Latrobe Valley Battery Energy Storage System

Environmental Management Plan

Planning Permit No. PA2101132-1

(Condition 7 & 9)

February 2023

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 1 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Latrobe Valley Battery Energy Storage System

Document Title: Environmental Management Plan
Revision: Final
Date: 17/02/2023

Document History and Status

Revision	Date	Description	Author	Review	Approved
1st Draft	29/07/2022	EMP and CEMP as standalone documents	Eva Reda (EMP), Jasmin Pasic (CEMP)	Bob Anderson (Fluence) Eliza Budd (Tilt Renewables)	
2nd Draft	29/09/2022	Combined EMP and CEMP	Eva Reda (EMP), Jasmin Pasic (CEMP)	Bob Anderson (Fluence) Eliza Budd (Tilt Renewables)	
3rd Draft	20/01/2022	Combined EMP and CEMP	Eva Reda (EMP), Jasmin Pasic (CEMP)	Bob Anderson (Fluence) Eliza Budd (Tilt Renewables)	
Final	17/02/2023	Combined EMP and CEMP	Eva Reda (EMP), Jasmin Pasic (CEMP)	Bob Anderson (Fluence) Eliza Budd (Tilt Renewables)	Eliza Budd (Tilt Renewables)

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 2 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Tilt Renewables Australia Pty Ltd
ACN 101 038 331

GPO Box 16080
Collins Street West
Melbourne
Victoria, 8007
Australia

Phone: +61 3 9654 3066
tiltrenewables.com

Table of Contents

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 3 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 4 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Acronyms and Abbreviations

AusNet	AusNet Services Pty Ltd
BESS	Battery Energy Storage System
Council	Latrobe City Council
CEMP	Construction Environment Management Plan (contained within this Plan)
DELWP	The Department of Environment, Land, Water and Planning
The Development	The Latrobe Valley BESS
The Development – Stage 1A	The Northern BESS facility (100MW/200MWh) of the Latrobe Valley BESS
The Development – Stage 1B	The Northern BESS facility (200MWh expansion of the Development - Stage 1A) of the Latrobe Valley BESS
The Development – Stage 2	The Southern BESS facility of the Latrobe Valley BESS
EMP	Environmental Management Plan (this Plan)
Fluence	Fluence Energy Pty Ltd
LVBS	Latrobe Valley Battery Energy Storage System
MWTS	Morwell Terminal Station
The Operator	Latrobe Valley BESS Project Trust as Trustee for Latrobe Valley BESS Hold Trust
the Planning Permit	Planning Permit No. PA2101132-1
P&E Act	*Planning and Environment Act 1987*
The Responsible Authority	The Minister for Planning (VIC)
Tilt Renewables	Tilt Renewables Australia Pty Ltd
VIC	Victoria

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 5 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

1.0 Introduction

1.1 Background

The Latrobe Valley Battery Energy Storage System (BESS) (the Development) is located in Morwell, Victoria, south of the Princes Freeway and adjacent to the existing Morwell Terminal Station (MWTS). The Development is being developed by Tilt Renewables Australia Pty Ltd (the Operator).

The Planning Permit was granted by the Minister for Planning (VIC) under the *Planning and Environment Act 1987* (P&E Act) on 16 November 2021, and an amendment to the Planning Permit approved on 24 June 2022 (the Planning Permit). The Planning Permit allows for the development of two separate BESS facilities, being the Northern BESS and Southern BESS and includes the associated works within the MWTS, including installation of a new 66/33 kv transformer. The Operator is developing the Development in stages, commencing with the Northern BESS (the Development - Stage 1A), with the potential for a 200MWh expansion (the Development - Stage 1B) at a later date. The Southern BESS (the Development - Stage 2) will also be developed at a later date.

This Environmental Management Plan (EMP) addresses the requirements of Condition 7 (Environmental Management Plan) and Condition 9 (Construction Environment Management Plan) of the Planning Permit. All reasonable and feasible measures as outlined in this EMP will be implemented as part of the Development.

In accordance with Condition 2 of the Planning Permit, the use and development will be generally in accordance with the endorsed EMP. In accordance with Condition 3 of the Planning Permit, the Development may be completed in stages in accordance with the endorsed development plans including any obligations under the Planning Permit.

1.2 Overview of the Development – Stage 1A

The main components of the Development – Stage 1A are as follows:

- A 100 MW / 200 MWh BESS facility, using the Fluence Gridstack storage system, including:
  - Battery module enclosures (“Gridstack cubes”)
  - Inverters
  - 33 kV/690 V transformers
  - Auxiliary transformers
  - Switchboard kiosks
  - A new access track connecting from the shared access road off Monash Way to the BESS site
  - Drainage infrastructure
  - Firefighting infrastructure
  - Other infrastructure including site office, relay room, toilet block, spares container and permanent car parking
- Connection asset works at MWTS, including:
  - New 66/33kV transformer, including associated infrastructure
- Temporary construction compound and laydown area

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 6 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The general layout of the Development is shown on Figure 1:

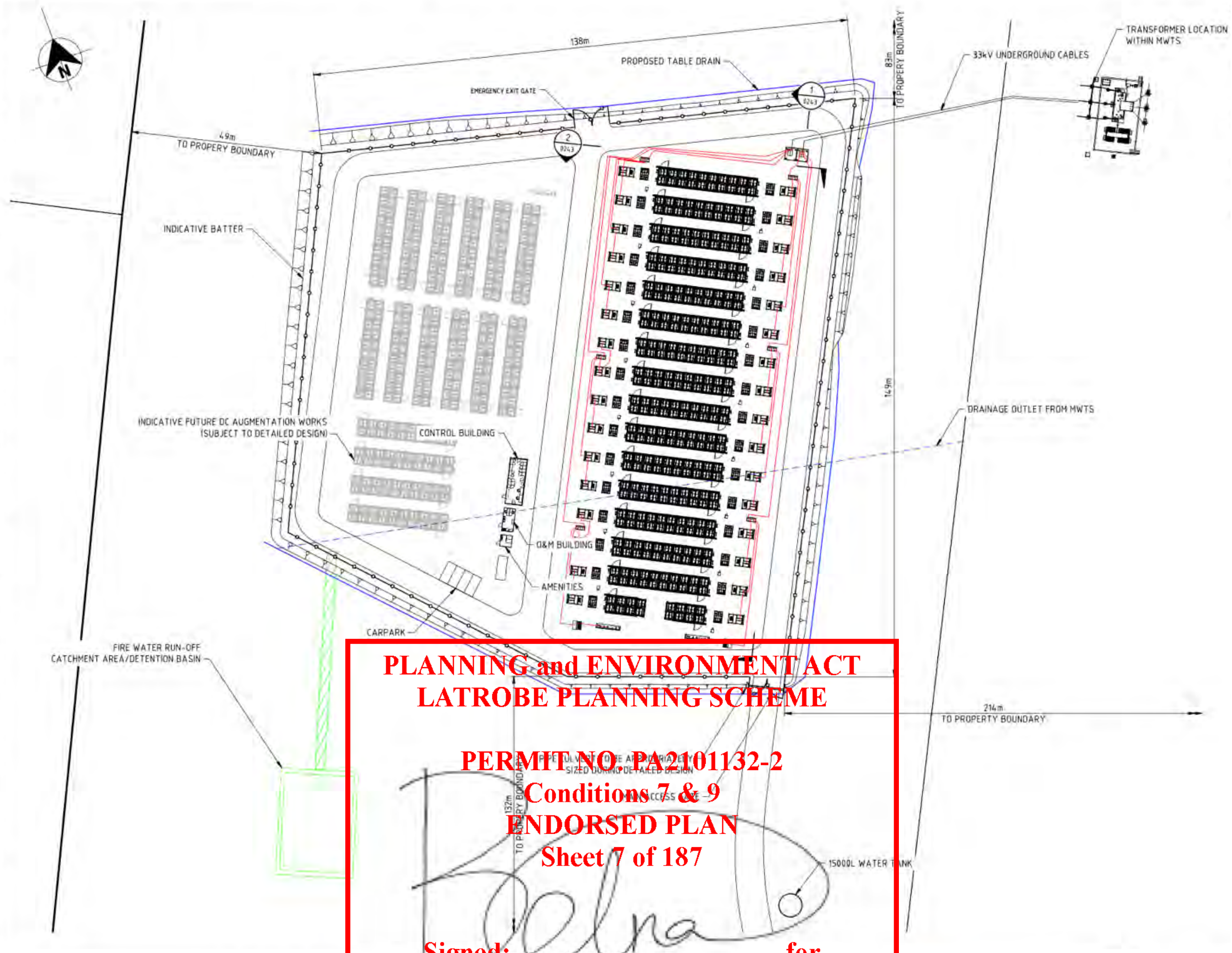


Figure 1 - Latrobe Valley BESS - Northern BESS Layout

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 7 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

1.3 Purpose of the Environmental Management Plan

The purpose of this EMP is to meet the Development's environmental due diligence requirements in accordance with the Planning Permit and all other relevant policies and legislation. This EMP outlines avoidance, mitigation, monitoring and administrative control measures in order to eliminate adverse impacts to the environment and human health during the construction and operation of the Development.

This EMP has been prepared by Acacia Environmental Management Pty Ltd.

Details of Condition 7 (Environmental Management Plan) and Condition 9 (Construction Environment Plan) of the Planning Permit to be addressed as part of this EMP is contained in Table 1 and Table 2 respectively.

Table 1 – Planning Permit Condition 7 (Environmental Management Plan)

Requirement	Where addressed in this EMP
7. Before development starts, excluding site preparation works, an Environmental Management Plan (EMP) must be submitted to, approved, and endorsed by the Responsible Authority. Once endorsed, the EMP will form part of the permit. The EMP must include:	Section 2
a. Measures to avoid and minimise amenity and environmental impacts during the operation of the BESS facility.	Section 2.1
b. Measures to mitigate any consequential impacts on native vegetation retained on and off site, including tree protection zones where necessary.	Section 2.1.1

Requirement	Where addressed in this EMP
c. Design measures and/or procedures to manage dust, odour, light spill, mud, flood, surface water quality and stormwater runoff.	Section 2.1.9 - 2.1.12
d. Procedures for weed management and control prior to construction and post construction that do not risk causing offsite soil contamination.	Section 2.1.14, 3.1.4
e. Vehicle and equipment hygiene measures to prevent the spread of weeds and pathogens to, from and within the site.	2.1.13 – 2.1.14
f. Fuel load management measures that are to be implemented including but not limited to vegetation management and possible grazing opportunities.	2.1.8
g. Any other measures to address the requirements of the CFA's Guidelines for Renewable Energy Installations.	2.1.8
h. Measures to manage, monitor and review erosion and control sediment-laden runoff.	2.1.11
i. Response measures to environmental incidents.	2.2.1
j. A program for recording and reporting environmental incidents.	2.2.2
k. The persons responsible for implementing the above measures, including procedures for staff training and communication.	2.3

Table 2 – Planning Permit Condition 9 (Construction Environment Management Plan)

Requirement	Where addressed in this EMP
9. The EMP must include a Construction Environment Management Plan (CEMP), which must include:	Section 3
a. Measures to avoid and minimise amenity and environmental impacts during the construction of the BESS facility	Section 3.1
b. Procedures to manage construction noise and vibration in accordance with the requirements of the Noise Control Guidelines (EPA Publication 1254) and the Environmental Guidelines for major construction sites (EPA Publication 480).	Section 3.1.6
c. Erosion and sediment control measures to ensure that no polluted and/or sediment laden runoff or other stormwater is discharged directly or indirectly onto adjoining land or into drains, watercourses or wetlands.	Section 3.1.7
d. Procedures to manage any dust emissions.	Section 3.1.7
e. Vehicle and equipment hygiene measures to prevent the spread of weeds and pathogens to, from and within the site.	Section 3.1.4
f. Locations of any construction waste storage and the method of storage and disposal.	Section 3.1.9
g. Appropriate stockpile and storage area management	
h. The location of any temporary buildings or works and procedures to remove these and reinstate the affected parts of the land when construction is complete.	Section 3.1.7
i. Measures to protect native vegetation being retained on site and in the vicinity of the subject land, including tree protection zones during and post construction. These measures must include: i. The erection of a native vegetation protection fence around all native vegetation to be retained on site and on any adjoining road reserves; and ii. The tree protection zones of all native trees to be retained and this to be marked on plan(s). All tree protection zones must comply with AS 4970-2009 Protection of Trees on Development Sites;	Section 3.1
j. A construction timetable, including typical daily start and end times.	Section 3.3
k. Road maintenance measures to be put in place for Monash Way to ensure its condition does not deteriorate during the construction phase of the project.	Section 3.1.4
l. Procedures to manage mud and debris on the surrounding road network which may occur during construction.	Section 3.1.7
m. Monitoring requirements for the rehabilitation/revegetation works and any vegetation/tree	Section 3.1.1, 3.1.2, 3.2

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 8 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Requirement	Where addressed in this EMP
protection areas being retained on site.	
n. The persons responsible for implementing the above measures, including details of a site contact/site manager.	Section 3.2

1.4 Legislation, Guidelines and Standards

Legislation

Legislation relevant to environmental management includes:

- *Catchment and Land Protection Act 1994* (CaLP Act)
- *Environmental Effects Act 1978*
- *Environment Protection Act 2017*, including *General Environmental Duty* and associated Environmental Protection Authority (EPA) Guidelines
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- *Environment Protection (Industrial Waste Resource) Regulations 2009*
- *Flora and Fauna Guarantee Act 1988* (FFG Act)
- *Planning and Environment Act 1987*
- *Wildlife Act 1975*

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 9 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Guidelines and Standards

Key guidelines, specifications, and policy documents relevant to this EMP include:

- AS 4282 Control of the obtrusive effects of outdoor lighting
- AS 4970-2009 Protection of Trees on Development Sites
- Environmental Guidelines for major construction sites (EPA Publication 480)
- Design Guidelines and Model Requirements for Renewable Energy Facilities (Country Fire Authority, 2022)
- Noise Control Guidelines (EPA Publication 1254)
- Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues (Noise Protocol)' (EPA Publication 1826.4)
- Waste Classification Assessment Protocol (EPA Publication 1827.2)

1.5 Existing Environment

A site visit was conducted on 25th July 2022 to gather contextual information.
The Development is located in the Latrobe Valley region of Gippsland, Victoria, approximately 150 km east of Melbourne. The project area is currently designated Industrial Zone (IN1Z) located within the Gippsland Plains bioregion, the West Gippsland Catchment Management Authority, and the Latrobe Local Government area.
The project site is comprised of vacant industrial land, with vegetation primarily consisting of exotic pasture grasses. The landscape is low relief, with a major drainage line traversing the site west from the MWTS, and a secondary channel joining it from the south-east; these feed into Bennett's Creek located on the site's western boundary.

The site also supports scattered patches of various aquatic habitats, including small farm dams, shallow drains, and low-lying sections of the property which contained sitting water and aquatic vegetation. A screening planting of native trees (Eucalyptus and Allocasuarina sp.) are present in the east of the project site, adjacent to the MWTS. A number of noxious weeds were also observed onsite, including a severe African Boxthorn infestation under the screening planting.

Figure 2 - The project site is vacant industrial land consisting mainly of exotic pasture grasses, with some scattered native aquatic habitats and drainage lines.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 10 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.0 Environmental Management Plan: Operational Phase

2.1 Environmental Management Requirements

In accordance with the legislation outlined in Section 1.4, all parties involved in the operation of the Northern Latrobe Valley BESS must take all reasonable and practicable steps to prevent and/or minimise any material harm to human health and the environment.
Environmental compliance will be managed on-site through implementation of the specific environmental procedures and control measures listed below. These address relevant potential environmental impacts arising from the project's operational phase, including all conditions in Condition 7 of the Planning Permit PA2101132-1.

2.1.1 Native Vegetation

The Latrobe Valley BESS Detailed Ecology Assessment (Aurecon, 2021) found that while the site is dominated by introduced pasture grasses, it also supported seven patches of native vegetation that provided low to moderate quality habitat, along with one scattered tree south of the MWTS. Of these, four habitat zones (HZ) and the scattered tree lie within or close to the footprint of the Northern BESS site.
These are mapped in Appendix A and include:

- Three patches of aquatic habitat (HZ 1, 4 and 5)
- One linear patch of native grassland (HZ 6)
- One large scattered Gippsland Red Gum, immediately south of the MWTS

Targeted surveys concluded a low likelihood of the occurrence of any federally or state protected flora in the project footprint.

⇒ *Control Measures*

- Native vegetation (**Appendix A**).must not be disturbed, trampled on, littered or polluted in any way, or used for any operational activities (such as material storage).
- If any damage occurs to native vegetation as a result of BESS operation, the appropriate environmental representative will be notified so that remediation strategies can be developed.
- Car parking, storage of heavy items, or storage of any material with the potential to contaminate or pollute soil, is prohibited within the structural root zone (SRZ) of the large Gippsland Red Gum. The SRZ is defined as a radius of 3.14m from the tree's trunk (calculated using Diameter at Breast Height 0.8m and Diameter at Buttress 0.88m). The SRZ can also be approximated by avoiding any ground directly below the tree's canopy. Optional permanent fencing can be installed as a tree protection zone if there is any likelihood of operational activities encroaching on the root zone.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 11 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.1.2 Fauna

Targeted surveys concluded a low likelihood of the occurrence of any federally or state protected fauna in the project footprint, however, site inspections confirmed a range of indigenous wildlife was using the site as habitat. While BESS operational impacts to biodiversity are anticipated to be minimal, due to its use as habitat for local wildlife, some general recommendations apply to the site.
Fencing used onsite must comply with relevant Australian fencing safety standards. However, the use of barbed wire fencing poses a threat to native wildlife (e.g. birds, bats, possums) by entanglement. Sections of barbed wire fencing positioned adjacent to native vegetation should have increased visibility and be monitored daily for trapped fauna. As the BESS will be unmanned during the operational phase, daily monitoring should be undertaken via existing surveillance systems installed around the perimeter of the facility.

⇒ *Control Measures*

- Native wildlife must not be disturbed in any way, including feeding or handling.
- Barbed wire fencing should be remotely inspected daily for trapped wildlife via existing surveillance systems. In the event that an animal is found injured on-site, a local wildlife carer should be contacted to advise on next steps. Wildlife rescuers can be contacted at Wildlife Victoria, (03) 8400 7300.
- Barbed wire fencing immediately adjacent to native vegetation should have improved visibility to wildlife, as long as these measures comply with relevant Australian Fencing Standards. This includes installing visible (and often audible) objects to the top strand, including flagging tape, plastic flags or metal tags.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 12 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2025

2.1.3 Noise

Condition 11 of the Planning Permit stipulates that all land use must comply with the EPA's Environmental '*Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues (Noise Protocol)*' (EPA Publication 1826.4).
The submitted Noise Impact Assessment (Aurecon 2021) identifies noise generating equipment across the entire Project site, including operations both within the BESS site and the MWTS. Identified noise sources include a 66/33 kV (150 MVA) Step-Up Transformer, Battery Containers (HVAC) and Invertor Containers. Overall sound power levels were derived from *AS 60076.10:2009 – Power transformers – Determination of sound levels* and combine noise generated from both the 33 kV BESS-side and 66 kV MWTS-side transformer components. The nearest identified Noise Sensitive Area (NSA) is located in a Farming Zone (FZ), 1900m away (Table 2). The assessment predicts the Latrobe Valley BESS will operate at 32 $dBL_{Aeq,30mins}$, which is 1 dB less than the project noise goal of 33 $dBL_{Aeq,30mins}$ based on the NIRV Recommended Maximum Noise Levels minus 10 dB. As such, the project will not require any permanent noise attenuation. Some general noise reduction recommendations therefore apply to this project.

Table 2 - Pre-construction Noise Impact Assessment (Aurecon 2021).

Equipment (Northern Site)	Predicted sound pressure level at NSA dBLAeq,30mins
33/66 kV Step-up Transformer	21
Inverters	24
Battery Containers	24
Total	32

The submitted Environmental Noise Assessment (Sonus, 2023) considers the noise at the dwellings located in proximity to the Latrobe Valley BESS and the associated 66 kV transformer within the MWTS. The assessment has been based on the final design layout and all electrical components of the facility, and has considered criteria determined in accordance with the Environment Protection Regulations 2021, and the Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues.

Based on the assessment of the proposed Latrobe Valley BESS, the noise requirements of the Noise Protocol will be achieved at all nearby residences. Mitigation measures are therefore not required to be implemented to achieve compliance with the Noise Protocol.
Additionally, Conditions13 and 14 of the Planning Permit stipulate that a Post-Construction Acoustic Assessment Report must be prepared 1 month and then 1 year after the commencement of use, by a suitably qualified acoustic engineer and submitted to the Responsible Authority. The report will assess compliance with the Noise Protocol and, where necessary, make recommendations to limit the noise impacts.

⇒ *Control Measures*

- Where reasonably practicable, noisy activities, including vehicle movements, should be minimised outside of standard hours by all staff. The standard Victorian daytime operating hours for commercial, industrial and trade premises are Monday to Saturday (excluding public holidays) from 7 am to 6 pm (source: EPA).
- Land use must comply with the EPA's Environmental 'Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues (Noise Protocol)'
- Post-Construction Acoustic Assessment Reports must be prepared 1 month, and then 1 year, after the commencement of use, by a suitably qualified acoustic engineer and submitted to the Responsible Authority. The report will assess compliance with the Noise Protocol and, where necessary, make recommendations to limit the noise impacts.

2.1.4 Dust

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO.: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 13 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

An unsealed access track will be constructed to link the BESS site to Monash Way. Frequent vehicle usage or high winds over extended hot and/or dry conditions may lead to the liberation of dust from this access track, which may lower air quality and can cause respiratory issues in exposed people and wildlife when generated in excessive amounts.

If excessive dust appears to be generated on-site and is visibly reaching a sensitive receptor and causing a health or environmental hazard, dust suppression measures should be undertaken.

⇒ *Control Measures*

- Water should be applied to the access track as a dust suppressant when required, as determined by the site supervisor. This may be applied via a water cart, sprinklers or a hand held hose.

2.1.5 Odour & Emissions

As batteries do not emit gasses during standard operation, the BESS site is not anticipated to produce any gasses, vapours, particulates, or odours that would significantly impact air quality or local amenity. As such, only basic control measures need to be implemented.

⇒ *Control Measures*

- In the event of any irregular/unexpected smoke or gas being detected (by sight or smell) to be emitted by the BESS, the environmental representative will be notified immediately so that response and mitigation strategies can be developed.

2.1.6 Light Spill

Light pollution can arise from the intrusion of excessively bright or poorly-directed lights onto neighbouring properties and/or the natural environment, either through direct illumination or by creating sky glow. This can have impacts on local amenity, and the health of native fauna by interrupting behavioural patterns and causing physiological stress. Light sensitive receptors may include nearby farm properties, native vegetation and its resident wildlife, and nocturnal wildlife using the airspace above the site (e.g. birds, bats, invertebrates). Research also indicates that light in the ultraviolet and blue end of the spectrum may be particularly disruptive to fauna (DEE, 2020).
Condition 10 of Planning Permit PA2101132 stipulates that all lighting installed and operated at the site must comply with *AS 4282 Control of the obtrusive effects of outdoor lighting*.

The Department of Energy and Environment (DEE) have published *National Light Pollution Guidelines for Wildlife* (2020; **Appendix C**); the suggested control measures will be included below. The Institute of Lighting Professionals (ILP) have published *Guidance Note 1 for the reduction of obtrusive light (2021)*, a document outlining useful practical recommendations for light installation (**Appendix D**). This document can be used in conjunction with the Australian Standards and guidelines to inform environmentally sensitive lighting design on-site.

⇒ *Control Measures*

- On-site lighting must be compliant with *Australian Standard 4282 Control of the obtrusive effects of outdoor lighting* **(Appendix C).**
- Sensitive lighting design should consider *National Light Pollution Guidelines for Wildlife* and *Guidance Note 1 for the reduction of obtrusive light* **(Appendix D).**
- Lighting should only be installed where necessary and should be the lowest intensity for the task required
- Use narrow beam lighting to illuminate only the areas required
- Use lights with reduced or filtered blue, violet and ultra-violet wavelengths
- Lights should be installed as far away as possible from sensitive receptors, have the highest practicable mounting height and point downward and away from receptors where possible
- For signage, use direct down-lighting and avoiding up-lighting
- Minimise glare by ensuring main beam angle from luminaries to observer does not exceed 70°, and using dark coloured and non-reflective architectural finishes, and non-reflective ground surfaces in illuminated areas e.g. near administrative buildings or BESS infrastructure
- Use adaptive light controls to manage light timing, intensity and colour
- Use existing landscape features to screen the light source from sensitive receptors
- If lights can't be pointed downwards, shields and baffles should be installed to keep light spill to a minimum

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 14 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.1.7 Waste Management

The *Environmental Protection Act 2017* provides a framework for the management of industrial waste. The EPA also sets out laws about managing industrial waste in the *Environment Protection (Industrial Waste Resource) Regulations 2009*. Waste must be sorted by the EPA's *Waste Classification Assessment Protocol (Publication 1827.2)* and managed according to its classification.

The operation of the BESS will produce end-of-life Lithium-ion battery waste. Li-ion batteries are Class 9 dangerous goods under the Australian Dangerous Goods Code and thus are classified as Priority Waste (EPA waste classification: e-waste, waste code T300) to which waste duties apply. As end-of-life processing will be undertaken by the battery supplier, waste batteries will not be stored onsite, hence no significant environmental risks are posed by waste batteries during BESS operation.

To guarantee this, the operations contractor shall ensure any waste processing obligations are specified within contracts with the battery unit supplier prior to operations commencing.

All waste should be managed according to the EPA's 'waste management hierarchy,' listed in order of preference:

⇒ *Control Measures*

- Where the generation of waste can be avoided this option shall be pursued (i.e. delivery of batteries pre-assembled to avoid packaging waste)
- Where possible disused items shall be recovered or repurposed for continued use
- Where waste generated on site cannot be recycled, it must be separated into categories according to the EPA's '*Waste Classification Guidelines*' (EPA, 2014), stored correctly and disposed of at licensed facilities according to the type of waste (i.e. batteries will be returned to technology suppliers for appropriate processing at end-of-life).
- Waste battery processing obligations of the battery supplier are to be specified in contracts with the supplier prior to operations commencing
- Adequate rubbish and recycling bins must be placed in convenient locations for use by site staff, and waste removed from site as soon as practicable.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 15 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.1.8 Fuel Load Management

Battery energy storage systems present a fire ignition risk to the surrounding environment through potential electrical and chemical hazards present during operation. BESS infrastructure may also be at risk of external ignition from bushfire (e.g. grassfires). Due to its highly cleared industrial surroundings, the Development is a Low Risk Environment and not designated as a Bushfire Prone Area or subject to any Bushfire Management Overlays.

Condition 53 of the Planning Permit outlines a set of requirements to mitigate fire risk by managing fuel loads and establishing fire breaks, based around recommendations published in *Design Guidelines and Model Requirements for Renewable Energy Facilities* (CFA, 2022).

The Planning Permit also requires a Risk Assessment, Risk Management Plan, and Fire Management Plan for the Latrobe Valley BESS to be submitted as standalone reports. These should form the basis of all fire management actions.
For the period that cattle grazing continues on-site during the operational phase of the project, it presents a convenient method of ongoing fuel load management through keeping grass at a minimum height. Grass must otherwise be kept below 100mm height during Fire Danger Periods.

