

ARTIFICIAL LIGHT MANAGEMENT PLAN

Eramurra Solar Salt Project

Client: Leichhardt Salt Pty Ltd

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LIST OF ACRONYMS

ALARP	As low as reasonably practicable
ALMP	Artificial Light Management Plan
BIA	Biologically Important Area
CPE	Cape Preston East
CPEEF	Cape Preston East multi-commodity export facility
DAWE	Department Agriculture, Water and the Environment
DCCEEW	Department of Climate Change, Energy, the Environment and Water
EPA	Environmental Protection Authority
EPBC	Environment Protection and Biodiversity Conservation Act
ERD	Environmental Review Document
FMB	Forty Mile Beach
GBRMPA	Great Barrier Reef Marine Park Authority
MNES	Matters of National Environmental Significance
MS	Ministerial Statement
MTMP	Marine Turtle Monitoring Program
Mtpa	Million tonnes per annum
PER	Public Environmental Review
WA	Western Australia

1 EXECUTIVE SUMMARY

Proposal name	Eramurra Solar Salt Project
Proponent name	Leichhardt Salt Pty Ltd
Ministerial Statement number	NA
Purpose of the Artificial Light Management Plan (ALMP)	The purpose of this ALMP is to outline how the Proponent will avoid, mitigate, and reduce potential impacts from artificial light generated by infrastructure during construction and operations of the Project relevant to marine turtle species occurring within its vicinity (<20 km; i.e. the Project Area).
Key environmental factor/s, outcome/s and/or objectives	<p>This ALMP relates to the factors of Marine Fauna, specifically marine turtles which are of conservation significance.</p> <p>The ALMP provides a combination of objective and outcome-based provisions to manage potential significant impacts on key environmental factors from artificial light associated with the Project. This hybrid approach will ensure that potential direct and indirect impacts to sensitive fauna (specifically marine turtles) are not greater than predicted.</p> <p>The specific outcome-based indicators proposed to achieve this are set to identify instances where hatchlings orient away from the ocean during their sea-finding at Cape Preston East and South West Regnard, as indicated by defined spread and offset angles (trigger criteria: spread angle >90° and offset angle >45° for one or more nest fans; threshold criteria: spread angle >120° and offset angle >60° for one or more nest fans).</p> <p>The specific objective-based indicators proposed to achieve this are:</p> <ul style="list-style-type: none"> • Implement the project to ensure that the minimum number and intensity of lights are in use • Implement the project to ensure that lighting is adapted for colour, intensity, and timing • Implement the project to ensure only the area intended is illuminated (to avoid light spill). • Implement the Project using nonreflective-dark coloured surfaces (where practicable).
Condition clauses (if applicable)	NA
Proposed construction date	TBC
ALMP required pre-construction?	Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>

2 CONTEXT, SCOPE, AND RATIONALE

2.1 Project Summary

Leichhardt is the Proponent of the Eramurra Solar Salt Project, a solar salt operation east of Cape Preston, approximately 55 km west-southwest of Karratha in the Pilbara region of WA (**Table 1**).

The Project will utilise seawater and natural solar evaporation processes to produce a concentrated salt product. The annual average production capacity is 5.2 Million tonnes per annum (Mtpa) with 6.8 Mtpa in a low rainfall year. The following infrastructure will be developed as part of the Project:

- Seawater intake, pump station and pipeline;
- Concentration ponds;
- Crystalliser ponds;
- Drainage channels and bunds;
- Process plant and product dewatering facilities;
- Water supply (desalination plant and/or groundwater bores);
- Bitterns disposal pipeline and outfall;
- Power supply and power lines;
- Pumps, pipelines, roads, and support buildings including offices and communications facilities;
- Workshops and laydown areas;
- Landfill; and
- Other associated infrastructure.

The export of salt is proposed via a trestle jetty. The jetty and associated stockpiles will be located at the Cape Preston East multi-commodity export facility (CPEEF) which also includes offshore navigation aids and deep-water anchorages for ocean-going vessels. This facility has been approved separately to the Project under Ministerial Statement (MS) 949.

Table 1: Summary of the Eramurra Solar Salt Project.

Project Title	Eramurra Solar Salt Project
Proponent Name	Leichhardt Salt Pty Ltd
Short Description	Leichhardt Salt Pty Ltd is seeking to develop a solar salt project in the Cape Preston East area, approximately 55 kilometres (km) west-southwest of Karratha in Western Australia. The Project will utilise seawater and evaporation to produce a concentrated salt product for export. The Project includes the development of a series of concentrator and crystalliser ponds and processing plant. Supporting infrastructure includes bitterns outfall, drainage channels, product dewatering facilities, desalination plant and/or groundwater bores, pumps, pipelines, power supply, access roads, administration buildings, workshops, laydown areas, landfill facility, communications facilities and other associated infrastructure. The Project also includes dredging at the Cape Preston East Port and either offshore disposal of dredge material or onshore disposal.

2.2 Approval History

The Project was referred to the Western Australian Environmental Protection Authority (EPA) under Part IV of the *Environmental Protection Act 1986* (EP Act) in June 2021. The EPA determined that the Project required a detailed assessment to determine the extent of the Project's direct and indirect impacts on several key environmental factors, including marine fauna, via a Public Environmental Review (PER).

The Project was also referred to the Commonwealth Department Agriculture, Water and the Environment (DAWE; now the Department of Climate Change, Energy, the Environment and Water (DCCEEW)) under the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* (EPBC Act) in 2022 as the Project proposed the potential to impact listed threatened and migratory species and communities. DAWE confirmed that the Project was a controlled action and required assessment as part of an accredited process under Section 1987 of the EPBC Act (EPBC 2021-9027).

The Environmental Review Document (ERD) submitted as part of the PER identified the potential for the Project to impact marine turtles. Marine turtles are listed as Matters of National Environmental Significance (MNES) under the EPBC Act and occur within the vicinity (<20 km) of the Project's infrastructure. Comments on the ERD from DCCEEW outlined the requirement of this Artificial Light Management Plan (ALMP) to measure and detect changes to marine turtle habitat quality from artificial light sources associated with the Project infrastructure.

2.3 Key Environmental Factors

The EPA Key Environmental Factors applicable to this ALMP are Marine Fauna. The EPA objective for Marine Fauna is to “protect fauna so that biological diversity and ecological integrity are maintained” (EPA 2016). The Project activities and associated potential artificial light impacts applicable to key environmental factors are summarised in Error! Reference source not found..

Table 2: Description of the key risks of the Project to key environmental factors.

EPA Objective	Protect marine fauna so that biological diversity and ecological integrity are maintained (EPA 2016).
Key Environmental Factor(s)	Marine Fauna – Marine Turtles
Key Risks	Dis- and/or misorientation of marine turtle hatchlings and increased mortality rate.

2.4 Approval Condition Requirements

The Project is currently being assessed and therefore there are not relevant conditions at this stage.

2.5 Scope and Purpose

The purpose of this ALMP is to outline how the Proponent will avoid, mitigate, and reduce potential impacts from artificial light generated by infrastructure during construction and operations of the Project relevant to marine turtle species occurring within its vicinity (<20 km; i.e. the Project Area).

Specifically, this ALMP is targeted at marine turtle species that have the potential to experience altered behaviours during key biological windows in response to artificial light. MNES relevant to this ALMP, with Biologically Important Areas (BIAs) or Habitat Critical to the species coinciding with the Project Area, are summarised in **Section 3**, alongside their listing status under both the (EPBC Act), and the *Biodiversity Conservation Act 2016* (BC Act).

This ALMP has been prepared in accordance with the State ‘Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans’ (EPA 2024) and the Commonwealth requirements under the EPBC Act, ‘Environmental Management Plan Guidelines’ (Commonwealth of Australia 2014).

2.6 Rationale and Approach

This ALMP is informed by a benchmark lighting assessment undertaken in 2022, which included an artificial light survey and modelling (refer to **Appendix A**). The assessment aimed to characterise the existing light environment and predict the visibility of Project-related light emissions at potential marine turtle nesting habitat within 20 km of Project infrastructure (Pendoley Environmental 2022). The modelling conducted as part of the artificial light assessment was based on the known locations of lit Project infrastructure at the time.

This ALMP also integrates findings from a Marine Turtle Monitoring Program (MTMP) conducted over two seasons (2022/23 and 2023/24) at potential nesting habitat, with a third season to be monitored in 2024/25. Habitat selection was guided by the initial artificial light assessment, focusing on areas where lit Project infrastructure could be visible. The purpose of the MTMP was to address the requirements of the National Light Pollution Guidelines (the guidelines; DCCEEW 2023) including evaluating the regional importance of nesting habitat and assessing baseline marine turtle hatchling behaviour when sea-finding on the beach. Furthermore, the findings of the MTMP were used to inform and justify outcome-based provisions outlined within this ALMP to measure compliance, with the goal of preventing impacts on marine turtle hatchling orientation behaviour.

Finally, this ALMP includes objective-based provisions and management targets, supported by regular auditing and a review process, to ensure ongoing compliance. These targets aim to ensure Project lighting is designed, implemented, and maintained in accordance with best practices, primarily mitigating potential impacts of artificial light on marine turtles in the Project Area, in addition to other fauna sensitive to artificial light.

Once endorsed, LEIC will publish this ALMP on their Project website and provide to the Department of Water and Environmental Regulation in a suitable electronic format for online publication.

2.7 Policy and Guidance Relevant to Marine Turtles

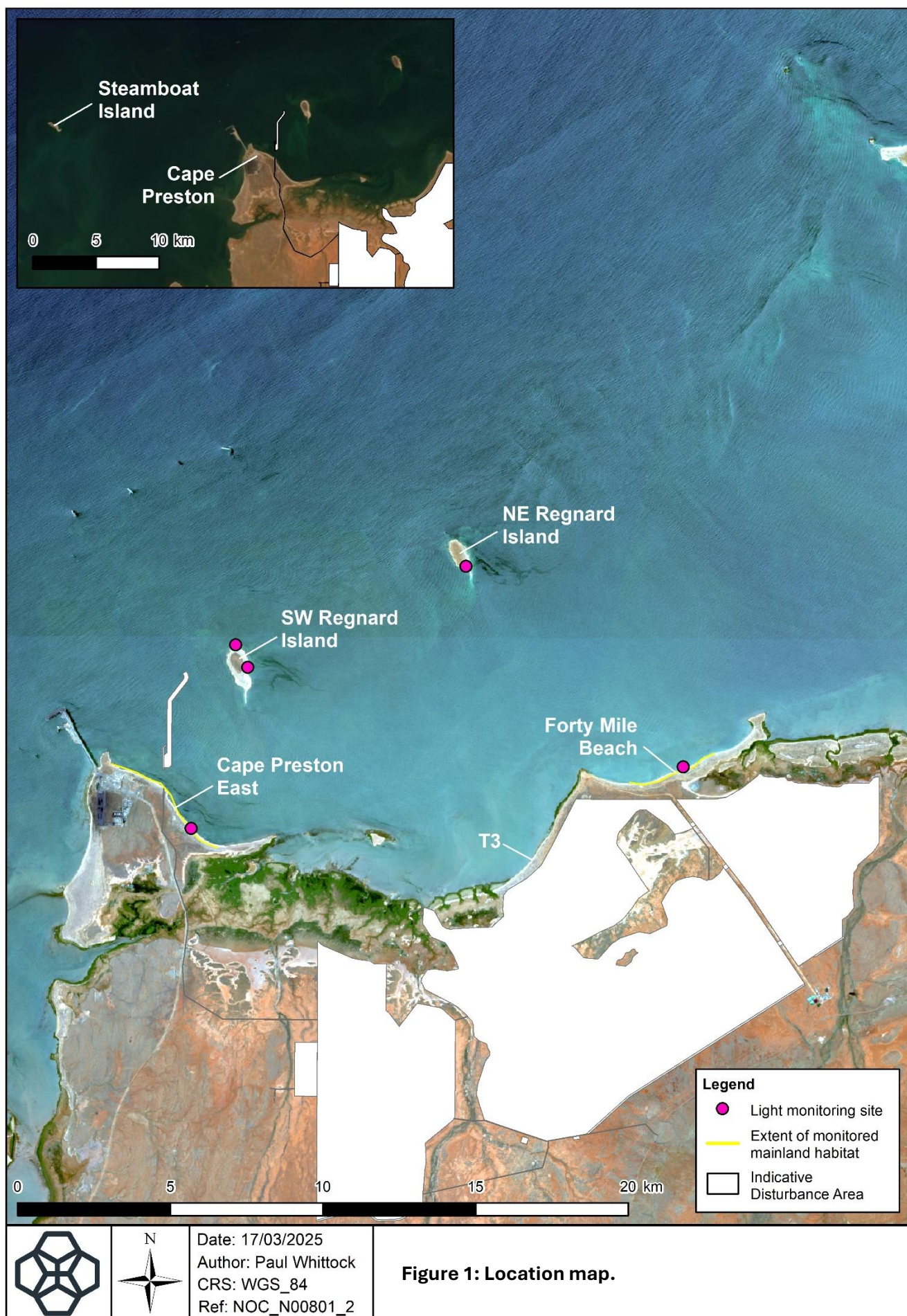
Guidance and policy documents relevant to marine turtles potentially impacted by lit-Project infrastructure include:

- National Light Pollution Guidelines for Wildlife (DCCEEW 2023);
- Recovery Plan for Marine Turtles in Australia 2017 – 2027 (Commonwealth of Australia 2017);

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- Environmental Assessment Guideline for protecting marine turtles from light impacts (EAG 5) (EPA 2010); and
- Marine Bioregional Plan for the North-west Marine Region (Commonwealth of Australia 2012).



3 DESCRIPTION OF THE PROTECTED MATTER: MARINE TURTLES

3.1 Approach

The approach taken to describe the marine turtle population within the Project Area followed the recommendations of the guidelines. This included the following descriptors:

- Conservation status of known species;
- Trends of their genetic stock (if known);
- The extent of nesting for that stock;
- Annual abundance of nesting turtles;
- Regional importance of the nesting habitat; and
- Seasonality of nesting/hatching.

To support aspects of this approach, the MTMP was conducted at beach habitat during the peak nesting and hatching periods for two seasons (2022/23 and 2023/24) for each species. Specifically, the program included the following surveys for each species in each season:

- Adult Nesting Population:
 - Hawksbill turtle (October/November): Track census conducted across 14-days and opportunistic ‘snapshot’ (single-day) surveys at selected locations.
 - Flatback and green turtles (January): Track census conducted across 14-days and opportunistic ‘snapshot’ surveys at selected locations.
- Hatchling Behaviour:
 - Hawksbill turtle: Orientation monitoring conducted across 14-days during a new moon period in January.
 - Flatback and green turtle: Orientation monitoring conducted across 14-days during a new moon period in February.

The initial selection of beach habitat for monitoring purposes was based on the outcomes of the artificial light assessment (Pendoley Environmental 2022), prioritising areas where lit Project infrastructure might be visible and located within 20 km. Following a review of MTMP results within the ERD in April 2024, DCCEE recommended adding a 2 km stretch of beach west of Forty Mile Beach (FMB) referred to as ‘T3’, for monitoring due to its proximity to lit Project infrastructure. This habitat had previously been surveyed by the Department of Biodiversity

Conservation and Attractions during an aerial survey in 2016/17, which recorded no turtle tracks (Fossette et al. 2021), and by O2 Marine in 2020/21, which documented a very low level of nesting activity with only one overnight track across four survey days (O2 Marine 2022). Given the very low nesting activity at this site and its proximity to the Project, the habitat will be monitored across 14-days during a new moon period in February/March 2025 solely to collect benchmark hatchling orientation data for inclusion in this ALMP.

The results of the MTMP are presented within Pendoley Environmental (2023, 2024) and are provided in **Appendix B** and summarised within **Sections 3.2** and **3.3**.

3.2 Marine Turtle Population(s) and Habitat

Three species of marine turtles were detected as nesting within the Project Area. These included flatback (*Natator depressus*), green (*Chelonia mydas*), and hawksbill (*Eretmochelys imbricata*) turtles.

Nesting activity was identified on offshore islands including SW Regnard, NE Regnard, and Steamboat, as well as on the mainland at CPE and Cape Preston West (**Figure 1**). No nesting activity was observed during the adult turtle track census and snapshot surveys conducted at FMB on the mainland, nor during snapshot surveys at Potter and Unnamed islands in 2022/23. A summary description of the population and habitat for each species of marine turtles is provided in **Table 3**.

3.3 Behaviour

The orientation of hatchling turtle tracks left in the sand on beach habitat after their emergence was used as an indicator of their behaviour when sea-finding. Furthermore, the occurrence of moderate or severe dis- or misorientation of a nest fan was used to understand the current impact of the light environment on hatchling behaviour (as per Salmon & Witherington 1995 and Witherington et al. 1996), which is defined as follows:

- Moderate:
 - Disorientation: Spread angle of 90° to 180°
 - Misorientation: Offset angle of 30° to 90°
- Severe:
 - Disorientation: Spread angle exceeds 180°
 - Misorientation: Offset angle exceeds 90°

Table 3: Summary description of the population of each marine turtle species detected within the Project Area. *Refer to Pendoley Environmental (2024) for the methodology and criteria for estimating abundance and assigning the importance of each population.

Description of Marine Turtle Population within the Project Area		Flatback Turtle (<i>Natator depressus</i>)	Green Turtle (<i>Chelonia mydas</i>)	Hawksbill Turtle (<i>Eretmochelys imbricata</i>)
Conservation status	State (BC Act)	Vulnerable	Vulnerable	Vulnerable
	Commonwealth (EPBC Act)	Vulnerable and Migratory	Vulnerable and Migratory	Vulnerable and Migratory
	International (IUCN Red List)	Data Deficient	Endangered	Critically Endangered
Genetic stock (Commonwealth of Australia 2017)	Title	Flatback-Pilbara (F-Pil)	Green-North West Shelf (G-NWS)	Hawksbill-Western Australia (H-WA)
	Trend	Unknown	Stable	Unknown
Seasonality (Commonwealth of Australia 2017)	Nesting	October to March (Peak: November to January)	November to March (Peak: December to February)	November to March (Peak: January)
	Hatching	February to March	January to May (Peak: February to March)	January to May (Peak: February to March)
Extent of nesting for the stock		Broad: Island and mainland habitat from North West Cape (western extent) to Port Hedland (eastern extent)	Broad: Island and limited mainland habitat from Gnarlaloo (western extent) to Cape York, Qld (eastern extent)	Moderate: Island habitat from Lowendals (western extent) to Dampier Archipelago (eastern extent)
Presence of Critical Nesting Habitat		Yes	Yes	Yes
Presence of Biologically Important Areas		Yes: Reproduction and Foraging	Yes: Reproduction and Foraging	Yes: Reproduction and Foraging
Annual abundance of nesting turtles and % of genetic stock*	2022/23	2 – 3 individuals (0.04 %)	1 – 2 individuals (0.01 %)	6 – 7 individuals (0.18 %)
	2023/24	3 – 4 individuals (0.05 %)	2 – 3 individuals (0.01 %)	21 – 24 individuals (0.60 %)
Regional importance of the nesting habitat*		Unimportant	Unimportant	Unimportant

The orientation metrics for a total of 33 hatched nests were recorded across the monitored habitat over both seasons, including at SW Regnard ($n = 4$), NE Regnard ($n = 2$), and Steamboat ($n = 22$) islands, and on the mainland at CPE ($n = 5$).

No nest fans on SW Regnard Island, NE Regnard Island, and at CPE showed signs of moderate dis- or misorientation. At Steamboat Island, nest fans situated on the centre of the sand spit had the largest spread and/or offset angles out of all locations, with five showing moderate disorientation exceeding a spread angle of 90° and nine showing moderate misorientation exceeding an offset angle of 30°. No nest fans at any area of habitat recorded signs of severe dis- or misorientation.

The results of monitoring at T3, scheduled for February/March 2025, will be incorporated into the next revision of this ALMP (refer to **Section 3.1**).

3.4 Threatening Process: Artificial Light

Adverse effects of artificial light on marine turtle behaviour are well recognised by a substantial body of research (see Witherington & Martin 2003; Lohmann et al. 1997; Salmon 2003 for reviews). Artificial lighting can impact individuals at different stages of the life cycle, including nesting adult females and hatchlings.

