LEICHHARDT SALT PTY LTD

ERAMURRA SOLAR SALT PROJECT: MARINE TURTLE MONITORING 2022/23

Prepared by

Pendoley Environmental Pty Ltd

For

Leichhardt Salt Pty Ltd

10 May 2023

PENDOLEY ENVIRONMENTAL

PENDOLEY ENVIRONMENTAL

DOCUMENT CONTROL INFORMATION

TITLE: ERAMURRA SOLAR SALT PROJECT: MARINE TURTLE MONITORING 2022/23

Disclaimer and Limitation

Document History

Revision	Description	Date received	Date issued	Personnel
Draft	Report Draft		30/03/2023	B. Moore, Dr. P. Whittock, Dr. K. Pendoley
Rev IA	Technical and Editorial Review	30/03/2023	06/04/2023	Dr P. Whittock
Rev IB	Technical Review	06/04/2023	13/04/2023	Dr K. Pendoley, A. Mitchell
Rev A	Client review	08/05/2023	10/05/2023	R. Flugge, P. Ranford, G. Edwards
Rev 0	Final report issued	10/05/2023	10/05/2023	B. Moore

Printed:	10 May 2023
Last saved:	10 May 2023 04:11 PM
File name:	P:\06 Projects\J106 Leichhardt\05 Programs\J106002 Eramurra Marine Turtle Monitoring\04 Technical Reports\LEIC_MarineTurtleMonitoring_Rev0.docx
Project manager:	B. Moore
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Eramurra Solar Salt Project: Marine Turtle Monitoring 2022/23
Client	Leichhardt Salt Pty Ltd
Client representative:	R. Flugge
PENV report number:	J106002-1
LEIC report number:	ESSP-EN-14-TRPT-0019
Cover photo:	Hatchling Emergence, Cape Preston

EXECUTIVE SUMMARY

Leichhardt Salt Pty Ltd (LEIC) is the Proponent for the Eramurra Solar Salt Project, a proposed solar salt operation in the Pilbara region of Western Australia (WA). The Project is targeting average production of 5.2 million tonnes per annum of high-grade salt from seawater using a series of evaporation and crystallisation ponds. The development envelope for the Project occurs adjacent to Citic Pacific's Sino Iron export facility at Cape Preston, WA.

In response to comments received from the Environmental Protection Authority, LEIC engaged Pendoley Environmental (PENV) to undertake benchmark marine turtle nesting surveys in the vicinity of the Project, to determine the species and abundance of marine turtles nesting and hatching on nearby (within 20 km of the Project) beaches. This includes beaches on the mainland coast and islands offshore from the Project. Data from the surveys was then used to inform a risk assessment, which considered the potential for Project lighting to impact hatchling behaviour, and the Project's contribution to the cumulative impact of lighting on the turtle population of the North West Shelf.

Three field surveys were undertaken at suitable nesting habitat on mainland and island beaches in October 2022 (Field Survey 1; FS1), January 2023 (Field Survey 2; FS2), and February 2023 (Field Survey 3; FS3). The surveys were designed to target the peak nesting and hatching periods for hawksbill (*Eretmochelys imbricata*), flatback (*Natator depressus*), and green turtles (*Chelonia mydas*). All field surveys were a minimum of 14 days in duration, as per the recommendations of the National Light Pollution Guidelines for Wildlife (NLPGW). For those surveys undertaken in October and January, the 14-day period represents the mean inter-nesting period for turtles in the North West Shelf Region, and nesting results can be used to estimate the relative annual index of marine turtle nester abundance for each species.

The field surveys focused on four routine monitoring locations and four opportunistic monitoring locations. The routine monitoring locations included North East (NE) Regnard Island, South West (SW) Regnard Island, Forty Mile Beach (FMB), and Cape Preston East (CPE) beach. Steamboat Island began as an opportunistic monitoring island in the October survey, however, became a routine monitoring location following identification of nesting activity from two days of opportunistic survey in October. The other opportunistic monitoring locations included Unnamed Island, Cape Preston West Beach, and Potter Island. A total of 45 survey days were undertaken for the 2022/23 nesting season.

Hawksbill nesting activity accounted for the greatest number of tracks in the overall monitoring period. The highest density of nesting activity occurred on SW Regnard Island, particularly along the northern shoreline of the island. Overall nesting success (the number of successful nests as a percentage of the total number of overnight tracks) was low for hawksbill turtles in FS1 at 15 %, meaning the majority of hawksbill tracks represented unsuccessful nesting attempts (53 %) or false crawls (32 %). Flatback and green turtle nesting was found to be present but marginal when combined for all routine monitoring beaches.

Nest fan data was reflective of the nester abundance for each beach, with nest fans rarely encountered on the routine beaches, except for Steamboat Island. A total of 23 nest fans were recorded over the January and February surveys, with 17 (74 %) occurring on Steamboat Island. The remaining fans occurred on SW Regnard Island (*n* = 2), NE Regnard Island (*n* = 1), and Cape Preston East (*n* = 3). Hatchling species included flatback (*n* = 8), hawksbill (*n* = 14), and unknown (*n* = 1). Positive

identification of hatchling species was determined from track characteristics and the presence of dead or live hatchlings at the surface of the nest cone. Where this was not possible, the emergence was determined to be of unknown species.

Nest fans indicated marine turtle hatchlings successfully oriented seaward after emergence at SW Regnard Island, NE Regnard Island, and Cape Preston East beach. At Steamboat Island, the majority of fans occurred on the southernmost spit, and as a result had much larger spread and offset angles. Emergence patterns on island spits are typically irregular, due to the presence of the ocean across multiple bearings to the nest cone, and the position of the nest further back on the beach. Despite this, the nest fans at Steamboat Island also indicated that hatchlings oriented seaward.

Artificial light data was collected for LEIC in June 2022 at SW Regnard Island, NE Regnard Island, CPE and FMB, and reported on in **Appendix D**. An additional site was monitored during FS2 (January 2023) at Steamboat Island. This was collected opportunistically after moderate turtle nesting activity was identified at Steamboat Island in FS1, to form part of the benchmark light dataset for the Project. Steamboat Island was in the top three monitored locations for sky brightness, behind CPE (brightest) and equivalent to the eastern beach of SW Regnard Island. Sino Iron's export facility at Cape Preston was the largest contributor to visible artificial light at Steamboat Island.

A risk assessment was undertaken using a standard risk assessment matrix, with modified definitions for consequence and likelihood ratings relevant to hatchling turtles and the regional nesting population. The risk assessment applied to SW Regnard Island, NE Regnard Island, CPE beach and FMB. The process assessed the potential for artificial light to cause mis- or disorientation of hatchling sea turtles of all species occurring in the vicinity of the Project, leading to a reduced fitness or mortality, when compared to 'benchmark' (Pre-construction) light conditions. The risk assessment used light modelling (**Appendix D**) to determine the predicted change in light attributable to the Project and proposed Cape Preston East Export Facility (CPEEF), including its intensity, visibility, and directionality at nesting habitat. The modelling represents the unmitigated ('worst-case') visibility of light associated with the Project and CPEEF under clear-sky conditions during a new moon period.

The risk assessment found the risk at NE Regnard Island, SW Regnard Island and FMB to be 'Low'. At CPE beach, the risk was assessed as 'Medium', due to the proximity of nesting habitat to the proposed CPEEF, deemed likely to have potential to change hatchling behaviour in its modelled state. However, due to the small size of the overall nesting population in proximity to the Project, any impact is not expected to have a detectable effect on the respective genetic stocks of each species.

It is recommended that the Project consider the ways in which the lighting design can be revised to better meet the Best Practice Lighting Design Principles outlined in the NLPGW. Principles such as reducing the Correlated Colour Temperature (CCT) of outdoor lighting, reducing the number of lights, considering smart lighting controls, and applying shielding or recessing to lights will reduce the visibility of light at turtle nesting beaches, and also reduce the impact on other species of wildlife, and on dark sky conservation values.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

4WD	Four-wheel drive
BoM	Bureau of Meteorology
CCT	Correlated Colour Temperature
CPE	Cape Preston East
CPEEF	Cape Preston East Export Facility
CPW	Cape Preston West
EPA	Environmental Protection Authority
FMB	Forty Mile Beach
F-Pil	Pilbara stock, Flatback turtles
FS	Field Survey
G-NWS	North West Shelf stock, Green turtles
H-WA	Western Australia stock, Hawksbill turtles
FMB	Forty Mile Beach
LED	Light-emitting diode
LEIC	Leichhardt Salt Pty Ltd
NE	North East
NLPGW	National Light Pollution Guidelines for Wildlife
OGV	Ocean-going vessel
PENV	Pendoley Environmental
SW	South West
TSV	Trans-shipment vessel
UAV	Unmanned Aerial Vehicle
WA	Western Australia
WOS	Whole of Sky

1 INTRODUCTION

1.1 Project Description

Leichhardt Salt Pty Ltd (LEIC) is the Proponent for the Eramurra Solar Salt Project (hereafter, 'the Project'), a proposed solar salt operation in the Pilbara region of Western Australia (WA). The Project is targeting an average production rate of 5.2 million tonnes per annum (Mtpa) of high-grade salt from seawater, with up to 6.8 Mt of salt deposited in a low rainfall year. The Project will be located to the east of Citic Pacific's Sino Iron Project at Cape Preston, WA.

The Project will require development of concentrator and crystallisation ponds and construction of a processing plant and other supporting infrastructure. Nearshore, dredging of a shipping channel will provide access to a trestle jetty at the Cape Preston East Export Facility (CPEEF), which was referred and approved separately to the Project. However, construction of the CPEEF will occur in conjunction with the Project construction.

1.2 Scope Context

LEIC engaged Pendoley Environmental (PENV) to undertake benchmark artificial light monitoring at turtle nesting habitat in the vicinity of the project in June 2022, in response to comments received from the Environmental Protection Authority (EPA) on their draft Environmental Scoping Document (14th March 2022):

"Undertake a baseline light survey to identify the current light environment and undertake a light spill study to consider the direction and intensity of the expected light sources to determine whether the Proposal will attract turtle hatchlings or otherwise alter their behaviour. The light spill study will consider cumulative lighting impacts on the turtle population of the North West Shelf."

The outcome of the artificial light study identified that there was insufficient information available on the nesting population of turtles at Cape Preston and surrounding beaches to conduct an artificial light impact assessment. Further marine turtle surveys were recommended, designed in line with the recommendations of the National Light Pollution Guidelines for Wildlife (NLPGW, Commonwealth of Australia 2020), to understand the species abundance and distribution of nesting and hatching marine turtles.

1.3 Previous Marine Turtle Monitoring Effort

PENV is aware of three reports that have previously captured marine turtle data in proximity to the Project. An overview of each report, including the scope, survey duration and limitations (with respect to the objectives of the NLPGW) are provided in **Appendix A**.

In general, there is limited data available regarding the abundance and distribution of nesting turtles on the islands and mainland beaches within 20 km of the Project. This is especially true for hawksbill turtles (*Eretmochelys imbricata*), as previous surveys have been conducted outside of the reported peak nesting period for the Pilbara region, which occurs over October–November (Commonwealth of Australia 2017). In addition, all previous surveys have been short in duration (<6 days), and so no nester abundance estimate of any marine turtle species could be derived from the results.

There is no existing data available on hatchling orientation for any species in the vicinity of the Project. One report (Imbricata 2013), made assumptions about the potential impact to hatchlings using adult nesting distribution and artificial light data, however this was not informed by hatchling fan data. Collecting benchmark information on hatchling orientation was therefore identified as one of the main objectives of the 2022/23 survey season (**Section 1.4**).

1.4 Scope of Work and Objectives

This report details the outcomes of benchmark marine turtle monitoring undertaken to estimate the abundance and distribution of marine turtles nesting within the vicinity of the Project, and record hatchling behaviour. Marine turtle surveys were undertaken over the 2022/23 austral summer, and were designed to record information on hawksbill, flatback (*Natator depressus*), and green (*Chelonia mydas*) turtles in line with the recommendations of the NLPGW (Commonwealth of Australia 2020).

Data was collected to meet the following objectives:

- Identify the species of turtles nesting on the beaches;
- Identify the abundance and distribution of adult tracks on the nesting beaches; and
- Record benchmark data on hatchling orientation.

2 METHODS

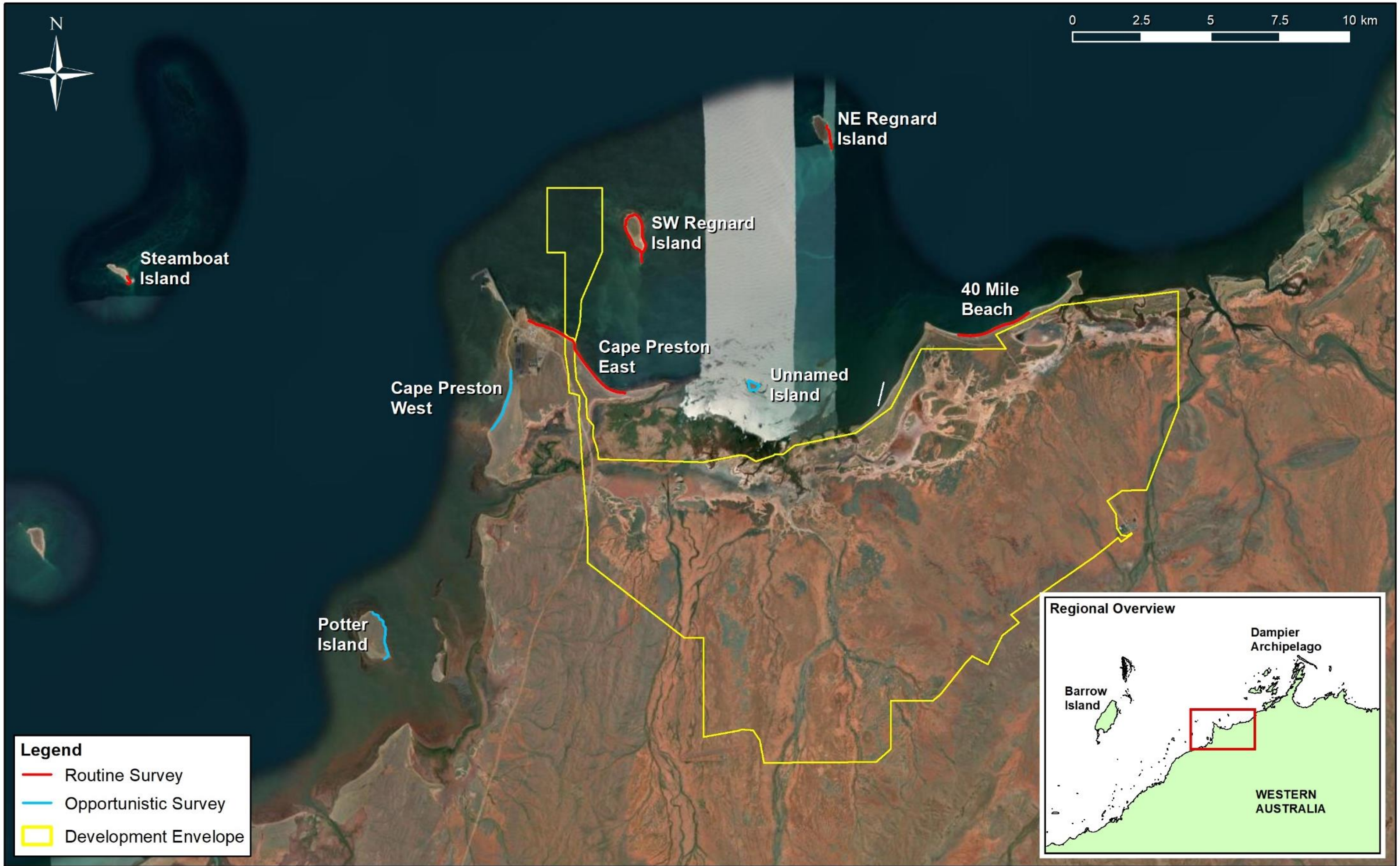
2.1 Survey Location and Schedule

Marine turtle nesting and hatching surveys were conducted at islands and along the mainland coast in the vicinity of the Project over the 2022/23 marine turtle nesting season (**Figure 1**). Three field surveys were undertaken over October 2022 – February 2023, including:

- **Field Survey 1 (FS1; 19th October – 2nd November 2022):** Targeted the peak of the hawksbill turtle nesting season over one 14-day inter-nesting period (**Section 2.3**).
- **Field Survey 2 (FS2; 10th – 25th January 2023):** Targeted the peak of the green and flatback turtle nesting season over one 14-day inter-nesting period and peak hawksbill hatching season.
- **Field Survey 3 (FS3; 13th – 28th February 2023):** Targeted the peak of green and flatback hatching season over one 14-day period.

Peak nesting and hatching periods were determined for the relevant genetic stock for each species, as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017). This includes the North West Shelf stock of green turtles (G-NWS), the Pilbara stock of flatback turtles (F-Pil), and the Western Australia stock of hawksbill turtles (H-WA).

Suitable sandy beach habitat was surveyed to determine the presence and abundance of nesting activities, and hatchling orientation. The work program and survey methods were tailored based on the objectives of each survey, with the potential impact beaches prioritised according to the rationale provided in **Table 1**.



J10602 Eramurra Marine Turtle Monitoring

Figure 1: Field survey locations for the Eramurra Solar Salt Project, Western Australia.

Drawn: B. Moore
Date: 31/01/2023
Drawing File Ref: J10602-1261-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

Table 1: Survey site selection rationale.

Location	Rationale
South West (SW) Regnard Island	Routine monitoring location (all surveys). Data deficient for hawksbill, green and flatback turtles and hatchling orientation (all species). 1.3 km from proposed shipping channel (closest point), 3.5 km from trestle jetty (closest point) and 4.0 km from proposed port infrastructure and salt stockpile.
North East (NE) Regnard Island	Routine monitoring location (all surveys). Data deficient for hawksbill, green and flatback turtles and hatchling orientation (all species). 11 km from proposed pump station flood lighting (closest point).
CPE Beaches (north and south)	Routine monitoring location (all surveys). Data deficient for hawksbill turtles and hatchling orientation (all species). Adjacent to proposed CPE port infrastructure and stockpile.
Steamboat Island	Opportunistic monitoring location (FS1) and routine monitoring location (FS2 and FS3). Data deficient for hawksbill, green and flatback turtles and hatchling orientation (all species). Surveyed opportunistically in FS1 due to long distance (>15 km) from Project. Surveyed routinely in FS2 and FS3 after nesting activity was detected here by FS1 opportunistic surveys.
Cape Preston West (CPW) Beach	Opportunistic monitoring location (FS1 and FS2). Data deficient for hawksbill turtles. Surveyed opportunistically due to its position on the west side of existing Cape Preston infrastructure and Port – Project will be shielded by Cape Preston. Difficult to access on foot.
Unnamed Island	Opportunistic monitoring location (FS1 and FS2). Beaches considered unlikely to support nesting due to beach characteristics and mangroves. Monitored to verify absence of nesting activity.
Potter Island	Opportunistic monitoring location (FS1 and FS2). Beaches considered unlikely to support nesting due to beach characteristics and mangroves. Monitored to verify absence of nesting activity.
Forty Mile Beach (FMB; Gnoorea)	Routine monitoring location (all surveys). Data deficient for hawksbill turtles and hatchling orientation (all species). 2.5 km from pump station flood lighting. Open to off-road vehicles and campers.

2.2 Work Program

An overview of the work scopes conducted for each field survey is provided in **Table 2**, with methodology detailed in the following sections. A daily location schedule for each field survey is provided in **Appendix B.**

Table 2: Field survey work program. Locations marked with '*' were only monitored via opportunistic ('snapshot') survey for the period indicated. NE = North East; SW = South West; CPE = Cape Preston East; FMB = Forty Mile Beach; CPW = Cape Preston West.