⇒ *Control Measures*

- Refer to Fire Risk Management Plan for comprehensive fuel load control measures
- A fire break area of at least ten (10) metres width must be maintained around the perimeter of the facility.
- There will be a 10m APZ (asset protection zone) maintained from the facility fence to the nearest equipment i.e. within the perimeter.
  - ⇒ The width of the fire break must be scaled to the risk of surrounding vegetation, including screening vegetation.
  - ⇒ The fire break must commence from the vegetation screening inside the property boundary
  - ⇒ Fire breaks must be constructed using either mineral earth or non-combustible mulch such as crushed rock.
  - ⇒ Fire breaks must be free of vegetation, including grass, at all times, and free of all combustible and extraneous materials at all times (e.g., this area must not be used for the storage of materials or the placement of infrastructure of any kind).

- Grass within the facility must be maintained at below 100mm in height during the declared Fire Danger Period. Cattle grazing can present a low-effort means of minimising grass height.
- There must be a clearance of at least 2 metres between the lowest branches and ground level within the vegetation screening (landscape buffer) zone.
- Staff will have access to and be familiar with the Fire Risk Management document
- Staff must be aware and trained in emergency response procedures, as per the Emergency Response Plan which will be available at the Emergency Information container located at the entrances to the site
- Staff must be made aware of the location of fire water storage tanks, which will be located south of the BESS site (**Appendix F**)

Surface Water Quality Measures

Operators of the Latrobe Valley BESS are required to ensure that the energy storage system and ancillary infrastructure are operated and maintained to reduce impacts to catchment water quality that may arise through the pollution of any surface water, stormwater and floodwater associated with the site.

2.1.9 Flood

A hydrology and flood risk assessment (Aurecon 2021) found that the Development is prone to minor local flooding, particularly at the northern boundary of the site. To protect the environment from pollution in the event of a flood, any hazardous materials must be fixed a minimum of 0.6 metres above the nearest applicable 1% AEP flood level as defined by the *Proposed Condition 1% AEP Event – Maximum Flood Level (m AHD) in the Latrobe Valley Battery Energy Storage System (BESS) Tilt Renewables Desktop Hydrology and Flood Risk Assessment – Phase 2*.

To minimise flood risk, drainage lines on site should also be regularly inspected to ensure sediment accumulation or other blockages would not impede their functioning at times of high rainfall.

⇒ *Control Measures*

- All hazardous materials must be fixed a minimum of 0.6 metres above the nearest applicable 1% AEP flood level.
- Regularly inspect drainage lines for sediment accumulation or blockages, and clear material build-up where necessary.

2.1.10 Stormwater Runoff

Under Condition 32 of Planning Permit PA2101132, a Stormwater Management Plan (SMP) must be endorsed in writing by the WGCMA. The SMP will outline measures to ensure all stormwater discharge from the development will meet the *Urban Stormwater Best Practice Environmental Management Guidelines* (CSIRO, 1999). The SMP should be referred to for all control measures relating to stormwater runoff.

⇒ *Control Measures*

- Refer to the Stormwater Management Plan for comprehensive stormwater control measures

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 16 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.1.11 Erosion & Sediment Control

Erosion and sedimentation pose risks to the surrounding environment and local amenity through the transport of soil or other particulate matter away from its place of origin and its deposition onto other land surfaces or into water bodies. This can adversely impact water quality, thereby harming aquatic organisms, by reducing light penetration, actively smothering organisms, or introducing excess nutrients which encourage toxic algal blooms.

It is incumbent on the development to ensure that no nearby waters, including Bennett's Creek, experience sedimentation as a result of the project.

The presence of the BESS facility is anticipated to slightly increase impermeable surfaces in the landscape, which would lead to an overall increase in surface water runoff and potentially increased erosion risks.

However, the site area is relatively small compared to total catchment size, and is flat with water-retaining properties such as high vegetation coverage and the presence of small water bodies that can limit the speed of any moving water which may displace particulates. The site inspection showed no signs of past or current erosion taking place. As such, the project is unlikely to result in significant impacts to local hydrology and surface water quality during its operation.

At the time of writing, final drainage designs were not available, however any features such as settling ponds, drainage lines, or sediment filters, should be maintained and monitored to prevent sediment accumulation.

⇒ *Control Measures*

- Vegetation (e.g. grasses) should be retained and encouraged to colonise any areas of bare soil surrounding the facilities as it provides the easiest and most effective means of erosion control. Additional creekline revegetation outlined by the Waterway Management Plan will further reduce erosion risk.
- Erosion and sediment control features (e.g. settling ponds, drainage lines) should be maintained and monitored to prevent sediment accumulation.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 17 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.1.12 Mud

Excess mud or soil deposited on ground surfaces (e.g. by dirty vehicles) can adversely impact water quality by entering waterways during times of heavy rainfall. It is therefore important that all vehicles entering the site are in a clean condition and that significant amounts of mud are not transported or tracked onto the site ground surfaces e.g. access paths, car parks.

⇒ *Control Measures*

- All vehicles entering/leaving site shall be clean and free of accumulated mud/soil, and no significant amounts of dirt or mud shall be transported or tracked onto the site ground surfaces (e.g. access paths, carparks).
- Appropriate equipment for maintaining good vehicle hygiene must be accessible on site when needed. This may include wash down bays, a regular or high-pressure hose for caked-on mud, an air blaster for dust.

Biosecurity Measures (Section 2.1.13 to 2.1.14)

Operators of the Latrobe Valley BESS are obligated to ensure that noxious plant or pathogen species are not introduced to/spread from the site as a result of works. This will be achieved through appropriate weed control and vehicle hygiene.

2.1.13 Vehicle Hygiene

Without appropriate biosecurity measures in place, pathogens that pose environmental and/or agricultural risks (e.g. Dieback, *Phytophthora cinnamomic*) can be spread to and from sites by being transported in mud or soil attached to project-related vehicles. It is therefore important that all vehicles entering or leaving the site are in a clean condition and that no dirt or mud are transported or tracked onto the sealed public road network.

⇒ *Control Measures*

- All vehicles entering/leaving site shall be clean and free of accumulated mud/soil. Furthermore, all the dirt or mud transported or tracked onto the sealed public road network shall be cleaned.
- Appropriate equipment for maintaining good vehicle hygiene must be accessible on site when needed. This may include wash down bays supplied with disinfectant, a regular or high-pressure hose for caked-on mud, an air blaster for dust.
- Any vehicles, footwear or equipment that have come from an area known to harbour any restricted soil-borne pathogen (especially if they have been off-road within these locations), shall be required to apply Phytoclean or similar bleach-based product to all surfaces which may come into contact with the ground as a precautionary measure. The rate for vehicle application is 200ml Phytoclean/10L water. The rate for footbath application is 1L Phytoclean/10L water.

2.1.14 Weed Management

Noxious weeds that pose significant environmental or agricultural threats are classified and regulated under the *Catchment and Land Protection Act 1994* (CaLP Act). The CaLP Act provides a legislative framework for the management of private and public land across regions of Victoria, requiring landholders to take all reasonable steps to eradicate 'regionally prohibited weeds,' and to stop the growth and spread of 'regionally controlled weeds' on their land.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 18 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 3 - Infestations of noxious weeds such as African Boxthorn (Lycium ferocissium) were observed onsite and must be controlled during the operational phase of the BESS..

A list of the noxious weeds observed on site, and legal obligations for their control under the CaLP Act, is summarised in **Table 3**. While the majority of weed management will be completed before the commencement of BESS operation, regular monitoring should be undertaken to determine the continued presence of noxious weeds and consequent frequency of follow-up treatments. Weeds must be controlled across the extent of the property, including areas not in the direct vicinity of the project footprint; this will also reduce the need for follow-up weed control by reducing seed spread into the BESS site. Weed control should be undertaken by qualified land management contractors.

Table 3 *- List of noxious weeds observed onsite and their CaLP status*

Common Name	Scientific Name	CaLP Status - West Gippsland	Requirement
African Boxthorn	*Lycium ferocissimum*	Regionally controlled	Stop spread
Artichoke thistle	*Cynara cardunculus*	Regionally prohibited	Eradicate
Blackberry	*Rubus fruticosus sp. agg.*	Regionally controlled	Stop spread
Cape Broome	*Genista monspessulana*	Regionally controlled	Stop spread
Patterson's Curse	*Echium plantagineum*	Regionally controlled	Stop spread
Scotch Thistle	*Onopordum acanthium*	Regionally controlled	Stop spread
Spear Thistle	*Cirsium vulgare*	*Regionally controlled*	Stop spread
Sweet Briar	*Rosa rubiginosa*	*Regionally controlled*	Stop spread

Weeds can also be introduced to/spread from the site by the presence of seeds, plant matter or contaminated soil on personnel clothing, footwear, vehicle bodies, and tyres. As such, appropriate vehicle and footwear hygiene should be maintained by all personnel (see section 2.1.13).

⇒ *Control Measures*

- Routine monitoring for the presence of CaLP listed weeds on-site should be conducted by the environmental representative. A comprehensive list of controlled weeds can be sourced from Agriculture Victoria. Any incidental observations by other personnel should be reported to the environmental representative
- Weed control should be carried out as needed by a suitably qualified contractor. All resultant green waste should be removed from site and taken to a licenced waste facility.
- Appropriate vehicle hygiene measures shall be undertaken in accordance with Section 5.7.1.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 19 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.2 Incident Management Requirements

2.2.1 Environmental Incident Response

Incidents that threaten human health and/or the environment should be responded to in proportion to their potential impact.

Emergencies

Any sudden disaster or accident that causes or threatens to cause severe harm to human health or damage to property or the environment is classified as an emergency and requires immediate action to limit its impact e.g. fire, flood, sudden large-scale loss of containment.

Emergency situations should have been identified through the risk assessment procedure, and have an emergency response plan in place, which must be implemented.

Under Condition 58 of the Planning Permit, an Emergency Management Plan must be developed for the entire Project site (including BESS facilities and MWTS) in conjunction with the relevant fire authority for:

I. Bushfire/grassfire
II. Electrical infrastructure faults and fire
III. BESS damage or faults, including battery monitoring faults, temperature increases above normal operating parameters, electrical faults, chemical spills or reactions, off-gassing, thermal runaway, smoke and fire

Emergency information and procedures will be familiar and available to staff, located at the Emergency Information Container installed at each road entry to the site.

All emergencies must be reported after the incident has been responded to (see Section 6.2).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 20 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Non-emergency incidents

Other incidents should be responded to as soon as reasonably practicable, and in accordance with relevant documentation e.g. Safety Data Sheets, EMP. Guidance from the Environmental or OH&S Representative should be sought where needed. All incidents should be reported (see section 6.2).

2.2.2 Incident Recording & Reporting

Reporting to the EPA

Under Section 32 the *Environmental Protection Act* (2017), there is a duty to notify the Authority of notifiable incidents. A pollution incident must be reported to the EPA if it causes or threatens a significant adverse effect on human health and/or the environment (examples are leaks, spills, unintended/unauthorised deposits). This obligation applies even when the incident is contained, and even if actual harm didn't eventuate. The person who conducted the activity has the responsibility to report it.

Notifiable incidents include:

- Uncontrolled or unplanned releases that can cause material harm
- Release of a material that is considered dangerous or toxic
- A substance that is harmful to water or land in large quantities (e.g. surfactants and organic material)
- The material is a 'substance of concern' in the *Environment Protection Regulations 2020*
- The clean-up would cost $10,000 or more

In the event of a notifiable incident occurring, the EPA must be contacted on 1300 372 842 (24 hours), who will ask for details of the incident. An incident report form will be e-mailed and must be submitted within five business days.

In-house Reporting

Incidents that are not notifiable incidents but still pose a risk to human health and the environment should be reported and managed through an in-house incident reporting system. This can be used to record:

- Environmental damage
- Injuries and accidents
- Near misses
- Health and safety issues
- Environmental/safety protocol breaches and misconducts in the worksite

The process of incident reporting should involve:

- Employee recording details of an incident (including time, location, personnel and witnesses involved, description of the event, injuries/damage caused, responses taken)
- OH&S team investigating an event to determine its possible causes
- OH&S team documenting any corrective actions taken
- OH&S team analyse the event to eliminate/reduce future risks by implementing the hierarchy of controls, and to determine potential uncontrolled hazards on the worksite
- OH&S representative communicates the incident, response and any resulting changes to work procedures to stakeholders and other relevant personnel

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 21 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.3 Personnel Requirements – Operational Phase

2.3.1 Staff Competency, Training & Awareness

All personnel engaged in on-site works during the operation phase of the Latrobe Valley BESS shall:

- Hold the required competencies relevant to their work
- Undertake a site induction before commencing any works, in which they are made aware of any environmentally sensitive areas (e.g. native vegetation) and environmental protocols e.g. vehicle hygiene, waste storage locations, use of spill kits
- Comply with site biosecurity protocols inclusive of vehicle cleanliness and external treatments
- Be made aware of the prescribed site activity hours for works to occur
- Be made aware of and have easy access to the Environmental Management Plan, and any other related documents including all Risk Management Plans
- Be trained in the incident reporting and response procedures and be aware of their personal environmental responsibilities
- Have access to emergency numbers and be familiar with emergency response plans

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 22 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2.3.2 Personnel Responsibilities – Operational Phase

A summary of recurring actions and monitoring requirements during the operational phase, and the responsible parties, are listed below:

Table 3 - Summary of reporting requirements and responsibilities

Frequency of Check	Detail	Responsible Party
Ad-hoc	Barbed wire fencing to be monitored remotely for trapped wildlife via site surveillance systems	Operations Site Manager
	Ensure all personal vehicles and equipment free of mud, soil, plant matter	All employees
Weekly	Erosion and sediment controls inspected to ensure no excessive accumulation of sediment has taken place.	Operations Site Manager
Monthly	Inspect site for presence of noxious weeds	Operations Site Manager
As required	Water to be applied as dust suppressant when access track visibly generating dust that impacts sensitive receptors	Operations Site Manager
	Operational noise monitoring to confirm predicted noise levels would not exceed NML at any off site receiver location.	Operations Site Manager
	Excess sediment accumulated in any sediment control devices to be removed	Operations Site Manager
	Follow-up weed control of all noxious weeds onsite	Operations Site Manager
	Mow all grass on-site to <100mm during Fire Danger Period	Operations Site Manager
	All vegetation within fuel break to be removed, and screening planting tree branches below 2m lopped	Operations Site Manager
	All staff inducted and regularly trained in environmental protocols	Operations Site Manager

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 23 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.0 Construction Environmental Management Plan

3.1 Construction Environmental Management Requirements

Environmental compliance during the construction phase shall be managed on site through the implementation of specific environmental procedures, control measures and monitoring as listed below. 'This applies to both the main BESS site and the works within the MWTS as required.

Biodiversity Protection (Section 3.1.1 – 3.1.5)

3.1.1 Native Vegetation Removal

A permit is required to remove, lop, or destroy any native vegetation, including dead vegetation, as enacted under the municipal planning scheme via Clause 52.17 '*Native Vegetation'* of the Victorian Planning Provisions (VPP).

Native vegetation removal must be restricted to that which is reasonably unavoidable, with evidence of impact minimisation to native vegetation communities required before offsets are authorised.
Once permitted, native vegetation clearing must comply with permit conditions and be undertaken by appropriately qualified personnel, and any biodiversity losses must be appropriately compensated by offsetting in accordance with legislative requirements. During the works phase, if any further native vegetation removal is required in addition to what has been authorised by the permit, works shall be held until consultation with the project ecological consultants has taken place.

AusNet have advised that the remnant scattered tree (Tree 1) in the southern end of the MWTS may require trimming to allow for the transportation of the 66 kV transformer. As such, as a worst-case scenario, it has been assumed that minimal lopping, limited to less than 1/3 of this tree's foliage, will be undertaken to allow access of the transformer. As detailed in the table of exemptions in Clause 52.17 (DELWP 2017b), the requirement to obtain a permit does not apply to:

- Lopping and pruning for maintenance:
  Lopping or pruning native vegetation, for maintenance only, provided no more than 1/3 of the foliage of each individual plant is lopped or pruned. This exemption does not apply to:
  The pruning or lopping of the trunk of a native tree; or Native vegetation on a roadside or railway reservation.

The DELWP Assessors Handbook (DELWP 2018) also stipulates that only excessive lopping, (defined as any lopping beyond 1/3 of the trees foliage), would result in the assumed loss of the tree. Therefore, as only minimal lopping of Tree 1 is required (limited to less than 1/3 of the tree's foliage), this action would be exempt from requiring a planning permit under Clause 52.17.

As such, the Project would not trigger the requirement for a permit under Clause 52.17 of the Latrobe planning scheme, and no native vegetation offsets are required. However, the lopping should be carried out by a qualified arborist.

Other than above mentioned and based on the current design, all infrastructure associated with the construction and operation of the Project is proposed to be located outside patches of native vegetation. As such, all patches of native vegetation within the Project area can be retained.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 24 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.1.2 Protection of Retained Native Vegetation

Where any works are required in close proximity to the areas of native vegetation recorded, including works within the main BESS site and within the MWTS, appropriate vegetation protection zones should be established to ensure no construction vehicles or personnel enter these areas. A tree protection zone should also be established around the planted vegetation recorded in the south east of the Project area as well as within and adjacent to the existing Morwell Terminal Station (MWTS).

Vegetation/tree protection zones should be fenced beyond the canopy drip line of the vegetation/tree and appropriately signed as ‘no-go zones’.

If works are to be undertaken in the planted vegetation zone, and removal of the trees is considered, please refer to Section 3.1.1. If branches of planted trees become damaged during works, they should be removed with a clean cut by a suitably qualified arborist and the project ecological consultant shall be notified.

The Morwell BESS Detailed Ecology Assessment (Aurecon, 2021) found that seven patches of native vegetation provided low to moderate quality habitat. These include:

- Three patches of aquatic habitat (HZ 1, 4 and 5)
- One linear patch of native grassland (HZ 6)
- One large, scattered Gippsland Red Gum within the MWTS

Prior to the commencement of works these patches should be isolated from works using temporary fencing and labelled as a ‘Vegetation Protection Zone’ to avoid damage from works being undertaken nearby (**Appendix A**).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 25 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Retained vegetation shall also be identified on the construction alignment sheets, and personnel informed of the location of retained vegetation and works prohibited in the zone.

3.1.3 Fauna Management

Vegetation on the project site, including the main BESS site and within the MWTS, may be providing current habitat for protected native fauna, particularly hollow-dependent fauna, ground-dwelling species, and species breeding at the time of construction.
Immediately prior to works being conducted, a visual inspection of the work zone must be undertaken to confirm no ground nests are present. Any nests must be relocated by a qualified animal handler before works commence.

In the event that wildlife is encountered on-site during the active works phase, all activity shall cease, and a local wildlife carer shall be engaged to advise on next steps. Any fencing on-site should also be checked regularly for fauna which may have become trapped or entangled.

3.1.4 Biosecurity and Weed Control

Noxious weeds and pathogens with significant environmental or agricultural impacts can be introduced to/spread from the construction site by the presence of seeds, plant matter or contaminated soil on contractor clothing, footwear, vehicle bodies, tyres, or other construction-related tools and equipment. A site inspection confirmed the presence of noxious weeds regulated under the *Catchment and Land Protection Act 1994*, including African boxthorn, Blackberry, Artichoke thistle, Cape broom and Sweet Briar, which have the potential to spread from site without proper control measures in place.

The following Weed Management Plan **(Table 4)** should be implemented prior the commencement of the construction works, including those associated with the MWTS works. Weed Control works should be conducted by a suitably qualified contractor.

Table 4 - Pre-construction Weed Management Plan for the Project Site

Common Name	Scientific Name	CaLP Status - West Gippsland	Requirement	Action	Timing
African Boxthorn	*Lycium ferocissimum*	Regionally controlled	Stop spread	Cut-and-paint glyphosate as per label.	Any
Artichoke thistle	*Cynara cardunculus*	Regionally prohibited	Eradicate	Spray any on-label broad spectrum or broadleaf specific herbicide, as per label rate	Spring-Summer
Blackberry	*Rubus fruticosus* spp. agg.	Regionally controlled	Stop spread	Folair spray with Garlon as per label	Summer
Cape Broome	*Genista monspessulana*	Regionally controlled	Stop spread	Hand pull, cut-and-paint, Folair spray small plants with Garlon as per label	Spring-Summer
Patterson's Curse	*Echium plantagineum*	Regionally controlled	Stop spread	Spray any on-label broad spectrum or broadleaf specific herbicide, as per label rate	Spring
Scotch Thistle	*Onopordum acanthium*	Regionally controlled	Stop spread	Spray any on-label broad spectrum or broadleaf specific herbicide, as per label rate	Spring-Summer
Spear Thistle	*Cirsium vulgare*	Regionally controlled	Stop spread	Spray any on-label broad spectrum or broadleaf specific herbicide, as per label rate	Spring-Summer
Sweet Briar	*Rosa rubiginosa*	Regionally controlled	Stop spread	Folair spray with Garlon as per label	Summer

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 26 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

As a biosecurity control measure, all development-related vehicles and equipment shall enter and leave the site in clean condition, free from mud, soil, seeds and plant matter, and no plant material or soil shall be transported or tracked onto the sealed public road network.

Dedicated vehicle washdown bays shall be installed near access/egress points to ensure hygiene requirements are met. Appropriate equipment cleaning stations should also be located on-site, and should include bleach-based cleaning products for removal of soil-borne pathogens. Any vehicles, equipment or PPE that have come from an area known to harbour any restricted soil-borne pathogen, such as the Cinnamon Fungus (*Phytophthora cinnamomi*), shall be required to apply Phytoclean or similar bleach-based product to all surfaces which may come into contact with the ground as a precautionary measure.

All personnel will undergo training in biosecurity hygiene practices, such as removing seeds and mud from clothing and footwear, and appropriate cleaning of vehicles.

Additionally, soil should not be moved or stockpiled across property boundaries. Green waste, including material from vegetation removal activities, should be chipped, removed from site and disposed of at licensed locations, such as municipal transfer stations.

3.1.5 Personnel Induction for Biodiversity Protection Measures

Prior to the commencement of works, including those associated with the MWTS works, a Pre-Start site walkthrough involving relevant site managers shall be undertaken to identify environmentally sensitive areas and outline the required protection measures. These include

- location of native vegetation to be retained,
- restricted activities within vegetation protection zones,
- protocols if wildlife is encountered on-site,
- washdown locations and procedures.

1. **Biodiversity Protection Control Measures to be Implemented:**

- Native vegetation to be retained shall be clearly flagged on-site as not to be disturbed, the fencing may also be used in order to prevent works being carried out there.
- Minimal lopping, limited to less than 1/3 of the tree's foliage and removal of branches that became damaged during works must be carried out by a qualified arborist.
- If wildlife or nests are encountered during works, a qualified animal handler must be called for relocation. Wildlife rescuers can be contacted through Wildlife Victoria, (03) 8400 7300. Fencing should also be regularly checked for entangled wildlife.
- All vehicles entering and leaving the site shall be clean and free of accumulated mud/soil and no dirt or mud shall be transported or tracked onto the sealed public road network. To facilitate this, a designated vehicle wash-down bay shall be established near access/egress points prior to works commencing.
- Any vehicles, equipment or PPE coming from an area known to harbour restricted soil-borne pathogen must have Phytoclean or similar bleach-based products applied (as per label instructions) to all surfaces and equipment which may come into contact with the ground.
- A Pre-Start site walkthrough involving relevant site managers shall be undertaken in order to identify environmentally sensitive areas and outline the required biodiversity protection measures.
- Weed management of the site should be carried out by a suitably qualified contractor according to the Weed Management Plan (Table 1) if possible, prior to construction works.
- Page Break

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 27 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.1.6 Noise & Vibration

In order to minimise the impacts of elevated noise to nearby receptors, works shall be limited to normal working hours of construction, with the exception of rare events where safety requirements necessitate works outside of standard hours. Standard hours of operation are as follows:

Weekday (Mon-Fri)	7:00am – 6:00pm
Saturday	7:00am – 1:00pm
Sunday or Public Holiday	No works permitted on public holidays[1]

All project personnel shall be informed of noise sensitivities related to the project and of the location of nearby noise sensitive receptors. Nearby receptors should be notified as early as possible regarding the likely duration and nature of noise generating activities. Loud tasks should be scheduled to less sensitive times where possible (*e.g.* Delay rock breaking tasks to late morning or early afternoon).

Vehicle movements, including deliveries outside standard hours, shall be minimised and avoided where possible. All plant and equipment shall be well-maintained and where possible, fitted with silencing devices. The site supervisor will complete routine monitoring to assess construction noise levels and evaluate whether the mitigation measures in place are adequate.

[1] except for exceptional circumstances involving network restoration or outages to minimize customer interruptions.

Please refer to Chapter 4 of EPA Publication 1834, 'Civil construction, building and Demolition Guide' (Nov 2020) and Noise Control Guidelines (EPA Publication 1254) for more information.

1. Noise Management Control Measures to be implemented:

- Communicate potential noise and vibration impact to nearby residents and receptors.
- Works limited to standard hours of construction except where safety requirements dictate an alternative approach.
- Schedule high impact works for less sensitive times of day.
- Vehicle movements, including deliveries outside normal working hours should be minimised and avoided where possible.
- Ensure all plant and equipment is well maintained and where possible, fitted with silencing devices.
- Implement training to induct staff on noise sensitivities.
- Complete routine monitoring to evaluate construction noise levels and evaluate whether the mitigation measures in place are adequate or require revision.

3.1.7 Erosion, Sediment And Dust

During construction, including works within the MWTS, all efforts should be made to prevent movement of sediment off-site across property boundaries. Flows of surface water should be directed away from sensitive areas (*e.g.* away from soil stockpiles and areas of unstable soil). Any water contaminated with sediment should be directed into sediment retention structures and prevented from entering drains or waterways. Scalping and vegetation removal should be minimised where possible and should be staged by stripping areas only when necessary and undertaking progressive stabilisation and/or rehabilitation (*e.g.* through the use of geotextiles, seeding or revegetation).
Sediment traps, such as silt fences, shall be installed along the boundaries of the site to prevent sediment movement into the nearby Bennett's Creek (**Appendix B**), as well as around soil stockpiles.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 28 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The Desktop Hydrology and Flood Risk Assessment – Phase 2 (Aurecon, 2021) notes that the proposed northern BESS infrastructure position overlays an existing stormwater drain, however, this will be managed by an upstream diversion of the flow path around the BESS site through a new roadside drain and a cross drainage culvert (**Appendix B)**.

Works over extended hot and/or dry conditions may lead to the liberation of dust from access roads and stockpile areas. As such, water shall be applied to these areas as a dust suppressant as required (*i.e.* if liberated dust is visibly reaching a sensitive receptor and causing a health or environmental hazard). Water can be applied via a water cart, sprinklers or a handheld hose. During extreme weather conditions (*i.e.* high winds) activities likely to generate dust shall be halted until conditions settle.

Excavated soil generated during construction to be stockpiled on site shall be surrounded by a silt fence and covered in the event of high wind or rain events. If the stockpile is anticipated to be left for longer than 28 days, it shall be seeded with sterile rye grass to minimise sediment movement.

All project related vehicles leaving site shall be clean and free of mud and soil deposits. To this end, a designated wash down bay shall be identified by the site supervisor at any points of access/egress before works commence.

During construction works a number of sediment control measures shall be in place with the aim of slowing the flow of water across the site and intercepting sediment before it moves off site. Appropriate mitigation measures such as energy dissipators, silt fences and scour protection will be required during the construction phase of works.