In general, artificial light most disruptive to marine turtles is rich in short wavelength blue and green light (400 – 550 nanometre (nm)) (Fritsches 2012; Pendoley 2005; Witherington 1992). The attractiveness to light differs by species (Horch et al. 2008; Pendoley 2005; Wang et al. 2007; Witherington & Bjorndal 1991a, 1991b), however, green, flatback, hawksbill and loggerhead turtles all show increased sensitivity to wavelengths <600 nm (Fritsches 2012; Pendoley 2005; Levenson et al. 2004). Furthermore, green and flatback turtles show stronger preference for blue light <500 nm (Fritsches 2012; Pendoley 2005). Thus, cooler, whiter lights are more likely to attract turtles in comparison to warmer, amber or red lights.

While the spectral composition of light is an important contributing factor to potential disruption of natural marine turtle behaviour, intensity has also shown to be equally important. High intensity, long wavelength light can cause a similar impact to low intensity, short wavelength light. Therefore, it is important that both intensity and spectral emission are considered and mitigated during Project lighting design.

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 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.

To determine the Likelihood score, Project-related light sources were evaluated based on their directionality, intensity, and visibility within modelling outputs (refer to Pendoley Environmental 2022). These outputs were generated for nesting habitats within the Project Area, including at CPE, SW Regnard Island, NE Regnard Island, and FMB. The modelling outputs represent the unmitigated ('worst-case') visibility of Project-related light under clear-sky conditions during a

new moon period. The evaluation considered the potential for these lights to cause dis- or misorientation of hatchling turtles of all species at the habitat (flatback, green, and hawksbill), potentially reducing fitness or increasing mortality compared to ‘benchmark’ (pre-construction) light conditions. Note that this approach to the risk assessment differs from the one in Pendoley Environmental (2024), which evaluated the risk of cumulative lighting across the horizon, including proposed lighting from the Project and CPEEF, and existing sources such as Citic Pacific’s Sino Iron Project.

For the Consequence score, the approach involved an assessment of the abundance and nesting success of adult marine turtles at nesting habitat areas during the 2022/23 and 2023/24 monitoring seasons (refer to Pendoley Environmental 2024). Due to the low recorded nester abundance of all three species across the Project Area (**Table 3**), the cumulative contribution of nesting females to the genetic stock of each species was estimated to be <1 %. Additionally, the nesting success of hawksbill and flatback turtles was low in both seasons, while green turtle nesting success was not evaluated due to the minimal overnight nesting activity recorded.

As a result, each monitoring location met the Insignificant consequence criteria under the risk assessment matrix. This indicates that, due to the low levels of nesting observed within the Project Area, any potential impacts caused by artificial light are not expected to have implications on the respective genetic stocks of these turtle species.

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 Outcomes

4.2.1 Cape Preston East

At CPE, light from the Project infrastructure will be visible as a source of sky glow on the horizon and is not shielded by vegetation or localised topography. As a result, there is a possible likelihood of impact on the sea-finding behaviour of hatchling turtles from the sky glow. The likelihood and consequence rankings therefore considered the inherent risk to be Low at CPE.

4.2.2 South West Regnard Island

The assessment of lighting visibility indicated that nesting habitat at the northern end will be largely shielded from Project lighting by a tall dune. On the eastern side of the island, the dune elevation is lower, meaning horizon brightness will be more noticeable due to contributions to sky glow from the Project infrastructure. The highest density of marine turtle nesting at the island

occurs at the northern end and is therefore shielded from most of the Project light sources on the mainland.

There is a possible likelihood of impact on the sea-finding behaviour of hatchling turtles from the sky glow on the mainland. The likelihood and consequence rankings therefore considered the inherent risk to be Low at SW Regnard Island.

4.2.3 North East Regnard Island

The beach habitat will experience a small increase in sky glow on the horizon associated with the Project infrastructure. The habitat is largely shielded from the mainland by a tall dune, and as a result the glow is only predicted to be visible above the elevated dune horizon. This glow is therefore unlikely to impact on the orientation of hatchlings. As a result, the likelihood and consequence rankings considered the inherent risk to be Low at NE Regnard Island.

4.2.4 Steamboat Island

The nesting habitat is situated ~15 km from the Project on the mainland. As a result of this distance, any visible Project-related artificial light is likely to be of low intensity sky glow. Furthermore, the Project-related light on the mainland will be shielded by the existing Cape Preston (Sino Iron) causeway and offloading facility, further reducing the visibility of any light spill. The glow is therefore unlikely to impact on the orientation of hatchlings. As a result, the likelihood and consequence rankings considered the inherent risk to be Low at Steamboat Island.

4.2.5 Forty Mile Beach

The evaluation of lighting visibility indicated only a small change in horizon brightness will be detected at FMB from the Project infrastructure. This lighting will largely be shielded at the habitat by a tall, hind dune, which creates a natural, dark barrier between the beach and Project lighting. This lighting is therefore unlikely to impact on the orientation of hatchlings and the likelihood and consequence rankings considered the inherent risk to be Low at FMB.

5 ARTIFICIAL LIGHT MANAGEMENT PLAN COMPONENTS

5.1 Approach

This ALMP provides both objective and outcome-based approaches to manage significant residual impacts on marine turtles. Outcome-based provisions are applied where an achievable and measurable outcome can be established (EPA 2021). Objective-based provisions are applied where the monitoring of an action or target is more effective or appropriate than a measurable outcome (EPA 2021). This hybrid management plan will ensure that potential direct and indirect impacts to marine fauna from artificial light are not greater than predicted. Management provisions have been prioritised using a risk-based approach informed by best management practice and industry standards, with the aim of ensuring the risks of secondary or indirect impacts are minimised, typically to the level of ‘as low as reasonably practicable’ (ALARP). Triggers for early response and adaptive management (**Section 5.2**) have been developed to further ensure the management objectives are achieved and performance is continually improved. Management actions (safeguards and controls) and performance targets have been assigned to ensure the associated objectives are achieved.

To reduce impacts of artificial light on marine turtles during construction and operations, a management program including outcome and objective-based provisions has been designed. Outcome-based provisions specify measurable threshold and trigger criteria specific to hatchling turtle behaviour, and objective-based provisions outline general management targets for best practice lighting design and control measures. Leichhardt has committed to implementing, verified by regular auditing.

5.2 Management Program

5.2.1 Outcome-based Provisions

A risk-based approach was applied to identify and prioritise outcome-based provisions relevant to the threatening process (**Section 3.4**) and the EPA’s environmental factor and objective (see **Table 2**), while incorporating the outcomes of the risk assessment (**Section 4**).

As a result, outcome-based provisions were established for monitoring hatchling turtle behaviour at CPE and SW Regnard due to the direct visibility of artificial lighting from Project infrastructure at those locations (see **Table 4**). Based on the outcomes of the risk assessment,

no provisions have been set for monitoring other locations, including NE Regnard Island, Steamboat Island, and FMB.

Over two seasons of baseline monitoring of hatchling turtle behaviour at CPE and SW Regnard Island, nine hatched nests were recorded: five at CPE and four at SW Regnard (refer to **Section 3.3**). However, this limited sample size restricts the ability to establish trigger and threshold limits for detecting statistically significant changes in behaviour-based criteria using this baseline data.

To address this limitation and ensure the behaviour-based criteria are informed by evidence-based knowledge, measurable hatchling orientation criteria are proposed, incorporating a combination of spread and offset angles that are based on conservative values of moderate and severe disorientation as defined in Salmon & Witherington (1995) and Witherington et al. (1996). Given that no hatched nests at these locations exhibited signs of moderate or severe disorientation during baseline, these criteria would enable the identification of the first instance where some hatchlings, during sea-finding, orient in a direction away from the ocean, potentially increasing their mortality rate.

5.2.2 Objective-based Provisions

Objective-based provisions are outlined in **Table 5**. These provisions include management targets aligned with best practice measures in the guidelines, with specific lighting control measures (management actions) that will be implemented. Both internal and external audits will be conducted against these management actions to ensure Project lighting is compliant with best practice and mitigating impacts to marine turtles and other light-sensitive fauna in the Project Area.

Table 4: Outcome based provisions for hatchling turtle behaviour.

EPA Factor	Marine Fauna
Environmental Values	Marine Turtles
Key Impacts	Increase in mortality rate of marine turtle hatchlings due to impacts from artificial light.
Key Risks	Disorientation/misorientation of marine turtle hatchlings during sea-finding activities.
Conditions	N/A
Outcome	There will be no instances where hatchlings orient away from the ocean during their sea-finding at Cape Preston East and South West Regnard as a consequence of light emissions from the Project.

Indicators Trigger/Threshold Criteria	Response Actions	Monitoring	Timing and Frequency of Monitoring	Reporting
<u>Trigger Criteria</u> The spread angle exceeds 90° and offset angle exceeds 45° for one or more nest fans at any monitoring location	<p>If an exceedance in trigger criteria is reported within a single season:</p> <ul style="list-style-type: none">Undertake an independent lighting audit that reviews all Project-related light sources. Where problematic lighting is identified, remedial actions will be implemented prior to the next marine turtle hatching season (beginning 1st January). Remedial actions may include:<ul style="list-style-type: none">Changing the spectral emission.Reducing the intensity.Implementing additional shielding or changing directionality.Implementing smart systems to reduce lighting use when not required. <p>If an exceedance in trigger criteria is reported within two consecutive seasons:</p> <ul style="list-style-type: none">Undertake a desktop assessment of artificial light monitoring data and marine turtle hatchling behaviour to determine cause. The assessment will rate the level of impact associated with the exceedance and recommend remedial actions. Remedial actions will be implemented prior to the next marine turtle hatching season (beginning 1st January) and may include additional mitigation measures as per the single-season exceedance, and/or intervention in hatchling emergence to prevent or reduce the impact to a level below the trigger criteria.	Monitoring will be conducted at CPE and SW Regnard and involve hatchling orientation (see Table 6) and artificial light monitoring (see Table 7).	<p>Hatchling orientation will be conducted over a 14-day period during a new moon in the peak hatching season for flatback, green, and hawksbill turtles (i.e. seven days either side of the new moon that occurs in February). Artificial light monitoring will be undertaken concurrently with hatchling orientation monitoring.</p> <p>Monitoring will be undertaken each season during construction and for two seasons post-construction / during operations.</p> <p>If threshold criteria are exceeded at any location, an additional season of monitoring may be required pending the outcomes of a desktop assessment.</p>	<p>One annual report on the results of the monitoring survey (including artificial light), assessing results against trigger and threshold criteria. The report should also review if existing trigger/threshold criteria are appropriate and suggest amendments if required.</p> <p>The first post-construction/ operations annual report will verify the artificial light modelling outputs for the Project infrastructure.</p>
<u>Threshold Criteria</u> The spread angle exceeds 120° and offset angle exceeds 60° for one or more nest fans at any monitoring location	<p>If an exceedance in threshold criteria is reported within a single season:</p> <ol style="list-style-type: none">Undertake an independent lighting audit that reviews all Project-related light sources. Where problematic lighting is identified, remedial actions will be implemented prior to the next marine turtle hatching season (beginning 1st January). Remedial actions may include:<ul style="list-style-type: none">Changing the spectral emission.Reducing the intensity.Implementing additional shielding or changing directionality.Implementing smart systems to reduce lighting use when not required.Undertake an assessment of artificial light monitoring data and marine turtle hatchling behaviour to determine cause. The assessment will rate the level of impact associated with the exceedance and recommend remedial actions. Remedial actions will be implemented prior to the next marine turtle hatching season (beginning 1st January) and may include additional mitigation measures as per the single-season exceedance, and/or intervention in hatchling emergence to prevent or reduce the impact to a level below the threshold criteria.			

Table 5: Objective based provisions.

EPA Factor - Objective	Marine Fauna - To protect marine fauna so that biological diversity and ecological integrity are maintained.
Environmental Values	Marine Turtles
Key Impacts	Increases in mortality rate of marine turtle hatchlings due to impacts from artificial light.
Key Risks	Disorientation/misorientation of marine turtle hatchlings during sea-finding activities.
Conditions	N/A
Outcome	There will be no instances where hatchlings orient away from the ocean during their sea-finding at Cape Preston East and South West Regnard as a consequence of light emissions from the Project.

Management Target	Management Action	Monitoring	Timing and Frequency of Monitoring	Reporting
Implement the project to ensure that the minimum number and intensity of lights are in use	<ul style="list-style-type: none"> All non-essential lighting to be switched off when not in use, including during construction. Any lighting required to be switched on will emit the minimum intensity required to achieve its objective. Develop a best practice lighting guidance document that all employees will implement. 	On-site audits of Project facility lighting to ensure compliance against the management targets.	<p>At least one annual internal audit at least six weeks prior to every marine turtle hatchling season (1st January).</p> <p>One external audit every three years, at least six weeks prior to the marine turtle hatching season (1st January).</p> <p>Additional audits to be scheduled as necessary (e.g. following major changes in Project facilities / infrastructure).</p>	One report following the external lighting audit every three years demonstrating compliance against the management targets and/or where remedial actions are required.
Implement the project to ensure that lighting is adapted for colour, intensity, and timing	<ul style="list-style-type: none"> External lighting at the following Project facilities to utilise True Amber or 2200K CCT LED emitters, including: <ul style="list-style-type: none"> Wash plant Power station All pump stations and pump station intakes Wet salt inload hopper Operations building. Workshop Ensure lighting on infrastructure is switched off when not in use where possible (e.g. pump stations). 			
Implement the project to ensure only the area intended is illuminated (to avoid light spill)	<ul style="list-style-type: none"> Shielding of all lights to achieve an upward waste light output ratio (ULR) of 0% (by incorporating shielding, housings or recessing of fittings) All lighting to be directed downwards using targeted asymmetrical distribution to illuminate only the specific areas of need, while minimising reflectance in all areas. All lighting to be mounted as low as possible while meeting minimum lighting objectives in all areas. All transparent windows/doors of buildings to have opaque (block-out) blinds/curtains/shutters fitted and in use at night during the marine turtle season unless visibility is operationally required. During construction, ensure mobile lighting towers are not oriented towards marine turtle nesting habitat where possible, and keep the height as low as possible. 			
Implement the Project using non-reflective, dark coloured surfaces (where practicable)	<ul style="list-style-type: none"> Consider exterior finishes on all buildings to be matte and have a maximum reflective value of 30 %. All other surfaces, including roads and conveyors, to be matte and have a maximum reflective value of 30 % unless not technically feasible or a safety risk. 			

5.3 Monitoring Program

5.3.1 Hatchling Turtle Orientation

The monitoring of the orientation of post-emergence hatchling turtle tracks on the beach will allow for any disruption of artificial light associated with Project infrastructure to be detected during construction and operations (see **Table 6**).

Table 6: Overview of the hatchling turtle orientation work scope.

Hatchling Turtle Orientation	
Objective	Quantify the immediate post-emergence sea finding behaviour of hatchling turtles on the beach.
Method	The sea finding orientation of hatchling turtles will be monitored by measuring the bearing of the tracks that appear within a 'nest fan' on the beach after hatchlings emerge from the nest and crawl to the ocean. Measurements of a nest fan will be recorded if five or more hatchling tracks are sighted from a hatched clutch, indicated by a localised depression in the sand which marks the point of emergence ('nest cone'). A sighting compass will be used to measure the bearing of the outermost tracks of the nest fan (vectors A and B) and the bearing of the most direct route to the ocean (vector X) relative to the nest cone. Bearings will be measured from either the point where the aforementioned tracks cross the high tide line, or five metres from the clutch emergence point (whichever distance is shortest). Single hatchling tracks that are more than 30° from the outermost track of the main fan will be recorded as outliers, following methodology guidance of Pendoley (2005).
Monitoring Location(s)	<ul style="list-style-type: none"> • Cape Preston East (construction and operations) • SW Regnard Island (construction and operations)
Timing	Peak hatching period during a new moon phase in February.
Frequency	Monitoring of hatching activity should be conducted every two days across a minimum period of 14-days at each monitoring location.
Sample Size	No minimum requirement, noting limitations for baseline data comparison.
Indicator(s)	<p>For each nest fan, the following indicators will be measured and reported:</p> <ul style="list-style-type: none"> • Spread angle: This describes track dispersion from the emergence point, capturing the spread of all hatchling pathways toward the ocean. A larger value indicates greater dispersion or variation in ocean finding bearings and may indicate disruption to natural hatchling sea finding ability. • Offset angle: This describes the degree of deflection of tracks from the most direct route to the ocean. A smaller value indicates a more direct route (i.e. less deviation from the most direct route) and a larger value demonstrates greater deviation from the most direct route, which may indicate disruption to the natural sea finding ability of hatchlings.

5.3.2 Artificial Light Monitoring

The monitoring of artificial light concurrently with hatchling orientation will allow for a comprehensive interpretation of hatchling behaviour, particularly where there is an exceedance in trigger/threshold metrics.

Table 7: Overview of the artificial light monitoring work scope.

Artificial Light Monitoring	
Objective	Quantify artificial light visible at representative marine turtle habitat.
Method	Artificial light data will be captured at each monitoring location using an all-sky light monitoring camera (DSLR camera with a fisheye lens that captures the entire sky and surrounding horizon). The cameras should be deployed on tripods at ~60 cm height. Multiple images should be captured over several nights from each location. Suitable images will be processed to quantify light intensity in the entire image in visual magnitudes / arcsec ² .
Monitoring Location(s)	<ul style="list-style-type: none"> • Cape Preston East (construction and operations) • SW Regnard Island (construction and operations)
Timing	Peak hatching period during a new moon phase in February.
Frequency	One new moon phase, concurrent with hatchling orientation monitoring.
Indicator(s)	<ul style="list-style-type: none"> • Zenith Brightness (average brightness in the 0 – 30 degree field of view) • Horizon Brightness (average brightness in the 60 – 90 degree field of view) • Sector Brightness (average brightness in specific regions/bearings towards the Project).

6 ENVIRONMENTAL REPORTING

6.1 Incident Reporting

Incidents are reported in accordance with Leichhardt's Incident Reporting and Investigation Standard (LEI-HSEC-STD-0003).

7 ROLES AND RESPONSIBILITIES

Leichhardt's roles and responsibilities relevant to the implementation of the ALMP are outlined in **Table 8**.

Table 8: Roles and Responsibilities for ALMP Implementation.

Role	Responsibility
Manager Sustainability	Ensure monitoring and management actions are implemented in accordance with this Plan. Ensure reporting to regulatory agencies is undertaken in accordance with this Plan.
Principal Environmental Advisor	Support the implementation of monitoring programs and maintain monitoring records. Support reporting, and the provision of data, to regulators as required under this plan. Deliver awareness training programs to personnel, contactors, and visitors. Ensure all personnel involved in fauna surveys are appropriately licensed and qualified.

8 STAKEHOLDER CONSULTATION

Leichhardt has consulted extensively with and will have ongoing consultation with all stakeholders who are affected by the Project. This includes (but not limited to):

- Traditional Owners (Wirrawandi Aboriginal Corporation);
- Neighbouring pastoral station lessees;
- State Government agencies (EPA, Department of Biodiversity, Conservation and Attractions; Department of Energy, Mines Industry Regulation and Safety; Department of Jobs, Tourism, Science and Innovation; Department of Transport; Department of Water and Environmental Regulation);
- DCCEEW;
- Pilbara Ports Authority;
- Local Government (City of Karratha);
- Karratha & Districts Chamber of Commerce and Industry;
- Western Australian Marine Science Institute; and

- Community / Peak Bodies (Western Australian Fishing Industry Council; Recfishwest; Campers at the Gnoorea Point camping area).

In addition to the consultation conducted in relation to the Project, additional consultation with key stakeholders in relation to the Illumination Plan will continue throughout the life of the Project. A summary of the stakeholder consultation undertaken in relation to the management of impacts to marine and terrestrial fauna is provided in **Table 9**.

Table 9: Summary of stakeholder consultation.

Stakeholder	Date	Issues/Topics	Leichhardt Response
DCCEEEW	April 2024	Inclusion of a monitoring program. performance standards, management triggers and timeframes and annual auditing in the Illumination Plan.	The ALMP includes this information.
EPA Services	April 2024	Provide details of the proposed artificial light management and ongoing monitoring regime to ensure significant impacts to nesting and hatching turtles.	The ALMP includes this information.

9 ADAPTIVE MANAGEMENT AND REVIEW

LEIC will undertake adaptive management to ensure that mitigation measures, monitoring programs and assessment of trigger and threshold criteria are successful in ensuring that the environmental objectives and outcomes are being met. This management approach will be based upon information gathered from:

- Evaluation of marine turtle hatchling orientation and artificial light monitoring data;
- Reviewing new information about artificial lighting technologies and equipment;
- Reviewing new information about artificial lighting impacts on marine turtles and other fauna;
- Incident reports; and
- Changes to operations.

