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ASHBURTON SALT: UPDATED ARTIFICIAL LIGHT MONITORING AND MODELLING REPORT

Prepared by

Pendoley Environmental Pty Ltd

For

AECOM

10 February 2023

ARTIFICIAL LIGHT ASSESSMENT SERVICES

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DOCUMENT CONTROL INFORMATION

TITLE: ASHBURTON SALT: UPDATED ARTIFICIAL LIGHT MONITORING AND MODELLING REPORT

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Document History

Revision	Description	Date received	Date issued	Personnel
Draft	Report Draft		18/01/2023	E. Charlton / P. Whittock
Rev IA	Internal Review	19/01/2023	27/01/2023	A. Mitchell
Rev A	Client review	27/01/2023	02/02/2023	A. Barrowcliff
Rev 0	Final report issued	02/02/2023	10/02/2023	P. Whittock

Printed:	10 February 2023
Last saved:	10 February 2023 03:50 PM
File name:	P:\06 Projects\J08 AECOM\J08010 K+S Ashburton Salt - Light Monitoring 2022\04 Technical Reports\J08010 Ashburton Salt Updated Artificial Light Monitoring and Modelling Report_2023_Rev0.docx
Author:	Elliott Charlton / Paul Whittock
Project manager:	Dr Paul Whittock
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Ashburton Salt: Updated Artificial Light Monitoring and Modelling Report
Client	AECOM
Client representative:	Ashlee Barrowcliff
Report number:	J08010
Cover photo:	Raw fisheye image captured by a Sky42 camera (credit: Pendoley Environmental)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Background

K plus S Salt Australia Pty Ltd (K+S) is proposing to develop a solar salt project on the Western Australia coast approximately 40 km south-west of Onslow. The project, named the Ashburton Salt Project will include the construction of solar salt concentration and crystallisation ponds, associated infrastructure, and marine facilities including a jetty and transhipment area.

In 2019, Pendoley Environmental (PENV) completed a benchmark artificial light monitoring and modelling program (referred to herein as the light program) to predict potential changes to the light environment from the project. The outcomes of the light program were used by AECOM to assess the impact that any detected change in artificial light may have on protected marine turtle species present on nearby sensitive habitat when nesting/hatching within the project's Environmental Review Document (ERD; K+S 2021) and marine fauna impact assessment (AECOM 2021).

Following a review of the ERD and marine fauna impact assessment by the Western Australian Environmental Protection Authority (EPA), several comments and requests for further detail were received that related to the light program (see **Appendix A**).

1.1.1 Benchmark Artificial Light Monitoring and Modelling Program

The benchmark light program included pre-construction monitoring of the existing artificial light within the region of the project, and the modelling of the predicted artificial light from the project (see Pendoley Environmental 2020). The outputs of the monitoring and modelling work scopes were then combined to generate the cumulative predicted light environment within the region of the project, post-construction, from the viewpoint of identified sensitive habitat and with consideration of existing light.

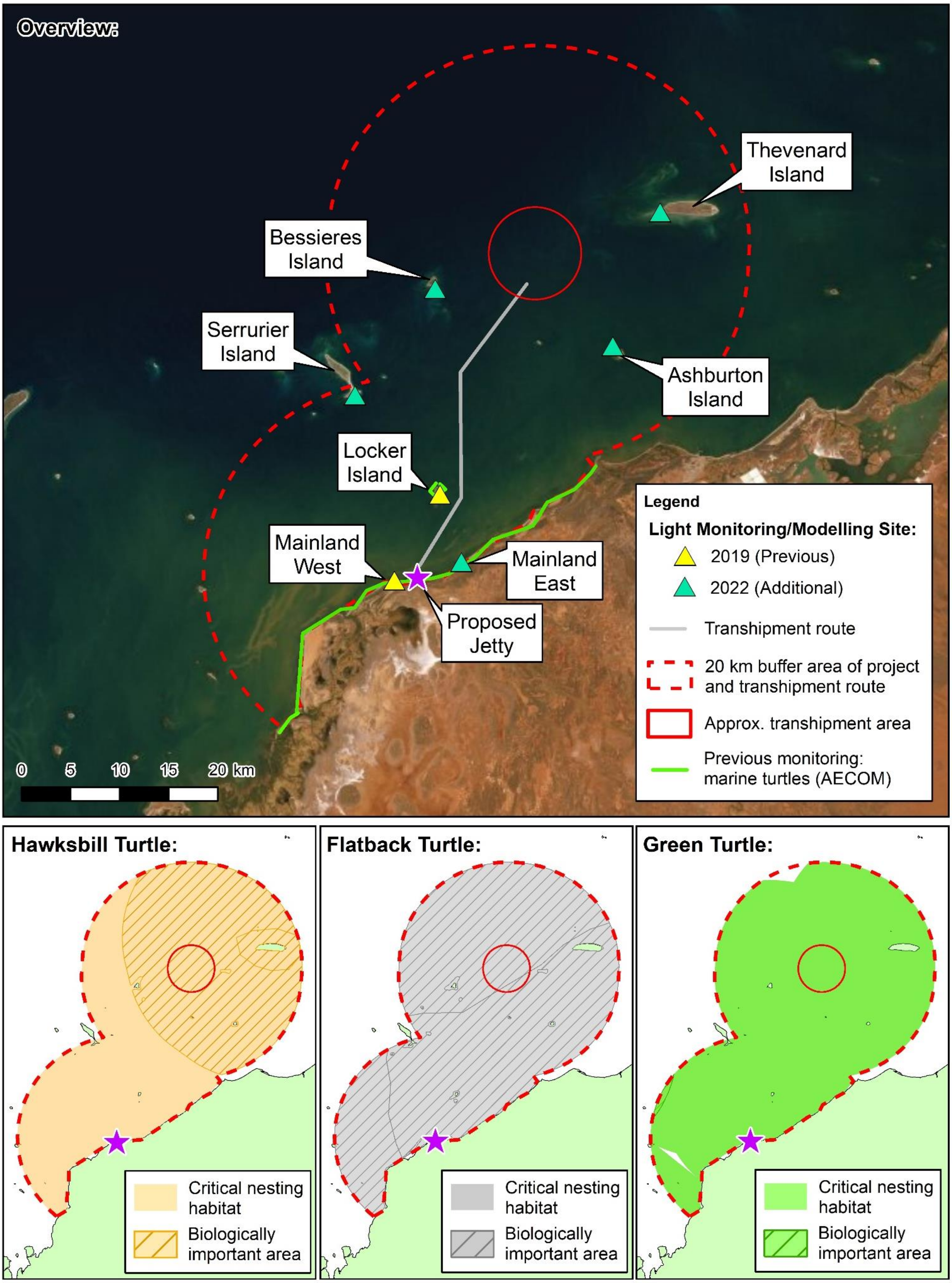
The light monitoring work scope involved the capture of night-time imagery at selected monitoring sites situated in proximity to the project area in May 2019 (**Figure 1**). Sites were selected in discussion with AECOM, and targeted potential marine turtle nesting habitat in the region in proximity to project infrastructure, including Locker Island and three sites on the mainland to the west of the proposed jetty. Site selection was not informed by the results of a marine turtle survey (noting only two days of survey had been completed in December 2018 prior to the light monitoring field survey) nor by any monitoring guidelines or recommendations within the *National Light Pollution Guidelines for Wildlife including Marine Turtles* (NLPGW; Commonwealth of Australia 2020) which were released in 2020 after the light monitoring field survey.

Light modelling of a particular development relies on a lighting inventory which, at the time the modelling work scope was completed, was not available for the project. Therefore, a lighting inventory was generated based on high level assumptions determined in consultation with AECOM and K+S (refer to Pendoley Environmental 2020 for further detail). Furthermore, no lights for the transhipment vessel (TSV) or larger ocean-going loading vessel (OGV) were included in the lighting inventory for the model as it was considered out of scope by K+S at the time. This was on the basis there would be little control over lighting on the vessel and it was unknown what vessel would be used/there was a lack of any lighting inventory for it.