Location	Track Census			Hatchling Orientation		
	FS1	FS2	FS3	FS1	FS2	FS3
NE Regnard Island	✓	✓	✓	-	✓	✓
SW Regnard Island	✓	✓	✓	-	✓	✓
Steamboat Island	✓ *	✓	✓	-	✓	✓
Unnamed Island	✓ *	✓ *	-	-	-	-
Potter Island	✓ *	✓ *	-	-	-	-
CPE	✓	✓	✓	-	✓	✓
FMB	✓	✓	✓	-	-	✓
CPW	✓ *	✓ *	-	-	-	-

2.3 Field Survey 1

Field Survey 1 (FS1) was conducted over 19th October – 2nd November 2022, with the objective of completing a track census of adult nesting activity during the peak hawksbill turtle nesting period for the Pilbara (nominally October and November; Commonwealth of Australia 2017), over a 14-day inter-nesting period. The survey was completed by one PENV field member, supported by a vessel master and deckhand from Oceanic Offshore.

2.3.1 Track Census

2.3.1.1 Data Capture

The October track census was completed using an unmanned aerial vehicle (UAV) launched and landed by a qualified remote pilot from the survey vessel. Aerial imagery was captured at routine monitoring beaches using a DJI Phantom 4 Pro UAV. The UAV flew along pre-programmed flight paths over suitable nesting habitat on NE Regnard Island, SW Regnard Island, CPE and FMB for each day of FS1 (**Appendix B**). In addition, other beaches in the vicinity of the Project were monitored with the UAV on an opportunistic basis, which involved conducting one-off, 'snapshot' flights over Unnamed Island, Potter Island, Steamboat Island and CPW.

The UAV was flown at a ground speed of 4.5 – 4.8 ms^{-1}, 30 m above ground level, and captured images at two-second intervals. Each image was georeferenced with the UAV's position at time of capture. At this speed, altitude, and capture frequency, the UAV recorded images at a high ground sampling distance of 0.8 cm^2 per pixel an 75 % overlap, which is necessary for the generation of a high resolution orthomosaic.

2.3.1.2 Data Processing

Aerial imagery was stitched into a single georeferenced orthomosaic for each survey day using Pix4D Mapper Pro software (v4.7.5). Each orthomosaic was visually screened in QGIS (v3.28.2) for overnight nesting activity. New activity was identified by comparing imagery from each new survey day with imagery from the previous day. Turtle species, location, and type of nesting activity ('false crawl', 'attempt', 'nest', or 'unknown'; **Table 3**) were identified for each track by a qualified marine scientist using track and nest characteristics, including track width, shape and orientation of flipper marks, tail drag marks, and displaced sand. A subset of the classified tracks (40 %) was then reviewed by a qualified marine turtle biologist, to verify the correct identification of tracks and nests. Example imagery generated from the UAV flights is provided in **Appendix C**.

Table 3: Definitions of turtle nesting activity.

Activity	Definition
Nest	A female turtle successfully laid a clutch of eggs, covered and camouflaged the nest before returning to the sea.
Attempt	A female turtle attempted to lay a clutch of eggs, by digging a nest, or part thereof, but not actually depositing her eggs before returning to the sea.
False Crawl	A female turtle crawled on the beach and made no digging attempt before returning to the sea without laying.
Unknown	The nesting activity could not be determined from the track characteristics.

2.4 Field Survey 2

Field Survey 2 (FS2) was conducted over 10th – 25th January 2023, with the objective of completing a track census of adult nesting activity during the peak green (December to February, inclusive) and flatback (November to January, inclusive) nesting period for the Pilbara region (Commonwealth of Australia 2017), over a 14-day inter-nesting period. In addition, a hatchling orientation survey was conducted on beaches where hawksbill nesting activity was observed in FS1, to collect nest fan data from recently emerged hawksbill hatchlings during the peak hatching period (December to February, inclusive; Commonwealth of Australia 2017). The survey was scheduled over a new moon period as recommended by the NLPGW (new moon: 22nd January 2023; Commonwealth of Australia 2020).

2.4.1 Track Census

The January track census was largely completed on-foot by two PENV field personnel at routine monitoring beaches to increase the detectability of hatchling tracks surveyed concurrently (**Section 2.4.2**). Species information, nesting activity (**Table 3**) and a GPS location was recorded on a field tablet for each adult track encountered during the daily beach walks.

Due to the size of the survey area and logistical constraints of reaching and walking all beaches on every day of the program, beaches were instead monitored on every second day of the program, alternating between mainland beaches (CPE and FMB) and island beaches (NE Regnard, SW Regnard, and Steamboat islands). The survey was therefore conducted over a 16-day period, to ensure each beach was visited for a total of at least 14 days (refer to **Appendix B** for full survey schedule).

The results of the October survey indicated that adult tracks above the high tide mark remained visible for multiple days, including preservation of key features that allow for species and activity identification. Examples of the preservation of adult tracks on CPE and SW Regnard Island are provided in **Appendix C**. There was high confidence that for the January survey, routine monitoring beaches could be surveyed every second day of the program and still derive an accurate abundance estimate, provided weather conditions were not adverse (i.e. gale-force winds, rainfall, or cyclone). Each survey day therefore captured nesting activity from the previous two nights.

All routine monitoring beaches were surveyed on foot, with the exception of FMB, which was surveyed via UAV. This is because no hawksbill nesting activity was detected at FMB during the October survey (**Section 3.3**), and there is no historical data available indicating hawksbills use this beach for nesting (PENV 2009; O2 Marine 2022). Therefore, it was considered unlikely that hawksbill hatchling fans would be encountered on this beach in January.

Opportunistic monitoring beaches (Unnamed Island, Potter Island, and CPW) were also surveyed by UAV in a single snapshot survey at each location. All UAV imagery collected during the January survey was processed and analysed as per the methods in **Section 2.3.1.1** and **2.3.1.2**.

2.4.2 Hatchling Orientation

2.4.2.1 Data Collection

Hatchling fans were surveyed concurrently with the on-foot track census. Whilst it is acknowledged that hatchling fans are more susceptible to being erased by wind when surveyed on alternate days (when compared to adult tracks), this approach was adopted due to the following rationale:

- The size and remoteness of survey beaches made it logistically difficult for the survey team to patrol all beaches on foot every day of the field program, taking into account weather, vessel transit times, tidal movements, health and safety considerations, and the terrain governing access to beaches. In addition, it was not desirable to survey hatchling fans in the late afternoon due to the heat, and reduced detectability of hatchling fans as a result of a high sun angle.

- Hatchlings may take multiple nights to emerge from a nest, having the potential to create more than one fan over successive nights. Therefore, there may be multiple opportunities to record some of the emergence event (i.e. one fan), provided the weather is conducive to detecting hatchling fans (i.e. absence of rain or high winds).

A nest fan was recorded if five or more hatchling tracks were sighted from a hatched clutch. Hatchling tracks fan out from a localised depression in the sand which marks the point of emergence. A sighting compass was used to measure the bearing of the outermost tracks of the nest fan (vectors A and B, **Figure 2**) and the bearing of the most direct route to the ocean (vector X, **Figure 2**). Bearings were measured from the point where the track crossed the high tide line. Single hatchling tracks that were more than 30˚ from the outermost track of the main fan were recorded as outliers.

Positive species identification was made based on hatchling track characteristics (size and number of tracks), and from the presence of alive and dead hatchlings at the surface of the nest cone. In general, flatback hatchling tracks are easily identifiable from hawksbill and green tracks based on their size. In contrast, hawksbill and green tracks are difficult to tell apart, and identification of species at this level only occurred where there was a hatchling present at the surface.

2.4.2.2 Data Analysis

Offset and spread angles were calculated for bearings measured from each nest fan to determine the spread of hatchling tracks from the point of emergence, and the degree to which hatchlings diverged from the most direct route to the ocean.

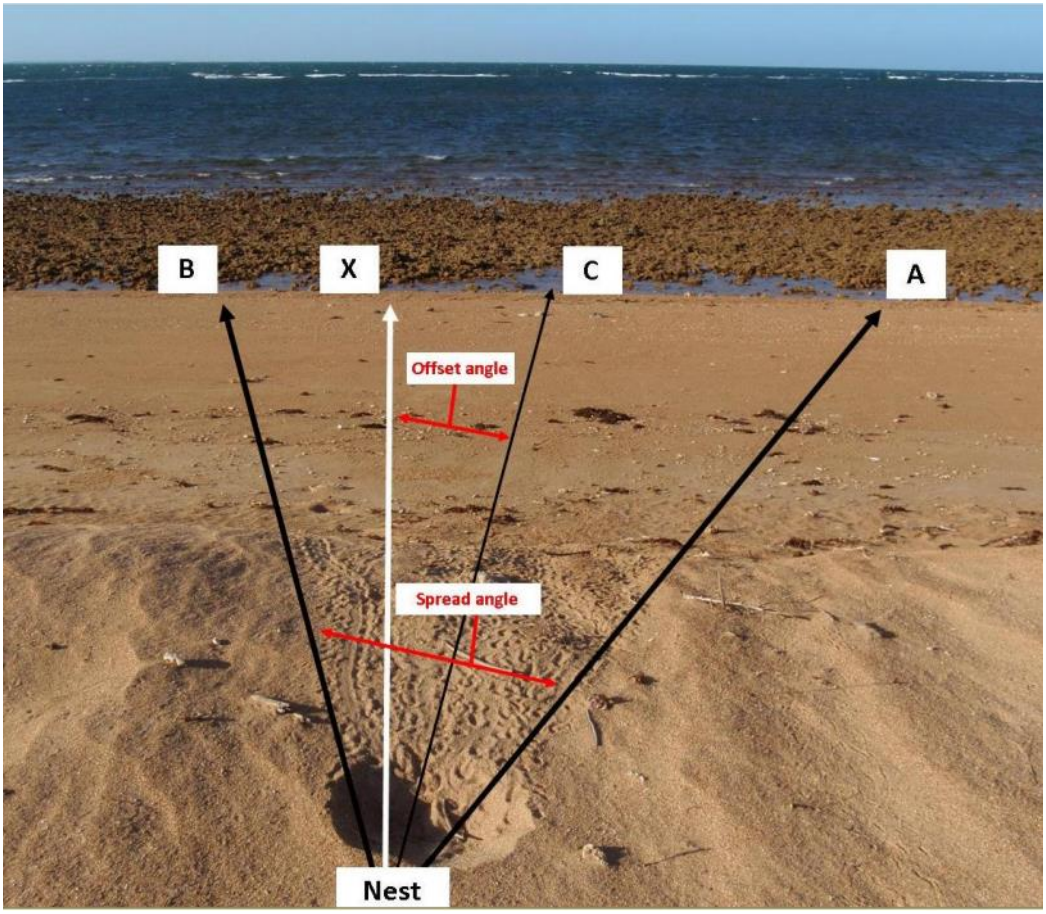


Figure 2: Hatchling orientation measurements describing hatchling spread and offset.

2.4.3 Artificial Light Monitoring

2.4.3.1 Data Collection

A Sky42 artificial light monitoring camera was deployed on Steamboat Island for four nights over the new moon period, the 18th, 19th, 21st and 22nd of January 2023. The camera features a calibrated Canon EOS 700D DSLR combined with a fish-eye lens and custom-built hardware to acquire low-light images of the entire night sky. It was deployed on a tripod (~60 cm above ground level) on an area of sandy beach suitable for turtle nesting (**Figure 3**).

Figure 3: Sky42 Camera deployed on Steamboat Island, January 2023.

Artificial light monitoring of the other routine monitoring sites (NE Regnard Island, SW Regnard Island, FMB, and CPE) was undertaken for LEIC in June 2022, and reported in **Appendix D**. The images represent a pre-construction lighting environment at turtle nesting habitat, and can be used for comparison purposes in the future if required to determine the construction and operational contributions to the artificial light environment.

2.4.3.2 Data Analysis

All suitable images at Steamboat Island were processed using specialised software to determine 'whole-of-sky' (WOS) and 'horizon' sky brightness. WOS is the mean value of light (including direct light and sky glow, natural and artificial) in the entire image, and horizon brightness is the mean value of light within the 60 – 90° outer band, considered most relevant to marine turtle vision (**Figure 4**). All images have been quantified in units of visual magnitudes per square arc second (Vmag/arcsec^2), a common unit used to measure astronomical sky brightness that represents light intensity on an inverse logarithmic scale.

Note that the colour coding used in the processed imagery represents the scale and intensity of light and is not representative of the colour of light as perceived by a human or turtle eye, or Sky42 camera.

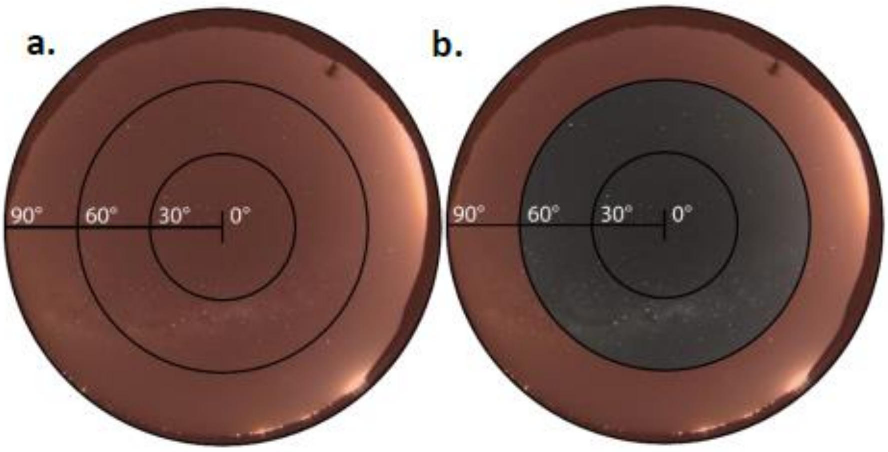


Figure 4: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60 – 90°). Shaded area denotes the region of the sky being measured.

2.5 Field Survey 3

Field Survey 3 (FS3) was conducted over 13th – 28th February 2023, with the objective of recording hatchling fans during the peak flatback and green turtle hatching period (both February – March, inclusive; Commonwealth of Australia 2017). The survey was scheduled over a new moon period as recommended by the NLPGW (new moon: 20th February 2023; Commonwealth of Australia 2020). Information on adult nesting activity was also captured during this period, however the results do not form part of an adult nester abundance estimate as they were recorded outside of the reported peak nesting period for all species.

2.5.1 Hatchling Orientation

Hatchling fans were surveyed on-foot at four survey locations, including NE Regnard Island, SW Regnard Island, Steamboat Island, and CPE. As per FS2, the island locations were surveyed on alternate days to the mainland beaches (**Appendix B**) for the reasons outlined in **Section 2.4.2**. FMB was also surveyed in conjunction with CPE, however the survey was conducted by 4WD vehicle, due to the long survey distance and extreme weather conditions encountered in February. Two 4WD vehicles were used to survey the beach in convoy, driving at a speed of 5 – 10 km/hr, with field personnel scanning suitable nesting habitat for signs of hatchling activity (i.e. hatchling tracks or nest cone).

Hatchling fan data from FS3 was analysed as per **Section 2.4.2.2.**

2.5.2 Track Census

Information on adult tracks, including the species, nesting activity and GPS location, were recorded concurrently with the hatchling orientation surveys at routinely monitored locations. No opportunistic surveys were undertaken during the February survey as it was outside the reported peak nesting period for all species.

3 RESULTS

3.1 Field Conditions

All three field surveys were completed as planned over the scheduled dates (**Section 2.1, Appendix B**). Each survey was impacted by adverse weather to some extent, which resulted in weather standbys or restricted access to some of the beaches. The following alterations to the field schedule were made due to poor weather:

- **Field Survey 1**: One weather standby day (all locations on 24th October; **Appendix B**) due to winds in excess of 40 km/hr, which was unsuitable for UAV flights and difficult for the vessel to access the islands. Field work resumed as normal on the 25th October, where it was determined that tracks from the previous two nights were still visible in UAV imagery, despite the strong winds.

- **Field Survey 2:** One weather standby day for CPE due to rain (22nd January; **Appendix B**), causing the 4WD access route to become flooded. CPE was surveyed by UAV from the vessel on the next survey day (23rd January) to ensure continuation of the adult track census.

- **Field Survey 3:** Two weather standby days occurred for FMB in the final days of the field survey due to heavy rain and thunderstorms (25th and 27th February; **Appendix B**). The road out to the beach was closed by local authorities, making access impossible. Due to the absence of any adult turtle nesting activity recorded in FS1 and FS2, no further effort was made to monitor FMB as it was determined the likelihood of encountering hatchling fans was extremely low.

Field conditions were suitable (low-moderate wind and clear skies) for the majority of the field season, which encompassed a total of 45 survey days. Weather data from the Bureau of Meteorology (BoM) at nearby Mardie Station (40 – 60 km from survey locations) is displayed for all survey periods in **Figure 5**. Maximum daily temperatures for the period ranged from 27.8 – 46.1 °C, and total rainfall was 120.4 mm. Widespread and heavy rain during the latter half of FS3 (22nd – 27th February; **Figure 5**) may have impacted the detectability of hatchling fans, however the localised nature of showers made it difficult to predict where and when rainfall would occur. The field survey continued as scheduled despite the rain to complete one full season of turtle monitoring, as per the recommendations of the NLPGW (Commonwealth of Australia 2020).

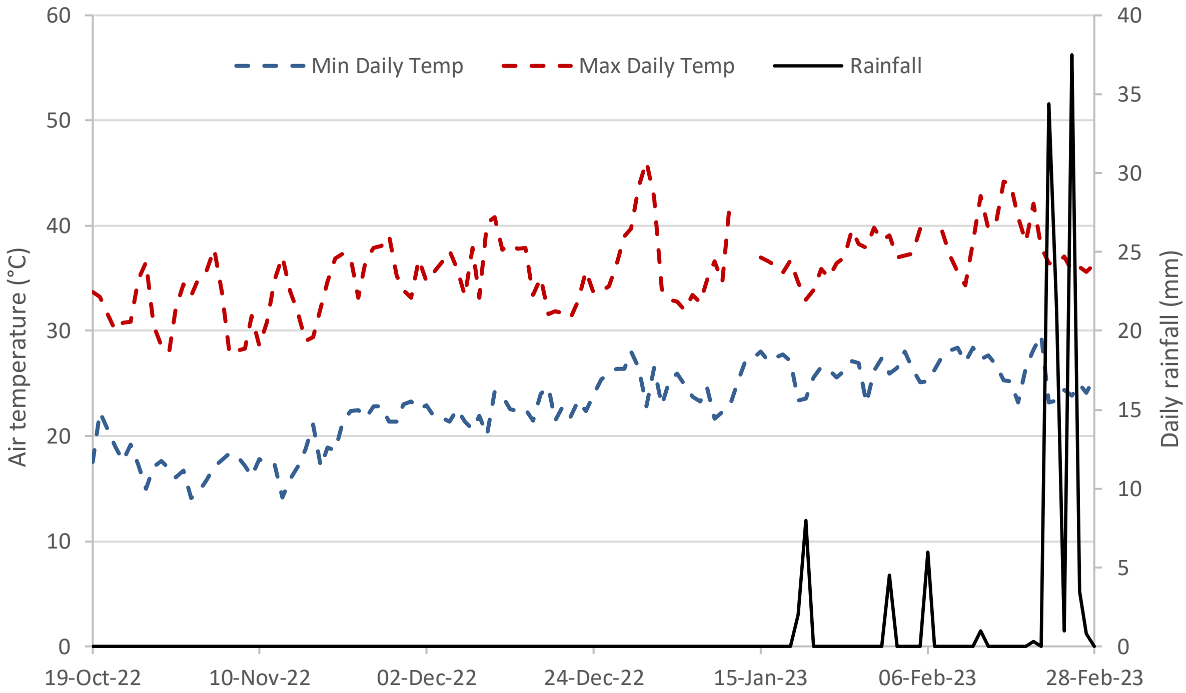


Figure 5: Daily rainfall and air temperature recorded at Mardie, Western Australia, between 19th October 2022 and 28th February 2023. Source: Mardie Station (station 005008), BoM.

3.2 Nesting Habitat

3.2.1 Cape Preston East

The beach along the east of Cape Preston features ~4 km of suitable nesting habitat for marine turtles. The southern beach (~2.5 km) has a shallow slope and sandy approach, wide beach face and low primary dune that is densely vegetated (**Figure 6**). It is bounded at either end by intertidal rock platforms. The northern beach (~1.5 km) has a shallower nearshore approach, a rocky intertidal platform and a tall, steeply sloping primary dune that is also densely vegetated (**Figure 6**).