Adaptive management will involve implementing additional mitigation measures and/or corrective actions (as outlined in **Table 4** and **Table 5**) and systematically adapting management measures and monitoring programs to ensure the environmental outcomes or objectives are met.

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Appendix A: Benchmark Lighting Assessment (Pendoley Environmental 2022)

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



DOCUMENT CONTROL INFORMATION

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

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LIST OF APPENDICES

Appendix A: Eramurra Solar Salt Project Lighting Inventory
Appendix B: Relative Contribution of Light Sources

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	Transshipment 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 Transshipment Vessel (TSV), navigation markers, and Ocean-Going Vessels (OGVs), located at anchorages within a designated transshipment 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

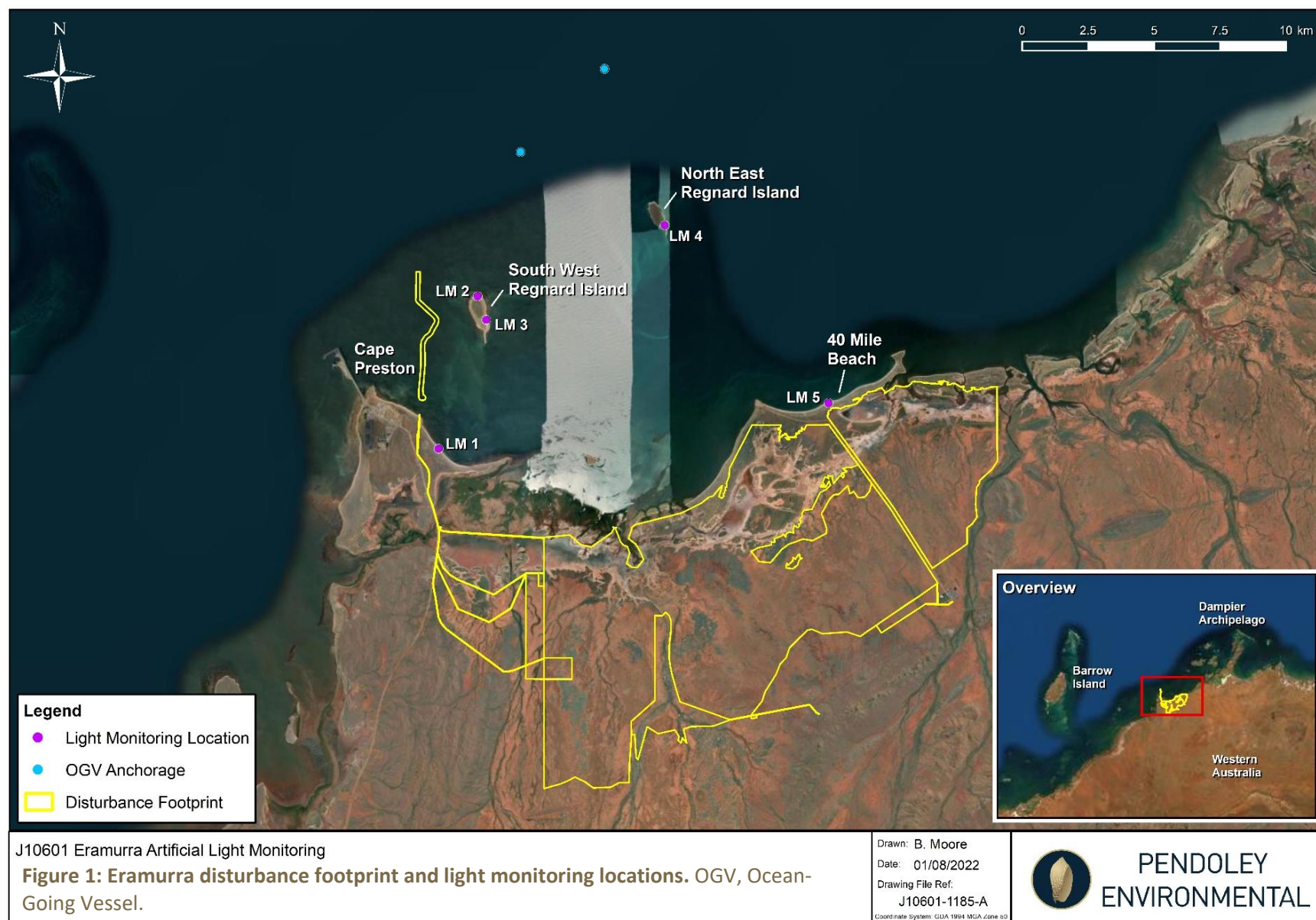
2.1 Light Monitoring

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



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.

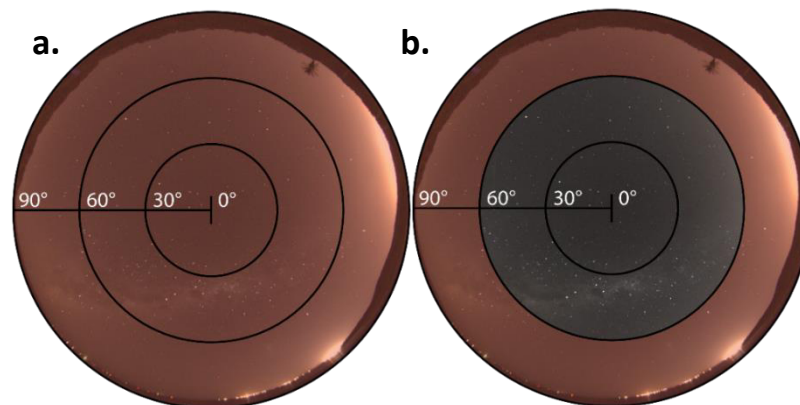


Figure 3: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60 – 90°). Shaded areas denote the region of the sky being measured.

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 ($\text{W/m}^2/\text{sr}$) to units of photometric luminance ($\text{Vmag}/\text{arcsec}^2$). 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 ($V_{\text{mag}}/\text{arcsec}^2$). Note that the scale is inverse logarithmic, brightness increases with decreasing $V_{\text{mag}}/\text{arcsec}^2$ values.

Location	WOS (0 – 90°) ($V_{\text{mag}}/\text{arcsec}^2$)			Horizon (60 – 90°) ($V_{\text{mag}}/\text{arcsec}^2$)		
	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%).

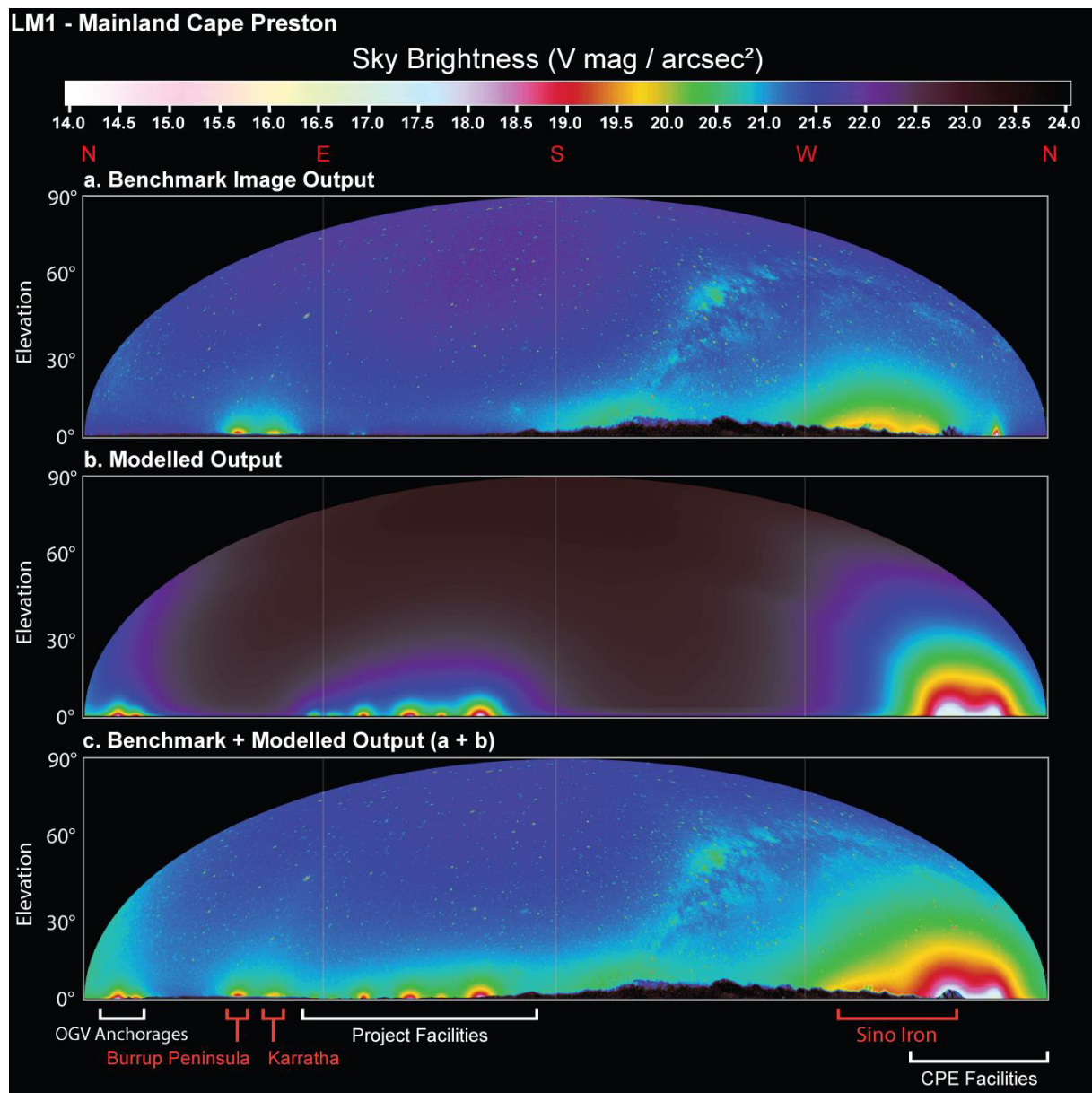


Figure 4: Artificial light modelling results for LM1 (mainland Cape Preston): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources,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

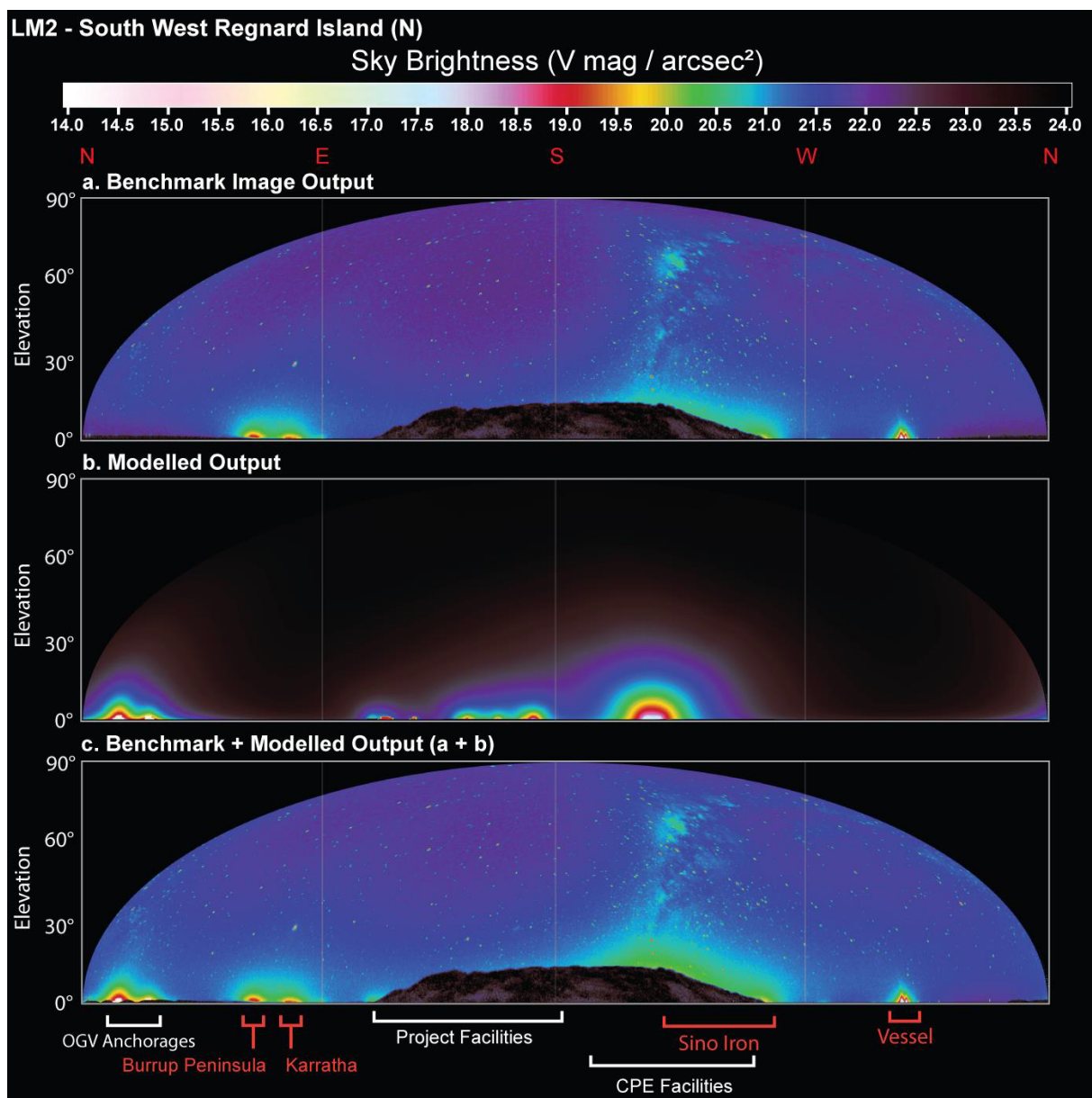


Figure 5: Artificial light modelling results for LM2 (South West Regnard Island [N]): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing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

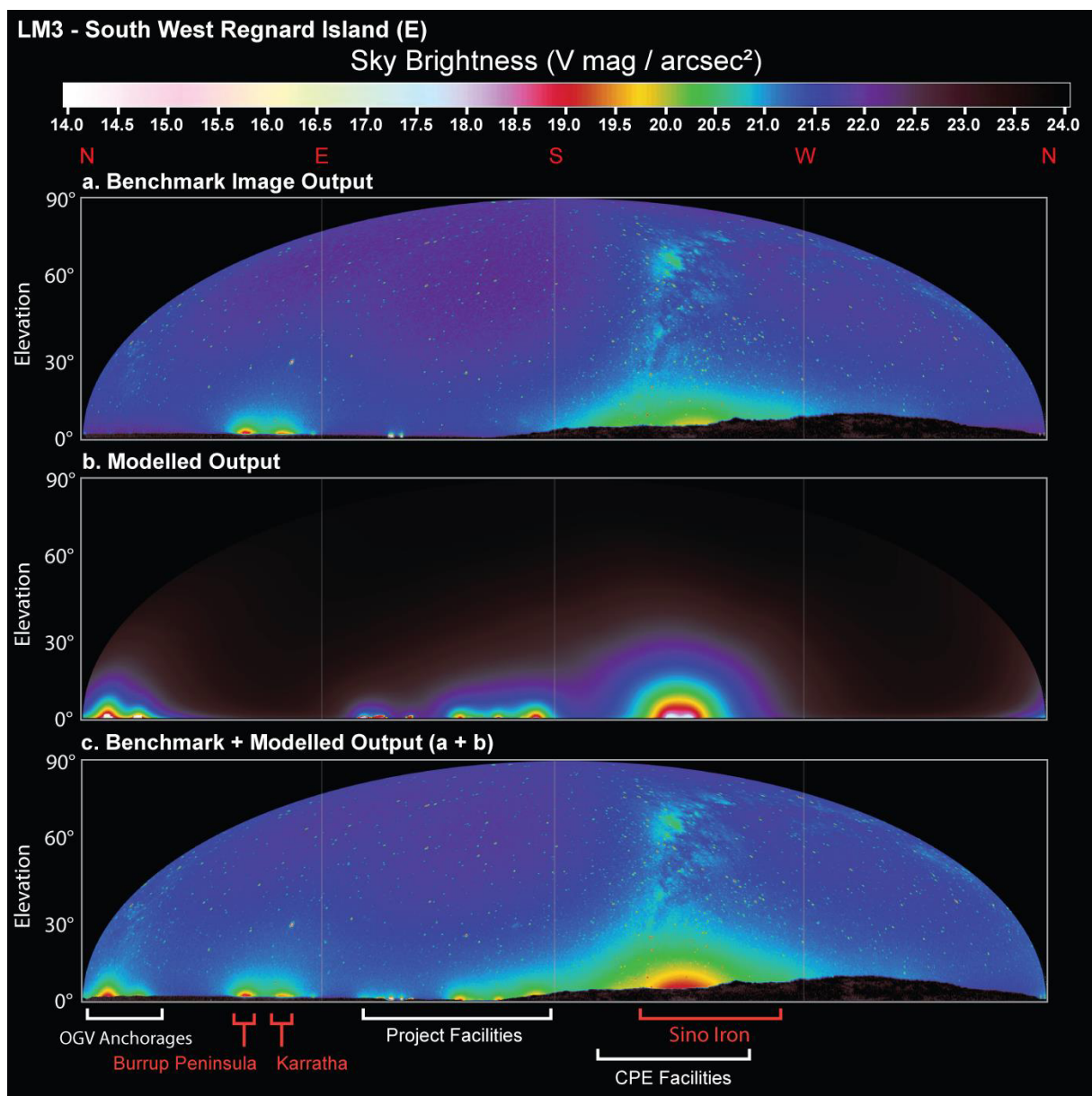


Figure 6: Artificial light modelling results for LM3 (South West Regnard Island [E]): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing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

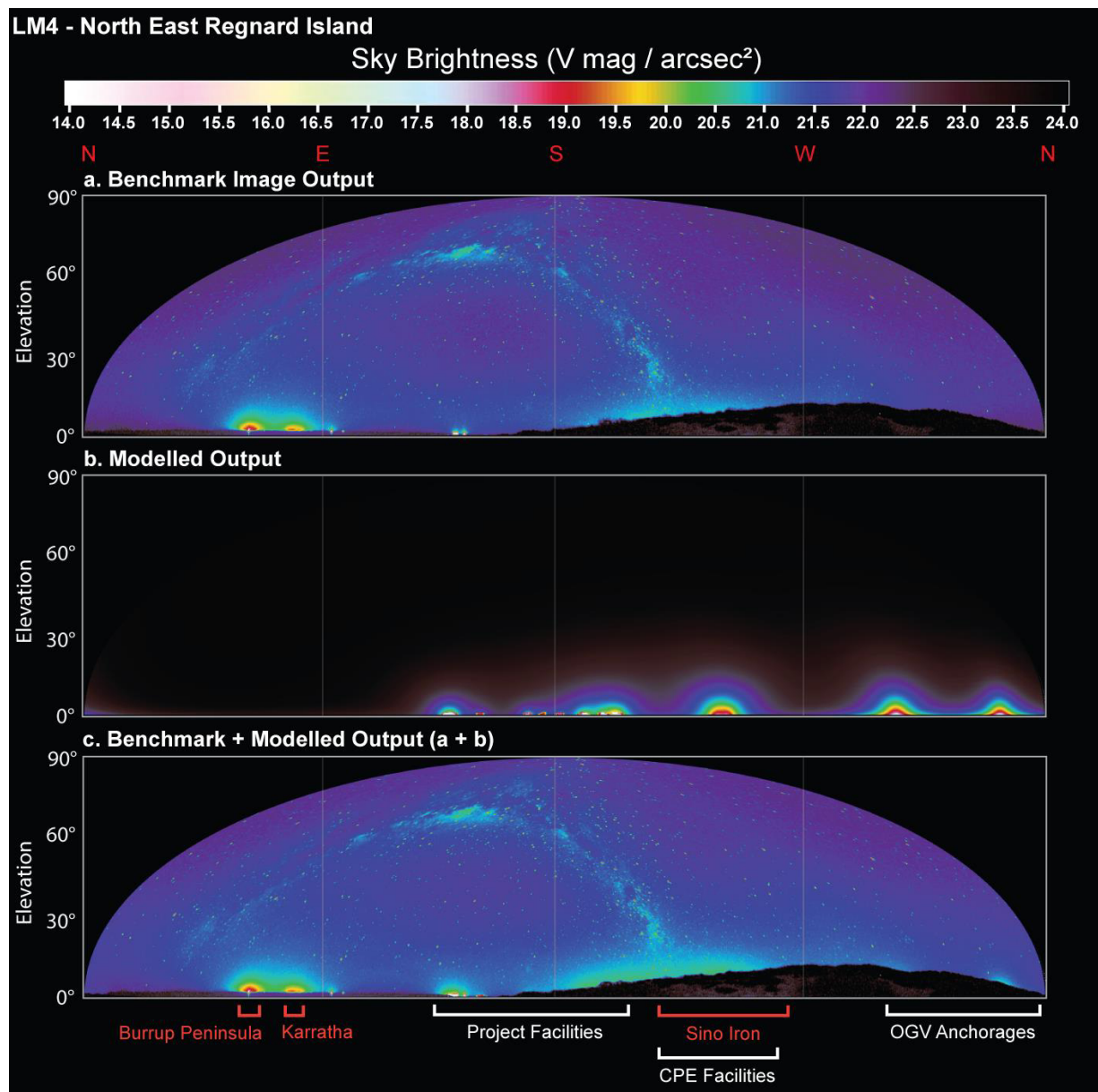


Figure 7: Artificial light modelling results for LM4 (North East Regnard Island): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light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