1.2 Scope of Work

PENV were engaged by AECOM to update the benchmark light program conducted at Locker Island and the mainland (LM3) monitoring sites to address the comments received by the EPA. Furthermore, to ensure compliance with the guidance and recommendations of the NLPGW which were released after the initial benchmark light program, PENV were requested to undertake artificial light monitoring and modelling at additional sites situated at potential sensitive nesting habitat within a 20 km buffer of the project infrastructure (including the offshore transhipment area and mainland jetty). This buffer area is a specific recommendation made in the NLPGW and within which, marine turtle species-specific impacts need to be considered from artificial light generated from the project and associated vessel movements (Commonwealth of Australia 2020).

This technical report outlines the results of the updated artificial light modelling work at the previously monitored sites, and the artificial light monitoring and modelling at the additional monitoring sites. The outcomes of the light modelling work can be considered in context of potential impacts to marine turtles at the sensitive sites within any update of the ERD or marine fauna impact assessment (if required).



J08010 AECOM: K+S Ashburton Salt Project

Figure 1: Location map showing light monitoring/modelling sites, project areas, and marine turtle habitat areas.

Drawn: P. Whittock
Date: 18/01/2023
Drawing File Ref: PENV-J08009-1198-A
Coordinate System: GDA 2020 MGA Zone 50

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2 METHODOLOGY

2.1 Light Monitoring

2.1.1 Field Survey

Monitoring was undertaken at five additional sites during one field survey between 22nd and 28th November 2022, coinciding with a new moon period (24th November 2022) (**Table 1** and **Figure 1**). The two previous monitoring sites are also shown in **Figure 1** and **Table 1** (refer to Pendoley Environmental [2020] for further detail about field data capture).

Table 1: Latitude and longitude of all light monitoring sites. Refer to **Figure 1** for geographical location.

Monitoring site		Latitude	Longitude
Previous (2019)	Mainland West (LM3)	-21.80092	114.73666
	Locker Island	-21.71672	114.76704
Additional (2022)	Mainland East	-21.78311	114.79116
	Ashburton Island	-21.59352	114.93788
	Bessieres Island	-21.52902	114.76534
	Serrurier Island	-21.62546	114.69534
	Thevenard Island	-21.46041	114.97175

2.1.2 Data Capture

Artificial light data was captured at each monitoring site using a Sky42 light monitoring camera and was consistent with previous monitoring. 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. Cameras were deployed overnight at all locations and images were downloaded every other day.

Weather conditions for the survey were favourable for light monitoring i.e. clear sky, on every night of the field survey.

2.1.3 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 2**). 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.

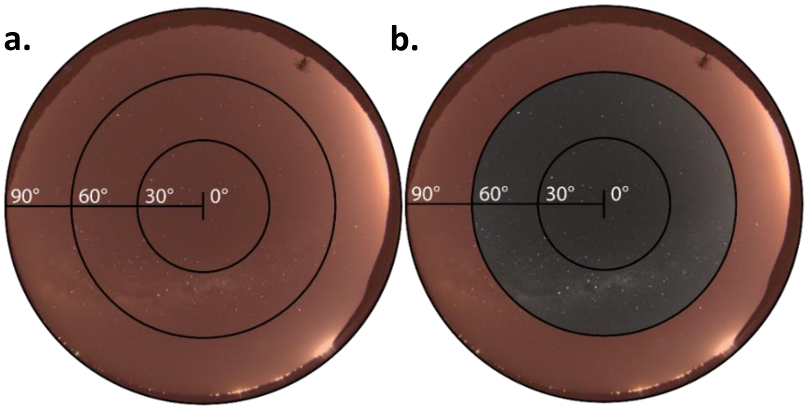

Figure 2: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60 – 90°). Shaded areas denote the region of the sky being measured.

2.2 Light Modelling

Light modelling was undertaken for all previous and additional monitoring sites shown in **Figure 1**.

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).
- Latitude and longitude coordinates for the observer viewpoints (Error! Reference source not f ound.).
- 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 infrastructure and vessels, **including OGVs and TSVs**, based on information provided by K+S.

A summary of the lighting inventory, including changes from the previous assessment, is provided in **Appendix B**.

2.2.2 Outputs

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

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

2.2.3 Scenarios

The potential for marine turtles to be impacted by artificial light can be minimised by reducing or removing the visibility of direct light. This can be achieved by several means, including shielding of fixtures or smart controls such as curfews, motion sensors, and dimming.

Specifically, for the project, K+S stated that the jetty lighting could be completely switched off when no vessel loading is taking place. This therefore formed the basis for the two scenarios that were modelled separately:

- **Scenario 1:** 'Worst' case with the lighting on the jetty switched **on** at all times.
- **Scenario 2:** 'Best' case with the lighting on jetty switched **off** when not in use (other lighting remains on).

2.2.4 Assumptions

The lighting inventory was generated under the following assumptions:

- Only external lighting has been considered in the model (i.e. omits internal lighting that may be reflected externally).
- Only one dumping bridge will be illuminated at a time. The central bridge was selected for inclusion in the light modelling.
- Lights on the jetty are 3 m above the height of the structure.
- The jetty was facing in a northwest direction.
- 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.
- TSV lighting was generated using engineering designs and consultation with CSL Australia and AECOM.
- One OGV is included at the closest anchorage site within the transhipment area.

- One TSV is included alongside the OGV.
- Only the end of the jetty is illuminated (in Scenario 1; see **Section 2.2.3**).

2.2.5 Limitations

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

- Model results have not yet been definitively ground-truthed for large-scale projects (Linares et al. 2018, 2020), however, the technical approach outlined within this report is considered current with the most recent literature, subject matter expert input, and best practice.
- The precision of the model outputs is directly related to the level of input detail. Much of the lighting design is still conceptual and may be changed prior to construction.
- The model has converted units of absolute radiance ($W/m^2/sr$) to units of photometric luminance ($Vmag/arcsec^2$). Where absolute radiance represents light equally across the whole visible spectrum, visual magnitudes represent only the human visual (green) band of the spectrum and may not fully represent light as perceived by marine turtles or seabirds.
- Monitoring locations selected for benchmark data collection and subsequent modelling represent only a single viewpoint at each location. These locations have been selected based on the distribution of nesting activity and are considered to be most appropriate for determining potential impacts on hatchlings. However, the potential for impact is likely to change based on the specific location of a nest emergence (e.g. differences in dune topography, vegetation, beach slope). In this regard, the results should be interpreted with caution.

3 RESULTS

3.1 Light Monitoring

Several sources of horizon light were visible within the captured imagery at varying levels of brightness and at different bearings from each monitoring site (see **Figures 3 – Figure 9**). Notable existing light sources included:

- Wheatstone LNG Facility;
- Wheatstone Accommodation Camp;
- Macedon LNG Facility;
- Tubridgi Gas Facility;
- Onslow; and
- Exmouth.

The brightest source of light on the horizon was the Wheatstone LNG Facility which appears as bright skyglow at all sites as well as a direct source from nearby Ashburton Island (**Figure 3a**). Similarly, light from the Macedon LNG Facility is also visible from all monitoring sites, although it is substantially darker than the Wheatstone LNG Facility and, at some sites, both sources have an overlapping bearing (see **Figure 3a** and **Figure 7a**).

The visibility of other sources of light at each site was dependent on the bearing of the light source and whether the source was shielded from nearby dunes or other localised topographic features. For example, artificial light from Exmouth was only visible from Locker Island (**Figure 5a**) and shielded elsewhere, and the Tubridgi Gas Facility was visible from all sites except Locker Island, Mainland West, and Thevenard Island.