The conditions at CPE were excellent for adult track preservation, with tracks persisting for weeks to months on this beach. Adult tracks were present underneath hatchling fans detected on the beach in January, which were likely made by the adult turtle who had laid the clutch months prior (refer to cover image).

Figure 6: Cape Preston East Beaches. A. Southern Beach; B. Northern Beach.

3.2.2 South West Regnard Island

SW Regnard Island is located ~4 km offshore to the northeast of Cape Preston. The island is predominantly bounded by intertidal rock platforms and reef, and features a long and thin sand spit extending from the south of the island that becomes fully submerged on a high spring tide. Viable nesting habitat is fragmented around the island, typically consisting of a thin sandy area between the top of the high tide line and the base of the tall primary dune (**Figure 7**). The total length of beach supporting nesting is estimated to be 1.1 km.

Track preservation at SW Regnard Island was moderate, with adult tracks persisting for multiple days to weeks (field observations; **Appendix C**). During the January survey, cones of sand were observed to have been deposited over the top of nesting habitat from higher up on the dune (where the highest density of hawksbill nesting was observed in October; **Figure 7b**), and predation of shallow nests (~20 – 30 cm) deep was common (predators undetermined).

Figure 7: South West Regnard Island. A. Beach at northern extent illustrating typical nesting habitat; B. Cones of sand deposited over area of highest nesting activity.

3.2.3 North East Regnard Island

NE Regnard Island is located ~12 km northeast from Cape Preston, and ~7.5 km north of FMB (**Figure 1**). The island is predominantly bounded by intertidal rock and reef, with a long and thin sand spit extending from the south of the island that becomes fully submerged during a high spring tide. Suitable nesting habitat occurs along a ~500 m stretch of beach, extending north from the sand spit, along the eastern shoreline (**Figure 8**).

Track preservation on NE Regnard was moderate, with adult tracks lasting for days to weeks. There were a number of old and deep body pits, possibly indicative of green turtle nesting activity (**Figure 8**). Predation was also evident on the island, however due to the overall low level of nesting activity it was not encountered as frequently as on SW Regnard Island.

Figure 8: North East Regnard Island. A. Nesting habitat; B. Old body pits.

3.2.4 Steamboat Island

Steamboat Island is located ~15 km offshore from Cape Preston in a north-westerly direction. The island is predominantly bounded by intertidal rock and reef, with only a short length of beach present on either side of sand spit at the southern end of the island (**Figure 9**). The primary dune behind the beach is low and moderately vegetated, and the total length of beach supporting nesting is estimated at 280 m. Recreational use of the island was observed during the January survey, including human and domestic dog tracks on the nesting beach.

Track preservation on Steamboat Island was poor and highly dependent on wind direction. This is because the island is not shielded from south-westerly winds by the mainland (i.e. as Cape Preston provides some wind-sheltering for SW and NE Regnard), and does not have a tall hind-dune. Track preservation was therefore variable, with fresh adult tracks lasting no more than one week. Despite this, new adult tracks were still detectable every second day, as confirmed by field observations during the program (i.e. tracks recorded two days prior were still visible at the next visit).

Figure 9: Nesting beach at Steamboat Island.

3.2.5 Forty Mile Beach (Gnoorea)

FMB is a southwest-northeast oriented beach to the east of Cape Preston, approximately 5.5 km in length (**Figure 1**). Similar to CPE, the length of the beach above the high tide line consists of habitat that would be suitable for turtle nesting, however the beach is open for public recreational use, including the use of off-road vehicles along the length of it (**Figure 10**). There is a campsite (Gnoorea) at the western end of the beach and a small boat ramp. The dune behind the beach is tall and densely vegetated, and the nearshore approach is shallow, with a reef platform extending ~1 km offshore from the beach.

Figure 10: Forty Mile Beach.

3.2.6 Cape Preston West

The beach along the west of Cape Preston features ~3 km of potentially suitable nesting habitat for marine turtles (**Figure 11**). The beach is oriented in a north-south direction, and has a shallow nearshore approach, with a reef platform extending up to 1 km from shore. The primary dune is low but densely vegetated, and some taller hills exist behind the dunes creating a natural topographic barrier between the eastern and western sides of the cape.

Figure 11: Cape Preston West.

3.2.7 Potter Island

Potter Island is located ~12 km to the southwest of Cape Preston (**Figure 1**), similar in size to SW Regnard Island. The western shoreline of the island is colonised by mangroves, and the eastern shoreline is predominantly intertidal and subaerial rock (**Figure 12**). There is a small stretch of sandy beach at the south-eastern extent of the island, that may be suitable for turtle nesting.

Figure 12: Potter Island.

3.2.8 Unnamed Island

Unnamed Island is a small, inshore island located between Cape Preston and FMB (**Figure 1**). Mangroves are present along much of the shoreline, as well as a large reef platform to the north of the island. Potential nesting habitat was identified as a very short section of beach on the southern shoreline, forming a small spit (**Figure 13**).

Figure 13: Unnamed Island.

3.3 Track Census

3.3.1 Routine Survey

FS1 recorded 34 overnight hawksbill tracks, including 11 false crawls, 18 attempts, and five nests (excluding Steamboat Island data, **Table 4**). The nesting success rate (the number of successful nests as a percentage of the total number of overnight tracks) for this species during the peak of the nesting season was therefore 14.7 %. Three tracks from an unknown species were also recorded during the October survey on SW Regnard: one nest and two false crawls. The species could not be determined as the tracks occurred just at the top high-tide mark, where the up and down portions of the track had been washed away, or occurred underneath other tracks.

FS2 recorded 10 overnight hawksbill tracks, including one nest, eight attempts and one false crawl, resulting in a similar nesting success rate (10 %) to October (**Table 4**). Flatback tracks totalled seven, including two nests, four attempts, and one false crawl, resulting in a nesting success rate of 28.5 %. Two green nests were also recorded, with no other tracks, making nesting success 100 % for this species.

FS3 recorded one overnight track, which was a nesting attempt by a hawksbill turtle on Steamboat Island. No other fresh adult tracks were recorded for the February survey period (**Table 4**).

The species and nesting activity distributions at routine monitoring beaches (including Steamboat Island) are displayed in **Figure 14 – Figure 17** for FS1 and FS2. No data is displayed for FMB as no adult tracks were detected there during any survey.

Table 4: Track census results for routinely surveyed locations for the 2022/23 nesting season. N = Nest; A = Attempt; FC = False Crawl. Numbers in red are from tracks recorded on line-in day or during an opportunistic survey, where the age of the track could not be determined. * = Steamboat Island was only surveyed opportunistically in FS1.

Location	Hawksbill			Flatback			Green			Unknown		
	N	A	FC	N	A	FC	N	A	FC	N	A	FC
Field Survey 1												
SW Regnard	5 (1)	15 (9)	10 (4)	-	-	-	-	-	-	1 (2)	- (1)	2
NE Regnard	-	-	1	-	-	-	-	-	-	-	-	-
Steamboat*	- (9)	- (3)	- (3)	-	-	-	-	-	-	- (1)	-	- (2)
CPE	- (1)	3 (1)	-	-	-	-	-	-	-	- (3)	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	**5 (11)**	**18 (13)**	**11 (7)**	**-**	**-**	**-**	**-**	**-**	**-**	**1 (6)**	**- (1)**	**2 (2)**
Field Survey 2												
SW Regnard	1	5 (4)	-	- (1)	1 (1)	-	-	-	-	-	-	-
NE Regnard	-	-	-	-	-	-	1	-	-	-	-	-
Steamboat	- (1)	3	1	2 (2)	3 (2)	1 (1)	1	-	-	-	-	-
CPE	-	-	-	-	-	-	-	-	-	-	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	**1 (1)**	**8 (4)**	**1**	**2 (3)**	**4 (3)**	**1 (1)**	**2**	**-**	**-**	**-**	**-**	**-**
Field Survey 3												
SW Regnard	- (1)	-	-	- (1)	-	-	-	-	-	-	-	-
NE Regnard	-	-	-	-	-	-	-	-	-	-	-	-
Steamboat	-	1 (1)	-	- (1)	- (2)	-	-	-	-	-	-	-
CPE	-	-	-	-	-	-	-	-	-	-	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	**- (1)**	**1 (1)**	**-**	**- (2)**	**- (2)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

3.3.1.1 Nester Abundance

Estimates of nester abundance typically assume that 70 – 80 % of turtles of each species would be available for nesting during the mean 14-day inter-nesting period at the respective peak of the nesting season (Whittock et al. 2014). An overall nester abundance has been estimated for each species by combining the track census data for all routine monitoring locations, excluding Steamboat Island. For example, the nester abundance estimate for hawksbill turtles is determined from all nesting data at SW Regnard Island, NE Regnard Island, CPE beach and FMB from FS1, with the same applied for flatback and green turtles from nesting data in FS2. Where the nester abundance is estimated to be zero for a species based on track census results (i.e. no nests detected), observations from outside the survey period are considered to ensure nesting activity is adequately represented.

Nester abundance estimates are used in the risk assessment to determine the nesting habitat contribution to the respective regional genetic stocks (**Section 4.1.1**). Steamboat Island has been excluded from the overall nester abundance estimates as it was not assessed in the risk assessment, for reasons outlined in **Section 4.1.3**. Where possible, Steamboat Island's nester abundance estimate is reported separately.

Hawksbill Turtles

Based on successful nest counts for the 14-day survey in October 2022, the overall nester abundance estimate for hawksbills nesting during the October peak is 6 – 7, with SW Regnard experiencing the heaviest use.

Nester abundance could not be calculated for Steamboat Island as a 14-day track census was not undertaken here in October.

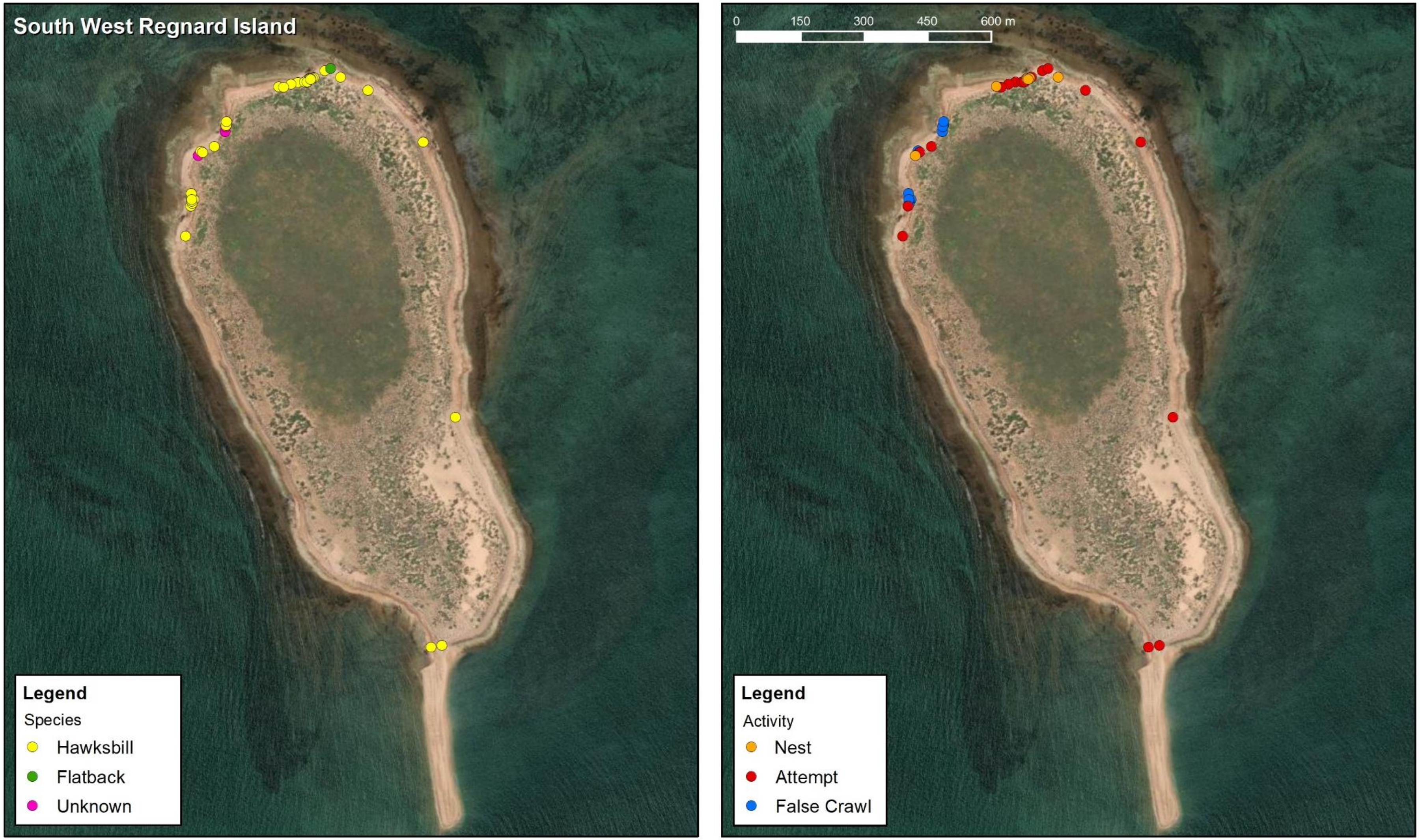
Flatback Turtles

Based on successful nest counts for the 14-day survey in January 2023, the overall nester abundance estimate for flatbacks is zero. Observations outside the survey period suggest that this estimate is not representative of flatback nesting activity, with one nest recorded at SW Regnard Island on line-in day, and two hatched nests recorded on CPE during the January survey. Therefore, for the purpose of providing an estimate to risk assess, the nester abundance has been estimated as 2–3 individuals based on these observations.

At Steamboat Island, the nester abundance estimate of flatback turtles from the January track census is also zero, although a nest laid outside of the survey period suggests nesting is present but nominal.

Green Turtles

Based on successful nest counts for the 14-day survey in January 2023, the overall nester abundance estimate for green turtles is 1–2. At Steamboat Island, the nester abundance is also estimated at 1–2 individuals. No green nesting activity was detected outside of the survey period at routine monitoring locations.



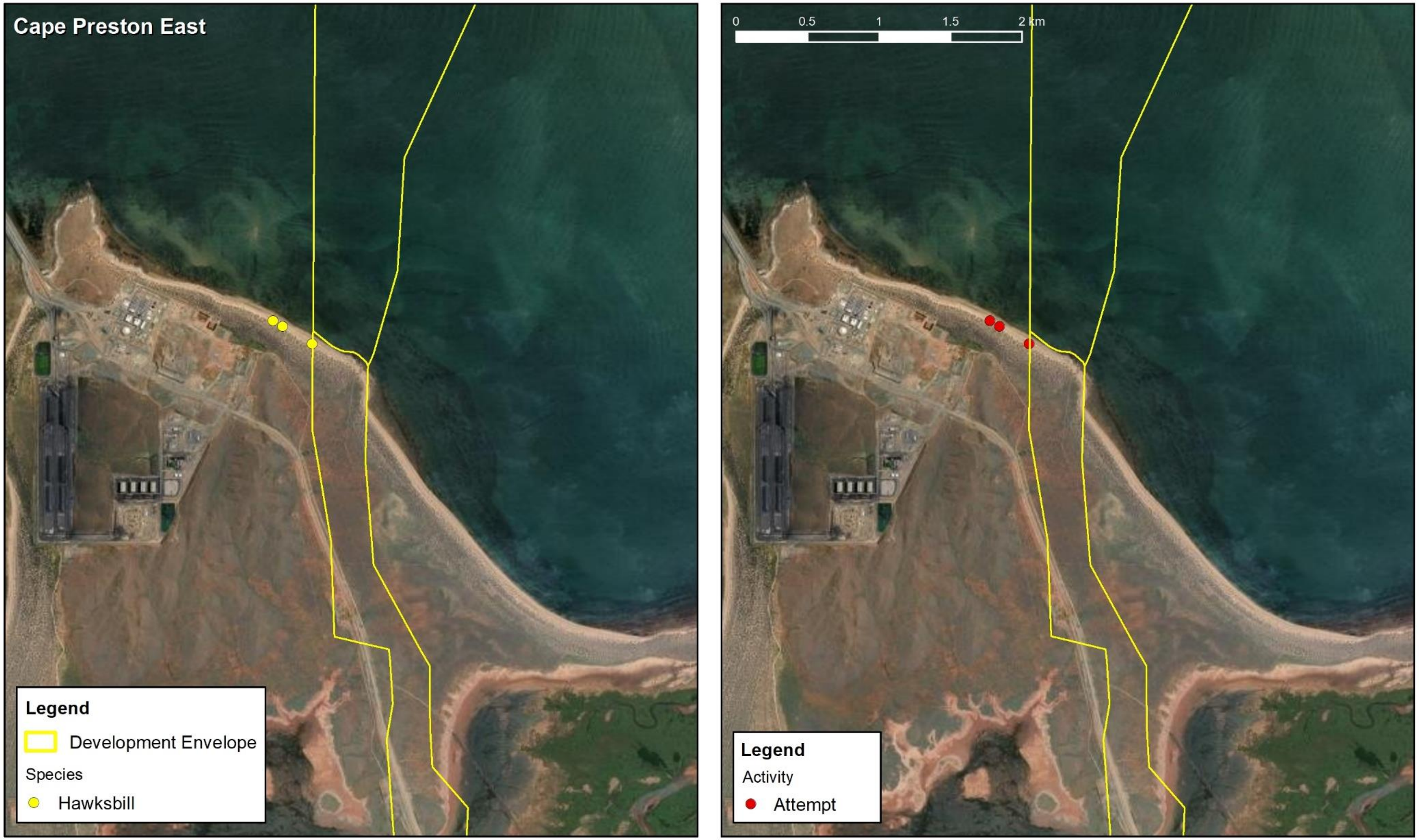
J10602 Eramurra Marine Turtle Monitoring

Figure 14: South West Regnard Island combined track census results for FS1 (14 days, October 2022) and FS2 (15 days, January 2023).

Drawn: B. Moore
Date: 31/01/2023
Drawing File Ref: PENV-J10602-1263-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

Figure 15: North East Regnard Island combined track census results for FS1 (14 days, October 2022) and FS2 (15 days, January 2023).



