modification of existing groundwater conditions in adjacent algal mat and mangrove areas.
- Dredging leading to increased water turbidity, potentially resulting in shading or smothering of nearshore BCH.
- Movement of marine vessels leading to increased water turbidity, potentially resulting in shading or smothering of nearshore BCH.
- Discharge of bitterns into nearshore waters and potential impacts to nearshore BCH.
- Effects on the ability of mangroves/algal mats to adapt to climate change.

5.4 Related Studies Used to Inform Assessment of Potential Impacts

5.4.1 Modelling Studies

Several modelling studies have been undertaken to assist with the assessment of potential impacts, to identify potentially suitable mitigation measures, and to develop management plans. The key areas of modelling relevant to the BCH assessment are detailed below.

Marine and Coastal Assessment and Modelling (Water Technology 2021a)

Hydrodynamic and coastal processes models were developed to represent the existing movement of marine waters and tidal flows within the receiving marine environment, including intertidal areas (under both extreme and normal weather conditions). These models were used to assess the potential changes to tidal flows from salt pond infrastructure and seawater pumping, impacts from the proposed discharge of bitterns (taking into account the results of the bitterns ecotoxicology assessment) and to generate modelling outputs related to dredge plumes and sediment deposition from dredging. These included the potential impacts on hydrology and water quality of the system, and on sensitive receptors and their key habitats.

Nutrient Pathways Assessment and Modelling (Water Technology 2021b)

Modelling of hydrology and nutrient flows in the Project area was undertaken to investigate, document, illustrate and map the existing surface water flow regime and nutrient pathways that support important environmental values of the system. Understanding any potential changes in nutrient pathways as a result of the Project is important for assessing potential nutrient flow related impacts to marine and intertidal ecosystem productivity.

Ashburton Solar Salt Project Hydrogeological Investigation (GHD 2021a)

Hydrogeological field investigations were undertaken and a hydrogeological conceptual model was developed; the latter forms the basis of numerical groundwater modelling undertaken to assist in an assessment of likely environmental impacts associated with the Project development. The groundwater modelling incorporated density-driven flow functionality to account for density effects of hypersaline groundwater present at the site. The calibrated numerical model was used to provide quantified estimates of groundwater regime change due to construction and operation of ponds and to inform impact assessment on environmental receptors, in particular, mangroves.

5.4.2 Environmental Monitoring at Existing Salt Projects on Pilbara Coast

To help guide assessments made on the basis of outputs from the above modelling studies, important insight can be gained from the results of environmental monitoring undertaken at other Pilbara Salt projects constructed within similar settings. The extent of recorded changes to receptors such as mangroves and shallow groundwater conditions within tidal flats can provide useful context to the potential changes predicted by modelling studies. Both the Port Hedland and Onslow Salt projects have also been constructed primarily on expansive areas of salt flats landward of the mangroves and coastal zone and hence environmental monitoring data collected at those locations are of relevance to this assessment.

In addition to their similarity in settings and scale (i.e. several thousand hectares of ponds constructed on salt flats), their existence over several decades (Port Hedland since 1965, Onslow since 1990) provides insight into both longer term and more regional scale factors beyond those localised to the immediate vicinity of salt ponds. For example, factors related to the modification to infrequent hinterland water flows to coastal mangroves areas and nearshore areas from salt pond projects, and the impoundment of large areas of salt flats.

5.5 Assessment of Potential Impacts to Intertidal Habitats

5.5.1 Direct habitat loss from Project

The proponent has recognised that the avoidance of mangroves and algal mats is an important design constraint for the Project. As the design progressed, the following modifications were made to minimise direct impacts to mangroves and algal mats:

- Alignment of the western boundary of concentration ponds was moved further east to minimise direct loss of algal mats and provide greater areas of setback or buffer areas to accommodate potential indirect impacts to mangroves from edge effects such as localised seepage.
- Appropriate culverts / drainage diversions designed to maintain existing tidal and surface water flows.

Notwithstanding these design measures, small areas of mangroves and algal mats will be cleared and impounded within the pond system and these impacts represent areas of permanent habitat loss. These areas are associated with the seawater intake channel and nearby concentrator ponds as shown in Figure 14. The design of the salt field was intersected with the mapped intertidal habitats to determine area (ha) estimates of intertidal BCH loss from clearing/impoundment. Table 7 provides the predicted areas of habitat loss and places the extent of loss in the context the proposed LAUs, the Tubridgi Point to Tent Point coastal sector and the broader Exmouth Gulf area.

Table 7 Predicted areas of intertidal BCH loss from clearing and impoundment

Intertidal BCH Type	Direct Loss (ha)	Total Intertidal LAU North (ha)	Total Intertidal LAU South (ha)	Total Tubridgi to Tent Pt (ha)	Total East Exmouth Gulf (ha)	% of Intertidal LAU North	% of Intertidal LAU South	% of Tubridgi to Tent Pt	% of East Exmouth Gulf
Mangroves	3.94	540	1,645	3,724	11,742	0.73	0	0.11	0.03
Transitional Mud Flats	17.81	1,980	2,040	7,990	20,747	0.90	0	0.22	0.09
Algal Mats	12.74	3,350	2,034	6,199	11,617	0.38	0	0.21	0.11
Samphires	36.36	459	6	879	2141	7.88	2.83	4.14	1.70
Sandy Beaches	0.99	128	5	298	1,040	0.77	0	0.33	0.10
Tidal Creeks	0.30	297	206	876	2,710	0.10	0	0.03	0.01
TOTAL	**72.14**	**6,754**	**5,936**	**1,9966**	**49,577**	**1.07**	**<0.010**	**0.31**	**0.12**

The areas of predicted intertidal BCH loss are small, being 3.94 ha,12.74 ha and 17.81 ha for mangroves, algal mats and transitional mud flats respectively. This direct loss represents:

- <1% of total areas in the LAU North.
- <0.3% of total areas in the Tubridgi Point to Tent Point coastal sector.
- <0.2% of total areas along the Eastern Exmouth Gulf.

No direct loss of mangroves and algal mats is predicted to occur within Intertidal BCH LAU South.

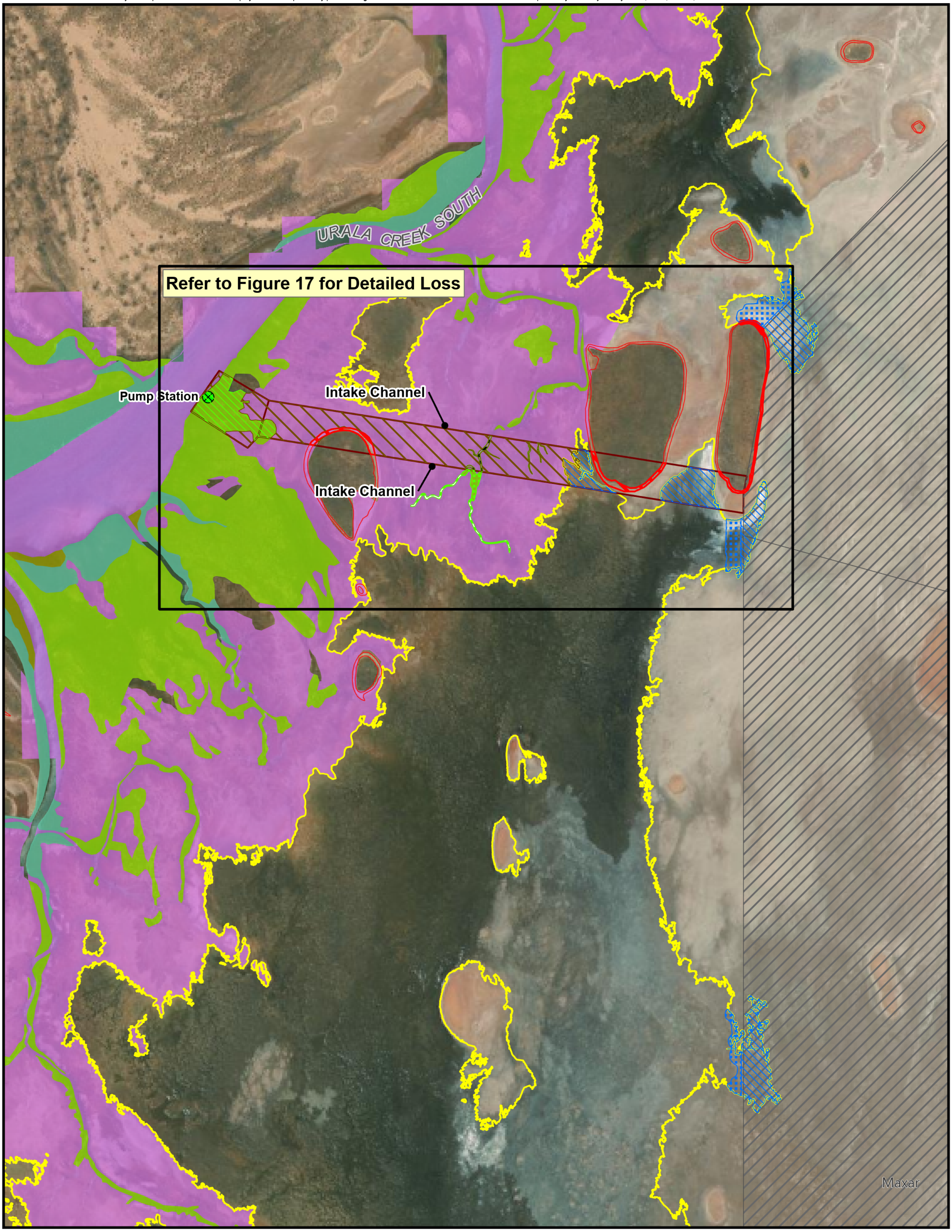
Mangrove loss is confined to areas requiring clearing for the seawater intake channel (~150 m wide disturbance corridor) and pump station. Mangroves in this area are comprised of structural variants of monospecific *Avicennia marina* (mangrove associations Am2 and Am3) which are widely represented in Exmouth Gulf and the Onslow coastline. Direct disturbance will be confined to low open mangroves (Am3: monospecific *Avicennia marina* mangrove association) which are comparatively less structurally complex and less productive than the closed canopy mangrove associations located further downstream from the intake channel and pump station. Studies related to productivity (e.g. Above Ground Biomass, AGB) in Pilbara mangroves indicate that closed canopy mangrove forests (i.e. Am1, Am2, Rs & Rs/Am associations) represent those with much higher productivity rates by comparison with the more scattered canopy mangroves such as the Am3 association that will be subject to direct disturbance from construction of the intake channel and pump station (Alongi et.al 2000, Clough et.al 1997, LEC 1992).

As noted in Section 2.3.1, three of the mangrove species recorded from the Project area (*Aegialitis annulata*, *Aegiceras corniculatum* and *Bruguiera exaristata*) have Exmouth Gulf as their southern range limit, with records of these species typically associated with more sheltered and complex mangrove creeks such as those near Tent Point (Biota 2005). The field survey undertaken for the Project study area recorded these three species in a similar setting at Site KS 64, located in a sheltered side creek near the mouth of Urala Creek South. This area will not be directly affected by the Project and there is not expected to be any clearing of mangrove species at their range limits.

The estimate for the direct losses to intertidal samphires (36.36 ha) includes areas cleared due to the construction of infrastructure and also areas fringing islands within the pond system that are likely to be permanently inundated by filling the ponds. This direct loss represents 7.9% of samphire extent in LAU North, less than 5% of the Turbridgi Point to Tent Point sector and less that 2% of the overall samphire extent in East Exmouth Gulf. Advice has been sought from Biota (flora/vegetation specialist) regarding the significance of the potential impacts to samphire vegetation in relation to local and regional distribution, listed flora species etc. This advice is provided below:

- The samphire vegetation within the Ashburton Salt study area did not contain any significant species.
- The samphire vegetation within the Ashburton Salt study area is considered to be of local rather than regional significance, and of “somewhat elevated conservation significance”.
- Given the small proportional loss predicted for the Ashburton Salt Project is unlikely to have significant impacts on the biological diversity and ecological integrity of samphire communities or species regionally.
- Due to the relatively low proportional loss of mapped samphire communities, the Project impacts on samphire are considered to be low/marginal.

Asmall area of sandy beach (0.99 ha) is required to be disturbed for the conveyor and a small area of a minor tidal sub-creek (0.3 ha) is required to be disturbed for the seawater intake. The proportional size of these areas represents <0.8% of total areas in LAU North, <0.4% of total areas in the Tubridgi Point to Tent Point coastal sector and 0.1% or less of total areas within East Exmouth Gulf.



PROJECT ID	60597242
CREATED BY	SMITHS9
APPROVED BY	A.BOUGHER
LAST MODIFIED	27 OCT 2022

AECOM
www.aecom.com

N

DATUM GDA 1994 MGA Zone 50

1:20,000
(when printed at A4)

0 100 200 300 400
Meters

Data sources:

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).Geoscience Australia, Streetpro

LEGEND

- Intertidal Samphires
- Pump Station
- Pond Layout (Option 8)
- Embankment (Option 8)
- Algal Mat Mapping

Mangrove Mapping

- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins
- AmRs:Tall, dense *Rhizophera styosa* on seaward margins
- Transitional Mudflat Mapping

Predicted Habitat Loss

- Indirect Habitat Loss for Interdidal Samphires (0.09 Ha)
- Direct Habitat Loss for Interdidal Samphires (1.7 Ha)
- Direct Habitat Loss for Algal Mat (12.7 Ha)
- Indirect Habitat Loss for Algal Mat (3.9 Ha)
- Direct Habitat Loss for Mangroves (3.9 Ha)
- Direct Habitat Loss for Tidal Creek (0.3 Ha)
- Direct Habitat Loss for Transitional Mudflats (17.8)
- Indirect Habitat Loss for Tidal Creeks (0.2 Ha)
- Potential Indirect Habitat Loss For Mangroves(0.3 Ha)

Predicted Habitat Loss
Urala Creek South

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

14

Map Document: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\10_Benthic_Hab_Survey_Feb2020\G60597242_Figures_Update_v2.aprx (SmithS9)

A4 size

5.5.2 Modification to tidal flows from the alignment of salt field infrastructure

5.5.2.1 Description of potential impacts

The construction of infrastructure across tidal creeks and within intertidal areas has the potential to modify tidal flows. Due to the lack of significant freshwater input into the arid Pilbara intertidal zone from hinterland areas, tidal inundation is the dominant recharge mechanism responsible for maintaining the suitable groundwater/soilwater conditions required for intertidal BCH growth/survival and for maintaining tidal creek and coastal lagoon habitats (refer to Section 5.5.7). It follows that modifications to tidal wetting and drying regimes can potentially impact Pilbara intertidal BCH. Case studies (Gordon 1988) involving the placement of infrastructure such as causeways, levees and roads across tidal creeks indicates that the localised changes to tidal flows arising from such structures may result in the following:

- Localised erosion of creek banks in the immediate vicinity of the culverts.
- Reduction in tidal flushing and the extent of tidal flat inundation in areas upstream from a restriction point. The decrease in tidal inundation may cause increasing groundwater/soilwater salinities and this could result in loss of mangroves in marginal fringing environments which have high salinities under natural conditions.
- Impoundment of water at higher than natural levels, which can result in mangrove decline and death due to sustained inundation of pneumatophores and a decline in water quality. This ponding effect has been observed during spring tides in areas immediately upstream from a restriction point when ebbing tidal waters cannot recede to normal levels prior to the next incoming (flood) tide.

5.5.2.2 Assessment of potential impacts

A numerical modelling approach was utilised to evaluate the change in tidal hydrodynamics associated with the proposed development. The DHI MIKE FM Hydrodynamic model (HD) used by Water Technology (2021a) is a general modelling system for simulation of flows in oceans, estuaries, bays and coastal areas. The model simulates unsteady three-dimensional water flows driven by density variations, bathymetry as well as external forcing from meteorologic influences, tide, ocean current and river inflows.

Model outputs showing predicted changes to tidal inundation patterns were generated for six representative scenarios:

- Spring tide: seasonal high spring tide conditions (at high water, and 4 and 8 hours after high water)
- Spring tide plus sea level rise (SLR): ambient spring tide plus 0.4 m sea level rise.
- 2-year ARI: Storm event with a two year return interval.
- 20-year ARI: Storm event with a 20-year return interval.
- 500-year ARI Cyclone: Synthetic cyclone with a 500 year return interval.

Figure 15 provides the modelling outputs for the differences in water levels (cms) between existing and developed scenarios during spring tide conditions. Figure 16 presents outputs from a one year simulation of tidal inundation; this shows the predicted changes to percentage submergence, with both the ponds and seawater intake channel embankment walls in place, as well as seawater intake pumping from Urala Creek South.

In general, the modelling outputs show that, due to the alignment of salt pond outer levees being located well landward (> 800 m) of the mangrove zone and above Mean High Water Spring (MHWS) elevations, there is not expected to be any significant modifications to tidal flows to/from mangrove, samphire and algal mat areas between the ponds and Urala Creek that are likely to cause impacts. There are no predicted changes to percentage submergence time (over one year) for all mangrove, algal mat or samphire habitats surrounding Urala Creek (North and South), due to the large setback between the seaward embankments and the mangrove zone (with the exception of a small area of mangroves near the intake channel, as discussed below).

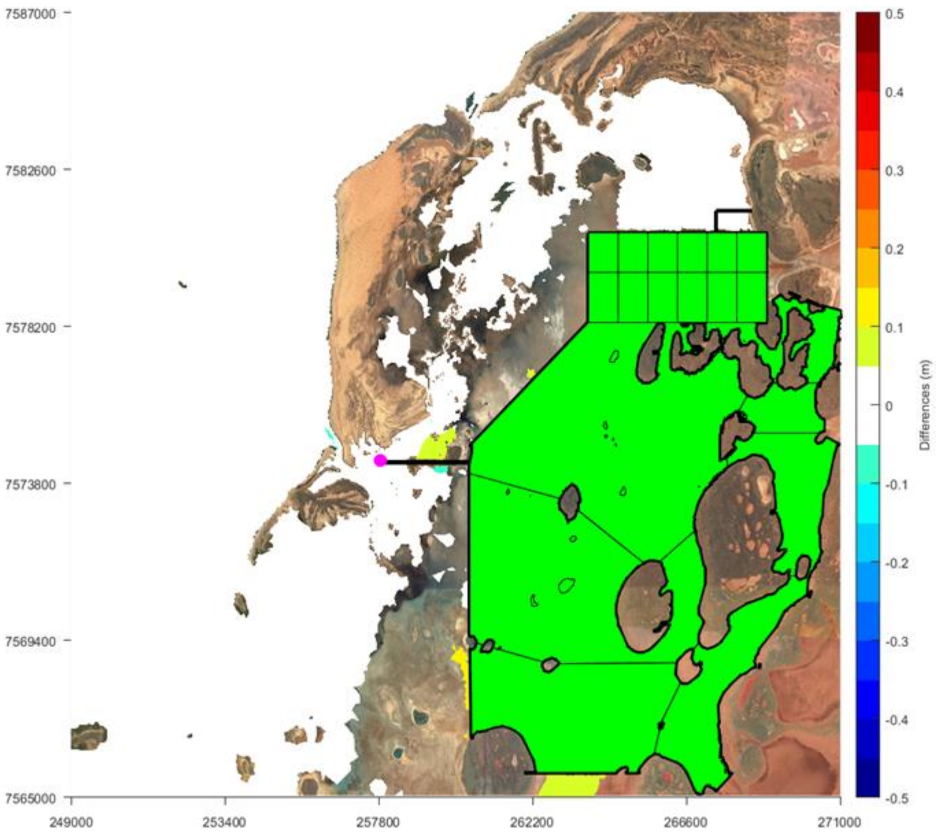
Changes to percentage submergence times of within 10% are not considered to be significant due to the natural variability in tidally regulated drying/wetting regimes experienced by mangroves, and also given consideration of modelling limitations related to the vertical accuracy (~20 cm) of the Digital Elevation Model (DEM) upon which the modelling is based (i.e. the implication of 20 cm DEM vertical resolution in a very flat landscape, where elevation gradients are in the order of 1:5,000 [Biota 2005]).

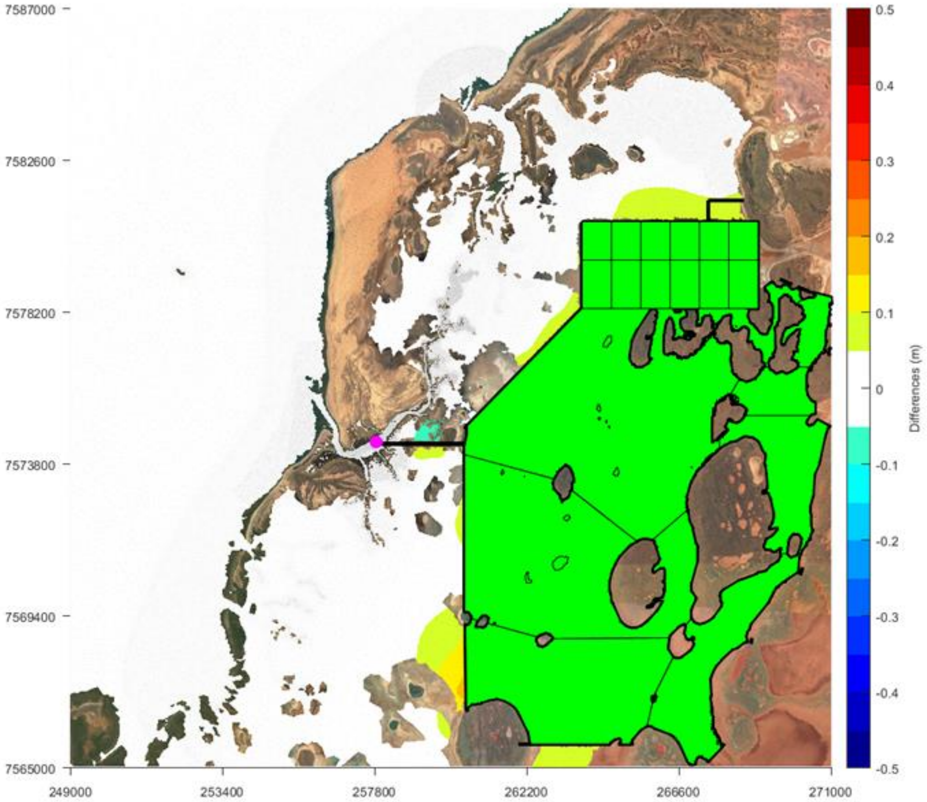
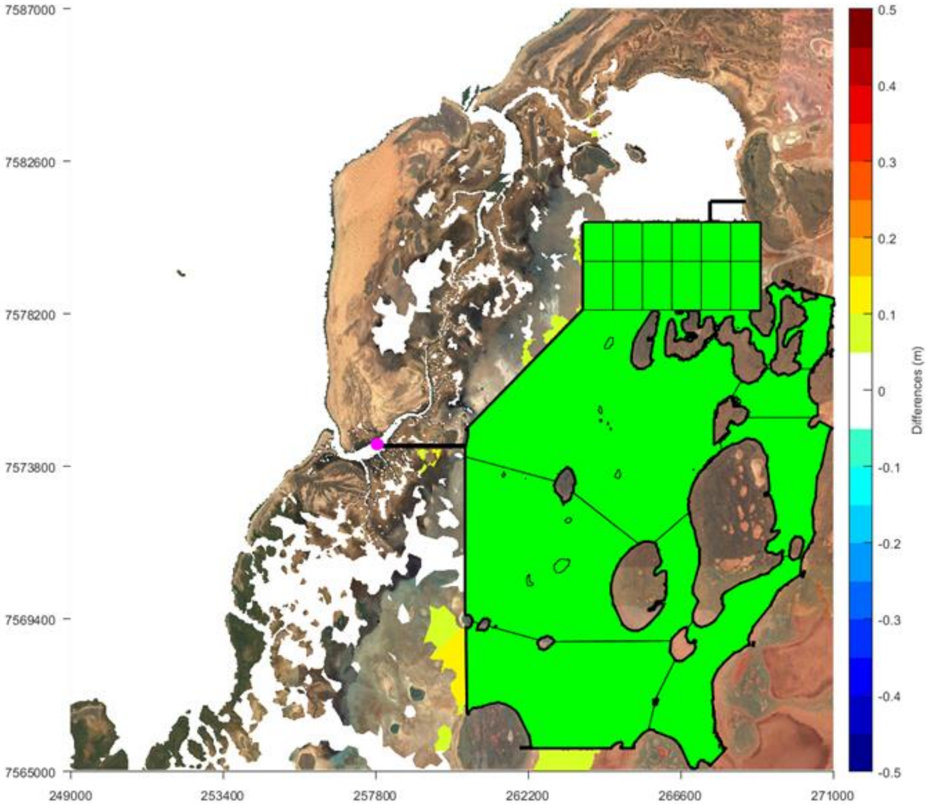
Changes due to overall pond layout

The modelling outputs showing changes in water level and inundation time indicate that the proposed development is predicted to have very minimal impacts to water levels or duration of tidal inundation.

Localised areas on tidal flats adjacent to pond levees are predicted to experience increases in water levels and submergence times due to the pond embankment walls acting as a barrier to the flooding tidal waters (Figure 15 and Figure 16). The barrier effect is predicted to elevate water levels and temporarily pond water on tidal flats next to the levees, in areas that are currently only inundated very infrequently during particular spring tides. In the period four hours after high water (during spring tides) some tidal waters are predicted to be temporarily ponded on tidal flats immediately next to CP1, CP2 and the western and northern levees of the crystalliser ponds (Figure 15). By eight hours after high tide, most of this water is predicted to have drained away, leaving some remnant ponded areas (~10 cm deep). These predicted ponded areas are largely on bare tidal flat or salt flat areas just landward of the algal mat zone; these would currently experience highly saline conditions that preclude algal mat growth, and the introduction of the lower salinity water in the remnant pools may provide conducive conditions for development of new algal mat areas, or the expansion of peripheral algal mat areas toward the levees.

Localised ponding is predicted to occur near the intake channel – this is discussed below.

Scenarios	Differences (Developed – Existing)
Spring Tide (2020-4-11 4:30)	

Scenarios	Differences (Developed – Existing)
4 hours after hig tide (2020-4-11 8:30)	
8 hours after (2020-4-11 12:30)	

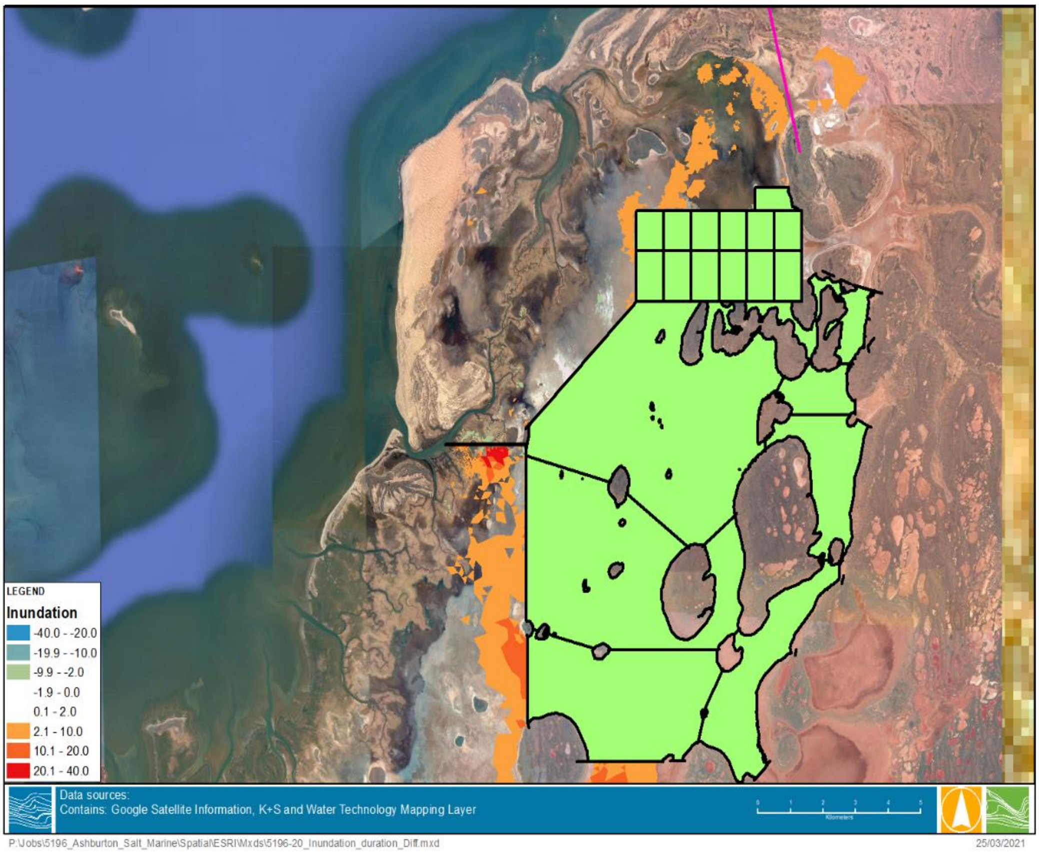
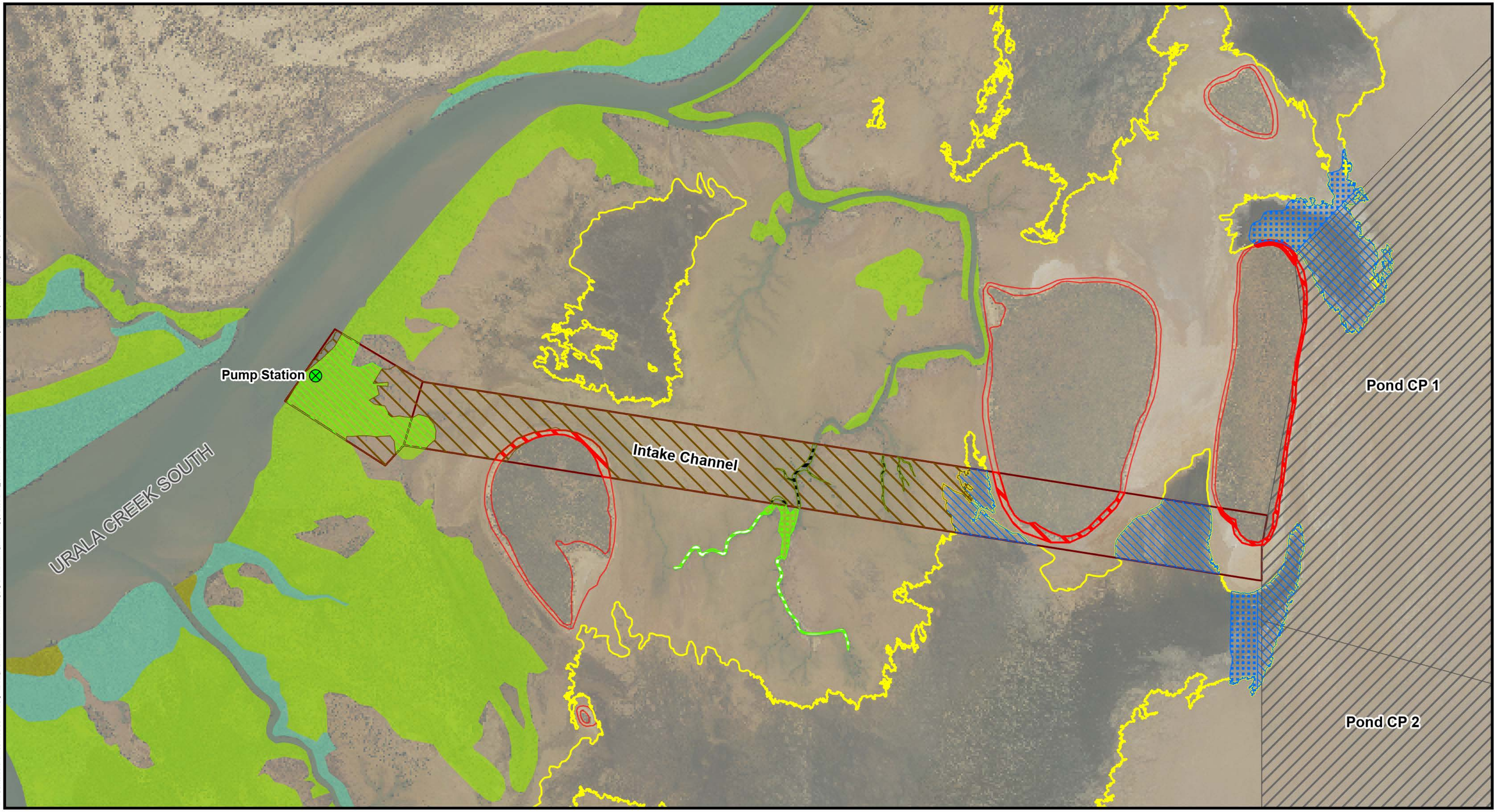


Figure 15 Differences in tidal inundation (% time submerged) over 1 year (2015) between pre and post development scenarios

Changes due to the intake channel

As the proposed intake channel extends westward from CP1, across tidal flats and towards Urala Creek South, it traverses over the upper reaches of a small tidal sub-creek that originates from the main Urala Creek South channel at a point approximately 1 km north from the pump station (Figure 16). At the location where the intake channel intersects the small sub-creek, the tidal channel is narrow (~5 m wide) and fringed by scattered low *Avicennia marina* shrubs, typical of mangrove communities at the landward edge of mangrove zones (Plate 35).

Plate 35 Narrow sub-creek at survey site KS36 located near the proposed intake channel alignment.



PROJECT ID 60597242
CREATED BY SMITHS9
APPROVED BY A.BOUGHER
LAST MODIFIED 27 OCT 2022

AECOM
www.aecom.com

N

1:12,000 (when printed at A4)

DATUM GDA 1994 MGA Zone 50

0 100 200 300
Metres

Data sources

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010) Geoscience Australia, Streetpro

LEGEND

- Pump Station
- Pond Layout (Option 8)
- Embankment (Option 8)
- Algal Mat Mapping
- Intertidal Samphires

Mangrove Mapping

- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins
- AmRs:Tall, dense *Rhizophera styosa* on seaward margins

Predicted Habitat Loss

- Indirect Habitat Loss for Interdidal Samphires (0.09 Ha)
- Direct Habitat Loss for Interdidal Samphires (1.7 Ha)
- Direct Habitat Loss for Algal Mat (12.7 Ha)
- Indirect Habitat Loss for Algal Mat (3.9 Ha)
- Direct Habitat Loss for Mangroves (3.9 Ha)
- Potential Indirect Habitat Loss For Mangroves(0.3 Ha)
- Direct Habitat Loss for Tidal Creek (0.3 Ha)
- Indirect Habitat Loss for Tidal Creeks (0.2 Ha)
- Direct Habitat Loss for Transitional Mudflats (17.8)

Intake Channel Area Potential BCH Loss

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure 16

The hydrodynamic modelling indicated that localised changes in the tidal inundation regime will occur during spring tides at an area upstream from the intersection of the intake channel with the sub-creek (Figure 15 & Figure 16). The modelling predicts these changes to be:

- During the modelled April spring high tide, backing up of water on the northern side of the channel in the order of 10 cm, and a reduction in water level on the southern side of the channel, also in the order of 10 cm. This is due to the physical barrier effect of the seawater intake channel embankments which impede the flow of tidal waters in a southerly direction during the incoming tide. By eight hours after high tide (ebb tide conditions), the water is predicted to have drained away from the northern side of the intake channel, with water levels returning to normal.
- During the modelled April spring low tide, backing up of water on the southern side of the seawater intake channel in the order of 10 cm, due to the physical barrier effect of the intake channel embankments impeding the flow of tidal waters in a northerly direction during the receding of tide.
- The percentage time submergence modelling output (Figure 17) shows increases of 10-40% in this area.

The construction of the intake channel across the sub-creek will effectively serve as a barrier to tidal flows into a small area (0.34 ha) of mangroves and remove tidal flow from a small portion of the sub-creek (0.26 ha) located upstream from the intake channel (Figure 16). This will result in:

- Removal of tidal flows to/from the small area (0.34 ha) of mangroves during neap tides that currently occurs via the “intersected” sub-creek.
- Impact to the minor sub-creek itself due to removal of tidal flows from 0.26 ha of tidal sub-creek. It should be noted that this is at the upper most reaches (~ 300 m) of two branches of a minor sub-creek approximately 2 to 5 m wide (Plate 35). This portion of the sub-creek is not considered to contribute significantly to tidal submergence in the area given it is only submerged with higher tides and larger sub-creeks exist nearby that also direct tidal waters in to the area (as evidenced by the increase in tidal submergence time predicted in the area due to the barrier effect of the seawater intake embankment) (Water Technology, 2021a).
- Ponding immediately upstream from the intake channel when, during spring tides, tidal water emanating from sub-creeks further to the south-west will flood much of the tidal flat area up to the pond system levees and then, on the ebb tide, the retreating (ebbing) water will not be able to exit via the “intersected” sub-creek and hence extended ponding may occur, as indicated by the modelling outputs shown in Figure 15 and Figure 17 (increases in percentage time submergence is predicted to be between 10 and 40% in this area; Water Technology 2021a).

Therefore the intake channel “barrier” has the potential to impact the health of a small area of mangroves upstream from the intake channel intersection point, resulting in indirect impacts to 0.34 ha of mangroves and 0.26 ha of tidal creek at this location is considered likely at the location shown in Figure 18. This prediction is consistent with localised indirect impacts to mangroves documented from other locations in the Pilbara where roads and causeways have been constructed across tidal creeks, resulting in similar modification to tidal flows in mangroves upstream from a constriction point (Gordon 1988).

Conversely the increases in water levels and tidal submergence in this area, could cause expansion of algal mats onto the bare mudflat areas which will experience increases in inundation and therefore may developed salinity gradients conducive to algal mat growth.

5.5.2.3 Mitigation measures

A Mangrove, Samphire and Algal Mat Monitoring Program will be implemented as part of a Mangrove, Samphire and Algal Mat Management Plan (MSAMMP) that integrates the monitoring of mangrove, samphire and algal mat health/status with the monitoring of shallow groundwater conditions (including salinity), and mapping showing Project-related changes in habitat distribution.

A Surface Water Management Plan (SWMP) will be implemented to further assess potential changes to surface water and nutrient flows and concentrations. The SWMP will include revised surface water modelling including borrow pits and final culvert /drainage diversion designed to minimise impacts and maintain environmentally important surface water regimes, particularly those important to samphire. The SWMP will include a weather station to monitor rainfall and climatic conditions as well as quarterly and rainfall event-based estuarine and surface water flow/volume and quality monitoring.

A Groundwater Management and Monitoring Plan (GMMP) will be implemented which includes groundwater monitoring to ensure any project related changes to groundwater and related changes to intertidal BCH are understood and potential impacts can be mitigated.

5.5.2.4 Predicted outcome

Due to the alignment of salt pond levees being located well landward (> 800 m) of the mangrove zone, and above MHWS elevations, there is not expected to be any significant modifications to tidal flows to/from mangrove, algal mat and samphire areas, or any impacts to these habitats from this factor, with the exception of a small area of low scattered mangroves (0.34 ha) that fringe the sub-creek upstream from the intake channel. The construction of the intake channel across the sub-creek will effectively serve as a barrier to tidal flows that currently move through the 0.26 ha of sub-creek channel to the small area (0.34 ha) of mangroves.

Increases in water levels and submergence times are predicted to occur in localised areas on tidal flats immediately next to the pond levees due to the levees acting as a barrier to the flooding tidal waters. These areas where ponding may occur are largely on bare tidal flat or salt flat areas just landward of the algal mat zone and would currently only be inundated very infrequently during particular spring tides. They would currently experience highly saline conditions that preclude algal mat growth, and the introduction of the lower salinity water in the remnant pools (i.e. from ponding) may provide conducive conditions for development of new algal mat areas, or the expansion of peripheral algal mat areas toward the levees.

5.5.3 Pumping of seawater and potential reduced tidal inundation of mangrove and algal mat areas

5.5.3.1 Description of potential impacts

Operation of the salt field is dependent on the pumping of large volumes of seawater from intake pumps at Urala Creek South. The location of the seawater intake in Urala Creek South is shown in Figure 16

The extraction of seawater has the potential to modify the existing tidal prism and reduce the tidal inundation regime upstream from the pump station, including in adjacent mangrove and algal mat areas. Tidal wetting and drying regimes are key mechanisms that regulate salinity gradients in mangrove and tidal flats areas, and such gradients play an important role in the distribution of BCH within the intertidal zone (Section 2.3.3). For example, the dominant mangrove species in the study area (*Avicennia marina*) has the greatest salinity tolerance of the Pilbara mangrove species and occurs in areas where groundwater salinity reaches up to 90 ppt (approximately 2.5 times seawater) (Gordon 1988). A reduction in the tidal prism from seawater pumping has the potential to reduce the period and frequency of tidal inundation, increase salinities and modify mangrove health (and in the longer term alter the distribution of the mangrove zone and mangrove associations within that zone).

5.5.3.2 Assessment of potential impacts

Modelling of changes to tidal inundation patterns within mangrove and algal mats undertaken by Water Technology (2021a) was based on the predicted pumping requirements of:

- A seawater intake consisting of multiple pumps with openings facing downward at 0.5 m above the bottom of the intake pond (floor level at -4 m AHD elevation).

- Maximum intake rate of approximately 10.97 m^3/s, representing the highest monthly intake in November (~29 GL).
- An annual seawater intake estimated to be 250 GL. The peak intake is required in October to December when evaporation rates are highest, with an estimated monthly intake during the peak months of 29 GL per month. This includes all seawater required for the evaporation ponds, wash plant and bitterns dilution water.

Modelling was done on a conservative basis by representing the seawater intake as continuous pumping in both low and high tide conditions. However, it is understood that pumping will not occur during low tide.

Figure 15 provides the modelling output for changes in percentage time inundated from the development scenario which includes both the ponds and seawater pumping. This did not indicate any detectable pumping-related changes to the percentage of time that mangrove and algal mat areas are inundated.

Figure 17 provides tidal submergence curves for both the existing base case and worst case (maximum pumping) scenarios when the Urala Creek South pump station is operating. The tidal ranges (or upper and lower elevations) over which mangrove and algal mats occur are overlaid onto the submergence curves to assess potential reductions in inundation time in those habitats. The upper and lower elevations of the mangroves and algal mats were determined using the Lidar DEM, mangrove and algal mat mapping, as well as published data (Biota 2005):

- Mangrove habitat is typically located above mean sea level (MSL) but below MHWS level. There are instances when individual mangroves may grow slightly beyond this range; however, based on available data it is reasonable to conclude the typical elevation range is approximately 0 to 0.7 m above MSL for the lower to upper range of the mangrove zone.
- Algal mat habitat is typically located above the range of mangrove habitat, with the upper limit approximating highest astronomic tide (HAT). Based on available data it is reasonable to conclude the typical elevation range is approximately 0.8 to 1.1 m above MSL for the lower to upper range of the algal mat zone.

By assessing the differences between the existing and developed scenario submergence curves, the estimated changes in inundation or submergence time are as follow.

Mangroves

- At the lower elevation or seaward edge of the mangrove zone (~0 above MSL) there is a predicted reduction in time submerged from ~50% to ~48%.
- At the upper elevation or landward edge of the mangrove zone (~0.7 m above MSL) there is no predicted reduction in time submerged (with ~5% both pre- and post-development).

Algal Mats

- At the lower elevation of the algal mat zone (~0.8 m above MSL) there is no predicted reduction in time submerged (with ~3% both pre- and post-development).
- At the upper elevation of the algal mat zone (1.1 m above MSL) there is no predicted reduction in time submerged (with ~1% both pre- and post-development).

The very small reduction (~2%) in annual submergence times in mangroves at the lower elevations of their range (i.e. along the margins of the main Urala Creek South channel) is not likely to impact mangroves and the small extent of the reduction is likely to fall within the natural annual variability. These areas will continue to receive regular tidal inundation and no loss of mangroves is likely to occur as result of the localised hydrodynamic changes from seawater pumping.

At higher elevations within the mangrove zone, and in algal mat areas, there is no predicted reduction in submergence time and hence no impacts are predicted from seawater pumping. Samphire vegetation communities occur above the elevation range of the mangroves and no changes are predicted to tidal inundation time above the mangrove elevation range and therefore there is no predicted impacts to samphires from seawater pumping within Urala Creek South.

These predictions are likely to be conservative, given pumping is not expected to be undertaken at low tide, whilst modelling has used a constant pumping regime at both high and low tide.