3.2 Light Modelling

Updated light modelling was completed for each monitoring site under both Scenarios 1 (‘worst’ case) and 2 (‘best’ case), and the processed results are shown in **Figures 3b** - **Figure 9b**. The modelled output for each scenario was then combined with the respective benchmark light monitoring data for each site to create a cumulative result (see **Figures 3c** - **Figure 9c**).

3.2.1 Visibility of Project Lighting within Modelled Outputs

3.2.1.1 Offshore Island Monitoring Sites

At Ashburton Island, light emissions from the TSV and OGV at the transhipment area are visible in the model output (**Figure 3b**) but would be naturally shielded by the island topography meaning it is unlikely to be visible from the nesting habitat on the south and southwest sides of the island (**Figure 3c**). The project jetty and infrastructure are barely visible within the modelled output (**Figure 3b**) and are not discernible as separate light sources in the benchmark + modelled output (**Figure 3c**).

At Bessieres, light emissions from the TSV and OGV at the transhipment area are visible in the model output (**Figure 4b**) and are clearly visible offshore as a separate source of light in a NNE direction from the island in the benchmark + modelled output (**Figure 4c**). The project jetty and infrastructure are barely visible within the modelled output (**Figure 4b**) and are not discernible as a separate light source in the benchmark + modelled output (**Figure 4c**).

At Locker, light emissions from the TSV and OGV at the transhipment area are visible in the model output (**Figure 5b**) but would be naturally shielded by the island topography meaning it is unlikely to be visible from the nesting habitat on the south side of the island (**Figure 5c**). The project jetty and infrastructure are visible within the modelled output (**Figure 5b**) and are visible as a separate source of light on the mainland in a southerly direction from the island in the benchmark + modelled output (**Figure 5c**).

At Serrurier, light emissions from the TSV and OGV at the transhipment area are visible in the model output (**Figure 6b**) but would be naturally shielded by the island topography meaning it is unlikely to be visible from the nesting habitat on the south side of the island (**Figure 6c**). The project jetty and infrastructure are barely visible in a southerly direction from the island within the modelled (**Figure 6b**) and the benchmark + modelled output (**Figure 6c**).

At Thevenard, only light emissions from the TSV and OGV at the transhipment area are visible in the model output (**Figure 7b**), with the project jetty and infrastructure not discernible as a separate source of light. The light emissions from the TSV and OGV are visible offshore in a southwest direction from the island within the benchmark + modelled output (**Figure 7c**).

3.2.1.2 Mainland Monitoring Sites

At the Mainland East site situated to the east of the project jetty, light emissions from the TSV and OGV at the transhipment area are barely visible in a northerly direction from the site within the modelled (**Figure 8b**) and the benchmark + modelled outputs (**Figure 8c**). The project jetty and infrastructure are visible within the modelled output (**Figure 8b**) and are not discernible as a separate light source in the benchmark + modelled output due to shielding from a dune and localised topography (**Figure 8c**).

At the Mainland West site situated to the west of the project jetty, light emissions from the TSV and OGV at the transhipment area appear similar to the Mainland East site and are barely visible in a northerly direction from the site within the modelled (**Figure 9b**) and the benchmark + modelled outputs (**Figure 9c**). The project jetty is clearly visible within the modelled output (**Figure 9b**) and appears as a separate light source in northeast direction from the site in the benchmark + modelled output (**Figure 9c**). The project infrastructure is also visible within the modelled output (**Figure 9b**) but is not discernible as a separate light source in the benchmark + modelled output due to shielding from a dune and localised topography (**Figure 9c**).

3.2.2 Quantified Change between Benchmark and Benchmark + Modelled Output

With the inclusion of the modelled project lighting, the largest increase to benchmark light levels for both WOS and horizon areas are predicted to occur at the Mainland West site which is situated close to the jetty (+216 % WOS and +514 % horizon), and the smallest increase at Ashburton Island (+8 % WOS and +6 % horizon) (**Table 2**). The second largest change is predicted for Bessieres Island with a +14 % increase in WOS brightness and +15 % increase in horizon brightness. The other monitored sites, including the Mainland East site, all experienced an +11 % increase in WOS brightness, and varying increases in horizon brightness (+9 to +11 %; **Table 2**) due to shielding from nearby dunes and localised topographic features, and existing visible light sources on an overlapping bearing with the project location. Under Scenario 2 when lights from the jetty are switched off, the predicted change in light emissions visible from the Mainland West site shows a +11 % increase for both WOS and horizon areas on benchmark levels which was a substantially lower increase than under Scenario 1 (+216 % WOS and +514 % horizon increase**; Table 2**). All other sites showed no change in brightness between scenarios on benchmark levels.

Table 2: Comparison of benchmark and benchmark + modelled sky brightness values for both whole-of-sky and horizon areas for each monitoring site. The scale is inverse logarithmic meaning that brightness increases with decreasing Vmag/arcsec^2 values. S1 = Scenario 1, S2 = Scenario 2. * = Note: due to updated image processing methodology since 2019, there is a minor difference in stated benchmark values of Locker Island and Mainland West from the previous assessment.

Monitoring site	Whole-of-sky (0 – 90°) (Vmag/arcsec^2)					Horizon (60 – 90°) (Vmag/arcsec^2)				
	Benchmark	Benchmark + Modelled		Change (%)		Benchmark	Benchmark + Modelled		Change (%)	
		S1	S2	S1	S2		S1	S2	S1	S2
Ashburton Island	21.17	21.09	21.09	+8	+8	20.72	20.66	20.66	+6	+6
Bessieres Island	21.57	21.43	21.43	+14	+14	21.31	21.16	21.16	+15	+15
Locker Island*	21.43	21.32	21.32	+11	+11	21.24	21.12	21.12	+11	+11
Mainland East	21.54	21.43	21.43	+11	+11	21.29	21.20	21.20	+9	+9
Mainland West*	21.43	20.18	21.32	+216	+11	21.22	19.24	21.10	+514	+11
Serrurier Island	21.54	21.43	21.43	+11	+11	21.30	21.20	21.20	+10	+10
Thevenard Island	21.51	21.40	21.40	+11	+11	21.21	21.12	21.12	+9	+9

3.2.3 Comparison between 'Worst' Case and 'Best' Case Lighting Scenarios

A comparison of the WOS and horizon brightness at each monitoring site between Scenario 1 ('worst' case) and Scenario 2 ('best' case) is shown in **Table 3**. Except for the Mainland West site, there was no detectable difference between the scenarios at any of the monitoring sites i.e. the change was 0 %. At the Mainland West site which, out of all monitoring sites, is situated closest to the proposed jetty on the mainland (see **Figure 1**), the WOS and horizon brightness decreased by 65 % and 82 %, respectively, between Scenario 1 i.e. all jetty lighting switched on, and Scenario 2 i.e. all jetty lighting switched off.

Table 3: Comparison of Scenario 1 and Scenario 2 cumulative sky brightness values for whole-of-sky and horizon views at each monitoring site. Note that the scale is inverse logarithmic meaning that the brightness increases with decreasing Vmag/arcsec^2 values.