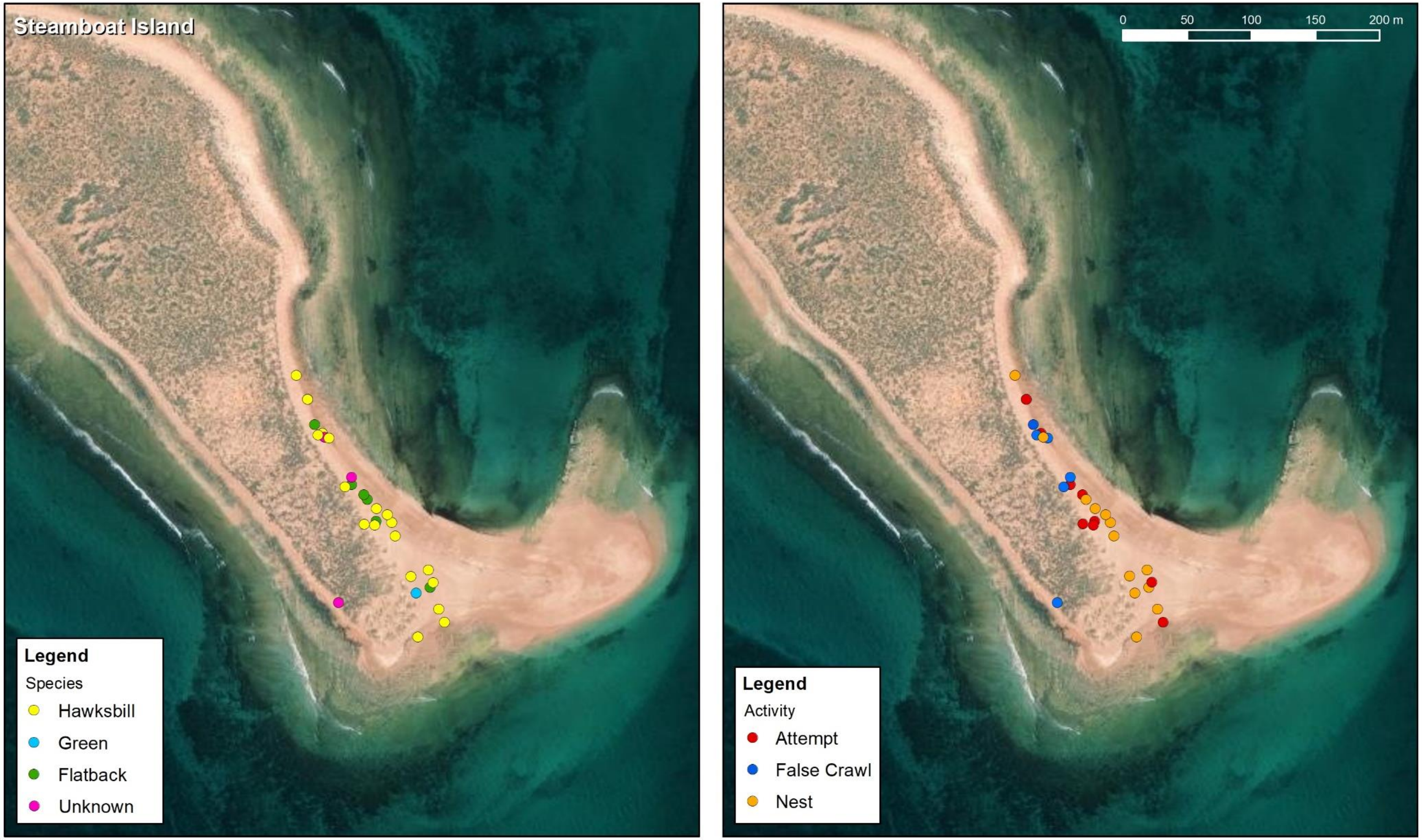
J10602 Eramurra Marine Turtle Monitoring

Figure 16: Cape Preston East combined track census results for FS1 (14 days, October 2022) and FS2 (15 days, January 2023).

N

Drawn: B. Moore
Date: 08/03/2023
Drawing File Ref:
PENV-J10602-1283-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL



J10602 Eramurra Marine Turtle Monitoring

Figure 17: Steamboat Island combined track census results for FS1 (2 days opportunistic, October 2022) and FS2 (15 days, January 2023).

N

Drawn: B. Moore

Date: 15/03/2023

Drawing File Ref:

PENV-J10602-1264-A

Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

3.3.2 Opportunistic Survey

There was no nesting activity identified on Unnamed Island or Potter Island in either opportunistic survey from October or January.

At CPW, one track was identified as a false crawl in October. In January, four attempts were recorded, one nest, and one track where the activity could not be determined. Tracks could not be accurately assigned to a species as all tracks were old and wind-blown, erasing many of the identifying features required to make a classification.

3.4 Hatchling Orientation

A total of 20 hatchling fans were recorded during FS2 and occurred on CPE (*n* = 3), Steamboat (*n* = 14), SW Regnard (*n* = 2), and NE Regnard (*n* = 1) islands. Two of the fans at CPE were from the same nest on different nights, and fan metrics were almost identical for both emergence events, resulting in an almost direct overlap of spread and offset angles (**Figure 19**). FS3 recorded a total of three hatchling fans, all occurring on Steamboat Island. Of these, eight fans were from flatback nests, 14 from hawksbill nests, and one where the species was not identified.

Summary statistics for all hatchling orientation metrics (pooled for both surveys), including nest fan spread and offset angles, are provided in **Table 5**. All nest fans are displayed in **Figure 18** – **Figure 20**. Fans on CPE, SW Regnard, and NE Regnard Islands showed no signs of mis- or dis-orientation, with all fans having small spread and offset angles, indicating dispersal along the most direct route to the ocean. There were also no outliers recorded for these fans.

Table 5: Summary statistics for nest fans. FB = flatback; HB = hawksbill; Unk = unknown species. Where a mean was not able to be calculated (i.e. where *n* = 1), the individual spread and offset angle is given. Standard deviation was not calculated for sample size ≤ 3.

Statistic		Steamboat	SW Regnard	NE Regnard	Cape Preston East
n		17 (FB, HB)	2 (HB)	1 (Unk)	3 (FB)
Spread Angle (degrees)*	**Mean**	57.4	46.0	37.0	74.7
	St. Dev	26.9	NA	NA	NA
Offset Angle (degrees)*	**Mean**	20.5	5	18.5	6
	St. Dev	17.6	NA	NA	NA

J10602 Eramurra Marine Turtle Monitoring

Figure 18: Nest fan spread and offset angles at South West Regnard Island (*n* = 2) and North East Regnard Island (*n* = 1).

Drawn: B. Moore
Date: 03/03/2023
Drawing File Ref:
PENV-J10602-1276-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

J10602 Eramurra Marine Turtle Monitoring

Figure 19: Nest fan spread and offset angles at Cape Preston East (*n* = 3).
Northernmost fans (*n* = 2) are from the same nest and almost directly overlapping.

N

Drawn: B. Moore
Date: 03/03/2023
Drawing File Ref: J10602-1277-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

J10602 Eramurra Marine Turtle Monitoring

Figure 20: Nest fan spread and offset angles at Steamboat Island (n = 17). Fans have been arbitrarily separated and displayed in inset panels due to high overlap.

Drawn: B. Moore
Date: 14/03/2023
Drawing File Ref: J10602-1278-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

It was common for hatchling fans occurring towards the centre of the spit on Steamboat Island to have larger spread angles and multiple outliers, due to the position of the ocean on either side of the nest (**Figure 20**). It was also common to observe circuitous hatchling tracks in this area, and in some cases nest fans could not be determined for these emergences. Hatchlings use natural cues for seafinding, including moving towards the brightest horizon over the ocean and away from tall dark silhouettes, such as those formed by dunes behind the beach (Lohmann & Lohmann 1996; Salmon et al. 1992; Limpus & Kamrowski 2013). These cues may be obscured for hatchlings emerging on spits due to:

- nests being set far back form the water or situated in shallow swales behind the high tide line or amongst nest pits and hummocks in high density nesting area;
- the shortest distance to the ocean occurring on multiple and opposite bearings from the emergence point; or,
- a low dune profile behind the sand spit, reducing the scale and influence of a tall dark horizon behind the nests.

3.5 Artificial Light Monitoring

The Sky42 camera at Steamboat Island (**Figure 20**) recorded the clearest imagery on 22nd January 2023 and was therefore selected to generate the median whole-of-sky (WOS; 0 – 90°) and horizon (0 – 30°) brightness values, considered the most relevant to marine turtle vision. Brightness values are presented in **Table 6** alongside benchmark data from other locations monitored in June 2022 (**Appendix D**). Steamboat Island was in the top three locations for benchmark sky brightness, behind CPE (brightest) and equivalent to SW Regnard (SE).

Three major light sources are visible at Steamboat Island (**Figure 21**), and all are associated with Citic Pacific's iron ore mining operations:

- Cape Preston Export Facility;
- Sino Iron Mine; and,
- Vessels at anchor.

Table 6: Benchmark sky brightness values at monitored locations for the Eramurra Solar Salt Project. Note that the scale is inverse logarithmic, meaning smaller values denote brighter skies.

Location	Sky Brightness (Vmag/arcsec^2)	
	Whole-of-Sky	Horizon
Steamboat Island	**21.05**	**20.86**
NE Regnard	21.22	21.09
SW Regnard (N)	21.19	20.98
SW Regnard (SE)	21.07	20.85
CPE	20.89	20.52
FMB	21.36	21.26

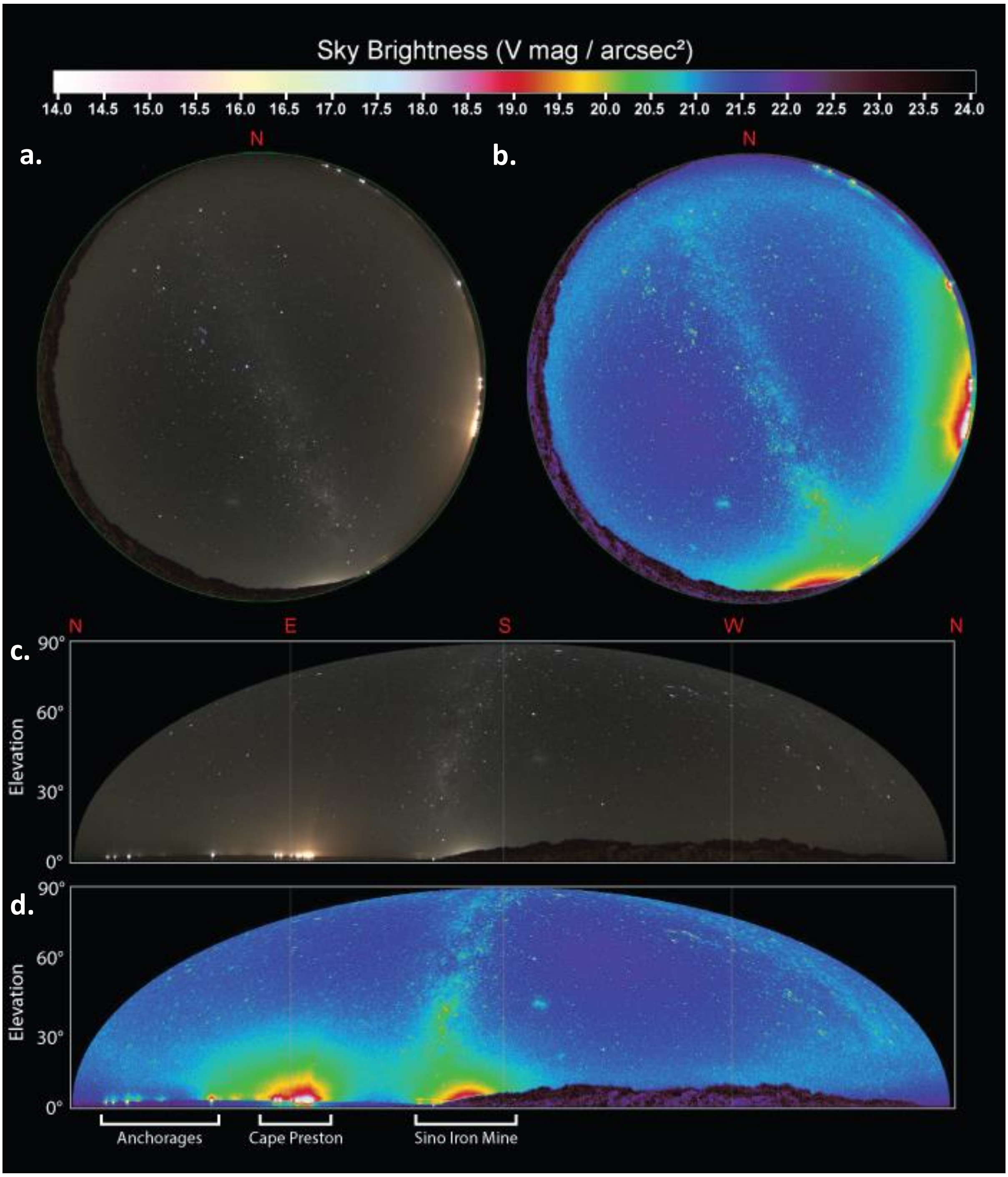


Figure 21: Artificial light monitoring at Steamboat Island on 22nd January 2023. a. Clearest raw circular image; b. Processed circular image; c. Equirectangular raw image; d. Equirectangular processed image.

4 RISK ASSESSMENT

4.1 Approach

The potential for artificial light to impact on the sea-finding behaviour of hatchling turtles in the vicinity of the Project was assessed using a risk assessment matrix (**Table 7**), modified from the Great Barrier Reef Marine Park Authority Environmental Assessment and Management Risk Management Framework (GBRMPA 2017). The matrix applies a score to the 'Likelihood' of an impact occurring, and the potential 'Consequence' of the impact occurring, and combines these scores to determine an overall risk rating.

This process assessed the potential for artificial light to cause mis- or disorientation of hatchling sea turtles of all species occurring in the vicinity of the Project (hawksbill, flatback and green), leading to a reduced fitness or mortality, when compared to 'benchmark' (Project pre-construction) light conditions. The Project lighting environment, and that of the Cape Preston East Export Facility (CPEEF) has been modelled using a preliminary lighting inventory provided to PENV, detailed in **Appendix D**. The modelling represents the unmitigated ('worst-case') visibility of light associated with the Project and CPEEF under clear-sky conditions during a new moon period.

The risk assessment considered light sources both individually (i.e. directionality, intensity and visibility of light from each source), and cumulatively (i.e. the cumulative contribution to visible direct light and sky glow from existing and proposed sources, as informed by light modelling), to determine an overall risk rating to hatchlings emerging at each routine monitoring location: CPE, SW Regnard Island, NE Regnard Island and FMB. A description of each Consequence criteria is provided in **Section 4.1.1,** and each Likelihood criteria is provided in **Section 4.1.2.**

Table 7: Risk Assessment Matrix.

Likelihood (see Table 11 for definition)	**Consequence (see Table 10 for definition)**				
	Insignificant 1	*Minor* 2	*Moderate* 3	*Major* 4	*Catastrophic* 5
Almost certain 5	**Medium** 5	**High** 10	**High** 15	**Extreme** 20	**Extreme** 25
Likely 4	**Medium** 4	**Medium** 8	**High** 12	**High** 16	**Extreme** 20
Possible 3	**Low** 3	**Medium** 6	**Medium** 9	**High** 12	**High** 15
Unlikely 2	**Low** 2	**Low** 4	**Medium** 6	**Medium** 8	**High** 10
Rare 1	**Low** 1	**Low** 2	**Low** 3	**Medium** 4	**Medium** 5

4.1.1 Description of Consequence Criteria

When determining the consequence of the impact, two factors were considered:

1. The significance of the nesting population at impact sites, based on the relative contribution of breeding individuals to the overall genetic stock (**Section 4.1.1.1**); and
2. The length of time over which turtle hatchlings may be exposed to the impact (**Section 4.1.1.2**).

4.1.1.1 Significance of Nesting Population

As per the NLPGW (Commonwealth of Australia 2020), when determining the consequence score of a development's risk assessment, it is necessary to consider the significance of potential impact sites to marine turtle nesting, relative to the overall genetic stock of the nesting species. Benchmark marine turtle monitoring undertaken during the 2022/23 breeding season successfully recorded nesting activity data during the peak breeding period of each known marine turtle species across one inter-nesting cycle, allowing for an estimate of the annual abundance of adult nesters for each species at routine monitoring locations (see **Section 3.3.1.1**).

To compare the estimated annual abundance of adult nesters within the vicinity of the Project to the overall genetic stock, it was also necessary to estimate the overall annual nester abundance for each stock. For the purpose of this impact assessment, nester abundance estimates for each regional genetic stock (H-WA, F-Pil and G-NWS), were informed using the following resources:

- IUCN Red List Assessments (https://www.iucnredlist.org/): These assessments are available for each marine turtle species at a scale of the overall population within Australia and, for some species, each genetic stock/subpopulation. The assessments include estimates of the population abundance for some nesting sites and for the overall stock/subpopulation.
- Queensland Government Department of Environment and Science Turtle Nesting Distribution Abundance and Migration Atlas Project: Provides an estimated range of annual nesters at areas of nesting habitat (Queensland Government 2021). Note that only those areas with an estimated range of 101 – 500 nesting females per year or above were considered within the population estimate.

The upper estimate for the annual abundance of adult nesters within the vicinity of the project presented in this report was then divided by the total annual abundance of adult nesters for each genetic stock to determine the percentage contribution to the overall stock for each species. One limitation within the NLPGW is that it does not include a threshold for when the percentage contribution of marine turtle nesting to the genetic stock is considered significant. Therefore, this assessment used the Queensland Government's definition for matters of state environmental significance specific to marine turtle nesting areas (Queensland Government 2022) to determine the threshold of significance, including:

- Highly significant = >40 % of the species or genetic stock rely on the nesting area
- Significant = >1 % of the species or genetic stock rely on the nesting area
- Present but insignificant = <1 % of the species or genetic stock rely on the nesting area

Note that this approach only considers the significance of marine turtle nesting as interpreted from the NLPGW, that is to 'understand the size and importance of the population', and excludes other factors that could contribute to the overall importance of a nesting area, such as the species' conservation status or recovery potential, location within its range of nesting, cumulative exposure to existing threats, cultural significance to Aboriginal communities, or its economic/scientific/recreational/educational value.

The combined nester abundance for each stock at all routine monitoring locations (NE Regnard Island, SW Regnard Island, CPE and FMB), as determined from surveys over the 2022/23 nesting period are provided in **Table 8**, alongside the estimated nester abundance for each relevant genetic stock. A level of significance was assigned according to the 'Contribution to Genetic Stock' estimate.

Table 8: Relative significance of each species of marine turtle nesting in the vicinity of the project in relation to its contribution to the overall genetic stock.

Species	Genetic Stock	Project: Annual Nester Abundance	Genetic Stock: Annual Nester Abundance	Contribution to Genetic Stock (%)	Level of Significance
Hawksbill	**H-WA**	6 – 7	4,000	0.18	Insignificant
Flatback	**F-Pil**	2 – 3	8,000	0.04	Insignificant
Green	**G-NWS**	1 – 2	25,000	0.01	Insignificant
Cumulative Total		9 – 12	37,000	0.03	Insignificant

4.1.1.2 Duration of Impact

The duration of impact describes the time over which a species is exposed to an impact, which in the case of the Project describes the time over which artificial light emissions (from construction and operational phases of the Project and CPEEF) are visible from nesting habitat. For the purpose of this assessment, impact durations have been categorized as short-term, medium-term or long-term (**Table 9**).

The generation time of a species is used by the IUCN when assessing the potential impact of threats and estimating the risk of their extinction. Using a generational scale for the relevant species is considered to be more appropriate than a year scale (O'Grady et al. 2008). In this assessment, the generation time of marine turtles is defined as the age of their sexual maturation and commencement of breeding, which is estimated at 30–35 years for Indo-Pacific hawksbill turtles (Mortimer & Donnelly 2008), 12–23 years for flatback turtles (Tomaszewicz et al. 2022; IUCN data deficient) and 30–40 years for green turtles (Seminoff 2004).

Table 9: Description of impact duration

Descriptor	Duration
Short term	A period that is less than five years
Medium term	A period longer than five years and shorter than the generation time of the local marine turtle species.
Long term	A period longer than the generation time of the local marine turtle species.

4.1.1.3 Consequence criteria

Consequence criteria derived from the above rationale are provided in **Table 10**.

Table 10: Definition of consequence descriptions.

Description	Definition
Insignificant	The population is insignificant relative to the size of the genetic stock (<1%).
Minor	The population is significant and artificial light will be visible from their habitat short-term. There will be no detectable effect at a population level.
Moderate	The population is significant and artificial light will be visible from their habitat medium-term. There may be a negative effect on the population before recovering.
Major	The population is significant and artificial light will be visible from their habitat long-term. There may be a detectable decline in the population that may recover over a prolonged period.
	The population is very significant and artificial light will be visible from their habitat medium-term. There may be a detectable decline in the population that may recover over a prolonged period.
Catastrophic	The population is very significant and artificial light will be visible from their habitat long-term. The population may become extinct and will not recover.

4.1.2 Description of Likelihood Criteria

Hatchling sea turtles typically emerge from their nest on the beach at night (Mrosovsky & Shettleworth 1968) and must crawl rapidly to reach the ocean to avoid predation (Salmon 2003). They find the ocean using a combination of topographic and brightness cues, orienting towards the lower, brighter oceanic horizon, and away from elevated darkened silhouettes of dunes and/or vegetation behind the point of their emergence on the beach (Pendoley & Kamrowski 2015; Lohmann et al. 1997; Limpus & Kamrowski 2013; Salmon et al. 1992). Artificial light can interfere with these cues, influencing their sea-finding behaviour (Withington & Martin 2003; Pendoley & Kamrowski 2015; Kamrowski et al. 2014). As a result, hatchlings may become disorientated - where they crawl in circuitous paths; or misorientated - where they move in the wrong direction, resulting in an increased mortality rate due to exhaustion, dehydration, or increased exposure to predation (Withington & Martin 2003; Lohmann et al. 1997; Salmon 2003).