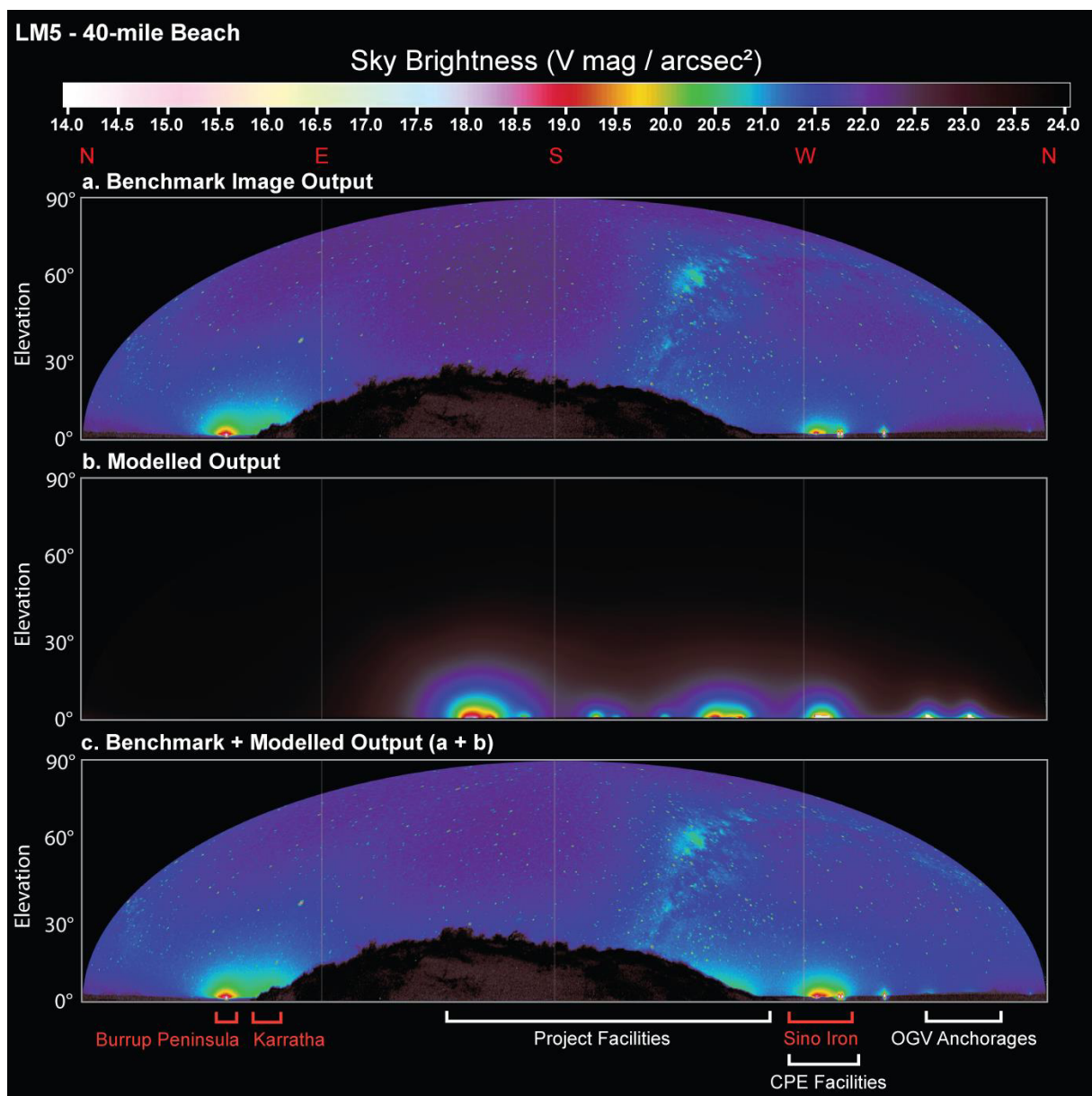


Figure 8: Artificial light modelling results for LM5 (40-Mile Beach): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white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

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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:

- 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.

Appendix B: Marine Turtle Monitoring Reports (Pendoley Environmental 2023, 2024)

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**



DOCUMENT CONTROL INFORMATION

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

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Rev IB	Technical Review	06/04/2023	13/04/2023	Dr K. Pendoley, A. Mitchell
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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.

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LIST OF APPENDICES

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Appendix B: Field Survey Schedule
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Appendix D: Benchmark Artificial Light Monitoring and Modelling Report

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

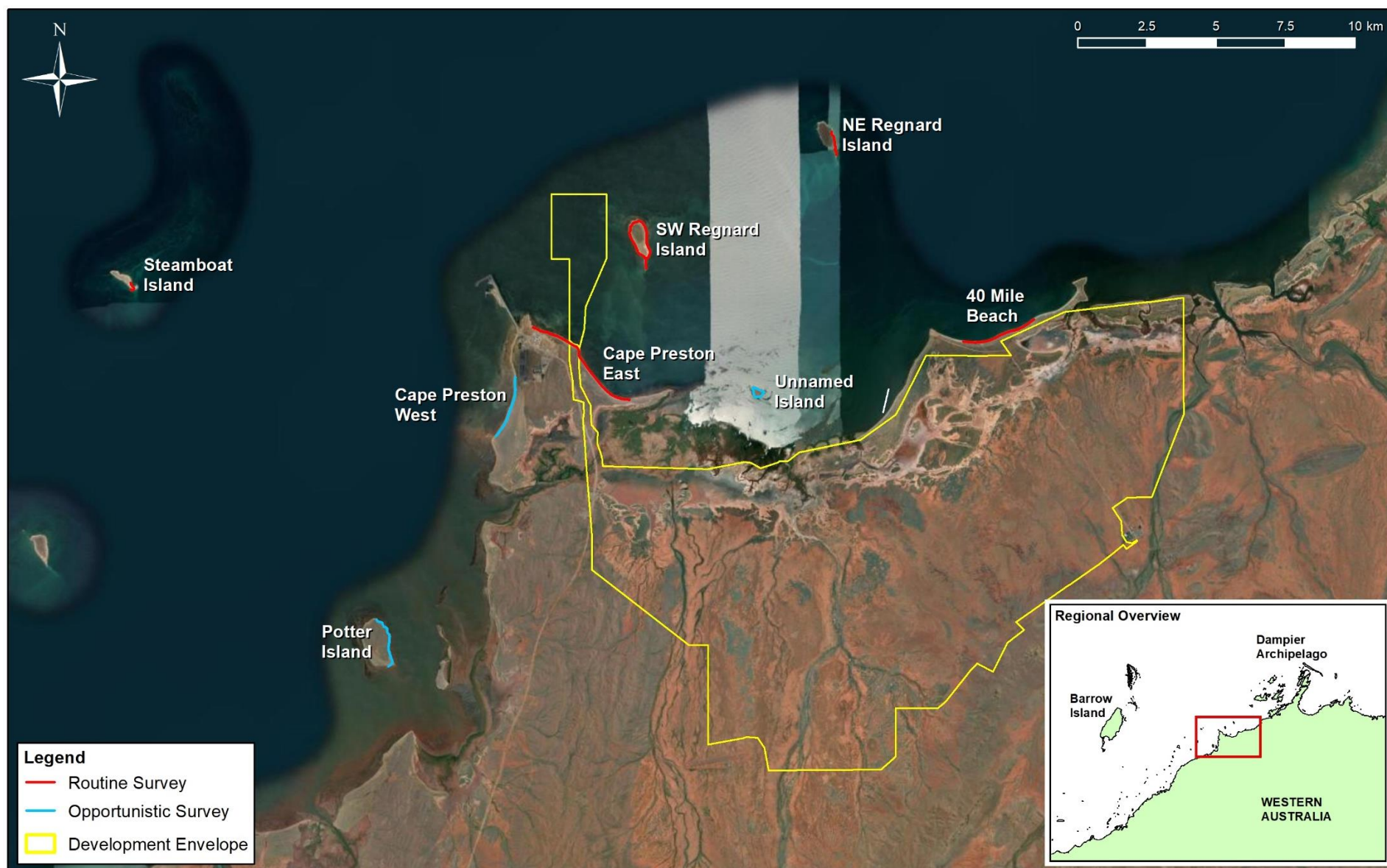
2.1 Survey Location and Schedule

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 cm² per pixel at 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.

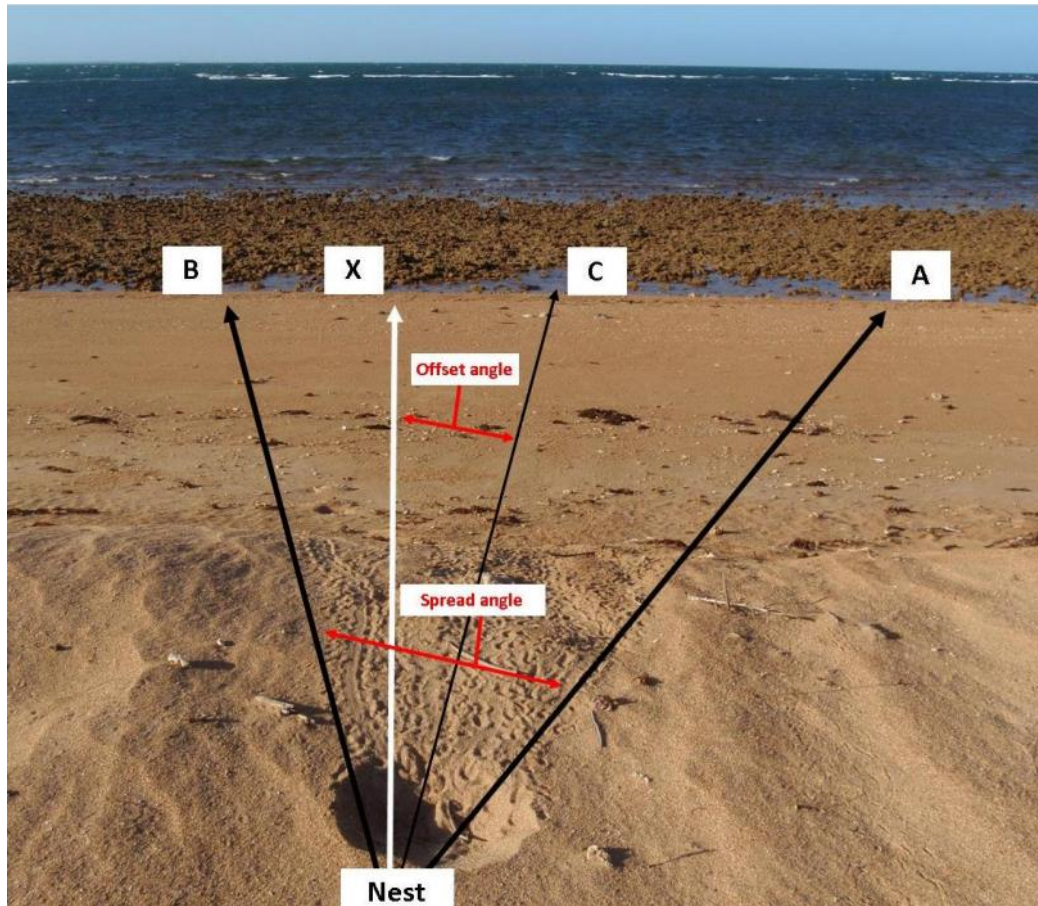


Figure 2: Hatchling orientation measurements describing hatchling spread and offset.

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 ($V_{mag}/arcsec^2$), 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.

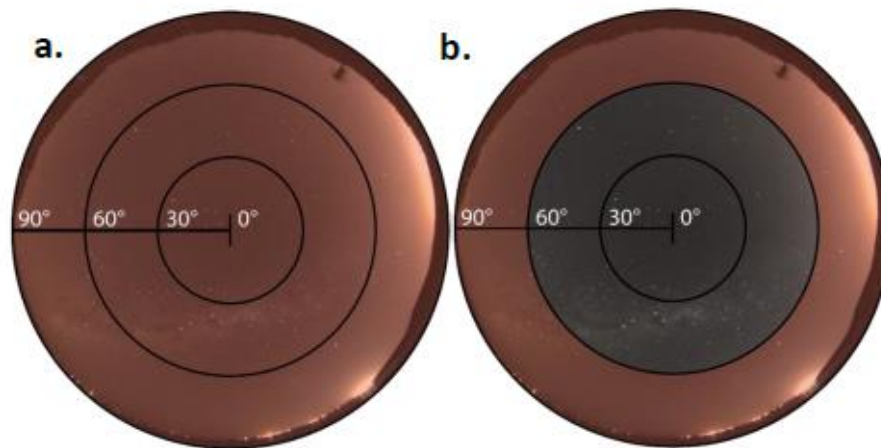


Figure 4: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60 – 90°). Shaded area denotes the region of the sky being measured.

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).

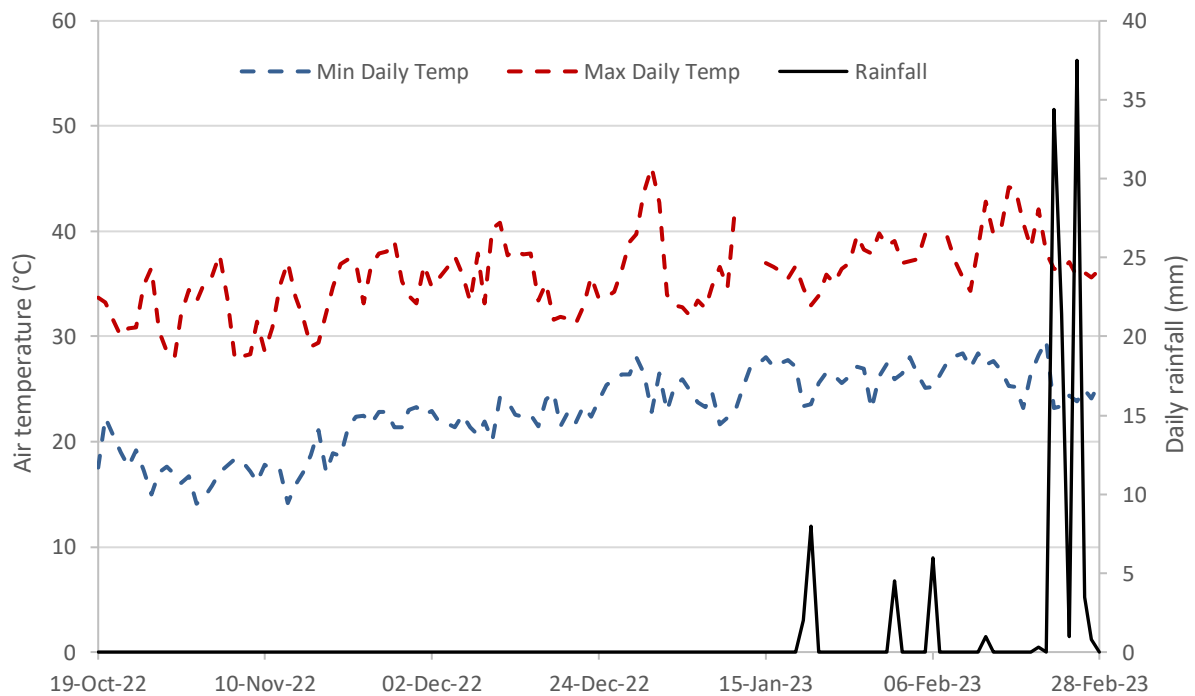


Figure 5: Daily rainfall and air temperature recorded at Mardie, Western Australia, between 19th October 2022 and 28th February 2023. Source: Mardie Station (station 005008), BoM.

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 (Whitlock 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.









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.

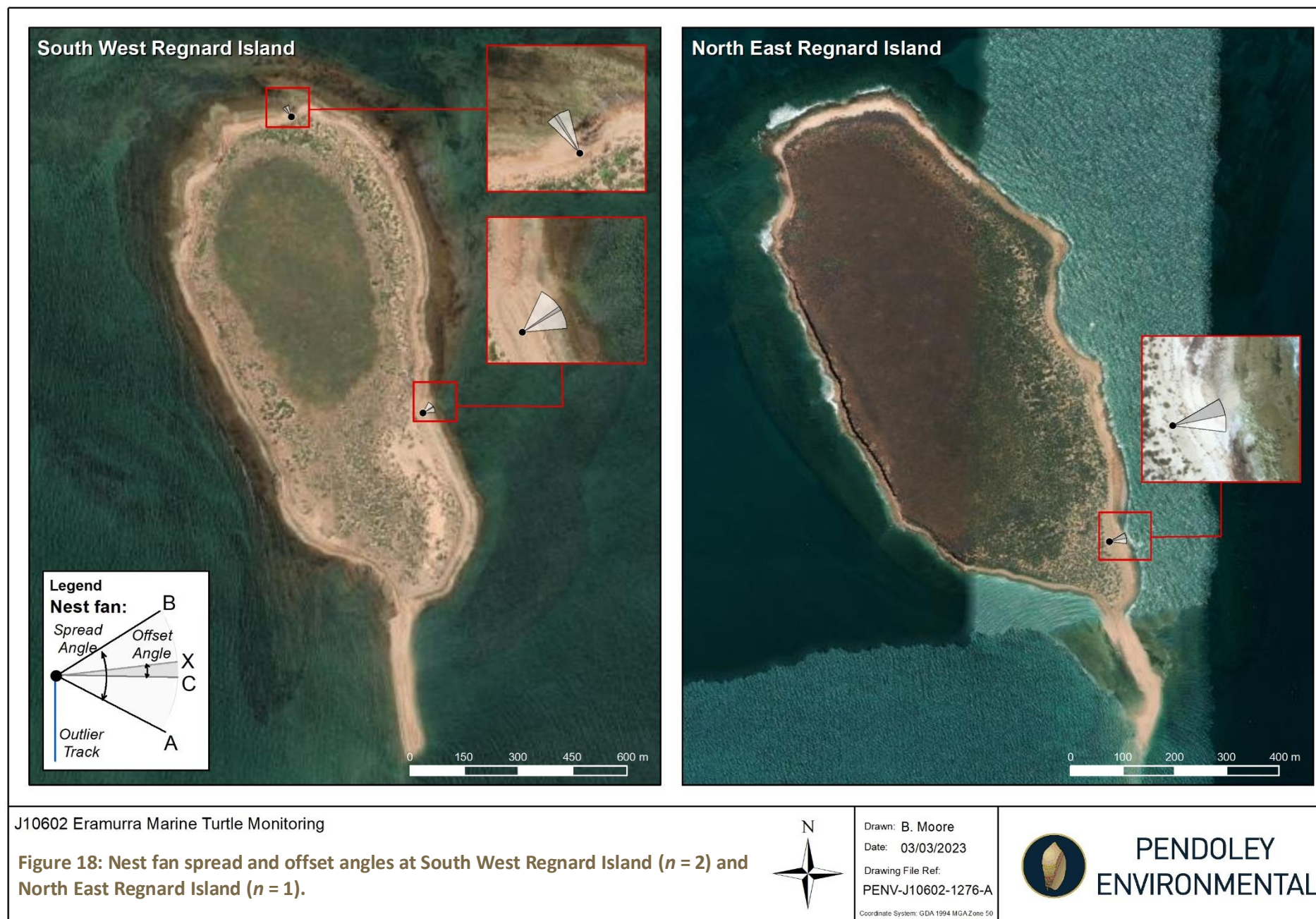
3.4 Hatchling Orientation

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
<i>n</i>		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





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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.