Monitoring site	Whole-of-sky (0 – 90°) (Vmag/arcsec^2)			Horizon (60 – 90°) (Vmag/arcsec^2)		
	Scenario 1	Scenario 2	Change (%)	Scenario 1	Scenario 2	Change (%)
Ashburton Island	21.09	21.09	0	20.66	20.66	0
Bessieres Island	21.43	21.43	0	21.16	21.16	0
Locker Island	21.32	21.32	0	21.12	21.12	0
Mainland East	21.43	21.43	0	21.20	21.20	0
Mainland West	20.18	21.32	-65	19.24	21.10	-82
Serrurier Island	21.43	21.43	0	21.20	21.20	0
Thevenard Island	21.40	21.40	0	21.12	21.12	0

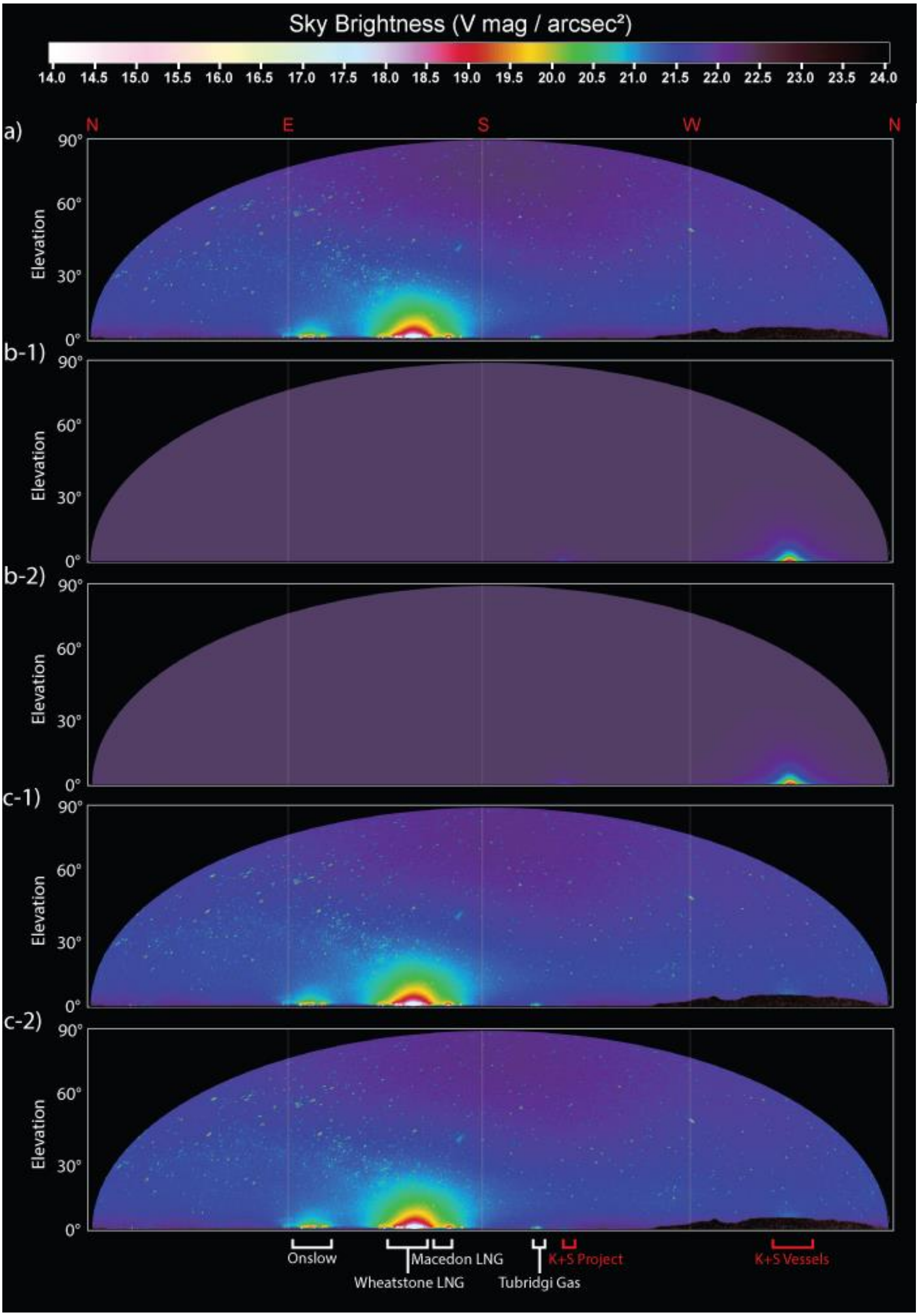

Figure 3: Artificial light modelling results for Ashburton Island: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

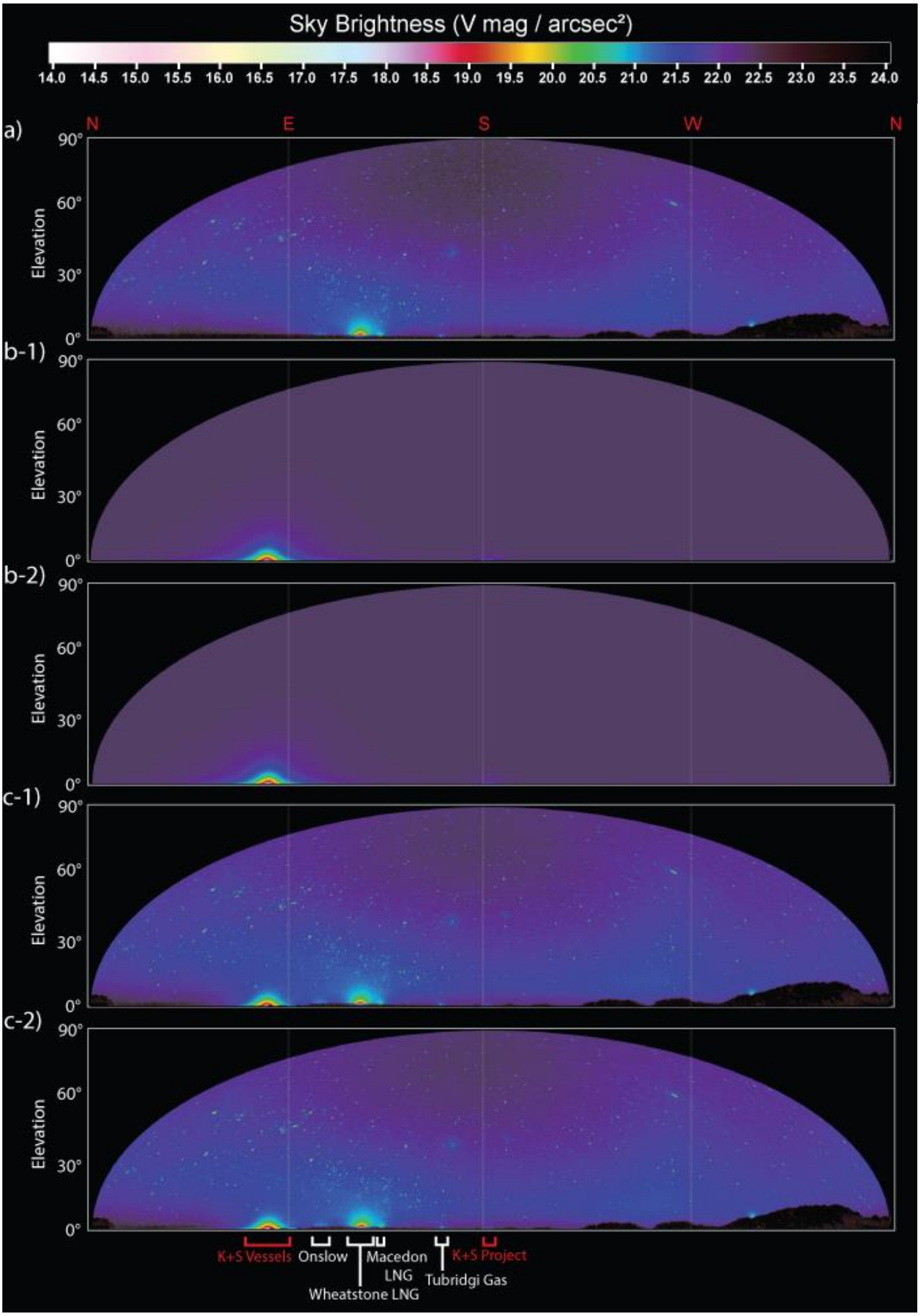

Figure 4: Artificial light modelling results for Bessieres Island: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