The NLPGW recommends that when assessing the likelihood of the effect of a development's light on hatchling turtles, the risk assessment should consider how they will perceive visible light from their habitat and whether it could influence their sea-finding behaviour described above (Commonwealth of Australia 2020). The likelihood assessment was undertaken by a PENV Subject Matter Expert, who considered the modelled light emissions for the Project (**Appendix D**) alongside numerous physical and biological variables to determine the likelihood of sources impacting hatchling behaviour. Major factors considered include:

- Presence/absence of a tall, dark silhouette behind the habitat;
- Natural shielding of light from vegetation or topographic features;
- Orientation of light sources and distance from the nesting habitat;
- Wavelength and intensity of modelled light; and
- Hatchling turtle perception of light.

Likelihood criteria were then applied to each routine monitoring location, as per the definitions in **Table 11**.

Table 11: Definition of likelihood descriptions.

Description	Definition
Rare	Hatchling turtles could be dis- and misoriented but will reach the ocean. May occur during new moon conditions but only when light is amplified by atmospheric conditions such as the presence of cloud.
Unlikely	Hatchling turtles could be dis- and misoriented but will reach the ocean. May occur during new and full moon conditions but only when light is amplified by atmospheric conditions such as the presence of cloud.
Possible	Hatchling turtles could be dis- and misoriented meaning some hatchlings may not reach the ocean. May occur during new moon conditions under all atmospheric conditions.
Likely	Hatchling turtles could be dis- and misoriented meaning some hatchlings may not reach the ocean. May occur during new and full moon conditions under all atmospheric conditions.
Almost certain	Hatchling turtles could be severely dis- and misoriented meaning most will not reach the ocean. May occur throughout the hatching season during all moon phases and atmospheric conditions.

4.1.3 Limitations

The following limitations apply to this risk assessment:

- The risk assessment could not be applied to Steamboat Island as no nester abundance estimate could be derived for hawksbill turtles, which were only surveyed opportunistically in FS1, and modelling of Project lighting was also not undertaken at this location. Steamboat Island was not initially considered as a routine monitoring location due to the long distance (>15 km) from the Project footprint and the absence of historical nesting data, and therefore priority was given to monitor closer sites that supported known nesting habitat (as informed by reports listed in **Appendix A**).

- To ensure full compliance with the recommendations of the NLPGW, a second season of repeated monitoring is required to corroborate the nester abundance estimate. However, based on the very low level of adult nesting recorded in 2022/23 and its consistency with the findings of the short surveys undertaken by PENV in 2008 (PENV 2009) and O2 Marine over 2020–2022 (see **Appendix A**; O2 Marine 2022), it is unlikely that the findings of a further season of monitoring would change the designated level of significance of the area for marine turtle nesting.

- The risk assessment only considers light as it is visible to hatchlings emerging on a beach, and makes no assumptions about the visibility of light or its influence on the dispersal patterns of hatchlings once they reach the water. There are many additional directional cues thought to impact hatchlings in the water, such as wave, light and current cues (Lohmann & Lohmann 1996; Pilcher et al 2000; Wilson et al 2018), and these factors cannot be accounted for with the information presently available for the Project site.

- The Project lighting inventory is in the preliminary stages of planning and proposed mitigation measures consistent with the Best Practice Lighting Design Principles (outlined in the NLPGW) have not been disclosed to PENV at the time of assessment. Therefore, no assessment of the residual risk to hatchling turtles (i.e. the reduced risk that Project lighting poses after mitigation measures have been applied) has been undertaken.

4.2 Risk Assessment

Due to the low nester abundance of all three species recorded during the 2022/23 monitoring season, the cumulative contribution of nesting females to the genetic stock of each species was <1 %. Each monitoring location therefore meets the **Insignificant** consequence criteria under the risk assessment matrix, as the contribution for each location is even less than the cumulative estimate. This means, that due to the low level of nesting observed in the vicinity of the Project, any impacts caused by light are not expected to have implications on the respective genetic stocks.

Likelihood criteria are discussed for each location in the following sections, and an overall risk rating assigned taking into account the universal consequence rating of **Insignificant**.

4.2.1 Cape Preston East

CPE beach was predicted to be the brightest location from light modelling due to development of the CPEEF (LM1, **Appendix D**). Although approved separately to the Project, this site is subject to assessment from a cumulative perspective, as it will contribute to the cumulative artificial light footprint with Cape Preston (Citic Pacific) and the Eramurra Solar Salt Project (Leichhardt). At Cape Preston East beach, light from the CPEEF will be directly visible from nesting habitat as the topography at this location provides minimal natural shielding of direct light and sky glow from the proposed port lighting. Other Project facilities and the ocean-going vessel (OGV) anchorages will also be visible as sources of sky glow on the horizon.

Due to construction of the CPEEF occurring through potential nesting habitat, and the intensity of lighting proposed for the facility, there is a **Likely** likelihood that there will be an impact on the emergence behaviour of hatchling turtles. Hatchlings may crawl up the beach towards port infrastructure or become entrained in light on the beach and crawl in circuitous patterns in proximity to it. This may result in some hatchlings not making it to the ocean due to exhaustion or increased exposure to predation.

The likelihood and consequence rankings consider the inherent risk to be **Medium** at CPE (**Table 12**).

4.2.2 South West Regnard Island

Project lighting visibility was assessed from two locations on South West Regnard Island in June 2022, informed by the limited information available on nesting distribution (prior to the 2022/23 monitoring season). Results showed that nesting habitat at the northern end of the island (LM2, **Appendix D**), will largely be shielded from Project lighting and CPEEF by a tall dune. New light sources will contribute to the cumulative glow visible above the elevated dune horizon on the same bearing as the existing Sino Iron facilities at Cape Preston. The greatest change in horizon brightness will result from the addition of the OGV anchorages, which are visible as direct and unshielded sources of light directly offshore from the beach.

On the eastern beach of SW Regnard Island (LM3; **Appendix D**), the increase in horizon brightness is predicted to be higher than the northern beach, as the dune is lower at this location. The increase will primarily be caused by the contribution to sky glow from the CPEEF on the same bearing as Cape Preston (Sino Iron), however some glow from the Project facilities and OGV Anchorages will also be visible.

The results of the 2022/23 monitoring season indicated that SW Regnard Island has the busiest nesting habitat (of all routine monitoring locations) for hawksbill turtles. The distribution of activity matched that reported in a 2008 survey (PENV 2009), where the highest density of nesting occurred at the northern end of the island, and is therefore shielded from most of the current and future light sources proposed for the mainland. However, the proposed trans-shipment vessel (TSV) route runs along the length of the western shoreline of the island, within ~1 km at the closest point, and transient light from TSVs may be directly visible to hatchlings as vessels approach the OGV anchorages to the north of the island.

As nesting occurs on fragmented lengths of beach around the island, the visibility of light from nesting habitat is variable. There is a **Possible** likelihood of impact on the sea-finding behaviour of hatchling turtles, either from the cumulative sky glow on the mainland, which is bright at the east and southern ends of the island but some distance away, or from the vessels, which are transient light sources but much closer to the nesting habitat.

The likelihood and consequence rankings consider the inherent risk to be **Low** at SW Regnard Island (**Table 12**).

4.3 North East Regnard Island

The nesting beach on NE Regnard Island will experience a small increase in glow on the horizon associated with the Project facilities and CPEEF (LM4**, Appendix D**). The nesting beach is largely shielded from the mainland by a tall primary dune, and as a result the glow is only predicted to be visible above the elevated dune horizon. The brightest sources of light visible at NE Regnard Island are the Burrup Peninsula and Karratha townsites, and these are located offshore from the beach, and up to 50 km away.

The cumulative glow from the Project facilities, CPEEF and Cape Preston (Sino Iron) is **Unlikely** to impact on the orientation of hatchlings at NE Regnard Island due to the distance of light sources from the island, and the moderating influence of the dunes, which creates a tall, dark horizon for hatchlings to orient away from. Sky glow from the Project and CPEEF may be amplified by atmospheric conditions (i.e. cloud and aerosols) on some nights, and it is under these circumstances that the accumulation of sky glow from Cape Preston could cause a change in hatchling behaviour.

The likelihood and consequence rankings consider the inherent risk to be **Low** at NE Regnard Island (**Table 12**).

4.4 Forty Mile Beach

The nesting beach at FMB is very marginal, with no nesting by any species detected during the 2022\23 monitoring season. Historical reports have recorded nominal flatback nesting activity on the beach (i.e. one track per survey), and it is noted that the beach has moderate 4WD use, which may deter adults nesters from laying here.

Modelling predicts FMB is to experience only small changes in horizon brightness from the benchmark state as a result of new Project development and the CPEEF (LM5; **Appendix D**). The CPEEF will occur on the same bearing as Cape Preston (Sino Iron), and will contribute to cumulative sky glow, increasing the overall visibility of light to the west of the beach. The visibility of Project lighting at FMB will be different according to a hatchlings position on the beach, and generally be visible as glow above the elevated dune horizon, if visible at all.

The cumulative light from the Project and CPEEF is **Unlikely** to impact on hatchling behaviour at FMB due to the tall hind dune creating a natural, dark barrier between the beach and Project lighting. When the cumulative glow of all facilities is amplified by cloud, the light may be bright enough to cause mis- or disorientation in some hatchlings.

The likelihood and consequence rankings consider the inherent risk to be **Low** at FMB (**Table 12**).

Table 12: Risk assessment outcome.

Location	Consequence	Likelihood	Ranking
Cape Preston East	Insignificant	Likely	Medium
South West Regnard	Insignificant	Possible	Low
North East Regnard	Insignificant	Unlikely	Low
Forty Mile Beach	Insignificant	Unlikely	Low

4.5 Recommendations

Despite the consequence of light impacts from the Project being described as **Insignificant** for each genetic stock, the potential for light causing a change in the behaviour of individual hatchlings is considered **Possible** and **Likely** at SW Regnard Island and CPE, respectively. It is therefore recommended that the Project consider the ways in which the lighting design can be revised to better meet the Best Practice Lighting Design Principles (Commonwealth of Australia 2020).

Many of the lights proposed the preliminary lighting inventory (**Appendix D**) consist of 5000 K – 6000 K (cool white) LEDs that range in height from 1 m (salt truck) to 29 m (salt stockpile dozer). This lighting substantially exceeds the colour temperature of lighting recommended by the NLPGW, which recommends all outdoor lighting to be Amber or PC Amber, with a CCT closer to 2000 K. The sky glow associated with bright white light sources with a high proportion of short wavelength blue and green light has a greater potential to impact on hatchling turtles, as well as other species of wildlife such as seabirds and shorebirds, and on dark sky conservation values. It is therefore noted that the current lighting inventory does not comply with the Best Practice Lighting Design Principles, notably colour temperatures of 5000 K – 6000 K are unacceptable for general usage across the Project facilities.

It is recommended that a comparative assessment of lighting design alternatives, in consultation with qualified lighting practitioners, be undertaken to identify the minimum number and intensity of lights required to meet lighting objectives. In addition, the application of smart lighting controls, shielding and recessing should be applied where possible to further reduce light spill. Further information on how mitigation measures can be applied to the Project and CPEEF is provided in PENV (2023).

5 CONCLUSION

Marine turtle monitoring was undertaken over the 2022/23 summer to investigate the distribution and abundance of species nesting on beaches in the vicinity of the Eramurra Solar Salt Project. Three routine surveys, each spanning a minimum of 14 days, identified three species of turtles nesting: green, hawksbill and flatback. Nesting activity was spread across SW Regnard Island, NE Regnard Island, Steamboat Island and CPE beach. Of the three species, hawksbill turtles were the most abundant, with the highest activity recorded on SW Regnard Island during the October two-week monitoring period.

In addition to adult nesting activity, hatchling fans were recorded during the second two surveys to establish a benchmark of hatchling behaviour. Fans were recorded on SW Regnard Island, NE Regnard Island, CPE beach and Steamboat Island. There was no evidence of mis- or disorientation in the fans recorded, however some of the fans on Steamboat Island were irregular (i.e. wide spread angles and multiple outliers) due to their position on the island spit.

A risk assessment was undertaken to evaluate the potential for artificial light occurring in the vicinity of the Project to cause mis- or disorientation of hatchling sea turtles. The assessment was informed by a light modelling report prepared separately for LEIC (**Appendix D**), and considered other physical and biological factors that influence hatchling sea-finding behaviour, as well as the relative contribution of nesting females to the relevant genetic stocks. The assessment determined the inherent (unmitigated) risk to be **Low** at NE Regnard Island, SW Regnard Island and FMB, and **Medium** at CPE beach. Despite the low risk outcomes of the assessment, it is recommended that the Project review and apply mitigation measures to external lighting to reduce the likelihood of impact on individual hatchlings, according to the Best Practice Lighting Design Principles outlined in the NLPGW.

6 REFERENCES

COMMONWEALTH OF AUSTRALIA (2017) Recovery Plan for Marine Turtles in Australia. Department of the Environment and Energy.

COMMONWEALTH OF AUSTRALIA (2020) National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds. Department of the Environment and Energy.

GBRMPA (2017) Risk Assessment – Permission System. Great Barrier Reef Marine Park Authority. Document No. 100429.

IMBRICATA (2013) Baseline Report. Marine Turtle Nesting Habitat and Light Spill Assessment on the Eastern Beach of Cape Preston, Western Australia. Prepared by Imbricata for GHD Australia, Perth, Western Australia, February 2013.

KAMROWSKI, R.L., LIMPUS, C., PENDOLEY, K. & HAMANN, M. (2014) Influence of industrial light pollution on the sea-finding behaviour of flatback turtle hatchlings. *Wildlife Research* 41 (5), 421-434.

LIMPUS, C.J. & KAMROWSKI, R.L. (2013) Ocean-finding in marine turtles: the importance of low horizon elevation as an orientation cue. *Behaviour,* 150, 863–893.

LOHMANN, K.J. & LOHMANN, C.M. (1996) Orientation and open-sea navigation in sea turtles. *The Journal of Experimental Biology,* 199, 73–81.

LOHMANN, K.J., WITHERINGTON B.E., LOHMANN C.M.F. & SALMON M. (1997) Orientation, navigation, and natal beach homing in sea turtles, in The Biology of Sea Turtles. Volume I, P.L. Lutz and J.A. Musick, Editors., CRC Press: Washington D.C. p. 107-135.

MORTIMER, J.A. & DONNELLY, M. (2008) Hawksbill Turtle (*Eretmochelys imbricata*). IUCN Red List of Threatened Species. Available: https://www.iucnredlist.org/species/8005/12881238.

MROSOVSKY, N. & SHETTLEWORTH, S.J. (1968) Wavelength preferences and brightness cues in the water finding behaviour of sea turtles. *Behaviour*, 32, 211-257.

O2 MARINE (2022) Eramurra Solar Salt Project Turtle Nesting Study Report. Prepared by O2 Marine for Leichhardt Salt Pty Ltd, Perth, Western Australia.

O'GRADY, J., REED, D., BROOK, B. & FRANKHAM, R. (2008) Does extinction risk scale better to years of generations? *Animal Conservation,* 11, 442–451.

PENDOLEY, K.L. & KAMROWSKI, R.L. (2015) Influence of horizon elevation on the sea-finding behaviour of hatchling flatback turtles exposed to artificial light-glow. *Marine Ecology Progress Series*, 529, 279–288.

PENV (2009) Forty Mile Beach Area, North East and South West Regnard Islands. Prepared by Pendoley Environmental for Apache Energy, Perth, Western Australia, January 2009.

PENV (2023) Eramurra Solar Salt Project: Best Practice Lighting Design Technical Memo. Prepared by Pendoley Environmental for Leichhardt Salt Pty Ltd, Perth, Western Australia, in prep.

PILCHER, N.J., ENDERBY, S., STRINGELL, T. & BATEMAN, L. (2000) Nearshore Turtle Hatchling Distribution and Predation, in Sea Turtles of the Indo-Pacific: Research, Management and Conservation. N. Pilcher and G. Ismail, Editors. Asean Academic Press, p. 151–166.

QUEENSLAND GOVERNMENT (2021) Turtle Nesting Distribution Abundance and Migration Atlas. Queensland Government Department of Environment and Science. Available: https://apps.information.qld.gov.au/TurtleDistribution/, June 2021.

QUEENSLAND GOVERNMENT (2022) Sea turtle nesting areas mapping. Queensland Government Department of Environment and Science. Available: https://environment.des.qld.gov.au/management/planning-guidelines/sea-turtle-nesting-areas-mapping, September 2022.

SALMON, M. (2003) Artificial night lighting and sea turtles. *Biologist*, 2003 (50), 163-168.

SALMON, M., WYNEKEN, J., FRITZ, E. & LUCAS, M. (1992) Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues. *Behaviour,* 122, 1–2.

SEMINOFF, J.A. (2004) Green Turtle (*Chelonia mydas*). IUCN Red List of Threatened Species. Available: https://www.iucnredlist.org/species/4615/11037468.

TOMASZEWICZ, C.N., AVENS, L., SEMINOFF, J.A., LIMPUS, C.J., FITZSIMMONS, N.N., GUINEA, M.L., PENDOLEY, K.L., WHITTOCK, P.A., VITENBERGS, A., WHITING, S.D. & TUCKER, A.D. (2022) Age-specific growth and maturity estimates for the flatback sea turtle (*Natator depressus*) by skeletochronology. *Plos One* 17(7): e0271045.

WHITTOCK, P.A., PENDOLEY, K.L. & HAMANN, M. (2014) Inter-nesting distribution of flatback turtles *Natator depressus* and industrial development in Western Australia. *Endangered Species Research*, 26, 25 – 38.

WILSON, P., THUMS, M., PATTIARATCHI, C., MEEKAN, M., PENDOLEY, K., FISHER, R. & WHITING, S (2018) Artificial light disrupts the nearshore dispersal of neonate flatback turtles *Natator depressus. Marine Ecology Progress Series*, 600, 179–192.

WITHERINGTON, B. & MARTIN, R.E. (2003) Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches. Florida Fish and Wildlife Conservation Commission FMRI Technical Report TR-2: Jensen Beach, Florida. p. 84.

Appendix A: Past Marine Turtle Monitoring Report Outcomes

Table A1: Summary of previous marine turtle monitoring effort and reporting in the vicinity of the Eramurra Project.

Scope	Survey Duration	Results Summary	Limitations
PENV (2009) Forty Mile Beach Area, North East and South West Regnard Islands. Prepared by Pendoley Environmental for Apache Energy, Perth, Western Australia, January 2009.			
Scope	**Survey Duration**	**Results Summary**	**Limitations**
A marine turtle track census was undertaken on foot on NE and SW Regnard Islands, Unnamed Island, and all potential marine turtle nesting beaches on the mainland within a 10 km radius of FMB.	One survey: 9th – 14th Dec 2008 (6 days)	• Hawksbill nesting activity recorded at SW and NE Regnard Islands. • Green track recorded on SW Regnard Island. • Flatback nesting activity recorded at FMB.	• Survey duration was short (≤4 days at each survey location) and only took place during the peak flatback and green nesting period for the Pilbara region, missing the October period for peak hawksbill nesting. • No hatchling orientation data provided.
Imbricata (2013) Marine Turtle Nesting Habitat and Light Spill Assessment on the Eastern Beach of Cape Preston, Western Australia. Prepared by Imbricata for GHD Australia, Perth, Western Australia, February 2013.			
Scope	**Survey Duration**	**Results Summary**	**Limitations**
Turtle nesting habitat assessment involving track census and incubation success at mainland beaches on the east side of Cape Preston. Additional light spill study undertaken.	Two surveys: 12th – 15th Nov 2012 (4 days) 11th Feb (1 day)	• Mainland beaches provided suitable nesting habitat for egg chamber construction. • Estimated a low nesting population of marine turtles on CPE beaches.	• Limited survey duration and sample size (one nest excavated). • Estimated size of the nesting population without surveying over a biologically significant period (i.e. 14 days). • Did not survey the Regnard Islands • Made assumptions about hatchling behaviour without recording any hatchling orientation metrics.
O2 Marine (2022) Eramurra Solar Salt Project Turtle Nesting Study Report. Prepared by O2 Marine for Leichhardt, Perth, Western Australia.			
Scope	**Survey Duration**	**Results Summary**	**Limitations**
Turtle nesting surveys (track census) were undertaken using a UAV to identify the species present, population, and their significance at key nesting beaches in proximity to the Project, including the mainland and NE and SW Regnard Islands.	Five surveys: 15th – 18th Dec 2020 (4 days) 19th – 22nd Jan 2021 (4 days) 15th – 18th Feb 2021 (4 days) 15th – 18th Mar 2021 (4 days) 18th – 21st Jan 2022 (4 days)	• Flatback and green nesting activity recorded on mainland beaches at CPE and FMB.	• No survey during peak hawksbill nesting period (Oct/Nov). • Only one 4-day survey at Regnard Islands (Jan 2022). • Survey duration was too short to provide abundance estimate or information on regional significance. • Survey design did not comply with the recommendations of the NLPGW.