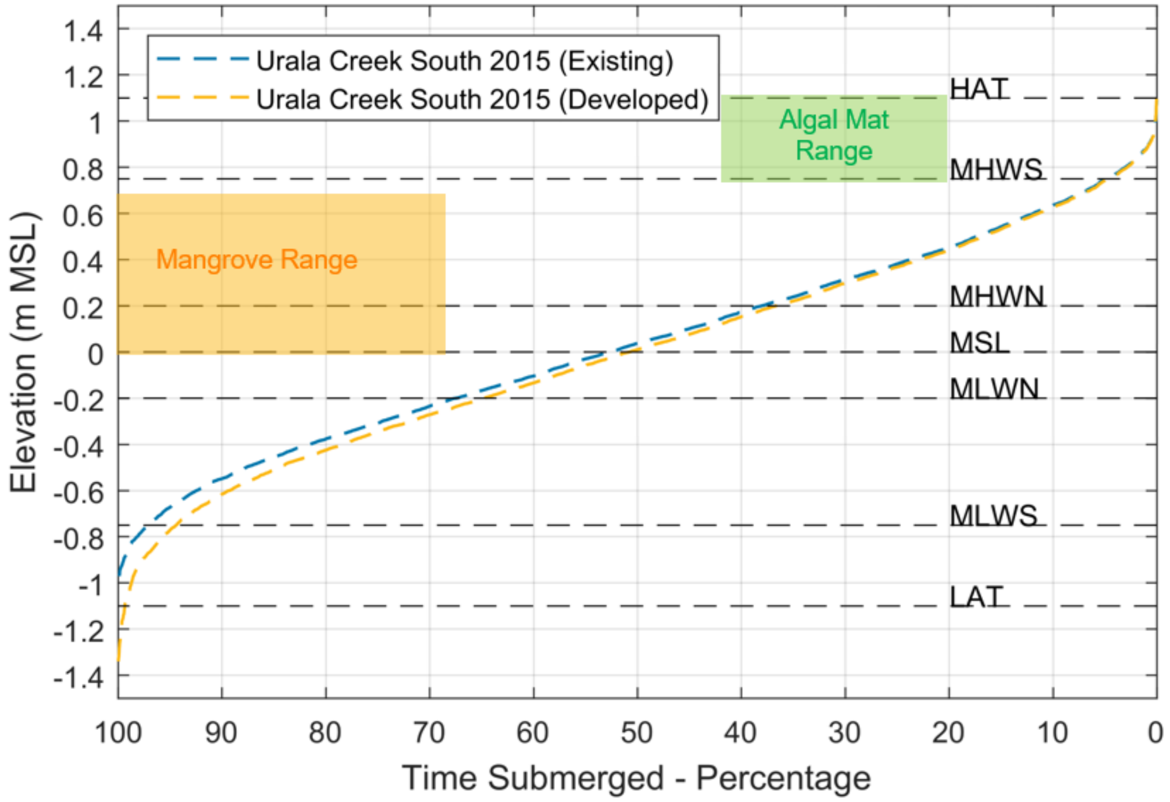


Figure 17 Pre and post-development tidal submergence curves predicting reduction in tidal inundation in mangrove and algal mat zones from seawater pumping at Urala Creek South (Water Technology 2021a)

5.5.3.3 Mitigation measures

The primary mitigation measure will be the implementation of a Mangrove, Samphire and Algal Mat Monitoring Program that integrates the monitoring of habirathealth/status with the monitoring of shallow groundwater conditions and mapping showing Project-related changes in habitat distribution.

5.5.3.4 Predicted outcome

Modelling outputs provide a spatial context to Project-related changes in submergence times. An assessment of pre- and post-development tidal submergence curves indicates that any pumping-related changes to submergence times are not predicted to result in impacts to mangroves, samphires and algal mats.

5.5.4 Pond-related seepage and modification to shallow groundwater conditions

5.5.4.1 Description of potential impacts

Localised seepage on tidal flats next to perimeter levees

The placement of large volumes of water within ponds on tidal mudflats has the potential to produce hydraulic loading effects which could result in modified shallow groundwater conditions and changes to mangroves and tidal flats areas immediately adjacent to the outer embankments (this is sometimes referred to as a “seepage effect”).

The containment of large volumes of water in ponds constructed within a high tidal flat setting can establish a hydrostatic head between the pond water level and the shallow groundwater level in tidal flat and mangrove areas adjacent to the pond levee (Sagramore 1995).

The differential can displace the highly saline groundwater of the tidal flats, creating a zone of impact on adjacent mangrove habitats that extends out approximately 100 -150 m from the toe of the levee until the hydrostatic head dissipates.

In the 1990s, Cargill Salt (now Dampier Salt - Port Hedland Operations) expanded the solar salt pond system by including the construction of a new concentration pond (Pond 0) and intake pumps on intertidal flats next to existing concentration ponds and also new bitterns ponds next to existing crystalliser ponds. A Mangrove Monitoring Program and Rehabilitation Plan implemented for the project included the monitoring of shallow groundwater conditions and changes in mangrove health and distribution. Results of monitoring over several years showed:

- Upon the filling of Pond 0 with seawater there was an initial increase in groundwater salinities from the displacement of existing high salinities and an elevation of water tables (i.e. waterlogging) on adjacent tidal flats and in mangroves where they occurred immediately next to the Pond 0 levee (Gordon et al. 1995, LDM 1998).
- In the situations where the pond levees were located very close to, if not adjoining, the mangroves, there was a seepage-related zone of impact to mangroves that occurred as a band parallel to the levee, approximately 30-40 m wide, and modification to groundwater conditions were recorded up to approximately 100-150 m out from the levee (LDM 1998).
- While the elevated water tables continued (due to hydrostatic head effect), by approximately 12 months after Pond 0 filling the groundwater salinities, after initially increasing, were reduced due to the seepage of seawater from Pond 0 into the seepage zones on adjacent tidal flats. Groundwater salinities in these seepage zones decreased to levels below pre-pond filling conditions and to approximately 50 ppt, thus providing suitable salinities for mangrove colonisation to occur (Gordon et al. 1995).
- In subsequent years, mangrove seedling recruitment has occurred within seepage zones on tidal flats immediately next to the Pond 0 levee, where seepage of lower salinity Pond 0 water has diluted high groundwater salinities and accumulated water on the tidal flats. In several areas, this has occurred as a narrow band approximately 20 m wide out from the toe of the levee (LDM 1998). The combined effect of a dispersal barrier or mangrove propagule deposition zone (due to presence of the levee), and the low salinity conditions from the seepage of Pond 0 water, has provided conditions conducive for natural seedling recruitment and growth (Plate 36). In some areas the mangrove recruitment has occurred in high tidal flats areas that did not previously support mangroves, and at ground elevations above those where mangroves normally occur.
- As part of mangrove rehabilitation works, trial transplanting of seedlings within the seepage zone indicated that the potential for successful re-vegetation by planting was likely to be confined to areas where considerable natural or unassisted seedling recruitment was already occurring, or was anticipated to occur (e.g. seepage zones next to Pond 0 levee (Plate 37) (LDM 1998, 2000).
- Due to hypersaline brines contained with the bitterns pond, the seepage effect that resulted from the filling of newly constructed bitterns ponds developed an area of crystallised salt (salt crusts) and associated pools of highly saline water out (~100 m) on mudflats adjacent to the ponds. By comparison, no salt crusts formed on tidal flats next to Pond 0 due to the relatively low salinity water (slightly above seawater) in Pond 0. A channel or trench was excavated on tidal flats next to the bitterns pond to collect the highly saline water and to intercept or break the mechanism causing this effect. Aerial photography flown two months later showed that the areas of crystallised salt and pools of highly saline water were absent.

Plate 36 **Natural recruitment and growth of mangrove seedlings in the seepage zone on tidal flats next to the Dampier Salt – Port Hedland Pond 0 levee.**

Plate 37 **View within the same seepage zone as Plate 26 showing seedlings that were transplanted into the plot three years previously, as plants approximately 15-20 cm high. Note the equivalent heights of shrubs outside of the plot (in background) that have developed from natural or unassisted recruitment.**

Groundwater salinity increases within mangrove areas

Tidally-regulated salinity gradients established across the mangrove zone influence both the occurrence of the different mangrove species (due to differing salinity tolerance limits) and the mangrove community structure (see Section 2.3.3). With increasing tidal elevation through landward sections of the mangrove zone, the reduction in tidal inundation, in combination with high evaporation rates, results in groundwater and soilwater salinities that are beyond the threshold tolerated by mangroves (approximately 90 ppt).

Due to the arid conditions and high salinities experienced by mangroves on the Pilbara coast, salinity increases and resulting localised tree stress and mortality are naturally occurring events, particularly in the uppermost reaches of tidal creeks and adjacent areas, where low stunted mangroves intergrade to mudflats devoid of mangroves.

Monitoring of shallow groundwater conditions and mangrove health on tidal flats next to salt ponds at Port Hedland indicates that salinity increases have the potential to cause impacts to mangroves (Gordon et al. 1995, LDM 1998), although it should be noted that water table elevation (i.e. waterlogging effect) also occurred in association with the salinity increases. The monitoring showed changes to groundwater conditions and mangrove health were confined to areas approximately 100-150 m out from pond levees and there were no changes recorded in mangrove areas that were separated from pond levees by large expanses of mud flats (i.e. hundreds of metres), as is the case for the proposed Ashburton Salt Project which is >800 m from the mangrove zone.

Interpretation of hydrogeological models developed for the Project indicate that the filling of the ponds may promote additional recharge (over the footprint of ponds) and salt loading, and subsequently create a local groundwater mound that may affect groundwater flow directions and groundwater quality (GHD 2021a).

5.5.4.2 Assessment of potential impacts

Seepage on tidal flats next to perimeter levees

The distance between the landward edge of mangroves located at the upper reaches of tidal creek systems and the western levee of the concentration ponds is approximately 800 m or greater, and the distance between the crystalliser ponds and the mangroves is 1.5 km or greater. Experience from other salt fields in the Pilbara (Gordon et al 1995, LDM 1998) indicates that:

- Salt pond generated seepage zones are typically confined to 30-50 m out from the pond (Gordon et al 1995, LDM1998) and hence the extent of setback (>800 m) proposed for this Project is predicted to be sufficient to prevent seepage-related impacts to mangroves.

- While salt pond-generated seepage zones can result in impacts to mangroves if insufficient setback occurs, there is also the potential for new mangrove habitat to develop within seepage areas where lower salinity conditions are established that are conducive for mangrove recruitment (i.e. during spring tides, mangrove seeds or propagules are deposited in the seepage zones due to the barrier effect of the levees and they then grow in the lower salinity conditions).

A numerical groundwater model was used to simulate the key hydrogeological processes of the Project area and its surrounding environs. The key issue simulated by the modelling was the potential for seepage from the salt ponds to migrate and impact on the receiving environment (GHD 2021a). The nature of interaction between the salt ponds and groundwater will be complex due to hydraulic, salinity (concentration) and density effects which vary over time. The relationship of these factors is shown in the conceptual diagram of the predictive modelling scenario (Figure 18.

Key findings from the modelling of groundwater level changes (including seepage) and interpreted changes to environmental receptors are:

- The water table beneath the footprint of salt ponds is shallow, typically around 0.3 to 0.5 m below surface. When the salt ponds are filled, the water table quickly equilibrates with the pond water level (within a matter of a few days). The spatial extent of waterlogging depends to a large degree on the depth to groundwater and effect of evapotranspiration (Figure 19. As the rate of evapotranspiration is greater than the rate of seepage of pond water, the extent of potential waterlogging is largely constrained to a narrow area (~50 m wide) immediately adjacent to the pond boundary (Figure 20 and hence the seepage zones and associated waterlogging are not expected to impact mangroves.
- The predicted water tables depths (< 1.0 m below ground level [BGL]) (Figure 20) within mangrove areas are consistent with data recorded from monitoring in reference sites (i.e. undisturbed mangroves) in Pilbara mangroves where water tables become elevated (i.e. close to the ground surface) during spring tides, and then gradually lower during the neap tide phase to approximately 0.5 – 1.0 m BGL (Gordon et al 1995, LDM 1998).
- Modelling indicates that seepage and subsequent evaporation of seepage water expressed at ground level has the potential to form a crystallised salt layer (salt crust) on the ground surface on localised areas of tidal flats immediately next to the pond levees (Figure 21). The modelling output shown in Figure 21 assumes that salt will be crystallised on the ground surface due to capillary action when groundwater depths are less than 0.3 m BGL and is based on a solubility limit of 350 g/L for precipitation. The predicted distribution of the salt crusts is largely within the predicted seepage zones and as a result they are not expected to impact mangroves given the distance from the mangrove zone. However, the predicted seepage zones do coincide with some small areas of algal mats and samphires adjacent to the western pond embankments and given these areas may become permanently submerged, it is assumed, on conservative basis, that these areas of algal mats (3.94 ha) and samphires (0.02 ha) may be impacted. Similar development and distribution of salt crust have been observed on tidal flats next to the Onslow Salt ponds.
- No ongoing seepage from the crystallisers due to the presence of thick salt crusts and intermittent filling of the crystallisers.
- The landward or eastern edges of the algal mats are much closer to the levees than are mangroves, and in some cases the landward edge of the algal mats is intersected by the pond levees. Algal mat distribution is controlled by dehydration and salinity at the landward margins of mat distribution, and invertebrate fauna predation at the lower or seaward margins, close to the uppermost reaches of tidal creeks. Due to the differing salinities of water and brines to be contained within the various concentrator ponds, and also within the crystalliser ponds, there is expected to be differing salinity gradients in seepage areas adjacent to each pond. Salinities in concentrator ponds CP1 and CP2 will be approximately 40 ppt and 60 ppt and hence the seepage from these ponds is likely to the provide much lower salinity conditions that those currently experienced in algal mat and salt flat areas adjacent to the western levees.

Such conditions may encourage the development of algal mats, or increased growth in peripheral algal mat areas near the levees until their salinity tolerance is reached.

Groundwater salinity increases beneath tidal flat and mangrove areas between the ponds and Urala Creek

The Project is predicted to develop additional recharge (over the footprint of ponds) and salt loading. It will create a local groundwater mound and effect groundwater flow directions and groundwater quality. Changes predicted from the modelling (GHD 2021a) are:

- Where the salt ponds are filled with fresher water than groundwater, seepage of pond water results in a gradual freshening of groundwater below. Where the difference in salinity between groundwater and pond water is smaller, this freshening effect occurs more quickly due to smaller density gradients (e.g. in the western part of Pond 1, in the fringing area of the hypersaline zone).
- The seepage of fresher pond water also displaces more saline existing groundwater, which becomes intercepted (trapped) by evapotranspiration in the low-lying areas immediately adjacent to the salt ponds. Over time, salts from existing hypersaline groundwater as well as those carried by seepage water accumulate in the groundwater outside the salt ponds, resulting in the formation of more saline and denser groundwater.
- The salinity front in shallow groundwater would propagate radially away from the ponds. Predictive simulations indicate that additional groundwater salinisation would occur west of the pond and create a halo of increased groundwater salinity around the perimeter of the pond complex.

During the assessment of the regional groundwater modelling outputs, it was recognised that the resolution of the model could influence the prediction of subtle variations that may otherwise be expected at a sub-grid or local scale. For example, the modelled concentrations were averaged over the thickness of each model layer and, in reality, there will be stratification of the top groundwater layer with lower sections of heavier/denser higher salinity water being overlaid by lower salinity or fresher water that receives more tidal flushing.

Due to anaerobic substrate conditions in which mangroves occur, they typically have shallow (0-0.5 m BGL) and spreading root systems with aerial root structures attached (such as pneumatophores in *Avicennia marina*) to facilitate gas exchange. Given the shallow root structure of mangroves, further analysis was undertaken to account for the salinity stratification and consequently better define the salinity increases predicted to occur within the zone of the mangroves' shallow root systems where tidal flushing results in less saline groundwater at the top of the water table which is tapped by mangrove roots. Salinity increases were estimated for the top 0.2 m of the water table to correlate with the zone of the water table (approximately 0.3-0.5 m BGL) into which mangrove roots would tap. The result of this analysis is shown in Figure 22 as a contour of maximum salinity increase of 15 kg/m^3 in the top 0.2 m of the water table after 50 years.

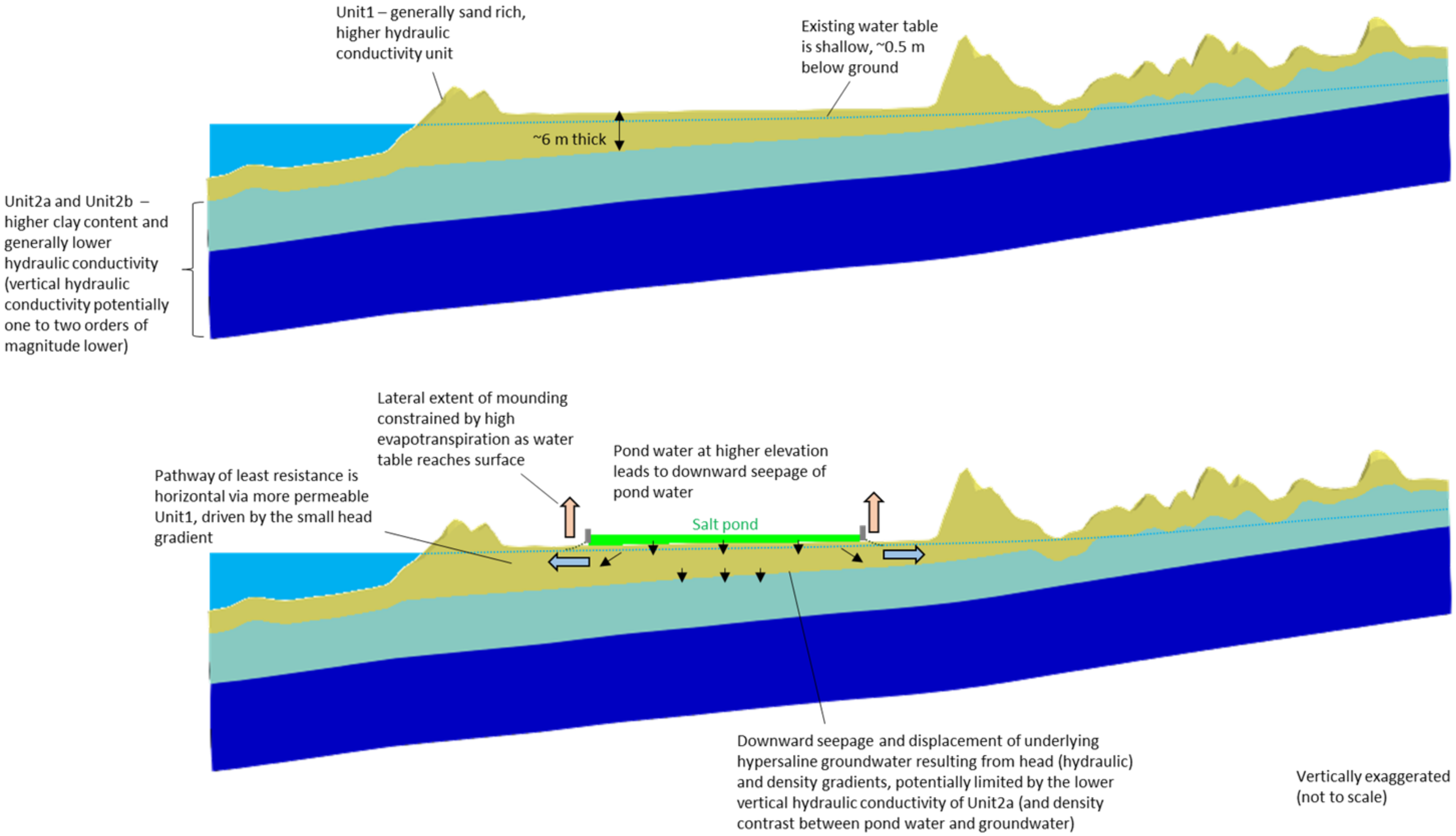
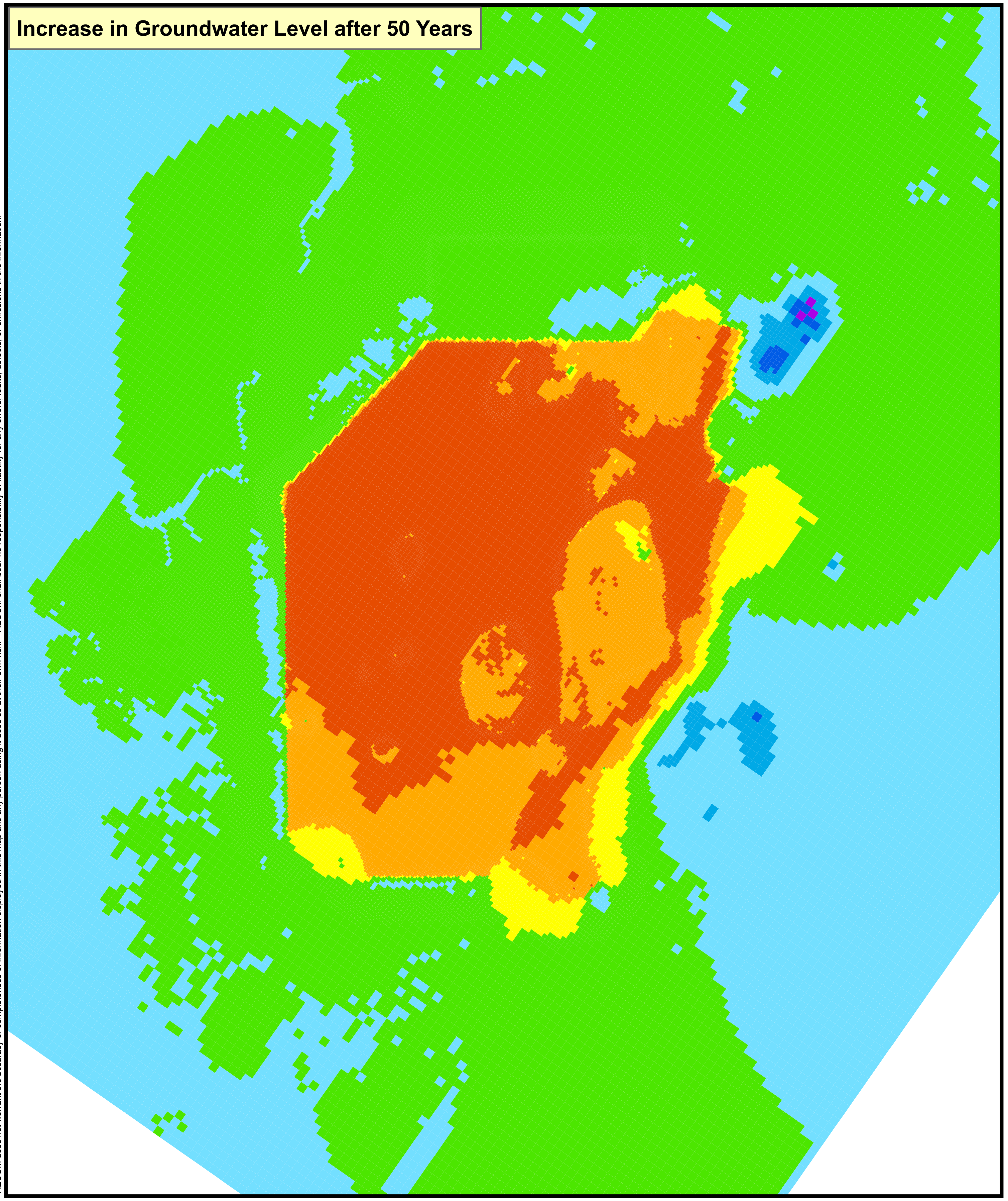
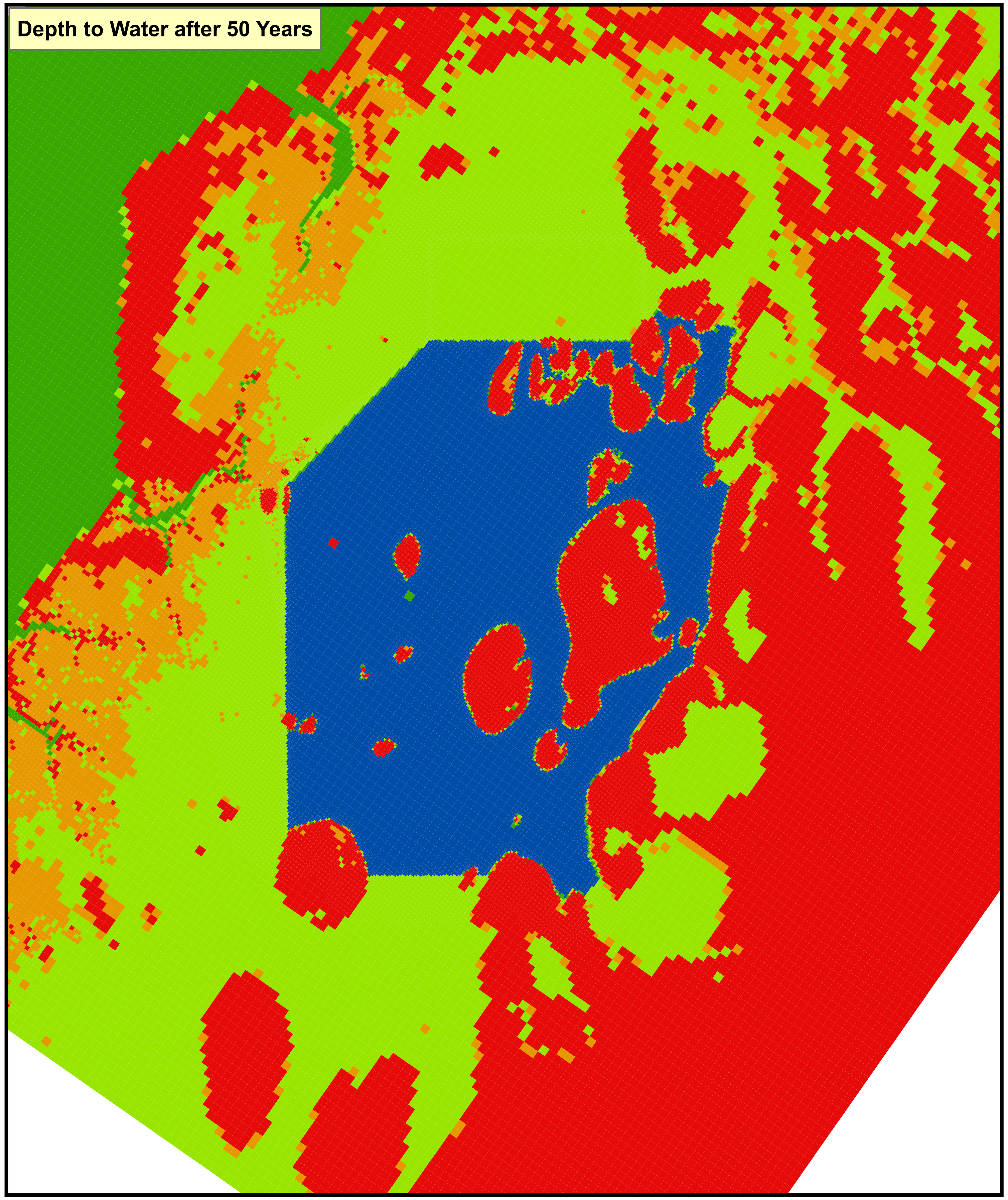


Figure 18 Conceptual diagram of the predictive groundwater modelling scenario (GHD 2021a)





PROJECT ID 60597242
CREATED BY SMITHS9
APPROVED BY ABOUGHER
LAST MODIFIED 28 OCT 2022

AECOM
www.aecom.com

N
1:120,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 1 2 3 4
Kilometers

Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

LEGEND

Increase in Groundwater Level after 50 Years
- -2 -1.5
- -1.5 - -1
- -1 - -0.5
- -0.5 - 0
- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2

Depth to Water after 50 Years
- >1
- ≤1.0
- ≤0.5
- ≤0.0
- ≤-0.5

Modelled changes to groundwater levels over the project area after 50 years

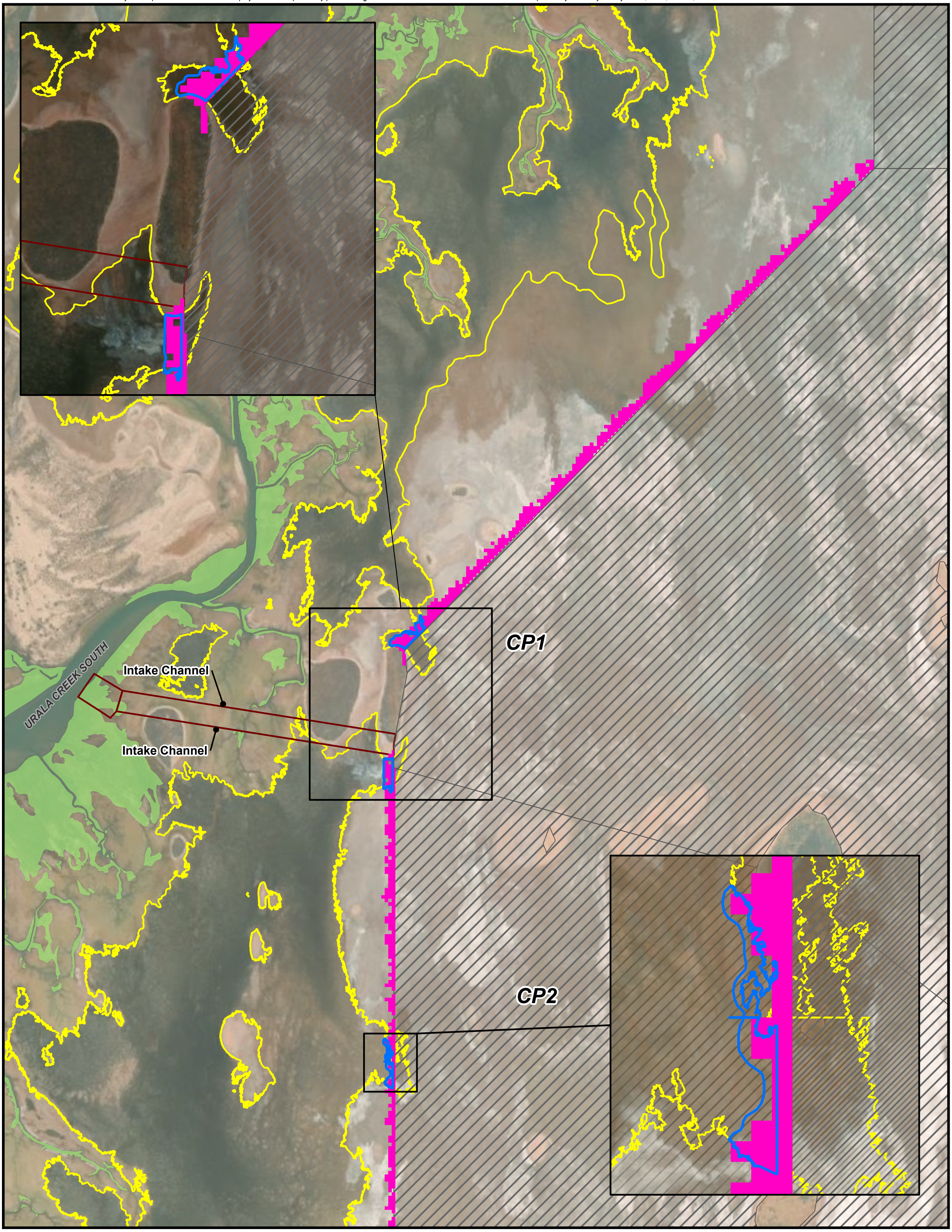
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
19

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\10_Benthic_Hab_Survey_Feb2020\G60597242_Figures_Update_v2.aprx (SmithS9)
Layout: G60597242_Fig20_GWChange_50yr_v1_A3L

A3 size



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY ABOUGHER
LAST MODIFIED 10 SEP 2021

AECOM
www.aecom.com

DATUM

1:35,000 (when printed at A4)

0 200 400 600 800 Metres

Data sources:GHD (2021); Preliminary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics
World Imagery: Maxar

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

LEGEND

- Seepage Zone
- Potential Indirect Habitat Loss for Algal Mats (3.92 Ha)
- Mangrove Mapping
- Algal Mat Mapping
- Pond Layout (Option 8)

Seepage zones on tidal flats next to CP1 and CP2 Identified from modelling

K PLUS S SALT AUSTRALIA PTY LTD

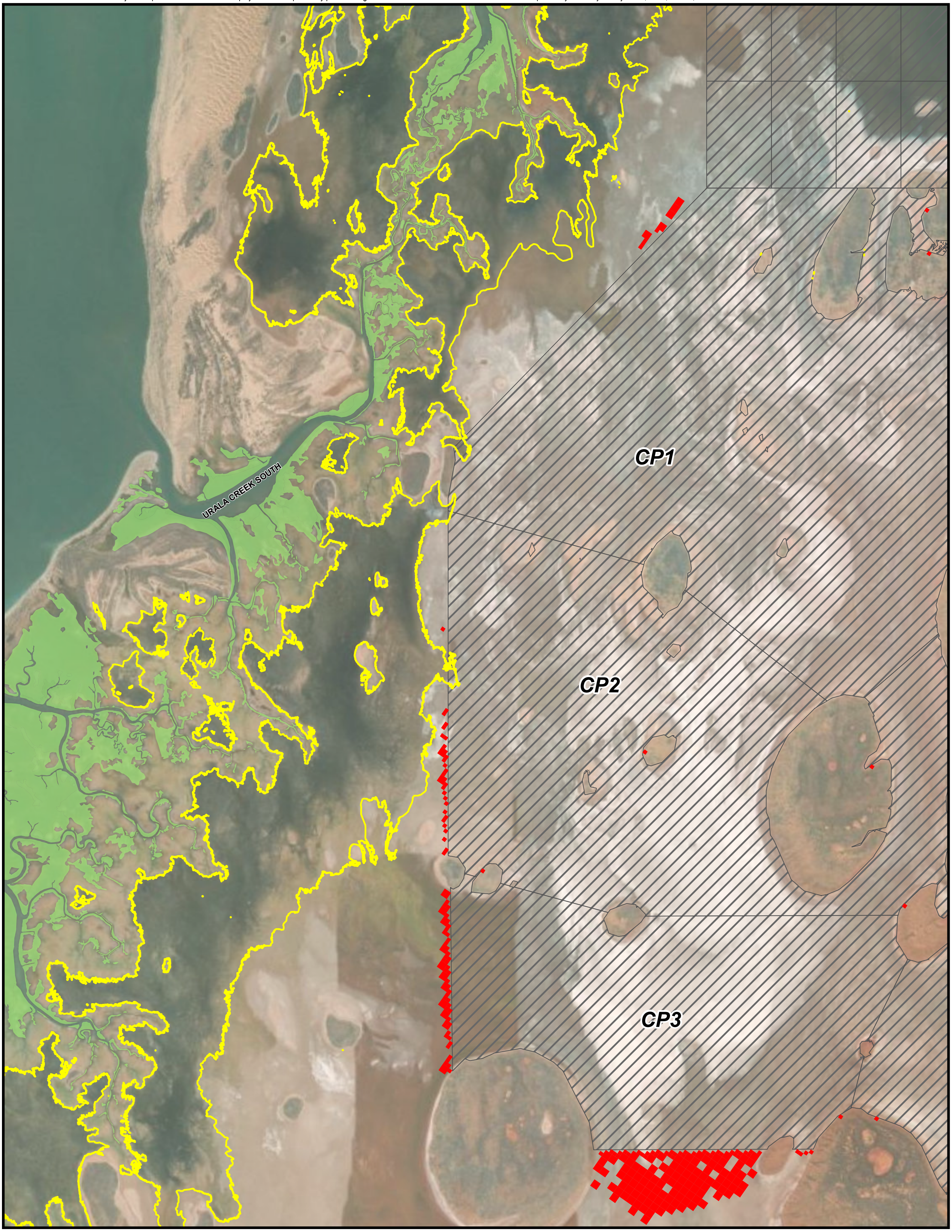
ASHBURTON SALT PROJECT

Figure **20**

Project File: \\AUPER1FP001.au.aecomnet.com\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\10_Benthic_Hab_Survey_Feb2020\G60597242_Fig5_Intertidal_Hab_Mapping_Update\G60597242_Figures_Update.aprx (kai.du)
Layout: G60597242_Fig21_GWChange_CP1_A4P

A4 size

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY ABOUGHER
LAST MODIFIED 10 SEP 2021

AECOM
www.aecom.com

DATUM GDA 1994 MGA Zone 50

N

1:65,000 (when printed at A4)

0 300 600 900 1,200
Meters

Data sources:GHD (2021); Preliminary Mangrove and Algal Mat: (Biota 2005 and 2016)World Imagery: Earthstar Geographics

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

LEGEND

- Predicted Salt Crusts after 50 Years (DTW <0.3m)
- Algal Mat Mapping
- Mangrove Mapping
- Pond Layout (Option 8)

Model Outputs Showing Predicted Salt Crusts after 50 Years (DTW <0.3m)

K PLUS S SALT AUSTRALIA PTY LTD

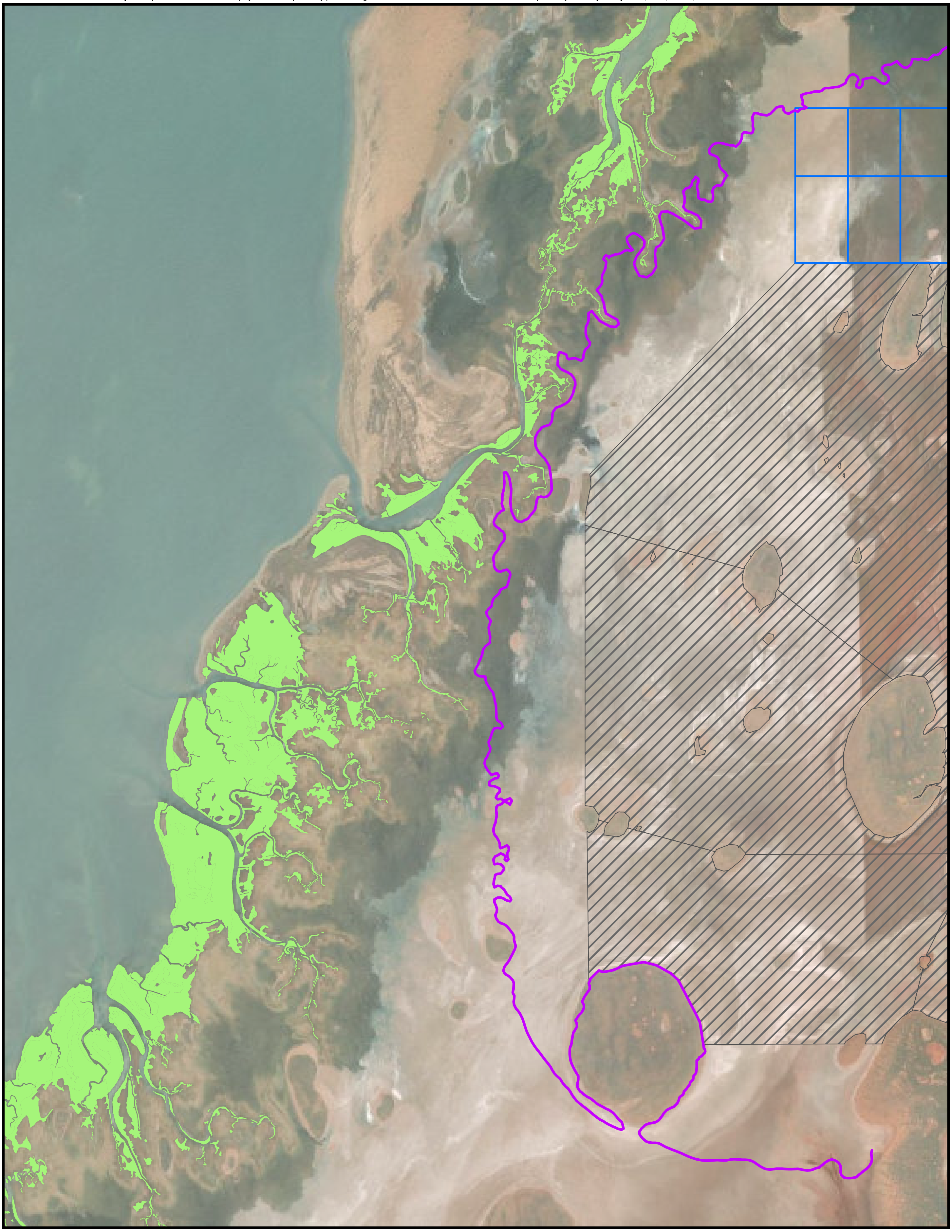
ASHBURTON SALT PROJECT

Figure

21

Project File: \\AUPER1FP001.au.aecomnet.com\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\10_Benthic_Hab_Survey_Feb2020\G60597242_Fig5_Intertidal_Hab_Mapping_Update\G60597242_Figures_Update.aprx (kai.du)
Layout: G60597242_Fig22_SaltCrusts_50yrs_A4P

A4 size



PROJECT ID	60597242
CREATED BY	SMITHS9
APPROVED BY	ABOUGHER
LAST MODIFIED	02 NOV 2022

AECOM
www.aecom.com

DATUM GDA 1994 MGA Zone 50

1:80,000
(when printed at A4)

0 500 1,000 1,500 2,000
Metres

Data sources:GHD (2021); Preliminary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

LEGEND

- Estimated Contour for Maximum Salinity Increases of 15 kg/m^3
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Mangrove Mapping

Modelled increases in groundwater salinity after 50 Years.

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

22

Due to the increasing influence of tidal inundation in areas between the contour line for the 50 year scenario (shown in Figure 22) and Urala Creek South it would be expected that the magnitude of salinity increases would decrease from a maximum of 15 kg/m^3 at the contour line to 0 kg/m^3 at the point where frequent tidal inundation regulates groundwater salinities and overrides any increases related to the pond system. These data suggest that there will not be any impacts to mangroves from Project-related salinity increases due to:

- The alignment of the contour line shown in Figure 22 are landward of the mangrove zone and the attenuation of potential salinity increases in mangrove areas from frequent tidal inundation indicate that any salinity increases in mangrove areas are likely to be within the natural fluctuation of salinities currently experienced in mangroves from tidal and seasonal factors.
- Salinity increases in mangrove areas, if they occur, are likely to be less than the salinity increase trigger levels (10-15 kg/m^3) used in mangrove monitoring programs in the Pilbara that are designed to correlate changes in mangrove health with changes in shallow groundwater conditions (URS 2010e, Chevron 2015).

Increases in groundwater salinity are not likely to result in impacts to algal mats as the mat structures occur as a 2-3 cm veneer on the ground surface and salinity conditions in that layer are regulated by surface water flows from either tidal inundation or rainfall events, rather than by connectivity to groundwater approximately 1 m below the ground surface.

The model outputs, and any subsequent interpretation of potential impacts, need to be considered in the context of conservative assumptions incorporated into the modelling, and inherent limitations in the model. These include:

- The predicted salinity changes do not account for potential siltation or crust development at the base of ponds which may in time decrease seepage and salt loading. While this is likely to happen, the magnitude of this effect is difficult to estimate in advance due to the highly site-specific nature of this process. As a consequence, salt loading from the pond complex may be smaller than predicted. This would also affect the extent, concentrations and timing of salts that could reach the mangrove communities, which are potentially overestimated by the modelling (GHD, 2021a).
- Simplified estimates of evapotranspiration have been used which may not account for lowered evapotranspiration caused by the salt crusts on the existing salt flats, which therefore may have resulted in resulted in an overestimate of the salinity increases in groundwater radiating from beneath the ponds (Cymod Systems, 2021).

5.5.4.3 Mitigation measures

Appropriate set back (>800 m) of pond levees has been incorporated into the Project design to avoid seepage-related impacts to mangroves and, most likely, any longer-term impacts related to salinity increases.

Another mitigation measure will be the implementation of a Mangrove, Samphire and Algal Mat Monitoring Program as part of a Mangrove, Samphire and Algal Mat Management Plan (MSAMMP) that integrates the monitoring of mangrove, samphire and algal mat health/status with the monitoring of shallow groundwater conditions (including salinity), and mapping showing Project-related changes in habitat distribution. Such mapping would capture the potential development of new habitat adjacent to the pond levees.

A key aspect to the Mangrove, Samphire and Algal Mat Monitoring Program will be to establish monitoring sites between the pond system and Urala Creek and collect baseline groundwater conditions against which to assess potential pond-related modification to salinity and water table depths. To achieve this, it is recommended that baseline sampling be conducted on a quarterly basis for at least a year prior to the primary pond (CP1) being filled.

In addition, a Groundwater Management and Monitoring Plan (GMMP) will be prepared for the Project which includes:

- Further baseline groundwater monitoring prior to construction:
  - Groundwater monitoring within the intertidal area of mangroves and samphire, with water level, and water quality measured via loggers at a sub-daily interval, to characterise tidal influences.
  - Additional piezometers / bores immediately downstream of proposed ponds, to provide baseline data prior to pond construction and filling.
- Refinement of the groundwater model including increased vertical resolution and incorporation of additional monitoring data collected.
- Ongoing groundwater monitoring program during construction and operations, including monitoring of water levels and water quality at various distances from filled ponds at sub monthly intervals.
- Appropriate groundwater monitoring criteria, trigger values, actions and contingency plans to prevent groundwater related environmental impacts.