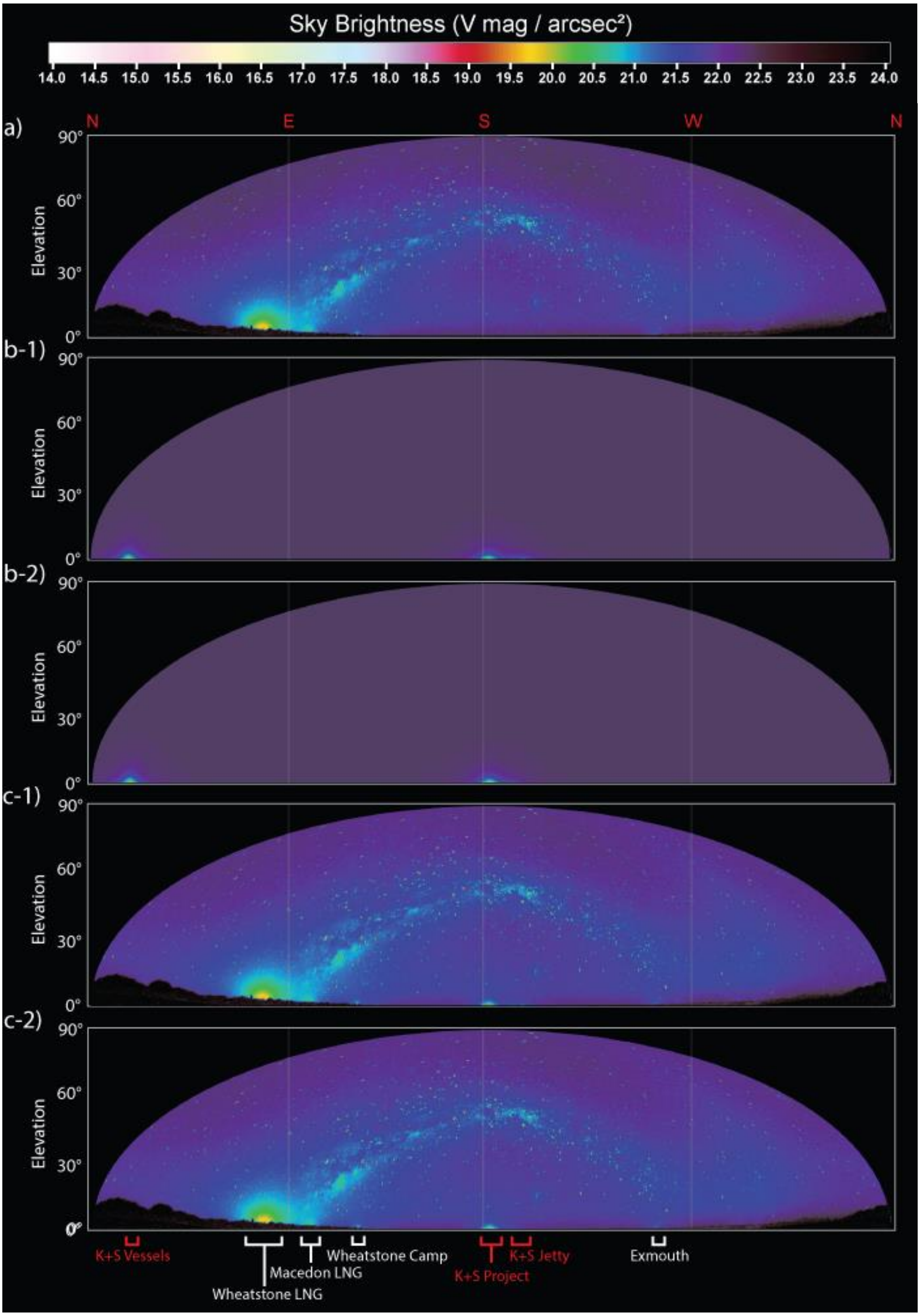

Figure 5: Artificial light modelling results for Locker Island: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

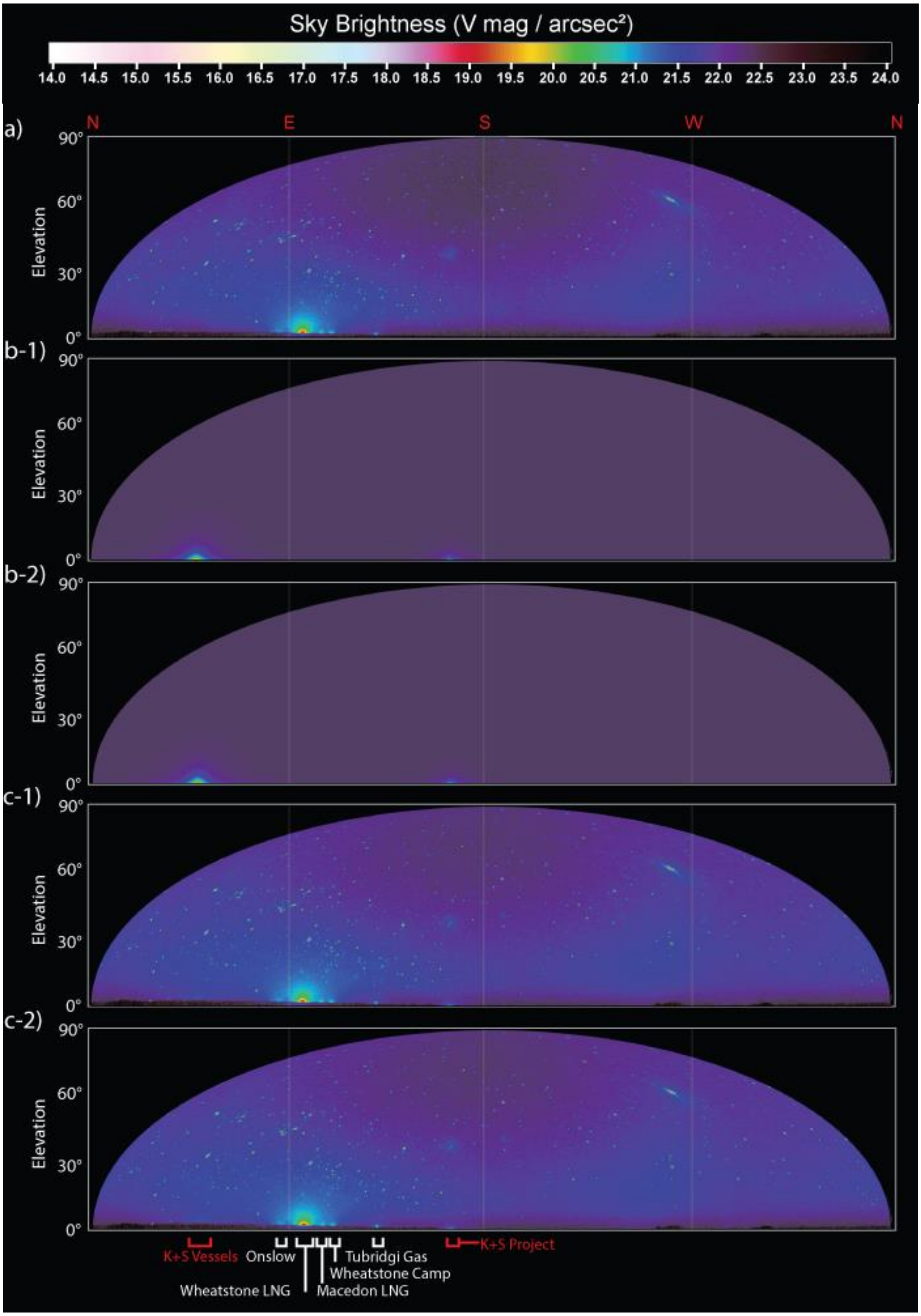

Figure 6: Artificial light modelling results for Serrurier Island: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