Generally, the amount of soil exposed at any one time should be minimised.

One of the measures that should be implemented is staging of excavation works and can be undertaken by:

- Stripping areas only when necessary and undertaking progressive rehabilitation
- Minimising the size of destabilized areas
- High risk works may be scheduled for the drier time of the year/time slot in the construction phase
- Exposed soil should be reseeded with sterile rye as soon as possible once the surface is finished.

Other than cleaning of accumulated mud/soil, to ensure the nearby Monash Way conditions do not deteriorate during the construction phase, other measures should be implemented such as:

- When possible, minimise site access to vehicles, eg restricting the access during wet weather conditions, minimising on and off site vehicle movements at all times requiring offsite parking etc.
- Regularly clean the Monash Way section near the construction site access point

1. **Erosion, Sediment and Dust Control Measures to be implemented:**

- Ensure that sediment control measures are installed prior to the commencement of works.
- A water cart will be made available for dust suppression on access tracks as required.
- Weekly monitoring, including any required maintenance, of the various sediment control measures will be carried out by the civil construction site manager (or delegate).
- Any areas of soil to be left bare after earth works shall be stabilised with geotextiles or direct seeding.
- Post construction, all temporary drainage features and disturbed areas will be reinstated and rehabilitated in order to achieve pre-construction natural flow characteristics. This excludes the pre-existing drainage line which will be re-routed around the BESS (**Appendix B**).
- Any unplanned excavations shall require approval from the Project Ecological Consultant prior to occurring.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 29 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.1.8 Chemicals

It is the responsibility of the site manager to ensure any chemicals used onsite are stored and handled safely in order to minimise the risks of spills and the possibility of impacts to human health and the environment. Consideration should be given to the following factors related to the safe storage and handling of chemicals onsite:

- The types of chemicals and fuels used and stored on site – control methods should be proportionate to potential impact.
- Quantities of chemicals and fuels used and stored on site – larger quantities have potential for larger impacts.
- Proximity to potential chemical receptors (anything which may be adversely affected by chemicals) – reducing the distance between chemicals and receptors creates potential for greater impact

Poor chemical management can impact human health and the environment in many ways, including:

- Contamination of land, ground and surface waters
- Loss of plant and animal life
- Emission of odour and toxic vapours
- Direct exposure to hazardous chemicals, resulting in skin irritation, respiratory distress, injury and illness
- Excessive nutrients in waterbodies, resulting in excessive plant/algal growth (eutrophication)
- Increased combustion and fire risk

When planning works, including works within the MWTS, steps should be taken to minimise the amount of hazardous substances stored and used on-site by utilising work processes which require smaller quantities of chemical, or substituting for less harmful chemicals where possible.

Chemicals must be stored in a properly sealed and labelled primary container, as well as a bunded and well-ventilated secondary containment area, away from any sensitive receptors (*e.g.* drainage lines, stormwater inlets, waterways, native vegetation). Bunding should be impervious to and compatible with stored chemicals, graded to a sump to allow for collection of spilled chemicals, and site run-off should be directed away from the bunded area. The slope around storage area should also be considered in the event of a spill, and it must be ensured that potential flow paths do not lead to sensitive receptors.

Spill kits shall be placed in the vicinity of chemical storage and refuelling areas and staff are to be trained in their use.

All chemicals must be disposed of in a lawful and appropriate way. EPA, local council and waste disposal facilities can provide more information on chemical disposal.

1. **Chemical Control Measures to be implemented:**

- Chemicals must be stored in a properly sealed and labelled primary container, as well as a bunded and well-ventilated secondary containment area, away from any sensitive receptors. Only compatible chemicals should be stored together.
- Store chemicals undercover where possible to exclude rainwater.
- Chemicals that are identified as dangerous goods and/or hazardous substances should be stored as per the Dangerous Goods (Storage and Handling) Regulations 2012 (available online).
- Minimise spills and splashes by using safe pouring or decanting techniques.
- Spill kits should be maintained and kept in close proximity to any chemical storage and refuelling areas and staff trained in their use. Spill kits should be compatible with materials being used.
- All personnel must be trained in incident response and spill management (ensure staff know location and content of spill kits, emergency contacts, disposal methods, etc.).
- Provide personal protective equipment (PPE) such as gloves, overalls, face shields, safety glasses or respirators and ensure PPE is used, cleaned and maintained properly.
- An up to date inventory should be kept on site, listing all substances stored, particularly dangerous goods and hazardous substances, and their locations.
- Refuelling will take place in a designated area within the works area, away from ignition sources and trees or vegetation and with appropriate controls to prevent any spills coming into contact with the ground.

3.1.9 Waste

Waste should be managed according to the waste management hierarchy as outlined in the *Environmental Protection Act 2017*. The hierarchy outlines preferable management options for waste management, these are (in order of preference):

- Avoidance
- Reuse
- Recycling
- Recovery of Energy
- Treatment
- Containment
- Disposal

Details and guidance relating to these management options are outlined in the industrial waste resource guidelines (IWRG) published by the EPA (**Appendix E**).

EPA Victoria categorises waste types into four broad categories:

- Fill materials,
- Solid inert waste from an industrial source,
- Putrescible waste from an industrial source, and;
- Prescribed industrial waste.

These are then further broken down into hazard categories, an outline of these categories and waste management options can be found in the EPA Victoria publication IWRG600.2 'Waste Categorisation'. Keeping records of the management, storage and disposal of waste can help demonstrate waste management practices. EPA may ask you at any time to supply information about your wastes.
Recommendations for waste record keeping can be found in Chapter 8 of EPA Publication 1834, 'Civil construction, building and Demolition Guide' (Nov 2020).

The designated construction waste storage area for Phase 1A of the Development will be located at the site of the future Phase 1B (to be built in subsequent phases), which is located directly west of the Project Area (**Appendix F**). Construction waste storage generated by the works within MWTS will be kept within the temporary construction site and laydown area within the MWTS shown on at the site plan **(Appendix G).**

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 30 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

1. **Waste Management Control Measures to be implemented:**

- Separate all waste generated on site into categories labelled in accordance with the EPA's 'Waste Classification Guidelines'.
- Store and handle all waste on site in accordance with its classification.
- Clearly label waste storage areas and containers to ensure accurate sorting and ease of collection by a particular service provider (for recycling, recovery or disposal).
- Do not receive or dispose of any waste on site.
- Remove all waste from site as soon as practicable and ensure it is recycled or sent to an appropriately licenced waste facility for disposal.

3.1.10 Cultural Heritage

A cultural heritage site is an area containing physical evidence of past human activity. It may comprise buried artefacts, human remains, structures or surface elements. The EPBC Act protects nationally significant Aboriginal and non-Aboriginal cultural heritage sites, and Aboriginal Heritage Act protects it at the state level. The Project area, including the MWTS is not subject to any cultural heritage overlays, and was not found to contain any sites of Aboriginal or Colonial cultural significance (Aurecon, 2021). There is a low chance of unexpected finds by employees within the project site during operation.

1. **Cultural Heritage Control Measures to be implemented** (adapted from *Cultural Heritage Management Plan*, Aurecon 2021)

Refer to the Cultural Heritage Management Plan (CHMP) for a comprehensive set of control measures related to Cultural Heritage during the construction phase of The Development, including the works within the MWTS. High level recommendations include:

- Prior to the commencement of any personnel (including site staff and contractors) working on site, personnel must view a brief video presentation prepared by the Registered Aboriginal Party. This will outline the CHMP purpose, the type and nature of Aboriginal cultural material that may potentially be found onsite, and management and/or contingency plans.

- Where Aboriginal cultural heritage (including suspected human remains) is discovered during construction, the following must occur:

  1. The person who identified the find will immediately notify the person in charge of the activity
  2. The person in charge of the activity must cease all works within 15 m of the discovery
  3. The discovery area must be cordoned by a suitable barrier (e.g. safety webbing or an equivalent barrier) and works may continue outside of this area
  4. The Sponsor (Tilt Renewables) representative must contact a Heritage Advisor and the relevant Registered Aboriginal Party (if appointed) of the find within 24 hours of the discovery
  5. The Sponsor or the Sponsors representative must contact a HA and the relevant RAP (if appointed) of the find within 24 hours of the discovery.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 31 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.2 Responsibilities & Reporting

A summary of monitoring requirements and responsible parties is listed below:

Table 5 - Summary of reporting requirements and responsibilities

Frequency of Check	Detail	Responsible Party
Daily	Perimeter fencing will be inspected observed for signs of trapped or injured wildlife.	Site Supervisor
	Check that all areas of clearing and ground disturbance is limited to approved impact footprint.	Site Supervisor
	Any excavations left over night will be inspected each morning such that trapped fauna can be released.	Civil Contractor or Site Supervisor
Weekly	Erosion controls are in place and retain capacity to manage run-off events in accordance with guidelines.	Site Supervisor
	Storage and handling arrangements for oils, grease and fuel for construction plant are appropriately bunded and managed to prevent spills and that no evidence of spills exists.	Site Supervisor
	Spill kits are fully stocked and appropriate for the works being undertaken.	Site Supervisor
	Waste is appropriately segregated and being collected at a frequency to maintain site in a neat and tidy manner.	Site Supervisor
	Stockpiled materials are appropriately managed to prevent wind-blown dust or erosion.	Site Supervisor
As required	Ground excavations will be observed for signs of items of heritage value and works stopped and chance finds reported immediately.	Civil Contractor or Site Supervisor
	Construction noise monitoring to confirm predicted noise levels are not exceeded and to confirm need and effectiveness of noise mitigation measures.	Site Supervisor
	Records of all waste sent off-site will be retained on site.	Site Supervisor
	Post rainfall inspections to confirm sediment control functioning and need for active management of water levels or quality in sediment basin prior to discharge.	Site Supervisor

Site Contact Details:

Zenviron Pty Ltd | Level 5, 24 Honeysuckle Dr | Newcastle NSW 2300
PO Box 648 | Newcastle NSW 2300
T +61 2 4044 2541 | administration@zenviron.com
www.zenviron.com

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 32 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.3 Construction Timetable

Table 6 - Construction Timetable

Phase	Time	Additional Information
Phase 1 Construction	November 2023 – November 2024	Site Work Hours Mon – Fri: 7 am – 6 pm Sat: 7 am – 1 pm
Phase 1 Commissioning	November 2024 – March 2025	Commissioning end date pending Final Approval

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 33 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

3.4 Competency, Training & Awareness

All people engaged in on-site works during the either the construction, implementation or decommissioning phases shall:

- Hold the relevant competencies relevant to their work in addition to first aid training and a construction induction white card.
- Undertake a site induction before commencing any works.
- Undertake a Cultural Heritage Induction and familiarise themselves with any requirements listed as part of the Cultural Heritage Management Plan.
- Comply with site biosecurity protocols inclusive of vehicle cleanliness and external treatments.
- Be made aware of Vegetation Protection Zone locations and how to identify these areas.
- Be made aware of the prescribed site activity hours for works to occur.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 34 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

References

Aurecon (2021). Latrobe Valley Battery Energy Storage System – *Complex Cultural Heritage Management Plan*. Prepared for Tilt Renewables.

Aurecon (2021). Latrobe Valley Battery Energy Storage System - *Desktop Hydrology and Flood Risk Assessment – Phase 2*. Prepared for Tilt Renewables.

Aurecon (2021). Latrobe Valley Battery Energy Storage System – *Desktop Noise Impact Assessment*. Prepared for Tilt Renewables.

Aurecon (2021). Latrobe Valley Battery Energy Storage System - *Detailed Ecology Assessment*. Prepared for Tilt Renewables.

Aurecon (2021). Latrobe Valley Battery Energy Storage System – *Environmental Management Framework*. Prepared for Tilt Renewables.

Booth C. (2007). *Barbed Wire Action Plan*. Available online via: https://www.wildlifefriendlyfencing.com/WFF/This_-_action_plan_files/action_plan.pdf

Country Fire Authority (2020). Guidelines and Model Requirements for Renewable Energy Facilities. Accessed online https://www.cfa.vic.gov.au/plan-prepare/building-planning-regulations/renewable-energy-fire-safety

Department of Agriculture, Fisheries and Forestry (2013). Australian Soil Resource Information System (ASRIS) Database. Accessed 21 July 2022.

Department of Environment and Energy (DEE; 2020). *National Light Pollution Guidelines for Wildlife*. Accessed online via: https://www.agriculture.gov.au/sites/default/files/documents/national-light-pollution-guidelines-wildlife.pdf

Department of Jobs, Precincts and Regions (2018). GeoVic Database. Accessed 21 July 2022.

Environmental Protection Authority VIC (2021).*Civil Construction, Building and Demolition Guide* (Publication 1834)

Environmental Protection Authority VIC (2021). Environmental Guidelines for major construction sites (Publication 480).
Environmental Protection Authority VIC (2021). *Noise Control Guidelines* (Publication 1254)

Environmental Protection Authority VIC (2021). *Waste Classification Assessment* (Publication 1827.2)

Institute of Lighting Professionals (2021). *Guidance note 1 for the reduction of obtrusive light*. Accessed online via: https://theilp.org.uk/publication/guidance-note-1-for-the-reduction-of-obtrusive-light-2021/

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 35 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix A: Latrobe Valley BESS Vegetation Map

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 36 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 37 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Tilt Renewables - Latrobe Valley BESS Project
Vegetation Map

Legend

- Existing Native Vegetation
- Planted Vegetation
- Waterway Planting Zone
- Screen Planting Zone
- Gippsland Red Gum
- Vegetation Protection Zones
- Stock Exclusion Fencing
- Construction Footprint

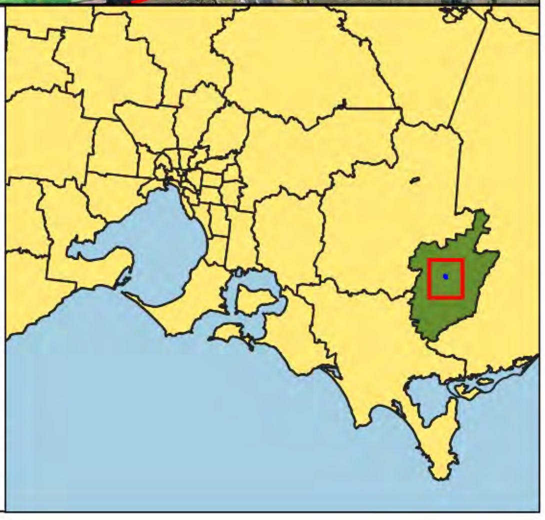
acacia

0 50 100 m

N

Job No.: G013
Date: 15/02/2022
Drawn By: Tim Gamble
Coordinate System: GDA 1994 MGA Zone 55

DATA SOURCES: Vicmap Data 2023, Nearmap 2023, Acacia Environmental 2023. Acacia Environmental Management does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Acacia Environmental Management is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.



Appendix B: Latrobe Valley BESS Drainage and Sediment Control Map

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 38 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 39 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Latrobe Valley BESS Project
Drainage and Sediment Control Map

Legend

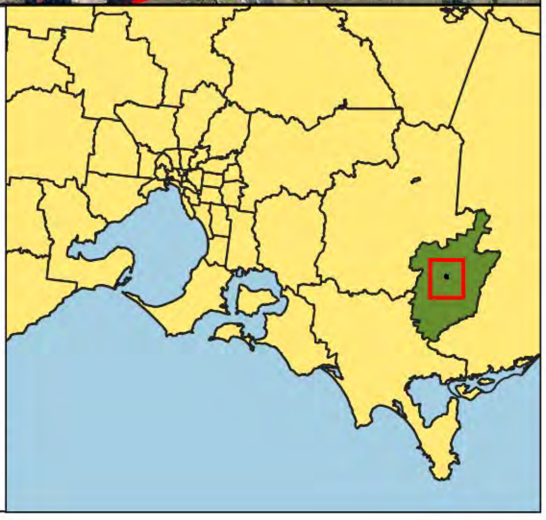
- Silt Fencing
- Drainage Outlet from MWTS
- Proposed Table Drain
- Fire Water Runoff and Detention Basin
- Stock Exclusion Fencing
- Construction Footprint

0 50 100 m

N

Job No.: G013
Date: 15/02/2023
Drawn By: Tim Gamble
Coordinate System: GDA 1994 MGA Zone 55

DATA SOURCES: Vicmap Data 2023, Nearmap 2023, Acacia Environmental 2023. Acacia Environmental Management does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Acacia Environmental Management is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.



Appendix C: National Light Pollution Guidelines for Wildlife

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 40 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Australian Government
Department of the Environment and Energy

GOVERNMENT OF WESTERN AUSTRALIA
Department of **Biodiversity, Conservation and Attractions**

Light Pollution Guidelines

National Light Pollution Guidelines for Wildlife

Including marine turtles, seabirds and migratory shorebirds

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 41 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

January 2020

Version 1.0

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 42 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Acknowledgments

The Department of the Environment and Energy (the Department) would like to acknowledge those who contributed to the development of these Light Pollution Guidelines.

Funding for the development of the Guidelines was provided by the North West Shelf Flatback Conservation Program in the Western Australian Department of Biodiversity, Conservation and Attractions and by the Australian Government's National Environmental Science Program (NESP) Emerging Priorities Funding.

These Guidelines are based on the draft written by Kellie Pendoley, Catherine Bell, Chris Surman and Jimmy Choi with contributions from Airam Rodriguez, Andre Chiaradia, Godfrey Bridger, Adam Carey, Adam Mitchell and Phillipa Wilson. Simon Balm, Steve Coyne, Dan Duriscoe, Peter Hick, Gillian Isoardi, Nigel Jackett, Andreas Jechow, Mike Salmon and Warren Tacey generously provided technical reviews of sections of this document.

The Department acknowledges the traditional owners of country throughout Australia and their continuing connection to land, sea and community. We pay our respects to them and their cultures and to their elders both past and present.

© Copyright Commonwealth of Australia, 2020.

The Light Pollution Guidelines are licensed by the Commonwealth of Australia for use under a Creative Commons Attribution 4.0 International licence with the exception of the Coat of Arms of the Commonwealth of Australia, the logo of the agency responsible for publishing the report, content supplied by third parties, and any images depicting people. For licence conditions see: https://creativecommons.org/licenses/by/4.0/

This report should be attributed as '*National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds, Commonwealth of Australia 2020*'.

The Commonwealth of Australia has made all reasonable efforts to identify content supplied by third parties using the following format '© Copyright, [name of third party]'.

Front cover images: Clown fish - DSEWPaC; Hawksbill Turtle hatchling – Scott Whiting; Mountain Pygmy Possum – Linda Broom; Black Browed Albatross – Alan Danks; Curlew Sandpiper – Brian Furby; Fleshfooted Shearwater - Richard Freeman.

Contents

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 43 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 44 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

National Light Pollution Guidelines

Introduction

Natural darkness has a conservation value in the same way that clean water, air and soil has intrinsic value. Artificial light at night is increasing globally by about two per cent per year[1]. Animals perceive light differently from humans and artificial light can disrupt critical behaviour and cause physiological changes in wildlife[2]. For example, hatchling marine turtles may not be able to find the ocean when beaches are lit[3], and fledgling seabirds may not take their first flight if their nesting habitat never becomes dark[4]. Tammar wallabies exposed to artificial light have been shown to delay reproduction[5] and clownfish eggs incubated under constant light do not hatch[6].

Consequently, artificial light has the potential to stall the recovery of a threatened species. For migratory species, the impact of artificial light may compromise an animal's ability to undertake long-distance migrations integral to its life cycle.

Artificial light at night provides for human safety, amenity and increased productivity. Australian legislation and standards regulate artificial light for the purpose of human safety. These Guidelines do not infringe on human safety obligations. Where there are competing objectives for lighting, creative solutions may be needed that meet both human safety requirements for artificial light and threatened and migratory species conservation.

The Guidelines outline the process to be followed where there is the potential for artificial lighting to affect wildlife. They apply to new projects, lighting upgrades (retrofitting) and where there is evidence of wildlife being affected by existing artificial light.

The technology around lighting hardware, design and control is changing rapidly and biological responses to artificial light vary by species, location and environmental conditions. It is not possible to set prescriptive limits on lighting. Instead, these Guidelines take an outcomes approach to assessing and mitigating the effect of artificial light on wildlife.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 45 of 187
Signature for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 1 Pink anemone fish and marine turtle laying eggs. Photos: Nigel Marsh and Robert Thorn.

How to use these Guidelines

These Guidelines provide users with the theoretical, technical and practical information required to assess if artificial lighting is likely to affect wildlife and the management tools to minimise and mitigate that affect. These techniques can be applied regardless of scale, from small, domestic projects to large-scale industrial developments.

The aim of the Guidelines is that artificial light will be managed so wildlife is:

1. **Not disrupted within, nor displaced from, important habitat; and**
2. **Able to undertake critical behaviours such as foraging, reproduction and dispersal.**

The Guidelines recommend:

1. Always using Best Practice Lighting Design to reduce light pollution and minimise the effect on wildlife.
2. Undertaking an Environmental Impact Assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.

Technical Appendices

The Guidelines are supported by a series of technical appendices that provide additional information about Best Practice Lighting Design, What is Light and How Wildlife Perceive it, Measuring Biologically Relevant Light, and Artificial Light Auditing. There is also a checklist for artificial light management, and species-specific information for the management of artificial light for Marine Turtles, Seabirds and Migratory Shorebirds. The range of species covered in taxa-specific appendices will be broadened in the future.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 46 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Regulatory Considerations for the Management of Artificial Light around Wildlife

These Guidelines provide technical information to guide the management of artificial light for *Environment Protection and Biodiversity Conservation Act (1999)* (EPBC Act) listed threatened and migratory species, species that are part of a listed ecological community, and species protected under state or territory legislation for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.

Environment Protection and Biodiversity Conservation Act (1999)

The EPBC Act regulates any action that will have, or is likely to have, a significant impact on a Matter of National Environmental Significance (MNES), including listed threatened and migratory species. Any action likely to have a significant impact on a MNES must be referred to the Australian Government for assessment. Further, it is an offence under the EPBC Act to kill, injure, take or trade a listed threatened, migratory or marine species in a Commonwealth area. Anyone unsure of whether the EPBC Act applies, is strongly encouraged to seek further information.

State and territory legislation and policy

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 47 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

State and territory environmental legislation and policy frameworks may also have provisions for managing threats, such as light, to listed species. For example, artificial light is a form of pollution regulated for impacts on humans and the environment under the Australian Capital Territory *Environment Protection Act 1997*. Consideration should be given to the function of relevant state and territory environment and planning legislation and policy concerning the protection of wildlife from artificial light.

Local and regional government requirements

Advice should also be sought from local government as to whether specific requirements apply in the area of interest concerning artificial light and wildlife. For example, the Queensland Government *Sea Turtle Sensitive Area Code* provides for local governments to identify sea turtle sensitive areas within local government planning schemes. Development in these areas will need to avoid adverse effects to sea turtles from artificial lighting.

Australian standards

Australian standards provide agreed limits for various lighting scenarios, generally for the purposes of human safety and for the provision of amenity. For example, Australian Standard DR AS/NZS 1158.3.1:2018 *Lighting for roads and public spaces pedestrian area (Category P) lighting* provides minimum light performance and design standards for pedestrian areas.

Australian standards also provide for consideration of environmental concerns. Australian Standard *AS/NZS 4282:2019 Control of the obtrusive effects of outdoor lighting* recognises the impact of artificial light on biota.

These Light Pollution Guidelines should be followed to ensure all lighting objectives are adequately addressed. This may require solutions to be developed, applied and tested to ensure lighting management meets the needs of human safety and wildlife conservation. The Case Studies illustrate examples of how a liquefied natural gas processing plant, a transport authority and a marine research vessel have addressed this challenge.

Associated guidance

These Guidelines should be read in conjunction with:

- EPBC Act 1999 Significant Impact Guidelines 1.1 Matters of National Environmental Significance
- EPBC Act 1999 Significant Impact Guidelines 1.2 Actions on, or impacting upon, Commonwealth land and Actions by Commonwealth Agencies
- Recovery Plans and approved conservation advices for listed threatened species
- approved Wildlife Conservation Plans for listed migratory species
- state and territory environmental legislation, regulations, and policy and guidance documents
- up-to-date scientific literature
- local and Indigenous knowledge.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 48 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Wildlife and Artificial Light

Vision is a critical cue for wildlife to orient themselves in their environment, find food, avoid predation and communicate[7]. An important consideration in the management of artificial light for wildlife is an understanding of how light is perceived by animals, both in terms of what the eye sees and the animal's viewing perspective.

Animals perceive light differently from humans. Most animals are sensitive to ultra-violet (UV)/violet/blue light[8], while some birds are sensitive to longer wavelength yellow/orange[9] and some snakes, can detect infra-red wavelengths[10] (Figure 2). Understanding the sensitivity of wildlife to different light wavelengths is critical to assessing the potential effects of artificial light on wildlife.

The way light is described and measured has traditionally focused on human vision. To manage light appropriately for wildlife, it is critical to understand how light is defined, described and measured and to consider light from the wildlife's perspective.

For a detailed explanation of these issues see What is Light and how do Wildlife Perceive it? The Glossary provides a summary of terms used to describe light and light measurements and notes the appropriate terms for discussing the effects of light on wildlife.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 49 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

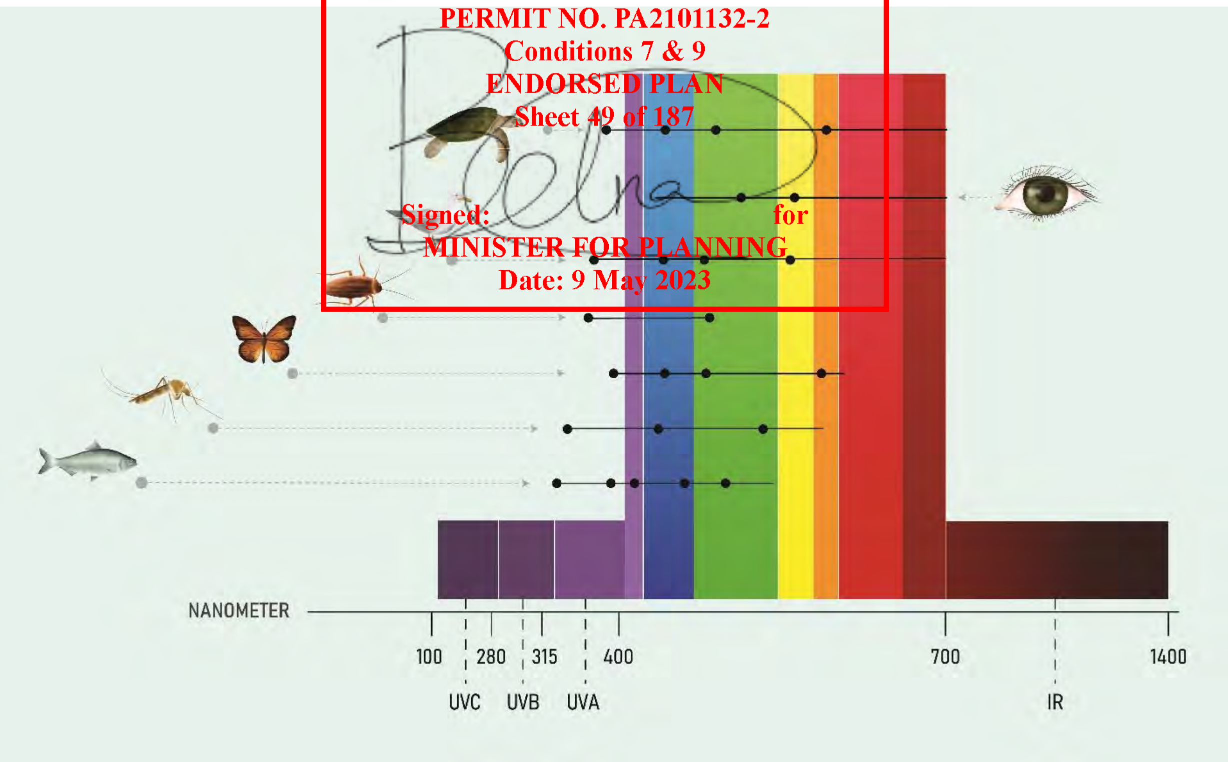


Figure 2 Ability to perceive different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivities. Figure adapted from Campos (2017)[8].