Appendix B: Field Survey Schedule

Table B1: Field Survey Schedule. X = survey day.

Date	Survey Location							
	SW Regnard Is.	NE Regnard Is.	Cape Preston East	Forty Mile Beach	Steamboat Is.	Cape Preston West	Potter Is.	Unnamed Is.
Field Survey 1								
19/10/2022	Transit							
20/10/2022	X	X	X	X				
21/10/2022	X	X	X	X	X		X	
22/10/2022	X	X	X	X				X
23/10/2022	X	X	X	X				
24/10/2022	Standby due to weather							
25/10/2022	X	X	X	X				
26/10/2022	X	X	X	X	X	X		
27/10/2022	X	X	X	X				
28/10/2022	X	X	X	X				
29/10/2022	X	X	X	X				
30/10/2022	X	X	X	X				
31/10/2022	X	X	X	X				
1/11/2022	X	X	X	X				
2/11/2022	X	X	X	X				
Field Survey 2								
10/01/2023			X	X				
11/01/2023	X	X			X			
12/01/2023			X	X				
13/01/2023	X	X			X			
14/01/2023			X	X				
15/01/2023	X	X			X	X		

16/01/2023			**X**	**X**				
17/01/2023	**X**	**X**			**X**			**X**
18/01/2023			**X**	**X**				
19/01/2023	**X**	**X**			**X**			
20/01/2023			**X**	**X**				
21/01/2023	**X**	**X**			**X**		**X**	
22/01/2023			Standby due to Weather	**X**				
23/01/2023	**X**	**X**	**X -** UAV		**X**			
24/01/2023			**X**	**X**				
25/01/2023	**X**	**X**			**X**			
Field Survey 3								
13/02/2023	Transit							
14/02/2023			**X**	**X**				
15/02/2023	**X**	**X**			**X**			
16/02/2023			**X**	**X**				
17/02/2023	**X**	**X**			**X**			
18/02/2023			**X**	**X**				
19/02/2023	**X**	**X**			**X**			
20/02/2023			**X**	**X**				
21/02/2023			**X**	**X**				
22/02/2023	**X**	**X**			**X**			
23/02/2023	Rostered Day Off							
24/02/2023	**X**	**X**			**X**			
25/02/2023			**X**	Road Closed				
26/02/2023	**X**	**X**			**X**			
27/02/2023			**X**	Road Closed				
28/02/2023	**X**	**X**			**X**			

Appendix C: Track Preservation

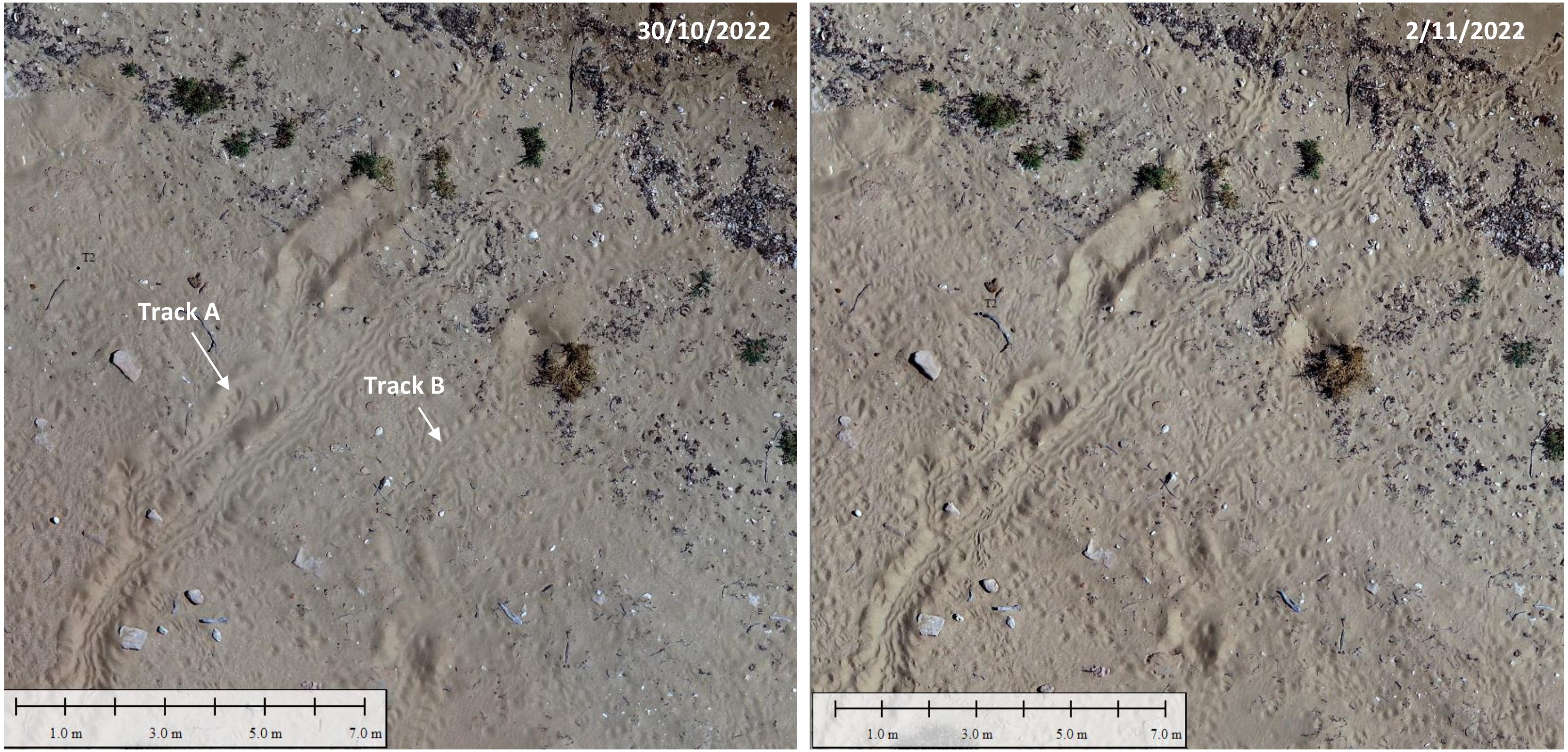


Figure C1: Example of track preservation on Cape Preston East. Track 'A' was made on 30/10/2022, track 'B' was recorded on line-in day on 20/10/2022. Both tracks are visible on the final day of track census on 2/11/2022, with enough features to identify species (hawksbill).

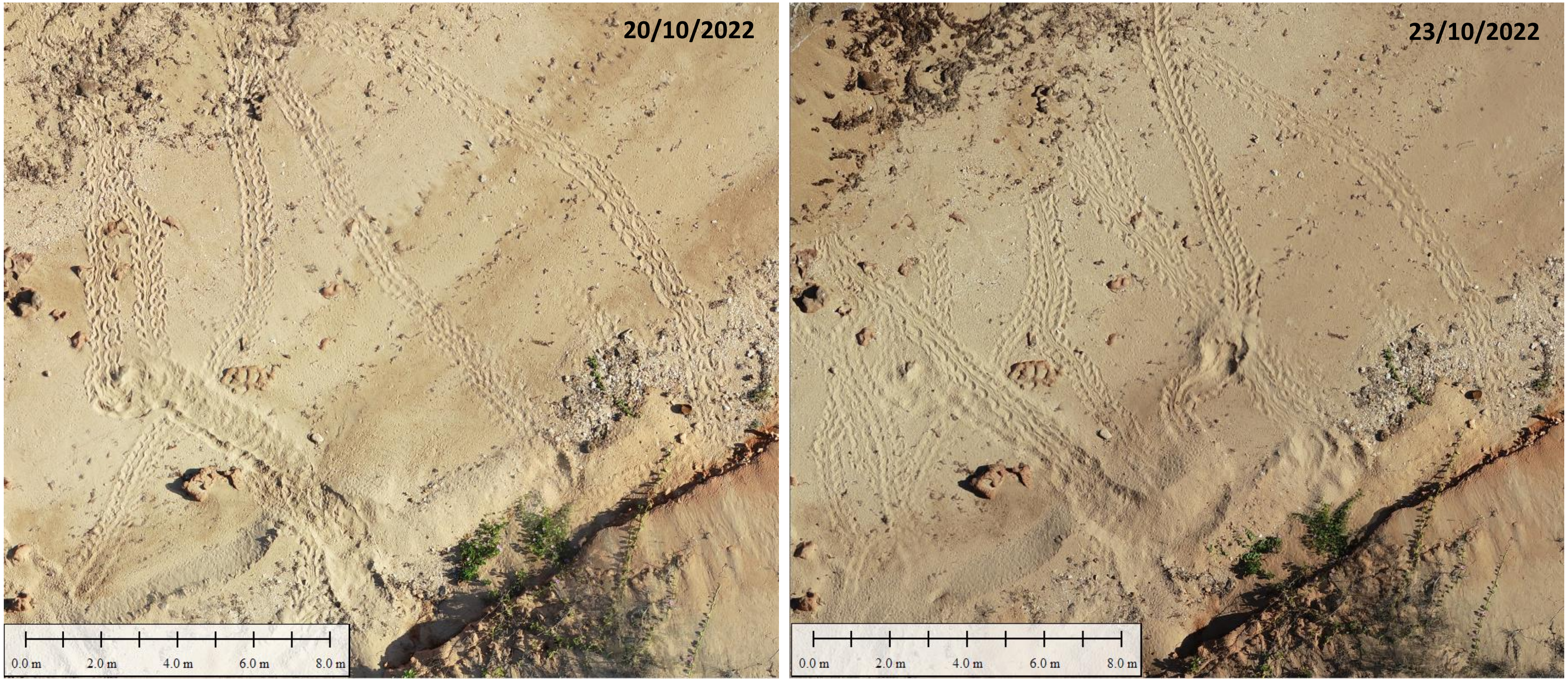


Figure C2: Example of track preservation on South West Regnard Island. All tracks in left image were made on, or prior to, line-in day on 20/10/2022, and are still visible on 23/10/2022 under new tracks, with enough features to identify species (hawksbill).

Appendix D: Benchmark Artificial Light Monitoring and Modelling Report

LEICHHARDT

ERAMURRA SOLAR SALT PROJECT: BENCHMARK ARTIFICIAL LIGHT MONITORING AND MODELLING

Prepared by

Pendoley Environmental Pty Ltd

For

Leichhardt Salt Pty Ltd

6 September 2022

ARTIFICIAL LIGHT ASSESSMENT SERVICES

PENDOLEY ENVIRONMENTAL

PENDOLEY
ENVIRONMENTAL

DOCUMENT CONTROL INFORMATION

TITLE: ERAMURRA SOLAR SALT PROJECT: BENCHMARK ARTIFICIAL LIGHT MONITORING AND MODELLING

Disclaimer and Limitation

This report has been prepared on behalf of and for the use of Leichhardt. Pendoley Environmental Pty Ltd. takes no responsibility for the completeness or form of any subsequent copies of this Document. Copying of this Document without the permission of Leichhardt is not permitted.

Document History

Revision	Description	Date received	Date issued	Personnel
Draft	Report Draft		05/09/2022	B. Moore / A. Mitchell / E. Charlton
Rev IA	Internal Review	05/09/2022	06/09/2022	B. Moore / P. Whittock
Rev A	Client review	06/09/2022	16/09/2022	R. Flugge /
Rev B	Comments addressed	16/09/2022	03/10/2022	B. Moore / A. Mitchell
Rev 0	Final report issued	16/10/2022	17/10/2022	B. Moore / A. Mitchell

Printed:	17 October 2022
Last saved:	17 October 2022 04:04 PM
File name:	P:\06 Projects\J106 Leichhardt\05 Programs\J106001 EramurraLightMonitoring 2022\04 Technical Reports\J10601_EramurraLightAssessment_Rev0.docx
Author:	B. Moore / A. Mitchell / E. Charlton
Project manager:	B. Moore
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Eramurra Solar Salt Project
Client	Leichhardt Salt Pty Ltd
Client representative:	R. Flugge
Report number:	J106001-1
Client report number:	ESSP-EN1-14-TRPT-0006
Cover photo:	Light Camera, NE Regnard Island

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

CPE	Cape Preston East
DSLR	Digital single-lens reflex
E	East
EPA	Environmental Protection Authority
GPS	Global Positioning System
N	North
nm	Nanometres
OGV	Ocean-going Vessel
PENV	Pendoley Environmental
S	South
SRTM	Shuttle Radar Topography Mission
TSV	Transhipment Vessel
Vmag/arcsec^2	Visual magnitudes per square arc second
W/m^2/sr	Watt per steradian per square metre (unit of radiance)
WA	Western Australia
WOS	Whole of Sky

1 INTRODUCTION

1.1 Project Description

Leichhardt Salt Pty Ltd (Leichhardt) is the Proponent for the Eramurra Solar Salt Project (the Project), a proposed solar salt operation in the Pilbara region of Western Australia (WA). The Project is targeting production of 4.2 million tonnes per annum of high-grade salt from seawater using a series of evaporation and crystallisation ponds. The Project will be located to the east of Citic Pacific's Sino Iron Project at Cape Preston, WA, and will require the development of concentrator and crystallisation ponds, construction of a processing facility, and construction of an export facility (Cape Preston East; CPE).

Although the CPE export facility will be constructed in conjunction with the Project, key elements of the facility have already been referred and approved under the *Environmental Protection Act 1986* and determined to be 'not a controlled action if undertaken in a particular manner' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPA 2020). The key elements already assessed are understood to include a trestle jetty at CPE, attended by a Transhipment Vessel (TSV), navigation markers, and Ocean-Going Vessels (OGVs), located at anchorages within a designated transhipment area to the north of South West Regnard and North East Regnard Islands.

1.2 Scope

In response to Leichhardt's draft Environmental Scoping Document (14th March 2022) for the Project, the Environmental Protection Authority (EPA) has requested a pre-construction light survey be undertaken, to address impacts to marine fauna. In particular, Leichhardt has been requested to:

"*Undertake a baseline light survey to identify the current light environment and undertake a light spill study to consider the direction and intensity of the expected light sources to determine whether the Proposal will attract turtle hatchlings or otherwise alter their behaviour. The light spill study will consider cumulative lighting impacts on the turtle population of the North West Shelf.*"

Leichhardt engaged Pendoley Environmental (PENV) to undertake artificial light monitoring to capture the pre-construction (or 'benchmark') lighting environment at known marine turtle nesting beaches in the vicinity of the Project's disturbance footprint, and light modelling to predict the visibility of future Project light emissions (including CPE) from the same beaches. Project facilities modelled for this purpose include:

- Project Facilities (i.e. associated with the Eramurra Solar Salt Project):
  - Pump station infrastructure
  - Operations and workshop buildings
  - Wash plant
  - Salt stockpile (stackers, dozer, loaders, trucks)
  - Power station
  - Crystalliser harvesters

  - Wet salt haulage truck

Additionally, while the CPE facility does not form part of the Project being assessed, it has been included in the modelling to provide a cumulative understanding of light emissions that will be visible post-construction of the Project. Facilities modelled as part of CPE include:

- Export Facilities:
  - Operations, workshop, and logistic buildings
  - Power station
  - Salt stockpile (stacker, dozer, conveyors, hoppers)
  - Salt trucks
  - Outload jetty
  - Shiploader boom
- Vessels:
  - TSVs
  - OGVs

Construction of the Project will also require dredging of the CPE Port for shipping access to the trestle jetty, however, lighting associated with dredging has not been included in this assessment as dredging is planned to occur outside of the turtle nesting and hatching season over the months of April to July.

Outputs from the modelling may be used to undertake an impact assessment of Project lighting on marine turtle behaviour, and consider cumulative lighting impacts on the marine turtle population of the North West Shelf, however this has not been addressed by this report due to insufficient information on the marine turtle populations nesting at the Regnard Islands.

2 METHODOLOGY

2.1 Light Monitoring

Monitoring was undertaken at three island and two mainland locations to capture the existing lighting environment at known turtle nesting beaches in proximity to the Project's disturbance footprint (**Table 1** and **Figure 1**). Monitoring was undertaken by two PENV personnel between 27th June and 1st July 2022, coinciding with a new moon period (29th June 2022). Island locations were accessed via vessel mobilising from Dampier each day, and mainland locations were accessed via four-wheel drive vehicle. Mainland locations (LM1 and LM5; **Figure 1**) could not be accessed directly via vessel because:

- LM1: The nearshore reef platform made it difficult to manoeuvre the vessel close to shore in strong winds.
- LM5: Restrictions imposed prevented access to port waters.

Table 1: Monitoring locations and coordinates.

Location	Latitude	Longitude
LM1: Mainland Cape Preston	-20.85500	116.22985
LM2: South West Regnard Island (N)	-20.80304	116.24437
LM3: South West Regnard Island (E)	-20.81084	116.24743
LM4: North East Regnard Island (S)	-20.77854	116.31259
LM5: 40-Mile Beach	-20.83994	116.37197

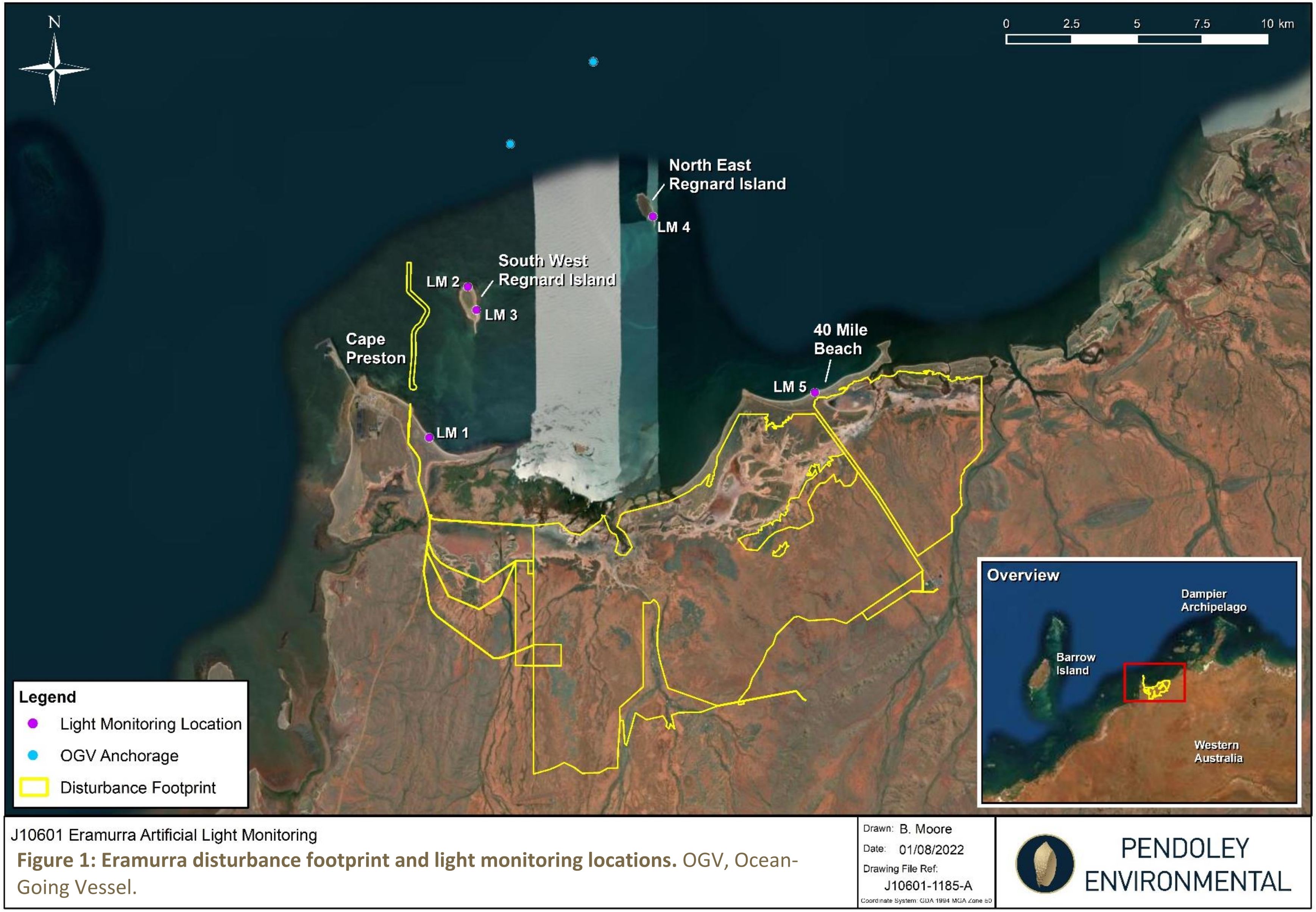


Figure 1: Eramurra disturbance footprint and light monitoring locations. OGV, Ocean-Going Vessel.