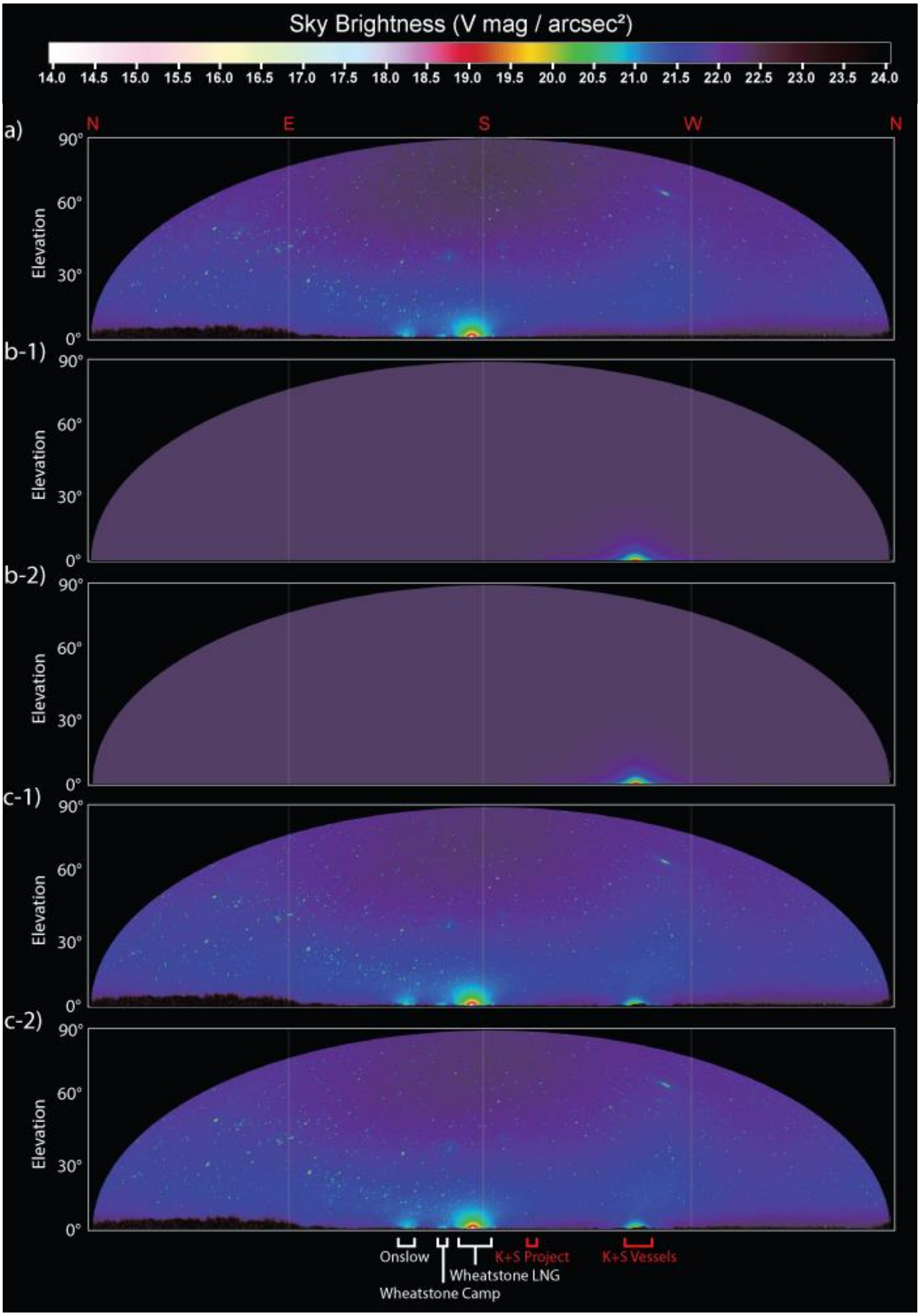

Figure 7: Artificial light modelling results for Thevenard Island: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

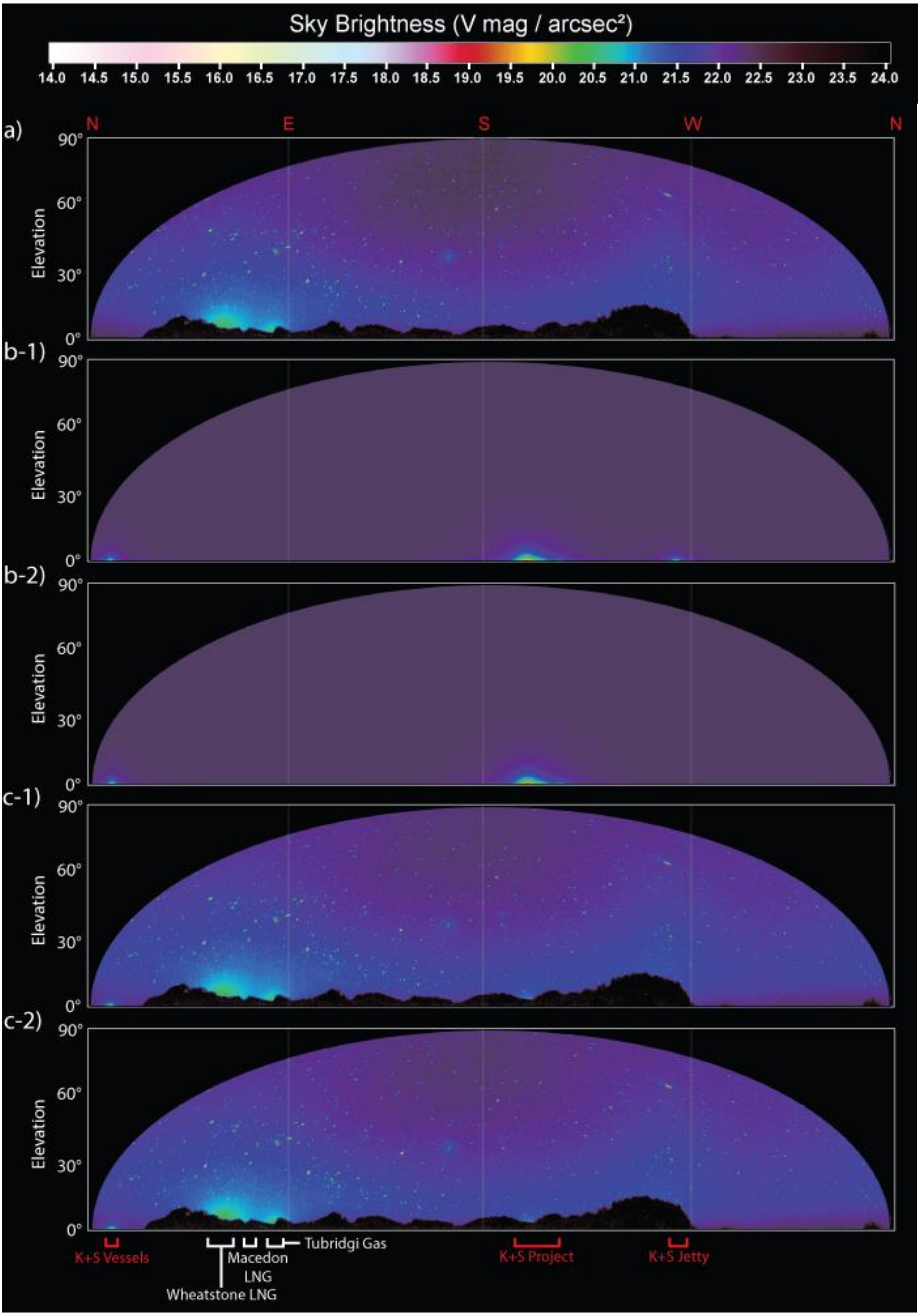

Figure 8: Artificial light modelling results for Mainland East: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