How light affects wildlife

Artificial light is known to adversely affect many species[2,11] and ecological communities[12,13]. It can change behaviour and/or physiology, reducing survivorship or reproductive output. It can also have the indirect effect of changing the availability of habitat or food resources. It can attract predators and invasive pests, both of which may pose a threat to listed species.

Behavioural changes in wildlife have been well described for some species. Adult marine turtles may avoid nesting on beaches that are brightly lit[14,15], and adult and hatchling turtles can be disoriented and unable to find the ocean in the presence of direct light or sky glow[3,15,16]. Similarly, lights can disorient flying birds, particularly during migration, and cause them to divert from efficient migratory routes or collide with infrastructure[17]. Birds may starve when artificial lighting disrupts foraging, and fledgling seabirds may not be able to take their first flight if their nesting habitat never becomes dark[4]. Migratory shorebirds may use less preferable roosting sites to avoid lights and may be exposed to increased predation where lighting makes them visible at night[4].

Physiological changes have been described in the Tammar Wallaby when exposed to artificial light, resulting in delayed reproduction[5], and clownfish eggs incubated under constant light do not hatch[6]. The stress hormone corticosterone in free living song birds has been shown to increase when exposed to white light compared with green or red light and those with high stress hormone levels had fewer offspring[18]. Plant physiology can also be affected by artificial light with changes to growth, timing of flowering and resource allocation. This can then have flow-on affects for pollinators and herbivores[13].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 50 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The indirect effects of artificial light can also be detrimental to threatened species. The Mountain Pygmy Possum, for example, feeds primarily on the Bogong Moth, a long distance nocturnal migrator that is attracted to light[19]. Recent declines in moth populations, in part due to artificial light, have reduced the food supply for the possum[20]. Changes in food availability due to artificial light affect other animals, such as bats[21], and cause changes in fish assemblages[22]. Lighting may also attract invasive pests such as cane toads[23], or predators, increasing pressure on listed species[24].

The way in which light affects a listed species must be considered when developing management strategies as this will vary on a case by case basis.

These Guidelines provide information on the management of artificial light for Marine Turtles, Seabirds and Migratory Shorebirds in the technical appendices. Consideration should be given to the direct and indirect effect of artificial light on all listed species for which artificial light has been demonstrated to negatively affect behaviour, survivorship or reproduction.

Light Emitting Diodes (LEDs)

During the life of these Guidelines, it is anticipated that light technology may change dramatically. At the time of writing, LEDs were rapidly becoming the most common light type used globally. This is primarily because they are more energy efficient than earlier light sources. LEDs and smart control technologies (such as motion sensors and timers) provide the ability to control and manage the physical parameters of lighting, making them an integral tool in managing the effects of artificial light on wildlife.

Whilst LEDs are part of the solution, consideration should be given to some of the characteristics of LEDs that may influence the effect of artificial light on wildlife. White LEDs generally contain short wavelength blue light. Short wavelength light scatters more readily than long wavelength light, contributing more to sky glow. Also, most wildlife is sensitive to blue light (Figure 2). More detailed consideration of LEDs, their benefits and challenges for use around wildlife are provided in the Technical Appendix What is Light and how does Wildlife Perceive it?

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 51 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

When to Consider the Impact of Artificial Light on Wildlife?

Is Artificial Light Visible Outside?

Any action or activity that includes externally visible artificial lighting should consider the potential effects on wildlife (refer Figure 3 below). These Guidelines should be applied at all stages of management, from the development of planning schemes to the design, approval and execution of individual developments or activities, through to retrofitting of light fixtures and management of existing light pollution. Best Practice Lighting Design is recommended as a minimum whenever artificial lighting is externally visible.

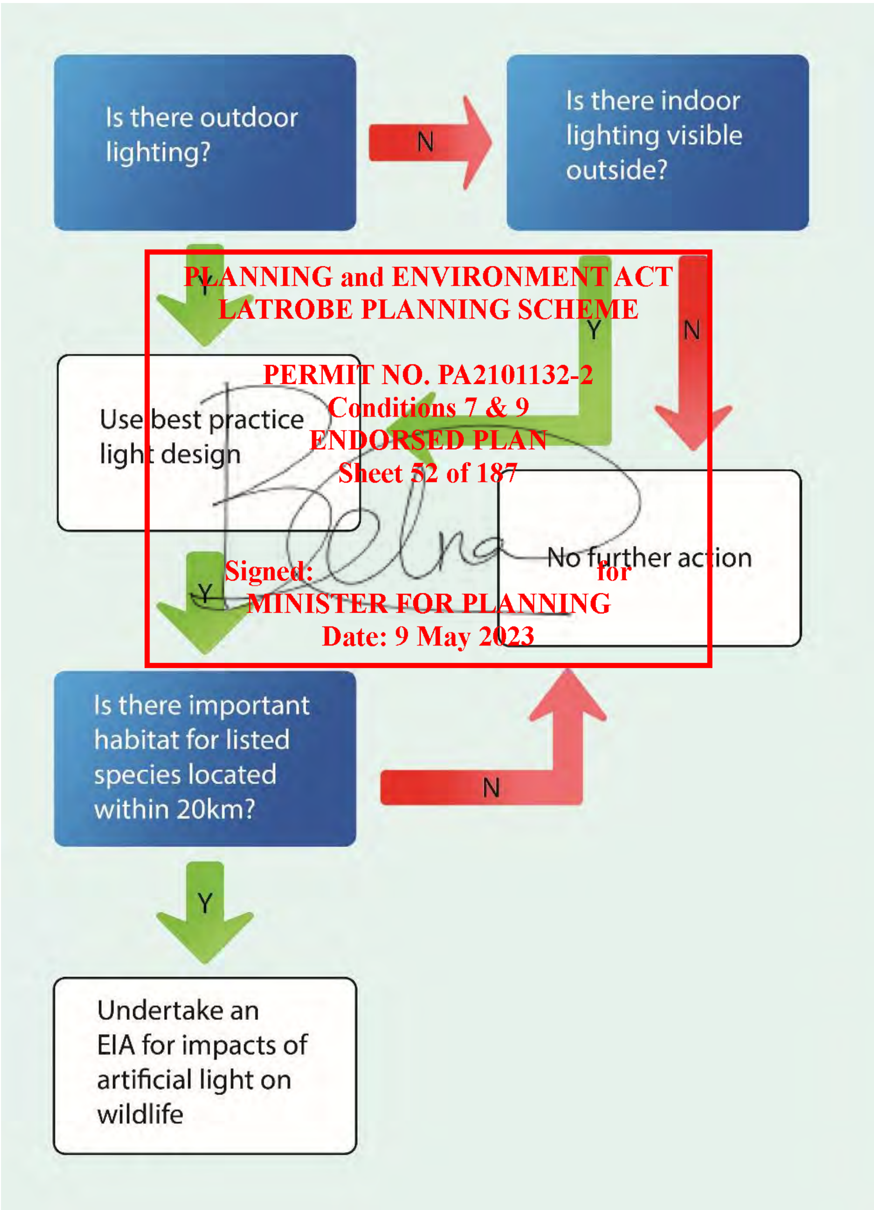


Figure 3 Decision tree to determine whether to undertake an environmental impact assessment for the effects of artificial light on wildlife.

Best practice lighting design

Natural darkness has a conservation value and should be protected through good quality lighting design and management for the benefit of all living things. To that end, all infrastructure that has outdoor artificial lighting or internal lighting that is externally visible should incorporate best practice lighting design.

Incorporating best practice lighting design into all infrastructure will not only have benefits for wildlife, but will also save energy and provide an economic benefit for light owners and managers.

Best practice lighting design incorporates the following design principles.

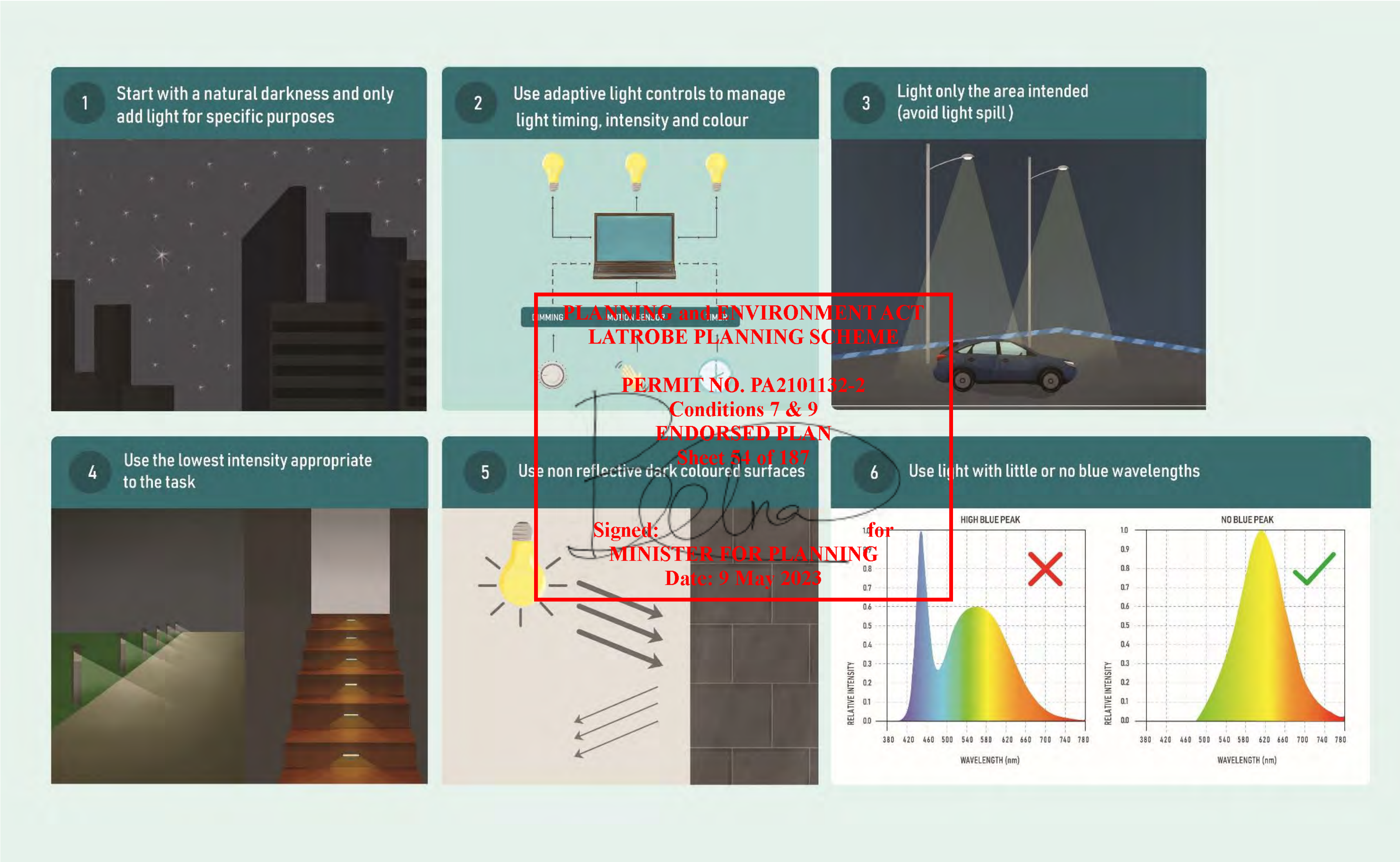
1. **Start with natural darkness and only add light for specific purposes.**
2. **Use adaptive light controls to manage light timing, intensity and colour.**
3. **Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill.**
4. **Use the lowest intensity lighting appropriate for the task.**
5. **Use non-reflective, dark-coloured surfaces.**
6. **Use lights with reduced or filtered blue, violet and ultra-violet wavelengths.**

Figure 4 provides an illustration of best practice light design principles. For a detailed explanation see Technical Appendix Best Practice Lighting Design.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 53 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023



PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 54 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 4 Principles for best practice lighting design.

Is there Important Habitat for Listed Species Located within 20km?

Important habitats are those areas necessary for an ecologically significant proportion of a listed species to undertake important activities such as foraging, breeding, roosting or dispersal. This might include areas that are of critical importance for a particular life stage, are at the limit of a species range or habitat, or where the species is declining. They may also be a habitat where the presence of light pollution may cause a significant decline in a listed threatened or migratory species.

Important habitat will vary depending on the species. For some species, areas of importance have been designated through recovery plans, conservation advice, and under planning regulations (for example Queensland Sea Turtle Sensitive Areas). Important habitat would include those areas that are consistent with 'habitat critical to the survival' of a threatened species and 'important habitat' for listed migratory species as described in the EPBC Act Significant Impact Guidelines[25]. Important habitat may include areas designated as Biologically Important Areas (BIAs), or in the case of migratory shorebirds, Internationally Important or Nationally Important Habitat. Consideration should be given to the ecological characteristics of Ramsar sites and the biological and ecological values of National and World Heritage Areas.

Species specific descriptions of important habitat can be found in Technical Appendices relating to Marine Turtles, Seabirds and Migratory Shorebirds. For other listed species see relevant information available in Associated guidance and Desktop Study of Wildlife.

Where there is important habitat for listed species that are known to be affected by artificial light within 20 km of a project, species specific impacts should be considered through an Environmental Impact Assessment (EIA) process.

The 20 km threshold provides a precautionary limit based on observed effects of sky glow on marine turtle hatchlings demonstrated to occur at 15-18 km[26,27] and fledgling seabirds grounded in response to artificial light 15 km away[28]. The effect of light glow may occur at distances greater than 20 km for some species and under certain environmental conditions. The 20 km threshold provides a nominal distance at which artificial light impacts should be considered, not necessarily the distance at which mitigation will be necessary. For example, where a mountain range is present between the light source and an important turtle nesting beach, further light mitigation is unlikely to be needed. However, where island infrastructure is directly visible on an important turtle nesting beach across 25 km of ocean in a remote location, additional light mitigation may be necessary.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 55 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Managing existing light pollution

The impact of artificial light on wildlife will often be the result of the effect of all light sources in the region combined. As the number and intensity of artificial lights in an area increases there will be a visible, cumulative increase in sky glow. Sky glow is the brightness of the night sky caused by the reflected light scattered from particles in the atmosphere. Sky glow comprises both natural and artificial sky glow. As sky glow increases so does the potential for adverse impacts on wildlife.

Generally, there is no one source of sky glow and management should be undertaken on a regional, collaborative basis. Artificial light mitigation and minimisation will need to be addressed by the community, regulators, councils and industry to prevent the escalation of, and where necessary reduce, the effects of artificial light on wildlife.

The effect of existing artificial light on wildlife is likely to be identified by protected species managers or researchers that observe changes in behaviour or population demographic parameters that can be attributed to increased artificial sky glow. Where this occurs, the population/behavioural change should be monitored, documented and, where possible, the source(s) of light identified. An Artificial Light Management Plan should be developed in collaboration with all light owners and managers to mitigate impacts.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 56 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Environmental Impact Assessment for Effects of Artificial Light on Wildlife

There are five steps involved in assessing the potential effects of artificial light on wildlife, and the adaptive management of artificial light requires a continuing improvement process (Figure 5). The amount of detail included in each step depends on the scale of the proposed activity and the susceptibility of wildlife to artificial light. The first three steps of the EIA process should be undertaken as early as possible in the project's life cycle and the resulting information used to inform the project design phase.

Marine Turtle, Seabird and Migratory Shorebird Technical Appendices give specific consideration to each of these taxa. However, the process should be adopted for other protected species affected by artificial light.

Qualified personnel

Lighting design/management and the EIA process should be undertaken by appropriately qualified personnel. Management plans should be developed and reviewed by appropriately qualified lighting practitioners in consultation with appropriately qualified wildlife biologists or ecologists.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 57 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

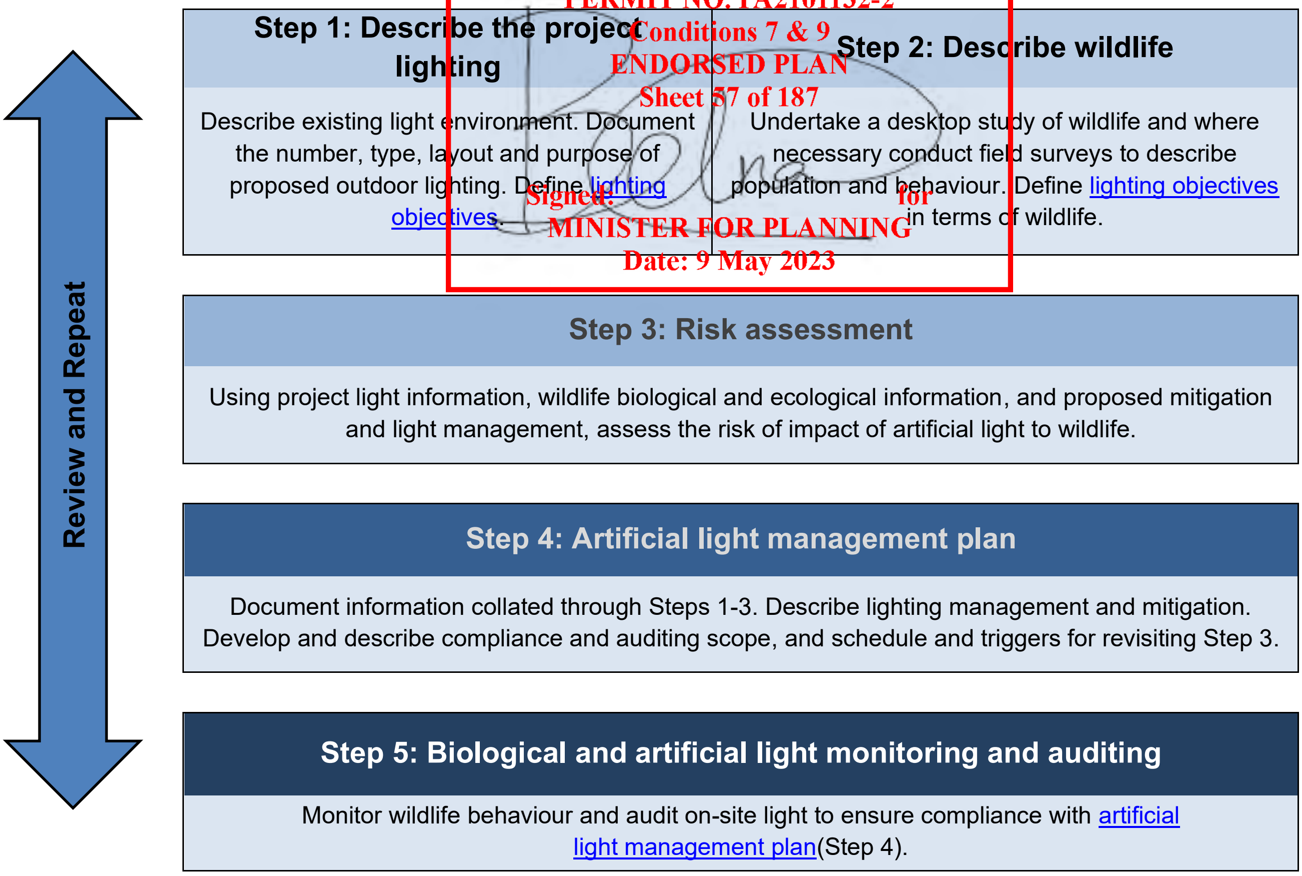


Figure 5 Flow chart describing the environmental impact assessment process.

Step 1: Describe the project lighting

Describe the existing light environment and characterise the light likely to be emitted from the site. Information should be collated, including (but not limited to): the location and size of the project footprint; the number and type of lights; their height, orientation and hours of operation; site topography and proximity to wildlife and/or wildlife habitat. This information should include whether lighting will be directly visible to wildlife or contribute to sky glow; the distance over which this artificial light is likely to be perceptible; shielding or light controls used to minimise lighting; and spectral characteristics (wavelength) and intensity of lights.

Project specific lighting should be considered in the context of the existing light environment and the potential for cumulative effects of multiple light sources. The information collected should be sufficient to assess the likely effects of artificial light on wildlife given the biology and ecology of species present (Step 2).

Where there will be a need to monitor the effectiveness of artificial light mitigation and management strategies (Step 5), baseline monitoring will be necessary. Measurements of the existing light environment should recognise and account for the biologically relevant short (violet/blue) and long (orange/red) wavelengths of artificial lighting (see Measuring Biologically Relevant Light).

Lighting objectives

During the planning phase of a project the purpose of artificial lighting should be clearly articulated, and consideration should be given as to whether artificial light is required at all. Lighting objectives should be specific in terms of location and times for which artificial light is necessary, whether colour differentiation is required and whether some areas should remain dark. The objectives should include the wildlife requirements identified in Step 2 and be consistent with the aims of these Guidelines.

For more information about developing lighting objectives see Best Practice Lighting Design.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 58 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Step 2: Describe wildlife

Describe the biology and ecology of wildlife in the area that may be affected by artificial light (species identified during the screening process, Figure 3). The abundance, conservation status and regional significance of wildlife will be described, as will the location of important habitat. Recognise biological and ecological parameters relevant to the assessment, particularly how artificial light will be viewed by an animal. This includes an animal's physiological sensitivity to wavelength and intensity, and its visual field.

Depending on the availability of information, scale of the activity and the susceptibility of wildlife to artificial light, this step may only require a desktop analysis. Where there is a paucity of information or the potential for effects is high, field surveys may be necessary. Where there will be a need to monitor the effectiveness of lighting mitigation and management strategies (Step 5), baseline monitoring will be necessary.

Desktop study of wildlife

A review of the available government databases, scientific literature and unpublished reports should be conducted to determine whether listed or protected wildlife that are susceptible to the effects of artificial light could be present. Tools to identify species or Important Habitat that may occur within 20 km of the area of interest include (but are not limited to):

- Protected Matters Search Tool
- National Conservation Values Atlas
- State and territory protected species information
- Scientific literature
- Local and Indigenous knowledge

To assess the risks to a species, an understanding of the animal's susceptibility to the effects of light should be evaluated, as well as the potential for artificial light to affect the local population.

The species conservation status should be identified and relevant population demographic and behavioural characteristics that should be considered include population size, life stages present and normal behaviour in the absence of artificial light. This step should also identify biological and ecological characteristics of the species that will be relevant to the assessment. This may include understanding the seasonality of wildlife using the area; behaviour (i.e. reproduction, foraging, resting); migratory pathways; and life stages most susceptible to artificial light. Consideration should also be given to how artificial light may affect food sources, availability of habitat, competitors or predators.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 59 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Field surveys for wildlife

Where there are insufficient data available to understand the actual or potential importance of a population or habitat it may be necessary to conduct field surveys. The zone of influence for artificial lighting will be case and species specific. Surveys should describe habitat, species abundance and density on a local and regional scale at a biologically relevant time of year.

Baseline monitoring

Where it is considered likely that artificial lighting will impact on wildlife, it may be necessary to undertake baseline monitoring to inform mitigation and light management (Step 5).

Field survey techniques and baseline monitoring needs will be species specific and detailed parameters and approaches are described in the Marine Turtles, Seabirds and Migratory Shorebirds Technical Appendices. Guidance from species experts should be sought for other species.

Step 3: Risk assessment

Using information collated in steps one and two, the level of risk to wildlife should be assessed. Risk assessments should be undertaken on a case by case basis as they will be specific to the wildlife involved, the lighting objectives and design, and the prevailing environmental conditions. Assessments should be undertaken in accordance with the *Australian Standard Risk Management – Guidelines (AS ISO 31000:2018)* (or superseding equivalent), which provides for adaptive management and continuous improvement. The scale of the assessment is expected to be commensurate with the scale of the activity and the vulnerability of the wildlife present.

In general, the assessment should consider how important the habitat is to the species (e.g. is this the only place the animals are found), the biology and ecology of wildlife, the amount and type of artificial light at each phase of development (e.g. construction/operation) and whether the lighting scenario is likely to cause an adverse response. The assessment should take into account the artificial light impact mitigation and management that will be implemented. It should also consider factors likely to affect an animal's perception of light; the distance to the lighting source; and whether light will be directly visible or viewed as sky glow. The process should assess whether wildlife will be disrupted or displaced from important habitat, and whether wildlife will be able to undertake critical behaviours such as foraging, reproduction, and dispersal.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 60 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Where a likely risk is identified, either the project design should be modified, or further mitigation put in place to reduce the risk.

If the residual risk is likely to be significant, consideration should be given as to whether the project should be referred for assessment under the EPBC Act and/or relevant state or territory legislation.

Step 4: Artificial light management plan

The management plan will document the EIA process. The plan should include all relevant information obtained in Steps 1-3. It should describe the lighting objectives; the existing light environment; susceptible wildlife present, including relevant biological characteristics and behaviour; and proposed mitigation. The plan should clearly document the risk assessment process, including the consequences that were considered, the likelihood of occurrence and any assumptions that underpin the assessment. Where the risk assessment deems it unlikely that the proposed artificial light will effect wildlife and an artificial light management plan is not required, the information and assumptions underpinning these decisions should be documented.

Where an artificial light management plan is deemed necessary, it should document the scope of monitoring and auditing to test the efficacy of proposed mitigation and triggers to revisit the risk assessment. This should include a clear adaptive management framework to support continuous improvement in light management, including a hierarchy of contingency management options if biological and light monitoring or compliance audits indicate that mitigation is not meeting the objectives of the plan.

The detail and extent of the plan should be proportional to the scale of the development and potential impacts to wildlife.

A toolbox of species specific options are provided in the Marine Turtles, Seabirds and Migratory Shorebirds Technical Appendices. Guidance from species experts should be sought for other species.

Step 5: Biological and light monitoring and auditing

The success of the impact mitigation and artificial light management should be confirmed through monitoring and compliance auditing. Light audits should be regularly undertaken and biological and behavioural monitoring should be undertaken on a timescale relevant to the species present. Observations of wildlife interactions should be documented and accompanied by relevant information such as weather conditions and moon phase. Consideration should be given to monitoring control sites. Monitoring should be undertaken both before and after changes to artificial lighting are made at both the affected site and the control sites. The results of monitoring and auditing are critical to an adaptive management approach, with the results used to identify where improvements in lighting management may be necessary. Audits should be undertaken by appropriately qualified personnel.

Baseline, construction or post construction artificial light monitoring, wildlife biological monitoring and auditing are detailed in Measuring Biologically Relevant Light, Light Auditing and species specific Marine Turtles, Seabirds and Migratory Shorebirds Technical Appendices.