Drawn: B. Moore

Date: 03/03/2023

Drawing File Ref:

J10602-1277-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 from 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

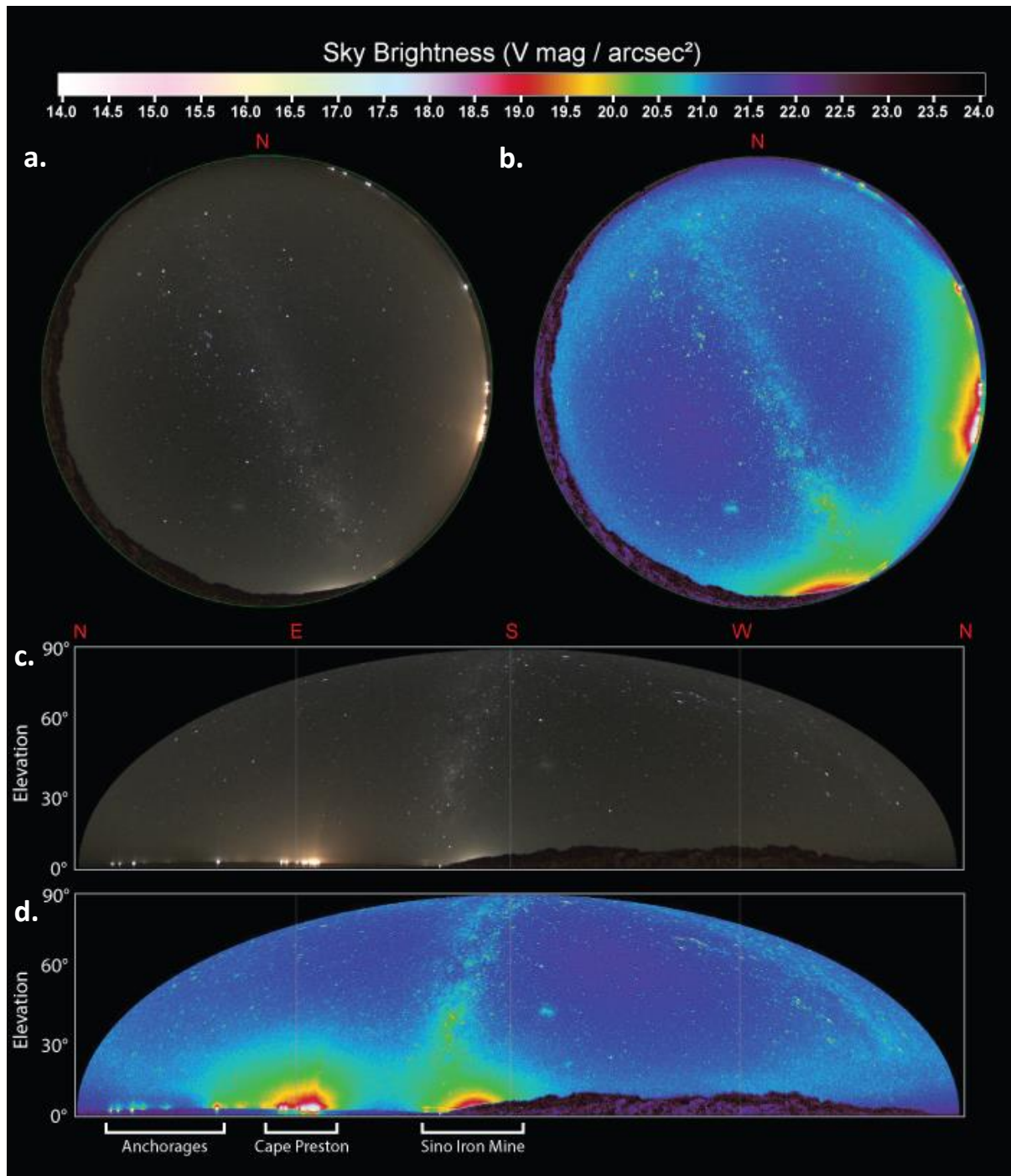


Figure 21: Artificial light monitoring at Steamboat Island on 22nd January 2023. a. Clearest raw circular image; b. Processed circular image; c. Equirectangular raw image; d. Equirectangular processed image.

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)				
	<i>Insignificant</i> 1	<i>Minor</i> 2	<i>Moderate</i> 3	<i>Major</i> 4	<i>Catastrophic</i> 5
<i>Almost certain</i> 5	Medium 5	High 10	High 15	Extreme 20	Extreme 25
<i>Likely</i> 4	Medium 4	Medium 8	High 12	High 16	Extreme 20
<i>Possible</i> 3	Low 3	Medium 6	Medium 9	High 12	High 15
<i>Unlikely</i> 2	Low 2	Low 4	Medium 6	Medium 8	High 10
<i>Rare</i> 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.

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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.

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: 9 th – 14 th Dec 2008 (6 days)	<ul style="list-style-type: none"> Hawksbill nesting activity recorded at SW and NE Regnard Islands. Green track recorded on SW Regnard Island. Flatback nesting activity recorded at FMB. 	<ul style="list-style-type: none"> 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: 12 th – 15 th Nov 2012 (4 days) 11 th Feb (1 day)	<ul style="list-style-type: none"> Mainland beaches provided suitable nesting habitat for egg chamber construction. Estimated a low nesting population of marine turtles on CPE beaches. 	<ul style="list-style-type: none"> 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: 15 th – 18 th Dec 2020 (4 days) 19 th – 22 nd Jan 2021 (4 days) 15 th – 18 th Feb 2021 (4 days) 15 th – 18 th Mar 2021 (4 days) 18 th – 21 st Jan 2022 (4 days)	<ul style="list-style-type: none"> Flatback and green nesting activity recorded on mainland beaches at CPE and FMB. 	<ul style="list-style-type: none"> 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

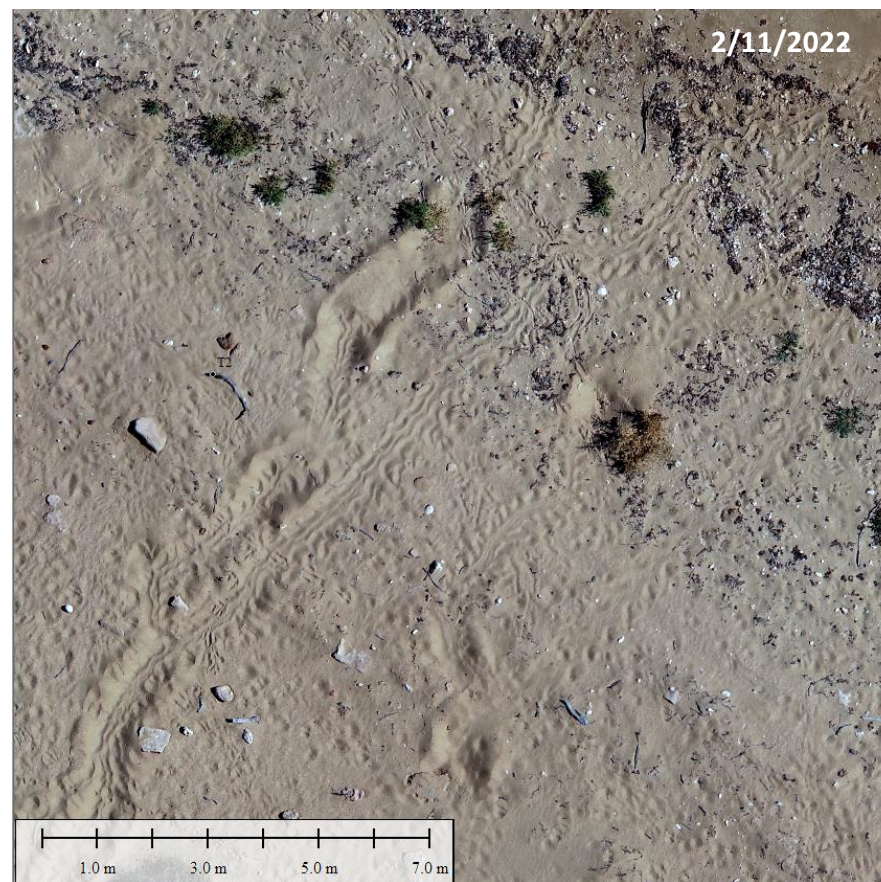
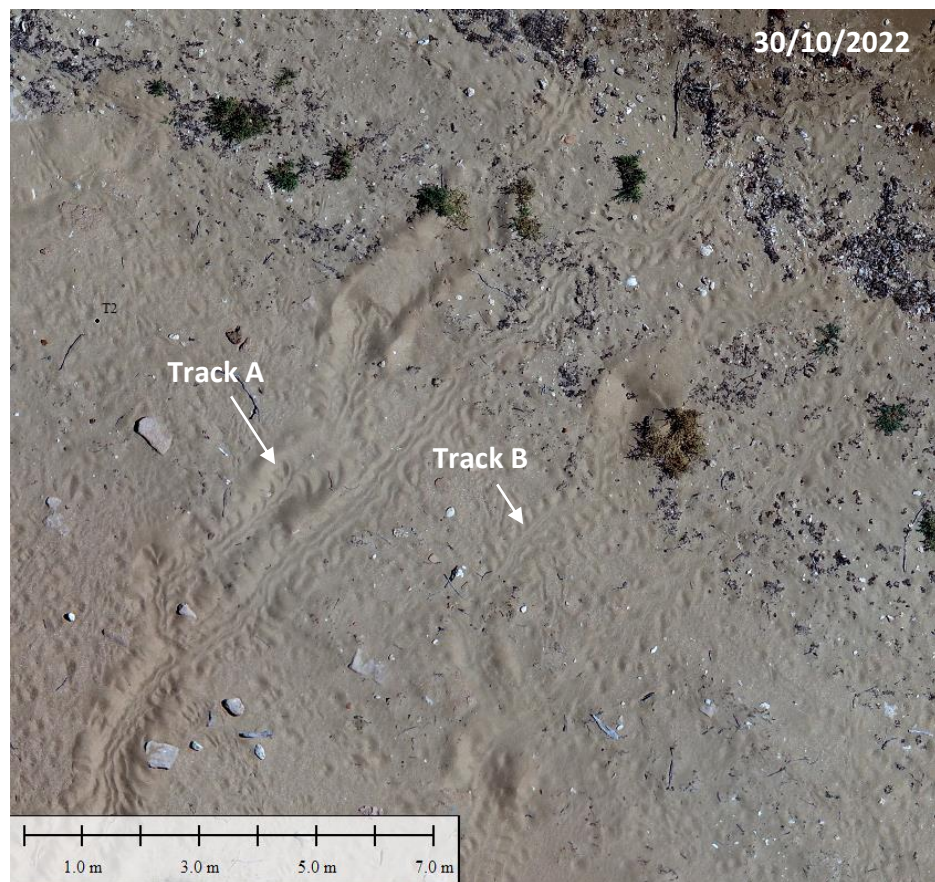


Figure C1: Example of track preservation on Cape Preston East. Track 'A' was made on 30/10/2022, track 'B' was recorded on line-in day on 20/10/2022. Both tracks are visible on the final day of track census on 2/11/2022, with enough features to identify species (hawksbill).



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



DOCUMENT CONTROL INFORMATION

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

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Appendix A: Eramurra Solar Salt Project Lighting Inventory
Appendix B: Relative Contribution of Light Sources

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	Transshipment 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 Transshipment Vessel (TSV), navigation markers, and Ocean-Going Vessels (OGVs), located at anchorages within a designated transshipment 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

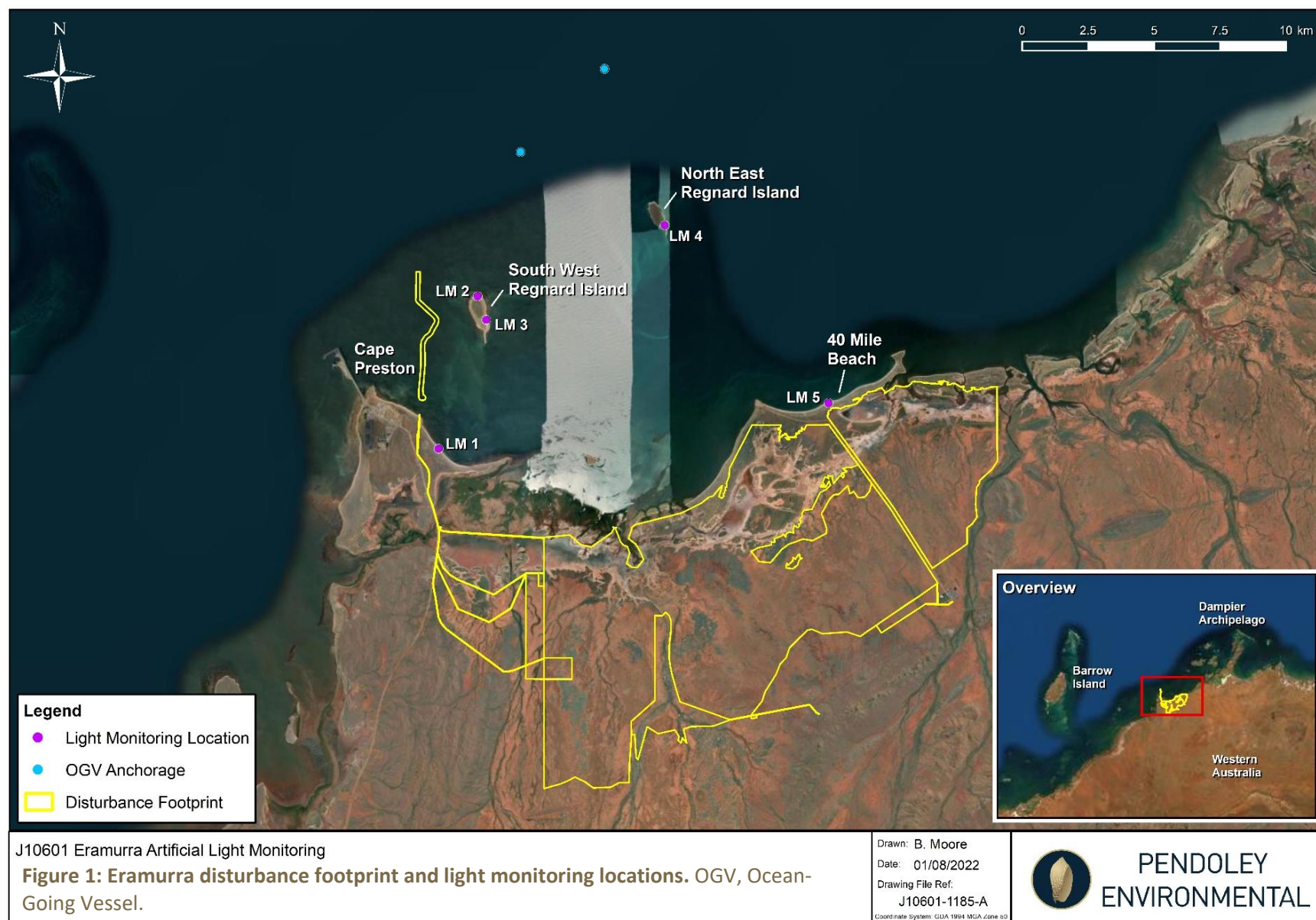
2.1 Light Monitoring

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



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.

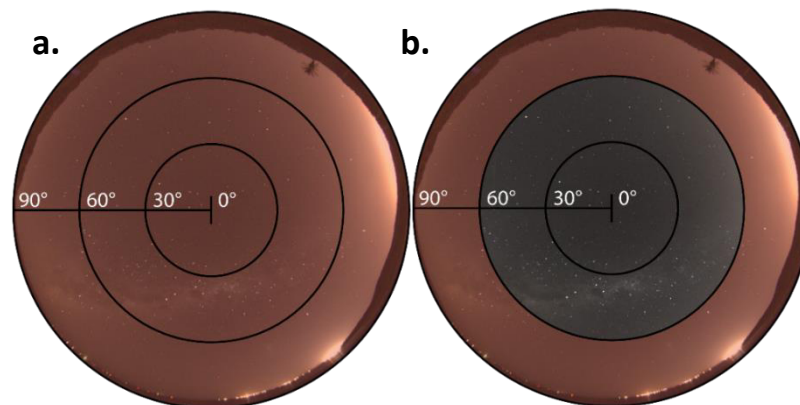


Figure 3: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60 – 90°). Shaded areas denote the region of the sky being measured.

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 ($\text{W/m}^2/\text{sr}$) to units of photometric luminance ($\text{Vmag}/\text{arcsec}^2$). 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 ($V_{\text{mag}}/\text{arcsec}^2$). Note that the scale is inverse logarithmic, brightness increases with decreasing $V_{\text{mag}}/\text{arcsec}^2$ values.

Location	WOS (0 – 90°) ($V_{\text{mag}}/\text{arcsec}^2$)			Horizon (60 – 90°) ($V_{\text{mag}}/\text{arcsec}^2$)		
	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%).

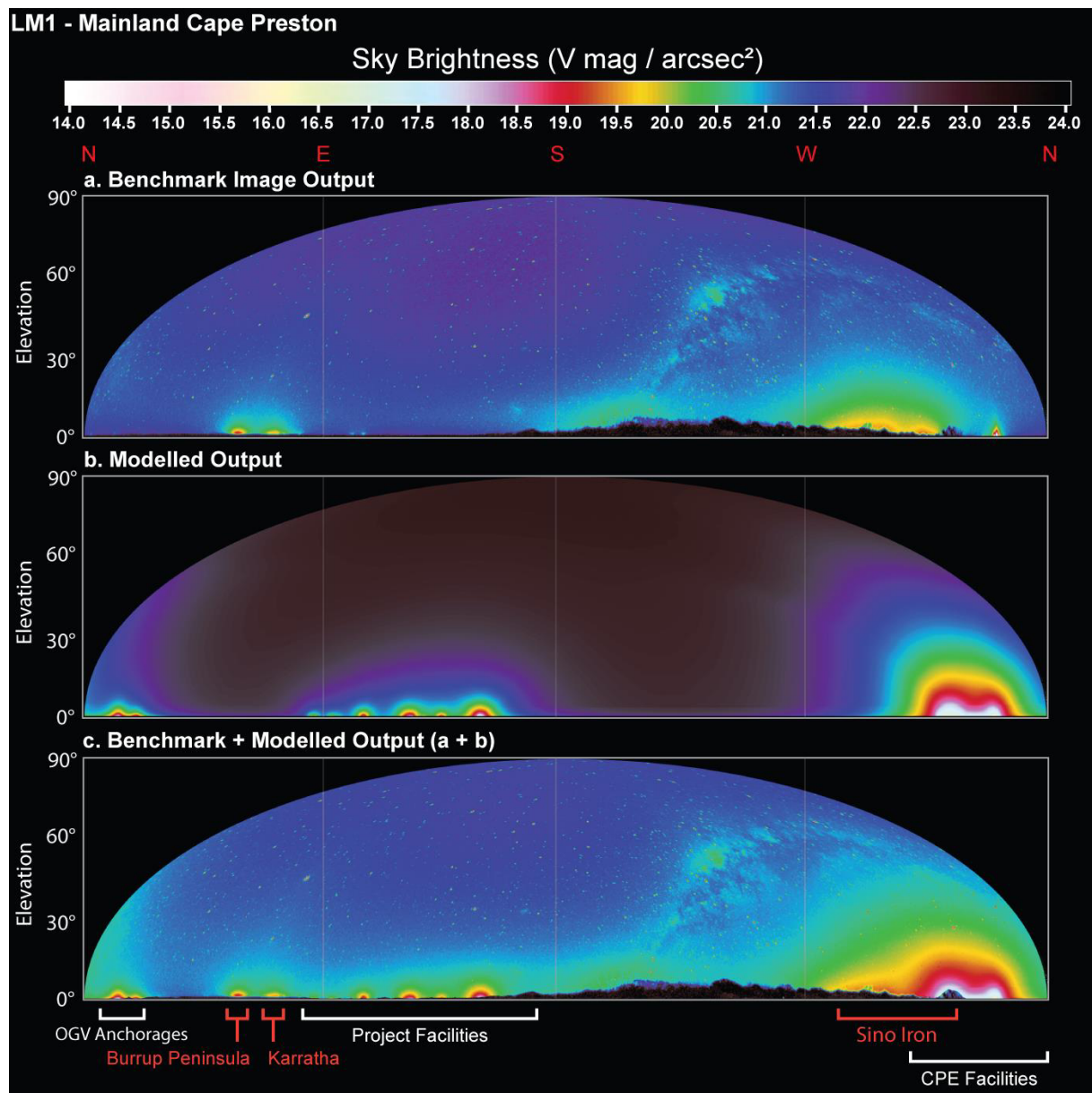


Figure 4: Artificial light modelling results for LM1 (mainland Cape Preston): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources,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