2.1.1 Data Capture

Artificial light data was captured at each survey location using a Sky42 light monitoring camera. The camera features a calibrated Canon EOS 700D DSLR combined with a fish-eye lens and custom-built hardware to acquire low-light images of the entire night sky. The cameras are built into a weatherproof housing with a protective lid that automatically opens during image capture and closes between capture intervals.

Sky42 light monitoring cameras were deployed on tripods (~60 cm high) on areas of sandy beach suitable for turtle nesting and were programmed to capture one long-exposure image every 10 minutes between sunset and sunrise. At North East Regnard and South West Regnard Islands, cameras were deployed between old marine turtle body pits (**Figure 2**). At mainland locations, there was no visible historic nesting activity and therefore cameras were deployed above the spring high tide mark. Cameras were deployed overnight at all locations and images were downloaded each day.

Weather conditions for the survey were favourable for light monitoring on every night of the field campaign, however, winds were strong during the day and made for long transit times on the vessel and difficulty in undertaking shore transfers, particularly at the 40-Mile Beach boat ramp.

Figure 2: Light monitoring camera deployment on North East Regnard Island between old body pits.

2.1.2 Data Analysis

All suitable images were processed using specialised software to determine 'whole-of-sky' (WOS) and 'horizon' sky brightness. WOS is the mean value of light (including direct light and sky glow, natural and artificial) in the entire image, and horizon brightness is the mean value of light within the 60 – 90° outer band, considered most relevant to marine turtle vision (**Figure 3**). All images have been quantified in units of visual magnitudes per square arc second (Vmag), a common unit used to measure astronomical sky brightness that represents light intensity on an inverse logarithmic scale.

Note that the colour coding used in the processed imagery represents the scale of intensity of light and is not representative of the colour of light as perceived by a human or turtle eye, or a Sky42 camera.

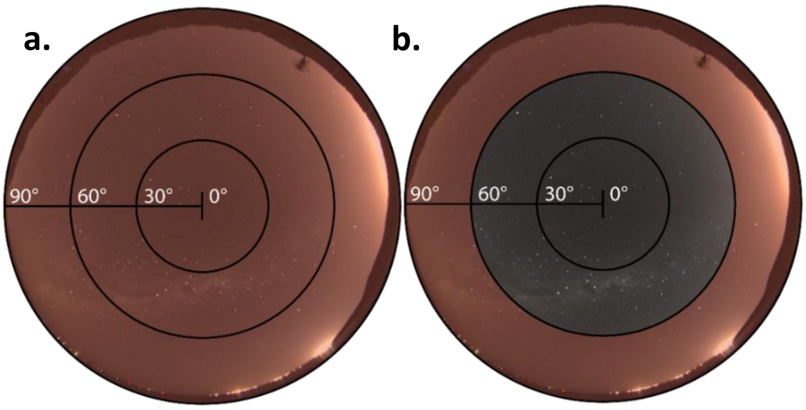


Figure 3: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60 – 90°). Shaded areas denote the region of the sky being measured.

2.2 Light Modelling

Currently, there are no standard commercial models for landscape scale modelling of artificial light emissions (Commonwealth of Australia 2020). Recognising the gap and the growing need to respond to both local and national regulatory concerns over artificial light impacts on wildlife and on dark sky conservation values required to meet the International Dark Sky Association Dark Sky Park certification requirements, PENV has developed a landscape-scale model of artificial light.

The ILLUMINA model is used as the base model for the work, selected for its ability to represent light across large areas and distances, and across the entire visible spectrum, including biologically meaningful light from 350 – 700 nm (Aube et al. 2005). ILLUMINA accounts for both line-of-sight light visibility and sky glow derived from atmospheric scattering of light. The model also addresses the attenuation of light over landscape scale distances and, consequently, the areal extent of glow across the sky can be modelled.

2.2.1 Inputs

The following general parameters were used as inputs into the model:

- Topography and reflectance: NASA Shuttle Radar Topography Mission (SRTM) digital elevation data (1 arc-second resolution).
- GPS coordinates for the observer viewpoints (**Table 1**).
- Weather conditions: all scenarios are considered free of any influencing atmospheric or weather conditions (sun, moon, rain or cloud).
- A detailed lighting inventory (light types, positions, heights, intensity) for the Project and CPE infrastructure and vessels, including OGVs and TSVs, based on information provided by Leichhardt. A summary of the lighting inventory is provided in **Appendix A**.

2.2.2 Outputs

All-sky modelled image: A projected all-sky modelled image 'as viewed' from each of the five monitoring locations was produced and combined additively with benchmark camera imagery to illustrate the predicted visible increase in brightness across the horizon and sky due to direct light and sky glow.

Direct light is defined as lighting that has line of sight visibility from the monitoring location, and sky glow is defined as light that is scattered or reflected into the area surrounding a direct light source.

2.2.3 Model Assumptions

The lighting inventory was assembled under the following assumptions:

- Only external lighting has been considered in the model (i.e. omits internal lighting that may be reflected externally).
- All modelled lighting is considered to have a completely spherical emission (i.e. light is emitted equally in all directions), with no shielding applied.
- Where manufacturer specifications on luminaire spectra were not available, PENV generated their own spectral power curves based on what is typical for the type/colour temperature of the luminaire.
- OGV lighting was merged and then divided evenly into three main areas on the vessel (front/middle/rear), as opposed to being placed in individual positions. Due to the distance of the OGVs from observer viewpoints (~6 km from the nearest site), it is not expected this simplification would meaningfully impact the results.
- Two OGVs are included: one at each of the anchorages north of the Regnard Islands (**Figure 1**).
- Two TSVs are included: one at berth at the end of the proposed trestle jetty, and one at the westernmost OGV anchorage.

2.2.4 Model Limitations

While the underlying science of light behaviour is well known, the methods required to measure and model light intensity and sky glow on a landscape scale are still in the research and development phase, and consequently, are constrained by the following limitations:

- Model results have not yet been definitively ground-truthed for large-scale projects (Linares et al. 2018, 2020), however, the technical approach outlined within this report is considered current with the most recent literature, subject matter expert input, and best practice.
- The precision of the model outputs is directly related to the level of input detail. Much of the lighting design is still conceptual and may be changed prior to construction.
- The model has converted units of absolute radiance ($W/m^2/sr$) to units of photometric luminance ($Vmag/arcsec^2$). Where absolute radiance represents light equally across the whole visible spectrum, visual magnitudes represent only the human visual (green) band of the spectrum and may not fully represent light as perceived by marine turtles or seabirds.

3 RESULTS AND DISCUSSION

3.1 Benchmark Light Monitoring

Artificial light data was successfully captured at all monitoring locations during the field campaign. A single clear image was selected from each monitoring location for analysis and processed results are shown in **Figures 4a** – **8a**.

Citic Pacific's Sino Iron Facility at Cape Preston, situated adjacent to the proposed CPE port facility, was the largest existing source of sky brightness on the horizon and was visible from all survey locations (**Figures 4a** – **8a**). Lighting from industry on the Burrup Peninsula and the Karratha townsite was also visible from all survey locations, however, the extent of sky glow visible from these sources was comparatively much smaller due to their distance from the monitoring locations. Direct light from vessels anchored to the northwest of South West Regnard Island was also visible (**Figure 5a**).

3.2 Light Modelling

The majority of lighting associated with Project facilities will consist of 5000 – 6000K (cool white) LEDs that range in height from 1 to 29 m. The majority of lighting at the CPE facilities is 2200K (orange) LED, with Amber LEDs on the outload jetty, and ranges in height from 1 to 27 m. Lighting on the OGVs is predominately fluorescent and High Pressure Sodium, with LED lighting ranging from 3500K (warm white) – 5000K (cool white). See **Appendix A** for a detailed light inventory for each source.

The modelling predicts that light emissions from the Project and CPE facilities will be visible from all monitored locations at varying intensities, with the CPE facilities either partially or directly overlapping with the bearing of the Sino Iron Facility (**Figures 4** – **8**).

At LM1 (mainland Cape Preston), the modelling indicates there will be a substantial increase in sky brightness (WOS: 170 %; horizon: 320 %), primarily due to the proximity of the site to the proposed CPE facility (**Table 2** and **Figure 4**). The height of the proposed CPE light sources (up to 40 m) and the low dune profile at LM1 indicates an observer at this location will have direct visibility of the bright CPE lighting (**Figure 4**). Lighting from the Project facilities and OGV anchorages will also be visible from LM1, however, this will primarily be comprised of sky glow, with the topography providing some shielding of direct light. Both the Project and OGV anchorage lighting will appear similar in size and intensity to the Burrup Peninsula and Karratha townsite lighting, located ~60 km from LM1.

At South West Regnard Island, the visibility of Project lighting will be influenced by the height of the primary dune, which will determine the amount of natural shielding provided from a viewpoint on the beach. At the northern extent of the island (LM2), introduction of the CPE lighting will increase the amount of glow visible on the same bearing as the existing Sino Iron Facility. The tall dune between the beach and the port, however, naturally shields any direct light emissions from the CPE facilities (**Figure 5**). Similarly, lighting from Project facilities will be almost entirely shielded at this location. The OGV anchorages are not shielded by any topography and are the largest contributor to increased sky brightness visible at this location (WOS: 65 %; horizon: 138 %; **Table 2**).

At the eastern beach of South West Regnard Island (LM3), the primary dune profile is much lower than at LM2. While the contribution of sky glow from all of the Project light sources will therefore be more visible (**Figure 6**), direct light from the anchorages is not visible, resulting in a lower overall increase in sky brightness (WOS: 22 %; horizon: 33 %; **Table 2**). CPE lighting will provide the greatest source of sky glow on the same bearing as the Sino Iron Facility, however, the low dune will provide shielding from direct light. The Project facilities and OGV vessels at anchor will emit glow of similar intensity and size as observed for the Burrup Peninsula and Karratha townsite at this location.

North East Regnard Island (LM4) and 40-Mile beach (LM5) are situated the furthest from the Project and are predicted to remain the darkest following construction (**Table 2**). This is both due to the attenuation of light with distance from the Project, and the natural shielding provided by the tall primary dunes at each location (**Figures 7** and **8**). At LM4, the addition of Project lighting will result in a marginal increase in sky glow at the top of the dune behind the beach (WOS: 13 %; horizon: 18 %), while the Burrup Peninsula and Karratha townsite will remain the most visible light source at this location (**Figure 7**). At LM5, addition of the Project and CPE infrastructure will result in a marginal increase in direct light and sky glow on the existing bearing of the Sino Iron Facility (WOS: 15 %; horizon: 17 %; **Figure 8**). OGV vessel lighting emissions are predicted to be negligible at both LM4 and LM5.

Table 2: Comparison of benchmark and benchmark + modelled (cumulative) sky brightness values (Vmag/arcsec^2). Note that the scale is inverse logarithmic, brightness increases with decreasing Vmag/arcsec^2 values.

Location	WOS (0 – 90°) (Vmag/arcsec^2)			Horizon (60 – 90°) (Vmag/arcsec^2)		
	Benchmark	Benchmark + Modelled	Change	Benchmark	Benchmark + Modelled	Change
LM1	20.89	19.82	170 %	20.52	18.94	327 %
LM2	21.19	20.64	65 %	20.98	20.03	138 %
LM3	21.07	20.85	22 %	20.85	20.52	34 %
LM4	21.22	21.08	13 %	21.09	20.91	18 %
LM5	21.36	21.20	15 %	21.26	21.08	17 %

While PENV only undertook modelling of the cumulative contribution of light sources from both the Project and CPE facilities, the relative contribution of these sources separately to horizon sky brightness has been estimated and outlined in **Appendix B: Table B1**. The results from this analysis confirm that the CPE facilities are the greatest contributor to horizon brightness at mainland Cape Preston and South West Regnard Island (LM1: 302 %; LM2: 135 %; LM3: 25 %). Once light emissions from Project facilities are added to the CPE facilities, horizon brightness increases by a further 6 % at LM1, 1 % at LM2, and 7 % at LM3. At North East Regnard Island and 40-Mile beach, there is a greater increase in brightness from the Project facilities (LM4: 11 %, LM5: 9%) than from the CPE facilities (LM4: 7 %, LM5: 8%).

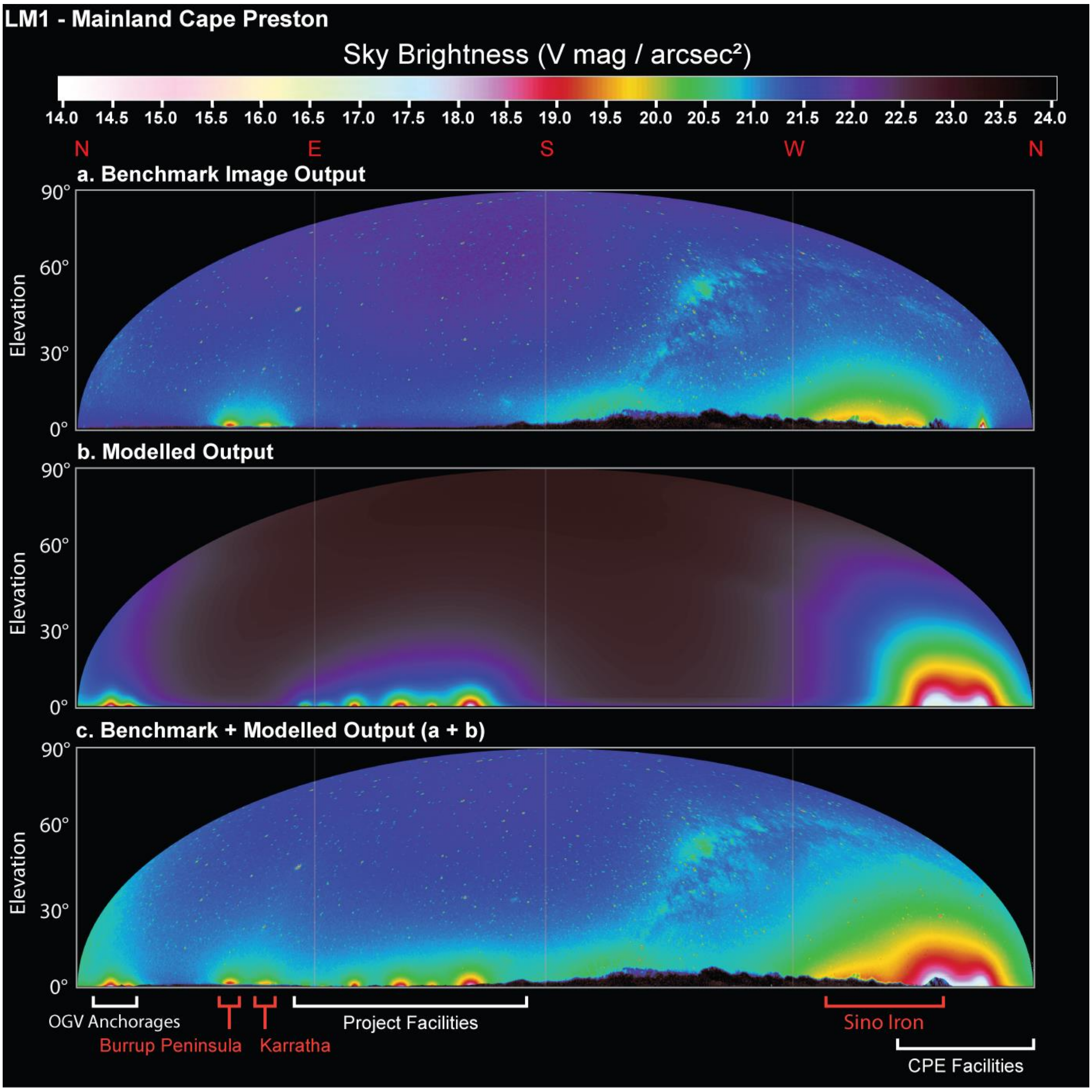


Figure 4: Artificial light modelling results for LM1 (mainland Cape Preston): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white labels = new light sources associated with the Project.

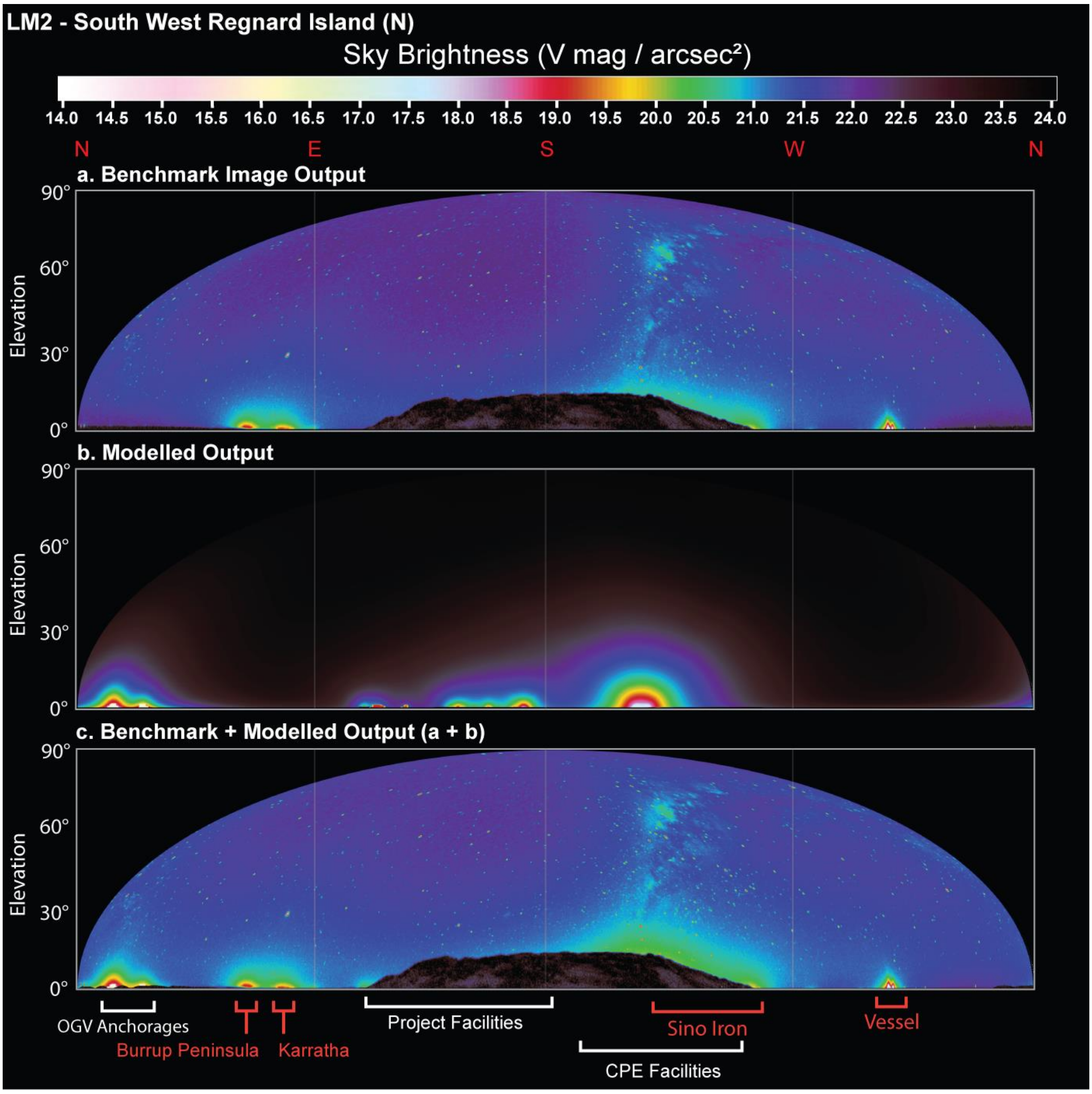


Figure 5: Artificial light modelling results for LM2 (South West Regnard Island [N]): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white labels = new light sources associated with the Project.