Review

Once light audits and biological monitoring have been completed, a review of whether the lighting objectives have been met should be conducted. The review should incorporate any changing circumstances and make recommendations for continual improvement. The recommendations should be incorporated through upgraded mitigations, changes to procedures and renewal of the light management plan.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 61 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Case Studies

Unlike many forms of pollution, artificial light can be removed from the environment. The following case studies show it is possible to balance the requirements of both human safety and wildlife conservation.

Gorgon Liquefied Natural Gas Plant on Barrow Island, Western Australia

The Chevron-Australia Gorgon Project is one of the world's largest natural gas projects. The liquefied natural gas (LNG) processing facility is on Barrow Island a Western Australian Class A nature reserve off the Pilbara Coast known for its diversity of fauna, including important nesting habitat for flatback turtles[29].

The LNG plant was built adjacent to important turtle nesting beaches. The effect of light on the turtles and emerging hatchlings was considered from early in the design phase of the project and species-specific mitigation was incorporated into project planning[29]. Light management is implemented, monitored and audited through a light management plan and turtle population demographics and behaviour through the *Long Term Marine Turtle Management Plan*[30].

Lighting is required to reduce safety risks to personnel and to maintain a safe place of work under workplace health and safety requirements. The lighting objectives considered these requirements while also aiming to minimise light glow and eliminate direct light spill on nesting beaches. This includes directional or shielded lighting, the mounting of light fittings as low as practicable, louvered lighting on low level bollards, automatic timers or photovoltaic switches and black-out blinds on windows. Accommodation buildings were oriented so that a minimal number of windows faced the beaches and parking areas were located to reduce vehicle headlight spill onto the dunes.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 62 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Lighting management along the LNG jetty and causeway adopted many of the design features used for the plant and accommodation areas. LNG loading activity is supported by a fleet of tugs that were custom built to minimise external light spill. LNG vessels are requested to minimise non-essential lighting while moored at the loading jetty.

To reduce sky glow, the flare for the LNG plant was designed as a ground box flare, rather than the more conventional stack flare. A louvered shielding wall further reduced the effects of the flare.

Lighting reviews are conducted prior to the nesting season to allow time to implement corrective actions if needed. Workforce awareness is conducted at the start of each turtle breeding season to further engage the workforce in the effort to reduce light wherever possible.

Figure 6 Liquefied natural gas plant on Barrow Island. Photo: Chevron Australia.

The *Long Term Marine Turtle Management Plan*[30] provides for the ongoing risk assessment of the impact of artificial light on the flatback turtles nesting on beaches adjacent to the LNG plant, including mitigation measures to minimise the risk from light to turtles. The plan also provides for an ongoing turtle research and monitoring program. The plan is publicly available.

Phillip Island

Victoria's Phillip Island is home to one of the world's largest colonies of listed migratory Short-tailed Shearwaters (*Ardenna tenuirostris*). It supports more than six per cent of the global population of this species[28]. Shearwaters nest in burrows and are nocturnally active at their breeding colonies. Fledglings leave their nests at night. When exposed to artificial light fledglings can be disoriented and grounded. Some fledglings may reach the ocean, but then be attracted back toward coastal lighting. Fledglings are also vulnerable to collision with infrastructure when disoriented and once grounded become vulnerable to predation or road kill[4] (Figure 7).

Phillip Island also attracts over a million visitors a year during peak holiday seasons to visit the Little Penguin (*Eudyptula minor*) ecotourism centre, the Penguin Parade®. Most visitors drive from Melbourne across a bridge to access the island. The increase in road traffic at sunset during the Easter break coincides with the maiden flight of fledgling shearwaters from their burrows[28].

In response to the deaths of fledglings, Phillip Island Nature Parks has an annual shearwater rescue program to remove and safely release grounded birds[28]. In collaboration with SP Ausnet and Regional Roads Victoria, road lights on the bridge to the island are turned off during the fledgling period[31]. To address human safety concerns, speed limits are reduced and warning signals put in place during fledgling season[31,32]. The reduced road lighting and associated traffic controls and warning signals, combined with a strong rescue program, have reduced the mortality rate of shearwaters[28].

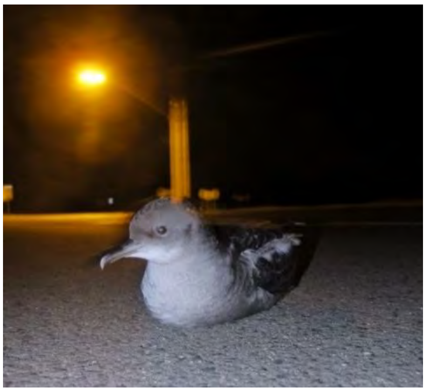


Figure 7 Short-Tailed Shearwater (*Ardenna tenuirostris*) fledgling grounded by artificial light, Phillip Island. Photo: Airam Rodriguez.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 63 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Raine Island research vessel light controls

The Queensland Marine Parks primary vessel *Reef Ranger* is a 24 m catamaran jointly funded by the Great Barrier Reef Marine Park Authority and the Queensland Parks and Wildlife Service under the Field Management Program (FMP). The *Reef Ranger* is often anchored at offshore islands that are known marine turtle nesting sites and is regularly at Raine Island, one of the world's largest green turtle nesting sites[33] and a significant seabird rookery.

Vessels often emit a lot of artificial light when at anchor and the FMP took measures to minimise direct lighting spillage from the vessel. A lights-off policy around turtle nesting beaches was implemented, where the use of outdoor vessel lights was limited, except for safety reasons.

The original fit out of the vessel did not include internal block-out blinds (Figure 8A). These were installed before the 2018-19 Queensland turtle nesting season. The blinds stop light being emitted from inside the vessel, therefore limiting light spill around the vessel (Figure 8B). This can make an important difference at remote (naturally dark) sites such as Raine Island.

Anecdotal evidence suggests hatchlings previously attracted to, and captured in, light pools around the vessel are no longer drawn to the *Reef Ranger*.

Figure 8 Vessel lighting management at Raine Island A. Vessel with decking lights, venetian blinds down and anchor light on; and B. Vessel with outside lights off, and block-out blinds installed (note the white anchor light is a maritime safety requirement). Photo: Queensland Parks and Wildlife Service.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 64 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix A – Best Practice Lighting Design

Natural darkness has conservation value in the same way as clean water, air and soil and should be protected through good quality lighting design.

Simple management principles can be used to reduce light pollution, including:

1. **Start with natural darkness and only add light for specific purposes.**
2. **Use adaptive light controls to manage light timing, intensity and colour.**
3. **Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill.**
4. **Use the lowest intensity lighting appropriate for the task.**
5. **Use non-reflective, dark-coloured surfaces.**
6. **Use lights with reduced or filtered blue, violet and ultra-violet wavelengths.**

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 65 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The application of best practice lighting design for all outdoor lighting is intended to reduce sky glow and minimise the effects of artificial light on wildlife.

Lighting Objectives

At the outset of a lighting design process, the purpose of artificial lighting should be clearly stated and consideration should be given as to whether it is required at all.

Exterior lighting for public, commercial or industrial applications is typically designed to provide a safe working environment. It may also be required to provide for human amenity or commerce. Conversely, areas of darkness, seasonal management of artificial light, or minimised sky glow may be necessary for wildlife protection, astronomy or dark sky tourism.

Lighting objectives will need to consider the regulatory requirements and Australian standards relevant to the activity, location and wildlife present.

Objectives should be described in terms of specific locations and times for which artificial light is necessary. Consideration should be given to whether colour differentiation is required and if some areas should remain dark – either to contrast with lit areas or to avoid light spill. Where relevant, wildlife requirements should form part of the lighting objectives.

A lighting installation will be deemed a success if it meets the lighting objectives (including wildlife needs) and areas of interest can be seen by humans clearly, easily, safely and without discomfort.

The following provides general principles for lighting that will benefit the environment, local wildlife and reduce energy costs.

Principles of Best Practice Lighting Design

Good lighting design incorporates the following design principles. They are applicable everywhere, especially in the vicinity of wildlife.

1. Start with natural darkness

The starting point for all lighting designs should be natural darkness (Figure 9). Artificial light should only be added for specific and defined purposes, and only in the required location and for the specified duration of human use. Designers should consider an upper limit on the amount of artificial light and only install the amount needed to meet the lighting objectives.

Figure 9 Start with natural darkness.

In a regional planning context, consideration should be given to designating 'dark places' where activities that involve outdoor artificial light are prohibited under local planning schemes.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 66 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

2. Use adaptive controls

Recent advances in smart control technology provide a range of options for better controlled and targeted artificial light management (Figure 10). For example, traditional industrial lighting should remain illuminated all night because the High-Pressure Sodium, metal halide, and fluorescent lights have a long warm up and cool down period. This could jeopardise operator safety in the event of an emergency. With the introduction of smart controlled LED lights, plant lighting can be switched on and off instantly and activated only when needed, for example, when an operator is physically present within the site.

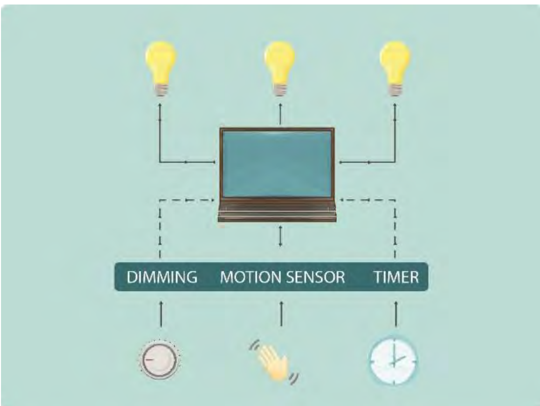


Figure 10 Use adaptive controls to manage light timing, intensity and colour.

Smart controls and LED technology allow for:

- remotely managing lights (computer controls)
- instant on and off switching of lights
- control of light colour (emerging technology)
- dimming, timers, flashing rate, motion sensors well defined directivity of light.

Adaptive controls should maximise the use of latest lighting technology to minimise unnecessary light output and energy consumption.

3. Light only the intended object or area - keep lights close to the ground, directed and shielded

Light spill is light that falls outside the area intended to be lit. Light that spills above the horizontal plane contributes directly to artificial sky glow while light that spills into adjacent areas on the ground (also known as light trespass) can be disruptive to wildlife in adjacent areas. All light fittings should be located, directed or shielded to avoid lighting anything but the target object or area (Figure 11). Existing lights can be modified by installing a shield.

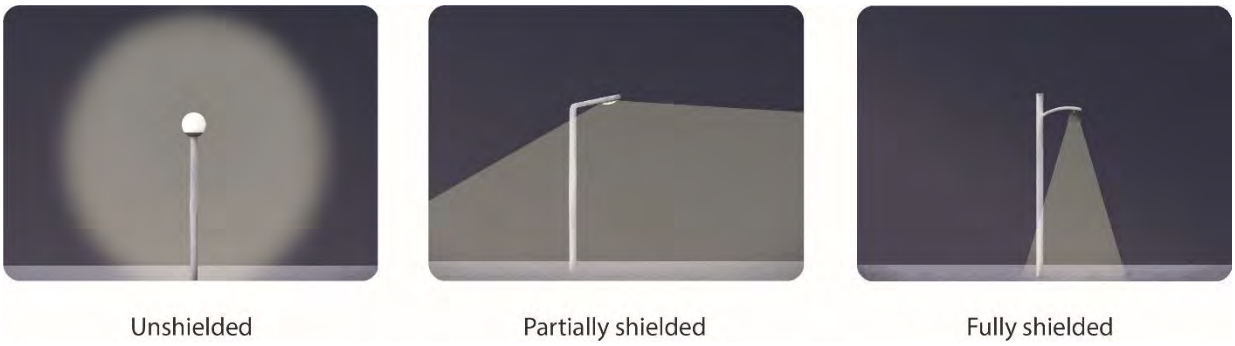


Figure 11 Lights should be shielded to avoid lighting anything but the target area or object. Figure adapted from Witherington and Martin (2003)[3].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 67 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Lower height lighting that is directional and shielded can be extremely effective. Light fixtures should be located as close to the ground as possible and shielded to reduce sky glow (Figure 12).

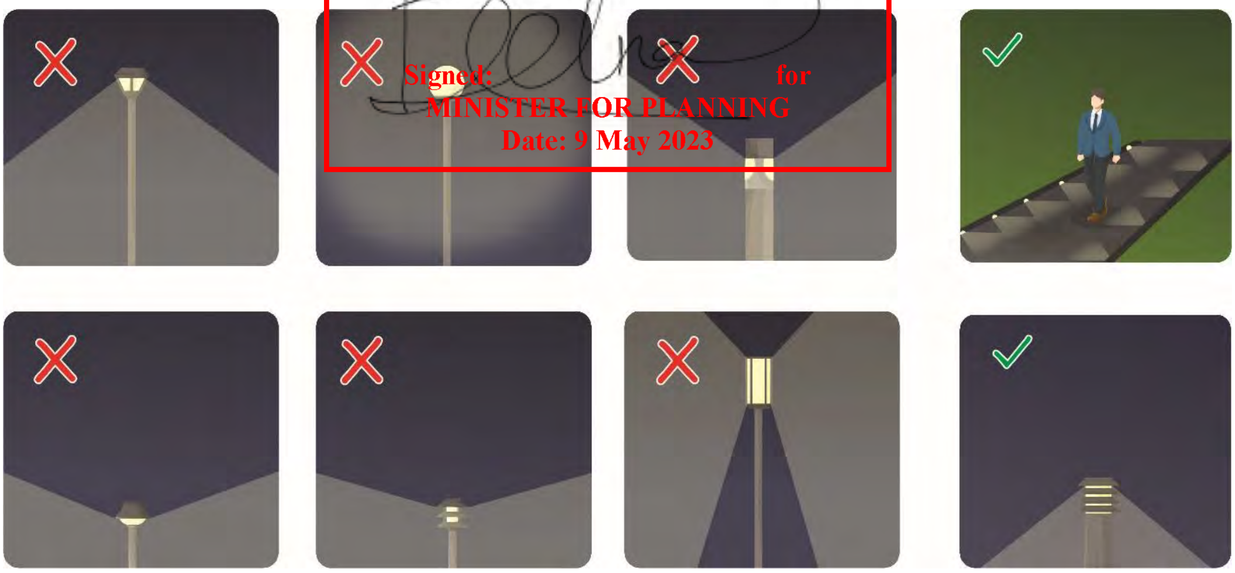


Figure 12 Walkway lighting should be mounted as low as possible and shielded. Figure adapted from Witherington and Martin (2003)[3].

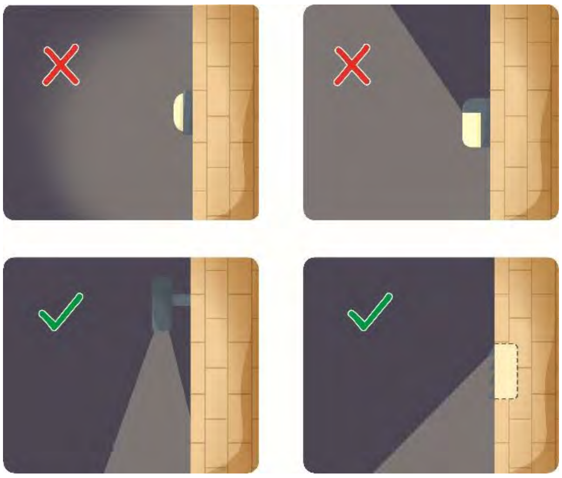


Figure 13 Lighting should be directed to ensure only the intended area is lit. Figure adapted from Witherington and Martin (2003)[3].

Artificial light can be prevented from shining above the horizontal plane by ensuring the luminaire is mounted horizontally relative to the ground and not at an angle, or mounted on a building so that the structure prevents the light shining above the horizontal plane, for example recess a light into an overhanging roof eave. When determining angle of the mounting, consideration should be given to the reflective properties of the receiving environment.

If an unshielded fitting is to be used, consideration should be given to the direction of the light and the need for some form of permanent physical opaque barrier that will provide the shielding requirement. This can be a cover or part of a building (Figure 13). Care should be taken to also shield adjacent surfaces, if they are lightly coloured, to prevent excessive reflected light from adding to sky glow.

Consideration should also be given to blocking light spill from internal light sources. This should include block-out blinds or shutters for transparent portions of a building, including sky lights, and use of glass in windows and balconies with reduced visible light transmittance values.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: 2021/152-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 68 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

4. Use appropriate lighting

Lighting intensity should be appropriate for the activity. Starting from a base of no lights, use only the minimum number and intensity of lights needed to provide safe and secure illumination for the area at the time required to meet the lighting objectives. The minimum amount of light needed to illuminate an object or area should be assessed during the early design stages and only that amount of light installed. For example, Figure 14 provides options from best to worst for lighting for a parking lot.

Figure 14 Lighting options for a parking area. Figure adapted from Witherington and Martin (2003)[3].

Off-the-shelf lighting design models

Use of computer design engineering packages that do not include wildlife needs and only recommend a standard lighting design for general application should be avoided or modified to suit the specific project objectives, location and risk factors.

Consider the intensity of light produced rather than the energy required to make it

Improvements in technology mean that new bulb types produce significantly greater amount of light per unit of energy. For example, LED lights produce between two and five times the amount of light as incandescent bulbs. The amount of light produced (lumen), rather than the amount of energy used (watt) is the most important consideration in ensuring that an area is not over lit.

Consider re-evaluating security systems and using motion sensor lighting

Technological advances mean that techniques such as computer managed infra-red tracking of intruders in security zones is likely to result in better detection rates than a human observer monitoring an illuminated zone.

Use low glare lighting

High quality, low glare lighting should always be a strong consideration regardless of how the project is to be designed. Low glare lighting enhances visibility for the user at night, reduces eye fatigue, improves night vision and delivers light where it is needed.

5. Use non-reflective, dark coloured surfaces

Light reflected from highly polished, shiny or light-coloured surfaces such as white painted infrastructure, polished marble or white sand can contribute to sky glow. For example, alternatives to painting storage tanks with white paint to reduce internal heating should be explored during front-end engineering design. In considering surface reflectance, the need to view the surface should be taken into consideration as darker surfaces will require more light to be visible. The colour of paint or material selected should be included in the Artificial Light Management Plan.

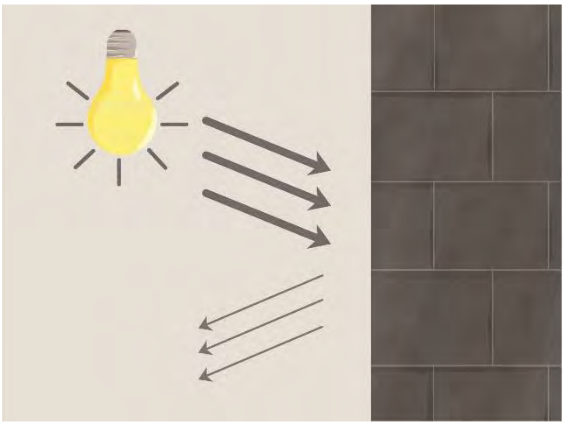


Figure 15 Use non-reflective dark coloured surfaces.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 69 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

6. Use lights with reduced or filtered out blue, violet and ultraviolet wavelengths

Short wavelength light (blue) scatters more readily in the atmosphere and therefore contributes more to sky glow than longer wavelength light. Further, most wildlife are sensitive to short wavelength (blue/violet) light (for detailed discussion see What is Light and how do Wildlife Perceive it?). As a general rule, only lights with little or no short wavelength (400 – 500 nm) violet or blue light should be used to avoid unintended effects. Where wildlife are sensitive to longer wavelength light (e.g. some bird species), consideration should be given to wavelength selection on a case by case basis.

When determining the appropriate wavelength of light to be used, all lighting objectives should be taken into account. If good colour rendition is required for human use, then other mitigation measures such as tight control of light spill, use of head torches, or timers or motion sensors to control lights should be implemented.

It is not possible to tell how much blue light is emitted from an artificial light source by the colour of light it produces (see Light Emitting Diodes). LEDs of all colours, particularly white, can emit a high amount of blue light and the Colour Correlated Temperature (CCT) only provides a proxy for the blue light content of a light source. Consideration should be given to the spectral characteristics (spectral power distribution curve) of the lighting to ensure short wavelength (400 – 500 nm) light is minimised.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 70 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix B – What is Light and how does Wildlife Perceive it?

A basic understanding of how light is defined, described and measured is critical to designing the best artificial light management for the protection of wildlife.

Humans and animals perceive light differently. However, defining and measuring light has traditionally focused exclusively on human vision. Commercial light monitoring equipment is calibrated to the sensitivity of the human eye and has poor sensitivity to the short wavelength light that is most visible to wildlife. Impacts of artificial light on wildlife vary by species and should be considered on a case by case basis. These issues should be considered when describing, monitoring and designing lighting near important wildlife habitat.

What is Light?

Light is a form of energy and is a subset of the electromagnetic spectrum that includes visible light, microwaves, radio waves and gamma rays (Figure 16). In humans, visible light ranges from 380 nm to 780 nm - between the violet and red regions of the electromagnetic spectrum. In animals, visible light ranges from 300 nm to greater than 700 nm, depending on the species. White light is a mixture of all wavelengths of light ranging from short wavelength blue to long wavelength red light.

The perception of different wavelengths as 'colour' is subjective and is described and characterised by how the human eye perceives light, ranging from red (700 nm), orange (630 nm), yellow (600 nm), green (530 nm), blue (470 nm), indigo (425 nm) and violet (400 nm) (Figure 16). Generally, this is not how animals see light (Figure 2).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 71 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

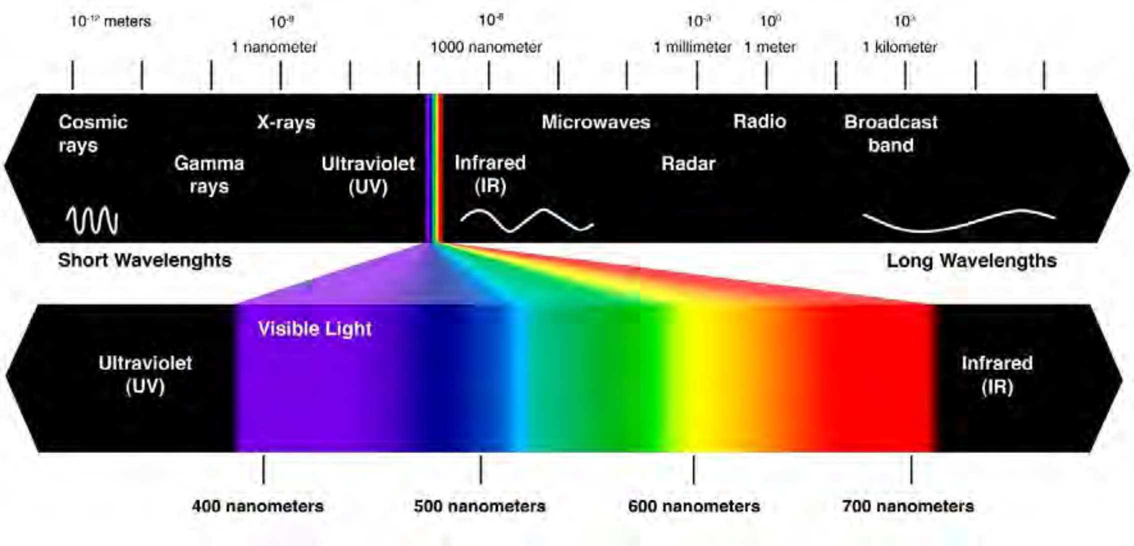


Figure 16 The electromagnetic spectrum. The 'visible light spectrum' occurs between 380-780 nm and is the part of the spectrum that the human eye can see. Credit: Mihail Pernichev[34].

Artificial light

Artificial light at night has many positive attributes. It can enhance human safety and provide for longer periods of work or recreation. However, it can also have a negative effect. For example, it can cause:

- physiological damage to retinal cells in human and animal eyes[35]
- disruption of the circadian cycles in vegetation, animals and humans[2,13,36]
- changes in animal orientation, feeding or migratory behaviour[19,37-39].

The biological mechanisms that cause these effects vary. It is necessary to understand some basic light theory and language in order to assess and manage the effect of light on wildlife. Some basic principles are briefly described in this section.

Vision in Animals

Vision is a critical cue for animals to orient themselves in their environment, find food, avoid predation and communicate[7]. Humans and wildlife perceive light differently. Some animals do not see long wavelength red light at all, while others see light beyond the blue-violet end of the spectrum and into the ultraviolet (Figure 17).

Both humans and animals detect light using photoreceptor cells in the eye called cones and rods. Colour differentiation occurs under bright light conditions (daylight). This is because bright light activates the cones and it is the cones that allow the eye to see colour. This is known as photopic vision.

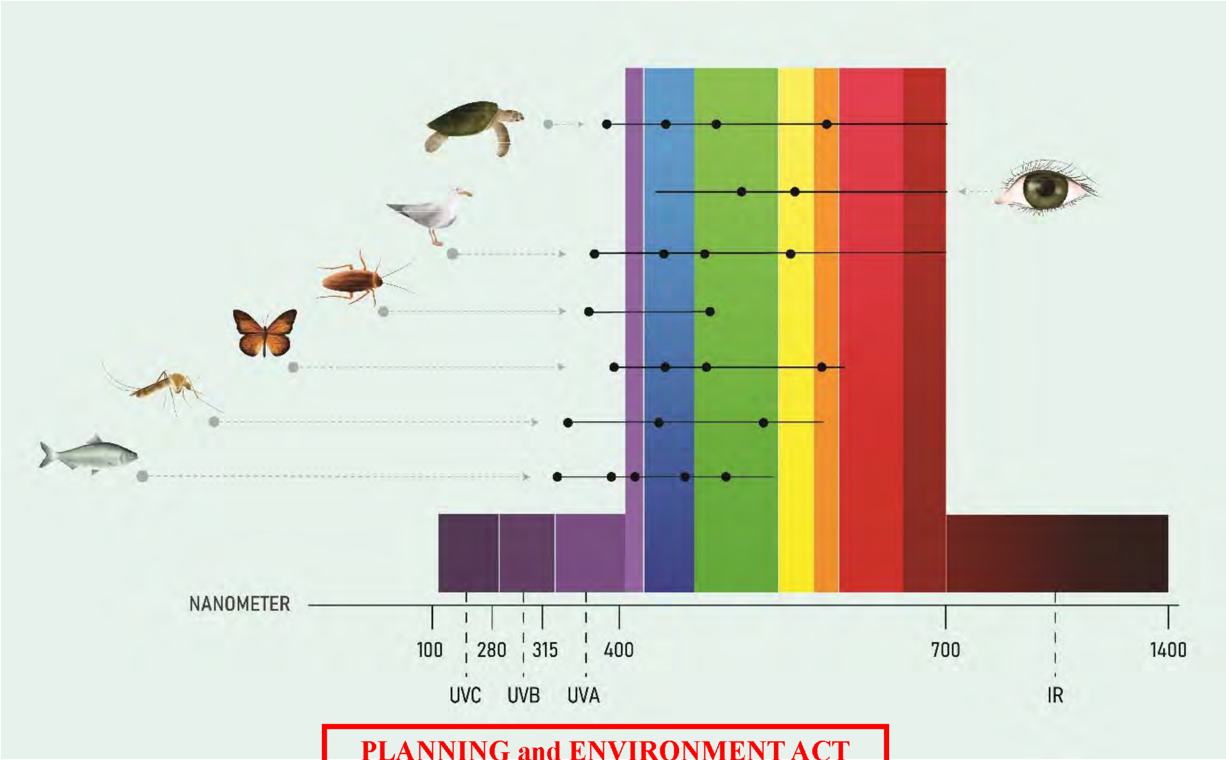
Under low light conditions (dark adapted vision), light is detected by cells in the eye called rods. Rods only perceive light in shades of grey (no colour). This is known as scotopic vision and it is more sensitive to shorter wavelengths of light (blue/violet) than photopic vision.