5.5.4.4 Predicted outcome

Key points from the above assessment are:

- Areas of elevated water tables (due to hydrostatic head effect) causing surface water expression and associated seepage is likely to occur after filling of the ponds. These seepage areas are likely to be confined to localised areas on tidal flats immediately next to ponds (i.e. ~50 m out from bases of levees) and hence waterlogging impacts to mangroves from seepage zones is not expected. Seepage zones containing highly saline water may develop salt crusts on the ground surface. These are not expected to occur in, or impact on mangrove areas, however an area of 3.92 ha of algal mats adjacent to the western pond embankments may be impacted. Seepage zones containing relatively lower salinity water (i.e. water from CP1) may provide suitable conditions for mangrove recruitment and possibly algal mat expansion as bands on tidal flats parallel to pond levees.
- Water tables depths beneath mangroves (< 1.0 m BGL) are predicted to be similar to those recorded from monitoring in reference sites (i.e. undisturbed mangroves) in Pilbara mangroves and no impacts are expected in mangroves from this factor.
- Modelling shows the potential for gradual increases in groundwater salinity beneath tidal flats adjacent to the ponds, beyond the localised seepage zones.
- Increases in groundwater salinity are not likely to result in impacts to algal mats as the mat structures occur as a 2-3 cm veneer on the ground surface and salinity conditions in that layer are regulated by surface water flows from either tidal inundation or rainfall events, rather than by connectivity to groundwater approximately 1 m below the ground surface.
- The modelling predicts that small increases in groundwater salinity may occur beneath mangrove areas (at depths below the shallow groundwater tapped by mangrove roots). However, due to the attenuation of potential salinity increases in mangrove areas from frequent tidal inundation and flushing of the shallow water table tapped by mangrove roots, it is likely that any salinity increases will be within the natural fluctuation of salinities currently experienced in mangroves from tidal and seasonal factors. Salinity increases in mangrove areas, if they occur, are likely to be less than the salinity increase trigger levels (10-15 kg/m^3) used in mangrove monitoring programs in the Pilbara that are designed to correlate changes in mangrove health with changes in shallow groundwater conditions. For the above reasons it is predicted that no impacts to mangroves from Project-related salinity increases will occur.

- Experience gained from monitoring at other salt fields in similar settings indicates that changes to groundwater conditions (both salinity and water table depths) and mangrove health were confined to areas approximately 100-150 m out from pond levees and there were no changes recorded in mangrove areas that were separated from pond levees by large expanses of mud flats (i.e. hundreds of metres), as is the case for the proposed Ashburton Salt Project, which is >800 m away from the mangrove zone.
- Given consideration of the previous monitoring data and the modelling outputs, it is expected that the setback or separation (> 800 m) between the proposed ponds and landward sections of the mangroves is sufficient to avoid impact to mangroves from pond-related changes to shallow groundwater conditions.

5.5.5 Increased sediment deposition from construction activities

5.5.5.1 Description of potential impacts

Key adaptations of mangrove trees to the intertidal environment are aerial root systems that allow for root respiration in the typically anaerobic muds. These occur as a network of cable roots (extending out from the base of the tree) and vertical roots (pneumatophores) in *Avicennia* species, and in the form of stilt roots or buttressed trunks in *Rhizophora* and *Ceriops* species. While mangroves are known to promote sedimentation due to their high stem density and complex aerial root structures, the deposition of sediment within mangrove areas has the potential to cause impacts to mangroves if the depositing material accumulates in excess of natural sedimentation rates, and to sufficient depths to bury the aerial root system. This can result in 'oxygen stress' on the mangrove roots as the lenticels (air breathing pores) on prop roots or pneumatophores become blocked (such blocking of lenticels and impairment of mangrove function can also occur from waterlogging/water ponding or hydrocarbon coating) (Pedretti & Paling 2010).

Examples of sediment deposition events amongst mangroves in the Pilbara and Northern Territory are:

- Erosion from non-vegetated surfaces or uncontained areas (e.g. levees, stockpiles, laydown areas, access roads) and subsequent deposition of material into adjacent mangrove areas (URS 2004, 2010e), sometimes causing localised tree stress.
- Discharge of return or tail water from the reclamation/settling ponds if water has a high silt loading and the released water spreads out onto low gradient tidal flat areas (where silts may be deposited) rather than being directed into tidal creek channels that act as conduits to remove the water and entrained sediment from the mangrove system (URS 2004).
- Uncontained dredge spoil entering mangrove areas – burial of *Avicennia* pneumatophores (aerial roots) by dredge spoil resulted in mangrove mortality on the Burrup Peninsula when either retaining bund walls were over-topped, or were not sufficiently impervious to contain the dredge spoil (LSC 1981, VCSRG 1996).
- TC Vance resulted in large-scale mortality of mangroves (~5,700 ha) with sediment burial of mangrove roots being one of the main factors (Paling et al. 2008).

A review of case studies of impacts from sediment burial of mangroves in Australia (Ellison 1998) provides examples of mangrove degradation and/or death from depths between 5 and 200 cm. The response of different mangrove species to root burial does not appear to be standardised and is likely to be a function of root architecture, tidal range, and sediment composition and grain size. Pneumatophore (aerial root) burial of around 10 cm appears to have caused the death of *Avicennia*; however, most case studies reviewed in Ellison (1998) documented burial of *Avicennia* by sediment depths ranging between 10 and 100 cm. There are occurrences where sand deposition has been sufficiently high to cover *Avicennia marina* pneumatophores completely, but this did not result in any ill effects. This usually occurs in extremely well-drained sands where mangroves have colonised road or natural rock margins (Pedretti & Paling 2010).

5.5.5.2 Assessment of potential impacts

Potential sources of Project-related sediment deposition in mangrove and algal mat areas are likely to be very localised and limited to:

- A temporary and localised increase in the turbidity of tidal waters inundating mangroves fringing Urala Creek South during construction of the intake pumps. Background turbidity concentrations along the Onslow coastline are high under existing conditions and mangroves in the area already cope with periods of very high turbidity during flood events. In this context, it is unlikely that any temporary increases to turbidity from the pump station construction works would result in additional sedimentation at a scale that could threaten mangrove communities.
- Construction of the outer or western levees for the pond system and intake channel. Prior to the containment of the levee fill materials by the placement of rock armour on sides of levees, there is the potential for some fill material to be washed into adjacent mangrove and algal mat areas. Localised sediment run-off during construction works within sensitive areas can be managed by employing appropriate sediment run-off measures and erosion control measures.

5.5.5.3 Mitigation measures

The Construction Environmental Management Plan will include management measures to reduce sediment and turbidity related impacts. Such measures are:

- Incorporate a buffer area between the outer disturbance boundary and the outer construction boundary (e.g. toe of the perimeter bund).
- Containment of sediment within perimeter levee walls in sensitive areas by use of geofabric and rock armour.

5.5.5.4 Predicted outcome

With the incorporation of appropriate control measures during the construction phase, it is not expected that indirect loss to mangrove algal mats will occur from Project-related sediment deposition.

5.5.6 Modification to nutrient pathways

5.5.6.1 Description of potential impacts

Within Exmouth Gulf and the local project catchment, significant biological productivity occurs along the eastern seashore where a system of intertidal and vegetated nearshore areas generate migrations (e.g. of prawns and fish) and movement of organic material (detritus) supporting biological productivity further up the food chain.

Altering nutrient pathways, sources and sinks in intertidal and subtidal areas, has the potential to affect primary and secondary productivity. Local ecosystems are nitrogen limited. Therefore ensuring nitrogen flows into and out of key habitat types is not significantly affected by the proposed Project, is important to the ongoing health of these intertidal and subtidal ecosystems.

5.5.6.2 Assessment of Potential Impacts

Water Technology (2021b) undertook a detailed Nutrient Pathways Assessment and Modelling study to:

- Develop a conceptual nutrient pathway model (descriptive diagram – Figure 12) and nutrient budget.
- Develop a numerical model simulating nutrient pathways related to tidal inundation and overland flows.
- Undertake project related impact assessment regarding nutrient pathways including:
    - Modelling impacts to tidal inundation and overland flow nutrient pathways.
    - Calculating nutrient loss, due to habitat loss.

The assessment focussed on nitrogen as previous studies and monitoring conducted for the project indicated it is the key limiting nutrient for local and regional marine and intertidal ecosystems. The assessment was very conservative because:

- Conservative nitrogen import and leaching rates were applied.
- Months which have limited inundation due to seasonally lower water levels were not considered, therefore increasing the potential nitrogen exports from algal mats.
- The annual estimate for nitrogen contribution from offshore waters was conservative, ignoring tidal exchange and using lower observed levels of ocean upwelling.
- The modelling results represent changes to nitrogen exports from the mouths of Urala Creek North and Urala Creek South only, and did not account for altered overland flow paths which may result in some nutrients being exported via different land/water interfaces.
- The design rainfall events used were considered extremely conservative as they applied a spatially constant rainfall rate over the entire model domain, which in reality would be very unlikely to occur due to the vast extent of the catchment.
- Estimated habitat modification areas were conservative with larger disturbance areas than expected being included in the salt flats and hinterland.
- Nitrogen losses associated with modelled overland flows and habitat modification overlap in the salt flats, and therefore were accounted for twice.

The full findings of the study are presented within a separate report by Water Technology (2021b). The study predicted small impacts to nutrient pathways in proportion to the total estimated nutrient flows into the project catchment and Exmouth Gulf. Water Technology (2021b) estimated:

- A local post-development proportional reduction in nitrogen flows into the project catchment of 0.8% of land and ocean sources.
- A regional post-development proportional reduction in nitrogen flows into the Exmouth Gulf of 0.24% of land and ocean sources.

Based on this highly conservative assessment, it can be concluded that the proposed development will not significantly alter nutrient exports or pathways due to the small scale of the predicted reductions and their infrequent nature, particularly when compared to the overall nitrogen budget of the Exmouth Gulf. Impacts related to nutrient pathways are not predicted to compromise existing environmental values including intertidal or subtidal BCH primary or secondary productivity.

5.5.6.3 Mitigation measures

Breakouts from the Ashburton River, combined with local runoff create sheet flow conditions across the lower catchment and flows that pass through the dune field and enter the salt flats near the proposed Project, are generally conveyed along more defined flow paths (Water Technology 2021b). Surface water modelling has been used to design drainage diversion and culvert locations for re-directing surface water flows around the Project (see yellow arrows in Figure 23). This will ensure that some nutrients are still exported around the project footprint via different land/water interfaces.

A Surface Water Management Plan (SWMP) will be implemented to further assess potential changes to surface water and nutrient flows and concentrations. The SWMP will include revised surface water modelling including borrow pits and final culvert /drainage diversion designs to minimise impacts and maintain environmentally important surface water regimes, particularly those important to samphire. The SWMP will include a weather station to monitor rainfall and climatic conditions as well as quarterly and rainfall event-based estuarine and surface water flow/volume and quality monitoring.

5.5.6.4 Predicted outcome

The salinity conditions required for the survival of mangroves along the Pilbara coast are maintained by tidal inundation and not by freshwater sources such as the fluvial input from the hinterland. Hence, no impacts to mangroves are predicted to occur due to Project-related modification to overland flows. Modelling of coastal hydrodynamics (see Section 5.5.2) predicts that there will be no changes to tidal inundation patterns within mangroves, samphires and algal mats.

The nutrient pathway modelling indicates that the nutrient-related changes are small in proportion to the total estimated nutrient flows into the local catchment and Exmouth Gulf with offshore sources of nutrient being by far the largest source of nutrients. Based on the modelling conducted, it can be concluded that the proposed development is not predicted to significantly alter nutrient exports or pathways due to the small scale of the predicted reductions and their infrequent nature, particularly when compared to the overall nitrogen budget of Exmouth Gulf. Impacts related to nutrient pathways are not predicted to compromise existing environmental values including intertidal and subtidal BCH primary or secondary productivity.

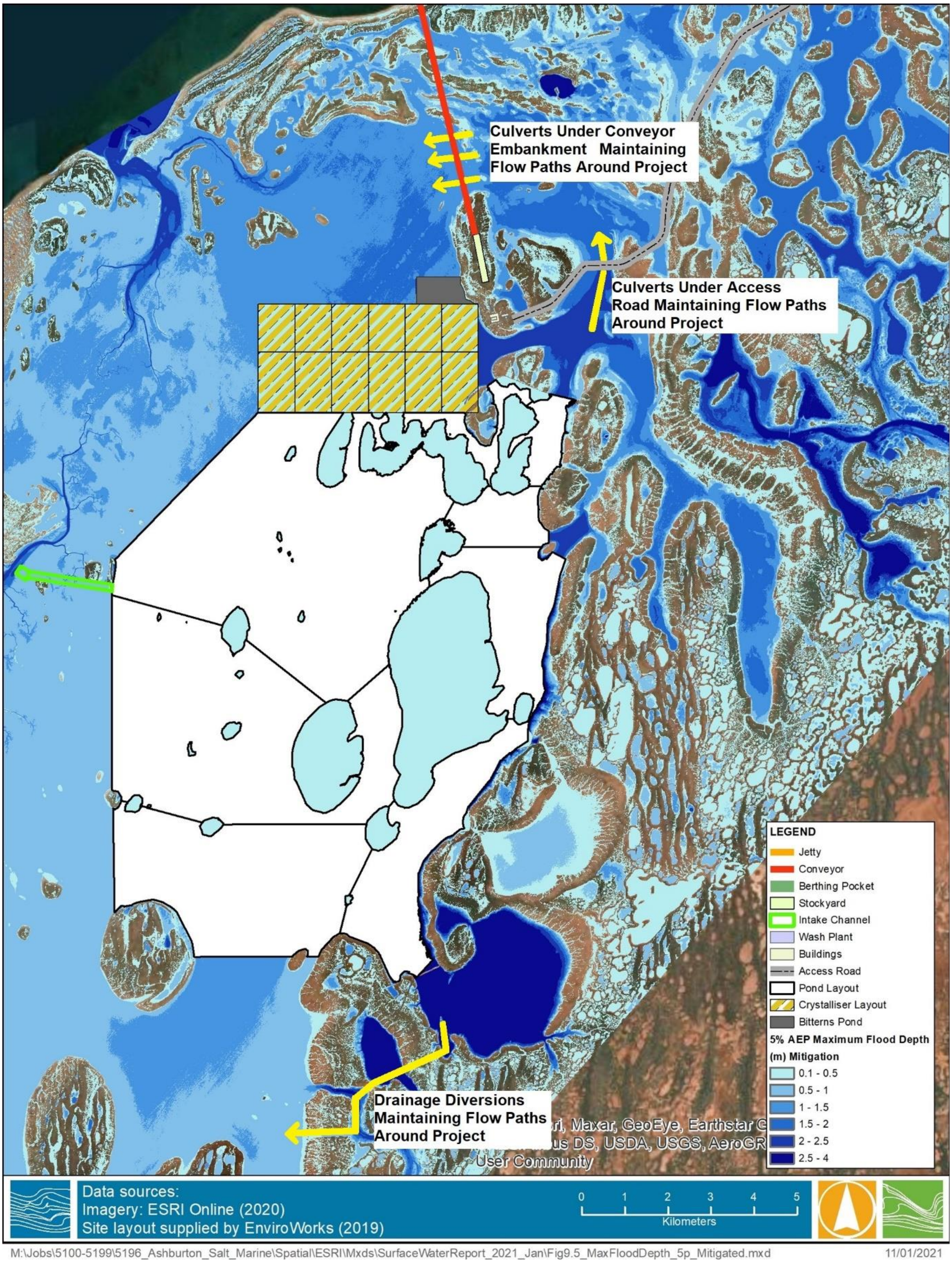


Figure 23 Diversion drains and culverts proposed for re-directing overland flows around salt ponds

5.5.7 Modification to infrequent freshwater flows from the hinterland to intertidal habitats

5.5.7.1 Description of potential impacts

Tidally-regulated salinity gradients established across the intertidal zone influence the distribution of habitats and in the case of mangroves, both the occurrence of the different species (due to differing salinity tolerance limits) and mangrove community structure (see Section 2.3.3). With increasing tidal elevation through landward sections of the mangrove zone, the reduction in tidal inundation, in combination with high evaporation rates, results in groundwater and soilwater salinities that are beyond the threshold tolerated by mangroves (approximately 90 ppt) (Gordon 1988, Gordon et.al 1995, Semeniuk 1983).

Salinity gradients are also likely to play a key role in determining the occurrence of algal mats. Algal mat is considered unlikely to be affected by shallow groundwater salinity given it forms a thin veneer on the mudflat surface and is not connected to the shallow groundwater. The salinity range and moisture requirement for algal mat is facilitated by the infrequent (often monthly) tidal surface flushing it receives during spring tides.

Due to the arid conditions and high salinities experienced by mangroves on the Pilbara coast, salinity increases and resulting localised tree stress and mortality are naturally occurring events, particularly in the uppermost reaches of tidal creeks and adjacent areas, where low stunted mangroves intergrade to mudflats devoid of mangroves.

If rainfall related freshwater flows were a key factor in regulating the salinity gradients required by mangroves and algal mat, there would be the potential that salinity increases may develop in the longer term due to the Project related modification of freshwater flows which could affect these intertidal habitats. However as described below under Section 5.5.7.2 freshwater flows are not considered to be a key factor regulating salinity gradients required by mangroves and algal mats in the Project intertidal area.

5.5.7.2 Assessment of potential impacts

In northern tropical parts of Australia (much further north than this Project), freshwater flows and freshwater seepage from the hinterland into the intertidal zone are substantial and have resulted in some mangrove zones being partly dependent on freshwater input for their survival. In the tropics, regular wet season rainfall provides freshwater seepage to the landward section of the intertidal zone. Consistent tropical freshwater input over several months each year dilutes potentially high salinity groundwater to levels where mangroves can grow in a zone of mangroves referred to as the hinterland fringe (typically a narrow band of mangroves occurring where tidal flats abut the tropical hinterland) (Semeniuk 1983).

By comparison, freshwater input to Pilbara mangroves is very irregular due to the arid climate and only occurs after significant rainfall events associated with cyclones, which occur relatively infrequently. Hence, groundwater salinities become very high beneath the extensive arid zone salt flats that are devoid of vegetation (GHD, 2021a). Under the Pilbara arid conditions, there is no sustained dilution of the hypersaline groundwater conditions by freshwater input (as occurs in the tropics) and hence no freshwater dependent hinterland fringe of intertidal BCH has developed within the arid Pilbara (Semeniuk 1983).

Rather the intertidal BCH habitats in the arid Pilbara are predominantly reliant on tidal flushing which promotes a reduction in salinity of shallow groundwater / soil water resulting in:

- Mangroves having a salinity tolerance of up to approximately 90 ppt (Gordon 1988, Gordon et.al 1995, Semeniuk 1983);
- Algal mats are reliant of surface tidal flushing and are not connected to the shallow groundwater.

In summary, at a regional scale, the salinity conditions required for the survival of mangroves along the arid Pilbara coast are maintained by tidal inundation and not by infrequent freshwater inputs. The Project area is typical of the arid Pilbara regional scale scenario described above. It has the typical arid Pilbara intertidal sequence (coast to landward) regulated by salinity gradients controlled by tidal flushing, consisting of:

- Mangroves;
- High tidal mudflats;
- Algal mats; and
- Samphires occurring within the intertidal zone.

Within the supratidal area, there are expansive areas (several kms) of salt flats extending landward from the algal mats to the hinterland, which reflects a lack of significant influence from freshwater sources, typical of the arid Pilbara.

Water Technology (2021c) conducted modelling to simulate rainfall flooding extent and duration for the Project area and found that rainfall events and flooding of the area occurs infrequently. It was estimated that the proposed Project area is flooded for a duration of:

- 20 days due to rainfall events that occur on average every 2 years;
- 29 days due to rainfall events that occur on average every 5 years;
- 41 days due to rainfall events that occur on average every 10 years; and
- 62 to 83 days for rainfall events that occur on average every 20 to 50 years respectively (Water Technology, 2021c).

Based on the Water Technology (2021c) assessment, it can be calculated that the area is inundated by rainfall events between 5 – 10% of the time, with long periods of drought between relatively short duration rainfall flooding events. This concurs with Geoscience Australia (2021) Water Observations from Space data which shows flooding of the adjacent hinterland area occurs between 5-10% of time (the adjacent hinterland is not tidally influenced and therefore is a reasonable indicator of local rainfall flooding frequency). This relatively low frequency and duration of rainfall related flooding of the Project area and surrounding intertidal habitat supports the characterisation of the local intertidal BCH being predominantly reliant on tidal flushing to establish required salinity gradients and provide moisture, rather than freshwater inundation.

Semeniuk (1983) recognises that at the small scale there can be freshwater seepage influencing mangrove distribution at localised areas within the Pilbara coast such as in tidal flat areas immediately next to limestone terrain or in alluvial fans. These scenarios either do not occur in the Project area or the very localised seepage (e.g. next to limestone terrain) would not be modified due to the alignment of the ponds.

Existing salt fields at Onslow and Port Hedland have large areas of ponds located between the hinterland and intertidal areas. These salt fields have similar pond alignments to the proposed Project and with similar potential to modify the movement of infrequent freshwater flows from the hinterland to intertidal areas. While these existing salt fields have been in operation for 30 and 50 years respectively, there is no evidence from mangrove monitoring programs and other observations that there has been any long term salinity increases or associated habitat deterioration that may be linked to a reduction in freshwater flows caused by the alignment of the salt ponds (Biota 2020b, LDM 1998). Impacts to mangroves have been detected due to pond related seepage/hydrostatic head mechanisms (i.e. waterlogging and salinity increases) in localised areas on tidal flats immediately next to salt ponds (as discussed in Section 5.5.4) however these impacts are linked to water levels in the ponds and not to the modification of infrequent freshwater flows from the hinterland.

5.5.7.3 Mitigation measures

Water Technology (2021c) developed models to simulate surface (fresh) water flows from terrestrial or hinterland areas and through the Project area to assess potential impacts of the proposed development on those flows and determine mitigation strategies. Breakouts from the Ashburton River, combined with local runoff create sheet flow conditions across the lower catchment and flows that pass through the dune field and enter the salt flats near the proposed Project, are generally conveyed along more defined flow paths (Water Technology 2021c). Surface water modelling has been used to design drainage diversion and culvert locations for re-directing surface water flows around the Project (see yellow arrows in Figure 23). This will ensure that some surface (fresh) water emanating from the hinterland will still be exported around the project footprint via different land/water interfaces.

A Mangrove, Samphire and Algal Mat Monitoring Program will be implemented as part of a Mangrove, Samphire and Algal Mat Management Plan (MSAMMP) that integrates the monitoring of mangrove, samphire and algal mat health/status with the monitoring of shallow groundwater conditions (including salinity), and mapping showing Project-related changes in habitat distribution.

A Surface Water Management Plan (SWMP) will be implemented to further assess potential changes to surface water and nutrient flows and concentrations. The SWMP will include revised surface water modelling including borrow pits and final culvert /drainage diversion designs to minimise impacts and maintain environmentally important surface water regimes, particularly those important to samphire. The SWMP will include a weather station to monitor rainfall and climatic conditions as well as quarterly and rainfall event-based estuarine and surface water flow/volume and quality monitoring.

A Groundwater Management and Monitoring Plan (GMMP) will be implemented which includes groundwater monitoring to ensure any project related changes to groundwater and related changes to intertidal BCH are understood and potential impacts can be mitigated.

5.5.7.4 Predicted outcome

The salinity conditions required for the survival of mangroves and algal mat along the arid Pilbara coast and within the Project area, are maintained by regular tidal inundation and not by infrequent freshwater sources such as the fluvial input from the hinterland.

Modelling of coastal hydrodynamics (see Section 5.5.2) predicts that there will be no significant changes to tidal inundation patterns within mangroves, samphires and algal mats located within the intertidal zone and within the LAUs (Water Technology 2021a). Hence, no impacts to these habitats are predicted to occur due to Project related modification to infrequent freshwater input from the hinterland to intertidal areas. This predicted outcome is supported by monitoring and observations from other salt fields in the Pilbara that have been in operation for several decades and which have similar pond alignments to the proposed Project.

5.6 Assessment of Potential Impacts to Subtidal BCH

5.6.1 Direct habitat loss from Project

Direct habitat loss to subtidal habitats will occur as a result of the jetty and barge loading platform construction and the dredging of the berthing pocket (Figure 24). A 700 m jetty is currently proposed to reach sufficient water depth to allow a 6 m draft transhipment barge ('transhipper') to enter the loading berth.

While the nearshore impact footprint from the Project is small in comparison to its terrestrial impact footprint, the proponent recognised that the avoidance of potentially ecologically significant BCH such as seagrass beds, and pavement reef with macroalgal and coral communities in the nearshore area, was an important design constraint for the Project. As the design progressed, the following modifications were made to reduce direct impacts to such habitats:

- Extending the jetty length to reach sufficient water depth to minimise the depth and volume of dredging required to allow safe under keel clearance for transhipment barges.
- Construction of a purpose-built, shallow draft transhipper specifically for the Project to further minimise the area, volume and depth of dredging required.

- Placing all dredged material onshore, to be used as construction material for the onshore infrastructure, thus avoiding direct impacts to BCH from disposal of dredge material at sea or from land reclamation.

Notwithstanding these design measures, small areas of direct loss of BCH will occur as a result of the jetty construction and dredging works (Figure 24). The jetty will accommodate a roadway structure for a 50-tonne mobile crane and a single conveyor for the out loading of the salt to the transhipper. The structure will be comprised of steel driven tubular piles with separate steel truss roadway modules simply supported on steel bents utilising steel jackets. The installation of the tubular support piles will result in direct habitat loss in the location of each support pile and likely disturbance to the surrounding seabed. Shading caused by the jetty itself will have direct impacts to any existing photosynthetic reliant biota which may inhabit the substrate underneath the jetty.

Dredging of the berthing pocket at the end of the jetty is required to allow the loaded transhipper adequate water depth to remain within the berthing pocket without tidal restriction. The berthing pocket is required to be of sufficient depth, length and width to allow the loaded transhipper sufficient under keel clearance to be able to navigate out of the berthing pocket. Based upon a laden/loaded draft limit of 6 m for the transhipper, the size of the required berthing pocket from World Association for Waterborne Transport Infrastructure (or PIANC) requirements has been estimated to be approximately 200 m long by 35 m wide x 2.5 m of seabed. Total dredge volume is estimated to be 17,000 m^3.

Direct habitat loss within the area to be dredged will comprise the removal of material from the berthing pocket, plus a nominal 20 m wide annulus around the berthing pocket to account for habitat smothering by the deposition of coarse sediments during the dredging operation.

The estimated total area of direct subtidal BCH loss is presented in Table 8 (totalling 2.62 ha). Loss of specific habitat types is calculated in Table 11 as follows:

- 2.3 ha of soft sediment (potential seagrass).
- 0.22 ha of macroalgae.
- 0.1 ha of macroalgae and sparse coral.

Table 8 Estimated total area of direct subtidal BCH loss

Component	Estimated Area of Direct Subtidal BCH Loss (ha)	Percentage of LAU
Jetty	0.83	0.017%
Berthing Pocket (including 20 m annulus)	1.79	0.036%
Total	**2.62**	**0.05%**

5.6.2 Dredging-related impacts

5.6.2.1 Description of potential impacts

In addition to the direct impact (physical removal) as a result of dredging activities, indirect impacts on some of the BCH may also occur. Dredging will generate plumes of turbid water containing elevated levels of suspended sediments and discharged tailwater will also contain some suspended sediments. These plumes of suspended sediments could impact upon marine organisms through clogging of feeding or respiratory structures or through a reduction in light penetration through the water column potentially leading to reduced growth or to mortality of light-dependent BCH. As the suspended sediments settle, this could lead to smothering of benthic communities in, and on, the seabed in the vicinity of the dredging and tailwater discharge locations, potentially leading to reduced growth or to mortality of biota.

The suspension of sediment into the water column during dredging also has the potential to lead to some liberation of toxicants into the water column, potentially affecting the health of some biota if concentrations are sufficiently high.

5.6.2.2 Assessment of potential impacts

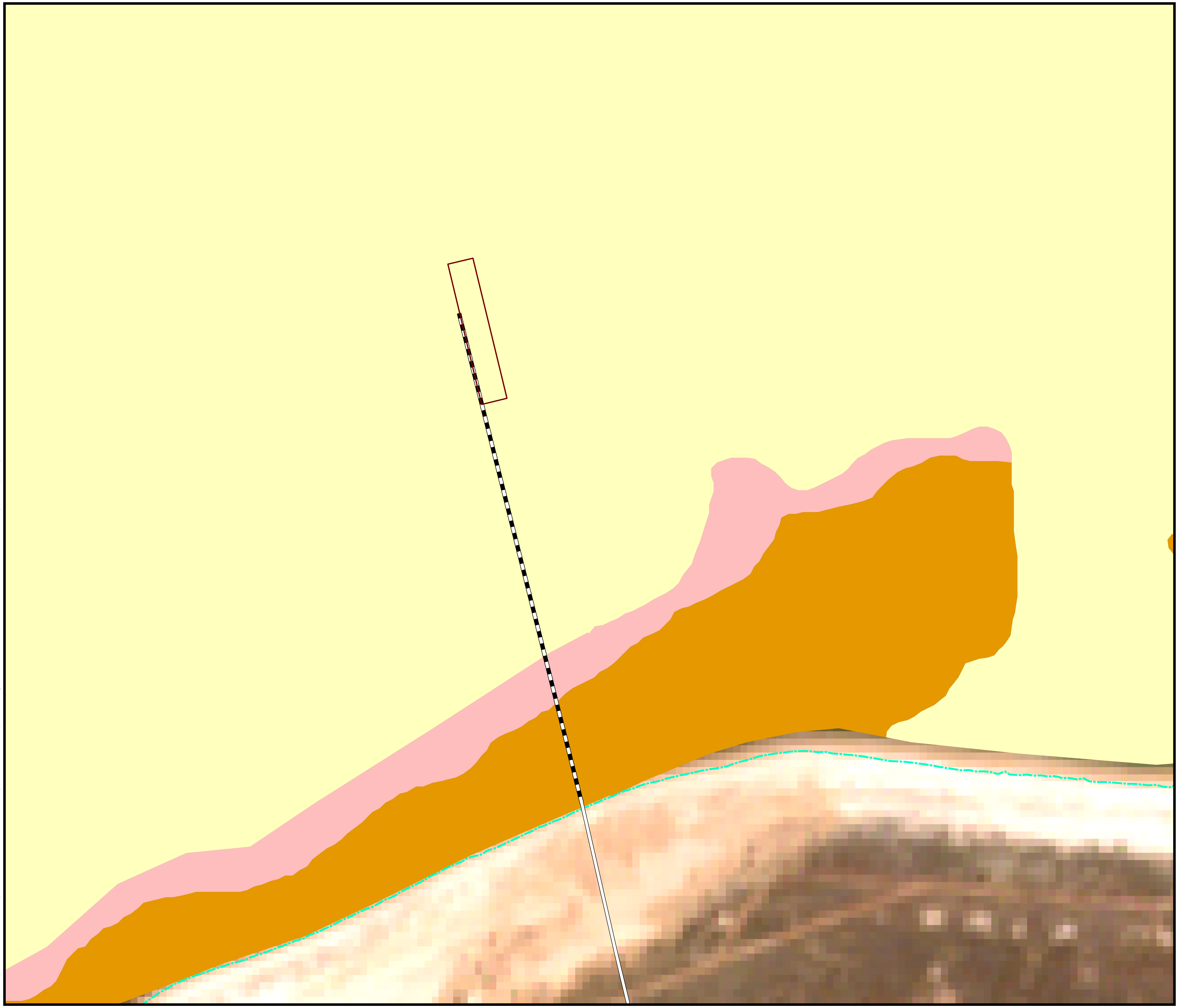
The amount and spatial extent of suspended sediment dispersed within the turbid plumes will vary in accordance with:

- The method of dredging (most likely cutter suction dredge).
- The extent to which sediments settle from the tailwater within the onshore dredged material dewatering ponds prior to release into the nearshore environment.
- The metocean conditions at the time of dredging.
- The sediment type. Geotechnical studies (GHD 2021b) indicate that the material to be dredged is primarily comprised of:
  - A surface layer (approximately 0.4-0.7 m thick) of unconsolidated clayey silt.
  - A subsurface layer (down to approximately 1.0-2.7 m below seabed) of medium density clayey sand.
  - A layer of stiff sandy clay, typically down to approximately 1.3-2.7 m below seabed.
  - Consolidated rock at typically 2.2 m below seabed.

Geochemical assessment

GHD (2021b) undertook a geochemical assessment of the unconsolidated material to be dredged. The analysis of samples from the dredging footprint indicated that:

- The concentrations of all metals in all samples were below the screening levels contained within the National Assessment Guidelines for Dredging (NAGD, Commonwealth of Australia 2009).
- The NAGD (Commonwealth of Australia 2009) screening level for arsenic was slightly exceeded in one sample. However, the 95% Upper Confidence Limit (UCL) across all samples was below the screening level, hence there no requirement for further analysis was indicated.
- Organic compounds (hydrocarbons, polychlorinated biphenyls and organochlorine pesticides) were not detected in any of the samples.



PROJECT ID 60597242
CREATED BY RNM
APPROVED BY ABougher
LAST MODIFIED 10 SEP 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 50 100 150 200
Meters

1:5,000 (when printed at A3)

LEGEND

- Jetty Alignment
- Conveyor
- Dredging Footprint
- Nearshore LAU

Habitat

- Macroalgae
- Macroalgae and Sparse Coral
- Soft Sediment

Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Overview of The Proposed Jetty Infrastructure and Dredging Footprint

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

24

Map Document: (\\AUPER1FP001.au.aecomnet.com\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\11_BCH_SubtidalMapping_Update_20200622\KS_SubtidalMapping_KD_20210401\KS_SubtidalMapping_KD_20210401.aprx) Plotted by: kai.du on 10/09/2021 1:01 PM

A3 size

- Radionuclides were detectable in the samples, but at levels that were below the NAGD (Commonwealth of Australia 2009) screening level.
- There is the potential for acid sulfate sediment to exist within the dredge pocket which could become exposed to air as a result of onshore disposal of dredged material (GHD 2021b). To mitigate this risk:
  - Dredge spoil is to be disposed and treated on land.
  - An Acid Sulfate Soils and Sediment Management Plan (ASSSMP) has been developed (GHD 2021c) outlining methods of handling, treating and monitoring dredge spoil and decant water.

With respect to toxicants:

- The Project area is a remote greenfield location with no known sources of anthropogenic contaminants.
- The only potential toxicants within the dredged sediment are naturally occurring metals, which as stated above showed 95% UCL's below NAGD screening levels (Commonwealth of Australia 2009).
- AECOM (2021b) undertook a Marine Ecotoxicology Assessment for the proposed Project including potential ecotoxicology of the dredged sediment, which found the ecotoxicology risk of this sediment to be low.

Sediment transport modelling

Water Technology (2021a) undertook sediment transport modelling for the proposed dredging program. The MIKE Mud Transport (MT) Model was coupled with the hydrodynamic model to investigate the transport and fate of sediments released into the water column throughout the dredging program. The MT module is designed to simulate suspension, transportation and deposition of non-cohesive and cohesive sediments under combined coastal processes. The model can be run under either coupled or decoupled mode so the hydrodynamic results can be reused to simulate different dredging scenarios. Total suspended solid (TSS) or equivalently suspended solid concentration (SSC) was modelled and used as an indicator to evaluate the potential impacts of the dredging plume.

Through interpretation of the sediment transport modelling (Water Technology 2021a), and background investigations into the potential tolerance of BCH in the Project area to increased SSC in the water column, it is possible to identify zones within which these communities may be at risk of impact from turbid plumes arising from the dredging operation and the tailwater release.

Three zones of impact have been identified to represent varying degrees of predicted direct and indirect impact to benthic communities as a result of the dredging activities and tailwater release. The definitions of these zones are consistent with the WA EPA guidance document Technical Guidance – Environmental Impact Assessment of Dredging Proposals (EPA 2016c) and reflect the likely range of impacts of dredging on benthic habitats.

Water Technology (2021a) adopted coral mortality thresholds presented by Fisher et al (2019) as the basis for defining the parameters for each zone. These take into account the potential exposure of BCH to increased SSC in terms of both frequency (represented by Water Technology [2021a] as the '20% cumulative probability/80th percentile') and intensity (represented by Water Technology [2021a] as the '28 days running average'). The use of hard coral thresholds was deemed appropriate for this assessment due to these communities, as mixed coral and macroalgae communities, being the closest BCH sensitive to reduced light conditions to the project disturbance footprint. While soft sediments across the project area have been assumed as potential seagrass habitat, no seagrass was observed within 1.8 km of the proposed jetty nearshore adjacent to the intertidal rock platform and not within approximately 2.3 km from the end of the jetty in an offshore direction during surveys (Geo Oceans 2019). Should seagrass be detected in closer proximity to the jetty and berth pocket during pre-construction baseline surveys, appropriate measures will be included into environmental management plans (e.g. the construction environmental management plan and dredging and dredge spoil placement management plan) to assess the potential impacts of these seagrass beds and implement appropriate monitoring based on thresholds for seagrasses.

The zones derived from the model outputs presented by Water Technology (2021a) are defined thus:

- **Zone of High Impact (ZoHI)**: Impacts in this zone areas are predicted to be severe and often irreversible (i.e. lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less [EPA 2016c]). Water Technology (2021a) defined this boundary of this zone to be where thresholds corresponding to a high probability of observing non-zero coral mortality were exceeded (SSC/TSS >6.9 mg/L for frequency, SSC/TSS >13.2 mg/L for intensity). Where the modelling did not predict a ZoHI (i.e. where these thresholds were not exceeded), the zone is considered to comprise the direct footprint of the dredged area and a 20 m wide annulus around the footprint. The latter accounts for the potential for smothering of BCH from coarse sediments liberated from the dredge during operations.
- **Zone of Moderate Impact (ZoMI)**: Within this zone, damage to benthic habitats and mortality of benthic biota may occur, primarily as a result of the indirect impacts from increased turbidity and sedimentation that may occur at times within the zone. Impacts within this zone are predicted to occur, but the disturbed areas may recover (after completion of the dredging). It is expected that there will be no long-term modification of the benthic habitats in this zone. The outer boundary of the ZoMI was defined by Water Technology (2021a) to be where the following thresholds were no longer exceeded - SSC/TSS >5 mg/L for frequency, SSC/TSS >9.3 mg/L for intensity.
- **Zone of Influence (ZoI)**: This zone includes the areas in which, at some time during the dredging works, benthic communities may experience (detectable) changes in sediment-related environmental quality outside the natural ranges that are normally expected. However, the intensity, duration and frequency of these changes is such that any damage to benthic habitats is likely to be reversible, and no mortality of benthic biota is expected to occur. The outer boundary of this zone was defined by Water Technology (2021a) to be where TSS was predicted to no longer exceed 2 mg/L.

The predicted ZoHI, ZoMI and ZoI for the dredging operations are shown in Figure 25 (summer) and Figure 26 (winter). These were derived from the modelling outputs from Water Technology (2021a) in the following manner:

- For each zone in each season, the model outputs for frequency and intensity, and for surface and bottom of the water column, were overlaid.
- The zone boundaries shown in Figure 25 and Figure 26 were delineated to show the greatest distance from the dredging area and tailwater discharge location of the 'combined' model outputs. Therefore, the figures show the largest areas over which impacts to BCH are predicted to potentially occur, whether due to the frequency or intensity of elevated SSC, and whether elevations occur in the surface layer or the bottom layer of the water column.

From Figure 25 it is apparent that, if dredging was to take place in summer, then:

- The ZoHI is predicted to be limited in extent to an area of 'soft sediment' habitat around the dredging footprint.
- The ZoMI is predicted to extend some 1.5 km eastwards from the dredging footprint, whilst remaining offshore over 'soft sediment' habitat and not encroaching upon the nearshore macroalgae and coral habitats.
- The ZoI is predicted to extend some 4 km eastwards from the dredging footprint, also not encroaching upon the nearshore macroalgae and coral habitats.
- Within the resolution of the model, there was no influence predicted to occur from the tailwater discharge; i.e. elevations in SSC were predicted to be limited to the immediate vicinity of the discharge location and were not predicted to enter the model domain at sufficient frequency or intensity to exceed the thresholds defined by Water Technology (2021a).

From Figure 26 it is apparent that, if dredging was to take place in winter, then:

- The ZoHI is predicted to be larger than in summer, but still limited in extent to an area of 'soft sediment' habitat in the general vicinity of the dredging footprint. There is evidence of a predicted ZoHI in the immediate vicinity of the tailwater discharge, extending over the macroalgae habitat at that location.

- The ZoMI is predicted to extend no further than approximately 0.5 km from the dredging footprint, well offshore from the nearshore macroalgae and coral habitats. The ZoMI associated with the tailwater discharge is predicted to extend only marginally further from shore than the ZoHI, with minimal encroachment upon mixed macroalgae and coral habitat.
- The ZoI is predicted to extend some 3 km westwards from the dredging footprint, though not encroaching upon the macroalgae and coral habitats offshore from Locker Point. In combination with the ZoI associated with the tailwater discharge, though, the ZoI is predicted to extend across macroalgae and coral habitats up to approximately 0.5 km either side of the base of the jetty.

With respect to sedimentation, the modelling by Water Technology (2021a) predicts that sediment deposition of >1 mm will only occur over 'soft sediment' habitat within 100 m of the dredging footprint.

PROJECT ID 60597242
CREATED BY ROB.MCGREGOR
APPROVED BY ABougher
LAST MODIFIED 29 SEP 2022

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometers

1:50,000 (when printed at A3)

LEGEND

- Jetty Alignment
- Conveyor
- Nearshore LAU

Summer

- ZoHI
- ZoMI
- ZoI
- Seagrass Observation Locations

Habitat

- Macroalgae
- Macroalgae and Sparse Coral
- Soft Sediment
- Assumed Seagrass (Feb. 2019)

Data sources: Preliminary Mangrove and Algal Mat (Data 2005 and 2016)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Zones of Impact and Influence as Modelled for Dredging Works Undertaken in Summer

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

25

Map Document: (\\na.aecomnet.com\lfs\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\11_BCH_SubtidalMapping_Update_20200622\KS_SubtidalMapping_KD_20210401\KS_SubtidalMapping_RNM_20220927.aprx) Plotted by: rob.mcgregor on 29/09/2022 1:32 PM

A3 size

PROJECT ID 60597242
CREATED BY ROB.MCGREGOR
APPROVED BY ABougher
LAST MODIFIED 29 SEP 2022

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometers

1:50,000 (when printed at A3)

LEGEND

- Jetty Alignment
- Conveyor
- Nearshore LAU
- Seagrass Observation Locations

Winter

- ZoHI
- ZoMI
- ZoI

Tailwater Discharge

- ZoHI
- ZoMI

Habitat

- Macroalgae
- Macroalgae and Sparse Coral
- Soft Sediment
- Assumed Seagrass (Feb. 2019)

Data sources Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Zones of Impact and Influence as Modelled for Dredging Works Undertaken in Winter

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure 26

Map Document: (\\na.aecomnet.com\lfs\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\11_BCH_SubtidalMapping_Update_20200622\KS_SubtidalMapping_KD_20210401\KS_SubtidalMapping_RNM_20220927.aprx) Plotted by: rob.mcgregor on 29/09/2022 1:32 PM

A3 size

5.6.2.3 Mitigation measures

There are several factors that inherently mitigate the risks of impacts to BCH from dredging and tailwater release:

- The area and volume of sediment to be dredged is limited (0.7 ha and 17,000 m^3).
- There is no requirement for disposal of dredged material at sea or to be used for coastal land reclamation.
- The dredging methodology (probably small cutter suction dredge) typically results in only very localised areas of elevated turbidity.
- Modelling predicts that plumes of elevated turbidity will not persist for more than a week following cessation of the dredging activity.

In addition to these factors, further mitigation measures will be included within a Dredging and Dredge Spoil Management Plan (DDSMP) developed prior to any dredging taking place. The DDSMP will identify:

- Monitoring to be undertaken of the duration of dredging.
- Specific management measures to be implemented based on trigger levels and results of monitoring.

The management measures to be implemented through the DDSMP will be dependent on the dredging method to be employed and may include:

- Timing dredging to coincide with favourable tidal conditions.
- Reducing the cutter suction dredge or backhoe dredge speed.
- Increasing pump speeds.
- Temporarily suspending dredging.
- Increasing tailwater residence time within the onshore dredged material dewatering pond. Turbidity levels within the pond will be monitored and tailwater will only be released when the level is below a defined trigger level. The latter will be determined on the basis of measured turbidity levels at nearshore reference locations established prior to the commencement of dredging.

It is anticipated that the development and implementation of the DDSMP, including the development of suitable trigger levels based on tolerance limits of sensitive marine habitats, and of management actions in the event of an exceedance of trigger levels, will effectively mitigate the risk of long-term impacts to the ecological function of the BCH in the Project area.

5.6.2.4 Predicted outcome

Modelling of turbid plumes from the dredging activity and tailwater release predicts that, outside of the area of direct impact, these activities pose a very minor risk of sustained impacts to BCH within the Nearshore LAU.

Macroalgae and Corals

It is evident from Figure 25 and Figure 26 that the ZoHI and ZoMI from the dredging activity, in both summer and winter, are predicted to not impinge upon macroalgal or coral habitats. If tailwater discharge was to occur in winter, then it is predicted that the ZoHI would impinge upon the macroalgae habitat on the intertidal pavement reef abutting the shoreline around the base of the jetty. Therefore, adopting the conservative approach that tailwater discharge may occur during winter, the predicted extent of potential irreversible loss of macroalgal habitat (as defined by EPA [2016c]) is 4.39 ha**.** This represents approximately 5.6**%** of the area of this habitat within the Nearshore LAU (Table 6).
It is noted that the ZoMI associated with tailwater discharge, if this was to occur in winter, is also predicted to impinge upon the mixed macroalgal and coral habitat on the intertidal pavement around the base of the jetty. However, this only extends marginally further from shore than the ZoHI and it is notable that any damage within the ZoMI is considered (in accordance with EPA [2016c]) to be recoverable; it is, therefore, not deemed to represent an area of BCH ‘loss’.

While the predicted ZoI from dredging and tailwater discharge (if these were to occur in winter) does impinge upon the fringing macroalgal and coral communities and habitat around the base of the jetty, it is emphasised that (in accordance with EPA [2016c]) the SSC levels within the zone are predicted to be below those which may lead to adverse effects upon them.