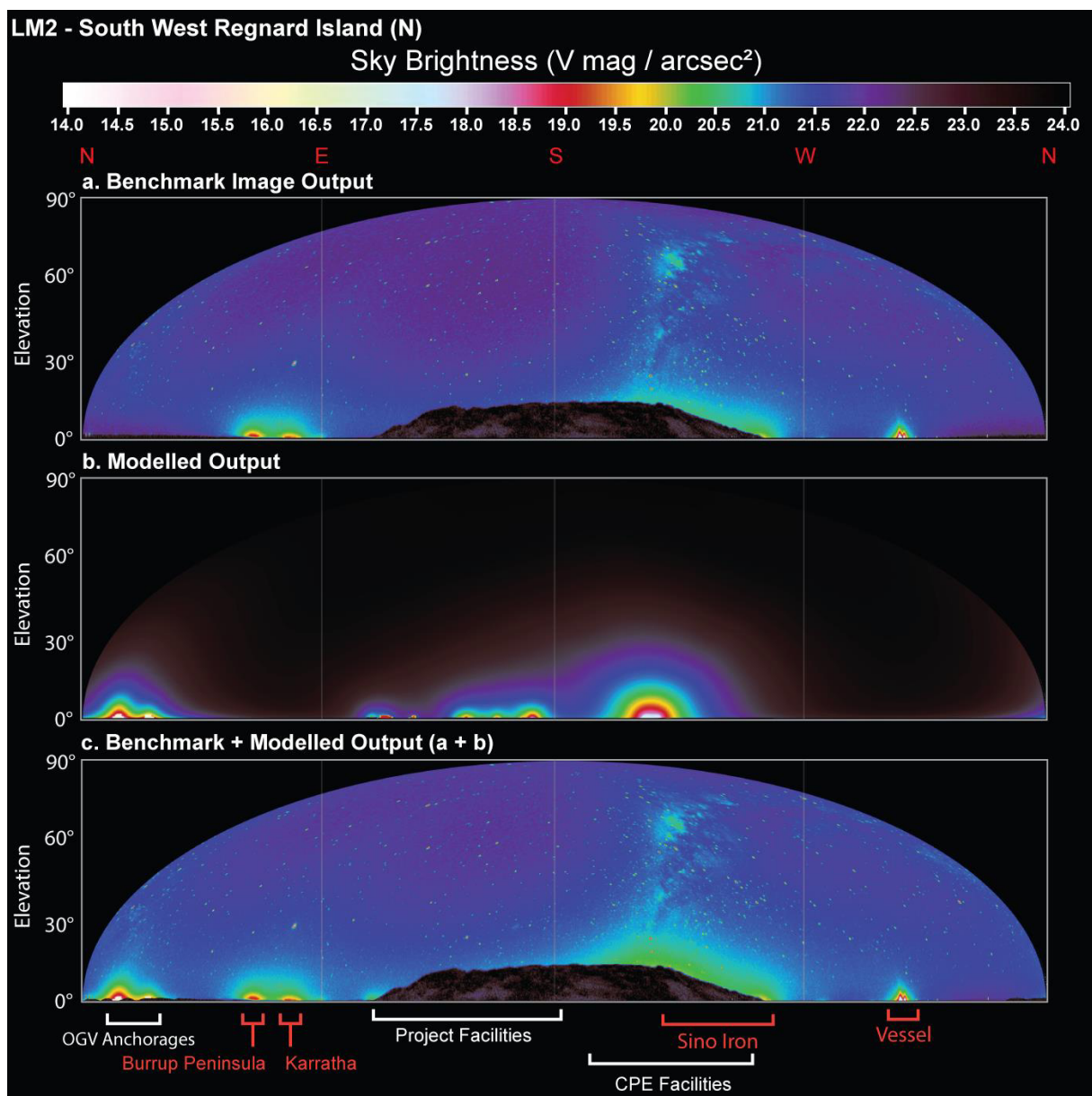


Figure 5: Artificial light modelling results for LM2 (South West Regnard Island [N]): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing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

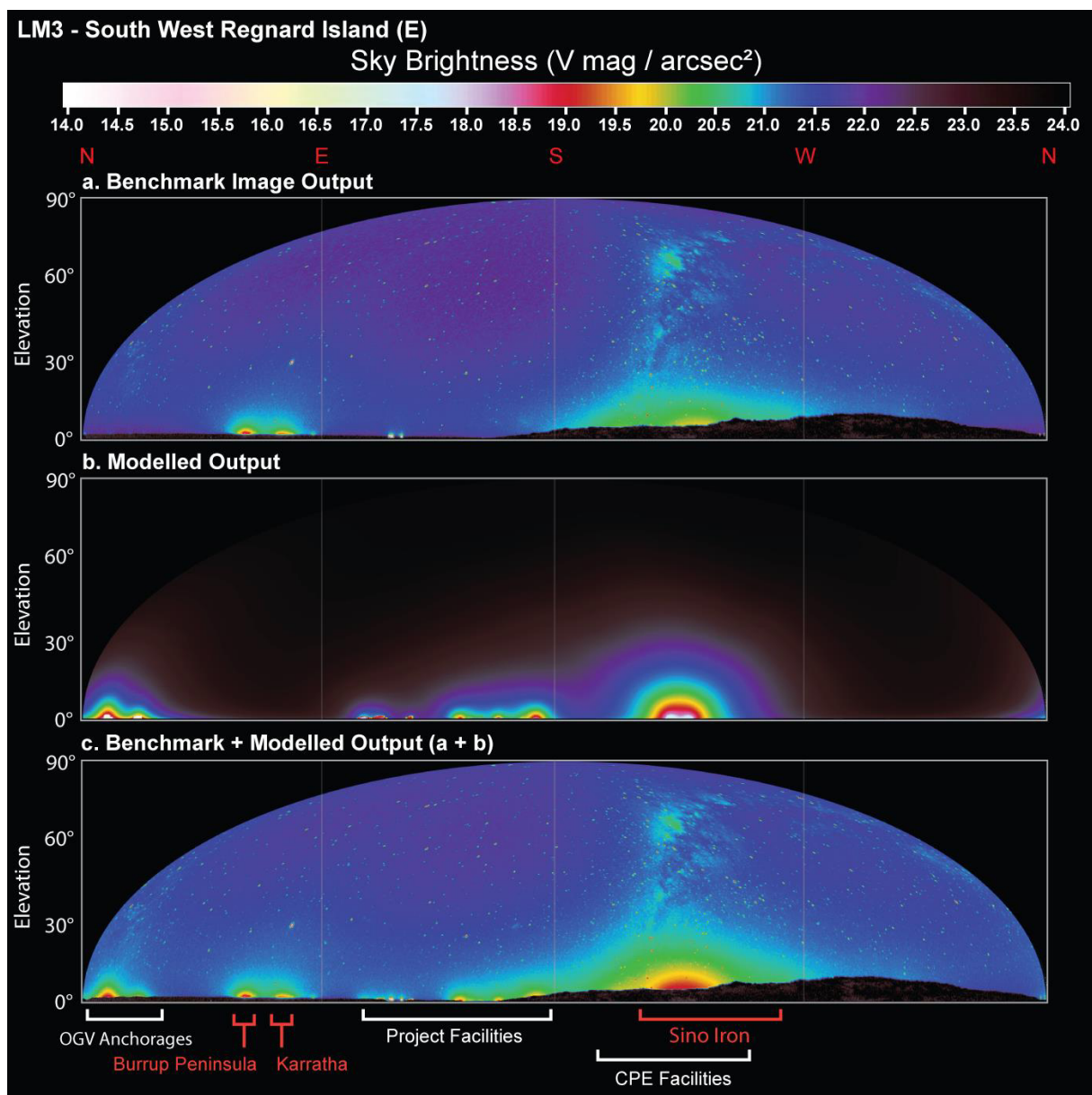


Figure 6: Artificial light modelling results for LM3 (South West Regnard Island [E]): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing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

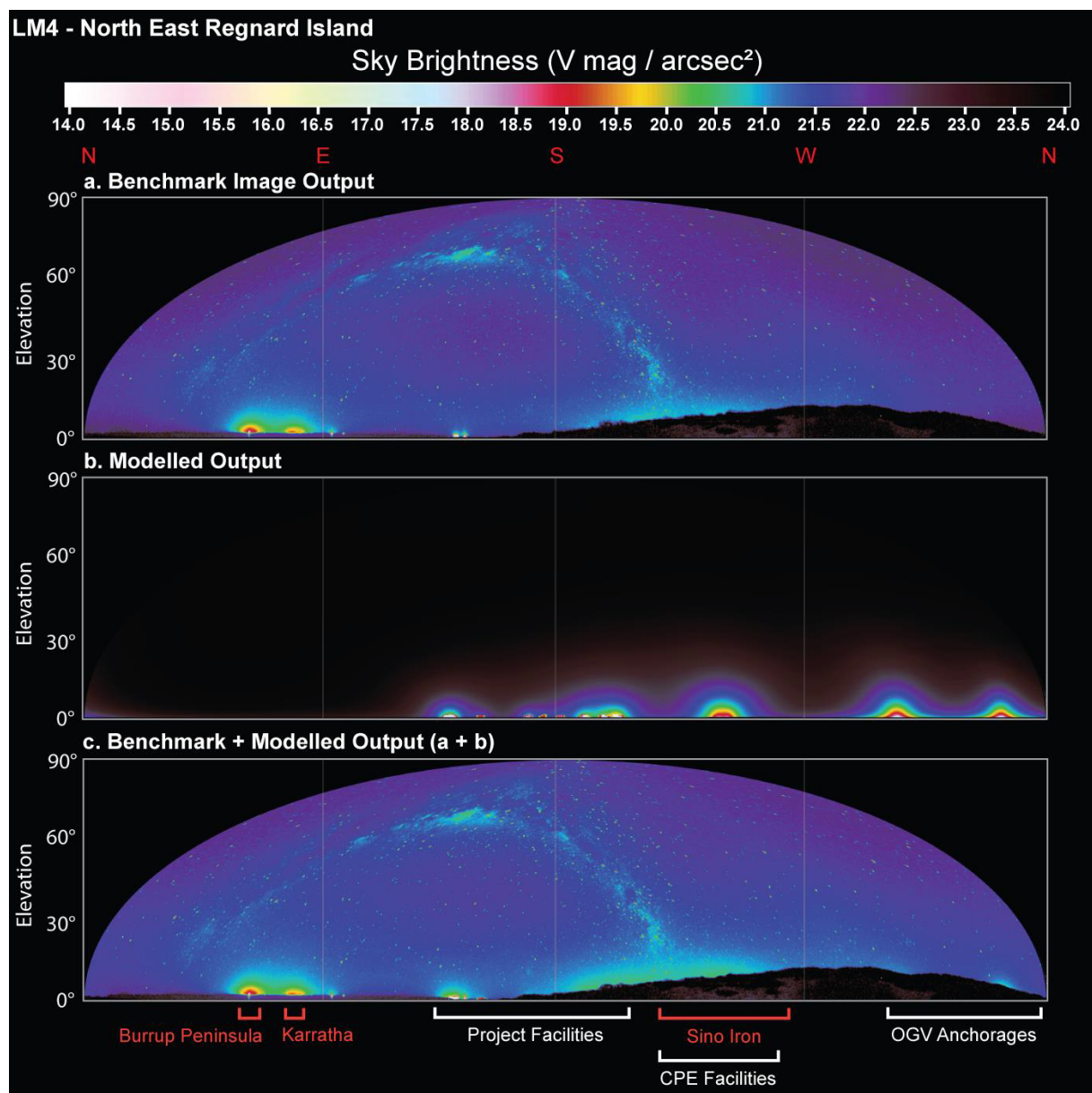


Figure 7: Artificial light modelling results for LM4 (North East Regnard Island): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light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

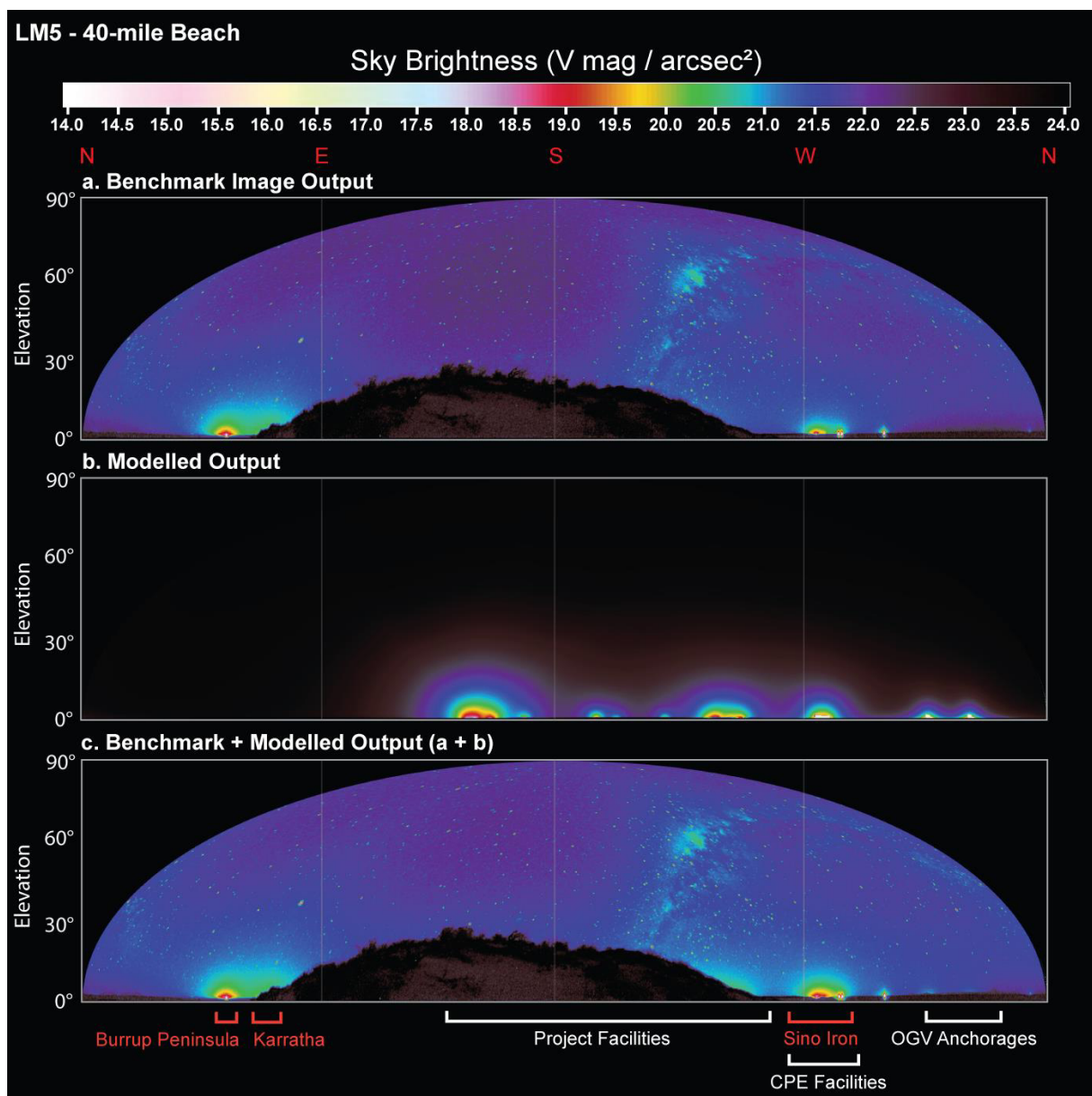


Figure 8: Artificial light modelling results for LM5 (40-Mile Beach): a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness based on light design provided by Leichhardt; c. Benchmark monitoring image + modelled brightness. Red labels = existing light sources, white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

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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

LEICHHARDT SALT PTY LTD

**ERAMURRA SOLAR SALT PROJECT: MARINE TURTLE
MONITORING 2023/24**



Prepared by

Pendoley Environmental Pty Ltd

For

Leichhardt Salt Pty Ltd

29 May 2024



**PENDOLEY
ENVIRONMENTAL**



DOCUMENT CONTROL INFORMATION

TITLE: ERAMURRA SOLAR SALT PROJECT: MARINE TURTLE MONITORING 2023/24

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Cover photo:	Hawksbill turtle nest, Steamboat Island

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 a second consecutive season of 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 conducted this season was then used to update and consolidate the light spill risk assessment conducted in 2022/23, 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 2023 (Field Survey 1; FS1), January 2024 (Field Survey 2; FS2), and February 2024 (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 two opportunistic monitoring locations. The routine monitoring locations included North East (NE) Regnard Island, South West (SW) Regnard Island, Steamboat Island, and Cape Preston East (CPE) beach. The opportunistic monitoring locations included Cape Preston West and Forty Mile Beach. A total of 45 survey days were undertaken for the 2023/24 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 the south-east side of Steamboat Island. Overall nesting success (the number of successful nests as a percentage of the total number of overnight tracks) was high for hawksbill turtles in FS1 at 36.2 %, meaning the majority of hawksbill tracks represented unsuccessful nesting attempts (47 %) or false crawls (17 %). 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 10 nest fans were recorded over the January and February surveys, with 5 (50 %) occurring on Steamboat Island. The remaining fans occurred on SW Regnard Island ($n = 2$), NE Regnard Island ($n = 1$), and CPE ($n = 2$). Hatchling species included hawksbill ($n = 4$), flatback ($n = 1$), and unknown ($n = 5$). Positive identification of hatchling species was determined from track characteristics and the presence of dead

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 CPE. At Steamboat Island, several nest fans occurred on a sand 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.

A risk assessment was undertaken using a standard risk assessment matrix, with modified definitions for consequence and likelihood ratings relevant to hatchling turtles, the regional nesting population, and the nesting success of breeding activities. The risk assessment applied to SW Regnard Island, NE Regnard Island, Steamboat Island, CPE, 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 at nearly all locations 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, Steamboat Island, and FMB to be 'Low'. At CPE, 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 meet the Best Practice Lighting Design Principles outlined in the NLPGW. Principles such as reducing the Correlated Colour Temperature 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 social surroundings, including dark sky conservation values.

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Appendix A: Field Survey Schedule
Appendix B: Track Preservation

ACRONYMS

BoM	Bureau of Meteorology
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
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

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 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 may 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 2023), to understand the species abundance and distribution of nesting marine turtles and hatchling turtle behaviour across two breeding seasons.

PENV therefore undertook monitoring surveys at known turtle nesting habitat in the vicinity of the Project during the 2022/23 breeding season (PENV 2023). The outcomes determined the species abundance and distribution of adult turtles during their respective peak nesting period for the region, including for hawksbill (*Eretmochelys imbricata*; October to November), flatback (*Natator depressus*; December to January), and green (*Chelonia mydas*; December to January) turtles (Commonwealth of Australia 2017). Furthermore, surveys were conducted during new moon conditions to capture data on the behaviour of hatchling turtles when orienting on the beach.

1.3 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 for a second consecutive breeding season. Marine turtle surveys were undertaken

over the 2023/24 austral summer, and were designed to record information on hawksbill, flatback (*Natator depressus*), and green (*Chelonia mydas*) turtles in line with the monitoring recommendations of the NLPGW (Commonwealth of Australia 2023).

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.

Where possible, monitoring data recorded this season (2023/24) will be presented in context with the results of the 2022/23 season.