The variation in the number and types of cells in the retina means animals and humans do not perceive the same range of colours. In animals, being ‘sensitive’ to light within a specific range of wavelengths means they can perceive light at that wavelength, and it is likely they will respond to that light source.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 72 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023



PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 73 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 17 Ability to perceive different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivity. Note the common sensitivity to short wavelength light across all wildlife. Figure adapted from Campos (2017)[8].

Sensitivity to blue light

Sensitivity to high energy, short wavelength UV/violet/blue light is common in wildlife (Figure 17). This light is strongly detected under scotopic (dark adapted) vision, particularly in nocturnal species. Short wavelength light at the blue end of the spectrum has higher energy than longer wavelength light at the red end of the spectrum. This is important to understanding the physical impact that the short wavelength, high energy UV/blue light has on damaging photoreceptor cells in the human eye[40]. Although not well described in wildlife, it is not unreasonable to expect that at high intensities blue light has the potential to damage photoreceptors in wildlife.

In addition to the potential for physical damage to the eye from exposure to blue light (400 - 490 nm), there is mounting evidence that exposure to these wavelengths at night may affect human and wildlife physiological functions. This is because a third type of photoreceptor cell has recently been identified in the retina of the mammalian eye – the photosensitive retinal ganglion cells (pRGCs). The pRGCs are not involved in image-forming vision (this occurs in the rods and cones), but instead are involved in the regulation of melatonin and in synchronising circadian rhythms to the 24-hour light/dark cycle in animals[41]. These cells are particularly sensitive to blue light[42]. Melatonin is a hormone found in plants animals and microbes. Changes in melatonin production can affect daily behaviours such as bird waking[43], foraging behaviour and food intake[44] and seasonal cues such as the timing of reproduction in animals, causing off-spring to be born during non-optimal environmental conditions[5].

Factors Effecting Perception of Light

Factors affecting how wildlife perceive light include the type of cells being employed to detect light (photopic vs scotopic vision); whether the light is viewed directly from the source or as reflected light; how the light interacts with the environment; and the distance from the light source. These influences are discussed below.

Perspective

Understanding an animal's perception of light will include consideration of the animal's visual field. For instance, when flying, birds will generally be looking down on artificial light sources, whereas turtles on a nesting beach will be looking up. Further, some birds' field of view will stretch around to almost behind their head.

Bright vs dim light

Understanding photopic and scotopic vision is important when selecting the colour (wavelength) and intensity of a light. In animals scotopic (dark adapted) vision allows for the detection of light at very low intensities (Figure 18). This dark adaption may explain why nocturnal wildlife are extremely sensitive to white and blue light even at low intensities.

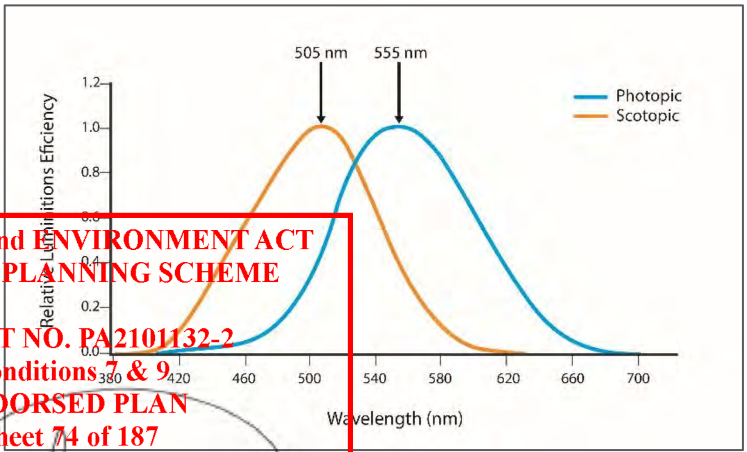


Figure 18 Scotopic and photopic luminosity functions in humans. Data source: [Luminosity functions](#).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 74 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Direct vs reflected

Understanding the difference between light direct from the source (luminance) and how much incident light illuminates a surface (illuminance) is important when selecting methods for measuring and monitoring light. Equipment used to measure illuminance and luminance is not interchangeable and will lead to erroneous conclusions if used incorrectly.

Luminance describes the light that is emitted, passing through or reflected from a surface that is detected by the human eye. The total amount of light emitted from a light is called luminous flux and represents the light emitted in all directions (Figure 19). Luminance is quantified using a Spectroradiometer or luminance meter.

Illuminance measures how much of the incident light (or luminous intensity) illuminates a surface. Illuminance is quantified using an Illuminance spectrophotometer or Lux meter.

The total amount of light emitted by a bulb is measured in lumens and is different to watts, which are a measure of the amount of power consumed by the bulb. Lumens, not watts, provide information about the brightness of a bulb.

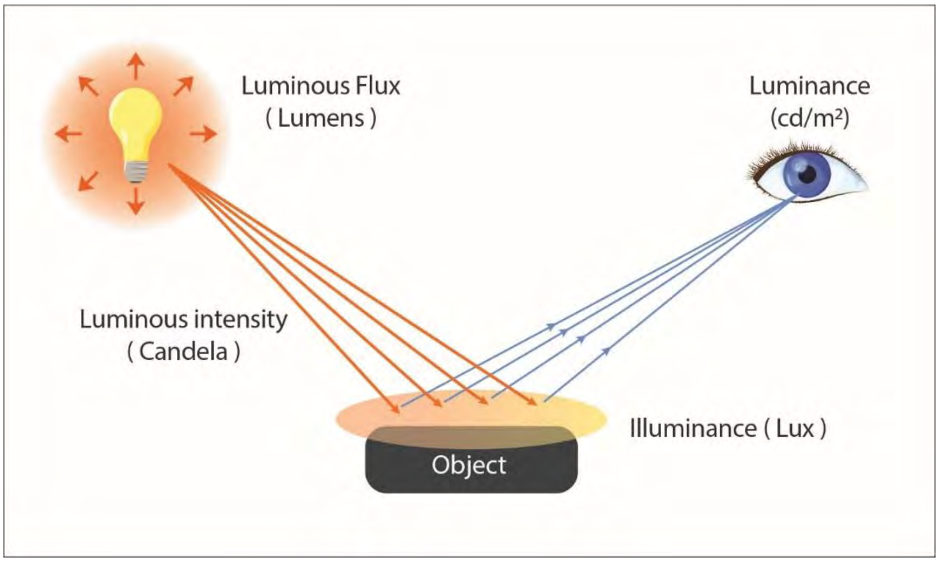


Figure 19 Luminous flux, luminance and illuminance.

Visibility of light in the environment

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 75 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The physical properties of light include reflection, refraction, dispersion, diffraction and scattering. These properties are affected by the atmosphere through which light travels. Short wavelength violet and blue light scatters in the atmosphere more than longer wavelength light such as green and red, due to an effect known as Rayleigh scattering[45].

Scattering of light by dust, salt and other atmospheric aerosols increases the visibility of light as sky glow while the presence of clouds reflecting light back to earth can substantially illuminate the landscape[46]. Hence the degree of overhead sky glow is a function of aerosol concentration and cloud height and thickness.

Direct light vs sky glow

Light may appear as either a direct light source from an unshielded lamp with direct line of sight to the observer, or as sky glow (Figure 20). Sky glow is the diffuse glow caused by source light that is screened from view, but through reflection and refraction the light creates a glow in the atmosphere. Sky glow is affected by cloud cover and other particles in the air. Blue light scatters more in the atmosphere compared with yellow-orange light. Clouds reflect light well adding to sky glow.

Figure 20 Sky glow created by lights shielded by a vegetation screen (circled left) and point sources of light directly visible (circled right).

Distance from light source

The physical properties of light follow the inverse square law which means that the visibility of the light, as a function of its intensity and spatial extent, decreases with distance from the source (Figure 21). This is an important factor to consider when modelling light or assessing the impact of light across different spatial scales, for example across landscape scales compared to within development footprint.

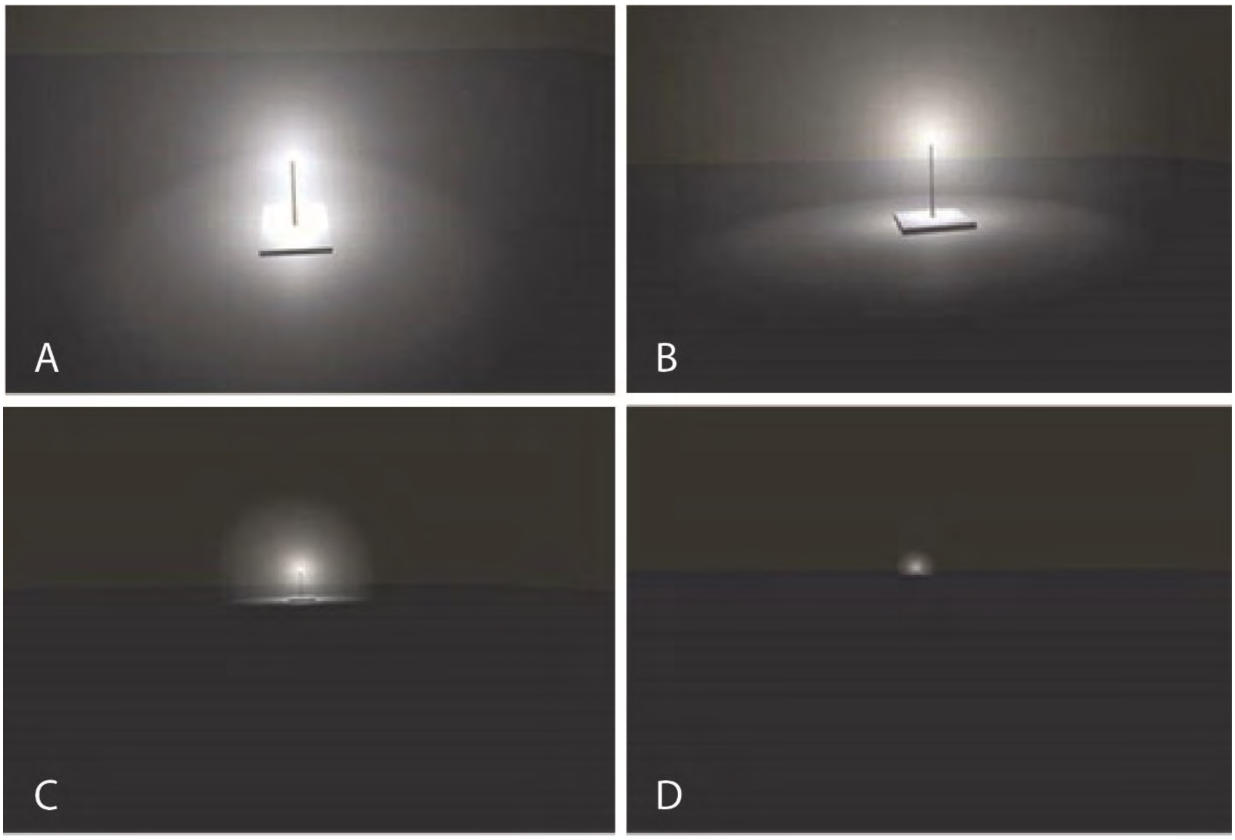


Figure 21 Modelled changes in the visibility of an unshielded 1000 W white LED viewed from A. 10 m; B. 100 m; C. 1 km and D. 3 km.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 76 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Measurement of Light

Light has traditionally been measured photometrically or using measurements that are weighted to the sensitivity of the human eye (peak 555 nm). Photometric light is represented by the area under the Commission International de l'Eclairage (CIE) curve, but this does not capture all light visible to wildlife (Figure 22).

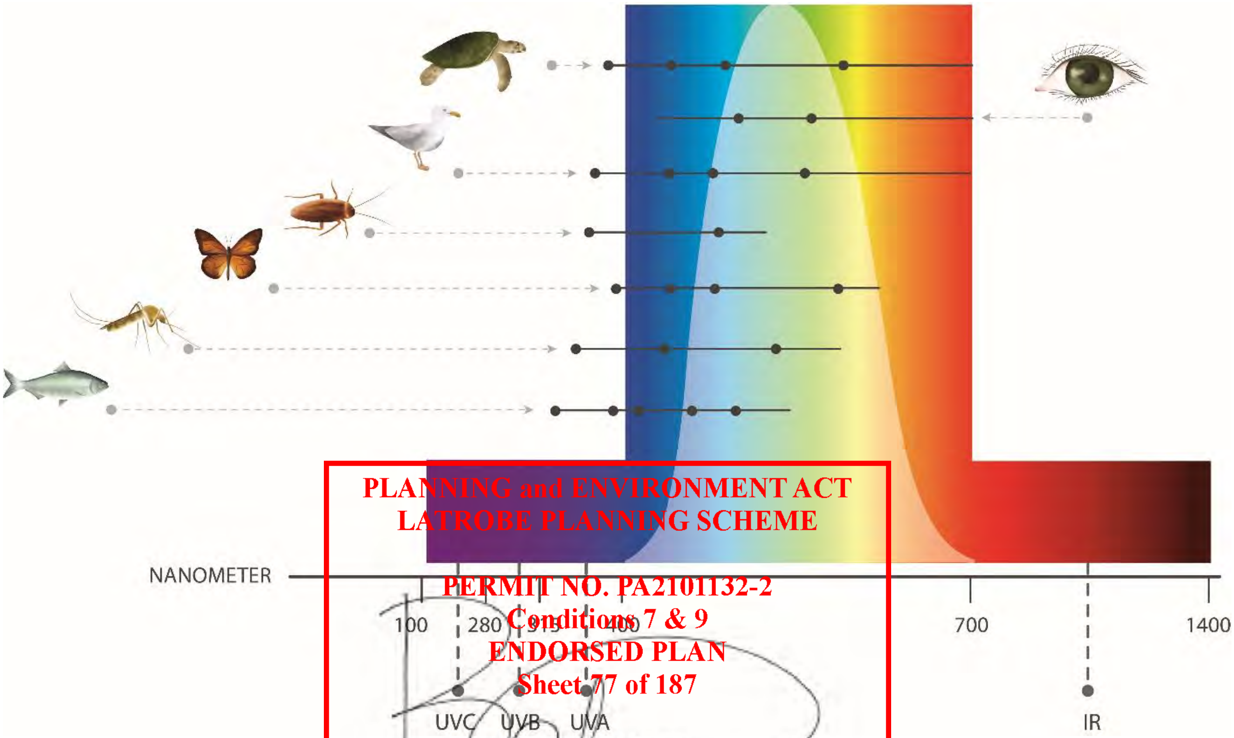


Figure 22 Photometric light represented by the area under the CIE curve (white area) compared with ability to perceive different wavelengths (black lines) and reported peak sensitivity (black dots) in humans and wildlife. Note the area under the CIE curve does not include much of the violet and ultra-violet light visible to many animals. Figure adapted from Campos (2017)[8].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 77 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

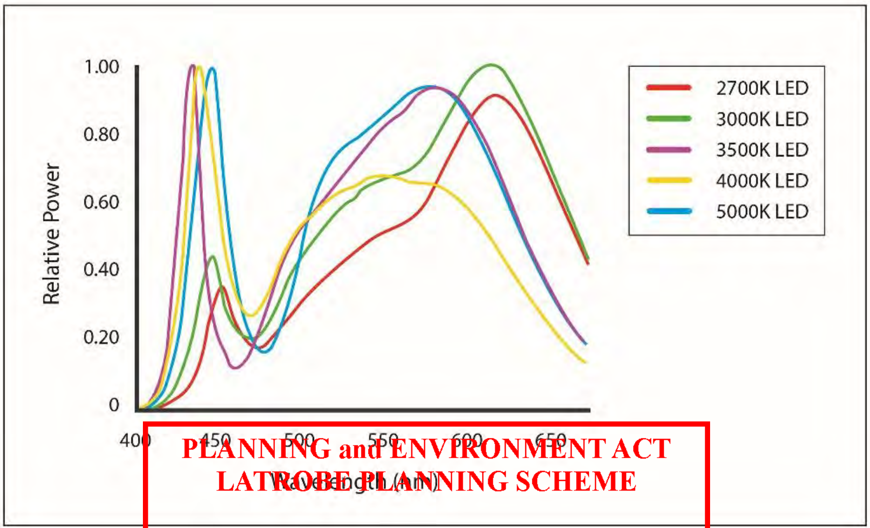
Light can also be measured radiometrically. Radiometric measurements detect and quantify all wavelengths from the ultra-violet (UV) to infrared (IR). The total energy at every wavelength is measured. This is a biologically relevant measure for understanding wildlife perception of light. Terminology, such as radiant flux, radiant intensity, irradiance or radiance all refer to the measurement of light across all wavelengths of the electromagnetic spectrum.

Understanding the difference between photometry (weighted to the sensitivity of the human eye) and radiometry (measures all wavelengths) is important when measuring light since many animals are highly sensitive to light in the blue and the red regions of the spectrum and, unlike photometry, the study of radiometry includes these wavelengths.

Photometric measures (such as, illuminance and luminance) can be used to discuss the potential impact of artificial light on wildlife, but their limitations should be acknowledged and taken into account as these measures may not correctly weight the blue and red wavelengths to which animals can be sensitive.

Spectral curve

White light is made up of wavelengths of light from across the visible spectrum. A spectral power curve (Figure 23) provides a representation of the relative presence of each wavelength emitted from a light source. A lighting design should include spectral power distribution curves for all planned lighting types as this will provide information about the relative amount of light emitted at the wavelengths to which wildlife are most susceptible.



PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 78 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 23 Spectral curves showing the blue content of white 2700-5000 K LED lights. Note the difference in relative power output in the blue (400 - 500 nm) wavelength range. Figure courtesy of Ian Ashdown.

Light Emitting Diodes (LEDs)

Light emitting diodes are rapidly becoming the most common light type globally as they are more energy efficient than previous lighting technology. They can be smart controlled, are highly adaptable in terms of wavelength and intensity, and can be instantly turned on and off.

Characteristics of LED lights that are not found in older types of lamps, but which should be considered when assessing the impacts of LEDs on wildlife, include:

- With few exceptions, all LED lights contain blue wavelengths (Figure 23 and Figure 24).
- The wattage of an LED is a measure of the electrical energy needed to produce light and is not a measure of the amount or intensity of light that will be produced by the lamp.
- The output of light produced by all lamps, including LEDs, is measured in lumens (lm).
- LED lamps require less energy to produce the equivalent amount of light output. For example, 600 lm output of light requires 40 watts of energy for an incandescent light bulb and only 10 watts of energy for a LED lamp. Another was to look at this is that a 100 W incandescent bulb will produce the same amount of light as a 20 W LED. Consequently, it is important to not replace an old-style lamp with the equivalent wattage LED.

- Different LED lights with the same correlated colour temperature (CCT) can have very different blue content (Figure 24) yet can appear, to the human eye, to be a similar colour. As the colour temperature of a white LED increases so can the blue content (Figure 23). Little or none of this increase in blue wavelength light is measured by photometric equipment (i.e. lux meter, luminance, illuminance meter, Sky Quality Meter – see Measuring Biologically Relevant Light).
- LED technology allows for tuneable RGB colour management. This has the potential to allow for species specific management of problematic wavelengths (e.g. blue for most wildlife, but also yellow/orange).

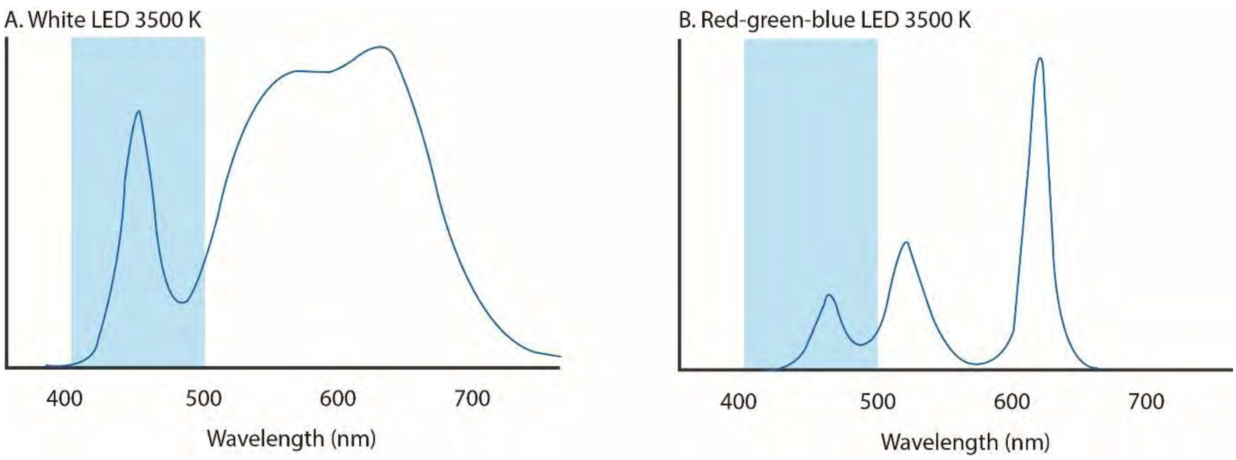


Figure 24 A comparison of the blue wavelength spectral content of two LED lights with the same CCT (3500k). The blue band shows the blue region of the visible spectrum (400–500 nm). The light in A has a much greater blue light content than B yet the two appear to the human eye as the same colour. For animals with differing sensitivities to light wavelength from humans, they may appear very different. Figure courtesy of Ian Ashdown.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 79 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Correlated colour temperature (CCT)

This describes the colour appearance of a white LED. It is expressed in degrees Kelvin, using the symbol K, which is a unit of measure for absolute temperature. Practically, colour temperature is used to describe light colour and perceived "warmth"; lamps that have a warm yellowish colour have low colour temperatures between 1000K and 3000K while lamps characterised by a cool bluish colour have a colour temperature, or CCT, over 5000K (Figure 25).

Correlated colour temperature does not provide information about the blue content of a lamp. All LEDs contain blue light (Figure 23) and the blue content generally increases with increased CCT. The only way to determine whether the spectral content of a light source is appropriate for use near sensitive wildlife is to consider the spectral curve. For wildlife that are sensitive to blue light, an LED with low amounts of short wavelength light should be chosen, whereas for animals sensitive to yellow light[9] LEDs with little or no light at peak sensitivity should be used[47].

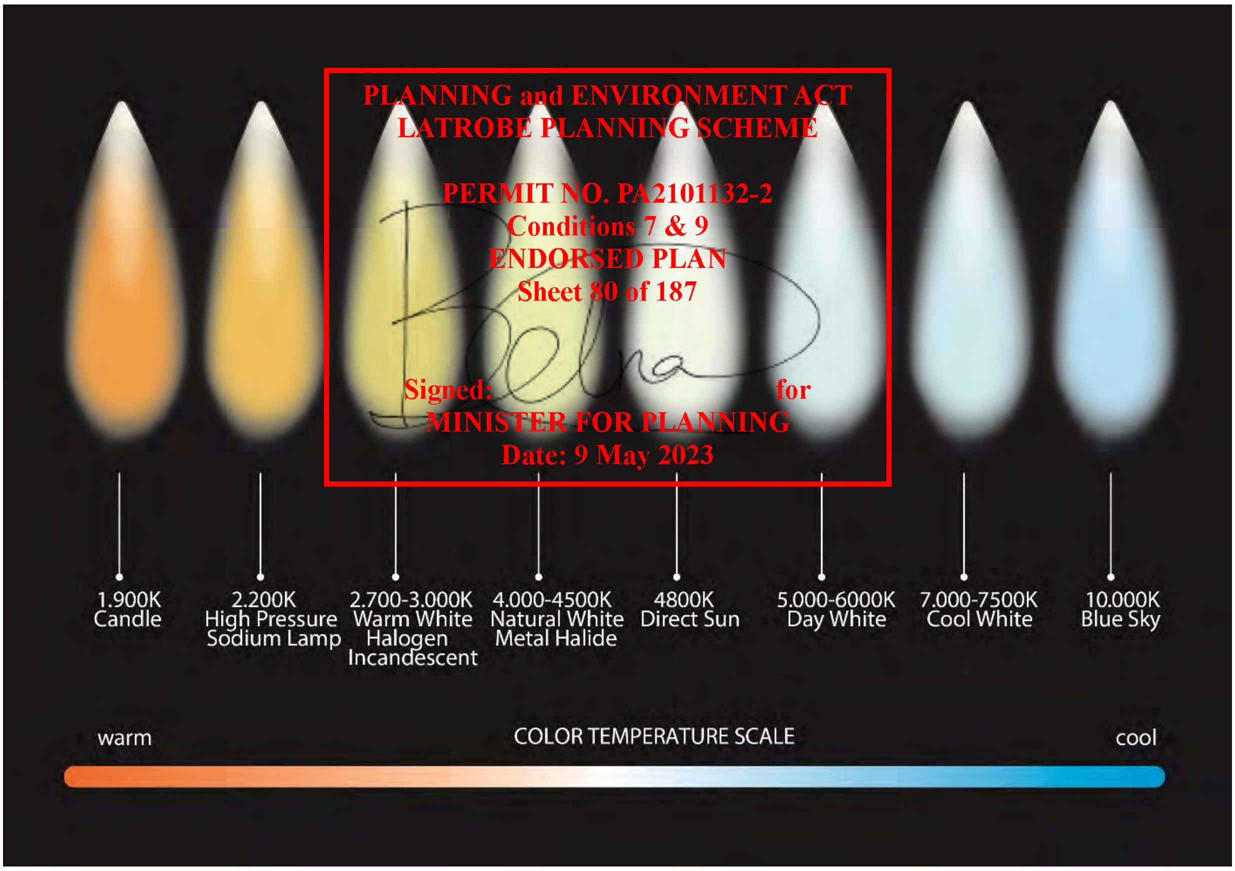


Figure 25 Correlated colour temperature (CCT) range from warm 1,000 K to cool 10,000 K.

Appendix C - Measuring Biologically Relevant Light

Animals and humans perceive light differently. Commercial light monitoring instruments currently focus on measuring the region of the spectrum most visible to humans. It is important to recognise and account for this fact when monitoring light for wildlife impact assessment purposes.

Commercial light modelling programs also focus on light most visible to humans and this should also be recognised and accounted for in the impact assessment of artificial light on wildlife.

Information critical to monitoring the effects of artificial light on wildlife include:

- **Spatial extent of sky glow**
- **Bearings and intensity of light sources along the horizon**
- **Visibility of light (direct and sky glow) from wildlife habitats**
- **Spectral distribution of lights sources.**

Describing the Light Environment

When describing the light environment consideration should be given to how wildlife is likely to perceive artificial light. Light measurements should be obtained from within important habitat and taken from a biologically relevant perspective (i.e. close to the ground/from the sky/under water). Consideration should also be given to elevation from the horizon, the spatial extent of sky glow and the wavelength distribution (spectrum) of light present.

It is important that light measurements are taken at appropriate times. This may include biologically relevant times (e.g. when wildlife is using the area). Baseline measurements should be taken when the moon is not in the sky and when the sky is clear of clouds and in the absence of temporary lighting (e.g. road works). Conditions should be replicated as closely as possible for before and after measurements.