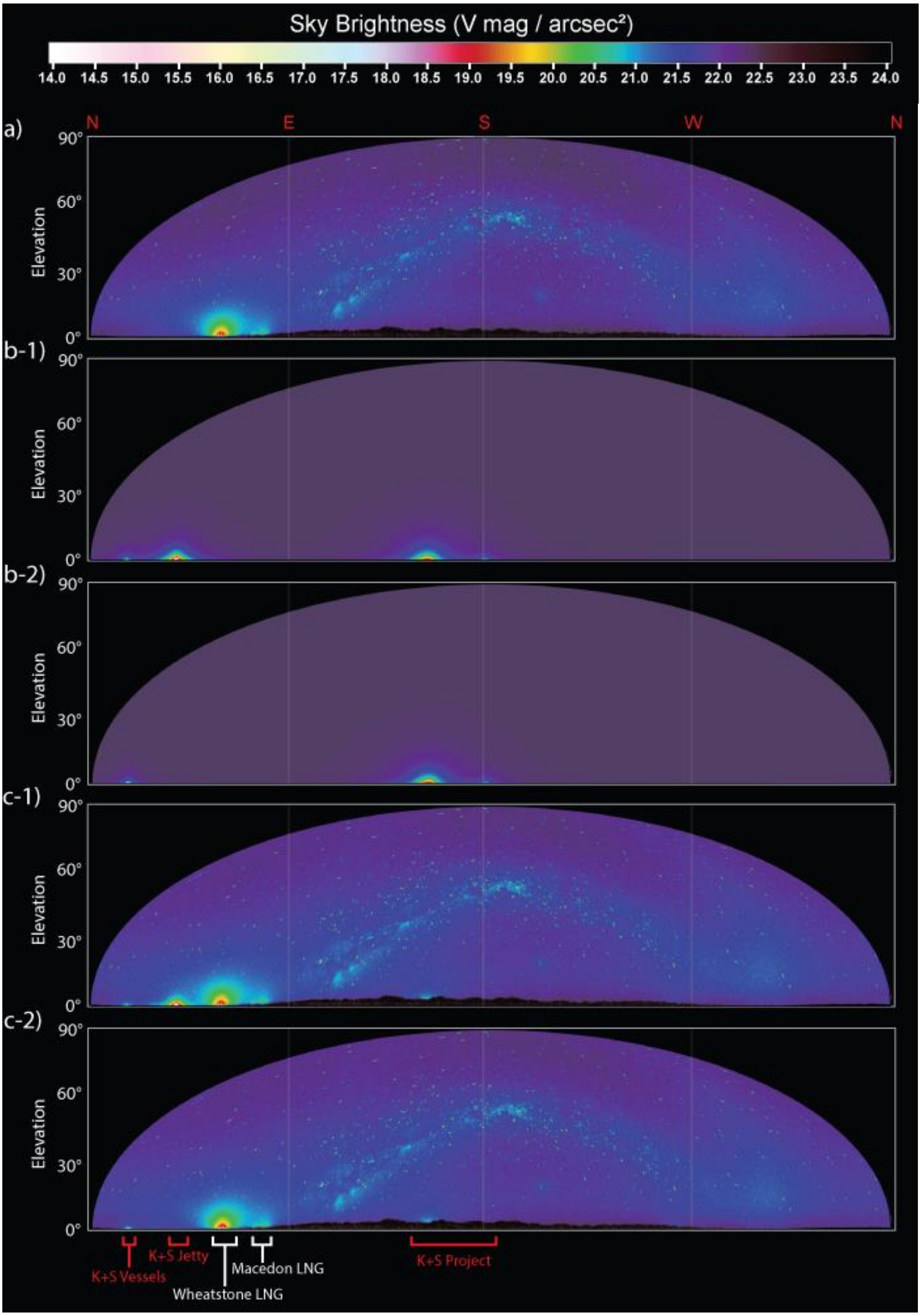

Figure 9: Artificial light modelling results for Mainland West: a. Benchmark all-sky processed image recorded during the light survey; b. Modelled brightness of the project under Scenario 1 (B-1) and Scenario 2 (B-2); c. Benchmark monitoring image + modelled brightness of the project under Scenario 1 (C-1) and Scenario 2 (C-2).

4 DISCUSSION

The updated modelling demonstrated that under a 'worst' case scenario with all jetty lighting switched on, light emissions from the project could increase the existing WOS and horizon brightness by up to 216 % and 514 % respectively at the monitoring site situated closest to the project jetty (Mainland West; **Table 2**). At this site, while the localised topography provides some natural shielding in the direction of the project, the jetty extends beyond this shielding allowing both direct light and sky glow to be visible (**Figure 9**). However, under a 'best' case scenario with all jetty lighting switched off, the change in WOS and horizon brightness at the same site is predicted to be an increase of 11 % indicating the importance of this lighting control. Note that the marine turtle surveys undertaken by AECOM in 2018 and 2019 recorded only one adult female turtle track to the west of the jetty indicating that this area is not likely to be significant for marine turtle nesting (AECOM 2021).

At the other mainland monitoring site (Mainland East), despite being relatively close to the project jetty (~4 km), the localised dune and beach headland/topography shielded the visibility of the modelled light resulting in a substantially smaller increase of 11 % WOS brightness and 9 % horizon brightness compared to the Mainland West site (**Table 2** and **Figure 8**). The importance of a dune in shielding artificial light is emphasised within the NLPGW which states that the most effective approach for the management of light near a nesting beach is to ensure there is a tall dark horizon behind the beach such as a dune and/or a natural vegetation screen (Commonwealth of Australia 2020). Despite this result, the difference in brightness between the Mainland West and Mainland East sites should be interpreted with caution and in consideration with the limitations highlighted in **Section 2.2.5** i.e. the result is based on one modelling viewpoint and the brightness at other nearby areas of habitat may have a direct line visibility of the jetty and other project infrastructure, appearing brighter and hence provide a greater risk of impact to marine turtles. This consideration is particularly relevant due to the presence of low-level marine turtle activity recorded in the vicinity of the monitoring site to the east of the jetty in 2018 and 2019 (AECOM 2021).

At the monitoring sites on the offshore islands, there was no detected difference in WOS and horizon brightness between the two modelled scenarios (**Table 3**), indicating that while effective at monitoring sites situated in proximity to the source on the mainland, the switching off of jetty lighting would have no influence on reducing the visibility of light at the monitored offshore islands. There were however detected increases in brightness from benchmark light levels with the inclusion of the modelled outputs, ranging from 8 to 14 % for the WOS area and 6 to 15 % for the horizon area. The range in percentage change between the sites is likely due to a combination of factors, including the proximity of the monitoring site to the modelled light source itself, the occurrence of shielding of the modelled light from existing dunes or localised topography, or the overlapping of the modelled light source with an existing source (see **Section 3.2.1**).

The predicted light emissions from the TSV and OGV vessels at the transhipment area were notably visible in the modelled outputs at the monitoring sites on Thevenard (**Figure 7c**) and Bessieres (**Figure 4c**) islands only, and shielded or barely visible at all other sites. When the vessels are operating in this area, it is likely that they will be a new source of offshore light on the horizon and will appear at different bearings depending on the perspective at these two nearby islands. This means that the risk of impact from the light source on a marine turtle will change spatially across the habitat depending on where an adult turtle nests or a hatchling emerges. The risk of impact may also be counteracted by the visibility and bearing of other sources of existing light, notably the Wheatstone LNG Facility which appears notably brighter at Thevenard Island compared to the modelled vessels.