2 METHODS

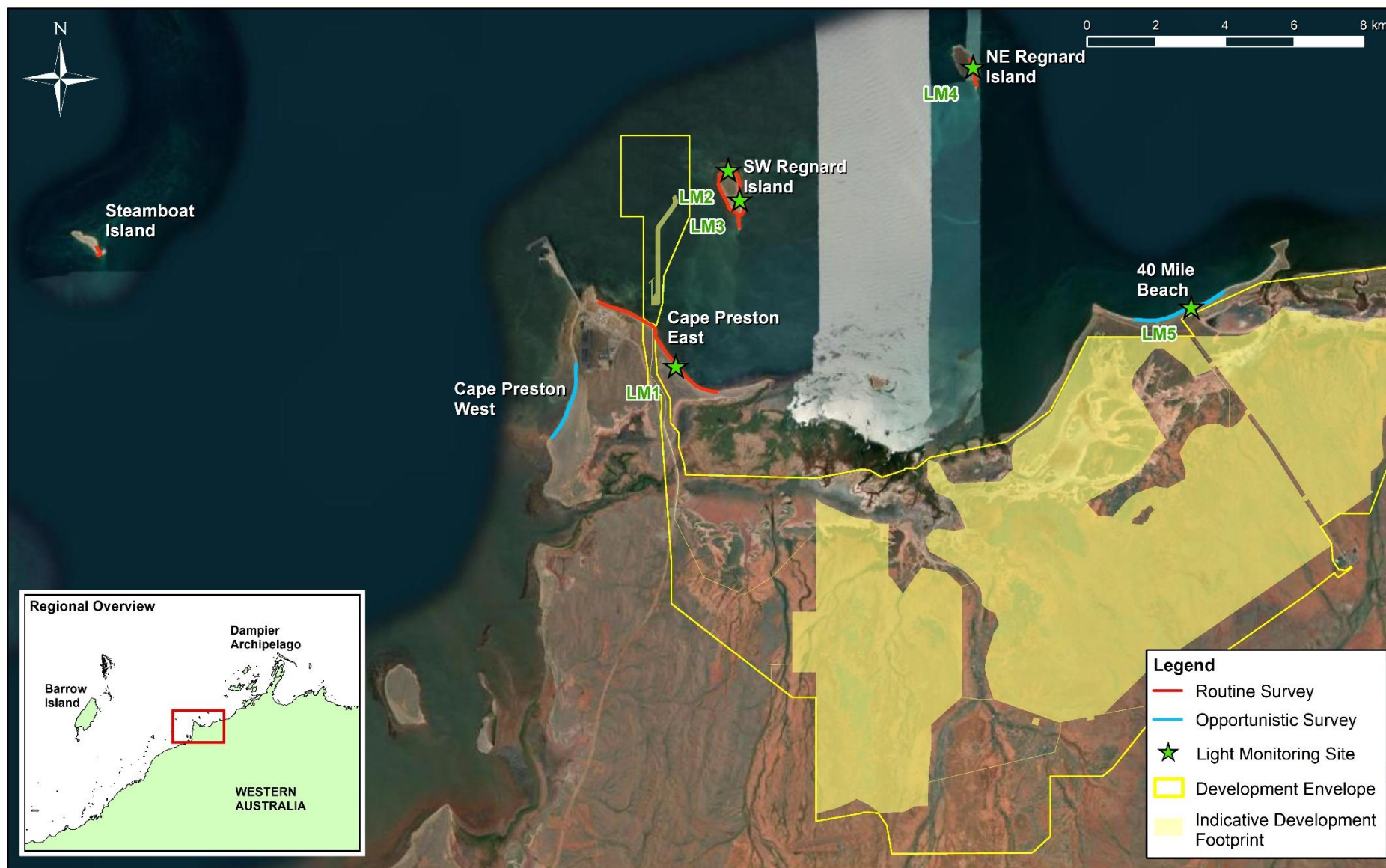
2.1 Survey Location and Schedule

Marine turtle nesting and hatching surveys were conducted at islands and along the mainland coast in the vicinity of the Project over the 2023/24 marine turtle nesting season (**Figure 1**). Three field surveys were undertaken over October 2023 – February 2024, including:

- **Field Survey 1 (FS1; 14th – 27th October 2023):** Targeted the peak of the hawksbill turtle nesting season over one 14-day inter-nesting period (**Section 2.3**).
- **Field Survey 2 (FS2; 4th – 19th January 2024):** Targeted the peak of the green and flatback turtle nesting season over one 14-day inter-nesting period and peak hawksbill hatching season (**Section 2.4**).
- **Field Survey 3 (FS3; 5th – 19th February 2024):** Targeted the peak of green and flatback hatching season over one 14-day period (**Section 2.5**).

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**.



J106003 Eramurra Marine Turtle Monitoring

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

Drawn: P. Whittock

Date: 23/05/2024

Drawing File Ref:

PENV-J106003-1449-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 marine turtle nesting activity 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 marine turtle nesting activity and hatchling orientation (all species). 11 km from proposed pump station flood lighting (closest point).
Cape Preston East (CPE) Beaches (north and south)	Routine monitoring location (all surveys). Data deficient for marine turtle nesting activity and hatchling orientation (all species). Adjacent to proposed CPE port infrastructure and stockpile.
Steamboat Island	Routine monitoring location (all surveys). Data deficient for marine turtle nesting activity and hatchling orientation (all species). 15 km from proposed port infrastructure and salt stockpile.
Cape Preston West (CPW) Beach	Opportunistic monitoring location (FS1 and FS2). Data deficient for marine turtle nesting activity. 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.
Forty Mile Beach (FMB; Gnoorea)	Opportunistic monitoring location (FS1 and FS2). Data deficient for marine turtle nesting activity 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 A**.

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	✓	✓	✓	-	✓	✓
CPE (North and South)	✓	✓	✓	-	✓	✓
FMB	✓*	✓*	-	-	-	-
CPW	✓*	✓*	-	-	-	-

2.3 Field Survey 1

Field Survey 1 (FS1) was conducted between 14th and 27th October 2023, 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 Bhagwan Marine.

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, Steamboat Island, and CPE for each day of FS1 (**Appendix A**). 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 CPW and FMB.

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 cm² per pixel and 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 turtle biologist using track and nest characteristics, including track width, shape and orientation of flipper marks, tail drag marks, and displaced sand.

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 between the 4th and 19th January 2024, 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: 11th January 2024; Commonwealth of Australia 2023).

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 were recorded on a field tablet for each adult turtle 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 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 A** 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. An example of the preservation of adult tracks on CPE is provided in **Appendix B**. 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.

Opportunistic monitoring beaches (CPW and FMB) were surveyed by UAV in a single snapshot survey at each location. This is because no hawksbill nesting activity was detected at these beaches during the October survey (**Section 3.3**) or in 2022/23 (PENV 2023), and there is no historical data available indicating hawksbills use these beaches for nesting (PENV 2009; O2 Marine 2022). Therefore, it was considered unlikely that hawksbill hatchling fans would be encountered on this beach in January. 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/or 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.

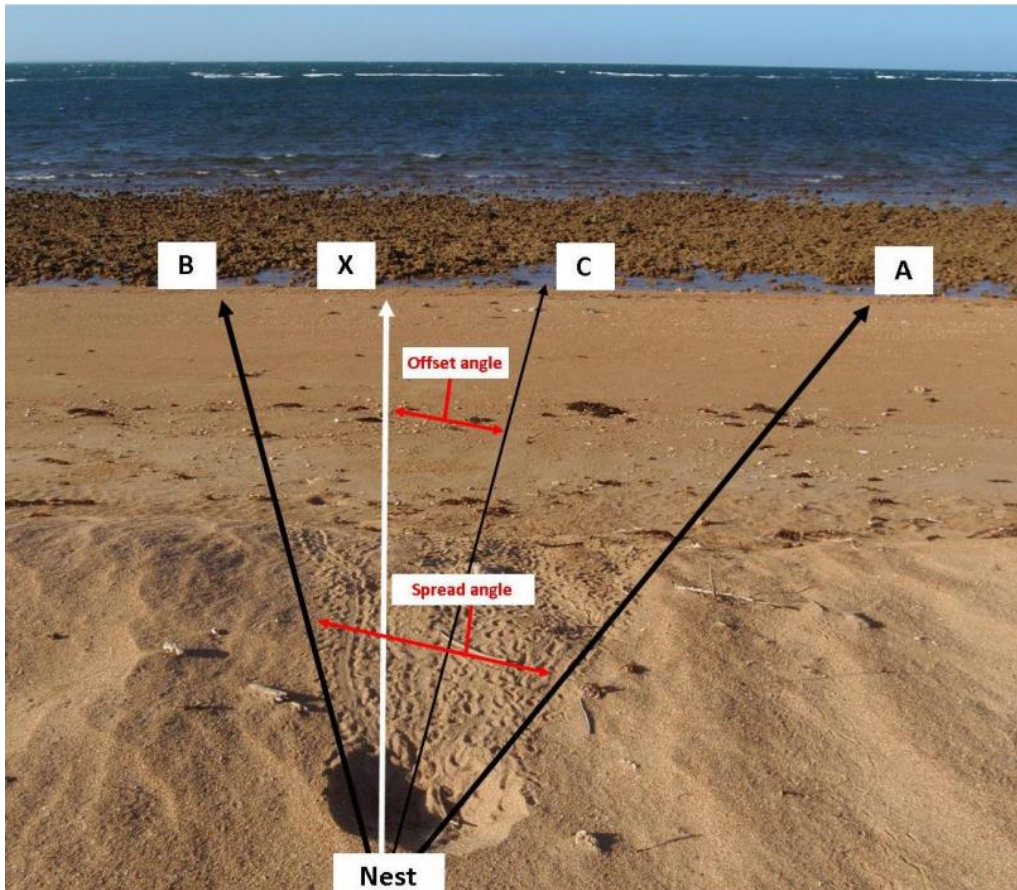


Figure 2: Hatchling orientation measurements describing hatchling spread and offset.

2.5 Field Survey 3

Field Survey 3 (FS3) was conducted between the 5th and 19th February 2024, 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: 10th February 2024; Commonwealth of Australia 2023). 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 A**) for the reasons outlined in **Section 2.4.2**. 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 FS3 in February as it was outside the reported peak nesting period for all species i.e. CPW and FMB were not monitored.

3 RESULTS

3.1 Field Conditions

All three field surveys were completed as planned over the scheduled dates (**Section 2.1** and **Appendix A**).

With the exception of some days in FS2, field conditions were generally suitable 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 3**. Maximum daily temperatures for the period ranged from 29.1 – 48.2 °C. There was very low rainfall recorded across the period, with two events recording a total rainfall of 6.2 mm.

FS2 was impacted by strong winds which limited the vessel use on certain days. This included the 15th January 2024 when only NE Regnard and SW Regnard were accessed (wind speed was 17 km/hr gusting to 50 km/hr), and on 17th January 2024 when wind gusts exceeded 50 km/hr and no islands were accessed (NE Regnard, SW Regnard, or Steamboat) (**Appendix A**). All other survey days, including those conducted at the mainland, were executed as planned.

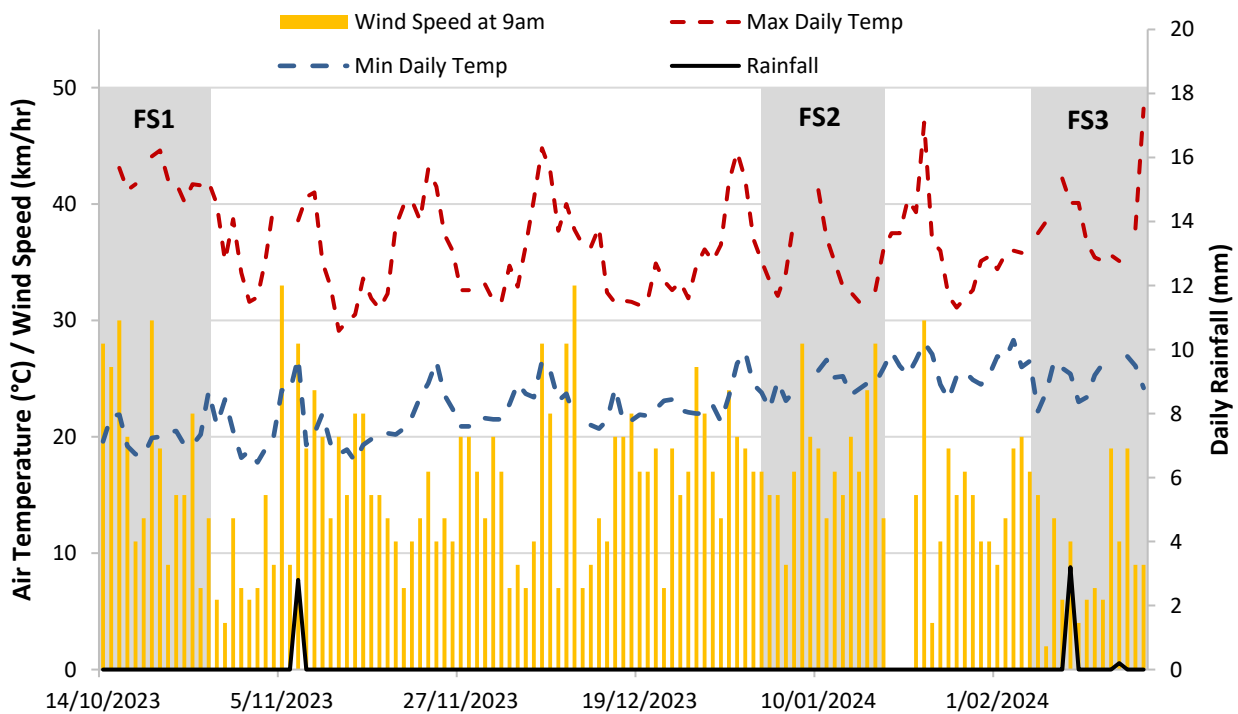


Figure 3: Daily rainfall, air temperature, and wind speed recorded at Mardie, Western Australia, between 14th October 2023 and 19th February 2024. Source: Mardie Station (station 005008), BoM. Grey shading indicates period of each field survey. Wind speed is taken as the measurement recorded at 9:00 am.

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 4a**). 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 4b**).

The conditions at CPE were excellent for adult track preservation, with tracks persisting for weeks to months on this beach.

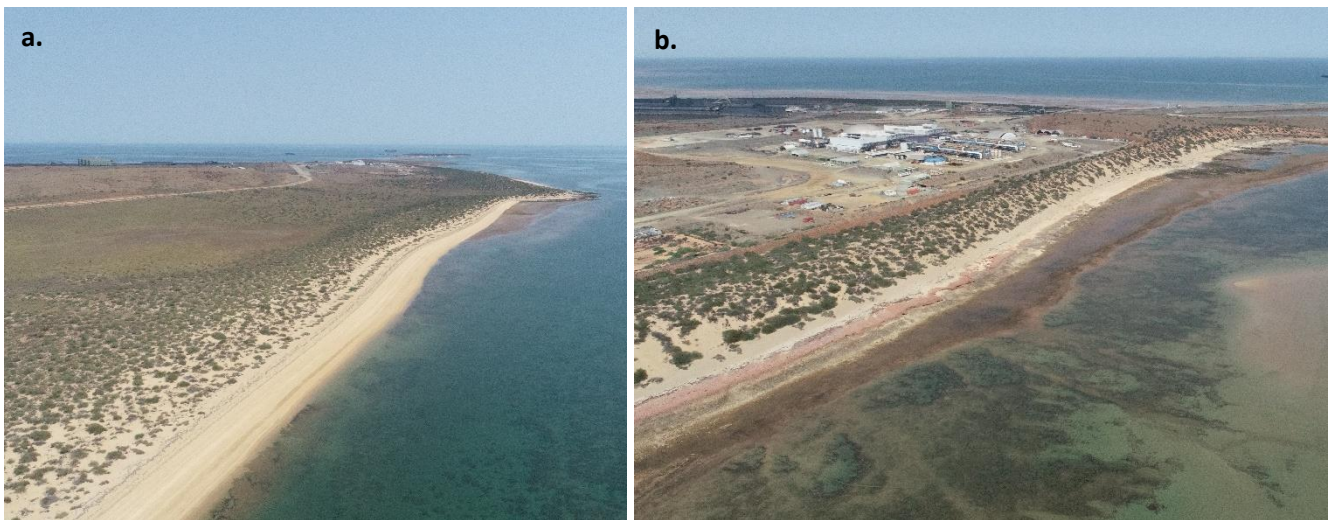


Figure 4: Cape Preston East Beaches: a. South; b. North

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. 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. No evidence of predation of any nests was recorded during FS2 in January or FS3 in February. On 13th January 2024, eggs that had been discharged by a hawksbill turtle on the surface of the sand were observed at the northern end of the island (**Figure 5**). The eggs were situated along the returning 'down' track of the adult turtle and were below the recent high tide line. This occurrence may be due to repeat failed nesting attempts and unsuitable nesting conditions for the construction of an egg chamber in the sand, potentially caused by presence of large rocks and/or shallow bedrock in this area.



Figure 5: Hawksbill turtle eggs discharged on the surface of the beach at the northern end of South West Regnard Island.

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.

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. No evidence of predation of turtle eggs or hatchlings was recorded on the island.

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 6**). 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 FS2 and FS3.

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 less than one week. Due to excessive wind conditions in FS2, there was a period of four days where the field team was unable to access the island and any tracks were erased prior to detection, as confirmed by field observations (i.e. tracks recorded four days prior were no longer visible) (see **Appendix A**).



Figure 6: 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 7**). 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 7: 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. 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.

3.3 Track Census

3.3.1 Routine Survey

FS1 recorded 47 overnight hawksbill tracks, including 8 false crawls, 22 attempts, and 17 nests (**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 36.2 % which was higher compared to 2022/23 (14.7 %). One track (false crawl) from an unknown species was also recorded during the October survey on NE Regnard. No tracks from other marine turtle species were recorded.

FS2 recorded 11 overnight hawksbill tracks, including eight attempts and three false crawls, resulting in a 0 % nesting success rate which was lower compared to 2022/23 (0 %) (**Table 4**). Flatback tracks totalled six, including three nests, one attempt, and two false crawls, resulting in a nesting success rate of 16.7 % which was lower compared to 2022/23 (28.5 %). Three green tracks were also recorded, consisting of two nests and one false crawl, making nesting success 66.7 % for this species.

FS3 recorded 12 overnight hawksbill tracks, including one nest, eight attempts, and three false crawls, resulting in a nesting success rate of 8.3 %. One flatback turtle nest was also recorded, with no other tracks, making nesting success 100 % for this species (**Table 4**).

The species and nesting activity distributions at routine monitoring beaches (including Steamboat Island) are displayed in **Figures 8 – 11** 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 2023/24 nesting season.
N = Nest; A = Attempt; FC = False Crawl. Numbers in **red** are from tracks recorded on the line-in day where the age of the track could not be determined.

Location	Hawksbill			Flatback			Green			Unknown		
	N	A	FC	N	A	FC	N	A	FC	N	A	FC
Field Survey 1												
SW Regnard	5 (0)	8 (8)	1 (1)	-	-	-	-	-	-	- (1)	- (1)	- (1)
NE Regnard	- (2)	- (1)	-	-	-	-	-	-	-	-	- (1)	1 (-)
Steamboat	11 (9)	13 (10)	7 (3)	-	-	-	-	-	-	-	-	-
CPE	1 (1)	1 (0)	-	-	-	-	-	-	-	- (3)	-	-
Total	17 (12)	22 (19)	8 (4)	-	-	-	-	-	-	0 (4)	0 (2)	1 (1)
Field Survey 2												
SW Regnard	- (1)	5 (17)	1 (2)	- (1)	- (1)	- (1)	-	-	-	-	- (1)	- (1)
NE Regnard	- (1)	- (1)	-	-	-	-	-	-	-	- (1)	-	-
Steamboat	- (2)	3 (3)	2 (-)	2 (-)	1 (-)	2 (-)	2 (1)	- (1)	1 (-)	-	- (1)	- (1)
CPE	- (1)	- (2)	-	1 (-)	-	-	- (1)	-	-	- (1)	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	- (5)	8 (23)	3 (2)	3 (1)	1 (1)	2 (1)	2 (2)	- (1)	1 (-)	- (2)	- (2)	- (2)
Field Survey 3												
SW Regnard	1 (-)	- (1)	-	-	-	-	-	-	-	-	-	-
NE Regnard	-	-	-	-	-	-	-	-	-	-	-	-
Steamboat	-	8 (3)	3 (1)	1 (3)	- (3)	-	-	-	-	-	- (1)	-
CPE	-	- (1)	-	-	-	-	-	-	-	-	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	1 (-)	8 (12)	3 (1)	1 (3)	- (3)	-	-	-	-	-	- (1)	-

3.3.1.1 Comparison with 2022/23

At SW Regnard Island, overnight nesting activity was primarily distributed across the island's northern side and in an area on the eastern side (**Figure 8**). Recorded species was entirely hawksbill turtles. This distribution and species use was consistent with 2022/23, which also recorded activity in these same areas from predominantly hawksbill turtles.