Measuring Light for Wildlife

Measuring light to assess its effect on wildlife is challenging and an emerging area of research and development. Most instruments used to measure sky glow are still in the research phase with only a few commercial instruments available. Further, the wide range of measurement systems and units in use globally makes it difficult to choose an appropriate measurement metric and often results cannot be compared between techniques due to variations in how the light is measured. There is currently no globally recognised standard method for monitoring light for wildlife.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 81 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Radiometric vs photometric measurement techniques

Radiometric instruments detect and quantify light equally across the spectrum (see Measurement of Light) and are the most appropriate instruments for monitoring and measuring light for wildlife management. However, while the techniques to measure radiometric light are well developed in physics, astronomy and medicine, they are less well developed in measurement of light in the environment. The instruments currently being developed are largely the result of academic and/or commercial research and development, are expensive, and require specialised technical skills for operation, data analysis, interpretation and equipment maintenance.

The majority of both commercial and research instruments quantify photometric light, which is weighted to the sensitivity of the human eye, as per the CIE luminosity function curve described in Measurement of Light. Due to many photometers being modified with filters to mimic human vision, they do not accurately represent what an animal with high sensitivity to the blue (400 - 500 nm) or the red (650 - 700 nm) regions of the spectrum will see (Figure 22). In these cases, the sensitivity to this additional light must be accounted for when reporting results.

When using photometric instruments for monitoring light this insensitivity to the short and long wavelength regions of the spectrum should be recognised and accounted for in the assessment of impact. Information on the spectral power distribution of commercial lights is readily available from manufacturers and suppliers and should be used to inform any artificial light impact assessment or monitoring program. An example of the spectral power distribution curves for various light sources is shown in Figure 26, along with an overlay of the CIE curve that represents the light that is measured by all commercial photometric instruments.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 82 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

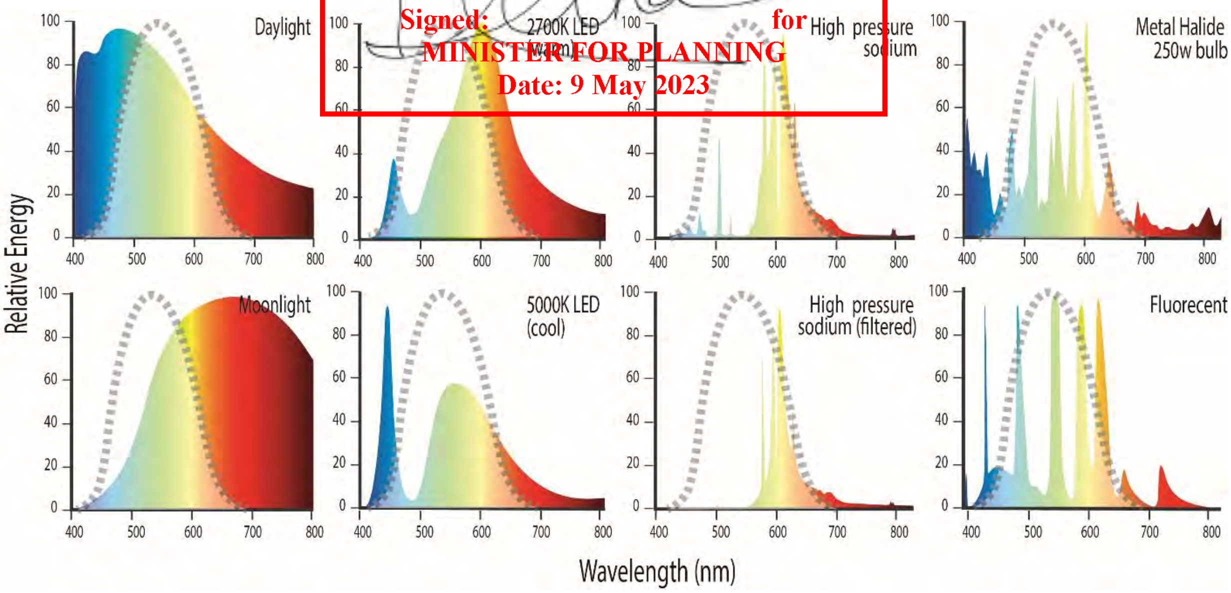


Figure 26 Photometric instruments only quantify light that is within the CIE curve (area under grey dashed line). This is shown in comparison with the spectral curves of a range of different light sources.

Recognising that light monitoring instruments for wildlife are in the developmental stage and that there is a lack of agreed methods and measurement units, monitoring programs should aim to measure relevant short and long wavelengths (if possible). The measurement methods should be clearly described including the region of the spectrum measured, and where not measures, how the short and long wavelength regions are being accounted for. Methods to do this might include a visual assessment of the colour of light in the sky from direct observation or imagery, where orange glow is typically associated with long wavelength rich lights (High Pressure Sodium, HPS, Low Pressure Sodium, LPS, PC Amber LED or Amber LED) and white glow is associated with white light sources rich in short wavelength blue light (white LEDs, halogens, fluorescents, metal halide etc.).

Alternatively photometric instruments can be used under conditions where the majority of light sources are the same, for example street lighting or industrial facilities. Monitoring results can be compared for measurements taken of the same light types (e.g. comparing two HPS sources, spatially or temporally), but in the context of wildlife monitoring cannot be used to compare light from an HPS and an LED since they have different wavelength distributions. This limitation must be taken into account when using photometric instruments to measure cumulative sky glow, which may include light from multiple sources and light types. Detailed qualitative spectral information on light types can also be collected to ground truth and confirm light types contributing to sky glow.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 83 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

A light monitoring program might therefore include the collection of a range of different characteristics of light (e.g. colour, light type, area, extent, spectral power distribution, and intensity) using various instruments and techniques. These methods and techniques, including all of the limitations and assumptions, should be clearly stated and considered when interpreting results. A review of various instrumental techniques for monitoring light is provided below.

In selecting the most appropriate measuring equipment to monitor the biological impacts of light on wildlife, it is important to decide what part of the sky is being measured: horizon, zenith (overhead) or whole sky. For example, marine turtles view light on the horizon between 0° and 30° vertically and integrate across 180° horizontally[48], so it is important to include measurement of light in this part of the sky when monitoring for the effects on hatchling orientation during sea-finding. In contrast, juvenile shearwaters on their first flight view light in three dimensions (vertically, from below and above) as they ascend into the sky. Overhead sky glow (zenith) measurements are important when the observer is trying to avoid glare contamination by point sources of light low on the horizon. Quantifying the whole of sky glow is important when measuring the effects of cloud cover, which can reflect light back to illuminate an entire beach or wetland.

The effect of light on wildlife is a function of the animal's sensitivity and response to light, and the cues it uses during orientation, dispersal, foraging, migrating etc. Most wildlife appear to respond to high intensity short wavelength light, point sources of light, sky glow and directional light. Consequently, the information likely to be needed to monitor light for wildlife includes:

- The brightness of the entire sky from horizon to horizon.
- The bearing to, intensity of and spectrum of light (point sources and sky glow) on the horizon. This will dictate the direction in which wildlife can be disoriented.

- The spatial extent of glow near the horizon. A large area of glow on the horizon is likely to be more visible and disruptive to wildlife than a small area of glow.
- Presence or absence of clouds. Clouds reflect light from distant sources very well, making an inland source highly visible on the coast, for example. Sky glow is a function of cloud height, albedo and thickness.
- Qualitative information on the light visible to wildlife. An image of light pollution visible from wildlife habitat can show the spatial extent of light in the sky and direction (see Figure 20) and in some cases provide information on the light source type (e.g. orange sky glow will be caused by HPS lights or amber LEDs).
- Emission spectra (colour) of the light. It is particularly important to identify light in the UV-blue region of the visible spectrum (<500 nm) since this is the light commonly visible and disruptive to wildlife.

Measurement Techniques

Currently, there are no generally agreed methods for measuring biologically relevant light for wildlife or for quantifying sky glow[49]. This is because most conventional methods of measuring light are photometric, quantifying only the light under the CIE curve that is most relevant to the human perception of light. Further, they do not consider the entire night sky.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 84 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

There is a need to develop reasonably priced, easily accessible and deployable, repeatable methods for monitoring biologically relevant light that captures the whole visual field to which wildlife may be exposed (generally horizon to horizon)[49]. These methods should be capable of quantifying all wavelengths of light equally (radiometric) including at least 380 – 780nm, or capable of being calibrated over the range of wavelengths of relevance for the species of interest. Optimal methods will have a sensitivity to detect and measure change at the low light levels represented by artificial light sky glow and must have the ability to differentiate between individual point sources of light (on a local scale) and sky glow on a landscape scale (i.e. over tens of kilometres).

It should be noted that measurements needed to assess the impact of sky glow to wildlife may need to be different from the measurements required to assess light for human safety.

Recognising that techniques to monitor biologically meaningful light are expected to continuously develop and improve, this section summarises the state of the science as of 2020 as an example of current techniques. It is anticipated novel methods will be developed with time that will meet the objectives of monitoring biologically meaningful light and where that occurs, the methods and techniques, including all of the limitations and assumptions, should be clearly stated for all monitoring programs.

Recent reviews have considered various commercial and experimental instrumental techniques used around the world for quantifying sky glow[49,50]. The reviews assessed the benefits and limitations of the various techniques and made recommendations for measuring light pollution. Some of these instruments, their benefits and limitations are discussed below and summarised in Table 1.

Light can be measured in different ways, depending on the objective, landscape scale and point of view and include:

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 85 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

- remote sensing
- one dimensional (single channel) instruments
- calibrated all-sky imagery (numerical and imaging)
- spectroscopy/spectroradiometry.

Remote sensing

The upward radiance of artificial light at night can be mapped via remote sensing using satellite or aerial imagery and optical sensors. This information has been used as a socioeconomic indicator to observe human activity, and increasingly as a tool to consider the impacts of artificial light on ecosystems[51]. Examples are:

- The New World Atlas of Artificial Night Sky Brightness
- Light Pollution Map

Benefits: The images are useful as broad scale indicators of light pollution and for targeting biological and light monitoring programs. This technique may be a good starting point to identify potentially problematic areas for wildlife on a regional scale. Images collected via drones or aircraft maybe useful for consideration of artificial light impacts on bird and bat migrations.

Limitations: Maps derived from satellite collected information have limited value in quantifying light for wildlife. The images are a measure of light after it has passed though the atmosphere and been subject to scattering and absorption. They do not give an accurate representation of the light visible to wildlife at ground level. The annual composite images are made from images collected under different atmospheric conditions and therefore they cannot be used to confidently quantify light within or between years. The most commonly used instrument (VIIRS DNB) is not sensitive to blue light, so light in this part of the spectrum is under sampled. As satellite with more sophisticated sensors are launched it is expected the value of this technique to biological monitoring will improve.

Application to wildlife monitoring programs: Whilst remote sensing tools may provide a good starting point for identifying artificial light that is problematic for wildlife on a regional scale, they are currently not an appropriate approach for measuring light as part of a wildlife monitoring program as they do not accurately quantify light as observed from the ground, they underestimate the blue content of light, and results are not repeatable due to environmental conditions. Images collected via aircraft or drone may have application for monitoring impacts on airborne wildlife.

One dimensional (single channel) instruments

These instruments measure sky glow using a single channel detector, producing a numerical value to represent sky glow, typically at the zenith. They are generally and portable and easy to use. They measure sky glow, but cannot derive point source information unless they are close enough such that most of the light detected is emitted from those sources. Examples of single channel instruments are discussed below.

Sky Quality Meter (SQM)

This is a small handheld unit that quantifies the light in an area of sky (normally directly overhead at the zenith). Early models had a field of view of around 135° with the more recent SQM-L model having a narrower 40° diameter field of view. It measures photometric light in units of magnitudes/arcsec^2 at relatively low detection limits (i.e. it can measure sky glow). Instrument accuracy is reported at ±10 per cent though a calibration study on a group of SQM instruments in 2011 found errors ranging from -16 per cent to +20 per cent[52]. Long term stability of SQMs has not been established.

Reviewers suggest that the first 3-4 measurements from a handheld SQM should be discarded, then the average of four observations should be collected by rotating the SQM 20° after each observation to obtain a value from four different compass directions so that the effects of stray light can be minimised or identified[20]. If the measurements vary by more than 0.2 mag/arcsec^2 the data should be discarded and a new location for measurements selected. Data should not be collected on moonlit nights to avoid stray light contaminating the results.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 86 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Benefits: The SQM is cheap, easy to use and portable. Some versions have data-logging capabilities that enable autonomous operation in the field. The sensitivity of the SQM is sufficient to detect changes in overhead night time artificial lighting under a clear sky.

Limitations: SQMs cannot be used to resolve individual light sources a distance, identify light direction nor can they measure light visible to many wildlife species. The precision and accuracy of the instrument can vary substantially and an intercalibration study is recommended to quantify the error of each instrument. Although the SQM is designed to have a photopic response, it is generally more sensitive to shorter wavelengths (i.e. blue) than a truly photopic response, but this will depend on the individual instrument. It is not very sensitive to longer (orange/red) wavelengths[50]. The SQM should not be used to measure light within 20° of the horizon as the detector is designed to measure a homogeneous sky (such as occurs at the zenith) and does not produce valid data when point at a heterogeneous field of view as observed at the horizon.

Application to wildlife monitoring programs: A sky quality meter can be used to measure sky glow directly overhead (zenith) at the wildlife habitat, however, it is important to recognise its limitations (such as the absence of whole of sky information and inability to measure point sources of light on the horizon) and follow methods recommended by Hänel et al (2018)[50] to ensure repeatability.

Dark Sky Meter

This is an iPhone app that uses the phone camera to collect light and generate a sky brightness value.

<u>Benefits</u>: It's cheap and easy to use.

<u>Limitations</u>: The Dark Sky Meter is a photometric instrument. It's restricted to Apple iPhones. It will not work on models older than the 4S and cannot be used to resolve individual lights or identify light direction. It is relatively imprecise and inaccurate[50] and cannot reliably measure light on the horizon.

<u>Application to wildlife monitoring programs</u>: The Dark Sky Meter app is not an appropriate tool for monitoring light impacts on wildlife as it doesn't measure biologically relevant light. It doesn't provide whole of sky information, it isn't able to resolve individual light sources and it is relatively imprecise and inaccurate. The Dark Sky Meter should be considered more of an educational tool than a scientific instrument.

Lux Meters and Luminance Meters

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 87 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Lux meters are commercially available instruments commonly used to measure individual light sources at close range (i.e. over metres rather than landscape scale). However, the inverse square law can be used to calculate the illuminance if the distance is known. Lux and luminance meters measure photometric light. Lux meters measure the light falling on a surface and luminance meters measure the light incident from a specific solid angle.

<u>Benefits</u>: Both can be cheap (with more expensive models available) and easy to use.

<u>Limitations</u>: Both types of devices are photometric, but measurements are weighted to human perception rather than wildlife. Depending on the sensitivity of equipment, detection limits may not be low enough to measure typical night sky brightness or illuminance and therefore cannot measure sky glow for wildlife monitoring purposes. Lux meters have no angular resolution and luminance meter are coarse so they cannot be used to measure distant light sources at the horizon precisely.

<u>Application to wildlife monitoring programs</u>: Commercial lux and luminance meters are not appropriate for the measurement of light in wildlife monitoring programs because they have low sensitivity and low accuracy at low light levels. Expensive tailored devices with enhanced sensitivity may exist, but are still not applicable to wildlife monitoring as they do not measure biologically relevant light and are not appropriate for use on a landscape scale.

Calibrated all-sky imagery

These instruments map and measure sky brightness by analysing photographic images of the whole sky. The images are processed to derive a luminance value for all or parts of the sky. One of the advantages of two dimensional (wide angle) imaging is that models of natural sources of light in the night sky can be subtracted from all sky imagery to detect anthropogenic sources[53]. Some examples of devices and techniques to map and measure night sky brightness using wide-angle images are discussed below.

All-Sky Transmission Monitor (ASTMON)

This charge-coupled device (CCD) astronomical camera with fish-eye lens has been modified by the addition of a filter wheel to allow collection of data through four photometric bands in the visible spectrum. The spectral range of the instrument is dependent on the sensitivity of the detector and the filters used, but has the advantage of being accurately calibrated on stars.

Benefits: The ASTMON was designed for outdoor installation and the Lite version is portable with a weather-proof enclosure allowing it to remain outdoors operating robotically for weeks. It reports data in magnitudes/$arcsec^2$ for each band and has good precision and accuracy[50]. Once the system is calibrated with standard stars, it can provide radiometric data for the whole night sky as well as resolve individual light sources.

Limitations: The ASTMON is expensive and requires specialised knowledge to operate and interpret data. The software provided is not open source and so cannot be modified to suit individual requirements. The ASTMON may no longer be commercially available. The CCD cameras used also have a limited dynamic range.

Application to wildlife monitoring programs: The ASTMON is appropriate for monitoring artificial light for wildlife as it provides whole night sky measurements that can be calibrated to give biologically relevant information that is accurate and repeatable.

Digital Camera Equipped with Wide Angle and Fisheye Lenses

This approach is similar to the ASTMON, except using a commercial digital camera with an RGB matrix rather than a CCD camera with filter wheel, making the system cheaper and more transportable. This system provides quantitative data on the luminance of the sky in a single image[54,55].

Benefits: The cameras are easily accessible and portable. When precision is not critical, the directional distribution of night sky brightness can be obtained. At the very least, the use of a digital camera with a fisheye lens allows for qualitative imagery data to be collected and stored for future reference and data analysis. If standard camera settings are used consistently in all surveys, it is possible to compare images to monitor spatial and temporal changes in sky brightness. This system also provides multi-colour options with red green and blue spectral bands (RGB).

Limitations: Cameras must be calibrated before use and this, together with the specific camera model, will dictate the precision of the measurements. Calibration for data processing requires lens vignetting (also known as flat fielding), geometric distortion, colour sensitivity of the

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 88 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

camera, and sensitivity function of the camera. Specialised knowledge is required to process and interpret these images. Also, like CCD cameras, the detectors in digital cameras have a limited dynamic range which can easily saturate in bright environments. In addition, fisheye systems often produce the poorest quality data at the horizon where the distortion due to the lens is the greatest.

Calibrating the camera is difficult and standard methods have not been developed. Laboratory or astronomical photometric techniques are generally used which require specialist knowledge and expertise. A precision of ~10 per cent can be achieved using this technique. Standard commercial cameras are calibrated to the human eye (e.g. photometric), however, the ability to obtain and process an image allows for qualitative assessment of light types (based on the colour of sky glow), which provides additional data for interpreting the biological relevance of the light.

Application to wildlife monitoring programs: A digital camera equipped with wide angle or fisheye lenses is appropriate for measuring light in wildlife monitoring programs as it provides horizon to horizon information with enough sensitivity and accuracy to detect significant changes in low light environments. Images allow for detection of both sky glow, light source type, and point source information. When data is manually processed biologically relevant measurements can be obtained. Because the system is fast, dynamics of sky glow and direct light can be monitored[56].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 89 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

All Sky Mosaics

This technique was developed by the US National Parks Service and provides an image of the whole of the sky by mosaicking 45 individual images. The system comprises a CCD camera, a standard 50 mm lens, an astronomical photometric Bessel V filter with IR blocker and a computer controlled robotic telescope mount. Data collection is managed using a portable computer, commercial software and custom scripts.

Benefits: The angular resolution, precision and accuracy of the system is good, and it is calibrated and standardised on stars. The images produced have high resolution. The system is best suited for long term monitoring from dark sky sites. However, with the addition of a neutral density filter, the luminance or illuminance of a near-by bright light source can be measured. Also, other photometric bands can be measured with the use of additional filters.

Limitations: The system is expensive and requires specialised knowledge to operate the system, analyse and interpret the data. These cameras are calibrated to the human eye with the inclusion of a visible filter, however the ability to obtain and process an image allows for qualitative assessment of light types in the (based on the colour of sky glow), which provides additional data for interpreting the biological relevance of the light. Measurement procedures are time consuming and require perfect clear sky conditions and single spectral band, or repeated measurements are required.

Application to wildlife monitoring programs: All sky mosaics would be an appropriate tool for monitoring of artificial light for wildlife. They provide whole of sky images with high resolution and with appropriate filters can be used to measure biologically relevant wavelength regions.

Spectroscopy/spectroradiometry

Different light types produce a specific spectral signature or spectral power distribution (for example Figure 26). Using a spectrometer it is possible to separate total sky radiance into its contributing sources based on their spectral characteristics. Being able to assess the impacts of different light sources is of relevance during this time of transition in lighting technology.

Where wildlife sensitivity to particular wavelength regions of light is known, being able to capture the spectral power distributions of artificial light and then predict how the light will be perceived by wildlife will be of particular benefit in assessing the likely impacts of artificial light.

This type of approach has been utilised in astronomy for a long time, but only recently applied to measurement and characterisation of light pollution on earth. An example of a field deployable spectrometer - the Spectrometer for Aerosol Night Detection (SAND) is described below.

Spectrometer for Aerosol Night Detection (SAND)

SAND uses a CCD imaging camera as a light sensor coupled with a long slit spectrometer. The system has a spectral range from 400 – 720 nm and is fully automated. It can separate sampled sky radiance into its major contributing sources.

Benefits: This approach can quantify light at specific wavelengths across the spectrum (radiometric) so it can measure light visible to wildlife. It can also be used to ‘fingerprint’ different light types.

Limitations: Calibration, collection and interpretation of these data requires specialist knowledge and equipment and is expensive. SAND does not provide whole sky information.

Application to wildlife monitoring programs: The use of a portable spectrometer that can identify light types based on their spectral power distribution or measure light at specific wavelengths of interest would be a useful contribution to a wildlife monitoring program. Unfortunately, the prototype SAND instrument is no longer in operation. However, this instrument exemplifies the type of approaches that will be of benefit for measuring light for wildlife in the future.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 90 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Most appropriate instrument for measuring biologically relevant light

The most appropriate method for measuring light for wildlife will depend on the species present and the type of information required. In general, an appropriate approach will quantify light across the whole sky, across all spectral regions, differentiating point light sources from sky glow and it will be repeatable and easy to use.

At the time of writing, the digital camera and fisheye lens technique was recommended by Hänel et al (2018) and Barentine (2019) as the best compromise between cost, ease-of-use and amount of information obtained when measuring and monitoring sky glow. Hänel et al (2018) did, however, recognise the urgent need for the development of standard software for calibration and displaying results from light monitoring instruments[50]. In the future, hyperspectral cameras with wide field of view might become available combining the advantages of spectroradiometry and all-sky imagery. However, such devices do not currently exist.

It should be noted that this field is in a stage of rapid development and this Technical Appendix will be updated as more information becomes available.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 91 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 1 Examples of instrumental light measurement techniques (modified from Hänel et al, 2018[50]). Abbreviations: Num. val. = Numerical value; Spec. Knowl. = Specialist Knowledge required; Req. calibration = requires calibration.

Instrument	Measurement Units	Detect Sky Glow	Data Type	Spectrum measured	Scale	Measures biologically relevant light	Commercially Available	Data Quality	Price#
Remote sensing:									
Satellite imagery	Various	Yes*	Images + num. val.	Single band	Landscape	No	Yes	Mod-high	Some datasets free
One dimensional:									
Sky Quality Meter (SQM)	$mag_{SQM}/arcsec^2$	Yes	Num. val.	Single band	Overhead	No§	Yes	Mod	< $300
Dark Sky Meter (iPhone)	$\sim mag_{SQM}/arcsec^2$	Yes	Num. val.	Single band	Overhead	No	Yes	Low	$0
Luxmeter	lux	No	Num. val.	Single band	Metres	No	Yes	Low	< $300
Two dimensional:									
ASTMON	$mag_V/arcsec^2$	Yes	Image + num. val.	Multi band filter wheel	Whole sky	Req. calibration	No	High	>$15,000
DSLR + fisheye	$\sim cd/m^2$, $\sim mag_V/arcsec^2$	Yes	Image + num. val..	Multi band RGB	Whole sky	Req. calibration	Yes	Mod-high	>$2,500
All sky mosaic	cd/m^2, $mag_V/arcsec^2$	Yes	Image + num. val..	Single band	Whole sky	Req. calibration	No	High	~ $20,000
Spectroradiometry:									
SAND¥	$W/(m^2nm\ sr)$	Yes	Spectral power curve	Multi band hyperspectral	Landscape	Yes	No	Mod-high	$7,000

Price as at 2018.

* Via modelling

§ Some sensitivity to short (blue) wavelengths, but not long (orange red) wavelengths.

¥ Spectrometer for Aerosol Night Detection (SAND).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 92 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Modelling Predicted Light

Available commercial light models

Most modelling software that is currently available is problematic as the models are weighted towards a human perception of light as represented by the CIE/photometric curve and do not account for the light to which wildlife are most sensitive. For example, most wildlife is sensitive to short wavelength violet and blue light (Figure 17), but little or none of this light is measured by commercial instruments and consequently it is not accounted for in current light models.

A second limitation of many light models for biology is the inability to accurately account for environmental factors, such as: atmospheric conditions (moisture, cloud, rain, dust); site topography (hills, sand dunes, beach orientation, vegetation, buildings); other natural sources of light (moon and stars); other artificial sources of light; the spectral output of luminaires; and the distance, elevation, and viewing angle of the observing species. Such a model would involve a level of complexity that science and technology has yet to deliver.

A final major limitation is the lack of biological data with which to confidently interpret a model outcome. Therefore, it is not possible to objectively estimate how much artificial light is going to cause an impact on a particular species, or age class, over a given distance and under variable environmental conditions.

Recognising these limitations, it can still be valuable to model light during the design phase of new lighting installations to test assumptions about the light environment. For example, models could test for the potential for light spill and line of sight visibility of a source. These assumptions should be confirmed after construction.

Development of modelling tools that can take account of broad spectral data and environmental conditions are in the early stages of development but rapidly improving[49].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 93 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix D – Artificial Light Auditing

Industry best practice requires onsite inspection of a build to ensure it meets design specifications. An artificial light audit should be undertaken after construction to confirm compliance with the artificial light management plan.

An artificial light audit cannot be done by modelling of the as-built design alone and should include a site visit to:

- **Confirm compliance with the artificial light management plan**
- **Check as-built compliance with engineering design**
- **Gather details on each luminaire in place**
- **Conduct a visual inspection of the facility lighting from the wildlife habitat**
- **Review the artificial light monitoring at the project site**
- **Review artificial light monitoring at the wildlife habitat.**

Following completion of a new project or modification/upgrade of the lighting system of an existing project, the project should be audited to confirm compliance with the artificial light management plan.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 94 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Step-by-Step Guide

The steps to carry out an artificial light audit include:

- Review of the artificial light management plan
- Review of best practice light management or approval conditions
- Review of as-built drawings for the lighting design
- Check for compliance with the approved pre-construction (front end) lighting design;
- Conduct a site inspection both during the day and at night to visually check and measure the placement, number, intensity, spectral power output, orientation, and management of each lamp and lamp type. Where possible this should be done with the lighting in operation and with all lighting extinguished.
- Measurements should be taken in a biologically meaningful way. Where there are limitations in measurements for wildlife these should be acknowledged.
- Record, collate and report on the findings and include any non-conformances. This should consider any differences between baseline and post construction observations. Where lighting outputs were modelled as part of the design phase, actual output should be compared with modelled scenarios.
- Make recommendations for any improvements or modifications to the lighting design that will decrease the impact on wildlife.