In summary, given the very low proportion of macroalgal and coral habitat within the Nearshore LAU that is predicted to be affected, it is considered that there is no credible risk of impacts from dredging and tailwater discharge leading to significant regional impacts to these communities, to other benthic communities that may be associated with them (e.g. benthic invertebrates) or to ecosystem function.

Seagrass

It is noted that:

- The ZoHI, ZoMI and ZoI boundaries shown in Figure 25 and Figure 26 are defined on the basis of coral tolerance limits; these are not directly applicable to seagrasses.
- If the 'soft sediment' habitat within the berthing pocket does support seagrass communities (at certain times of the year in some years), then dredging of the berthing pocket is highly likely to lead to 'loss' of this habitat due to the combined effects of increased seabed depth, shading by the jetty structure, and periodic disturbance of the seabed due to transhipper movements. This is a 'direct loss' and is addressed in Section 5.6.1 and included in Table 9.
- Outside of the berthing pocket, it is recognised that, due to the naturally turbid conditions of the nearshore waters, any seagrasses that may be present are potentially close to the lower limit of irradiance required to sustain them. Therefore, sustained additional turbidity (from dredging) may render the habitat unviable for their continued survival. However, as the dredging campaign is planned to be of short duration (less than one month), and turbid plumes are predicted to be no longer detectable within a week after dredging is completed, any impacts to seagrass would be temporary and localised. That is, there is a high potential for the seabed within the ZoMI to become recolonised by seagrasses (either from an existing seed bank within the area affected by elevated SSC, or from seeds being deposited from adjacent unaffected seagrass areas) unless there are natural stressors, or stressors from the bitterns discharge (see Section 5.6.3.1) that preclude this eventuality. As recovery could reasonably be expected to occur within five years of completion of dredging and tailwater discharge, as per EPA (2016c) it is considered that there is no credible risk of 'loss' of seagrass habitat (outside of the berthing pocket) due to these activities.
- While the ZoHI, ZoMI and ZoI presented are based on coral tolerance limits, it is considered that these zones provide a suitable assessment framework due to the absence of seagrass observations within 1.8 km of the dredge footprint or tailwater release point.

5.6.3 Bitterns discharge

5.6.3.1 Description of potential impacts

Bitterns is a hypersaline solution of concentrated seawater, formed as a waste product of solar salt operations. Approximately 70% of the sodium chloride is removed through the salt production process and therefore the bitterns waste product is rich in magnesium sulphate. Bitterns solutions generally have a salinity of around 300 PSU and a density of 1,250 kg/m^3. They are markedly denser than local seawater, which in the area has natural range of 35.0 to 53.5 PSU and a corresponding range in density of 1,027 to 1,041 kg/m^3. Being denser than the receiving seawater (negatively buoyant), the bitterns discharge will behave in a similar manner to the wastewater discharge from a desalination plant. The bitterns are, however, significantly more saline and denser than the wastewater from a desalination plant which, typically, may have a salinity of around 70 PSU and a density of 1,050 kg/m^3.

The key impact that bitterns can have on biota within the receiving environment is physio-chemical stress due to the high salinity which has osmotic effects on the cells of living organisms. The salinity component of bitterns is classified as a Physical Chemical (PC) stressor.

Given no additives are introduced during the solar salt production process, the only toxicants that exist in the bitterns wastewater are naturally occurring elements of seawater (specifically metals) which have been concentrated by the solar evaporation process. Metal toxicity or metal poisoning is the toxic or poisonous effect of certain metals in certain forms and doses on living organisms. Metals can bioaccumulate in the marine environment, contributing to their potential toxicity.

The Ashburton Salt Project will produce bitterns, which is proposed to be discharged from a specially designed and optimised diffuser located along the outer end of the proposed export jetty.

5.6.3.2 Assessment of potential impacts

To understand the potential impacts of the bitterns discharge on the water quality in and around the jetty location and the broader coastal environment, K+S commissioned Water Technology (2021a) to undertake detailed near and far-field modelling using the industry standard modelling packages, CORMIX and MIKE by DHI. The near field modelling in CORMIX focussed on understanding the dilution at the diffuser to meet the regulatory requirements and confirm the diffuser design concept and layout. The MIKE 3D hydrodynamic, waves, and advection-dispersion model was used to investigate far-field conditions, including the diffuser design, as well as salinity and toxicant assessment, and to define the size of predicted ecological protection areas (mixing zones) (Water Technology, 2021a). Environmental Quality Criteria (EQC) used for the modelling, based on an assessment of ecotoxicology and EPA guidelines are described further in the Marine Fauna report for the Project (AECOM, 2021).

A Whole of Effluent Test (WET) was undertaken for the Mardie Salt Project utilising a bitterns sample collected from Onslow Salt (O2 Marine 2019) . A review of the WET procedure, local marine water quality and background data collected by K+S for the Ashburton Salt Project, was undertaken by AECOM (2022). This review suggested that the species protection levels derived by that WET ecotoxicology assessment are suitable for application to the Ashburton Salt Project.

From the bitterns dilution modelling undertaken by Water Technology (2021a) and by applying the species protection levels derived from WET assessment (Figure 27), it was predicted that for the annually averaged bitterns discharge the modelled width (distance from the diffuser) of the:

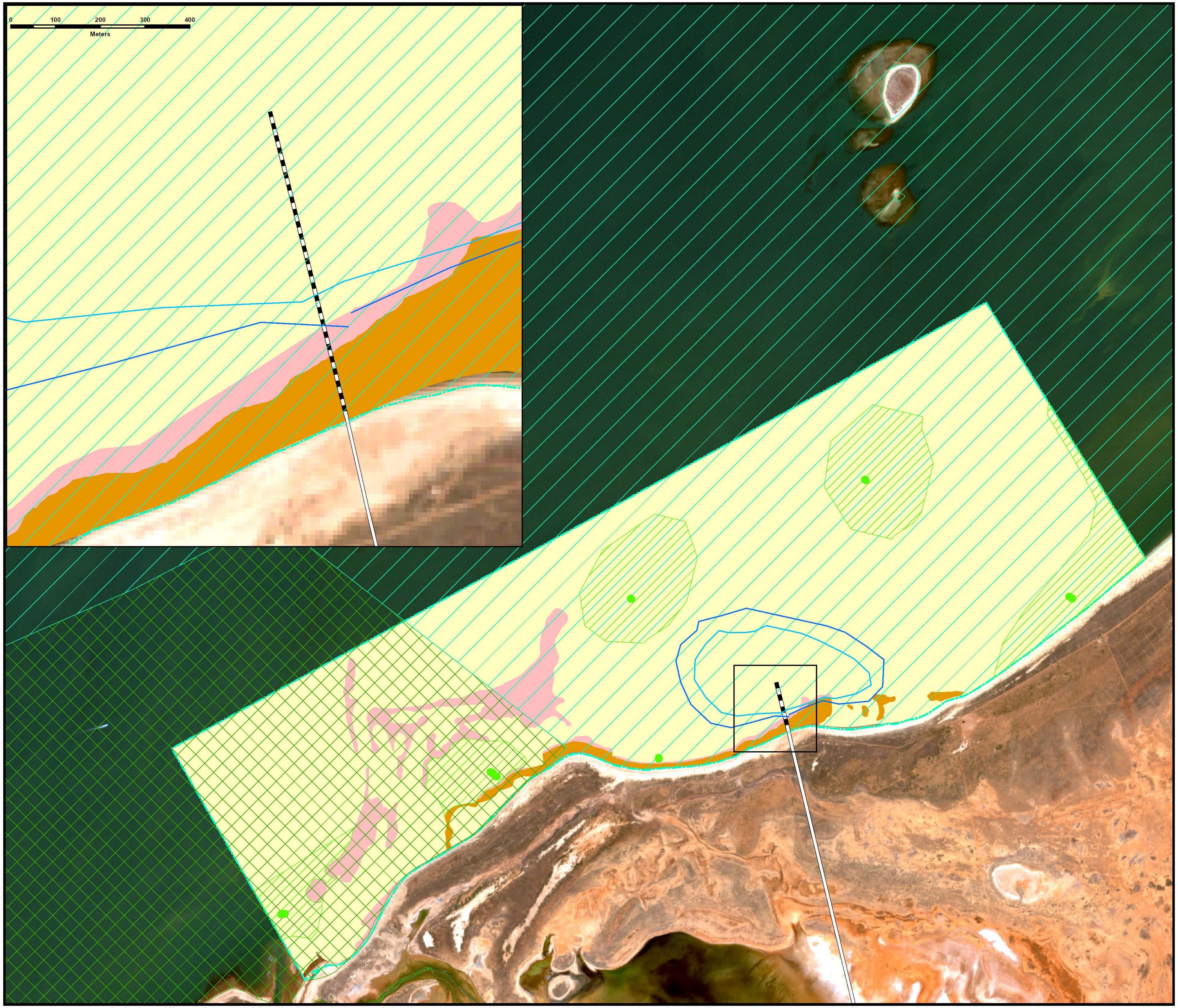
- Low Environmental Protection Area (LEPA) was less than 2,400 m in an along shore direction and 1,200 m in an offshore direction.
- Moderate Environmental Protection Area (MEPA) was less than 2,900 m in an alongshore direction and 1,700 m in an offshore direction.

For the worst-case scenario, the predicted size of the LEPA zone was less than 3,000 m in width, extending approximately 1,500 m from the end of the jetty. The MEPA was predicted to be approximately 4,300 m in width to approximately 2,000 m from the end of the jetty..

It is noted that the LEPA and MEPA are predicted to impinge upon a very small area of the macroalgal and sparse coral communities fringing the shoreline at the base of the jetty; however, they are not predicted to reach these habitat types offshore from Locker Point. Rather, they overlie 'soft sediment' habitat which may or may not, at certain times of the year in some years, support ephemeral seagrass communities.

However, in considering the area of potential seagrass habitat that may be affected by the bitterns discharge, it is important to recognise that it is predicted (from modelling) that the LEPA encompasses the berthing pocket, which is predicted to be rendered unsuitable habitat for seagrasses by the dredging works (refer Section 5.6.2.4). Therefore, only soft sediment (potential seagrass habitat) outside the berthing pocket should be considered potentially impacted by the bitterns, given the berthing pocket will be unsuitable seagrass habitat after dredging.

It has been assumed that the "soft sediment" habitat with the LEPA worst case zone will be permanently impacted and this area is unlikely to be conducive to the establishment of ephemeral seagrass communities. Whilst the soft sediment in the worst case MEPA may experience reduced water quality (relative to baseline/existing) this area is likely to be able to still support future seagrass habitat which might establish there in some years, given the worst case reduced water quality will only occur for a few months of the year (summer) and the worst case increase above background of between 2.2 and 1.6 PSU in salinity falls within the natural salinity variation for the site. While there may be detectable alterations to water quality within the MEPA during the periods of bitterns discharge, in accordance with water quality guidelines it is predicted that these will be of insufficient magnitude to result in irreversible changes to benthic communities that may be present within it. Hence, the area within the MEPA is not included within the 'area of loss' calculation.



PROJECT ID 60597242
CREATED BY ROB.MCGREGOR
APPROVED BY ABougher
LAST MODIFIED 31 OCT 2022

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometers

1:50,000 (when printed at A3)

LEGEND
- Jetty Alignment
- Conveyor
- Low Ecological Protection Areas
- Moderate Ecological Protection Areas
- Nearshore LAU
- Seagrass Observation Locations
- Assumed Seagrass (Feb. 2019)

Level of Ecological Protection (DWER, 2019)
- Maximum
- High

Subtidal Benthic Habitats

Habitat
- Macroalgae
- Macroalgae and Sparse Coral
- Soft Sediment

Data sources Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Bitterns Discharge Infrastructure Footprint and Mixing Zone

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

27

Map Document: (\\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\11_BCH_SubtidalMapping_Update_20200622\KS_SubtidalMapping_KD_20210401\KS_SubtidalMapping_RNM_20220927.aprx) Plotted by: rob.mcgregor on 31/10/2022 2:45 PM

A3 size

5.6.3.3 Mitigation measures

There are several aspects of Project design that inherently mitigate the risks of impacts to BCH from bitterns release:

- Prior to discharge, the bitterns flowing out of the crystalliser ponds will flow into a bitterns dilution pond. Seawater will be pumped into the bitterns dilution pond to dilute the bitterns to approximately a 1:1 ratio. The dilution pond will cover an area of approximately 70 ha and is designed to reduce the salinity of the bitterns before discharge to assist in achieving the required environmental quality criteria as well as improve the operational ability to manage the bitterns.
- Throughout the salt production process, no chemicals will be added at any stage of the process.
- The bitterns outfall point will be at the end of the jetty to take advantage of deeper water and greater tidal movement facilitate mixing upon discharge.
- Bitterns will be discharged through an upward facing diffuser which will force the bitterns to the surface, thereby facilitating enhanced mixing and diffusion with faster moving surface waters.
- The diffuser will be positioned such that the mixing zone is in an area of existing high disturbance such as the jetty berthing area and away from sensitive benthic habitats.

A Bitterns Discharge Environmental Monitoring and Management Plan (BDEMMP) will be developed and implemented to mitigate the risk of impacts from bitterns discharge on the receiving environment. The plan will be in line with EPA guidance (EPA 2016d) and will stipulate all aspects of monitoring including, but not limited to, delineation of a mixing zone (Figure 27), monitoring parameters and locations, monitoring frequencies and methods, management triggers, and management responses to trigger exceedances.

5.6.3.4 Predicted outcome

Adopting a conservative approach, it is assumed that the seabed habitat within the worst case LEPA will be unsuitable habitat for seagrasses, and any associated benthic communities, over the duration of bitterns discharge (due to salinity and temperature effects). As the bitterns discharge will continue for longer than five years, the worst case LEPA is considered to represent an area of ‘loss’ of soft sediment (potential seagrass habitat). The predicted area of indirect loss of ‘soft sediment’ habitat within the LEPA is 1.67 ha. This is additional to the predicted direct loss of this habitat within the LEPA that is associated with the presence of the jetty and the berthing pocket; as discussed in Section 5.6.2.4, this habitat is unlikely to support seagrasses over the duration of Project operation (refer Table 8).

Whilst the soft sediment in the worst case MEPA may experience reduced water quality (relative to baseline/existing) this area is likely to be able to still support future seagrass habitat which might establish there in some years, given the worst case reduced water quality will only occur for a few months of the year (summer) and the worst case increase above background of between 2.2 and 1.6 PSU in salinity falls within the natural salinity variation for the site. While there may be detectable alterations to water quality within the MEPA during the periods of bitterns discharge, in accordance with water quality guidelines it is predicted that these will be of insufficient magnitude to result in irreversible changes to benthic communities that may be present within it. Hence, the area within the MEPA is not included within the ‘area of loss’ calculation.

Overall, given the very low proportion of ‘soft sediment’ habitat within the Nearshore LAU that is predicted to be affected (<0.04% of the area of this habitat within the Nearshore LAU [Table 6]), it is considered that there is no credible risk of the bitterns discharge having a significant regional impact to seagrasses, or to other benthic communities that may be associated with them (e.g. invertebrates), or to ecosystem function.

5.6.4 Hydrocarbon spills

5.6.4.1 Description of potential impacts

The occurrence of a hydrocarbon spill associated with the project construction or operation is considered highly unlikely, though is considered here for completeness. Potential sources of hydrocarbon spills include:

- Vessel collision or grounding resulting in vessel damage and breach of fuel tanks.
- Equipment failure resulting in unplanned release of fuel from a vessel or construction equipment.
- Failure to properly contain an onshore spill resulting in runoff into the marine environment.
- Failure of stormwater control and / or treatment systems resulting in contaminated runoff entering the marine environment.

It is noted that no bunkering or vessel refuelling will take place at the project location during construction or operation.

While the likelihood of occurrence ins very low, any such release of hydrocarbons from these sources may result in the release of varying volumes and / or types of hydrocarbons.

5.6.4.2 Assessment of potential impacts

Potential impacts associated with hydrocarbon release will depend on:

- The location of the spill in relation to sensitive receptors
- The volume and type of material released
- The environmental conditions at the time of the spill (i.e. current direction)
- Whether the material reaches the shoreline or is contained offshore

The spill of hydrocarbons and subsequent contact with subtidal habitats may be mitigated by the typically buoyant nature of such hydrocarbons. A buoyant plume is less likely to come into prolonged contact with benthic habitats in deeper waters. Where a spill occurs in, or is carried into, shallower waters, greater impacts would be expected. Shallow subtidal reefs and sandy beaches are particularly susceptible to hydrocarbon spills. Loss of macroalgae and sparse hard coral habitats may occur and areas of bare sediment and / or potential seagrass habitat may be impacted.

Should a spill occur in, or be carried into Urala Creek, there is a risk of impacts to both coral and seagrass beds in the mouth of Urala Creek, and mudflat, samphire and mangrove habitats further up the creek. The nature of this environment is such that the spill may be dispersed across mudflats, where containment and removal can be difficult. Depending on the volume and type of material spilled, the impacts may result in reduced health or mortality of mangrove and samphire vegetation and impacts to mudflat environments.

5.6.4.3 Mitigation measures

Hydrocarbon spill prevention and management will be addressed in detailed management plans for the construction (CEMP) and Operations (OEMP) of the project. Alternatively, a standalone oil spill monitoring and management plan may be developed for the project. These plans will include the predictive modelling of spill scenarios to assist with the planning and management of any unplanned releases to the marine environment.

Prevention of spills will be the focus of these plans with mitigation and management measures provided, including:

- No bunkering of project vessels on site
- Refuelling of machinery only within designated areas
- Fuel storage and refuelling areas designed with appropriate spill prevention and containment mechanisms and equipment in place
- Spill kits present on site where any machinery is operating and on all project vessels

- Personnel trained in the spill response and use of spill kits to a level appropriate for their role and activities in which they are engaged.
- Vessel speed limits in place to prevent collisions

5.6.4.4 Predicted outcome

Hydrocarbon spills are considered highly unlikely after mitigation measures are applied and it is therefore anticipated that the outcome will be no loss of BCH resulting from hydrocarbon spills.

Should a spill occur, the outcome could potentially (depending on the location and type and volume of hydrocarbon released) result in decreased health and possible mortality of areas of macroalgae and sparse hard coral and / or potential seagrass habitat. Given the small areas of these habitats in the project area it is considered that there is no credible risk that these impacts would represent a significant impact to BCH on a regional level.

5.6.5 Introduced marine species

5.6.5.1 Description of potential impacts

A range of vessels will be engaged during the project construction phase, with longer term presence of transhipper and ocean going vessels servicing the project throughout the project operational phase.

Vessels will be sourced from within Australia and internationally, and will remain within the project region for varying durations during the construction operational project phases.

Vessels provide a vector for the potential introduction of introduced marine species (IMS) with varying levels of risk depending on their recent origin, cleanliness and use of ballast water.

State and Commonwealth agencies maintain a lists of IMS of concern and all vessels entering Australian waters are subject to strict quarantine legislation, which will be followed by all project related vessels. In Western Australia, the Department of Primary Industries and Regional Development (DPIRD) is responsible for biosecurity arrangements to manage the risks associated with IMS. Notwithstanding this, there have been instances in the past where IMS have been introduced to an area even where these legislation and regulations are in place. Based on this, it is considered remotely possible, though highly unlikely, that an IMS may be introduced as a result of vessels coming to the project area, either in ballast water, or hull fouling.

For an IMS to adversely impact a region (i.e. become an introduced marine pest [IMP]), as well as being introduced, it must establish itself under the local conditions to a degree where it impacts the quality of the local marine environment. Should this occur, potential impacts of IMP range from competition for habitat and food for local species, preying on local species and modifying the trophic food web. By their nature, IMP are likely to outcompete local species, potentially resulting in displacement of those species and also provide stock for further translocation from the newly established region to other parts of Australia or internationally.

5.6.5.2 Assessment of potential impacts

The establishment of an IMP as a result of project related vessel activities is considered highly unlikely, however, in the event that an IMP does become established, the potential impacts to BCH may include modification or loss of macroalgae / hard coral habitat, on nearshore reefs. Since most IMS of concern prefer a hard substrate to colonise, the soft substrate and potential seagrass communities are less likely to be impacted upon.

Impacts to marine fauna of conservation significance or commercially valuable species may occur should large areas of BCH be impacted upon, however, as noted in this report, the BCH in the project region is not considered to represent a large portion of habitat available regionally.

5.6.5.3 Mitigation measures

Risks associated with IMP will be managed through a project Marine Biosecurity Management Plan, or within the construction Environmental Management Plan for the project construction phase. These plans will include mitigation measures in line with industry best practice and biosecurity regulations and legislation of both State and Commonwealth agencies. This includes:

- Conducting vessel risk assessments prior to their entry into Australian or Western Australian waters as required by Commonwealth and State biosecurity regulations.
- Implementing all relevant measures to manage ballast water transfer and hull biofouling on project related vessels.
- Having in place a monitoring program that is commensurate with the IMP risk level of the project phase (i.e. risks associated with construction vs. operations).

5.6.5.4 Predicted outcome

With the proposed mitigation measures in place, the likelihood of the introduction of IMS or establishment of an IMP as a result of project related activities is considered very remote. The proposed mitigation measures, based on strict biosecurity legislation and regulations are anticipated to result in no IMP becoming established and therefore no impact to BCH within the project area.

6.0 Cumulative Loss Assessment within LAUs

This section aims to meet the requirements of EPA (2016b) for an assessment of BCH cumulative loss within the subtidal and intertidal habitats of the project area. Both Intertidal and Nearshore LAUs are proposed to reflect the proposed Project layout and BCH communities present. The proposed LAUs are shown in Figure 13. Consultation occurred with DWER Marine Ecosystems Branch in order to designate these proposed LAUs.

6.1 Historical Loss of Intertidal BCH

There are no known records or evidence of human-induced historical loss of intertidal BCH within the LAUs.

It is expected that, historically, there has been cycles of destruction and recovery of large areas of intertidal BCH in response to cyclones that had the potential to radically alter the current coastline due to their erosive power and ability to rapidly mobilise sediments. For example, there was large-scale destruction caused by TC Vance in 1999, when approximately 5,700 ha of mangrove habitat was damaged on the eastern side of Exmouth Gulf (Paling, Kobyrn & Humphreys 2008). Regeneration and recovery of mangroves occurred in the years subsequent to TC Vance and it was estimated that, by five years post-TC Vance, approximately 68% of mangrove habitat had returned to its former coverage.

6.2 Historical Loss of Subtidal BCH

There are currently no known records of human-induced historical loss of subtidal BCH within the LAUs. Nearshore habitat loss within the regional context has been restricted to impacts from trawling as part of the Exmouth and Onslow trawl fisheries; however, no known records of habitats exist prior to commencement of trawling.

The closest area of BCH loss to the Project area resulted from the dredging, trunkline construction, production jetty and port construction for the Wheatstone LNG project at Ashburton North, which is approximately 30 km north east of the nearshore Project area. Earlier instances of BCH loss also occurred due to the dredging and jetty construction for Onslow Salt, which is approximately 40 km north east of the Project's nearshore area.

6.3 Project-Related BCH Loss and Cumulative Loss Assessment

6.3.1 Direct loss

Construction of the concentration and crystalliser ponds, seawater intake channel (including pump station), jetty and berthing pocket will result in the direct loss of approximately 62 ha of intertidal BCH (see Section 5.5.1) and approximately 2.6 ha of subtidal BCH (see Section 5.6.1). The direct loss estimates derived from overlaying the predicted Project disturbance footprint are provided in Table 9.

Table 9 Direct BCH loss estimates within each LAU - Area (ha) & % of BCH type lost within each LAU.

	BCH	Intertidal LAU South		Intertidal LAU North		Locker Pt Nearshore LAU		Total (ha)
		ha	%	ha	%	ha	%	
Intertidal BCH	Mangroves	0	0	3.94	0.73%	0	0	3.94
	Transitional mudflat	0	0	17.81	0.90%	0	0	17.81
	Algal mat	0	0	12.74	0.38%	0	0	12.74
	Samphires	0.17	2.83%	36.19	7.88%	0	0	36.36
	Sandy beaches	0	0	0.99	0.77%	0	0	0.99
	Tidal creek	0	0	0.30	0.10%	0	0	0.30
Subtidal BCH	Soft sediment (potential seagrass)	0	0	0	0	2.3	0.08%	2.3
	Macroalgae	0	0	0	0	0.22	5.62%	0.22
	Macroalgae & sparse coral	0	0	0	0	0.1	0.04%	0.1

6.3.2 Indirect loss

The assessment of potential indirect impacts to BCH have been considered in Sections 5.5 and 5.6 for a range of Project-related factors. Predicted indirect losses are limited to:

- A small area of low scattered mangroves (0.34 ha) that fringe the (sub-creek upstream from the intake channel. The construction of the intake channel across the sub-creek will effectively serve as a barrier to tidal flows to/from this small area of mangroves and it is likely they will be impacted (Section 5.5.2).
- Approximately 0.24 ha of tidal sub-creek upstream from the intake channel will also be impacted by the embankment barrier effect to tidal flows (Section 5.5.2).
- Approximately 3.94 ha of algal mat which is predicted to be impacted by groundwater seepage at the perimeter of the western pond embankments (Section 5.5.4).
- Approximately 0.09 ha of samphires which is predicted to be impacted by groundwater seepage at the perimeter of the western pond embankments (Section 5.5.4).
- Approximately 4.39 ha of macroalgal habitat on the fringing intertidal platform reef around the base of the jetty (Section 5.6.2.4). This is predicted to be impacted by the tailwater discharge (if this occurs in winter), with recovery potentially taking in excess of five years.
- Approximately 217 ha of 'soft sediment' habitat (with the potential to support seagrass), 0.18 ha of macroalgae and 2.2 ha of macroalgae and sparse coral habitat due to impacts from the discharge of bitterns (Section 5.6.3.4).

The extent of potential indirect BCH losses has been added to the direct loss estimates to calculate the overall areas of potential Project-related cumulative loss below.

6.3.3 Cumulative Loss

The current spatial extent of each BCH type within each LAU is shown in Table 10. As there are no known records or evidence of human-induced historical loss it has been assumed that the current spatial extent represents the same as the pre-European extent. The area of BCH impacted within each LAU, after consideration of direct/indirect impacts and mitigation measures, is presented in Table 10 as irreversible loss, and expressed in both hectares and percentages of the pre-European extent. Total cumulative losses, also presented as hectares and percentages of the pre-European extent, are shown in Table 10. As it has been assumed that there has been no historical loss of BCH, the cumulative loss is limited to irreversible loss occurring from the Ashburton Salt Project.

Table 10 BCH Cumulative Loss Assessment

LAU	Loss Assessment	Intertidal BCH												Subtidal BCH					
		Mangroves		Transitional Mudflats		Algal Mat		Samphires		Sandy Beaches		Tidal Creek		Soft Sediment (potential seagrass)		Macroalgae		Macroalgae, Sparse Coral	
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Intertidal LAU South	Pre-European Extent	1645	0	2040	0	2034	0	6	0	5.3	0	206	0	0	0	0	0	0	0
	Current Extent	1645	100	2040	100	2034	100	6	100	5.3	100	206	100	0	0	0	0	0	0
	Irreversible Loss	0	0	0	0	0	0	0.17	2.83	0	0	0	0	0	0	0	0	0	0
	Cumulative Loss	0	0	0	0	0	0	0.17	2.83	0	0	0	0	0	0	0	0	0	0
Intertidal LAU North	Pre-European Extent	540	0	1980	0	3350	0	459	0	127.5	0	297	0	0	0	0	0	0	0
	Current Extent	540	100	1980	100	3350	100	459	100	127.5	100	297	100	0	0	0	0	0	0
	Irreversible Loss	4.28	0.79	17.81	0.9	16.68	0.5	36.28	7.90	0.99	0.78	0.54	0.18	0	0	0	0	0	0
	Cumulative Loss	4.28	0.79	17.81	0.9	16.68	0.5	36.28	7.90	0.99	0.78	0.54	0.18	0	0	0	0	0	0
Subtidal LAU	Pre-European Extent	0	0	0	0	0	0	0	0	0	0	0	0	4674	0	82	0	244	0
	Current Extent	0	0	0	0	0	0	0	0	0	0	0	0	4674	100	82	100	244	100
	Irreversible Loss	0	0	0	0	0	0	0	0	0	0	0	0	219.3	4.7	4.79	5.8	2.3	0.94
	Cumulative Loss	0	0	0	0	0	0	0	0	0	0	0	0	219.3	4.7	4.79	5.8	2.3	0.94
Totals (All LAUs)	Pre-European Extent	2185	0	4020	0	5384	0	465	0	132.8	0	503	0	4674	0	82	0	244	0
	Current Extent	2185	100	4020	100	5384	100	465	100	132.8	100	503	100	4674	100	82	100	244	100
	Irreversible Loss	4.28	0.2	17.81	0.44	16.68	0.31	36.45	7.84	0.99	0.7	0.54	0.11	219.3	4.7	4.79	5.8	2.3	0.94
	Cumulative Loss	4.28	0.2	17.81	0.44	16.68	0.31	36.45	7.84	0.99	0.7	0.54	0.11	219.3	4.7	4.79	5.8	2.3	0.94

7.0 Assessment of Cumulative Loss in Context of the EPA BCH Objective

7.1 Mitigation of Potential Impacts

The EPA's objective for BCH is to maintain biological diversity and ecological integrity and, as part of the approvals and regulatory framework, proponents are expected to mitigate potential impacts by following a hierarchy of mitigation principles (i.e. Avoid, Minimise, Rehabilitate and Offset). Measures by which K+S has mitigated potential impacts to BCH according to this hierarchy are summarised below.

7.1.1 Avoidance of BCH loss/damage

K+S has undertaken significant design optimisation to minimise the potential for environmental impacts and reduce BCH loss, including:

- Eight iterations of the pond design to minimise the footprint. Alignment of the western boundary of the concentration ponds was moved further east to minimise direct loss of algal mats, and to provide greater areas of setback or buffer areas to accommodate potential indirect impacts to mangroves from edge effects such as localised seepage. It should be noted that, as a result, the areal extent of loss from the Ashburton Salt Project is less than that from existing and proposed solar salt projects, and from other major infrastructure projects constructed within similar settings on the Pilbara coast.
- Detailed analysis of seawater intake options and locations.
- Detailed analysis of bitterns disposal options and locations.
- Detailed analysis of dredging options and dredged material disposal.
- Detailed analysis of product transhipment methodology and options.

As a result of design optimisation, the following additional changes have been made to the proposal:

- Reduction in size of development envelopes.
- Reduction in size of evaporation pond footprint.
- Increase in production to 4.7 MTPA without any increase in footprint (due to revision of process mass balance).
- Optimisation of jetty alignment (and associated conveyor alignment) to achieve improved bitterns mixing.
- Optimisation of seawater intake to minimise footprint, erosion/scour risk and changes to mangrove inundation.

7.1.2 Minimise impacts

7.1.2.1 Assessment approach

In addition to avoidance and minimisation of loss by consideration of design options, the proponent's approach to the EIA process has been to undertake rigorous assessments for key factors to enable realistic predictions of potential impacts to be determined. This includes:

- Detailed and conservative modelling studies related to coastal hydrodynamics, hydrogeological and groundwater conditions, nutrient pathways, sea level rise changes, bitterns discharge and toxicology, and dredging-related turbidity were undertaken to provide for an informed assessment of Project-related changes and potential impacts, while recognising the inherent limitations in the modelling.
- In some cases, the studies undertaken (e.g. intertidal habitat sea level rise adaptation and various water related modelling) represents new approaches to, and more rigorous modelling of, complex issues than have been implemented previously for EIA related to Pilbara intertidal areas.

- To help guide assessments made on the basis of outputs from the above modelling studies, insight was gained from the results of environmental monitoring undertaken at other Pilbara salt projects constructed within similar settings. The extent of recorded changes to receptors such as mangroves and shallow groundwater conditions within tidal flats provided on-ground context to potential changes predicted by modelling studies. Both the Port Hedland and Onslow Salt projects have also been constructed primarily on expansive areas of salt flats landward of the mangroves and coastal zone; hence, environmental monitoring data collected at those locations are of relevance to this assessment.

7.1.2.2 Management/Monitoring

A number of management and monitoring plans will be implemented as mentioned in previous sections of this report and mitigation measures regarding BCH are summarised below.

Construction Environmental Management Plan (CEMP)

The CEMP will include management measures to reduce sediment and turbidity related impacts. Such measures are:

- Incorporate a buffer area between the outer disturbance boundary and the outer construction boundary (e.g. toe of the perimeter bund).
- Containment of sediment within perimeter levee walls in sensitive areas by use of geofabric and rock armour.

Mangrove, Samphire and Algal Mat Management Plan (MSAMMP)

The MSAMMP would aim to manage the impacts from construction and operation activities to achieve the required environmental outcomes related to the protection of mangroves, samphire and algal mats. The plan would include environmental performance objectives, management actions, monitoring and reporting strategies. The monitoring plan would include:

- Mapping to monitor for Project related changes to mangrove, samphire and algal mat distribution and assess the extent of habitat loss in relation to predicted environmental outcomes.
- Monitoring of mangrove, samphire and algal mat health and habitat condition parameters that are linked to the main processes responsible for maintenance of mangrove, samphire and algal mat systems (e.g. tidal inundation, sedimentation/erosion, ground/soil water conditions). Monitoring of shallow groundwater/soil water conditions (water table depth and salinity) would be linked to the monitoring of mangrove and samphire health so that the response of vegetation to changes in groundwater and surface water conditions can be determined.
- Assessment of monitoring data against trigger levels for mangrove, samphire and algal mat habitat loss, health and habitat condition.
- Contingency measures and monitoring responses related to trigger level exceedances.

Groundwater Management and Monitoring Plan (GMMP)

A GMMP will be prepared for the Project which includes:

- Further baseline groundwater monitoring prior to construction:
    - Groundwater monitoring within the intertidal area of mangroves and samphires, with water level, and water quality measured via loggers at a sub-daily interval, to characterise tidal influences.
    - Additional piezometers / bores immediately downstream of proposed ponds, to provide baseline data prior to pond construction and filling.
- Refinement of the Groundwater Model including increased vertical resolution and incorporation of additional monitoring data collected.
- Ongoing groundwater monitoring program during construction and operations, including monitoring of water levels and water quality at various distances from filled ponds at sub monthly intervals.

- Appropriate groundwater monitoring criteria, trigger values, actions and contingency plans to prevent groundwater related environmental impacts.

Surface Water Management Plan (SWMP)

A Surface Water Management Plan (SWMP) will be implemented to further assess potential changes to surface water and nutrient flows and concentrations. The SWMP will include revised surface water modelling including borrow pits and final culvert /drainage diversion designs to minimise impacts and maintain environmentally important surface water regimes, particularly those important to samphire. The SWMP will include a weather station to monitor rainfall and climatic conditions as well as quarterly and rainfall event-based estuarine and surface water flow/volume and quality monitoring.

Dredging and Dredge Spoil Management Plan (DDSMP)

The DDSMP will be developed prior to any dredging taking place. It will identify:

- Monitoring to be undertaken of the duration of dredging.
- Specific management measures to be implemented based on trigger levels and results of monitoring.

The management measures to be implemented through the DDSMP will be dependent on the dredging method to be employed and may include:

- Timing dredging to coincide with favourable tidal conditions.
- Reducing the cutter suction dredge or backhoe dredge speed.
- Increasing pump speeds.
- Temporarily suspending dredging.
- Increasing tailwater residence time within the onshore dredged material dewatering pond. Turbidity levels within the pond will be monitored and tailwater will only be released when the level is below a defined trigger level. The latter will be determined on the basis of measured turbidity levels at nearshore reference locations established prior to the commencement of dredging.

It is anticipated that the development and implementation of the DDSMP, including the development of suitable trigger levels based on tolerance limits of sensitive marine habitats, and of management actions in the event of an exceedance of trigger levels, will effectively mitigate the risk of long-term impacts to the ecological function of the BCH in the Project area.

Acid Sulfate Soils and Sediment Management Plan (ASSSMP)

An ASSSMP has been developed (GHD 2021c) outlining methods of handling, treating and monitoring dredge spoil and decant water. The ASSSMP provides practical and concise mitigation and management measures including:

- A monitoring program for construction and commissioning including baseline information.
- Trigger levels and action criteria (contingency planning) with appropriate contingency responses and measures.

Bitterns Discharge Environmental Monitoring and Management Plan (BDEMMP)

A BDEMMP will be developed and implemented to mitigate the risk of impacts from bitterns discharge on the receiving environment. The plan will be in line with EPA guidance (EPA 2016d) and will stipulate all aspects of monitoring including, but not limited to, delineation of a mixing zone, monitoring parameters and locations, monitoring frequencies and methods, management triggers, and management responses to trigger exceedances.

7.1.3 Rehabilitate

Temporary disturbance of BCH areas due to construction will not occur (i.e. all disturbance is permanent for the life of the operation), therefore there will be no rehabilitation of BCH during the life of the operation.

However the Project is positioned to consider the creation of ongoing habitat for algal mat and mangroves as a part of Project closure and this will be explored as part of Closure Planning for the site. The effect of sea level rise will be considered during the closure planning process and it may be possible to create a “niche” environment for mangroves and/or algal mats which may enable them to continue in conjunction with the sea level rise changes discussed in Section 8.

An initial closure plan has been developed for the project and will continue to evolve during the life of the project. K+S preferred post closure land use is to leave the evaporation ponds in situ so that they become a “wetland” habitat for mangroves, algal mats and associated fauna (including migratory birds which require “wetland areas” for migratory stop over). This will also likely create habitat opportunities for the survival of mangroves and/or algal mats.

At the completion of operations, all building and structures will be removed from the site and the pond areas may be selectively reconnected to the existing tidal flat system. If ponds are to be reconnected, the closure plan will establish which bunds to breach that will enable inwards tidal movement bringing sediments and allowing tidal channels to expand naturally. Natural tidal flows will allow movement of mangrove plant and seed material which will passively revegetate the reconnected tidal areas. This will enhance the habitat values of the ponds to BCH and fauna post closure.

Other salt operations worldwide have similar closure plans in recognition of the important intertidal and fauna habitat that salt ponds create. One example is the Dry Creek Salt Operation (approximately 5000 ha in size) which is in its closure phase after operating in Adelaide since the late 1930s. The salt production operation has ceased with the site transitioning to alternative land uses. A potential end land use for the site being considered is to restore tidal connections to transition the land back to a natural salt marsh-mangrove ecosystem. To trial a tidal restoration strategy at the salt field, tidal gate infrastructure was designed and installed in the levee bank of one of the salt ponds (38 ha in size) (Mosley et al. 2019).

Monitoring of water quality, sediment quality, hydrology and benthic macroinvertebrates was undertaken prior to tidal restoration, and for an approximately 2 year period after tidal restoration commenced on 29 July 2017. Key outcomes of the trial were (Mosley et al. 2019):

- Tidal connection was successfully restored with regular wetting and drying cycles occurring driven by natural tidal variations.
- Salinity in the pond was rapidly restored to near coastal seawater conditions.
- pH, dissolved oxygen, dissolved metals, chlorophyll a and nutrients were being maintained at satisfactory levels during tidal exchange.
- No acid sulfate soil risks eventuated with near neutral soil pH being maintained.
- Improved sediment and water quality conditions enabled recolonisation by benthic invertebrates and benthic communities and habitat, with the restored intertidal mudflat habitat being utilised by local and migratory shorebirds.

The total area of salt evaporation ponds proposed by the Ashburton Salt Project is almost 9,000 ha. There is the potential that large areas of the evaporation ponds could, with appropriate post closure works, become functioning intertidal habitat hosting both mangroves and algal mats, possibly with greater resilience to sea level rise than some of the existing intertidal habitats predicted to be progressively lost due to the rate of sea level rise without the project in place.

7.1.4 Offsets

While K+S considers that offsets are not expected to be required for this factor, there is a range of environmental benefits to the local coastal ecosystem that may develop due to the presence and operation of the salt ponds. Based on investigations into salt pond ecology, and the results of environmental monitoring at salt fields in the Pilbara, the examples below provide an indication of the environmental benefits that may potentially develop within, and adjacent to, the proposed K+S salt pond system.

7.1.4.1 Biological productivity within salt ponds

At both the Dampier and Port Hedland solar salt fields, the pumping of large volumes of seawater into the primary concentration pond, and the movement and concentration (via evaporation) of seawater through a series of subsequent ponds has developed a biological system composed of a sub-set of species from adjacent tidal creeks and nearshore waters (Sammy 1976, DSL 1992, LDM 1996, Fisheries WA 2000, URS 2003).

Seawater pumped from adjacent tidal creeks passes through a screen mesh which allows small crustaceans, plankton and the eggs, larvae and juveniles of fish to pass through the pumps into the primary concentration pond. Individuals that survive passage through the pump system can then develop in the quiescent pond environment. Due to the large areas of the concentration ponds and volumes of water pumped, the abundance of biota such as fish can be considerable. Fisheries WA (2002) has estimated the fish populations to range in mass from 8 – 105 tonnes, depending on the method of estimation.

Some of the biota within the concentration ponds are reported to be important in the salt production process as some species ([e.g. filter-feeding fishes, brine shrimp [*Artemia*]) increase water clarity and therefore evaporation rates within the ponds, making salt production more efficient (Burnard 1991). There are also other species of fish and biota that do not necessarily contribute to water clarity to the same degree as filter feeding fishes (Fisheries WA 2002), but may play a significant role in maintaining the pond ecosystem.

7.1.4.2 Formation of sedimentary deltas within salt ponds

Migratory shorebird usage of deltas

Within the concentration ponds at the Port Hedland salt field, deltas have formed from the accumulation of fine sediments transported into the ponds by the pumping of tidal waters. The deltas support high densities of infauna and thereby attract a large number and diversity of migratory shorebirds (regularly up to 27 shorebird species) (LDM 1998, WABN 2021). Shorebird surveys conducted periodically since the early 1980s have identified the salt ponds as an important stop-over point for migratory shorebirds on the East Asia – Australian Flyway.

The Directory of Important Wetlands in Australia (ANCA 2005) has recognised the value to migratory shorebirds of the sedimentary deltas and shoreline habitats that have formed within the Port Hedland salt ponds. Within the “Human-made wetland” classification, ANCA (2005) identifies the Port Hedland saltworks as a nationally important wetland by meeting the following criteria:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance.

The Port Hedland saltworks are considered a “site of outstanding importance (up to 66,800 counted, national rank 8) for migrant shorebirds particularly during southward migration” (ANCA 2005). The number of waterbirds using the site annually is more than 20,000; allowing for onward movement of migrants, the number would probably exceed 50,000. The site supports at least 1% of the national populations of five abundant shorebird species, as well as the Mongolian plover (up to 668, WA rank 2), red-necked avocet (3000, national rank 10, WA rank 2), marsh sandpiper (500, national rank 4, WA rank 2), and broad-billed sandpiper (6000, national rank 1). The site also supports thousands of feeding Australian pelican, many of which are associated with a breeding colony on North Turtle Island in the Indian Ocean (ANCA 2005).

Birdlife Western Australia conducts annual migratory shorebird surveys at the Pond Hedland salt ponds and has identified that the estuarine ecosystems that have developed within the ponds are:

- A Key Biodiversity Area (KBA) for red-necked stint and sharp-tailed sandpiper because the saltworks support >1% of the world population for these species.
- Is the most important known Australian site for broad-billed sandpiper and the endangered Asian dowitcher (WABN 2019).

Birdlife Western Australia has also conducted annual migratory shorebird surveys at the Dampier saltworks since 2012 and these surveys have identified the area (particularly Pond 0 and Pond 1A) is a KBA as they support >1% of the world population for red-necked stint, curlew sandpiper and red-capped plover (WABN 2021).

Similarly, the importance of solar salt operations to shorebirds has been recognised in the recently released *Australian National Directory of Important Migratory Shorebird Habitat* (Weller et al. 2020). This report recognises the following existing salt operations as nationally important shorebird areas:

- Dampier Salt, Karratha
- Dampier Salt (formerly Leslie Salt or Cargill Salt), Port Hedland
- Onslow Salt

The nearby Onslow salt operation is described by the national directory as follows:

“Onslow is located in the southern extent of the Pilbara region in Western Australia, approximately 1,386 kilometres north of Perth. There is one major salt production facility in Onslow. The surrounding coastal environment is characterised by extensive areas of coastal intertidal sand flats and tidal creeks and inlets. There are several high tide roosting areas for shorebirds utilising the area, as well as significant areas of supratidal claypan. Most of these systems have been modified to control tidal inundation for the production of salt. The saltfield was built by enclosing a vast natural flat area facing the Indian Ocean with sea wall levees. The saltfield encompasses an area of 220 square kilometres, of which 87 square kilometres are occupied by operational ponds. The saltfield’s operational ponds are closely interconnected. They consist of six evaporation ponds of 77 square kilometres and 15 crystalliser ponds of 10 square kilometres. Seawater is pumped into the first evaporation pond, and brine flows through most of the evaporation ponds by gravity. Like other expansive salt evaporation facilities in the Pilbara region, the site continues to be a major migration stop-over area for shorebirds in the East Asia-Australasian Flyway. Despite the size of the site, and prevalence of a range of habitats for shorebirds, there is not much structured monitoring data available for the general area. With more data available the area would most likely identify as international significance for several species of migratory shorebird.”

On the basis of the information above, it is likely, that if developed, the Ashburton Salt Project would form additional valuable habitat for shorebirds to that existing at the nearby Onslow Salt operation and also be recognised in the future as internationally important shorebird habitat.