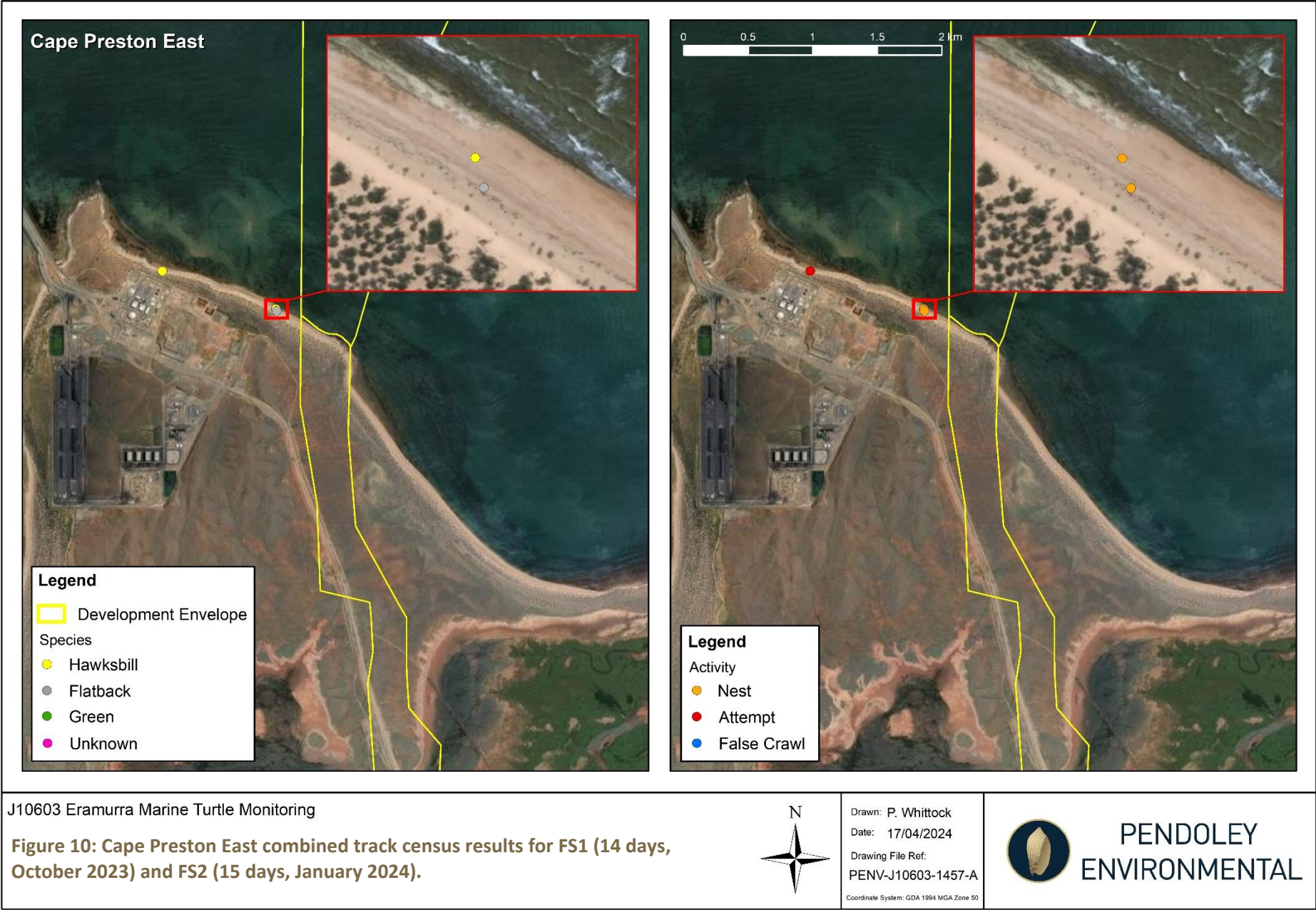
At NE Regnard Island, the limited overnight nesting activity was distributed on the north-west side of the island which was consistent with 2022/23 (**Figure 9**). Due to the low level of nesting activity, no comparison of recorded species is provided.

At CPE, all overnight nesting activity was recorded on the northern beach at CPE which was consistent with 2022/23 (**Figure 10**). Recorded species was a mixture of hawksbill ($n = 2$ tracks) and flatback ($n = 1$ track) turtles. This distribution and recorded species were largely consistent with 2022/23, with the exception of no overnight flatback nesting activity recorded in 2022/23.

At Steamboat Island, all overnight nesting activity was recorded on the island's south-east side, with some activity at the end of the sand spit (**Figure 11**). Recorded species was predominantly hawksbill turtle ($n = 33$ tracks), with some flatback ($n = 5$ tracks) and green ($n = 3$ tracks) turtles. This distribution and species use was consistent with 2022/23, which also recorded activity in these same areas from predominantly hawksbill turtles.









3.3.1.2 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 (Whitlock et al. 2014). An overall nester abundance has been estimated for each species by combining the track census data for all routine monitoring locations. For example, the nester abundance estimate for hawksbill turtles is determined from all nesting data at SW Regnard Island, NE Regnard Island, Steamboat Island, and CPE beach 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**).

Hawksbill Turtles

Based on successful nest counts for the 14-day survey in October 2023, the overall annual nester abundance estimate for hawksbills during the October peak is 21 – 24 individual turtles, with Steamboat Island experiencing the heaviest use. Note that this estimate is higher compared to 2022/23 due to the inclusion of Steamboat Island as a routine monitoring site this season. If data captured from Steamboat Island is excluded from this season, the estimate is 8 – 9 individual turtles which is comparable to 2022/23 (6 – 7 turtles).

Flatback Turtles

Based on successful nest counts for the 14-day survey in January 2024, the overall nester abundance estimate for flatbacks is 3 – 4 individual turtles. This estimate is comparable to what was reported in 2022/23 (2 – 3 turtles).

Green Turtles

Based on successful nest counts for the 14-day survey in January 2024, the overall nester abundance estimate for individual green turtles is 2 – 3, with no other green nesting activity detected outside of the survey period at routine monitoring locations. This estimate is comparable to what was reported in 2022/23 (2 – 4 individual turtles).

3.3.2 Opportunistic Survey

At FMB, one track was identified as an attempt during FS1 in October. The track could not be accurately assigned to a species as it was old and wind-blown, erasing many of the identifying features required to make a classification. At CPW, one flatback turtle track was identified as a false crawl during FS2 in January.

3.4 Hatchling Orientation

A total of 10 hatchling nest fans were recorded during FS2 in January ($n = 7$) and FS3 in February ($n = 3$) (**Table 5**). The seven nest fans recorded during FS2 occurred on CPE ($n = 2$), Steamboat ($n = 2$), SW Regnard ($n = 2$), and NE Regnard ($n = 1$) islands. All three nest fans recorded during FS3 occurred on Steamboat Island. From a species perspective, one fan was from a flatback nest, four from hawksbill nests, and five where the species was not identified.

Table 5: Summary statistics for nest fans. Where a mean could not be calculated (i.e. where $n = 1$), the individual spread and offset angle is given. Standard deviation was not calculated for sample size ≤ 3 .

Location	Spread Angle (°)				Offset Angle (°)			
	2023/24		2022/23 & 2023/24		2023/24		2022/23 & 2023/24	
	<i>n</i>	Mean \pm StDev	<i>n</i>	Mean \pm StDev	<i>n</i>	Mean \pm StDev	<i>n</i>	Mean \pm StDev
SW Regnard	2	58.5 \pm NA	4	52.3 \pm 14.0	2	5.8 \pm NA	4	5.4 \pm 1.1
NE Regnard	1	75.0 \pm NA	2	56.0 \pm NA	1	25.5 \pm NA	2	22.0 \pm NA
Steamboat	5	77.8 \pm 38.4	22	61.7 \pm 32.0	5	36.3 \pm 31.5	22	27.6 \pm 21.6
CPE	2	48.5 \pm NA	5	64.2 \pm 15.2	2	4.8 \pm NA	5	5.6 \pm 2.1

Summary statistics for all hatchling orientation metrics this season (pooled for both surveys) and when combined with the previous season (2022/23), including nest fan spread and offset angles, are provided in **Table 5**. All nest fans recorded this season are displayed in **Figure 12 – Figure 14**. Nest fans on SW Regnard Island, NE Regnard Island, and CPE 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 nest fans.

Three nest fans situated on the centre of the sand spit on Steamboat Island had larger spread and/or offset angles (**Figure 14**). Two of these recorded a spread angle of $>90^\circ$ and offset angle of $>60^\circ$, indicating severe mis- and dis-orientation.

These nest fans may have exhibited larger spread and/or offset angles due to their location on the sand spit and the access to the ocean on either side of the nest. When ocean finding, hatchlings use natural cues to orient themselves, 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:

- 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.





J10603 Eramurra Marine Turtle Monitoring

Figure 13: Nest fan spread and offset angles at Cape Preston East ($n = 2$).

Drawn: P. Whittock
Date: 17/04/2024
Drawing File Ref:
PENV-J10603-1459-A
Coordinate System: GDA 1994 MGA Zone 50



PENDOLEY
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4 RISK ASSESSMENT

The findings of the 2023/24 monitoring program, as detailed in this report, have been used to update and consolidate the light spill risk assessment conducted in the previous season (2022/23; PENV 2023). The incorporation of monitoring data from two breeding seasons at SW Regnard, NE Regnard, and CPE to assess the importance of the marine turtle population(s) and help inform the risk assessment, aligns with the recommendations of the NLPGW (Commonwealth of Australia 2023).

In 2022/23, Steamboat Island was not monitored routinely for the entirety of the monitoring program and therefore the importance of the marine turtle population that used the island could not be assessed in that season. Consequently, the island was not included within the 2022/23 risk assessment. However, this season, routine monitoring has been implemented, making Steamboat Island eligible for inclusion in this 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 6**), 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 dis-orientation 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 (see PENV 2022). 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, Steamboat 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 6: Risk Assessment Matrix.

Likelihood (see Table 10 for definition)	Consequence (see Table 9 for definition)				
	<i>Insignificant</i> 1	<i>Minor</i> 2	<i>Moderate</i> 3	<i>Major</i> 4	<i>Catastrophic</i> 5
<i>Almost certain</i> 5	Medium 5	High 10	High 15	Extreme 20	Extreme 25
<i>Likely</i> 4	Medium 4	Medium 8	High 12	High 16	Extreme 20
<i>Possible</i> 3	Low 3	Medium 6	Medium 9	High 12	High 15
<i>Unlikely</i> 2	Low 2	Low 4	Medium 6	Medium 8	High 10
<i>Rare</i> 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 0**).

4.1.1.1 Importance of Nesting Population

Approach

As per the NLPGW (Commonwealth of Australia 2023), when determining the consequence score of a development's risk assessment, it is necessary to consider the importance 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 and 2023/24 breeding seasons successfully recorded nesting activity data during the peak breeding period of each known marine turtle species across one inter-nesting cycle in each season, allowing for an estimate of the annual abundance of adult nesters for each species at routine monitoring locations (see **Section 3.3.1.2**).

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 important. 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 important = >40 % of the species or genetic stock rely on the nesting area
- Important = >1 % of the species or genetic stock rely on the nesting area
- Present but unimportant = <1 % of the species or genetic stock rely on the nesting area

One limitation is that this approach only considers the size of the population when assessing the importance of marine turtle nesting. To overcome this and provide additional context and supporting information, we also considered the nesting success of all species during their respective peak nesting periods across the project area. Note that 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, were excluded.

Outcome

The combined nester abundance for each stock at the routinely monitored locations in each season (2022/23: NE Regnard Island, SW Regnard Island, CPE and FMB; 2023/24: NE Regnard Island, SW Regnard Island, CPE and Steamboat Island), are provided in **Table 7**, alongside the estimated nester abundance for each relevant genetic stock. A level of importance was assigned according to the 'Contribution to Genetic Stock' estimate.

Table 7: Relative importance of each species of marine turtle nesting in the vicinity of the Project in relation to its contribution to the overall genetic stock. *2022/23 routine beaches include NE Regnard Island, SW Regnard Island, CPE, and FMB; **2023/24 routine beaches includes NE Regnard Island, SW Regnard Island, CPE, and Steamboat Island.

Species	Genetic Stock	Project: Annual Nester Abundance		Genetic Stock: Annual Nester Abundance	Contribution to Genetic Stock (%)		Level of Importance
		2022/23*	2023/24**		2022/23	2023/24	
Hawksbill	H-WA	6 – 7	21 – 24	4,000	0.18*	0.60	Unimportant
Flatback	F-Pil	2 – 3	3 – 4	8,000	0.04	0.05	Unimportant
Green	G-NWS	1 – 2	2 – 3	25,000	0.01	0.01	Unimportant
Cumulative Total		9 – 12	26 – 31	37,000	0.03	0.08	Unimportant

The combined nesting success for hawksbill and flatback turtles at all monitored nesting sites during the two monitoring seasons has been low (hawksbill: 2022/23: 14.7 %, 2023/24: 36.2 %; and flatback: 2022/23: 28.5 %, 2023/24: 16.7 %) (see **Section 3.3.1**). This indicates that the nesting habitat does not support a high rate of successful nesting and its importance is low. Note that for green turtles, the very low total number of overnight tracks (2 in 2022/23; and 3 in 2023/24) prevents any meaningful insights into the importance of the species' nesting success.

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 8**).

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 8: Description of impact duration.

Description	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 9**.

Table 9: Definition of consequence descriptions.

Description	Definition
Insignificant	The population is unimportant relative to the size of the genetic stock (<1 %).
Minor	The population is important 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 important 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 important 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.

Description	Definition
	The population is very important 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 important 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 2023). The likelihood assessment was undertaken by a PENV Subject Matter Expert, who considered the modelled light emissions for the Project alongside numerous physical and biological variables to determine the likelihood of sources impacting hatchling behaviour (see PENV 2022). 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 10**.

Table 10: 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 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) are not available 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 and 2023/24 monitoring seasons (**Table 7**), the cumulative contribution of nesting females to the genetic stock of each species was <1 %. Furthermore, the nesting success of hawksbill and flatback turtles in both seasons was low (nesting success for green turtles was not considered due to the very low number of overnight nesting activity). 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 (LM1; see **Figure 1**) was predicted to be the brightest location from light modelling due to development of the CPEEF. 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 11**).

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; see **Figure 1**), 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; see **Figure 1**), 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 and 2023/24 monitoring seasons indicated that SW Regnard Island supports more hawksbill turtle nesting than the adjacent mainland at CPE and nearby NE Regnard Island. The distribution of activity in both seasons (see **Section 3.3.1.1**) 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 northern side of 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 11).

4.3 North East Regnard Island

The nesting beach on NE Regnard Island (LM4; see **Figure 1**) will experience a small increase in glow on the horizon associated with the Project facilities and CPEEF. 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 11).

4.4 Steamboat Island

The nesting beach at Steamboat Island supports the highest level of marine turtle nesting activity out of all routinely monitored locations, with the majority of activity recorded from hawksbill turtles nesting on the beach situated on the island's south-east side.

The nesting beach is situated ~15 km from the Project Facilities on the mainland and ~19 km from the OGV anchorages. As a result of this distance, any visible Project-related artificial light is likely to be of low intensity sky glow. Furthermore, the closer Project-related light on the mainland will be shielded by the Cape Preston (Sino Iron) causeway and offloading facility, further reducing the visibility of any light spill (see **Figure 1**).

The cumulative glow from the Project facilities, CPEEF, and Cape Preston (Sino Iron) is **Unlikely** to impact on the orientation of hatchlings at Steamboat Island due to the distance of light sources from the island. 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 Steamboat Island (Table 11).

4.5 Forty Mile Beach

The nesting beach at FMB is very marginal, with no nesting by any species detected during the 2022/23 monitoring season and only one hawksbill turtle track in 2023/24. 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 (LM5 ; see **Figure 1**) is to experience only small changes in horizon brightness from the benchmark state as a result of new Project development and the CPEEF. 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 11).

Table 11: 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
Steamboat	Insignificant	Unlikely	Low
Forty Mile Beach	Insignificant	Unlikely	Low

4.6 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** at SW Regnard Island and **Likely** at CPE. Considering the Precautionary Principle, 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 2023). In addition, the best practice lighting design will further reduce the likelihood of any potential impact in the event of long-term climate change induced shifts in spatial and temporal nesting effort by the three species within the region.

5 CONCLUSION

Marine turtle monitoring was undertaken over the 2023/24 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:

hawksbill, flatback, and green. Nesting activity was spread across accessible nesting habitat at SW Regnard and Steamboat Islands, with lower levels of activity recorded at NE Regnard Island and CPE. Of the three species, hawksbill turtles were the most abundant, with the highest activity recorded on Steamboat 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 two seasons of hatchling behaviour (2022/23 and 2023/24). Fans were recorded on SW Regnard Island, NE Regnard Island, CPE, and Steamboat Island. There was no evidence of mis- or disorientation in the fans recorded, with the exception of some fans on Steamboat Island that were mis- and/or disorientated (i.e. wide spread angles) 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 (PENV 2022) and considered other physical and biological factors that influence hatchling sea-finding behaviour, as well as the relative importance of nesting females and the success of their breeding activities to the relevant genetic stocks. Due to the low nester abundance of all three species recorded during the 2022/23 and 2023/24 monitoring seasons, the cumulative contribution of nesting females to the genetic stock of each species was <1 % which was considered unimportant. Furthermore, the nesting success of hawksbill and flatback turtles in both seasons was low, indicating that the nesting habitat is unlikely to support breeding activities that provide an important contribution to the genetic stock.

The risk assessment determined the inherent (unmitigated) risk to be **Low** at NE Regnard Island, SW Regnard Island, FMB, and Steamboat, and **Medium** at CPE. 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. Furthermore, these mitigation measures and best practice measures will reduce the likelihood of impact to other light-sensitive species that may be present, including terrestrial mammals, bats, and migratory shorebirds/seabirds.

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Appendix A: Field Survey Schedule

Table A1: Field Survey Schedule. X = survey day.

Date	Survey Location					
	SW Regnard Is.	NE Regnard Is.	Cape Preston East	Steamboat Is.	40 Mile Beach	Cape Preston West
Field Survey 1						
13/10/2023	Transit					
14/10/2023	X	X	X	X		
15/10/2023	X	X	X	X	X	
16/10/2023	X	X	X	X		
17/10/2023	X	X	X	X		
18/10/2023	X	X	X	X		
19/10/2023	X	X	X	X		
20/10/2023	X	X	X	X		
21/10/2023	X	X	X	X		
22/10/2023	X	X	X	X		
23/10/2023	X	X	X	X		
24/10/2023	X	X	X	X		
25/10/2023	X	X	X	X		
26/10/2023	X	X	X	X		X
27/10/2023	X	X	X	X		
Field Survey 2						
04/01/2024			X			
05/01/2024	X	X		X		
06/01/2024			X			
07/01/2024	X	X		X		
08/01/2024			X		X	
09/01/2024	X	X		X		X
10/01/2024			X			
11/01/2024	X	X		X		
12/01/2024			X		X	
13/01/2024	X	X		X		
14/01/2024			X			
15/01/2024	X	X		Weather Standby		
16/01/2024			X			
17/01/2024	Weather Standby			Weather Standby		
18/01/2024			X		X	
19/01/2024	X	X		X		X
Field Survey 3						
05/02/2024			X			
06/02/2024	X	X		X		
07/02/2024			X			
08/02/2024	X	X		X		
09/02/2024			X			

Date	Survey Location					
	SW Regnard Is.	NE Regnard Is.	Cape Preston East	Steamboat Is.	40 Mile Beach	Cape Preston West
10/02/2024	X	X		X		
11/02/2024			X			
12/02/2024	X	X		X		
13/02/2024			X			
14/02/2024	X	X		X		
15/02/2024			X			
16/02/2024	X	X		X		
17/02/2024			X			
18/02/2024	X	X		X		
19/02/2024			X			

Appendix B: Track Preservation



Figure B1: Example of track preservation on Cape Preston East. a. Track recorded on 6th January 2024; and; b. Same track recorded on 18th January 2024.