5 REFERENCES

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Appendix A: Environmental Protection Authority comments and how they are addressed within this report.

Requirement	EPA Comment	Specific Query from EPA	Where addressed within this Report
Undertake a light study (including current baseline and predicted) to characterise the potential changes to the light environment and the implications this may have on threatened turtles.	Not adequate – Light modelling has been undertaken but several limitations in the modelling approach may affect how representative the model is and likely result in an under estimation of potential impacts	It is not clear why lights on loading vessel are not included in model?	**Section 2.2: Modelling** Light from transhipment vessel and ocean-going loading vessel were included as inputs into the model
		It is not clear why beach to the east of jetty was not considered in baseline data collection or light modelling given nesting activity was recorded there.	**Section 2.1.1: Light Monitoring: Data Capture and Figure 1** Light monitoring was undertaken on the beach to the east of the jetty and data incorporated into a model.
		Lighting from the ship also needs to be considered in the context of impacts to Locker Island turtles as indirect impacts of the project.	**Section 2.2: Modelling** Light from transhipment vessel and ocean-going loading vessel were included as inputs into the model
		The lighting impact assessment only considers hatchling disorientation to build a case it is better that lights on the jetty remain on so turtles are not disorientated by glow from facility lighting. However, this does not consider the potential for lighting from jetty to deter adult females from utilising the nesting beach or increase predation risk for hatchlings emerging from nests.	Out of scope – Not addressed within this report
Undertake appropriate marine fauna surveys to fill gaps identified above (*refers to the gaps identified within a desktop review of previous marine fauna surveys*).	Not adequate – Several limitations have been identified that influence the relevance of the surveys for informing EIA.	It is not clear why benchmark light studies were not conducted on the beach to the east of the jetty given that turtle nests were observed there.	**Section 2.1.1: Light Monitoring: Data Capture and Figure 1** Light monitoring was undertaken on the beach to the east of the jetty and data incorporated into a model.
Identify sources of noise and light (e.g. dock lights, jetty construction etc.) and ensure appropriate	Not adequate – The noise and light modelling have a	Noise and light from ocean going vessels have not been included despite being indirect impacts of the project.	**Section 2.2: Modelling** Light from transhipment vessel and ocean-going loading vessel were included as inputs into the model

Requirement	EPA Comment	Specific Query from EPA	Where addressed within this Report
mitigation/management/offset measures are in put in place. Undertake a light study (including current baseline and predicted) to characterise the potential changes to the light environment and the implications this may have on threatened turtles.	number of limitations in predicting impacts.	Noise and light management plans have not been included so it is not possible to ascertain whether they are appropriate in reducing impacts to the predicted level.	**Section 2.2: Modelling** Light from transhipment vessel and ocean-going loading vessel were included as inputs into the model **Section 2.1.1: Light Monitoring: Data Capture and Figure 1** Light monitoring was undertaken on the beach to the east of the jetty and data incorporated into a model.
		Not adequate – Light modelling has been undertaken but several limitations in the modelling approach may affect how representative the model is and likely result in an under estimation of potential impacts.	Out of scope – Not addressed within this report

Appendix B: Detailed Lighting Inventory

B1: UPDATED LIGHTING INVENTORY (2022)

Tables B1 – B3 outline the luminaires considered in the updated modelling assessment, including the quantity, height, spectral emission, and power (in lumens). Changes from the previous assessment (Pendoley 2020) primarily include the inclusion of the OGV (**Table B2**) and TSV (**Table B3**. Furthermore, conveyor lighting and safety lighting at the admin building has been removed and the number of general admin and jetty lights has been reduced. The inventory considered in the previous assessment is provided in **Section B2 – Table B4** for reference.

Table B1: Facility Lighting Inventory. * = excluded in Scenario 2.

Light Location	Description	Number	Height (m)	Spectrum	Power (lm)	Total Power (lm)
Jetty*	Jetty	20	14.5	3000K LED	1,500	30,000
Stacker and Reclaimer	Arms	10	20	3000K LED	1,500	15,000
Stacker and Reclaimer	Arms - safety	4	20	5000K LED	2,000	8,000
Stacker and Reclaimer	Body	12	15	3000K LED	1,500	18,000
Stacker and Reclaimer	Body - safety	10	15	5000K LED	2,000	20,000
Dumping Bridge	Top	12	15	3000K LED	1,500	18,000
Dumping Bridge	Spotlight	5	10	3000K LED	3,000	15,000
Dumping Bridge	Bottom	8	5	5000K LED	2,000	16,000
Admin	A1	40	3	3000K LED	1,500	60,000
Admin	A2	24	3	3000K LED	1,500	36,000
Admin	A3 (1)	8	3	3000K LED	1,500	12,000
Admin	A3 (2)	8	3	3000K LED	1,500	12,000
Wash Plant	Lighting	68	3	3000K LED	1,500	102,000
Wash Plant	Safety	7	3	5000K LED	2,000	14,000

Table B2: OGV Lighting Inventory.

Light Location	Description	Number	Height (m)	Spectrum	Power (lm)	Total Power (lm)
OGV	Deck lighting	4	20	3500K LED	4,800	19,200
OGV	Deck lighting	3	25	3500K LED	4,800	14,400
OGV	Deck lighting	5	30	3500K LED	4,800	24,000
OGV	Deck lighting	1	30	3500K LED	8,500	8,500
OGV	Floodlights	2	30	3500K LED	23,000	46,000
OGV	Walkway lighting	19	25	4000K LED	960	18,240
OGV	Walkway lighting	42	20	Cool White Fluorescent	4,000	168,000
OGV	Floodlights	12	20	HPS	47,000	564,000
OGV	Floodlights	4	30	HPS	47,000	188,000

Table B3: TSV Lighting Inventory.

Light Location	Description	Number	Height (m)	Spectrum	Power (lm)	Total Power (lm)
TSV	Deck Lighting	13	3	3000K LED	4,650	60,450
TSV	Deck Lighting	19	6	3000K LED	4,650	88,350
TSV	Deck Lighting	4	9	3000K LED	4,650	18,600

B2: PREVIOUS LIGHTING INVENTORY (2020)

Table B4: Previous Facility Lighting Inventory. Note: for reference only - not considered within this assessment.

Light Location	Description	Number	Height (m)	Spectrum	Power (lm)	Total Power (lm)
Jetty	Jetty	72	14.5	3000K LED	1,500	30,000
Conveyor	Conveyor	740	3	3000K LED	3000	2,220,000
Stacker and Reclaimer	Arms	10	20	3000K LED	1,500	15,000
Stacker and Reclaimer	Arms - safety	4	20	5000K LED	2,000	8,000
Stacker and Reclaimer	Body	12	15	3000K LED	1,500	18,000
Stacker and Reclaimer	Body - safety	10	15	5000K LED	2,000	20,000
Dumping Bridge	Top	12	15	3000K LED	1,500	18,000
Dumping Bridge	Spotlight	5	10	3000K LED	3,000	15,000
Dumping Bridge	Bottom	8	5	5000K LED	2,000	16,000
Admin	A1	160	3	3000K LED	1,500	240,000
Admin	A1 – Safety	16	3	5000K LED	2,000	32,000
Admin	A2	114	3	3000K LED	1,500	171,000
Admin	A2 – Safety	11	3	5000K LED	2,000	22,000
Admin	A3 (1)	32	3	3000K LED	1,500	48,000
Admin	A3 (2)	32	3	3000K LED	1,500	48,000
Admin	A3 (1) – Safety	3	3	5000K LED	2,000	6,000
Admin	A3 (2) - Safety	3	3	5000K LED	2,000	6,000
Wash Plant	Lighting	68	3	3000K LED	1,500	102,000