Mangrove and samphire colonisation within deltas

In addition to the transport of larval and juvenile crustaceans and fish into the primary concentration ponds via the seawater pumping, mangrove seeds (propagules) have also been entrained within the seawater and settled out within the sedimentary deltas and become established (Plate 38). As part of the mangrove monitoring and rehabilitation studies undertaken for the Port Hedland saltworks (LDM 1998), mapping of mangrove recruitment into the deltas (based on aerial photographs) calculated that approximately 19 ha of mangroves had colonised the deltas in the period between the commissioning of the concentration ponds in 1966, and 1993. Samphire are likely to follow a similar pattern colonising such deltas where the soil water conditions and salinity gradients become suitable for their growth.

Plate 38 Mangrove habitat established in a sedimentary delta within the Port Hedland salt ponds.

Plate 39 Mangroves and samphires occurring in a lower salinity seepage zone next to a tidal dam containing seawater. This area was previously devoid of mangroves due to high salinity conditions.

Seepage zones on tidal flats next to perimeter levees – mangrove recruitment and algal mat expansion

As indicated in Section 5.5.4.1 the combined effect of a dispersal barrier or mangrove propagule deposition zone (due to presence of a salt pond levee) and the low salinity conditions from the seepage of water from a primary concentration pond can provide conditions conducive for natural mangrove seedling recruitment and growth. A review of historical aerial photography, and an inspection of the mangroves growing next to the Port Hedland concentration ponds, indicated that mangrove habitat has formed in response to a seepage zone that developed following the construction of the levee and tidal dam in 1978 (LSC 1990). Established mangroves (3-4 m high) occupied a narrow strip parallel to, and up to 20-30 m out from, the levee (Plate 39). Prior to 1978, this area was samphire flat and it is likely that due to its tidal elevation, high groundwater salinities existed that precluded mangrove development; however, with the construction of the tidal dam, the seepage of lower salinity water provided suitable conditions for mangrove recruitment in a localised area.

The K+S proposed alignment of the CP1 and CP2 western levees is adjacent to the landward margins of algal mat distribution and, in some cases, the landward edge of the algal mats is intersected by the pond levees. Algal mat distribution is controlled by dehydration and salinity at the landward margins of mat distribution, and invertebrate fauna predation at the lower or seaward margins, close to the uppermost reaches of tidal creeks. Due to the differing salinities of water and brines to be contained within the various concentrator ponds, and also the crystalliser ponds, there is expected to be differing salinity gradients within seepage areas adjacent to each pond. Salinities in concentrator ponds CP1 and CP2 will be approximately 40 ppt and 60 ppt and hence the seepage from these ponds is likely to provide much lower salinity conditions than those currently experienced in algal mat and salt flat areas adjacent to the western levees. Such conditions may encourage the development of algal mats, or increased growth in peripheral algal mat areas near the levees, until their salinity tolerance is reached.

Section 5.5.2 provides modelling outputs showing predicted increases in water levels and submergence times in localised areas on tidal flats immediately next to the pond levees, due to the levees acting as a barrier to flooding tidal waters during spring tides. The areas where ponding may occur are largely on bare tidal flat or salt flat areas just landward of the algal mat zone and would currently only be inundated very infrequently during particular spring tides. As described above for the seepage zones, these areas would currently experience highly saline conditions that preclude algal mat growth, and the introduction of the lower salinity water (on this occasion from the ponding of tidal waters) may provide conducive conditions for enhancing peripheral algal mat areas or developing new algal mat areas.

7.2 Maintenance of Biological Diversity and Ecological Integrity

The EPA's environmental objective for this factor is to "protect BCH so that biological diversity and ecological integrity are maintained". In the context of this objective "ecological integrity" is listed as the composition, structure, function and processes of ecosystems and the natural range of variation of these elements (EPA 2016a). The discussion below summarises the predicted Project changes for key factors (scale of impacts, biodiversity, ecosystem productivity) and how those changes may influence biological diversity and ecological integrity.

7.2.1 Scale of impacts

7.2.1.1 Cumulative loss – LAUs and Eastern Exmouth Gulf

A summary of the cumulative loss estimates is provided in Table 11. As it has been assumed that there has been no historical loss of BCH, the cumulative loss estimates also represent the irreversible loss occurring from the Ashburton Salt Project. Assessment of direct and potential indirect impacts to BCH show a very small percentage of BCH loss within the LAUs (typically <1%) and when considered at the scale of Eastern Exmouth Gulf (<0.2%).

Table 11 Cumulative loss summary for the main BCH

Intertidal BCH Type	% of Intertidal LAU North	% of Tubridgi to Tent Pt	% of East Exmouth Gulf
Mangroves	0.79	0.11	0.04
Transitional Mud Flats	0.90	0.22	0.09
Algal Mats	0.50	0.27	0.14
Samphires	7.90	4.15	1.70
Sandy Beaches	0.77	0.33	0.10
Tidal Creeks	0.17	0.06	0.02
Total Intertidal BCH	**1.13**	**0.38**	**0.15**
Sub-tidal BCH Type	**% Total in Subtidal LAU**	**% Total in Study Area**	**% Total Exmouth Gulf**
Soft Sediment	4.7	2.45	
Macroalgae	5.8	3.28	
Macroalgae and Sparse Coral	0.94	0.82	
Total Subtidal BCH	**4.5**	**2.39**	**<0.01** [Note 1]

Table Note 1: Proportional loss of subtidal habitat within the Exmouth Gulf has been inferred by estimation using a proportional basis for nearshore areas of Exmouth Gulf.

It is not expected that habitat loss of these magnitudes could constitute a significant threat to the integrity or overall productivity of the marine ecosystem at the spatial scales of the LAUs or the Tubridgi Point to Tent Point coastal sector. A similar conclusion is made when consideration is given to the regional occurrence of habitats in the broader eastern Exmouth Gulf area, in which these same habitats are widely represented.

The small scale of impacts from the Project also needs to be considered in the context of natural cycles of destruction and recovery of large areas of intertidal BCH that occurred historically due to cyclones. Cyclones have the potential to radically alter the current coastline due to their erosive power and ability to rapidly mobilise sediments. Large scale destruction resulted from TC Vance in 1999 when approximately 5,700 ha of mangrove habitat was damaged on the eastern side of Exmouth Gulf. The authors of a paper documenting the extent of mangrove change caused by TC Vance noted that the scale of damage "exceeds any anthropogenic impact that has ever taken place in Western Australia by several orders of magnitude" (Paling, Kobyrn & Humphreys 2008). Regeneration and recovery of mangroves occurred in the years subsequent to TC Vance and it was estimated that by five years post-TC Vance, approximately 68% of mangrove habitat had returned to its former coverage.

In addition, it is of value to consider the duration and scale of impacts to BCH in the context of the resilience of mangrove systems to withstand, recover or adapt to potential human-related impacts. It should be noted that there is evidence in both the global and more local contexts that mangrove systems are highly resilient. In a discussion examining, in part, the fate of mangroves with global warming, Alongi (2008) reiterates that mangroves naturally exhibit a high degree of ecological persistence (i.e. constancy over time regardless of environmental perturbation) and resilience (the ability to recover from disturbance to some more or less persistent state, as described above for TC Vance). Over the last few thousand years for example, mangroves have undergone almost continual disturbance as a result of fluctuations in sea-level (Seashore Engineering 2021).

7.2.1.2 Cumulative loss – West Pilbara Coast

In the recent assessment of the Mardie Project, the EPA advised that all future salt proposals on the West Pilbara Coast (defined as the area from the bottom of the Exmouth gulf to Karratha) should include assessment of the potential regional and cumulative impacts to samphire, algal mat and mangrove habitat (EPA 2021).

A review of relevant EIA documents and mapping sources has been undertaken to provide a cumulative loss assessment for the West Pilbara Coast and place the relative scale of potential impacts from the Project within the regional context. Table 12 summarises data related to the mapped extent of habitats, cumulative loss from both existing and potential future impacts and the sources of impacts.

A review of relevant EIA documents and mapping sources has been undertaken to provide a cumulative loss assessment for the West Pilbara Coast and place the relative scale of potential impacts from the Ashburton Salt Project within the regional context. Table 14 summarises data related to the mapped extent of habitats, cumulative loss from both existing and potential future projects and the sources of impacts.

The estimate of the extent of mangroves (28,869 ha) occurring along the West Pilbara Coast was derived by sourcing:

- Detailed mapping for a total of 21,543 ha of mangroves covering 240 km of coastline.
- Less detailed mapping for a total of 7,326 ha of mangroves covering 110 km of coastline.

The estimate of the extent of algal mats (27,665 ha) occurring along the West Pilbara Coast was derived by sourcing:

- Detailed mapping for a total 18,173 ha of algal mats covering 230 km of coastline.
- Extrapolating the above algal mat distribution along the remainder of the West Pilbara Coast where detailed mapping has not occurred, for a total of 9,482 ha of algal mat covering 120 km of coastline.

The estimate of the extent of samphire (30,454 ha) occurring along the West Pilbara Coast was derived by sourcing:

- Detailed mapping for a total of 8,701 ha of samphire along 100 km of coastline.
- Extrapolating the above samphire distribution along the remainder of the West Pilbara Coast where detailed mapping has not occurred, for a total of 21,753 ha of samphire covering 250 km of coastline.

The cumulative loss estimates for mangroves, algal mat and samphire have been derived using:

- Historical and potential future losses as reported in EIA's and other sources as referenced in Table 12.
- Nominal or inferred historical losses of algal mats and samphire from coastal sectors for which no loss data is available have been derived by the extrapolating 50% of the extent of losses from those sectors of coast where loss data is available on a proportional basis using the length of coastal sectors (a conservative assumption given the unmapped coastline is largely undeveloped).

Given the scale of impacts to mangrove, algal mats and samphire predicted from the Ashburton Salt project, the contribution of these losses to cumulative losses for the West Pilbara Coast is very small. As a result of the Ashburton Salt Project, estimated cumulative losses would increase as follows:

- Mangroves
  - 3.96% without Ashburton Salt.
  - 3.98% with Ashburton Salt.
  - A difference of 0.02%
- Algal Mats
  - 6% without Ashburton Salt.
  - 6.06% with Ashburton Salt.
  - A difference of 0.06%
- Samphire
  - 8.39% without Ashburton Salt
  - 8.27% with Ashburton Salt
  - A difference of 0.12%.

Table 12 West Pilbara Coast cumulative loss assessment

Habitat	Method of Calculation	Coastal Sector	EIA/Data Source	Coastline Length (km)	Total Area (ha)	Cumulative Loss (ha)	% of Total Area With Project	% of Total Area Without Project	% Difference with & without Project
Mangroves	Detailed mapping	Exmouth Gulf East	Ashburton Salt – this report	100	11,742	4.3			
		Ashburton Delta-Onslow-Coolgra Point	Onslow Salt and Wheatstone LNG (URS, 2010)	50	1,450	6			
		Robe River Delta- Fortescue River Delta	Mardie Salt (Stantec, 2018), (EPA, 2021)	80	7,849	17			
		Cape Preston	Cape Preston Causeway (URS, 2008)	10	502	1			
		Detailed Mapping Sectors Total		*240*	*21,543*	*28*			
	Course mapping	Cape Preston East to Karratha	Dampier Salt Ponds (Gordon, 1987)	70	2,942	1,120			
		Global Mangrove Watch Data and satellite imagery Interpolation	Global Mangrove Watch (GMW, 2010)	40	4,384	-			
		Mangroves West Pilbara Coast Total		**350**	**28,869**	**1,148**	**3.98%**	**3.96%**	**0.02%**
Algal Mats	Detailed mapping	Exmouth Gulf East	Ashburton Salt – this report	100	11,617	16.7			
		Ashburton Delta-Onslow-Coolgra Point	Onslow Salt and Wheatstone LNG (URS, 2010)	50	2,012	432			
		Robe River Delta- Fortescue River Delta	Mardie Salt (Stantec, 2018), (EPA, 2021)	80	4,544	880			
		Detailed Mapping Sectors Total		*230*	*18,173*	*1,330*			
	Inferred	Remaining coastline - extrapolated from mapped sectors		120	9,482	347			
		Algal Mat West Pilbara Coast Total		**350**	**27,655**	**1,677**	**6.06%**	**6.00%**	**0.06%**
Samphire	Detailed mapping	Exmouth Gulf East (Mid-North Portion)	Ashburton Salt (Biota, 2005), (Biota, 2020)	60	2,141	36.45			

Habitat	Method of Calculation	Coastal Sector	EIA/Data Source	Coastline Length (km)	Total Area (ha)	Cumulative Loss (ha)	% of Total Area With Project	% of Total Area Without Project	% Difference with & without Project
		Wheatstone Plant Area	Onslow Salt and Wheatstone LNG (Biota, 2010)	8	2,449	686			
		Robe River Delta- Fortescue River Delta	Mardie Salt (Phoenix, 2020) (EPA, 2021)	32	4,111	346			
		Detailed Mapping Sectors Total		*100*	*8,701*	*1,068*			
	Inferred	Remaining coastline – extrapolated from mapped sectors		250	21,753	1,488			
		Samphire West Pilbara Coast Total		**350**	**30,454**	**2,556**	**8.39%**	**8.27%**	**0.12%**

7.2.2 Biodiversity and marine biogeography

Mangrove species recorded in the Project area are all expected to occur within other areas of the Exmouth Gulf. Three of the mangrove species recorded from the Project area, *Aegialitis annulata*, *Aegiceras corniculatum* and *Bruguiera exaristata*, have Exmouth Gulf as their southern range limit, with records of these species typically associated with more sheltered and complex mangrove creeks such as those near Tent Point (Biota 2005). The field survey undertaken for the Project recorded these three species in a similar setting in a sheltered side creek near the mouth of Urala Creek South. This area will not be directly affected by the Project and there is not expected to be any clearing of mangrove species at their range limits. The main, and possibly only, species to be impacted is *Avicennia marina* which is the dominant mangrove species on the Pilbara coast and has a wide distribution.

The mangrove zone is one of moderately high invertebrate fauna biodiversity and high primary productivity. A wide variety of invertebrates inhabit mangroves, dominated by molluscs, crustaceans and polychaetes. Most marine invertebrates and fish have planktonic larvae that live in the water column for periods ranging from a few days to a year or more. This is a distributional phase in the life cycle during which the larvae are moved about by currents and wave action. Longer-lived larvae are able to travel considerable distances, even across ocean basins. For example, four species of molluscs from South Africa are recorded to have reached the southwestern coast of Australia (Wells & Kilburn 1986) and other species are known to disperse over thousands of kilometres across the Atlantic and Pacific Oceans (Scheltema 1986a, 1986b, 1988). The planktonic distributional phase occurs in both intertidal and subtidal species. Even species that lack a planktonic distributional phase in their life cycle are able to move considerable distances by rafting on floating logs, *Sargassum* mats, etc. In general, marine plants also have mechanisms that allow their widespread distribution.

The net effect of the patterns of marine biogeography is that species in the Tubridgi Point to Tent Point area are generally distributed for thousands of kilometres along the northern Australian coastline, and into countries to the north such as Indonesia, Papua New Guinea and the Philippines (Wells 1990). Some species occur widely across the entire Indo-West Pacific. Relatively few species have restricted ranges, and those that do are on the scale of tens or hundreds of kilometres. Hence, due to their life cycle characteristics including larval and planktonic distributional phases, many intertidal and subtidal invertebrate species are widely distributed and it is not expected that any would be restricted to the Tubridgi Point to Tent Point area.

7.2.3 Productivity and nutrient cycles

Within Exmouth Gulf and the local project catchment, significant biological productivity occurs along the eastern seashore where a system of intertidal and vegetated nearshore areas generate migrations (e.g. of prawns and fish) and movement of organic material (detritus) supporting biological productivity further up the food chain.

Altering nutrient pathways, sources and sinks in intertidal and subtidal areas, has the potential to affect primary and secondary productivity. Local ecosystems are nitrogen limited. Therefore ensuring nitrogen flows into and out of key habitat types is not significantly affected by the proposed Project, is important to the ongoing health of these intertidal and subtidal ecosystems.

Water Technology (2021b) undertook a detailed Nutrient Pathways Assessment and Modelling study to:

- Develop a conceptual nutrient pathway model (descriptive diagram – Figure 12) and nutrient budget.
- Develop a numerical model simulating nutrient pathways related to tidal inundation and overland flows.
- Undertake project related impact assessment regarding nutrient pathways including:
  - Modelling impacts to tidal inundation and overland flow nutrient pathways.
  - Calculating nutrient loss, due to habitat loss.

The assessment focussed on nitrogen as previous studies and monitoring conducted for the project indicated it is the key limiting nutrient for local and regional marine and intertidal ecosystems.

The assessment was very conservative due to assumptions that were applied to nitrogen import and leaching rates, inundation and rainfall modelling and habitat modification calculations.

The full findings of the study are presented within a separate report by Water Technology (2021b). The study predicted small impacts to nutrient pathways in proportion to the total estimated nutrient flows into the project catchment and Exmouth Gulf. Water Technology (2021b) estimated:

- A local post-development proportional reduction in nitrogen flows into the project catchment of:
  - 7.7% of land sources.
  - 0.8% of land and ocean sources.
- A regional post-development proportional reduction in nitrogen flows into the Exmouth Gulf of:
  - 3.2% of land sources.
  - 0.24% of land and ocean sources.

Based on this highly conservative assessment, it can be concluded that the proposed development will not significantly alter nutrient exports or pathways due to the small scale of the predicted reductions and their infrequent nature, particularly when compared to the overall nitrogen budget of the Exmouth Gulf. Impacts related to nutrient pathways are not predicted to compromise existing environmental values including intertidal or subtidal BCH primary or secondary productivity.

7.2.4 Conclusions

The BCH assessments and associated modelling studies undertaken for this Project demonstrate that the EPA's environmental objective to "protect BCH so that biological diversity and ecological integrity are maintained" can be met with the implementation of appropriate management measures and monitoring plans. Key findings supporting this are:

- The scale of impacts to BCH are very low (typically <1% loss in LAUs,<0.2% loss in Exmouth Gulf and <0.1% West Pilbara Coast). Habitat losses of those magnitudes do not constitute a significant threat to the integrity or overall productivity of the intertidal and marine ecosystem.
- The extent of BCH loss from the Project is many orders of magnitude less than historical changes experienced from natural perturbations that have impacted Exmouth Gulf, from which the coastal and marine ecosystems have recovered, and/or adjusted from, without apparent reduction to biological diversity and ecological integrity.
- Potential indirect impacts to mangroves from the modification to tidal flows, pond-related seepage and modified groundwater conditions are largely avoided due to the location of the pond system and sufficient setback between the ponds and mangrove zone. This finding is supported by both the modelling studies and experience gained from other salt fields within similar settings on the Pilbara coast.
- While large areas of salt flat are to be covered by the Project footprint, the relative nutrient contribution from the salt flats is very low at local and regional scales. In addition, overland flows reaching coastal ecosystems via the salt flats can be maintained by incorporating measures (e.g. spillways, diversion channels) designed to re-direct overland flows around the pond system.
- In terms of biodiversity, when considering the regional distribution of habitats and marine biogeography, the diversity of mangrove species, algae species (within either algal mats or in subtidal habitats) and marine invertebrate fauna are likely to be well represented along the Pilbara coast and, as such, biodiversity is not expected to be impacted at either local or regional scales.
- Productivity modelling indicates that the proposed development will not significantly alter nutrient exports or pathways due to the small scale of the predicted reductions and their infrequent nature, particularly when compared to the overall nitrogen budget of the catchment and Exmouth Gulf. Impacts related to nutrient pathways are not predicted to compromise existing environmental values including intertidal or subtidal BCH primary or secondary productivity.

8.0 Project Constraints on Habitat Re-distribution from Sea Level Rise

This section assesses the response of intertidal and supratidal BCH to sea level rise and the potential impacts of the Project on this process. Predicting coastal response to sea level rise is not straightforward, as much of the understanding of coastal systems is based on observations from the 20th Century, or inference from recent millennia, which has involved a period of relative sea level stability. This limits available local evidence of processes active under rising sea levels, instead using of a global continuum of situations to guide a trajectory for the system's response, specifically through literature describing tidal network dependence on tidal prism. Recognising the complexity of these factors, and to assess how they may apply to the Tubridgi Point to Tent Point area, K+S commissioned a study by Seashore Engineering (2021) to understand the potential influence of the project on BCH response to sea level rise. This study provides an interpretation of anticipated changes to the adjacent coastal system from sea level rise and an evaluation of how these changes may be influenced by the proposed Project.

This section presents the results of the Seashore Engineering (2021 & 2022) assessments. It should be noted that predictions regarding the areas of BCH habitat which may be prevented from expanding by the Project have not been included with the cumulative loss calculations presented in Section 6.0 due to the extent of complexities involved and the uncertainties in the predictions regarding habitat migration and potential constraints of new habitat development by the project;

8.1 Description of Potential Impacts

General concepts regarding the potential responses of intertidal habitats to sea level rise include (Gilman et al. 2008):

- Landward expansion of habitats such as mangroves as environmental conditions suitable for recruitment and establishment into new areas become available. As mangrove species maintain their preferred hydroperiod (i.e. tidal inundation regime) they expand laterally into areas of higher elevation.
- Landward migration of the seaward edge of mangroves due to stresses caused by rising sea levels such as erosion and exposure to higher wave energies, and increased duration, frequency and depth of inundation.

The placement of pond infrastructure on expansive salt flats landward of the mangrove and algal mat zones therefore has the potential to modify sea level rise-related habitat distribution.

8.2 Assessment of Potential Impacts

An assessment of the effects of sea level rise on mangroves in Northwestern Australia (Semeniuk 1994) emphasises the need to understand a complexity of interacting factors related to the variable geomorphic, sedimentologic and hydrologic settings along the Western Australia coasts and mangrove population dynamics in the various climatic and habitat settings.

8.2.1 Intertidal and supratidal habitats and sea level change

Characteristic zonation of mangrove species within different tidal planes has led to a common practice of describing habitat according to hydroperiod (Crase et al. 2013) and implicitly suggesting mangroves will migrate with sea level. However, the association of plant and location is more complex. Despite individual mangroves being capable of occupying marginal locations, change to inundation patterns due to sea level rise is not expected to cause a directly correspondent change to mangrove distribution. Instead, suitable habitat is expected to change due to geomorphic response to sea level rise such as tidal channel expansion, within which mangrove-morphology interactions are a secondary, although not unimportant, process (van Maanen et al. 2015).

The main setting within which mangroves occur in the Urala Creek area is along tidal creeks where tidal flows provide suitable salinity conditions and support dispersion of mangrove propagules. The creek margins are highly dynamic, and creek networks may be subject to change in response to runoff flood events, marine inundation during storm events, tidal variability or mean sea level fluctuations (Perillo 2019).

Algal mats are comprised of opportunistic, highly persistent cyanobacteria which are able to take advantage of short-term benign conditions, such as seasonal rainfall or tidal inundation (Paling et al. 1989, Taukulis 2018). They may occur as a thin coating on surface sediments, or as a thick mat, comprised of multiple growth layers. Once developed, the algal mat helps to bind surface sediments and reduces permeability, potentially modifying local drainage and percolation pathways. Predictions regarding response of upper intertidal flats to sea level rise do not specifically account for algal mat interactions (Townend et al. 2011) but relate the predicted change to the distribution of tidal flows and disturbance events (Goodwin & Mudd 2019).

The opportunistic nature of algal mats and their capacity for nitrogen fixing suggests that their distribution is strongly related to hydroperiod. Consequently, inferred response to sea level rise is typically upward migration of the landward contour for existing algal mats (Seashore Engineering, 2021).

Samphire (*Teticornia spp*.) are perennial shrubs, with either a spreading or a more erect structure, up to 1 metre high. They are highly tolerant of saline and waterlogged conditions, commonly occurring as the first fringing community adjacent to the bare margins of salt lakes across Western Australia. Their shallow root structure determines that samphires are not bulwark species, preferentially occupying nearly flat land with infrequent bed disturbance – including effects of waves or bioturbation. Samphires mapped by Biota (2020a) within the Project area occur on the base of supratidal slopes at the supratidal/intertidal fringe, as well as in supratidal basins and channels upstream of where ephemeral drainage lines debouch onto the salt flats (at the salt flat hinterland fringe). Because samphire habitats have small coverage which is topographically controlled, future behaviour has been inferred via analysis of spatial distribution, tidal dynamics and sea level rise, as well as interpretation of the relationship to responses predicted for algal mats and mangroves. Samphire is anticipated to migrate under sea level rise, once sea level rise causes tidal inundation and bed mobility too frequent for samphire occupation. (Seashore Engineering, 2021).

8.2.2 Rationale for using tidal creek morphology and flux as a predictive tool for habitat re-distribution

Tidal creeks facilitate the exchange of water, nutrients and sediments between the expansive high tidal flat areas (including algal mats), mangrove and estuarine habitats and nearshore waters. Numerous small tidal creeks (sub-creeks) branch from the main Urala Creek channels and extend landward towards the broad tidal flats in which the Project is located (Section 2.2.2, Plates 3-8).

Tidal creeks serve as conduits for tidal flows into mangrove and algal mat areas and hence they play a determining role in maintaining suitable porewater salinities for their survival. Constraints provided by porewater salinities influence any anticipated response to sea level rise, such as the landward migration of mangroves and algal mats (Semeniuk 1994). The response of porewater salinity to sea level rise, which controls the mangrove-algal mat boundary, is not commonly simulated in predictive models, possibly due to greater reporting for the wet-dry tropics rather than arid settings. Processes contributing to porewater salinity include inundation, evaporation, infiltration, and drainage (Figure 28). In the arid west Pilbara setting, the extreme evaporation rates provide opportunity for an infiltration and desiccation sequence where there is substantially less water leaving the salt flats on the ebb tide than arrives on a flood tide. In some cases, shallow flooding moves onto the flats and does not return at all. Repeated flood events consequently result in an accumulation of porewater salinity.

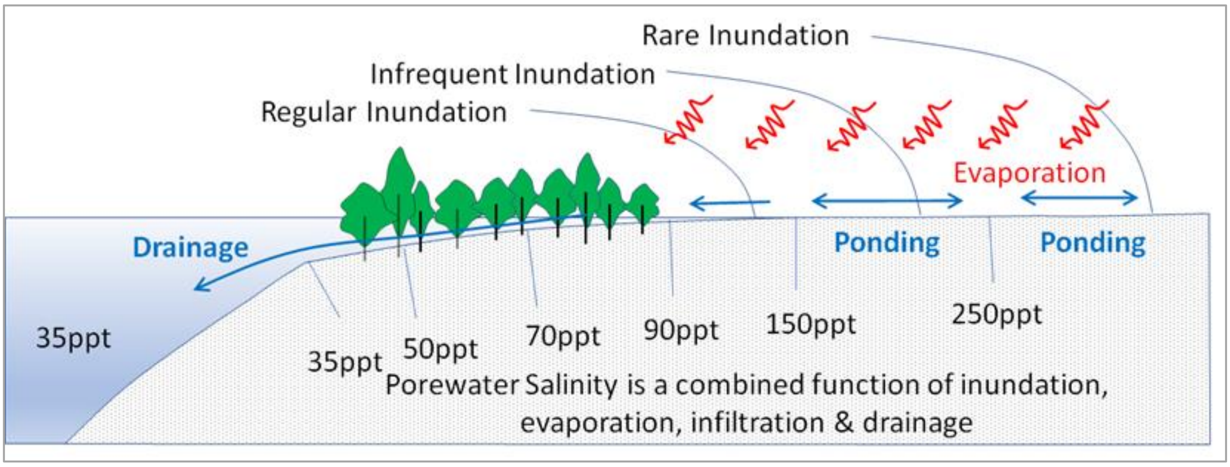


Figure 28 Factors controlling porewater salinity (Seashore Engineering, 2021)

In recognition of the role played by tidal creeks in controlling tidal flows, and ultimately habitat distribution, the approach of the Seashore Engineering (2021) study was to assess the variation of physical attributes of the tidal channel network and to explore how creek morphology changes with different volumes of tidal exchange. Consequently, changes in tidal exchange caused by sea level rise were used as a basis for predicting future morphodynamic and intertidal habitat response.

8.2.3 Tidal creek analysis and predicted changes due to sea level rise

LIDAR data were used to analyse the tidal channel network and develop an understanding of how the channels vary in dimension due to differences in tidal exchange. For each of seven primary channels, 31 secondary channels and 55 tertiary channels, the following morphometric characteristics were determined:

- Channel lengths and distance to the mouth.
- Contributing area, based upon approximate watershed lines between creeks.
- Hypsometric distribution, which describes the area occurring at different topographic levels.
- Relative areas of mangrove and algal mat.
- Sinuosity of the tidal creek structure.

Evaluation of sea level rise impacts has been undertaken using a widely used summary of projected sea level rise developed for coastal planning in Western Australia (Department of Transport 2010). This recommends a single forecast curve for sea level allowances, based on IPCC model projections:

- Allowance for 0.4 m of sea level rise over the next 50 years (by ~2070).
- Allowance for 0.9 m of sea level rise over the next 100 years (by ~2110).
- Sea level rise is projected to accelerate, with a rate of 8 mm per year reached by 2040-2050 and 12 mm per year reached by 2070-2080.

These data, together with modelled tidal flows (Water Technology 2021a) and information on sediment dynamics, were used to predict habitat response of mangroves and algal mats to sea level rise inland of Tubridgi Point.

8.2.4 Predicted response to sea level rise with and without the Project

Predicted effects of sea level rise on mangroves, algal mats and samphire with and without the proposed Project are summarised in Figure 29 below.

The Project is not expected to substantially affect the health or distribution of existing intertidal habitats. However, it will modify the development of some of the new potential mangrove and algal mat areas that would otherwise be expected to occur in response to low rates of sea level rise (before ~2050). After this point, increasing inundation and rates of sea level rise will lead to mangrove loss and stabilisation of algal mat areas with no new algal mat areas being developed (Seashore Engineering, 2021).

The Project will not substantially affect the health or distribution of samphire at the base of supratidal upslopes, which is predicted to contract under sea level rise until 2070, after which increasing rates of sea level rise are likely to lead to loss of this samphire (Seashore Engineering, 2021).

The Project will likely bring forward the salinisation of the supratidal basin/channel samphire areas occurring at the salt flat hinterland fringe, as embankments will cause an increase in tidal inundation frequency of these areas. Salinisation of these areas would occur under sea level rise by 2070 without the project in place and would be brought forward to 2055 with the project in place. However after this point increasing inundation and rates of sea level rise will lead to samphire loss with or without the project in place (Seashore Engineering, 2021).

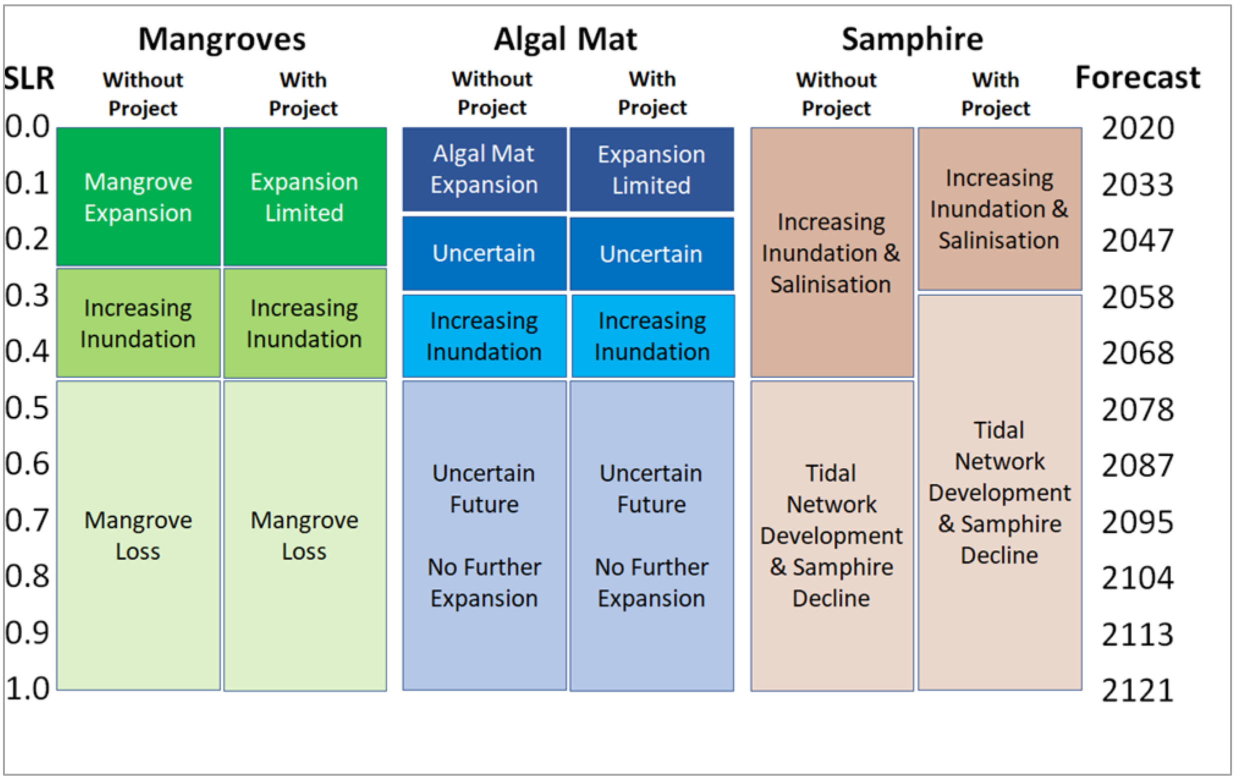


Figure 29 Mangrove, algal mat and samphire response to sea level rise with and without Project (Seashore Engineering, 2021)

8.2.5 Projection of future habitat areas and potential constraint by project

Seashore Engineering (2022) has used conceptual models developed for the response of mangrove and algal mats to sea level rise to estimate projections of habitat change related to the project. Area estimates were derived for sea level rise up to 2120 for scenarios both with and without the project. While substantial mangrove habitat loss due to sea level rise is predicted to occur beyond 2060 (with or without the project) this evaluation provides data on the relative extent of potential constraint from the project on habitat development at the scale of the study area (i.e. combined area occupied by both Intertidal LAUs) and the broader Exmouth Gulf East area over both shorter (next 50 years) and longer (next 100 years) timeframes.

Data on mangrove and algal mat habitat area estimates for the study area provided in Seashore Engineering (2022) have been extrapolated on a proportional basis to derive estimates for Exmouth Gulf East. The area estimates for the study area and Exmouth Gulf East provided are:

- Areas (ha) of mangrove and algal mat habitat from 2010-2120 both with and without the project, the reduction in habitat area due to the project and the percentage reduction due to the project (Table 13 for mangroves; Table 16 for algal mats).
- Net change (ha) and percentage net change in mangrove areas since 2010 both with and without the project, and the difference in percentage net change since 2010 due to the project. (Table 14).

The 2010 habitat areas used in this assessment align with areas shown in Table 10 (BCH Cumulative Loss Assessment) as the “Pre-European Extent” and “Current Extent” and represent baseline areas against which sea level rise related habitat area changes and project related constraint on habitat development are compared.

In addition to the assessment based on spatial metrics, consideration is also given to the impact on productivity from sea level rise and the potential project related constraints on new habitat development. Table 15 provides an assessment of changes to mangrove primary productivity in the study area and Exmouth Gulf East over the period 2010-2120 using primary production estimates for the mangrove *Avicennia marina* (2,350 g C m^{-2} $year^{-1}$ from Alongi et al. 2003) and the habitat areas shown in Table 13.

Seashore Engineering (2022) note that the projections of habitat change are sensitive to assumptions, including the forecast sea level curve and that the “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”.

Key findings related to the predicted areas of mangrove and algal mat habitat are:

Mangroves

- For the study area, mangrove habitat will expand from 2,185 ha to 2,468 ha by 2050 and then decrease to 1,394 ha by 2120. Constraint on new habitat development due to the project will reduce these areas by 140 ha (-5.6%) in 2050 and 40 ha (-2.9%) in 2120 (Table 13).
- For Exmouth Gulf East, mangrove habitat will expand from 11,742 ha to 13,263 ha by 2050 and then decrease to 7,491 ha by 2120. Constraint on new habitat development due to the project represents -1.0% in 2050 and -0.5% in 2120 (Table 13).
- For the study area, net changes to mangrove habitat since 2010 include an expansion of 283 ha (13%) by 2050 and a decrease of 791 ha (-36.2%) by 2120. Constraint on new habitat development due to the project will modify these net changes by -6.4% in 2050 and -1.8% in 2120 (Table 14).
- For the Exmouth Gulf East, net changes to mangrove habitat since 2010 include an expansion of 1,521 ha (13%) by 2050 and a decrease of 4,251 ha (-36.2%) by 2120. Constraint on new habitat development due to the project will modify these net changes by -1.2% in 2050 and -0.3% in 2120 (Table 14) .
- For the study area, mangrove primary productivity will increase from 51,348 to 57,998 Tonnes C m^{-2} yr^{-1} ha by 2050 and then decrease to 32,759 Tonnes C m^{-2} by 2120. Constraint on new habitat development due to the project will reduce productivity by 3,267 Tonnes C m^{-2} (-5.6%) in 2050 and 940 Tonnes C m^{-2} (-2.9%) in 2120 (Table 15).
- For Exmouth Gulf East, mangrove primary productivity will increase from 275,937 to 311,676 Tonnes C m^{-2} yr^{-1} ha by 2050 and then decrease to 176,044 Tonnes C m^{-2} by 2120. Constraint on new habitat development due to the project will reduce productivity by -1.0% in 2050 and -0.5% in 2120 (Table 15).

Algal mats

- For the study area, algal mat habitat will expand from 5,384 ha to 11,197 ha (108%) by 2060 and then not expand any further. Constraint on new habitat development due to the project will reduce this area by 563 ha (-5.0%)(Table 16) .
- For Exmouth Gulf East, algal mat habitat will expand from 11,617 ha to 24,160 ha by 2060 and then not expand any further. Constraint on new habitat development due to the project will reduce this area by 563 ha (-2.3%) (Table 16).

Table 13 Changes in mangrove areas due to sea level rise and potential constraint from project

Year	Sea Level Rise (m)	Mangrove Area (ha) Without Project		Mangrove Area (ha) With Project		Reduction in Area (ha) Due to Project	% Reduction in Area Due to Project	
		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf		Study Area	East Exmouth Gulf
2010	0.00	2,185	11,742	2,185	11,742	0	0.0	0.0
2020	0.04	2,261	12,150	2,224	12,113	-37	-1.6	-0.3
2030	0.09	2,341	12,580	2,265	12,504	-76	-3.2	-0.6
2040	0.15	2,420	13,005	2,305	12,890	-115	-4.8	-0.9
2050	0.22	2,468	13,263	2,329	13,124	-139	-5.6	-1.0
2060	0.31	2,408	12,940	2,291	12,823	-117	-4.9	-0.9
2070	0.41	2,277	12,236	2,210	12,169	-67	-2.9	-0.5
2080	0.52	2,104	11,307	2,064	11,267	-40	-1.9	-0.4
2090	0.64	1,924	10,339	1,884	10,299	-40	-2.1	-0.4
2100	0.76	1,744	9,372	1,704	9,332	-40	-2.3	-0.4
2110	0.88	1,567	8,421	1,527	8,381	-40	-2.6	-0.5
2120	1.00	1,394	7,491	1,354	7,451	-40	-2.9	-0.5

Table 14 Net changes to mangrove areas since 2010 due to sea level rise and constraint from project

Year	Sea Level Rise (m)	Mangrove Area (ha) Without Project		Mangrove Area (ha) Without Project		% Nett Change in Area Since 2010 Without Project	% Nett Change in Area Since 2010 with Project		Difference in % Nett Change Since 2010 Due to Project	
		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf
2010	0.00	0	0	0	0	0	0	0	0	0
2020	0.04	76	408	39	371	3.5	1.8	3.2	-1.7	-0.3
2030	0.09	156	838	80	762	7.1	3.7	6.5	-3.5	-0.6
2040	0.15	235	1,263	120	1,148	10.8	5.5	9.8	-5.3	-1.0
2050	0.22	283	1,521	144	1,382	13.0	6.6	11.8	-6.4	-1.2
2060	0.31	223	1,198	106	1,081	10.2	4.9	9.2	-5.4	-1.0
2070	0.41	92	494	25	427	4.2	1.1	3.6	-3.1	-0.6
2080	0.52	-81	-435	-121	-475	-3.7	-5.5	-4.0	-1.8	-0.3
2090	0.64	-261	-1,403	-301	-1,443	-11.9	-13.8	-12.3	-1.8	-0.3

Year	Sea Level Rise (m)	Mangrove Area (ha) Without Project		Mangrove Area (ha) Without Project		% Nett Change in Area Since 2010 Without Project	% Nett Change in Area Since 2010 with Project		Difference in % Nett Change Since 2010 Due to Project	
		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf
2100	0.76	-441	-2,370	-481	-2,410	-20.2	-22.0	-20.5	-1.8	-0.3
2110	0.88	-618	-3,321	-658	-3,361	-28.3	-30.1	-28.6	-1.8	-0.3
2120	1.00	-791	-4,251	-831	-4,291	-36.2	-38.0	-36.5	-1.8	-0.3

Table 15 Changes in mangrove primary productivity (Tonnes C m^{-2} year^{-1}) due to SLR and potential constraint from project

Year	Sea Level Rise (m)	Mangrove Productivity Without Project		Mangrove Productivity With Project		Reduction in Productivity Due to Project	% Reduction in Productivity Due to Project	
		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf		Study Area	East Exmouth Gulf
2010	0.00	51,348	275,937	51,348	275,937	0	0.0	0.0
2020	0.04	53,134	285,535	52,264	284,665	-870	-1.6	-0.3
2030	0.09	55,014	295,638	53,228	293,852	-1,786	-3.2	-0.6
2040	0.15	56,870	305,614	54,168	302,912	-2,703	-4.8	-0.9
2050	0.22	57,998	311,676	54,732	308,410	-3,267	-5.6	-1.0
2060	0.31	56,588	304,099	53,839	301,349	-2,750	-4.9	-0.9
2070	0.41	53,510	287,555	51,935	285,981	-1,575	-2.9	-0.5
2080	0.52	49,444	265,708	48,504	264,768	-940	-1.9	-0.4
2090	0.64	45,214	242,976	44,274	242,036	-940	-2.1	-0.4
2100	0.76	40,984	220,244	40,044	219,304	-940	-2.3	-0.4
2110	0.88	36,825	197,892	35,885	196,952	-940	-2.6	-0.5
2120	1.00	32,759	176,044	31,819	175,104	-940	-2.9	-0.5

Table 16 Changes in algal mat areas due to sea level rise and potential constraint from project

Year	Sea level rise (m)	Algal mat area (ha) without project		Algal mat area (ha) with project		Reduction in area (ha) due to project	% Reduction in area due to project	
		Study Area	East Exmouth Gulf	Study Area	East Exmouth Gulf		Study Area	East Exmouth Gulf
2010	0.00	5,384	11,617	5,384	11,617	0	0.0	0.0
2020	0.04	6,384	13,775	6,287	13,678	-97	-1.5	-0.7
2030	0.09	7,500	16,183	7,295	15,978	-205	-2.7	-1.3
2040	0.15	8,755	18,891	8,429	18,565	-326	-3.7	-1.7
2050	0.22	10,383	22,403	9,899	21,919	-484	-4.7	-2.2
2060	0.31	11,197	24,160	10,634	23,597	-563	-5.0	-2.3
2070	0.41	11,197	24,160	10,634	23,597	-563	-5.0	-2.3
2080	0.52	11,197	24,160	10,634	23,597	-563	-5.0	-2.3
2090	0.64	11,197	24,160	10,634	23,597	-563	-5.0	-2.3
2100	0.76	11,197	24,160	10,634	23,597	-563	-5.0	-2.3
2110	0.88	11,197	24,160	10,634	23,597	-563	-5.0	-2.3
2120	1.00	11,197	24,160	10,634	23,597	-563	-5.0	-2.3

8.3 Mitigation Measures

The effects of sea level rise will occur with or without the project in place. As climate change is a global issue, mitigation of this global issue by an individual Project is not possible. However, the Project is proposing to minimise its generation of greenhouse emissions so as not to contribute significantly to climate change.

In addition, the ability of the Project to support ongoing habitat for algal mat and mangroves as a part of Project closure will be explored as part of Closure Planning for the site. An initial closure plan has been developed for the project and will continue to evolve during the life of the project. K+S preferred post closure land use is to leave the evaporation ponds in situ so that they become a “wetland” habitat for mangroves, algal mats, samphire and associated fauna (including migratory birds which require “wetland areas” for migratory stop over).

At the completion of operations, all building and structures will be removed from the site and the pond areas may be selectively reconnected to the existing tidal flat system. If ponds are to be reconnected, the closure plan will establish which bunds to breach that will enable inwards tidal movement bringing sediments and allowing tidal channels to expand naturally. Natural tidal flows will allow movement of mangrove propagules (seeds) material which will passively revegetate the reconnected tidal areas. This will enhance the habitat values of the ponds to BCH and fauna post closure. The effect of sea level rise will be considered during the closure planning process and it may be possible to create a “niche” environment for mangroves and/or algal mats which may enable them to continue to exist in conjunction with the sea level rise changes to habitat distribution discussed in Section 8.2

8.4 Predicted Outcome

Substantial changes are predicted to occur to intertidal habitats due to sea level rise both in the study area and broader Exmouth Gulf East area(i.e. with or without the project). Net changes to mangrove habitat include an expansion of 13% by 2050 and a decrease of -36.2% by 2120. Net changes to algal mat habitat are an expansion of 108% by 2060 and then stabilisation. For Exmouth Gulf East these changes related to sea level rise represent large areas (several thousand hectares) of mangrove and algal mat habitat.