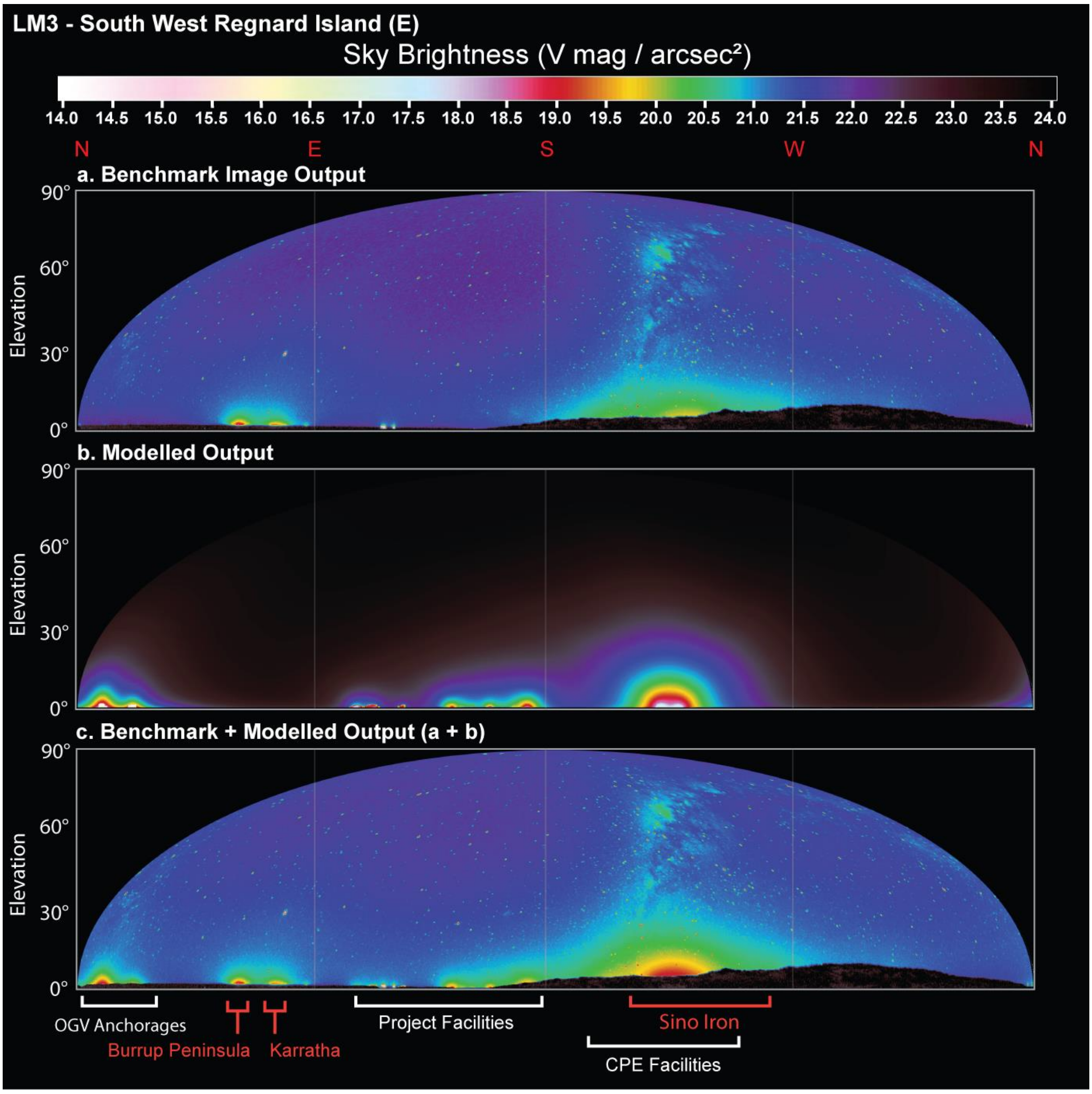


Figure 6: Artificial light modelling results for LM3 (South West Regnard Island [E]): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white labels = new light sources associated with the Project.

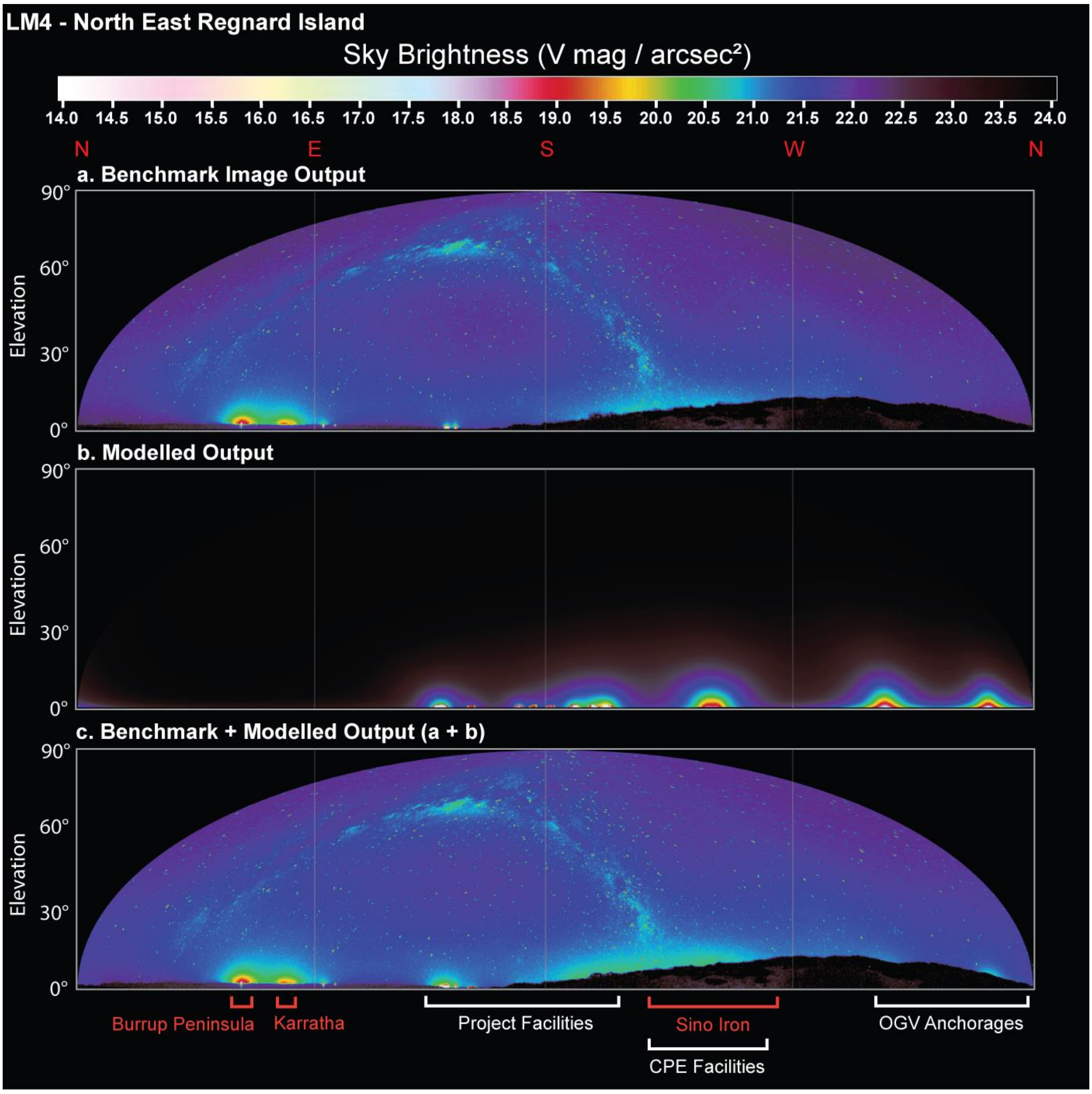


Figure 7: Artificial light modelling results for LM4 (North East Regnard Island): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white labels = new light sources associated with the Project.

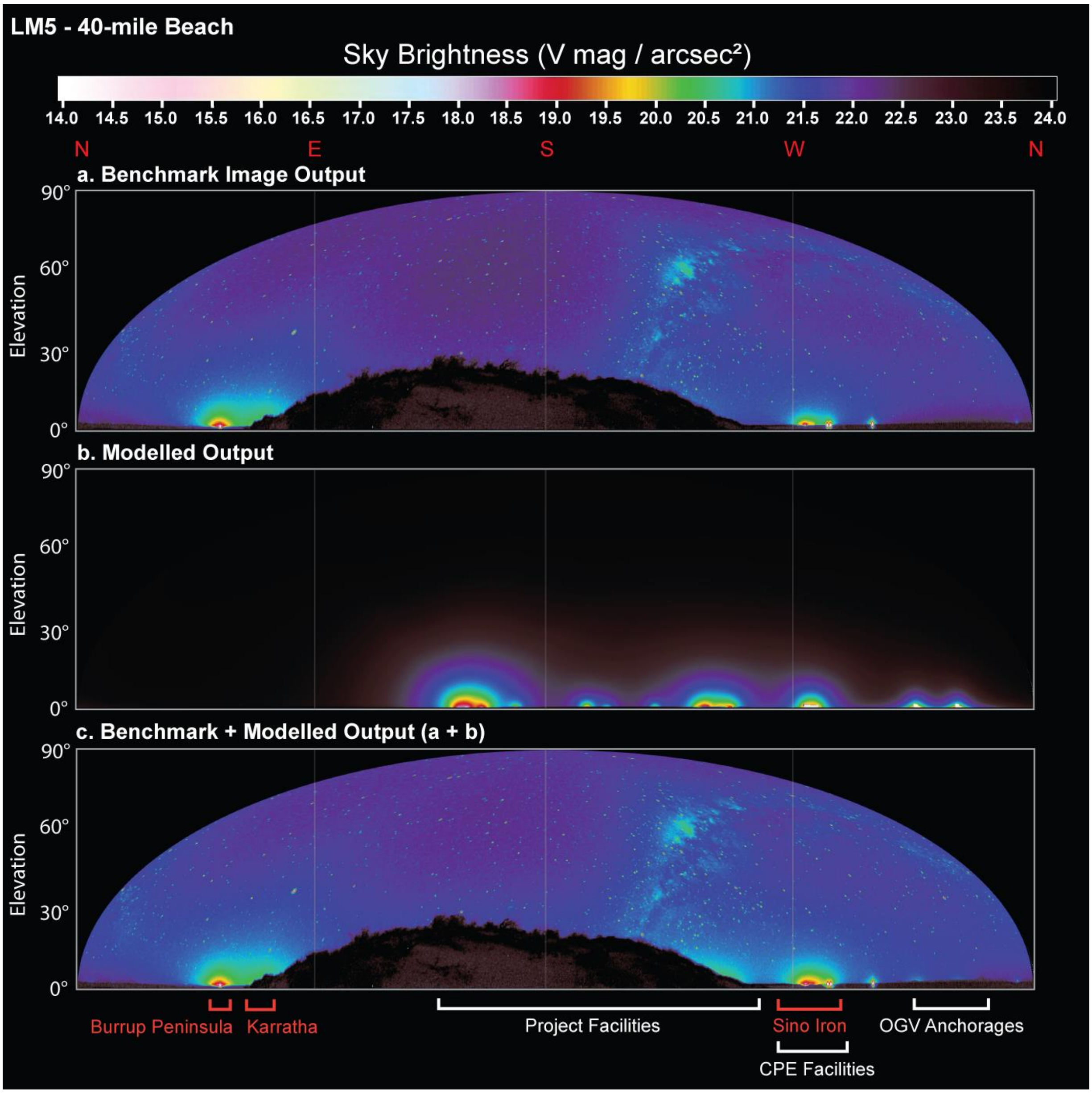


Figure 8: Artificial light modelling results for LM5 (40-Mile Beach): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white labels = new light sources associated with the Project.

4 CONCLUSION

Artificial light monitoring in the vicinity of the proposed Eramurra Project undertaken in June 2022 identified several existing light sources visible from monitored beaches, including the Citic Pacific Sino Iron facility and associated vessels, industrial lighting on the Burrup Peninsula, and the Karratha townsite. These sources were included in light modelling undertaken by PENV to provide a cumulative understanding of light emissions following the addition of Project lighting associated with the Eramurra Solar Salt Project, and CPE facility lighting (including OGVs and TSVs).

Light modelling of Project facilities predicts that the greatest change in brightness will occur at the beach directly adjacent to CPE (LM1). The topography at this location provides minimal natural shielding of both direct light and sky glow from the port facilities, and the Project facilities and OGVs are also visible as sources of sky glow on the horizon. Sites at South West Regnard Island will also experience a notable increase in brightness, but to a lesser degree than LM1. At the northern end of South West Regnard Island (LM2) the increase in brightness is primarily due to the OGV anchorages, which are visible as direct and unshielded sources of light from the beach. On the eastern beach of South West Regnard Island (LM3), the increase in brightness is attributed to sky glow from the Project and CPE facilities. At sites situated further from the Project, such as North East Regnard Island and 40-Mile Beach, the cumulative change in brightness resulting from Project lighting will be minimal.

5 REFERENCES

AUBE, M., FRANCHOMME-FOSSE, L., ROBERT-STAEHLER, P. & HOULE, V. (2005). Light Pollution Modelling and Detection in a Heterogeneous Environment: Toward a Night-Time Aerosol Optical Depth Retrieval Method. *The International Society for Optical Engineering* DOI: 10.1117/2.1200601.0028.

EPA. (2020). Cape Preston East – Multi-Commodity Export Facility – inquiry under section 46 of the *Environmental Protection Act 1986* to amend Ministerial Statement 949. Report and recommendations of the Environmental Protection Authority (Report 1680).

COMMONWEALTH OF AUSTRALIA. (2020). National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds.

LINARES, H., MASANA, E., RIBAS, S., AUBÉ, M., SIMONEAU, A. & BARA, S. (2020). Night Sky Brightness Simulation over Montsec Protected Area. 249.

LINARES, H., MASANA, E., RIBAS, S.J., GIL, M.G.-, FIGUERAS, F. & AUBÉ, M. (2018). Modelling the Night Sky Brightness and Light Pollution Sources of Montsec Protected Area. *Journal of Quantitative Spectroscopy and Radiative Transfer* 217: 178–188.

Appendix A: Eramurra Solar Salt Project Lighting Inventory

Table A1: Landside Project Facilities Lighting Inventory

Light Location	Light Type	Power (lm)	Number	Height (m)
Operations building	5000K LED	6325	10	2.5
Workshop	5000K LED	6325	10	5
Wet salt inload hopper	2200K LED	13140	8	9
Wash plant	2200K LED	13140	20	9
Salt stockpiles stacker	Red Light	6000	1	29
Salt stockpiles stacker delivery	2200K LED	13140	6	26
Salt stockpile dozer	6000K LED	6000	4	29
Salt loading FEL	6000K LED	6000	4	4
Salt truck	6000K LED	6000	4	1
Salt truck loading area	HPS	30000	8	9
Power station	4000K LED	19685	8	10
Harvester 1	6000K LED	13140	2	2
Harvester 1	2200K LED	6000	4	11
Harvester 2	6000K LED	13140	2	2
Harvester 2	2200K LED	6000	4	11
Wet salt haulage trucks	6000K LED	6000	4	2

Table A2: Port Facilities Lighting Inventory

Light Location	Light Type	Power (lm)	Number	Height (m)
Operations building	5000k LED	5500	8	2.5
TSV workshop/logistics building	5000k LED	5500	8	5
LEIC workshop	5000k LED	5500	8	5
PPA building	5000k LED	5500	8	2.5
MSIC barrier lighting	5000k LED	5500	8	4
Port power station	2200K LED	13140	4	3
Product salt inload hopper	2200K LED	13140	8	4
Port landside conveyors and outload hopper	2200K LED	13140	12	11
Salt stockpile stacker	Red Light	6000	1	27
Salt stockpiles stacker delivery	2200K LED	13140	6	19
Salt stockpile dozer	6000K LED	10000	4	14
Salt truck	6000K LED	6000	4	1
Jetty head apron	2200K LED	13140	12	10
Conveyor walkway lighting and shiploader	2200K LED	13140	8	6
Shiploader boom	Red Light	6000	1	10
Outload jetty 1	Amber LED	6000	60	1
Pump station (intake)	2200K LED	13140	10	3
Pump station PSC1	2200K LED	13140	4	4.5
Pump station PSE1	2200K LED	13140	4	4.5
Pump station PSE3	2200K LED	13140	4	2.5
Pump station PSE5	2200K LED	13140	4	2.5
Pump station PSR1	2200K LED	13140	4	4.5
Pump station PSW1	2200K LED	13140	4	4.5
Pump station PSW4	2200K LED	13140	4	4.5
Pump station PSW5	2200K LED	13140	4	2.5
Pump station PSW7	2200K LED	13140	4	2.5
Pump station PSW8	2200K LED	13140	4	1.5
Pump station PSW9	2200K LED	13140	4	1.5

Table A4: OGV Lighting Inventory

Light Description	Light Type	Power (lm)	Number	Height (m)
Deck lighting	3500K LED	4800	4	20
Deck lighting	3500K LED	4800	3	25
Deck lighting	3500K LED	4800	5	30
Deck lighting	3500K LED	8500	1	30
Floodlights	3500K LED	23000	2	30
Walkway lighting	4000k LED	960	19	25
Walkway lighting	Fluorescent	4000	42	20
Floodlights	HPS	47000	12	20
Floodlights	HPS	47000	4	30

Table A3: TSV Lighting Inventory

Light Description	Light Type	Power (lm)	Number	Height (m)
Deck lighting	4000K LED	12151	2	6
Walkway lighting	4000K LED	4876	12	3
Floodlight	5000K LED	27000	21	12

Appendix B: Relative Contribution of Light Sources

Table B1: Relative contribution of CPE and Project light sources to horizon sky brightness from each monitoring site. * = Estimated values

Location	Horizon Brightness (60 – 90°)					Is light from the Project facilities directly visible from nesting habitat?	Is light from the Project facilities visible as sky glow from nesting habitat?
	Benchmark (Vmag/arcsec^2)	Benchmark + CPE* (Vmag/arcsec^2)	Change from benchmark due to addition of CPE	Benchmark + CPE + Project (Vmag/arcsec^2)	Change from benchmark + CPE due to addition of the Project		
LM1	20.52	19.01	+ 302%	18.94	+ 6%	Yes	Yes
LM2	20.98	20.05	+ 135%	20.03	+ 1%	No	Yes
LM3	20.85	20.6	+ 25%	20.52	+ 7%	Yes	Yes
LM4	21.09	21.02	+ 7%	20.91	+ 11%	Yes	Yes
LM5	21.26	21.17	+ 8%	21.08	+ 9%	No	Yes

Note the following limitations apply to the above table:

1. Results for the Benchmark + CPE scenario have been estimated from the Benchmark + CPE + Project scenario (i.e. predicted cumulative emissions). The Benchmark + CPE scenario has not been modelled as a separate scenario at this time.