Seashore Engineering (20220 has identified that some areas of new habitat associated with sea level rise may potentially be constrained from developing due to project infrastructure by either modification to sea level rise related increases in tidal exchange (in the case of mangroves) or from the presence of the salt ponds being in areas that algal mats may expand in to.

For mangroves the constraint of new habitat development from the project is 140 ha in 2050 and 40 ha in 2120, this representing net changes -6.4% and -1.8% respectively for the study area and -1.2% and -0.3% for Exmouth Gulf East. For algal mats, the maximum constraint of new habitat development from the project is 563 ha in 2050, this representing a potential reduction of -5.0% for the study area and -2.3% for Exmouth Gulf East.

Given the magnitude of changes to habitat distribution that are predicted to occur from sea level rise (i.e. the extent of changes that will occur without the project) and the small proportions of habitat that maybe potentially constrained by the project at either the scale of the study area or Exmouth Gulf East, it is unlikely that they represent significant potential impacts or constitute a significant threat to the integrity or overall productivity of the intertidal and marine ecosystem.

The Project is positioned to consider the creation of ongoing habitat for algal mat and mangroves as a part of Project closure and this will be explored as part of Closure Planning for the site. K+S preferred post closure land use is to leave the evaporation ponds in situ so that they become a “wetland” habitat for mangroves, algal mats and associated fauna (including migratory birds which require “wetland areas” for migratory stop over). This will also likely create habitat opportunities for the survival of mangroves and/or algal mats.

At the completion of operations, all building and structures will be removed from the site and the pond areas may be selectively reconnected to the existing tidal flat system. If ponds are to be reconnected, the closure plan will establish which bunds to breach that will enable inwards tidal movement bringing sediments and allowing tidal channels to expand naturally. Natural tidal flows will allow movement of mangrove plant and seed material which will passively revegetate the reconnected tidal areas. This will enhance the habitat values of the ponds to BCH and fauna post closure.

The areas of potential constraint in new habitat development identified by Seashore Engineering (2021 & 2022) should be considered in the context of the area of habitat creation that could potentially be developed by the Project post closure. There is the potential that large areas of the evaporation ponds (which total 9,000 ha) could, with appropriate post closure works, become functioning intertidal habitat hosting both mangroves and algal mats, possibly with greater resilience to sea level rise than the existing intertidal habitats predicted to be progressively lost due to the rate of sea level rise with or without the project in place.

Therefore it is considered that the Project will not significantly impact the long term response of key intertidal habitats to sea level rise. In addition, the Project may be able to create a habitat niche as part of Project closure which could offer ongoing survival opportunities for mangroves and/or algal mat.

9.0 Conservation Significance

9.1 Wetland of National Importance

The proposed development is located within the Exmouth Gulf East wetland (WA007) which is listed in A Directory of Important Wetlands in Australia (ANCA 1993) (Figure 30). The Directory describes the significance of the wetland as "An outstanding example of tidal wetland systems of low coast of northwest Australia, with well-developed tidal creeks, extensive mangrove swamps and broad saline coastal flats". The criteria for listing the wetland are:

- It is a good example of a wetland type occurring within a biogeographic region in Australia.
- It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex. Specifically, the mangroves buffer the coast from erosion, especially during cyclones, which occur in this area in most years.
- It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles. Specifically, the site is one of the major population centres for dugongs in WA and its seagrass beds and extensive mangroves provide nursery and feeding areas for marine fishes and crustaceans in the Exmouth Gulf (ANCA 2005).

9.2 Guidance Statement for the Protection of Tropical Arid Zone Mangroves Along the Pilbara Coastline (EPA Guidance Statement No. 1, May 2001)

The EPA Guidance Statement (GS No. 1) for protection of tropical mangroves along the Pilbara coastline (EPA 2001) identifies areas that support arid zone mangroves that have special conservation significance. It also sets out the EPA's expectations for the protection of mangroves, while recognising current and potential future development areas. The proposed project coincides with an area designated within the GS No. 1 as 'Area 2 - Exmouth East Shore' (Giralia Bay to Yanrey Flats - Figure 30).

The guidelines contained in GS No. 1 are based on a study by Semeniuk (1997) to identify areas of regionally significant mangrove areas. This study recognised the "diversity of coastal types, diversity of habitats within a given coastal setting and diversity within habitat as factors leading to the heterogeneity of mangrove types along the Pilbara Coast and thus explicitly linked mangroves to geomorphic setting and habitats as a basis for their selection for conservation" (Brocx 2008). In the report 'Selection of Mangrove Stands for Conservation in the Pilbara Region of Western Australia - A Discussion' (Semeniuk 1997), the following information is provided about 'Area 2 - Exmouth East Shore' (Giralia Bay to Yanrey Flats - Figure 30).

"The areas encompassing Giralia Bay and Yanrey Flats along the eastern shore of Exmouth Gulf is located in the southwestern most part of the Pilbara Coast. It comprises large expanses of tidal flats and seaward fringing mangroves. Technically, the east shore of Exmouth Gulf is part of the Yanrey River delta, but it also contains some local limestone barrier islands (Simpson Island, Burnside Island and Tent Island). Though it is not diverse in terms of habitats, it represents, within Exmouth Gulf, a widespread and important mangrove system in that it exhibits insular-peninsular tidal flat topography and tidal creek networks, and a large scale continuous tidal flat mangrove formation. In regional terms, it is an important location for the fisheries of Exmouth Gulf. Throughout the main belt of mangroves there is a recurring pattern of two mangrove species, viz., *Avicennia marina* and *Rhizophora stylosa.* The tidal creek networks in the system provide some diversity of habitats, such as creek banks, point bars and shoals, where a larger range of mangroves occur (*Avicennia marina, Rhizophora stylosa, Aegialitis annulata* and *Aegiceras corniculatum).*The barrier limestone islands in the system provide some diversity of habitats, such as spits, beaches and limestone cliffs, in addition to tidal flats, and here the full range of six species of mangrove occur *(Aegialitis annulata, Aegiceras corniculatum, Avicennia marina, Bruguiera exaristata, Ceriops tagal* and *Rhizophora stylosa)"* (Semeniuk 1997a).

The five criteria below were used by Semeniuk (1997a) to select "Category A" (i.e. high conservation) areas and the key features of selected areas were assessed with respect to these criteria. The Ashburton River Delta was assessed as satisfying criteria one and four.

1. Representation of a coastal type and its accompanying mangroves.
2. Globally unique mangrove habitats and their assemblages.
3. Scientifically explicit mangrove/habitat relationships.
4. Clear and distinct examples of mangrove assemblages floristically.
5. Clear and distinct examples of mangrove assemblages structurally.

Within the GS No. 1 framework, ‘Area 2 - Exmouth East Shore’ is identified as being a Guideline 1 area of very high conservation value and “regionally significant” (Figure 30). It should be noted that the boundary of ‘Area 2 - Exmouth East Shore’ within GS No. 1 is only broadly defined and was based on the source document (Semeniuk 1997a) which provided a map at a scale of 1:1,000,000 showing the Pilbara coast and approximate boundaries of the 22 areas selected as “Category A” (i.e. high conservation) areas.

The EPA’s operational objective for GS No. 1 management areas is that no development should take place that would adversely affect the mangrove habitat, the ecological function of these areas and the maintenance of ecological processes which sustain the mangrove habitats.

GS No. 1 also states that the EPA will give these mangrove formations the highest degree of protection with respect to geographical distribution, biodiversity, productivity and ecological function.

9.3 Impacts to conservation significance of ‘Exmouth Gulf East Wetland’ and ‘Exmouth East Shore Mangrove Management Area’

In addition to providing the direct loss estimates for BCH within the proposed LAUs, Table 7 in Section 5.5.1 provides the loss estimates in the context of the overall eastern section of Exmouth Gulf, a similar area to that encompassed within Area 2 - Exmouth East Shore of GS No. 1 (EPA 2001) and the Exmouth Gulf East wetland (WA007) listed in ANCA (1993).

When considering the assessment undertaken in previous sections, the following key points support the conclusion that the Project does not threaten ecological function, biodiversity, productivity or conservation significance on a local or regional basis:

- The majority of the Ashburton Salt Project is located outside of the mangrove and algal mat zones. The location and design of the proposed Project is predicted to result in a very low scale of impacts to mangroves (<0.1%) and algal mats (<0.2%) within the eastern Exmouth Gulf area (Table 7, Figure 31).
- Tidal flows that are predominantly responsible for mangrove ecosystem maintenance are not impacted in either the Tubridgi Point - Urala Creek area or broader eastern Exmouth Gulf area.
- Sedimentation patterns are also likely to be maintained, so erosion and deposition within mangrove and tidal flats habitats is predicted to be within natural variation.
- Significant impacts to nutrient pathways, sources or sinks in the context of the local catchment or Exmouth Gulf are not predicted.
- Key geomorphic features within the eastern Exmouth Gulf, such as the Yanrey River Delta and the barrier islands of Tent Point and Tubridgi Point, will not be impacted.
- Overland flows from the Yanrey River Delta to the tidal flats and estuarine wetland system of eastern Exmouth Gulf will not be modified by the Project.

The functioning and ecological productivity of ‘Exmouth Gulf East wetland (WA007)’ and ‘Area 2 – Exmouth East Shore’ is reliant on expansive areas of mangroves and algal mats that are predicted to be subject to substantial changes in habitat area (both increases and decreases) in the future due to sea level rise. These changes that will occur with or without the project, represent several thousand hectares of mangrove and algal mat habitat and, in the case of mangroves, includes a loss of approximately 4,000 ha (or -36%) predicted to occur by 2120 (see Section 8.2.5).

Seashore Engineering (2022) has identified that some areas of new habitat associated with sea level rise may potentially be constrained from developing due to project infrastructure by either modification to sea level rise related increases in tidal exchange (in the case of mangroves) or from the location of salt ponds in areas that algal mats may expand in to. Given the magnitude of changes predicted to occur from sea level rise (i.e. the extent of changes that will occur with or without the project) and the small proportions of habitat that maybe potentially constrained by the project, it is unlikely that they represent significant potential impacts or constitute a significant threat to the integrity or overall productivity of the intertidal and marine ecosystem.

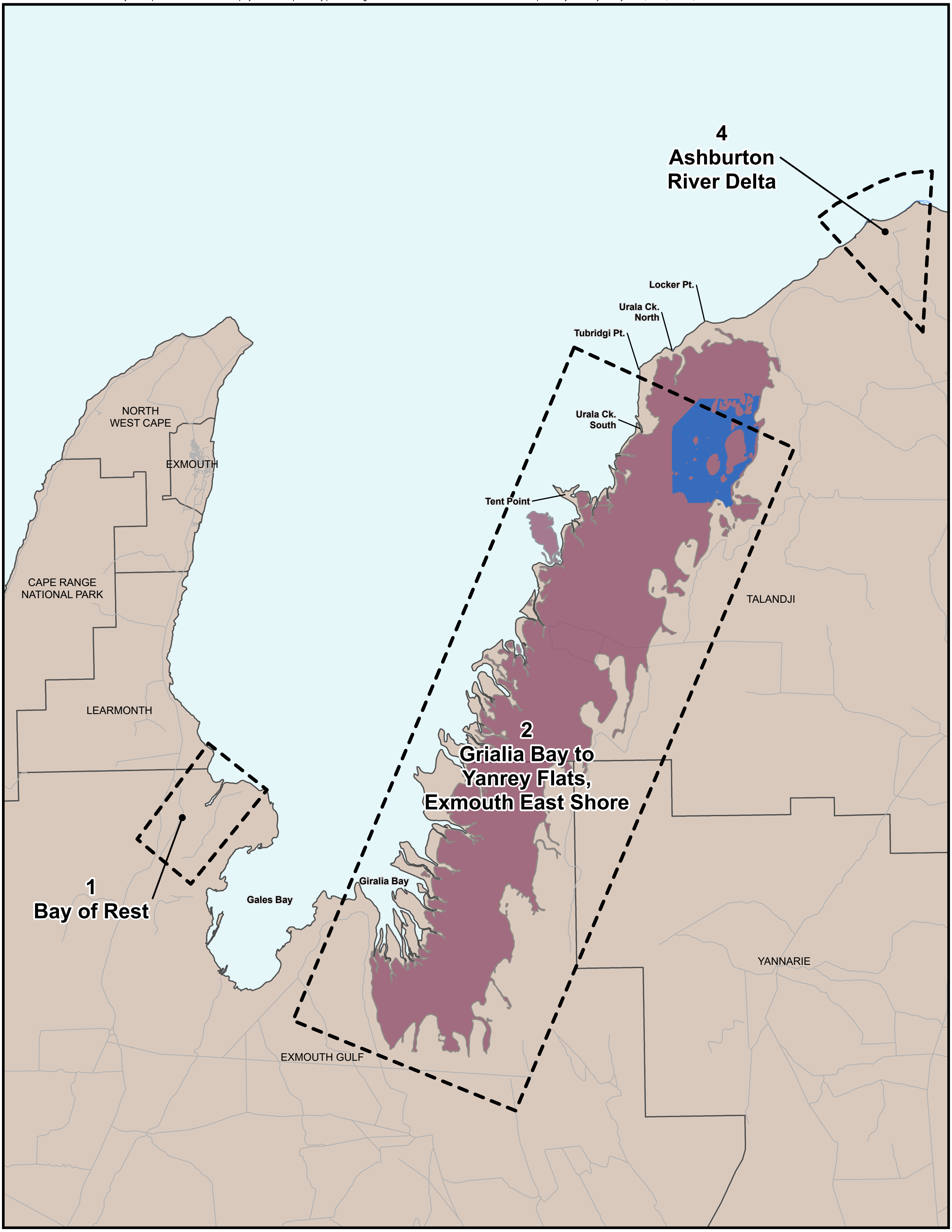
At the completion of operations, all building and structures will be removed from the site and the pond areas may be selectively reconnected to the existing tidal flat system. If ponds are to be reconnected, the closure plan will establish which bunds to breach that will enable inwards tidal movement bringing sediments and allowing tidal channels to expand naturally. Natural tidal flows will allow movement of mangrove propagules (seeds) which will passively revegetate the reconnected tidal areas. This will enhance the habitat values of the ponds post closure.

Other salt operations worldwide have similar closure plans in recognition of the important intertidal, benthic and fauna habitat that salt ponds create. One example is the Dry Creek Salt field (approximately 5000 ha in size) which is in closure stage after operating in Adelaide since the late 1930s. The Dry Creek Salt field has recently demonstrated a successful tidal reconnection trial for one of its salt evaporation ponds (38 ha in size) (Mosley et al. 2019).

The total area of salt evaporation ponds proposed by the Ashburton Salt Project is almost 9,000 ha. There is the potential that large areas of the evaporation ponds could, with appropriate post closure works, become functioning intertidal habitat hosting both mangroves and algal mats, possibly with greater resilience to sea level rise than the existing intertidal habitats, some of which are predicted to be progressively lost due to the rate of sea level rise, with or without the project in place.

Within the concentration ponds at the Port Hedland salt field, deltas have formed from the accumulation of fine sediments transported into the ponds by the pumping of tidal waters. The deltas support high densities of infauna and thereby attract a large number and diversity of migratory shorebirds (regularly up to 27 shorebird species) (LDM 1998, WABN 2021). It is likely, that if developed, the Ashburton Salt Project would form additional valuable habitat for shorebirds to that existing at the nearby Onslow Salt operation and also be recognised in the future as internationally important shorebird habitat.

In the long term, man-made salt pond habitats have the potential to augment the existing natural intertidal wetland and mangrove habitats within the ‘Exmouth Gulf East wetland (WA007)’ and ‘Area 2 – Exmouth East Shore MMA’, some of which are predicted to be lost due to sea level rise. This potential outcome is aligned with GS No. 1, which promotes providing the Exmouth East Shore MMA the highest degree of protection with respect to geographical distribution, biodiversity, productivity and ecological function.



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY A.BOUGHER
LAST MODIFIED 10 SEP 2021

AECOM
www.aecom.com

DATUM

N

1:600,000
(when printed at A4)

0 3 6 9 12
Kilometers

Data sources:

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).Geoscience Australia, Streetpro

LEGEND

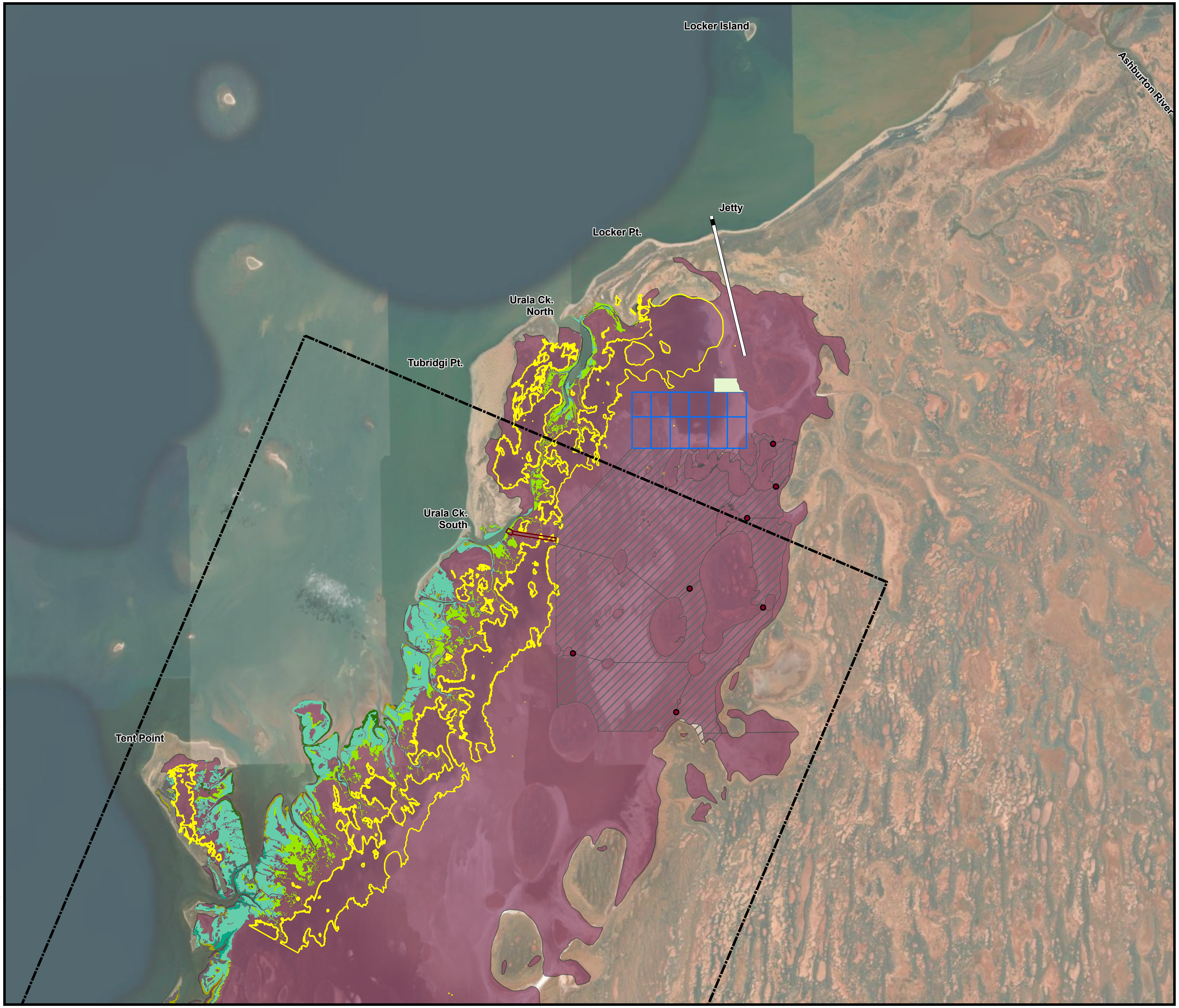
- Project Location
- Nationally Important Wetland (Exmouth Gulf East Wetland)
- EPA GS1 Mangrove Management Boundaries
- Road

Wetland of National Importance and EPA GS1 Exmouth Shore East area

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
30



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY ABougher
LAST MODIFIED 10 SEP 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 2 4 6 8
Kilometers

1:160,000 (when printed at A3)

LEGEND

- Jetty Alignment
- Conveyor
- GS1 Exmouth East Shore Mangrove Management Boundary
- Pond Layout Gates (Option 8)
- Bittens Pond (Option 8)
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Embankment (Option 8)
- Nationally Important Wetland (Exmouth Gulf East Wetland)
- Algal Mat Mapping (2019)

MangroveCo, Descriptio

- AM1:Tall dense *Avcicennia marina* on seaward margins
- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins
- AmRs:Tall, dense *Rhizophera styosa* on seaward margins
- Rs:Tall, dense Rhizophera styosa on seaward margins
- DEAD:Dead mangroves

Data sources:Prelimanary Mangrove and Algal Mat:
World Imagery: Earthstar Geographics

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Northern end of Nationally Important Wetland, EPA GS1 Exmouth Shore East area and Project Layout

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

31

10.0 References

Adame, MF, Virdis, B & Lovelock, CE 2010, Effect of geomorphological setting and rainfall on nutrient exchange in mangroves during tidal inundation. *Marine and Freshwater Research*, 61(10): 1197-1206.

Adame, MF & Lovelock, CE 2011, Carbon and nutrient exchange of mangrove forests with the coastal ocean. *Hydrobiologia*, 663(1): 23-50.

AECOM 2021a, *Ashburton Salt Project Marine Fauna Impact Assessment* Report Prepared for K+S Salt Australia Pty Ltd.

AECOM 2021b, *Ashburton Salt Ecotoxicology Assessment* Report Prepared for K+S Salt Australia Pty Ltd.

AECOM 2022 Technical Memorandum – Phase 2 Ecotoxicology Assessment, Ashburton Salt Project. Report for K+S Salt Australia Doc.60692046_1, Dated: 26 October 2022.

Alongi, DM 1989a, The role of soft–bottom benthic communities in tropical mangrove and coral reef ecosystems. *Review of Aquatic Science* 1: 243–280.

Alongi, DM 1989b, Benthic processes across mixed terrigenous-carbonate sedimentary facies on the central Great Barrier Reef continental shelf. *Continental Shelf Research*. 9: 629-663.

Alongi, DM 1996, The dynamics of benthic nutrient pools and fluxes in tropical mangrove forests. *Journal of Marine Research* 54: 123-148.

Alongi, DM 2008, Mangrove forests: Resilience, protection from tsunamis and responses to global climate change. *Estuaries, Coastal and Shelf Science* 76:1-13.

Alongi, DM, Clough, BF & Dixon, P 2003, Nutrient partitioning and storage in arid-zone forests of the mangroves *Rhizophora stylosa* and *Avicennia marina*. Trees (Berl) 17:51-60.

Alongi, DM, Tirendi, F & Clough, BF 2000, Below-ground decomposition of organic matter in forests of the mangroves *Rhizophora stylosa* and *Avicennia marina* along the arid coast of Western Australia. *Aquatic Botany* 68: 97-122.

Alongi, DM & Sasekumar, A 1992, Benthic communities. In: *Tropical Mangrove Ecosystems* (eds) Robertson AL & Alongi, AM. American Geophysical Union, Washington DC., USA, pp. 137–172.

ANCA 2005, *Directory of Important Wetlands in Australia.* Australian Nature Conservation Agency, last updated in 2005.

Biota 2003, *Onslow Salt Field Annual Environmental Report 2002-2003*. Unpublished report prepared for Onslow Salt Pty Ltd.

Biota 2005, Yannarie Salt Project*, Mangrove and Coastal Ecosystem Study. Baseline Ecological Assessment*. Report prepared for Straits Salt Pty Ltd by Biota Environmental Sciences Pty Ltd, September 2005.

Biota 2010, Wheatstone LNG Project - Vegetation and Flora Survey. Prepared for Chevron Australia Pty Ltd by Biota Environmental Sciences Pty Ltd.

Biota 2016, *Ashburton Salt Project – Algal mat and mangrove mapping* (in EnviroWorks Consulting 2017).

Biota 2020a, *Ashburton Salt Project Detailed Vegetation and Flora Survey.* Perth: Unpublished Data Prepared for K+S Salt Australia.

Biota 2020b. *Onslow Salt Annual Environmental Report (Aug 2019-Aug 2020).* Unpublished report prepared for Onslow Salt Pty Ltd, Perth.

Burnhard, E 1991, Pond marine life vital to salt quality. *Prospect.* June-August 1991: 9-11.

Chevron 2015, *Mangrove, Algal Mat and Tidal Creek Protection Management Plan*. Chevron Australia Pty Ltd, Perth, Western Australia.

Clough, BF, Dixon, P & Dalhaus, O 1997, Allometric relationships for estimating biomass in multi-stemmed mangrove trees. *Australian Journal of Botany*, 45: 1023-1031.

Coleman, P. (2016*) Samphires of the Adelaide and Mt Lofty Ranges region*, Government of South Australia.

Coles, R, Long, WJ, Watson, R & Derbyshire, KJ 1993, *Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, Northern Queensland, Australia*. In:

Commonwealth of Australia 2009, *National Assessment Guidelines for Dredging.* Commonwealth of Australia, Canberra.

Craig, GF 1983, *Pilbara Coastal Flora*. Western Australian Department of Agriculture, Perth.

Crase, B, Liedlof,f A, Vesk, PA, Burgman, MA & Wintle, BA 2013, Key factors influencing mangrove species distribution. *Global Ecology and Biogeography*, 22: 806-817. doi:10.1111/geb.12063

Cymod Systems 2021, *Ashburton Salt Project Groundwater Modelling Independent Review*. Report prepared for K+S Salt Australia Pty Ltd.

Dall, W, Hill, BJ, Rothlisberg, PC & Staples, DJ 1990, The Biology of Penaeidae. Advances. *Marine Biology* 27.

Damara 2010, *Coastal Geomorphology of the Ashburton River Delta and Adjacent Areas*. Prepared by Damara WA Pty Ltd for Chevron Australia Ltd. Report 82-01. (Appendix P1 of the Wheatstone EIS/ERMP).

Dampier Salt Limited 1992, *Report on the biology and aquaculture of Milkfish Chanos chanos at Dampier Salt 1990-1992*.

Department of Transport 2010, *Sea Level Change in Western Australia – Application to Coastal Planning*. Discussion Paper.

DHI Water and Environment 2010, *The Wheatstone Project Tolerance Limits Report*. Perth: Prepared for Chevron Australia Pty. Ltd.

DPIRD 2021, Samphires (*Tecticornia* species) for dryland salinity management in Western Australia. Accessed at: https://www.agric.wa.gov.au/soil-salinity/samphires-tecticornia-species-dryland-salinity-management-western-australia

Ellison, JC 1998, Impacts of Sediment Burial on Mangroves. *Marine Pollution Bulletin* 37: 420-426.

Environment Australia 2001, *A Directory of Important Wetlands*: Third edition.

EnviroWorks Consulting 2017, *Ashburton Salt Project: Draft Environmental Scoping Document*. Report to K+S Salt Australia. Doc: K04-J04, September 2017

EPA 2001, *Guidance Statement for protection of tropical arid zone mangroves along the Pilbara coastline*. Guidance for the Assessment of Environmental Factors Western Australia No. 1. Environmental Protection Authority, Perth, WA, April 2001.

EPA 2005, *Pilbara Iron Ore and Infrastructure Project: Port and North-South Railway (Stage A); Fortescue Metals Group Ltd: Report and recommendations of the Environmental Protection Authority*. EPA, Perth, WA.

EPA 2016a, *Environmental Factor Guideline: Benthic Communities and Habitats.* Environmental Protection Authority, December 2016.

EPA 2016b, *Technical Guidance - Protection of Benthic Communities and Habitats.* Environmental Protection Authority, December 2016.

EPA 2016c, *Technical Guidance - Environmental Impact Assessment of Marine Dredging Proposals.* Environmental Protection Authority, December 2016.

EPA 2016d, *Technical Guidance - Protecting the Quality of Western Australia's Marine Environment.* Environmental Protection Authority, December 2016.

EPA 2016e. Technical Guidance – *Flora and vegetation surveys for environmental impact assessment. Environmental Protection Authority*, Perth, WA.

EPA 2021, EPA Assessment of the Mardie Project. EPA Report 1704, June 2021.

EnviroWorks Consulting, 2016, *Ashburton Salt Project, EPA Referral Supporting Document*, K plus S Salt Australia Pty Ltd, K04-J04, October 2016.

Fisher, R, Jones, R, & Bessell-Browne, P 2019, Effects of dredging and dredging related activities on water quality: Impacts on coral mortality and threshold development. Report of Theme 4 – Project 4.9, prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia, 128 pp.

Fisheries WA, 2000, *Report on the first sampling trip to Cargill Salt fields, May - June 2000*.

Fisheries WA, 2002, Preliminary assessment and seasonal fluctuations in the fish biota inhabiting the concentrator ponds of Dampier Salt, Port Hedland, with options for the potential application of results (Eds Molony, B & Parry, G). *Fisheries Report* No. 133.

Fortescue Metals Group 2005, Stage A Port and Rail Project. Public Environmental Review. Unpublished report prepared by Fortescue Metals Group, Perth.

Fromont, Jane, Abdul Wahab, MA, Gomez, O, Ekins, M, Grol, M, & Hooper, JNA 2016, Patterns of Sponge Biodiversity in the Pilbara, Northwestern Australia. *Diversity* 8(4): 21.

Geo Oceans Pty Ltd 2019, Preliminary Benthic Habitat Mapping provided to AECOM

Geoscience Australia, 2021, Water Observations from Space, accessed online at https://www.ga.gov.au/dea/products/wofs

GHD 2018, *Ashburton Salt Project - Geotechnical, Hydrogeological and Acid Sulfate Soil Desktop Assessment.* Report produced for K + S Australia Pty Ltd.

GHD 2021a, *Ashburton Salt Project - Hydrogeological Investigation*. Report produced for K + S Australia Pty Ltd.

GHD 2021b, *Acid Sulfate Soil and Sediment Study*. Report produced for K + S Australia Pty Ltd.

GHD 2021c, *Acid Sulfate Soil and Sediment Management Plan* (ASSSMP). Report produced for K + S Australia Pty Ltd.

Gilman, E, Ellison, J, Duke, N & Field, C 2008, Threats to mangroves from climate change and adaptation options. *Aquatic Botany* 89(2): 237-250.

GMW 2010, Global Mangrove Watch – a new 2010 Global Baseline of Mangrove Extent. *Remote Sensing* 10 (10): 1669.

Goodwin, GC & Mudd, SM 2019, High platform elevations highlight the role of storms and spring tides in salt marsh evolution. *Frontiers in Environmental Science* 7: 62.

Gordon, D 1987, Disturbance to mangroves in tropical-arid Western Australia: hypersalinity and restricted tidal exchange as factors leading to mortality. Environmental Protection Authority, Perth, Western Australia Technical Series. No 12. June 1987.

Gordon, D 1988, Disturbance to mangroves in tropical-arid Western Australia: hypersalinity and restricted tidal exchange as factors leading to mortality. *Journal of Arid Environments* 15: 117-145.

Gordon, D, Bougher, A & LeProvost, I 1995, Use of Models for Detecting and Monitoring Change in a Mangrove Ecosystem in Northwestern Australia. *Environment International,* 21(5): 605-618.

Hutchings, PA & Recher, HF 1982, The fauna of Australian mangroves. *Proceedings of the Linnean Society of NSW* 106: 83-121.

John, J, Hay, M & Paton, J 2009, Cyanobacteria in benthic microbial communities in costal salt lakes in Western Australia. *Algological Studies* 130: 125-135.

Johnson, R 1990, Mangroves and Mangrove Birds of Western Australia. *Records of the Western Australian Museum*, Supplement No. 32.

Kirkman, H 1997, *Seagrasses of Australia*. Environment Australia, Canberra.

LDM 1996, *Environmental Management Programme (Extension of Salt Ponds, Port Hedland): Fish and Benthic Fauna Survey of Ponds.* Unpublished report to Cargill Salt by LeProvost Dames & Moore, Perth, Western Australia, Report No. R588.

LDM 1998, *Cargill Salt. Environmental Management Programme Annual Report 1997*. Report to Cargill Salt by LeProvost Dames & Moore, Perth, Western Australia. This included the following component reports: Progress and Compliance Report (Report No. R694); Mangrove Monitoring Programme and Rehabilitation Plan 1992-1997 Report (Report No. R678); Bitterns Discharge Monitoring Programme 1992-1997 Report (Report No. R691); Monitoring of Rehabilitation Sites (Report No. R695) and Shorebird Monitoring 1993-1997, Final Report

LDM 2000, *Cargill Salt Operations, Port Hedland.1999 Annual Environmental Report*. Unpublished Report to Cargill Salt by LeProvost Dames & Moore, Perth, Western Australia. This included the component report (Appendix E) Mangrove Rehabilitation Plan Survey, May 1999.

LEC 1991, *Intertidal Habitats of Onslow to Turbridgi Point Coast and Locker Island.* Report to West Australian Petroleum Pty Ltd by LeProvost Environmental Consultants, Perth, Western Australia, Report No. R343.

LEC 1992, *Design of Mangrove Monitoring Programmes and Mangrove Rehabilitation Plan. Report to Leslie Salt*. LEC Ref: J225, Report No. R372.

Loneragan, NR, Kangas, M, Haywood, MDE, Kenyon, RA, Caputi, N & Sporer, E 2013, *Impacts of cyclones and aquatic macrophytes on recruitment and landings of tiger prawns Penaeus esculentus in Exmouth Gulf, Western Australia.* Estuarine, Coastal and Shelf Science 127:46-58 Lovelock, CE, Ball, MC, Martin, KC & Feller, IC 2009, Nutrient enrichment increases mortality of mangroves. *PLoS One* 4(5).

Lovelock, C, Grinham, A, Fernanda Adame, M & Penrose, HM, 2010, Elemental composition and productivity of cyanobacterial mats in an arid zone estuary in north Western Australia. *Wetlands Ecology Management* 18: 37-47.

Lovelock, CE, Feller, IC, Fernanda Adame, M, Reef, R, Penrose, HM, Wei, L & Ball, MC 2011, Intense storms and the delivery of materials that relieve nutrient limitations in mangroves of an arid zone estuary. *Functional Plant Biology* 38: 514-522.

LSC 1981, *Mangrove Monitoring Programmes – Spoil Area No.4 and King Bay Causeway*. Report to Woodside Offshore Petroleum Pty Ltd by LeProvost Semeniuk and Chalmer, Perth, Western Australia, Report No. R011, October 1981.

LSC 1990, *Leslie Salt Extension of Salt Fields, Port Hedland, Consultative Environmental Review*. Report prepared by LeProvost Semeniuk and Chalmer, Perth, Western Australia, Report No. R302.

MBS Environmental 2018, *Learmonth Bundle Fabrication Facility – Exmouth Gulf Benthic Communities and Habitat Survey Report*. Report Prepared for Subsea 7 Australia Contracting Pty ltd.

McCook, LJ, Klumpp, DW & McKinnon, AD 1995, Seagrass communities in Exmouth Gulf, Western Australia: A preliminary survey. *Journal of the Royal Society of Western Australia* 78: 81-87

McMahon, K, Lavery, P, Statton, J, McCallum, R & Hernawan, U 2017, *Current state of knowledge regarding the effects of dredging-related ‘pressure’ on seagrasses.* Final Report of Theme 5 Project 1a of the Dredging Science Node of the Western Australian Marine Science Institution, WAMSI, Perth, Western Australia. 42 pp.

Milward, NE 1979, Mangrove-dependent biota. In: *Mangrove Ecosystems in Australia, Structure, Function and Management*. Clough, BF (eds). Proceedings of the Australian National Mangrove Workshop, AIMS, April 1979, Books Australia, pp. 302.

Morton, J 1990, *The Shore Ecology of the Tropical Pacific*. UNESCO Regional Office for Science and Technology - East Asia. pp. 282

Mosley, LM, Thomas, B, Fitzpatrick, R & Quinn J 2019, *Pathways to tidal restoration of the Dry Creek salt field*. Report to the Department for Environment and Water. The University of Adelaide.

O2 Marine 2019, Mardie Project: Whole Effluent Toxicity Assessment. Report for Mardie Minerals Limited, Report No. R190054, Revision 0, Dated 13/6/2019. Accessed at https://www.epa.wa.gov.au/sites/default/files/PER_documentation2/A05-3_WET_Report_2019.pdf

Oceanica 2006, *Marine and coastal environment of eastern Exmouth Gulf*. Unpublished report prepared for Straits Resources.

Odum, WE & Heald, EJ 1972, Trophic analyses of an estuarine mangrove community. *Bulletin of Marine Science* 2: 671–738.

Paling, E 1990, *Report on the Biological Environments near Onslow, Western Australia. Onslow Solar Salt field ERMP*, Volume II: Technical Appendices, Gulf Holdings, Perth, Western Australia.

Paling, EI, McComb, AJ & Pate, JS 1989, Nitrogen Fixation (Acetylene Reduction) in Nonheterocystous Cyanobacterial Mats from the Dampier Archipelago, Western Australia. *Australian Journal Marine & Freshwater Research* 40: 147-153.

Paling, EI, Kobryn, HT & Humphreys, G 2008, Assessing the extent of mangrove change caused by Cyclone Vance in the eastern Exmouth Gulf, northwestern Australia. *Estuarine Coastal and Shelf Science* 75: 1-11.

Pedretti, Y & Paling, E 2010, *Biodiversity associated with mangroves in the Port Hedland harbour: Stage 1*. Report to Fortescue Metals Group Ltd. Marine and Freshwater Research Laboratory Environmental Science, Murdoch University (Report No. MAFRA 10/2).

Penrose, H 2011, *Arid Zone Estuaries: nekton and trophic connectivity over heterogenous landscapes*. University of Queensland.

Perillo, GM 2019, *Geomorphology of Tidal Courses and Depressions*. In: Coastal Wetlands (2nd Edition): 221-261. Elsevier.

Phoenix Environmental Sciences 2020 *Detailed flora and vegetation survey for the Mardie Project* Report Prepared for BCI

Ray, S, Ulanowicz, RE, Majee, NC & Roy, AB 2000, Network analysis of a benthic food web model of a partly reclaimed island in the Sundarban mangrove ecosystem, India. *Journal of Biological Systems* 8: 263-249.

Robertson, AI & Alongi, DM (eds) 1992, *Coastal and Estuarine Studies. Tropical Mangrove Systems.* American Geophysical Union, Washington, DC.

Robertson, AI & Duke, NC 1990, Mangrove–fish communities in tropical Queensland, Australia: spatial and temporal patterns in densities, biomass and community structure. *Marine Biology* 104: 369–379.

Robertson, AI & Blaber, SJM 1992, Plankton, epibenthos and fish communities. In: *Tropical Mangrove Ecosystems*. Robertson, AI & Alongi, DM (eds). American Geophysical Union Press, Washington. pp. 173-224.

Rönnbäck, P 1999, The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics* 29: 235–252.

Sagramore 1995, *Cargill Salt Report, Seepage Study Concentration Ponds, Pickle Pond 9 and Brine Channel*. Report prepared by Sagramore Pty Ltd for Cargill Salt, June 1995.

Sammy, N 1976, *Dampier Salt Limited - Guide to the fishes in the Dampier Salt Field*.

Scheltema, RS 1986a, On dispersal and planktonic larvae of invertebrates: an eclectic overview and summary of problems. *Bulletin of Marine Science* 39: 290-322.

Scheltema, RS 1986b, Epipelagic meroplankton of tropical seas: its role for the biogeography of sublittoral invertebrate species. *UNESCO Technical Papers in Marine Science* 49: 242-249.

Scheltema, RS 1988, Initial evidence for the transport of teleplanic larvae of benthic invertebrates across the East Pacific barrier. *Biological Bulletin, Marine Biological Laboratory Woods Hole* 174: 145-152.

Seashore Engineering 2021, *Ashburton Salt Response to Sea Level Rise.* Unpublished Report Prepared for K+S Salt Australia.

Seashore Engineering 2022, *Ashburton Salt Projection of Future Habitat Area.* Unpublished Report Prepared for K+S Salt Australia.Technical Note SE099-02-Rev ASemeniuk, V 1983, Mangrove distribution in Northwestern Australia in relationship to regional and local freshwater seepage. V*egetation* 53: 11-31.

Semeniuk, V 1993a, The mangrove system of Western Australia 1993: Presidential Address. *Journal of the Royal Society of Western Australia* 76: 99–122.

Semeniuk, V 1993b, The Pilbara Coast: a riverine coastal plain in a tropical arid setting, northwestern Australia. *Sedimentary Geology* 83: 235-356.

Semeniuk, V 1994, Predicting the effect of sea-level rise on mangroves in Northwestern Australia. *Journal of Coastal Research* Vol 10, No. 4.

Stantec Australia Pty Ltd 2018, *Assessment of Mangal and Algal Communities for the Mardie Solar Salt Project*, Prepared for BCI Minerals Ltd.

Sutherland, JP 1980, Dynamics of the epibenthic community of roots of the mangrove Rhizophora mangle at Bahia de Buche, Venezula *Marine Biology* 58: 75-84.

Townend, I, Fletcher, C, Knappen, M & Rossington, K 2011, A review of salt marsh dynamics. *Water and Environment Journal* 25(4): 477-488.

URS 2004, *Darwin LNG Plant Mangrove Monitoring Programme 2003-04 Annual Report - Results of Mangrove Mapping; Surveillance and Groundwater Monitoring: and Sedimentation/Erosion Monitoring.* Report prepared for ConocoPhillips Australia Pty Ltd by URS Australia Pty Ltd, Perth, Western Australia, Report No. R1044, October 2004.

URS 2005, *Darwin LNG Project Mudwave Monitoring Survey – Final Survey, August 2005.* Report prepared for Bechtel Australia by URS Australia Pty Ltd, Perth, Western Australia, Report No. R1136, September 2005.

URS 2008, *Causeway to Cape Preston - Environmental Management Plan.* Prepared for Citic Pacific Mining Management Pty Ltd.

URS 2010a, *Wheatstone Project Benthic Primary Producer Habitat Loss*. Prepared for Chevron Australia Pty Ltd by URS Australia, Perth, Western Australia, (Appendix N11 of the Wheatstone EIS/ERMP).

URS 2010b, *Ashburton River Delta Mangrove System: Impact Assessment Report.* Prepared for Chevron Australia Pty Ltd by URS Australia, Perth, Western Australia, Report No. R1521, May 2010 (Appendix N4 of the Wheatstone EIS/ERMP).

URS 2010c, *Intertidal Habitats of Onslow Coastline, Western Australia*. Prepared for Chevron Australia Pty Ltd by URS Australia, Perth, Western Australia, Report No. R1426, February 2010 (Appendix N11 of the Wheatstone EIS/ERMP).

URS 2010d, *Survey of subtidal habitats off Onslow, WA.* Prepared for Chevron Australia Pty Ltd by URS Australia, Perth, Western Australia, Report No. R1473, May 2010 (Appendix N12 of the Wheatstone EIS/ERMP).

URS 2010e. *Mangrove Monitoring Programme, Construction Phase Monitoring Report (2006-2009).* Report to Fortescue Metals Group by URS Australia, Perth, Western Australia. Report No. R1497.

URS 2010f, *Benthic Primary Producer Habitats (Seagrass and Macroalgae) of the Wheatstone Project Area, WA.* Prepared for Chevron Australia Pty Ltd by URS Australia, Perth, Western Australia, Report No., May 2010 (Appendix N15 of the Wheatstone EIS/ERMP).

URS 2010d, *Survey of subtidal habitats off Onslow, WA.* Prepared for Chevron Australia Pty Ltd by URS Australia, Perth, Western Australia, Report No. R1473, May 2010 (Appendix N12 of the Wheatstone EIS/ERMP).

Vanderklift, M, Bearham, D, Haywood, M, Lozano-Montes, H, McCallum, R, Mc Laughlin, J, McMahon, K, Mortimer, N & Lavery, P 2017, *Natural dynamics: understanding natural dynamics of seagrasses of the north west of Western Australia*. Report of Theme 5 - Project 5.3 prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia, 55 pp.

van Maanen, B, Coco, G, & Bryan, KR 2015, On the ecogeomorphological feedbacks that control tidal channel network evolution in a sandy mangrove setting. *Proceedings. Mathematical, physical and engineering sciences* 471(2180): 2015.0115.

VCSRG 1996, *Study of the Impacts of Pilbara Coastal Developments on Arid Zone Mangroves - Stage 3: The Impacts of the Gas and Petroleum Industries*. Report to the Western Australian Department of Resources Development by V & C Semeniuk Research Group, Perth, Western Australia.

WABN 2019, Port Hedland Saltworks Survey, 8-9 November 2018. *Western Australian Bird Notes*, No 169, March 2019.

WABN 2021, Dampier Saltworks Shorebird Survey 2020. *Western Australian Bird Notes*, No 177, March 2021.

Waddington, K & Kendrick, G 2009, *Wheatstone - Survey of benthic habitats near Onslow, Western Australia (15 – 70 meters).* Centre for Marine Futures. Report produced for URS Australia Pty Ltd.

Wahab, M, Fromont, J, Gomez, O, Fisher, R & Jones, R 2017, Comparisons of benthic filter feeder communities before and after a large-scale capital dredging program. *Marine Pollution Bulletin* 122(1-2): 176-193.

Water Technology 2021a, *Ashburton Salt Project –Marine and Coastal Assessment and Modelling*. Report produced for K+S Salt Australia Pty Ltd. March 2021.

Water Technology 2021b, *Ashburton Salt Project – Nutrient Pathways Assessment and Modelling*. Report produced for K+S Salt Australia Pty Ltd. May 2021.

Water Technology 2021c, *Ashburton Salt Project – Surface Water Assessment and Modelling*. Report produced for K+S Salt Australia Pty Ltd. June 2021.

Weller, D, L. Kidd, C, Lee, S, Klose, R, Jaensch, R & Driessen, J 2020, *Australian National Directory of Important Migratory Shorebird Habitat*. Prepared for Australian Government Department of Agriculture, Water and the Environment, BirdLife Australia, Melbourne, Victoria

Wells, FE 1984, Comparative distribution of macromolluscs and macrocrustaceansin a North-western Australian mangrove system. *Australian Journal of Marine and Freshwater Research* 35: 591-596.

Wells, FE 1986, Distribution of molluscs across a pneumatophore boundary in a small bay in Northwestern Australia. *Journal of Molluscan Studies* 52: 83-90.

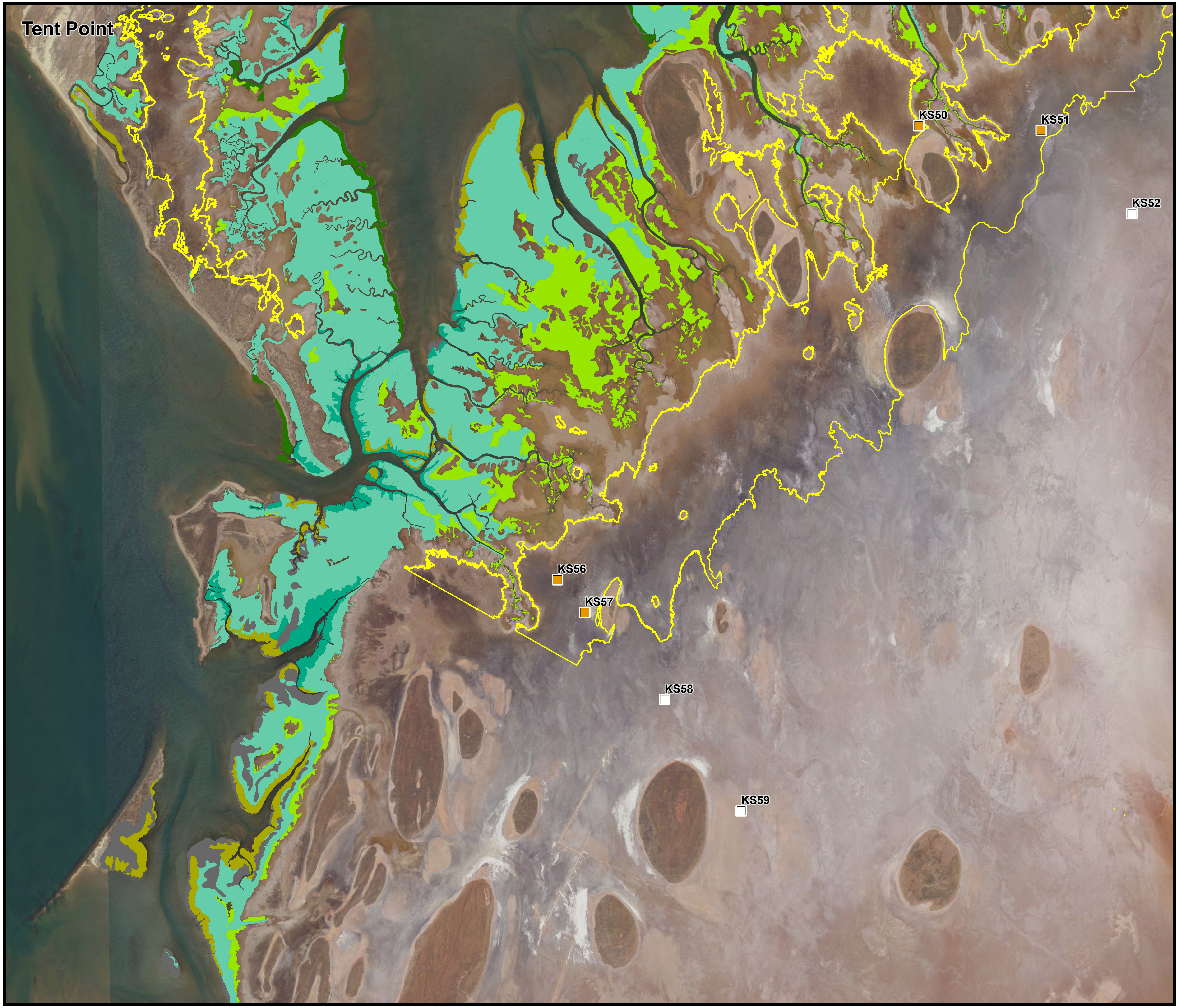
Wells, FE 1990, Comparative zoogeography of marine molluscs from northern Australia, New Guinea and Indonesia. *Veliger* 33: 140-144.

Wells, FE & Kilburn, RN 1986, Three temperate-water species of South African gastropods recorded for the first time in Western Australia, *Veliger* 28: 453-457.

Wilson, BR & Allen, GR 1987, Major components and distribution of marine fauna. In: *Fauna of Australia, General Articles, Volume 1A*. Dyne, GR & Walton, DW (eds). Australian Government Publishing Service, Canberra, pp. 43-68.

Appendix A

Mapping of Mangrove Associations



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY ABougher
LAST MODIFIED 07 JUL 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometres

1:45,000 (when printed at A3)

LEGEND

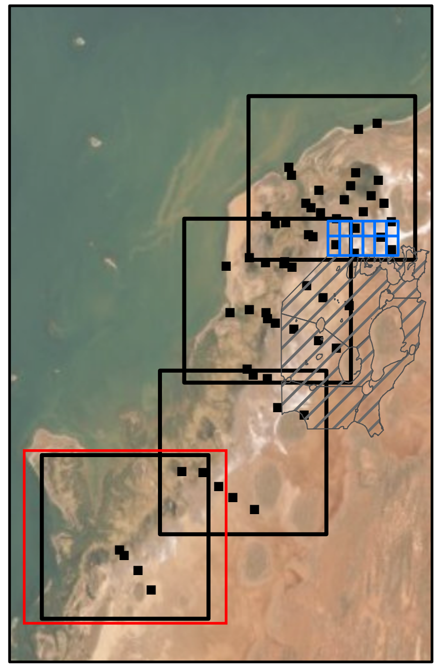
- Jetty Alignment
- Conveyor
- Algal Mat Mapping

Mangrove Mapping

- AM1:Tall dense *Avicennia marina* on seaward margins
- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins
- AmRs:Tall, dense *Rhizophera styosa* on seaward margins
- Rs:Tall, dense Rhizophera stylosa on seaward margins
- DEAD:Dead mangroves

Survey Sites Habitat Type

- Algal Mat
- Salt Flat



Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics
WMS: ; Landgate SLIP© Imagery (2013)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Mapping of Mangrove and Associations

K PLUS S SALT AUSTRALIA PTY LTD

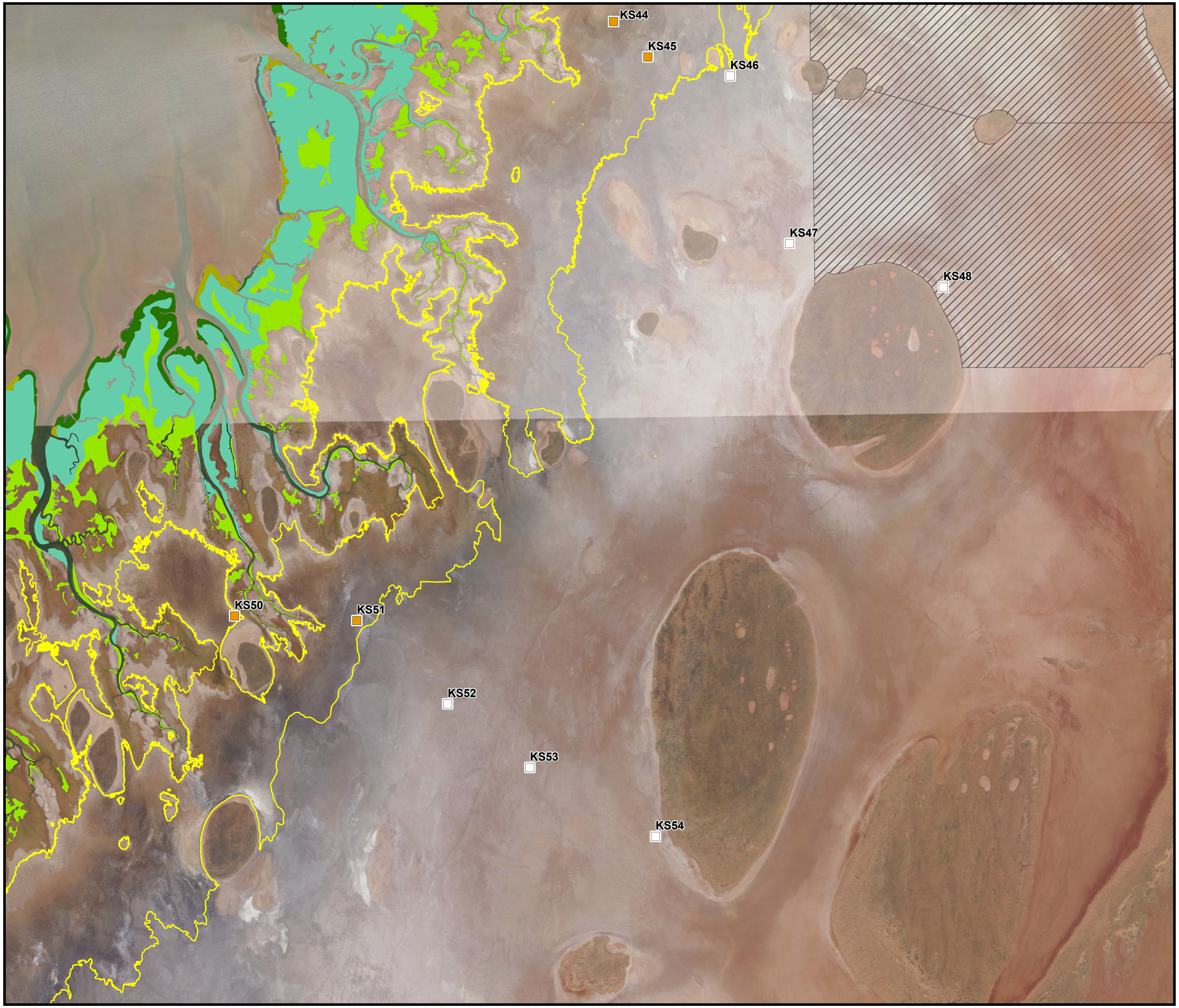
ASHBURTON SALT PROJECT

Appendix

A-1

Map Document: (\\AUPER1FP001.au.aecomnet.com\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\10_Benthic_Hab_Survey_Feb2020\G60597242_Fig5_Intertidal_Hab_Mapping_Update\G60597242_Figures_Update.aprx) Plotted by: kai.du on 7/07/2021 10:41 AM

A3 size



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY ABougher
LAST MODIFIED 07 JUL 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50
0 0.5 1 1.5 2
Kilometres
1:45,000 (when printed at A3)

LEGEND

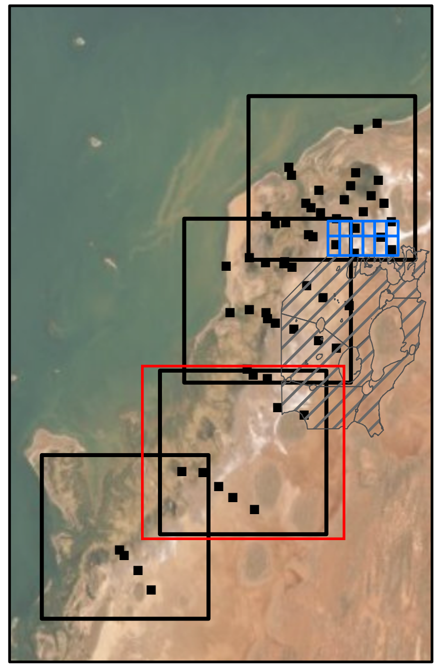
- Jetty Alignment
- Conveyor
- Pond Layout (Option 8)
- Algal Mat Mapping

Mangrove Mapping

- AM1:Tall dense *Avicennia marina* on seaward margins
- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins
- AmRs:Tall, dense *Rhizophera styosa* on seaward margins
- DEAD:Dead mangroves

Survey Sites Habitat Type

- Algal Mat
- Salt Flat



Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics
WMS: ; Landgate SLIP© Imagery (2013)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

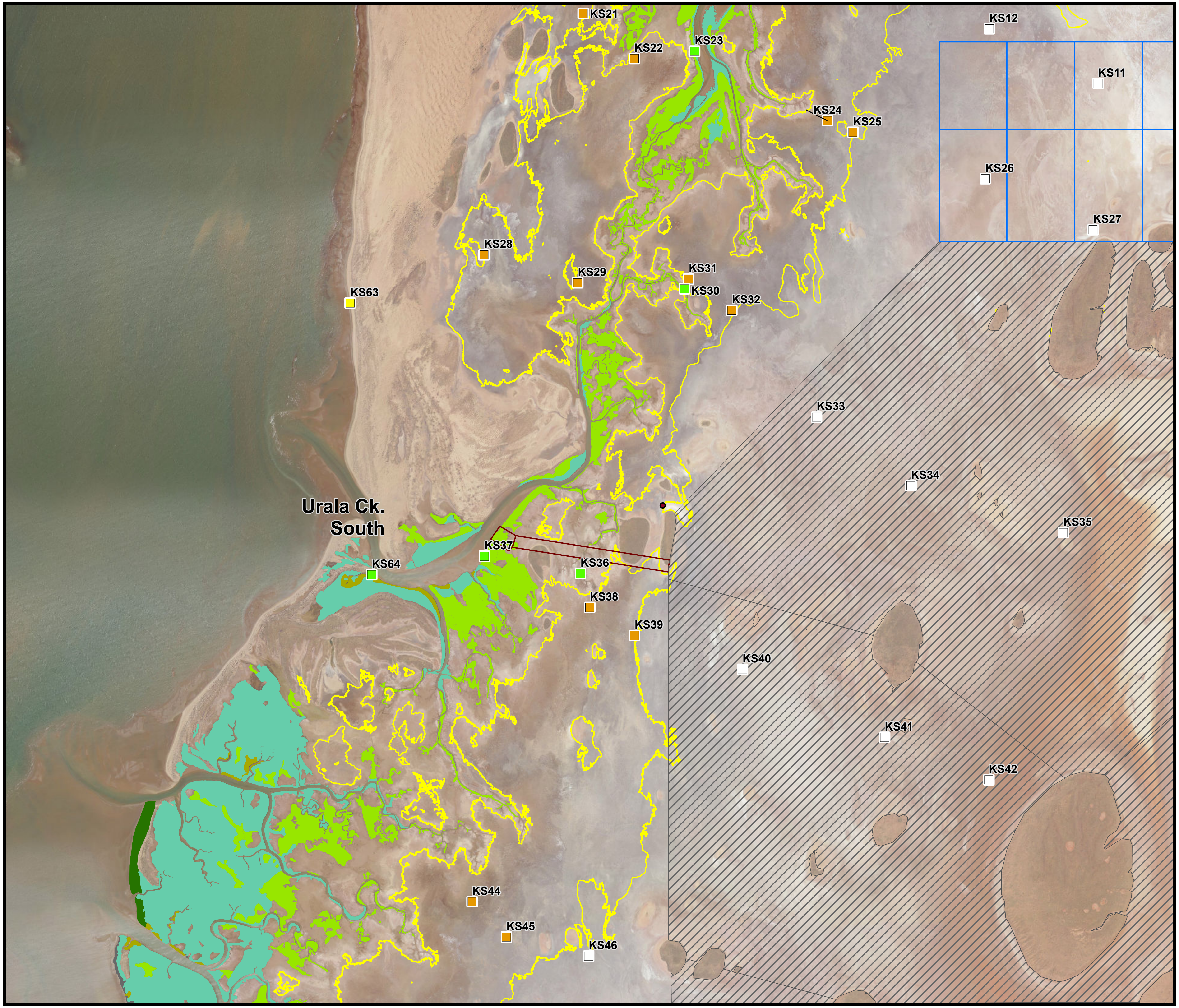
Mapping of Mangrove and Associations

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Appendix

A-2



PROJECT ID	60597242
CREATED BY	KAI.DU
APPROVED BY	ABougher
LAST MODIFIED	07 JUL 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometres

1:45,000 (when printed at A3)

LEGEND

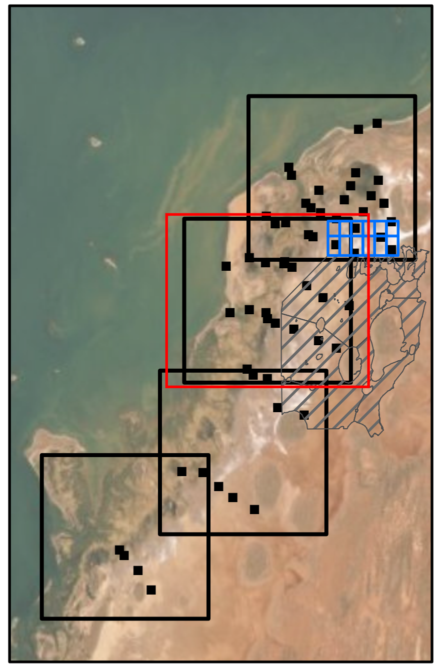
- Jetty Alignment
- Conveyor
- Pond Layout Gates (Option 8)
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Intake_and_Channel_20201203_region
- Algal Mat Mapping

Mangrove Mapping

- AM1:Tall dense *Avcicennia marina* on seaward margins
- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins
- AmRs:Tall, dense *Rhizophera styosa* on seaward margins
- DEAD:Dead mangroves

Survey Sites Habitat Type

- Algal Mat
- Beach
- Mangrove
- Salt Flat



Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics
WMS: ; Landgate SLIP© Imagery (2013)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

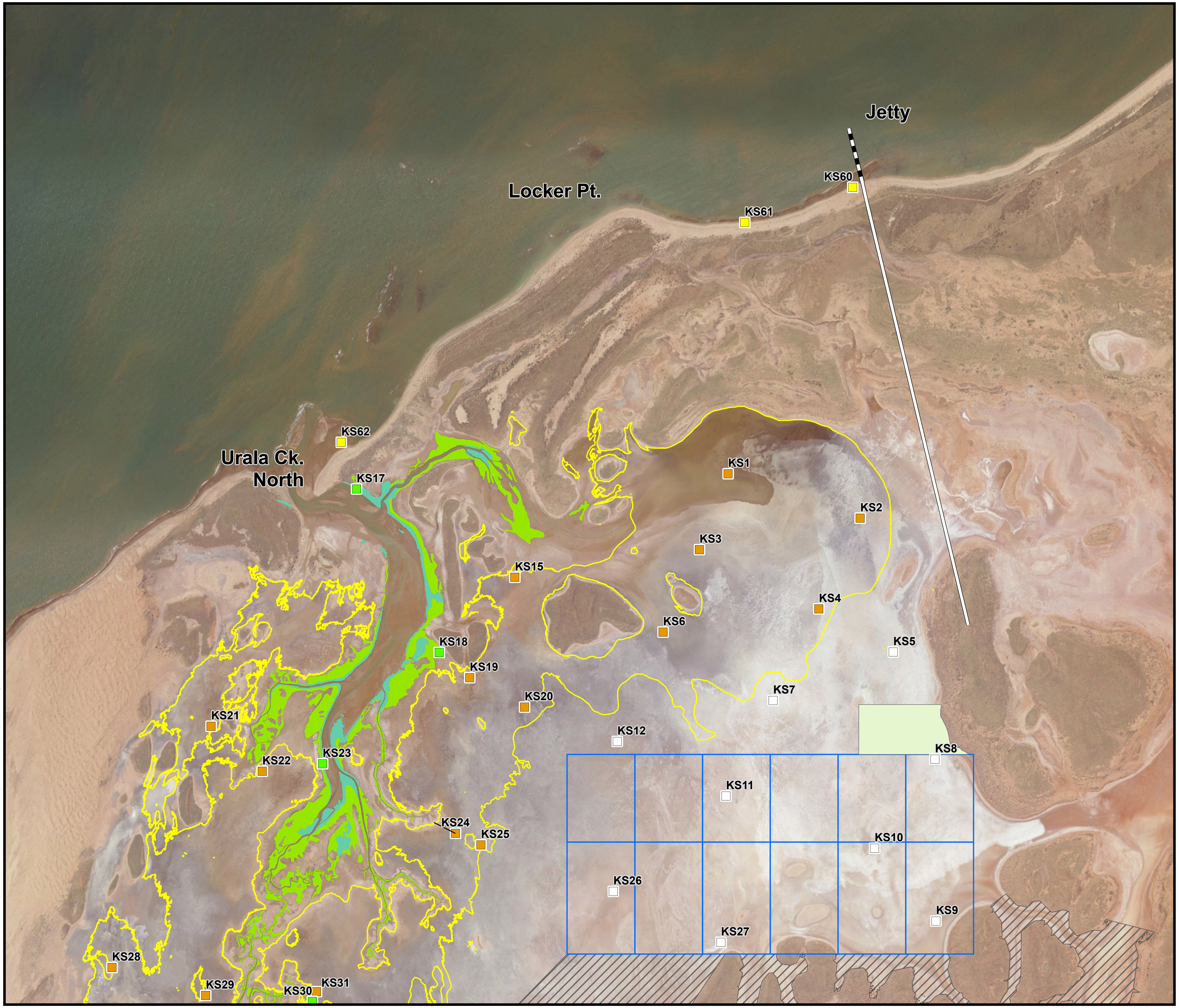
Mapping of Mangrove and Associations

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Appendix

A-3



PROJECT ID 60597242
CREATED BY KAI.DU
APPROVED BY ABougher
LAST MODIFIED 07 JUL 2021

AECOM
www.aecom.com

N

DATUM GDA 1994, PROJECTION MGA ZONE 50

0 0.5 1 1.5 2
Kilometres

1:45,000 (when printed at A3)

LEGEND

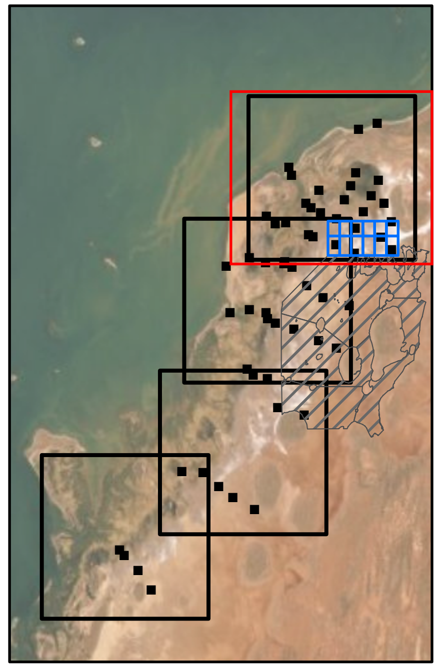
- Jetty Alignment
- Conveyor
- Bittens Pond (Option 8)
- Crystalliser (Option 8)
- Pond Layout (Option 8)
- Algal Mat Mapping

Mangrove Mapping

- AM2:Low, dense *Avicennia marina* shrubland
- AM3:Low, open to very open *Avicennia marina* scrub on landward margins

Survey Sites Habitat Type

- Algal Mat
- Beach
- Mangrove
- Salt Flat



Data sources:Prelimanary Mangrove and Algal Mat: (Biota 2005 and 2016)
World Imagery: Earthstar Geographics
WMS: ; Landgate SLIP© Imagery (2013)

Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Mapping of Mangrove and Associations

K PLUS S SALT AUSTRALIA PTY LTD

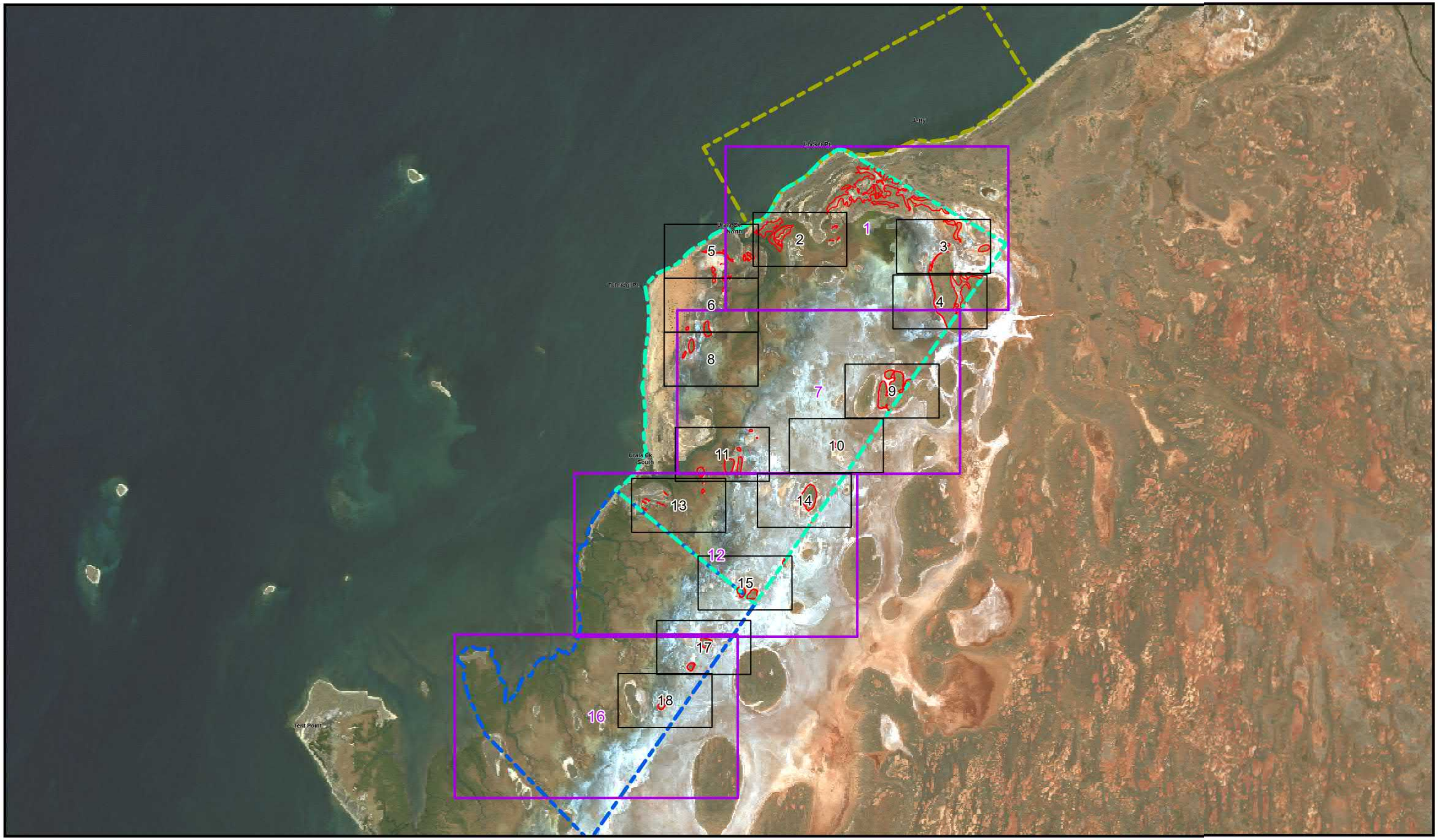
ASHBURTON SALT PROJECT

Appendix

A-4

Appendix B

Mapping of Intertidal Samphires



PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

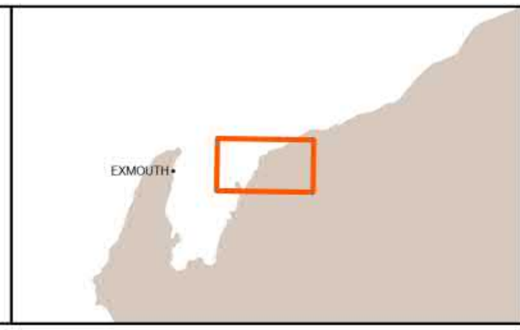
1:150,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 2 4 6
Kilometers

Data sources:
Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

Map Index (Page Number)
Scale
10000
30000

Intertidal LAU North
Intertidal LAU South
Locker Pt. Nearshore LAU
Intertidal Samphires



Mapping of Intertidal Samphires Index Sheet

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Cover_Page_A3L_v1

A3 size

PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM
www.aecom.com

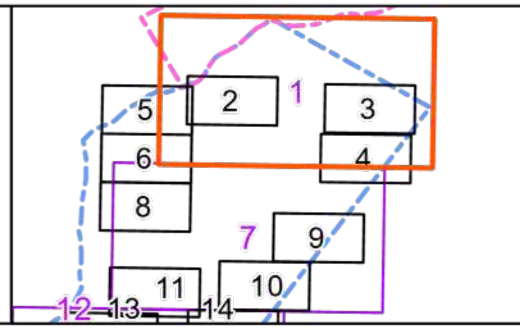
N
1:30,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500 1,000
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.1

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size

PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

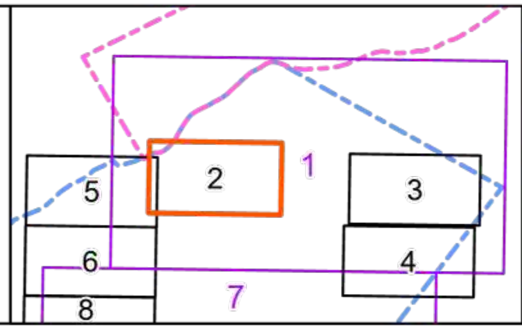
1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

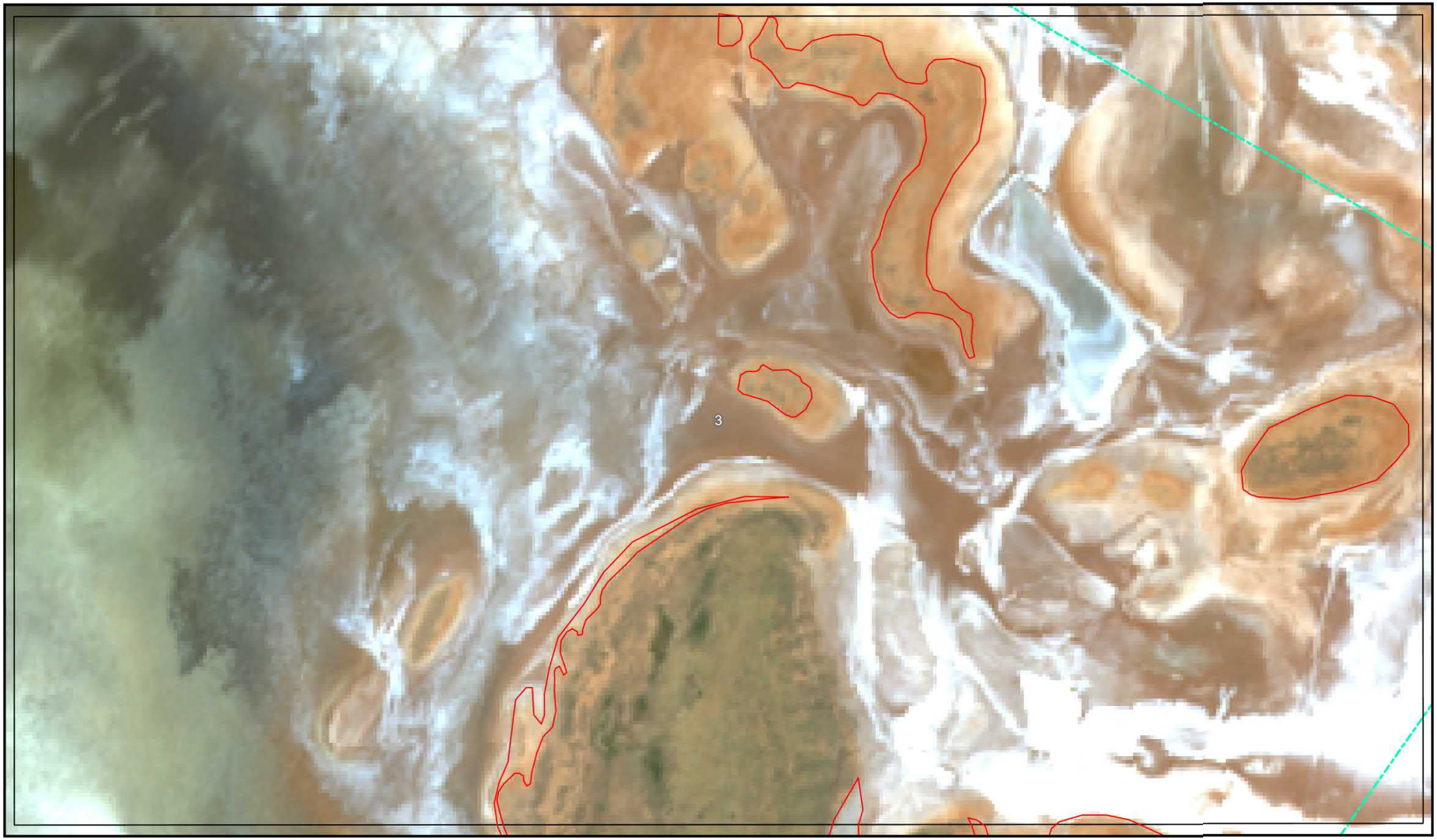
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.2

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM
www.aecom.com

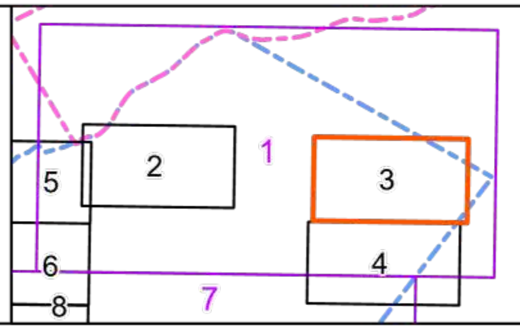
1:10,000 (when printed at A3)
N
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.3

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size

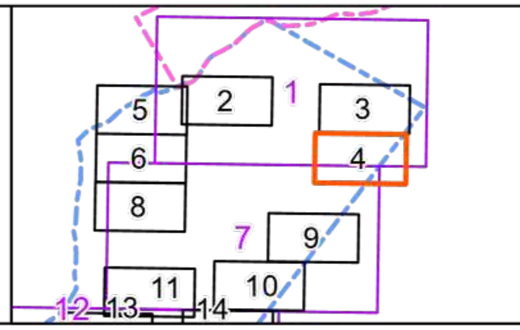
PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM
www.aecom.com

1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:
Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND
- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.4

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size

PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM

www.aecom.com

N

1:10,000 (when printed at A3)

DATUM GDA 1994 MGA Zone 50

0 500

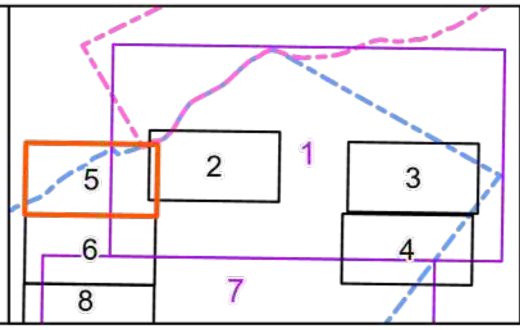
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

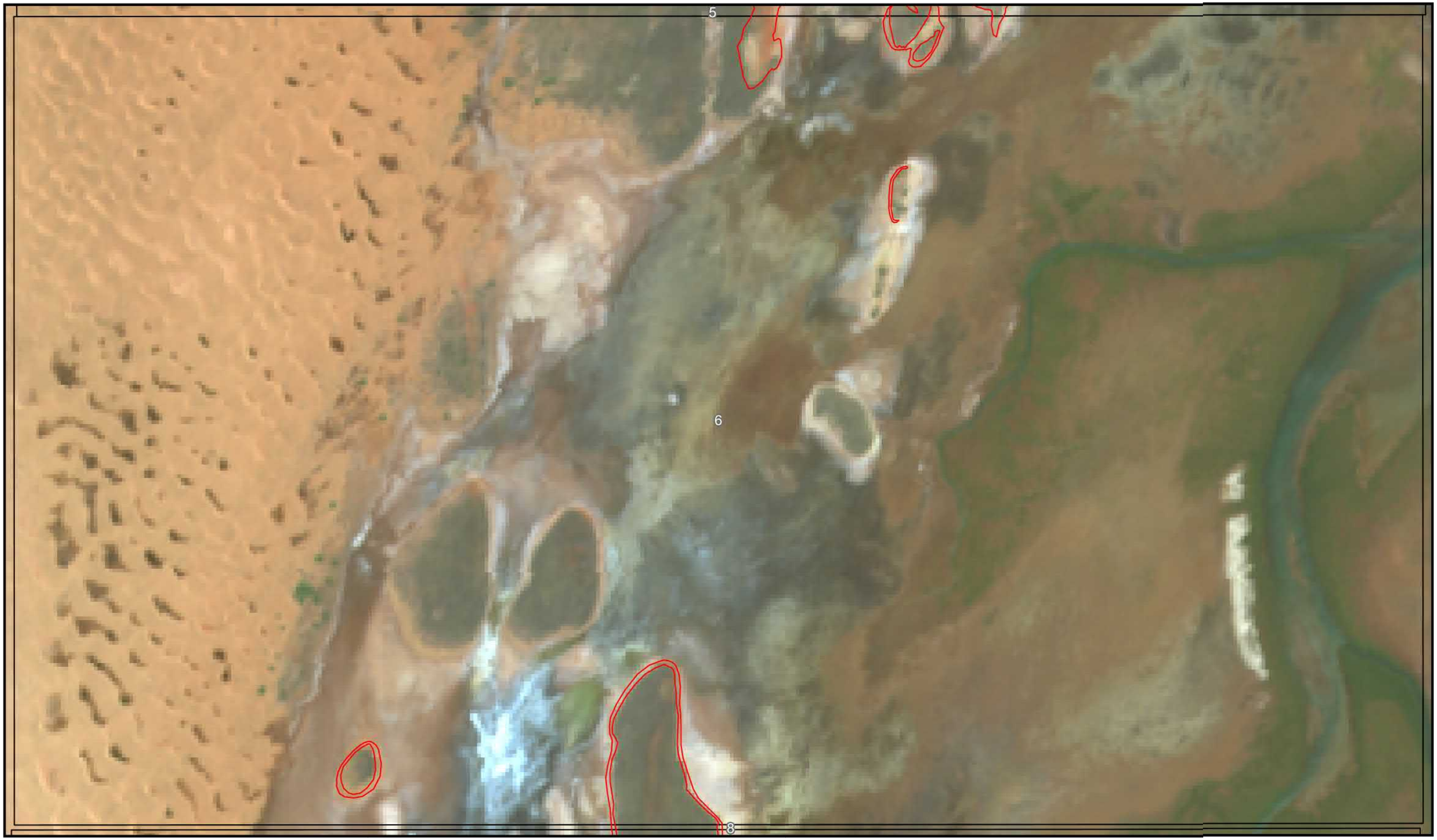
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

1

Pg.5



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

www.aecom.com

1:10,000 (when printed at A3)

DATUM GDA 1994 MGA Zone 50

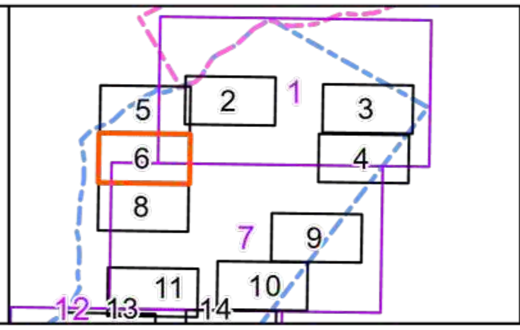
0 500 metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure

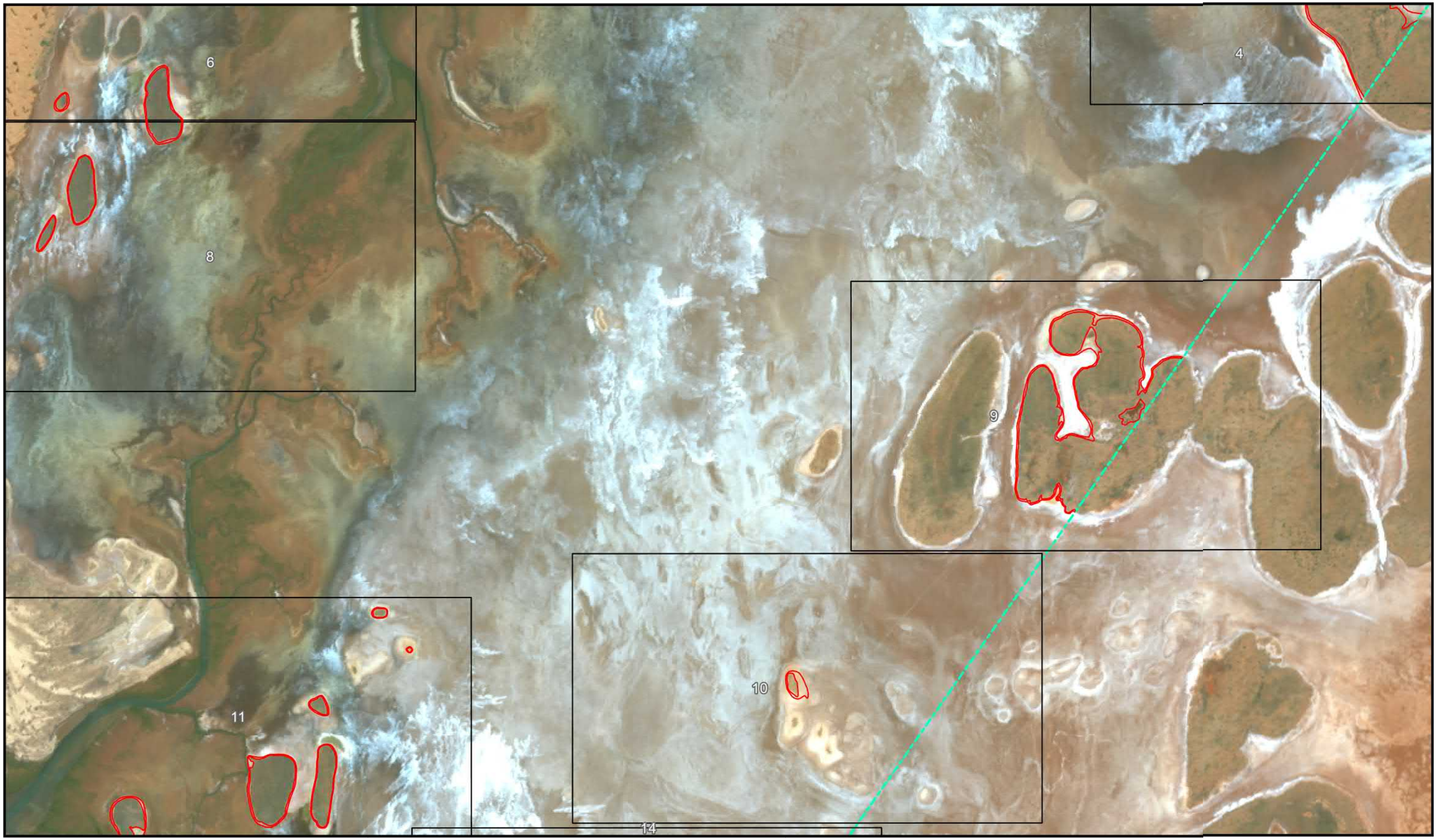
1

Pg.6

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)

Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM
www.aecom.com

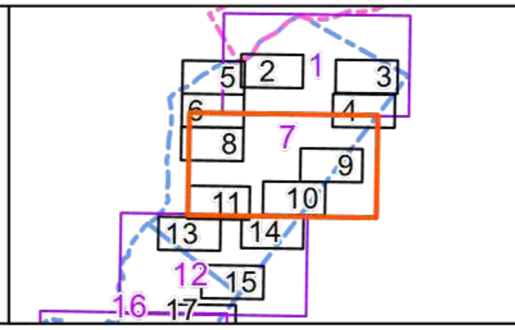
1:30,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500 1,000
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

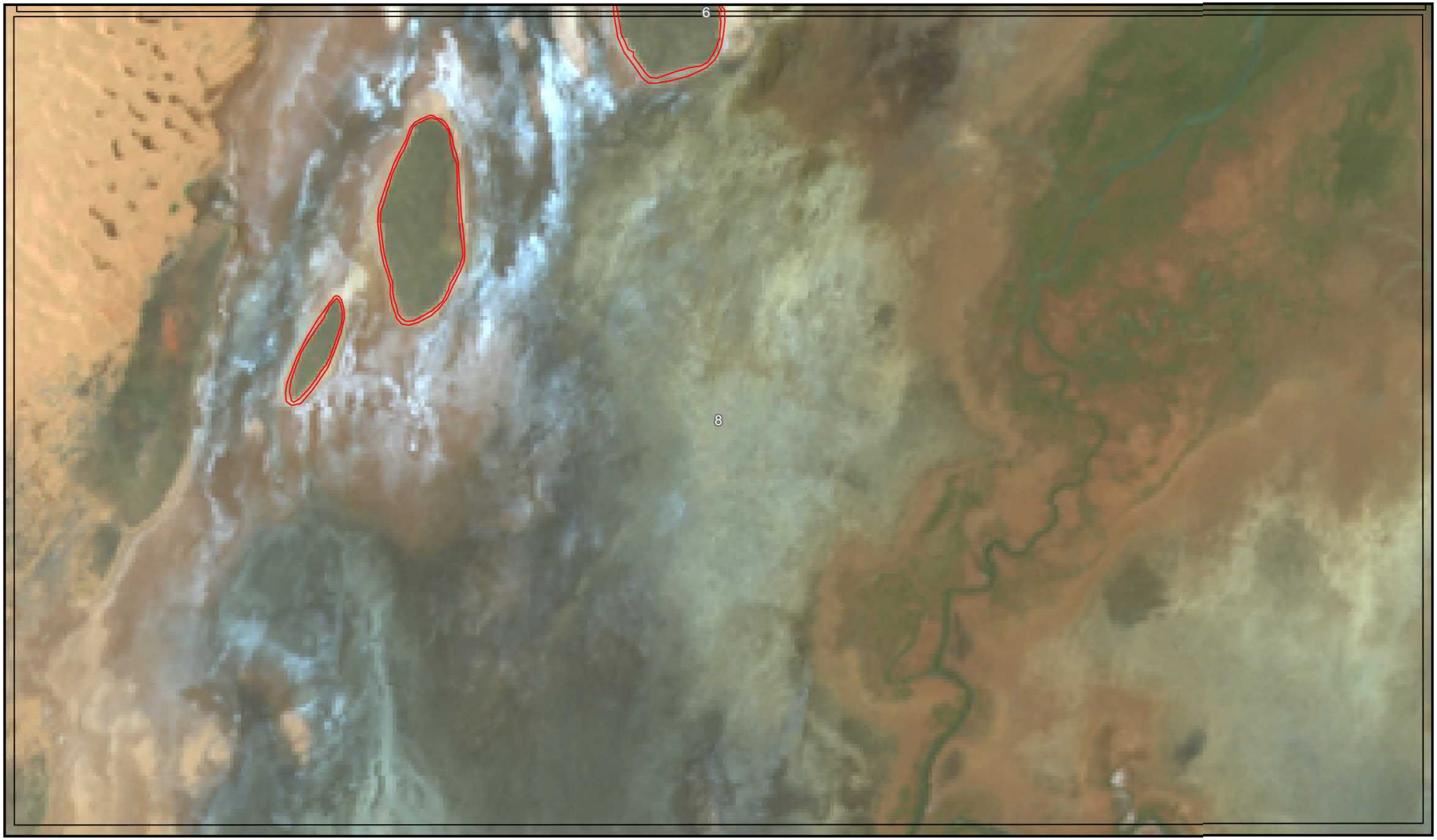
Figure

1

Pg.7

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



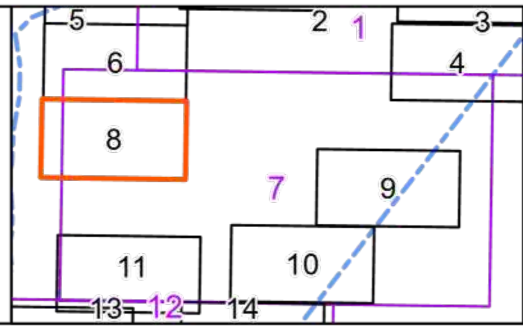
PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:
Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND
- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.8

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size

PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

www.aecom.com

1:10,000 (when printed at A3)

DATUM GDA 1994 MGA Zone 50

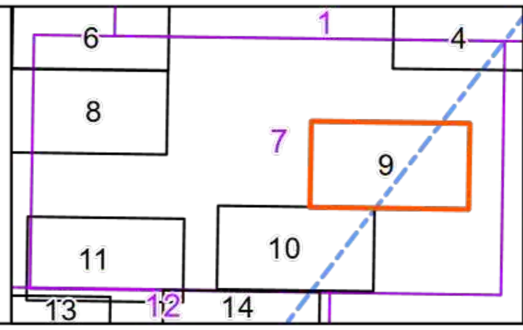
0 500 metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

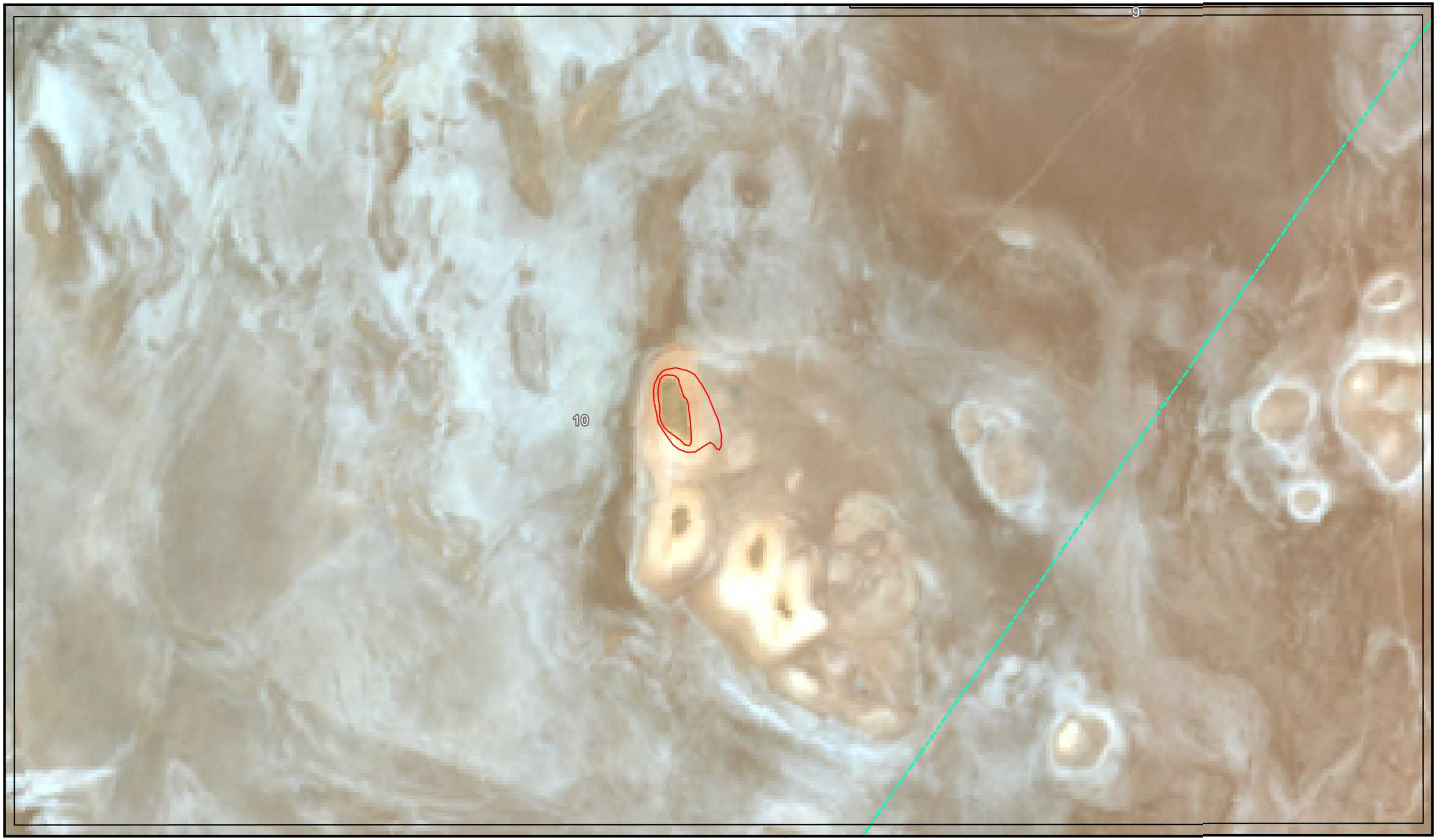
Figure

1

Pg.9

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



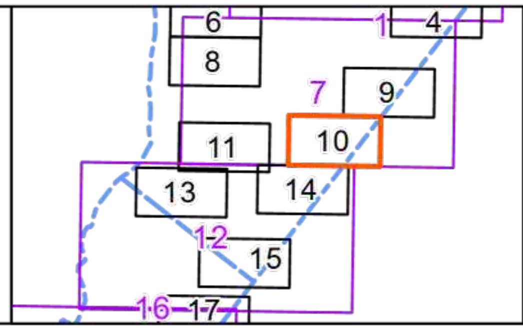
PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:
Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND
- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

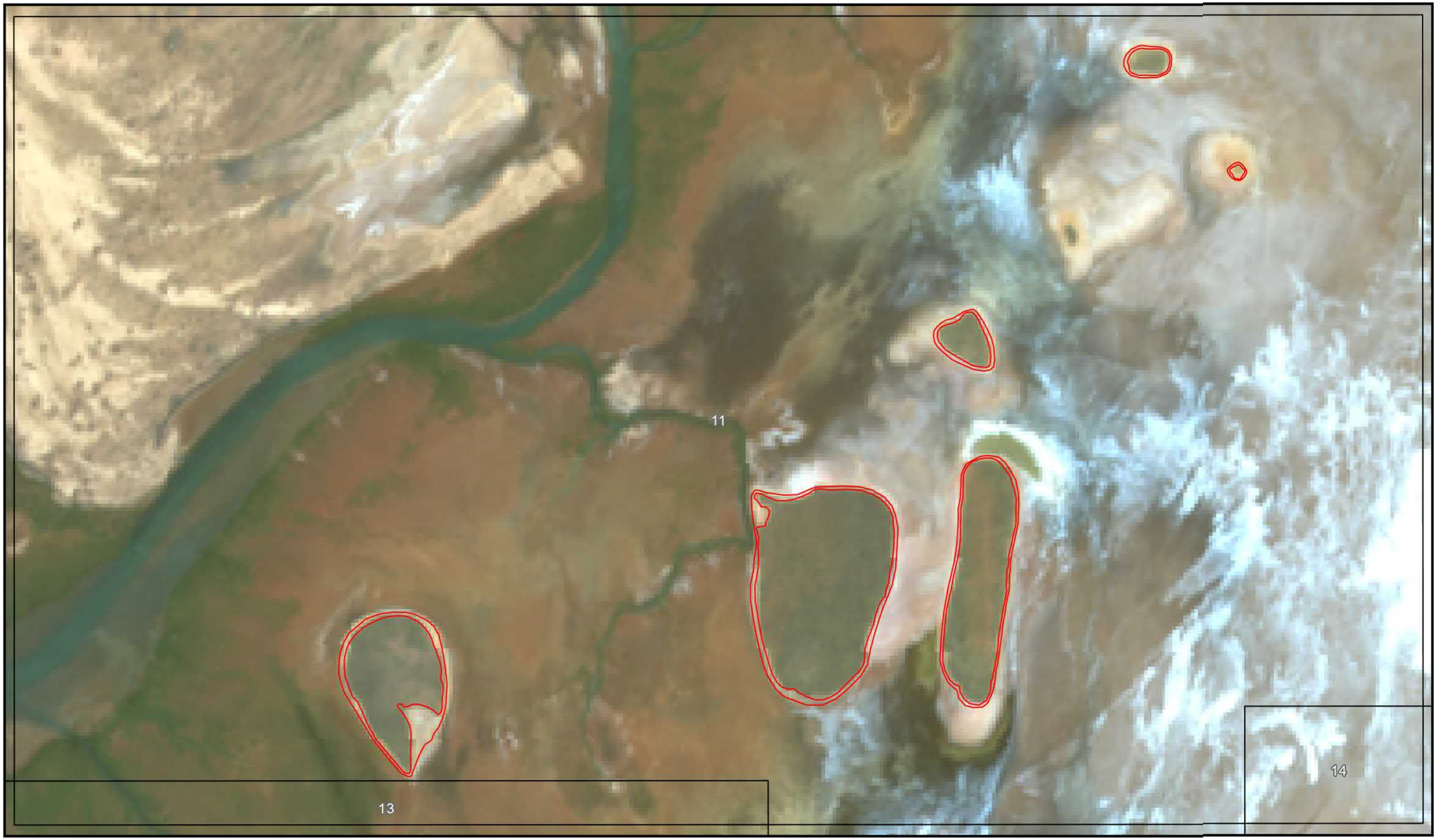
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.10

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



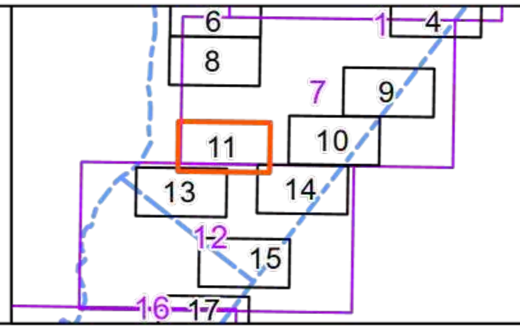
PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:
Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND
- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

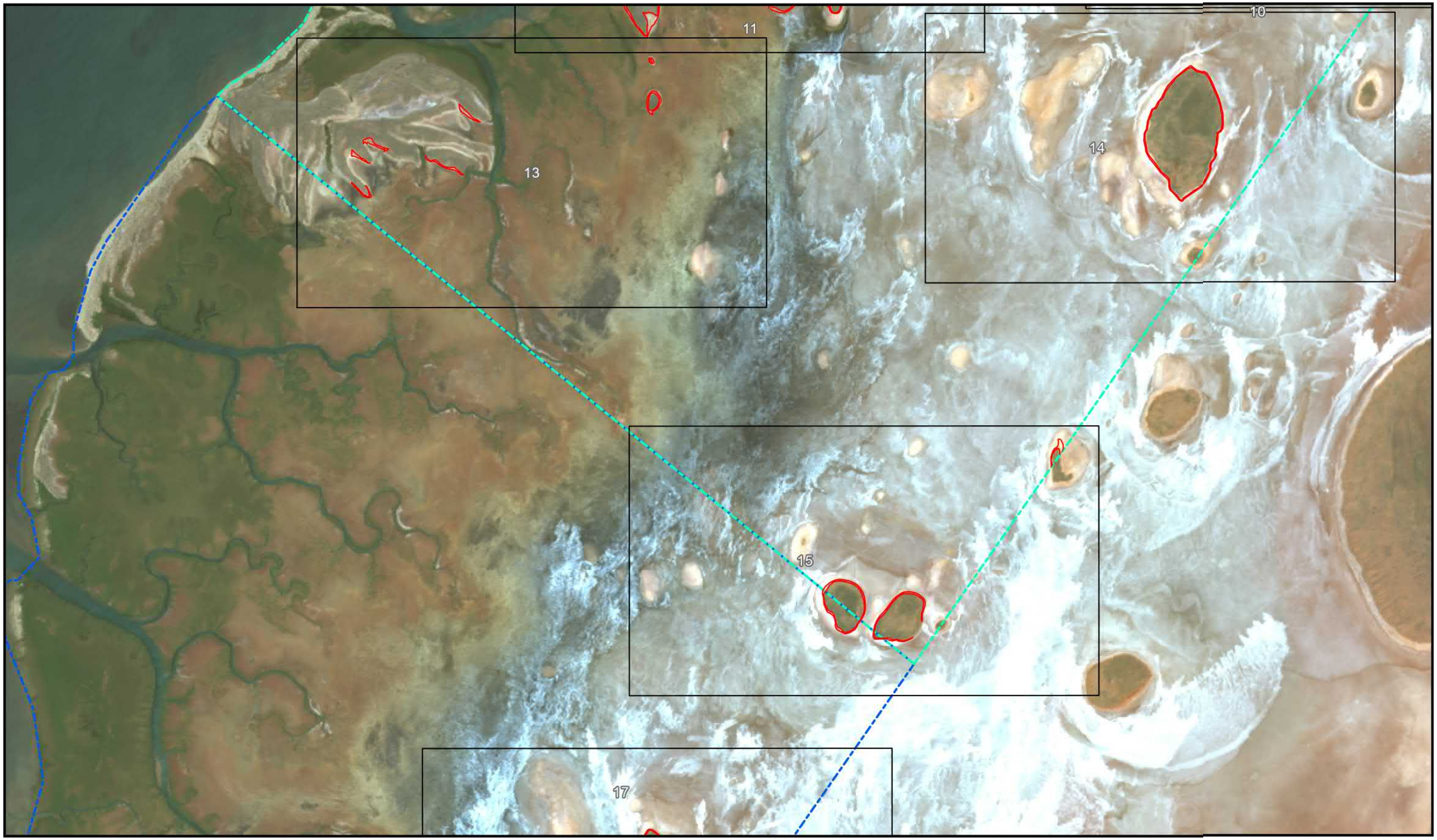
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.11

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

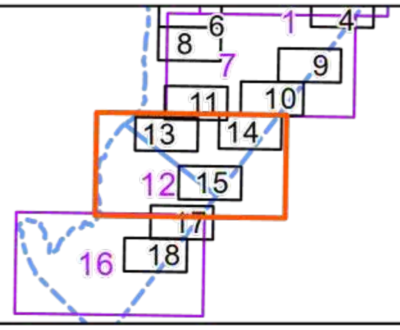
1:30,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500 1,000
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

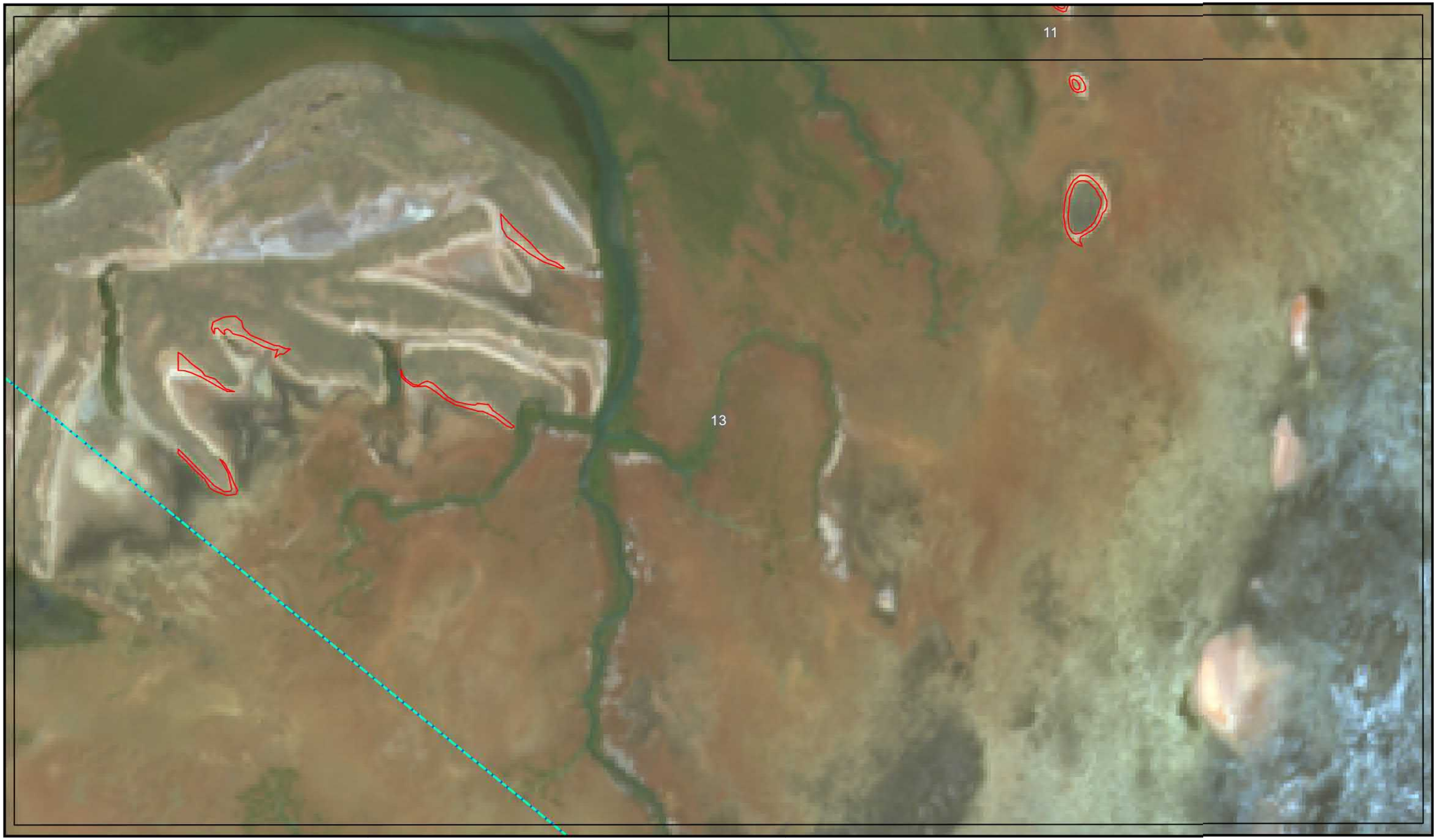
Figure

1

Pg.12

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

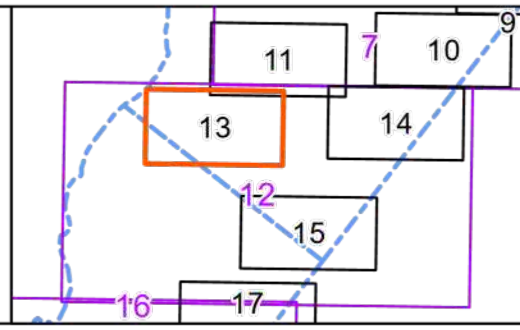
N
1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

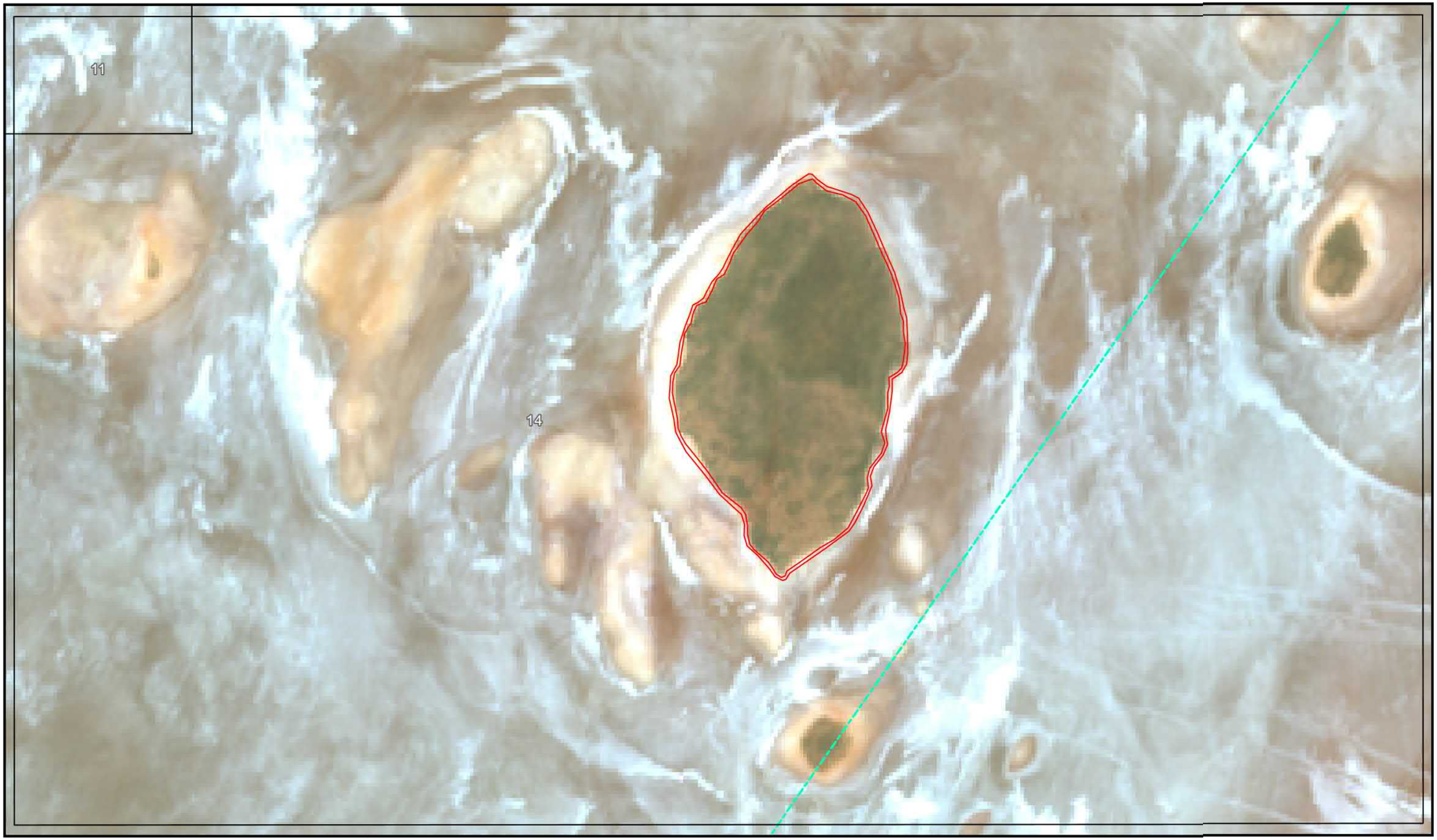
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.13

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

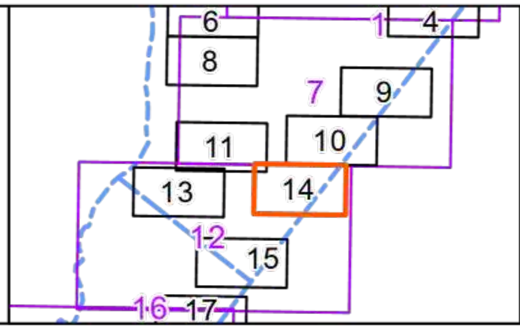
AECOM
www.aecom.com

1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

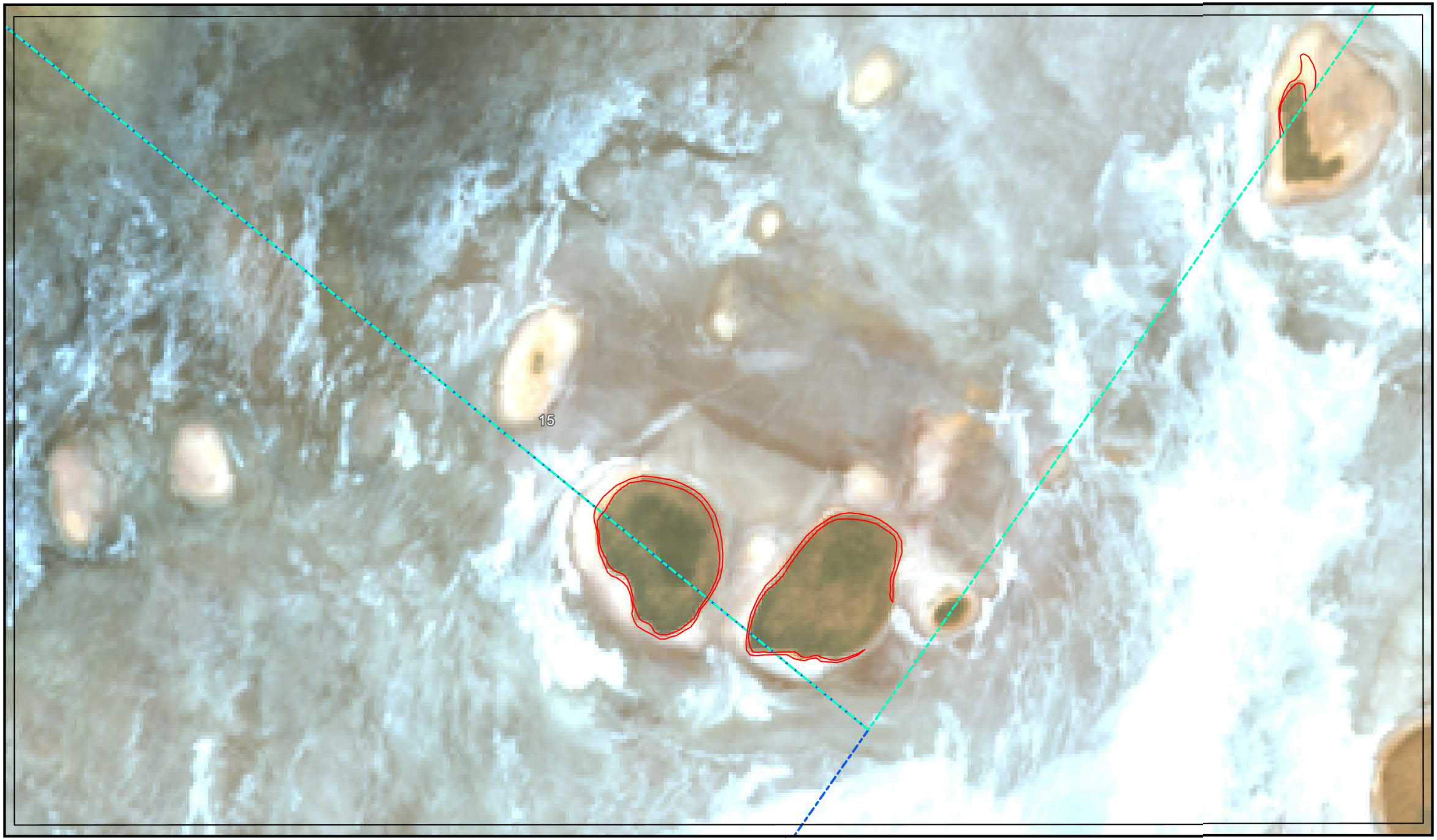
Figure

1

Pg.14

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 25 OCT 2022

AECOM
www.aecom.com

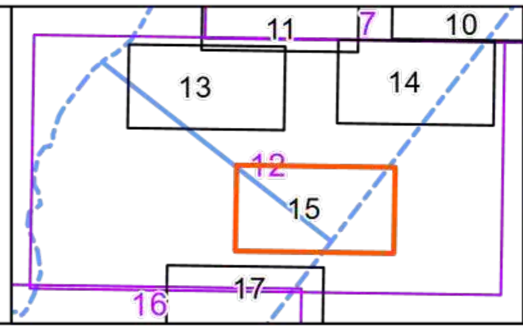
1:10,000 (when printed at A3)
N
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

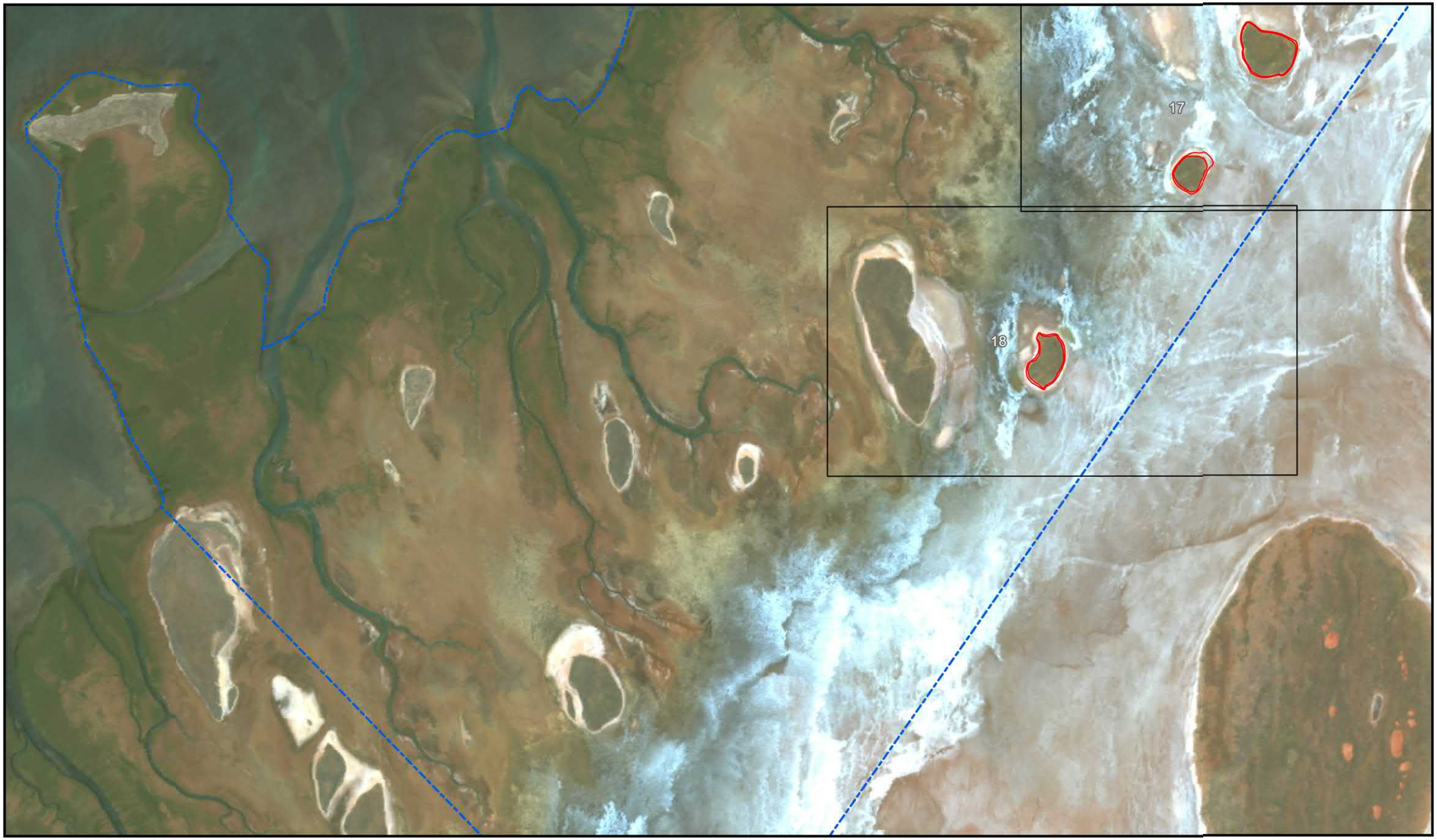
K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.15

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM

www.aecom.com

1:30,000 (when printed at A3)

DATUM GDA 1994 MGA Zone 50

0 500 1,000

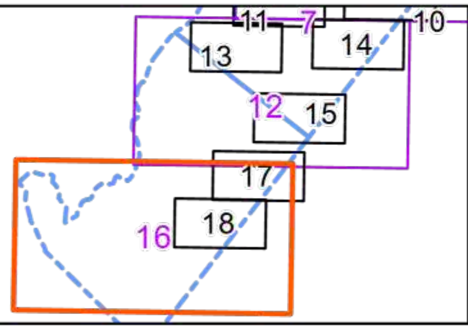
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

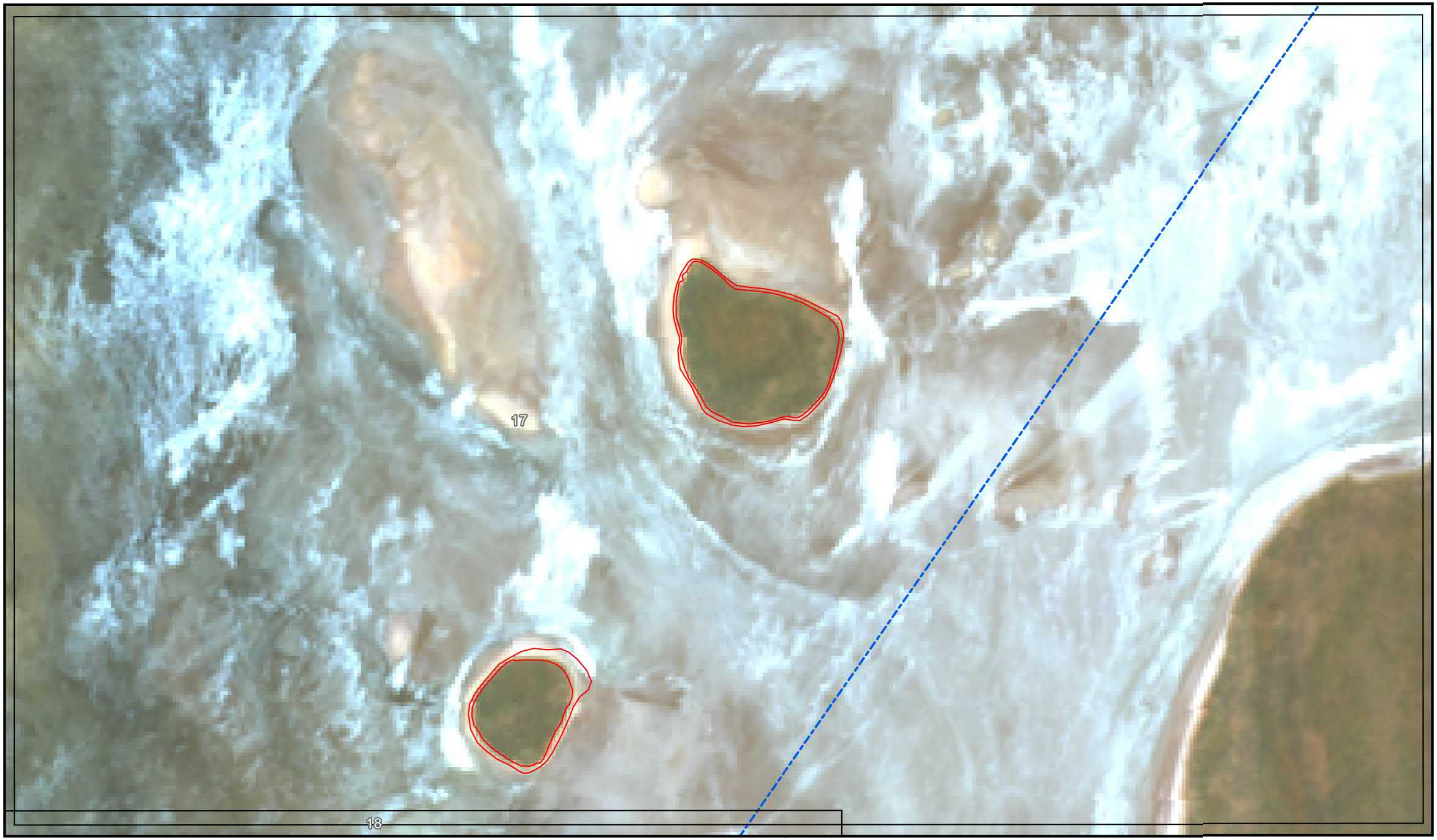
Figure

1

Pg.16

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM
www.aecom.com

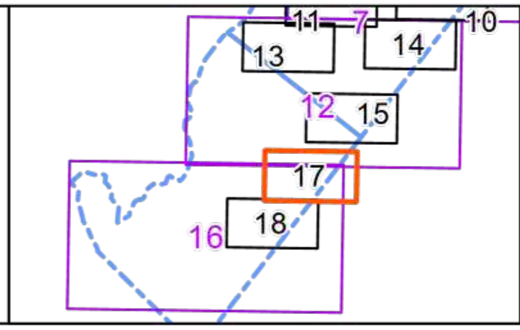
1:10,000 (when printed at A3)
N
DATUM GDA 1994 MGA Zone 50
0 500
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

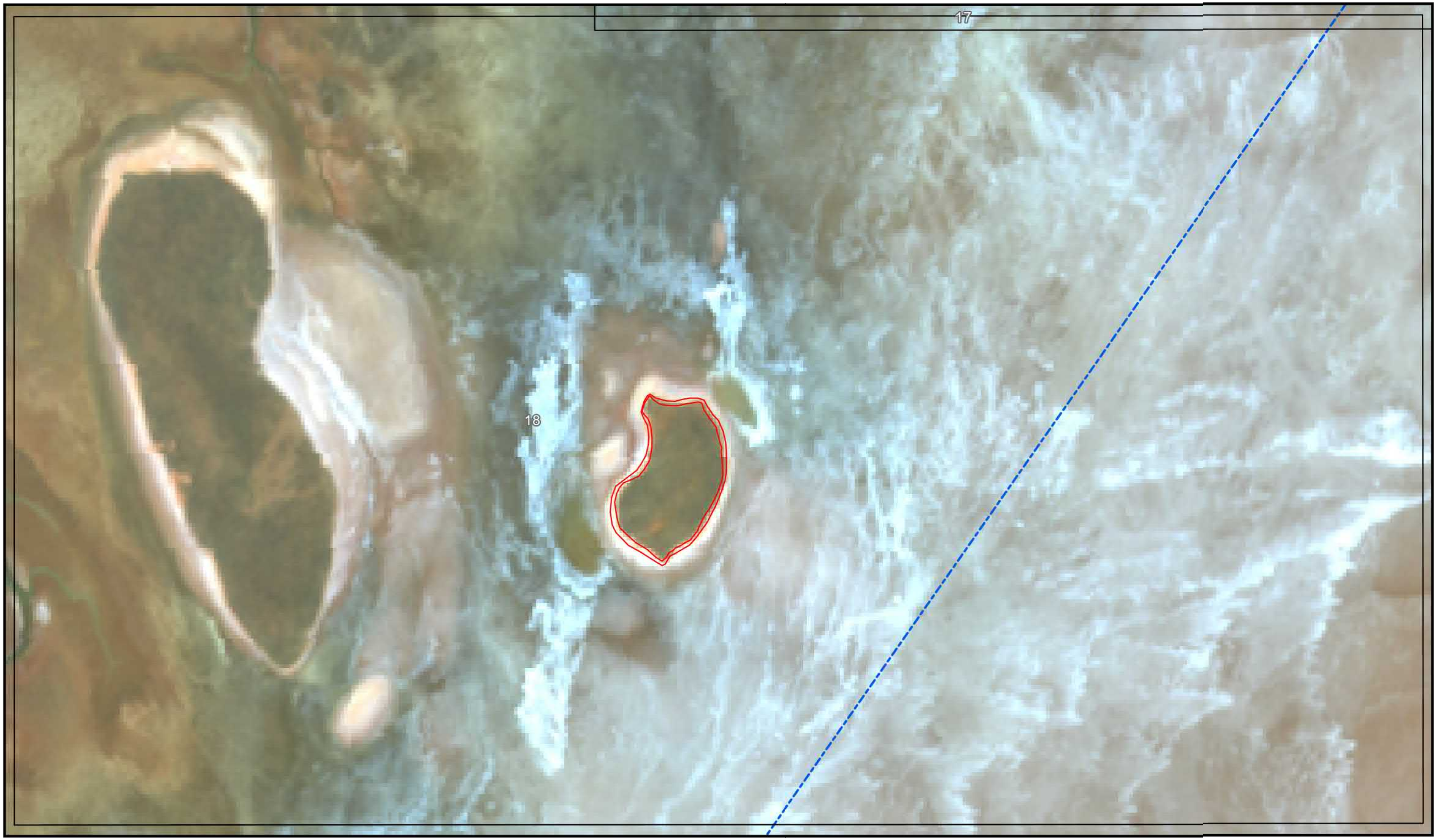
Figure

1

Pg.17

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size



PROJECT ID	60692046
CREATED BY	SMITHS9
APPROVED BY	INITIALS
LAST MODIFIED	25 OCT 2022

AECOM
www.aecom.com

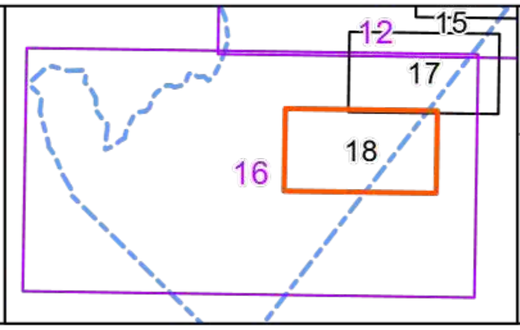
1:10,000 (when printed at A3)
DATUM GDA 1994 MGA Zone 50
N
0 500
metres

Data sources:

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Enlargement Map
- Intertidal LAU North
- Intertidal LAU South
- Locker Pt. Nearshore LAU
- Intertidal Samphires



Mapping of Intertidal Samphires

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
1
Pg.18

Project File: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\606X\60692046_KS_Ashburton_ERD\900_CAD_GIS\920_GIS\02_MXD_APRX\01_Benthnic_Communities_Habitats\G60692046_01_Benthnic_Com_Habitats.aprx (SmithS9)
Layout: G60692046_01_Fig1_Intertidal_Samphires_A3L_v1

A3 size

About AECOM

AECOM is the world's premier infrastructure consulting firm, delivering professional services throughout the project lifecycle – from planning, design and engineering to program and construction management. On projects spanning transportation, buildings, water, energy and the environment, our public- and private-sector clients rust us to solve their most complex challenges. Our teams are driven by a common purpose to deliver a better world through our unrivalled technical expertise and innovation, a culture of equity, diversity and inclusion, and a commitment to environmental, social and governance priorities. AECOM is a Fortune 500 firm and its Professional Services business had revenue of $13.2 billion in fiscal year 2022. See how we deliver what others can only imagine at aecom.com and @AECOM.

aecom.com