The audit should be conducted by an appropriately qualified environmental practitioner/technical specialist during a site visit. The audit should also include:

- A visual inspection of the facility lighting from the location of the wildlife habitat and where feasible the perspective of the wildlife (i.e. sand level for a marine turtle)
- Artificial light monitoring at the project site
- Artificial light monitoring at the wildlife habitat.

A post-construction site visit is critical to ensure no previously unidentified lighting issues are overlooked.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 95 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix E – Artificial Light Management Check List

Table 2 provides a check list of issues to be considered during the environmental assessment of new infrastructure involving artificial light, or upgrades to existing artificial lighting for both proponents and assessors. Table 3 provides a check list of issues to be considered for existing infrastructure with external lighting where listed species are observed to be impacted by artificial light. Relevant sections of the Guidelines are provided for each issue.

Table 2 Checklist for new developments or lighting upgrades.

Issue to be considered	Light owner or manager	Regulator	Further information
Pre-development			
What are the regulatory requirements for artificial light for this project?	Is an environmental impact assessment required? What other requirements need to be addressed?	What information should be sought from the proponent as part of the assessment process?	Regulatory considerations for the management of artificial light
Does the lighting design follow principles of best practice?	What is the purpose of the artificial light for this project?	Does the project use the principles of best practice light design?	Best practice light design
What wildlife is likely to be affected by artificial light?	Review species information within 20 km of the proposed development.	Assess species information.	Wildlife and artificial light
What light management and impact mitigation will be implemented?	What light mitigation and management will be most effective for the affected species?	Is the proposed management and mitigation likely to reduce the effect on listed species?	Species specific technical appendices and species expert guidance
How will light be modelled?	Is light modelling appropriate? How will the model be used to inform light management for wildlife?	Are the limitations of light modelling for wildlife appropriately acknowledged?	Modelling predicted light
Have all lighting-relevant considerations been included in the light management plan?	Have all steps in the EIA process been undertaken and documented in the light management plan?	Does the light management plan comprehensively describe all steps in the EIA process?	Environmental impact assessment for effects of artificial light on wildlife Light Management Plan
How will continuous improvement be achieved?	How will light management be evaluated and adapted?	Is a continuous review and improvement process described?	Light Management Plan

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 96 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Issue to be considered	Light owner or manager	Regulator	Further information
Post development			
How will lighting be measured?	What is the most appropriate technique(s) for measuring biologically relevant light and what are the limitations?	Ensure appropriate light measurement techniques are used and limitations of the methods recognised.	Measuring biologically relevant light
How will lighting be audited?	What is the frequency and framework for in-house light auditing?	How will the results of light audits feedback into a continuous improvement process?	Artificial light auditing
Is artificial light affecting wildlife?	Does the biological monitoring indicate an effect of artificial light on fauna and what changes will be made to mitigate this impact?	Is there a process for addressing monitoring results that indicate there is a detectable light impact on wildlife, and is it appropriate?	Wildlife and artificial light Light Management Plan Managing existing light pollution
What adaptive management can be introduced?	How will the results of light audits and biological monitoring be used in an adaptive management framework, and how will technological developments be incorporated into artificial light management?	What conditions can be put in place to ensure a continuous improvement approach to light management?	Light Management Plan

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 97 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 3 Checklist for existing infrastructure

Consideration	Light owner or manager	Regulator	Further information
Are wildlife exhibiting a change in survivorship, behaviour or reproduction that can be attributed to artificial light?	What listed species are found within 20 km of light source? Are there dead animals or are animals displaying behaviour consistent with the effects of artificial light?	Is there evidence to implicate artificial light as the cause of the change in wildlife survivorship, behaviour or reproductive output? Review existing environmental approvals.	Describe wildlife Wildlife and artificial light Regulatory considerations for the management of light Species expert advice
Is lighting in the area best practice?	Are there modifications or technological upgrades that could be made to improve artificial light management?	Are there individual light owners or managers who can be approached to modify current lighting?	Principles of best practice light management
Is the light affecting wildlife from a single source or multiple sources?	Are there multiple stakeholders that need to come together to address the cumulative light pollution?	Is there a role for government to facilitate collaboration between light owners and managers to address light pollution?	Managing existing light pollution Light Management Plan
Can appropriate monitoring be undertaken to confirm the role of artificial light in wildlife survivorship, behavioural or reproductive output changes?	How much light is emitted from my property and is it affecting wildlife?	Facilitate wildlife monitoring.	Field surveys for wildlife Measuring biologically relevant light Species expert advice
How will artificial light be audited?	What is the frequency and framework for in-house light auditing?	Can a light audit be undertaken on a regional scale?	Artificial light auditing
What adaptive light management can be introduced?	Are there improvements in lighting technology that can be incorporated into existing lighting?	What changes can be implemented in response to biological monitoring and light audits?	Specialist lighting engineer advice

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 98 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix F - Marine Turtles

Marine turtles nest on sandy beaches in northern Australia. There is a robust body of evidence demonstrating the effect of light on turtle behaviour and survivorship. Light is likely to affect the turtles if it can be seen from the nesting beach, nearshore or adjacent waters.

Adult females may be deterred from nesting where artificial light is visible on a nesting beach. Hatchlings may become misoriented or disoriented and be unable to find the sea or successfully disperse to the open ocean. The effect of light on turtle behaviour has been observed from lights up to 18 km away.

The physical aspects of light that have the greatest effect on turtles include intensity, colour (wavelength), and elevation above beach. Management of these aspects will help reduce the threat from artificial light.

Six species of marine turtles are found in Australia; the green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), flatback (*Natator depressus*) and leatherback (*Dermochelys coriacea*) turtles.

Light pollution was identified as a high-risk threat in the *Recovery Plan for Marine Turtles in Australia (2017)* because artificial light can disrupt critical behaviours such as adult nesting and hatchling orientation, sea finding and dispersal, and can reduce the reproductive viability of turtle stocks[57]. A key action identified in the Recovery Plan was the development of guidelines for the management of light pollution in areas adjacent to biologically sensitive turtle habitat.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 99 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 27 Loggerhead turtle. Photo: David Harasti.

Conservation Status

Marine turtles in Australia are protected under international treaties and agreements including the Convention on the Conservation of Migratory Species of Wild Animals (CMS, Bonn 1979), the Convention on International Trade in Endangered Species of Flora and Fauna (CITES, Washington 1973), and the CMS Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-east Asia (IOSEA, 2005). In Australia, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) gives effect to these international obligations.

All six species are listed under the EPBC Act as threatened, migratory and marine species. They are also protected under state and territory legislation.

The *Recovery Plan for Marine Turtles in Australia* (2017) identifies threats to marine turtles and actions required to recover these species[57]. To ensure the maintenance of biodiversity, the Plan considers marine turtles on a genetic stock basis rather than the species level. The Plan found light pollution to be a high-risk threat to five of 22 genetic stocks of marine turtles. The development and implementation of best practice light management guidelines was identified as a key action for promoting the recovery of marine turtles[57].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 100 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Distribution

Turtle nesting habitats include subtropical and tropical mainland and offshore island beaches extending from northern New South Wales on the east coast around northern Australia to Shark Bay in Western Australia. The extent of the known nesting range for each genetic stock can be found on the Department of the Environment and Energy's Species Profile and Threats Database and in the Recovery Plan[57].

Timing of nesting and hatching

Marine turtles nesting in the far north, between the Kimberley and Cape York, typically nest year round, but have a peak during the cooler winter months, while summer nesting is favoured by turtles nesting from the Central Kimberley south in Western Australia and along the Pacific coast of Queensland and Northern New South Wales. Specific timing of nesting and hatching seasons for each stock can be found in the Recovery Plan[57].

Important habitat for marine turtles

The effect of artificial lights on turtles is most pronounced at nesting beaches and in the nearshore waters, which might include internesting areas, through which hatchlings travel to reach the ocean. For the purposes of these Guidelines, Important Habitat for turtles includes all areas that have been designated as **Habitat Critical to Survival of Marine Turtles** and **Biologically Important Areas (BIAs)**, or in Queensland areas identified under local planning schemes as **Sea Turtle Sensitive Areas**.

- **Habitat Critical to the Survival of Marine Turtles** was identified for each stock as part of the development of the *Recovery Plan for Marine Turtles in Australia (2017)*. Nesting and internesting areas designated as Habitat Critical to the Survival of Marine Turtles can be found in the Recovery Plan or through the Department of the Environment and Energy's National Conservation Values Atlas.

- **Biologically Important Areas** (BIAs) are areas where listed threatened and migratory species display biologically important behaviour such as breeding, foraging, resting and migration. BIAs of highest relevance for the consideration of light impacts are nesting and internesting BIAs for each species. Marine turtle BIAs can be explored through the Department of the Environment and Energy's National Conservation Values Atlas.
    - The presence of a BIA recognises that biologically important behaviours are known to occur, but the absence of such a designation does not preclude the area from being a BIA. Where field surveys identify biologically important behaviour occurring, the habitat should be managed accordingly.
- **Sea Turtle Sensitive Areas** have been defined in local government planning schemes in accordance with the Queensland Government Sea Turtle Sensitive Area Code. These may be shown in local government biodiversity of coastal protection overlay maps in the planning scheme.

Effects of Artificial Light on Marine Turtles

The effect of artificial light on turtle behaviour has been recognised since 1911[58] and since then a substantial body of research has focused on how light affects turtles and its effect on turtle populations - for review see Witherington and Martin (2003)[3]; Lohmann et al (1997)[48]; and Salmon (2003)[59]. The global increase in light pollution from urbanisation and coastal development[60] is of particular concern for turtles in Australia since their important nesting habitat frequently overlaps with areas of large-scale urban and industrial development[61], which have the potential to emit a large amount of light, including direct light, reflected light, sky glow and gas flares[62,63]. Nesting areas on the North West Shelf of Western Australia and along the south-eastern coast of Queensland were found to be at the greatest risk from artificial light[61].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 101 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Effect of artificial light on nesting turtles

Although they spend most of their lives in the ocean, females nest on sandy tropical and subtropical beaches, predominantly at night. They rely on visual cues to select nesting beaches and orient on land. Artificial night lighting on or near beaches has been shown to disrupt nesting behaviour[3]. Beaches with artificial light, such as urban developments, roadways, and piers typically have lower densities of nesting females than dark beaches[59,64].

Some light types do not appear to affect nesting densities (Low Pressure Sodium, LPS[15], and filtered High Pressure Sodium, HPS), which excludes wavelengths below 540 nm)[65]. On beaches exposed to light, females will nest in higher numbers in areas that are shadowed[14,66]. Moving sources of artificial light may also deter nesting or cause disturbance to nesting females (e.g. flash photography)[67] .

Effect of artificial light on hatchlings emerging from the nest

Most hatchling turtles emerge at night[68] and must rapidly reach the ocean to avoid predation[69]. Hatchlings locate 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 beach[37,48,70]. They can also find the sea using secondary cues such as beach slope[48].

Sea finding behaviour may be disrupted by artificial lights, including flares[62], which interfere with natural lighting and silhouettes[3,26,37]. Artificial lighting may adversely affect hatchling sea finding behaviour in two ways: disorientation - where hatchlings crawl on circuitous paths; or misorientation - where they move in the wrong direction, possibly attracted to artificial lights[3,39]. On land, movement of hatchlings in a direction other than the sea often leads to death from predation, exhaustion, dehydration, or being crushed by vehicles on roads[69].

Wavelength, intensity and direction

Brightness is recognised as an important cue for hatchlings as they attempt to orient toward the ocean. Brightness refers to the intensity and wavelength of light relative to the spectral sensitivity of the receiving eye[3]. Both field and laboratory-based studies indicate that hatchlings have a strong tendency to orient towards the brightest direction. The brightest direction on a naturally dark beach is typically towards the ocean where the horizon is open and unhindered by dune or vegetation shadows[70].

The attractiveness of hatchlings to light differs by species[63,71,72], but in general, artificial lights most disruptive to hatchlings are those rich in short wavelength blue and green light (e.g. metal halide, mercury vapour, fluorescent and LED) and lights least disruptive are those emitting long wavelength pure yellow-orange light (e.g. high or low pressure sodium vapour)[63,73]. Loggerhead turtles are particularly attracted to light at 580 nm[74], green and flatback turtles are attracted to light <600 nm with a preference to shorter wavelength light over longer wavelength light[63,73], and many species are also attracted to light in the ultra violet range (<380 nm)[72,73].

Although longer wavelengths of light are less attractive than shorter wavelengths, they can still disrupt sea finding[37,63,75], and if bright enough can elicit a similar response to shorter wavelength light[76-78]. Hence, the disruptive effect of light on hatchlings is also strongly correlated with intensity. Red light must be almost 600 times more intense than blue light before green turtle hatchlings show an equal preference for the two colours[76]. It is therefore important to consider both the wavelength and the intensity of the light.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 102 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Since the sun or moon may rise behind the dunes on some nesting beaches, hatchlings attracted to these point sources of light would fail to reach the ocean. Hatchlings orientate themselves by integrating light across a horizontally broad (180° for green, olive ridley and loggerhead turtles) and vertically narrow ("few degrees" for green and olive ridleys, and 10° - 30° for loggerheads) "cone of acceptance" or "range of vision". This integration ensures that light closest to the horizon plays the greatest role in determining orientation direction, so it is important to consider the type and direction of light that reaches the hatchling[48].

As a result of these sensitivities, hatchlings have been observed to respond to artificial light up to 18 km away during sea finding[26].

Shape and form

Horizon brightness and elevation are also important cues for hatchling orientation. In laboratory and field studies hatchlings move away from elevated dark horizons and towards the lowest bright horizon[70,79]. However, in situations where both cues are present, hatchlings are more responsive to the effects of silhouettes and darkened horizon elevation than to differences in brightness. On a natural beach this behaviour would direct the hatchlings away from dunes and vegetation and towards the more open horizon over the ocean.

This hypothesis has been supported by field experiments where hatchling sea finding was significantly less ocean oriented when exposed to light at 2° elevation compared with 16° elevation, emphasising the importance of horizon elevation cues in hatchling sea-finding[37].

Effect of artificial light on hatchlings in nearshore waters

Artificial lights can also interfere with the in water dispersal of hatchlings[72]. Hatchlings leaving lit beaches spend longer crossing near shore waters and can be attracted back to shore[80,81]. At sea, hatchlings have been reported swimming around lights on boats[33,82] and in laboratory studies lights have attracted swimming hatchlings[83]. Recent advances in acoustic telemetry technology has allowed hatchlings to be passively tracked at sea, demonstrating that hatchlings are attracted to lights at sea and spend longer in the nearshore environment when lights are present[16,84]. This attraction can divert hatchlings from their usual dispersal pathway, causing them to linger around a light source, or become trapped in the light spill[84]. Hatchlings actively swim against currents to reach light, which is likely to reduce survival either from exhaustion and/or predation. An additional problem is that light sources are associated with structures that also attract fish (such as jetties), so there will be increased predation[24].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 103 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Environmental Impact Assessment of Artificial Light on Marine Turtles

Infrastructure with artificial lighting that is externally visible should implement Best Practice Lighting Design as a minimum. Where there is important habitat for turtles within 20 km of a project, an EIA should be undertaken. The following sections step through the EIA process with specific consideration for turtles.

The 20 km buffer for considering important habitat is based on sky glow approximately 15 km from the nesting beach affecting flatback hatchling behaviour[26] and light from an aluminium refinery disrupting turtle orientation 18 km away[27].

Where artificial light is likely to influence marine turtle behaviour, consideration should be given to employing mitigation measures as early as possible in a project's life cycle and used to inform the design phase.

Associated guidance

- *Recovery Plan for Marine Turtles in Australia* (2017)
- *Single Species Action Plan for the Loggerhead Turtle* (Caretta caretta) *in the South Pacific Ocean*
- Queensland Government Sea Turtle Sensitive Area Code

Qualified personnel

Lighting design/management and the EIA process should be undertaken by appropriately qualified personnel. Light management plans should be developed and reviewed by appropriately qualified lighting practitioners who should consult with an appropriately qualified marine biologist or ecologist.

People advising on the development of a lighting management plan, or the preparation of reports assessing the impact of artificial light on marine turtles should have relevant qualifications equivalent to a tertiary education in marine biology or ecology, or equivalent experience as evidenced by peer reviewed publications in the last five years on a relevant topic, or other relevant experience.

Step 1: Describe the project lighting

Information collated during this step should consider the Effects of Light on Marine Turtles. Turtles are susceptible to the effect of light on beaches and in the water, so the location and light source (both direct and sky glow) should be considered. Turtles are most sensitive to short wavelength (blue/green) light and high intensity light of all wavelengths. Hatchlings are most susceptible to light low on the horizon. They orient away from tall dark horizons so the presence of dunes and/or a vegetation buffer behind the beach should be considered at the design phase.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 104 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

Step 2: Describe marine turtle population and behaviour

The species and the genetic stock nesting in the area of interest should be described. This should include the conservation status of the species; stock trends (where known); how widespread/localised nesting for that stock is; the abundance of turtles nesting at the location; the regional importance of this nesting beach; and the seasonality of nesting/hatching.

Relevant species and stock specific information can be found in the *Recovery Plan for Marine Turtles in Australia (2017)*, Protected Matters Search Tool, National Conservation Values Atlas state and territory listed species information; scientific literature and local/Indigenous knowledge.

Where there is insufficient data to understand the population importance or demographics, or where it is necessary to document existing turtle behaviour, field surveys and biological monitoring may be necessary.

Biological monitoring of marine turtles

Any monitoring associated with a project should be developed, overseen and results interpreted by appropriately qualified personnel to ensure reliability of the data.

The objectives of turtle monitoring in an area likely to be affected by artificial light are to:

- understand the size and importance of the population;
- describe turtle behaviour before the introduction/upgrade of light; and
- assess nesting and hatchling orientation behaviour to determine the cause of any existing or future misorientation or disorientation.

The data will be used to inform the EIA and assess whether mitigation measures are successful. Suggested minimum monitoring parameters (what is measured) and techniques (how to measure them) are summarised in Table 4.

As a minimum, qualitative descriptive data on visible light types, location and directivity should also be collected at the same time as the biological data. Handheld-camera images can help describe the light. Quantitative data on existing sky glow should be collected, if possible, in a biologically meaningful way, recognising the technical difficulties in obtaining these data. See [Measuring Biologically Relevant Light](#) for a review.

Table 4 Recommended minimum biological information necessary to assess the importance of a marine turtle population and existing behaviour, noting that the risk assessment will guide the extent of monitoring (e.g. a large source of light visible over a broad spatial scale will require monitoring of multiple sites whereas a smaller localised source of light may require fewer sites to be monitored).

Target Age Class	Survey Effort	Duration	Reference
Adult Nesting	Daily track census over 1–1.5 internesting cycles at peak[57] of the nesting season (14–21 days). If the peak nesting period for this population/at this location has not been defined, then a study should be designed in consultation with a qualified turtle biologist to determine the temporal extent of activity (i.e. systematic monthly surveys over a 12-month period).	Minimum two breeding seasons	Eckert et al (1999)[85] Pendoley et al (2016)[86] Queensland Marine Turtle Field Guide NWSFTCP Turtle Monitoring Field Guide Ningaloo Turtle Monitoring Field Guide SWOT Minimum Data Standards for Sea Turtle Nesting Beach Monitoring
Hatchling Orientation	Minimum of 14 days over a new moon phase about 50 days* after the peak of adult nesting. Beach: Hatchling fan monitoring. In water: Hatchling tracking	Minimum two breeding seasons	Pendoley (2005)[63] Kamrowski et al (2014)[26] Witherington (1997)[87] Thums et al (2016)[16]

*Incubation time will be stock specific. Consult the Recovery Plan for Marine Turtles in Australia for stock specific information.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 105 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

To understand existing hatchling behaviour, it will be necessary to undertake monitoring (or similar approach) to determine hatchling ability to locate the ocean and orient offshore prior to construction/lighting upgrades.

A well-designed monitoring program will capture:

- hatchling behaviour[26,63,87] at the light exposed beach and a control/reference beach
- hatchling behaviour before project construction begins to establish a benchmark to measure against possible changes during construction and operations
- hatchling behaviour on a new moon to reduce the influence of moonlight and capture any worst case scenario effects of artificial light on hatching orientation
- hatchling behaviour on full moon nights to assess the relative contribution of the artificial light to the existing illuminated night sky.

Ideally, survey design will have been set up by a quantitative ecologist/biostatistician to ensure that the data collected provides for meaningful analysis and interpretation of findings.

Step 3: Risk assessment

The [Recovery Plan] states that management of light should ensure turtles are not displaced from habitat critical to their survival and that anthropogenic activities in important habitat are managed so that the biologically important behaviour can continue. These consequences should be considered in the risk assessment process. The aim of these Guidelines is that light is managed to ensure that at important nesting beaches females continue to nest on the beach, post nesting females return to the ocean successfully, emerging hatchlings orient in a seaward direction and dispersing hatchlings can orient successfully offshore.

Consideration should be given to the relative importance of the site for nesting. For example, if this is the only site at which a stock nests, a higher consequence rating should result from the effects of artificial light.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 106 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

In considering the likely effect of light on turtles, the risk assessment should consider the existing light environment, the proposed lighting design and mitigation/management, and the behaviour of turtles at the location. Consideration should be given to how the turtles will perceive light. This should include wavelength and intensity information as well as perspective. To assess how/whether turtles are likely to see light, a site visit should be made at night and the area viewed from the beach (approximately 10 cm above the sand) as this will be the perspective of the nesting turtles and emerging hatchlings. Similarly, consideration should be given to how turtles (both adults and hatchlings) will see light when in nearshore water.

Using this perspective, the type and number of lights should be considered to assess whether turtles are likely to be able to perceive light and what the consequence of the light on their behaviour is likely to be. The risk assessment should take into account proposed mitigation and management.

Step 4: Light management plan

A light management plan for marine turtles should include all relevant project information (Step 1) and biological information (Step 2). It should outline proposed mitigation. For a range of specific mitigation measures see the Mitigation Toolbox below. The plan should also outline the type and schedule for biological and light monitoring to ensure mitigation is meeting the objectives of the plan and triggers for revisiting the risk assessment phase of the EIA. The plan should outline contingency options if biological and light monitoring or compliance audits indicate that mitigation is not meeting the objectives of the plan (e.g. light is visible on the nesting beach or changes in nesting/hatchling behaviour are observed).

Step 5: Biological and light monitoring and auditing

The success of risk mitigation and light management should be confirmed through monitoring and compliance auditing. The results should be used to inform continuous improvement.

Relevant biological monitoring is described in Step 2: Describe marine turtle population and behaviour above. Concurrent light monitoring should be undertaken and interpreted in the context of how turtles perceive light and within the limitations of monitoring techniques described in Measuring Biologically Relevant Light. Auditing as described in the light management plan should be undertaken.

Review

The EIA should incorporate a continuous improvement review process that allows for upgraded mitigations, changes to procedures and renewal of the light management plan.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 107 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Marine Turtle Light Mitigation Toolbox

Appropriate lighting design/lighting controls and light impact mitigation will be site/project and species specific. Table 5 provides a toolbox of options for use around important turtle habitat. These options would be implemented in addition to the six Best Practice Light Design principles. Not all mitigation options will be relevant for every situation. Table 6 provides a suggested list of light types appropriate for use near turtle nesting beaches and those to avoid.

Two of the most effective approaches for management of light near important nesting beaches is to ensure there is a tall dark horizon behind the beach such as dunes and/or a natural vegetation screen and to ensure there is no light on or around the water through which hatchlings disperse.

Table 5 Light management options specific to marine turtle nesting beaches.

Management Action	Detail
Implement light management actions during the nesting and hatching season.	Peak nesting season for each stock can be found in the Recovery Plan for Marine Turtles in Australia[57].
Avoid direct light shining onto a nesting beach or out into the ocean adjacent to a nesting beach.	Adult turtles nest in lower numbers at lit beaches[14].
Maintain a dune and/or vegetation screen between the nesting habitat and inland sources of light.	Hatchlings orient towards the ocean by crawling away from the tall, dark horizon provided by a dune line and/or vegetation screen.
Maintain a dark zone between turtle nesting beach and industrial infrastructure.	Avoid installing artificial light within 1.5 km of an industrial development[78].
Install light fixtures as close to the ground as practicable.	Any new lighting should be installed close to the ground and reduce the height of existing lights to the extent practicable to minimise light spill and light glow.
Use curfews to manage lighting.	Manage artificial lights using motion sensors and timers around nesting beaches after 8 pm.
Aim lights downwards and direct them away from nesting beaches.	Aim light onto the exact surface area requiring illumination. Use shielding on lights to prevent light spill into the atmosphere and outside the footprint of the target area.
Use flashing/intermittent lights instead of fixed beam.	For example, small red flashing lights can be used to identify an entrance or delineate a pathway.
Use motion sensors to turn on lights only when needed.	For example, motion sensors could be used for pedestrian areas near a nesting beach.
Prevent indoor lighting reaching beach.	Use fixed window screens or window tinting on fixed windows, skylights and balconies to contain light inside buildings.
Limit the number of beach access areas or construct beach access such that artificial light is not visible through the access point.	Beach access points often provide a break in dune or vegetation that protects the beach from artificial light. By limiting the number of access points or making the access path wind through the vegetation, screen light spill can be mitigated.
Work collectively with surrounding industry/private land holders to address the cumulative effect of artificial lights.	Problematic sky glow may not be caused by any one light owner/manager. By working with other industry/stakeholders to address light pollution, the effect of artificial light may be reduced more effectively.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 108 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Management Action	Detail
Manage artificial light at sea, including on vessels, jetties, marinas and offshore infrastructure.	Hatchlings are attracted to, and trapped by, light spill in the water.
Reduce unnecessary lighting at sea.	Extinguish vessel deck lights to minimum required for human safety and when not necessary. Restrict lighting at night to navigation lights only. Use block-out blinds on windows.
Avoid shining light directly onto longlines and/or illuminating baits in the water.	Light on the water can trap hatchlings or delay their transit through nearshore waters, consuming their energy reserves and likely exposing them to predators.
Avoid lights containing short wavelength violet/blue light.	Lights rich in blue light can include: metal halides, fluorescent, halogens, mercury vapour and most LEDs.
Avoid white LEDs.	Ask suppliers for an LED light with little or no blue in it or only use LEDs filtered to block the blue light. This can be checked by examining the spectral power curve for the luminaire.
Avoid high intensity light of any colour.	Keep light intensity as low as possible in the vicinity of nesting beaches. Hatchlings can see all wavelengths of light and will be attracted to long wavelength amber and red light as well as the highly visible white and blue light, especially if there is a large difference between the light intensity and the ambient dark beach environment.
Shield gas flares and locate inland and away from nesting beach.	Manage gas flare light emissions by: reducing gas flow rates to minimise light emissions; shielding the flame behind a containment structure; elevating glow from the shielded flare more than 30° above hatchling field of view; containing pilot flame for flare within shielding; and scheduling maintenance activity requiring flaring outside of turtle hatchling season.
Industrial/port or other facilities requiring intermittent night-time light for inspections should keep the site dark and only light specific areas when required.	Use amber/orange explosion proof LEDs with smart lighting controls and/or motions sensors. LEDs have no warmup or cool down limitations so can remain off until needed and provide instant light when required for routine nightly inspections or in the event of an emergency.
Industrial site/plant operators to use head torches.	Consider providing plant operators with white head torches (explosion proof torches are available) for situations where white light is needed to detect colour correctly or when there is an emergency evacuation.
Supplement facility perimeter security lighting with computer monitored infra-red detection systems.	Perimeter lighting can be operated if night-time illumination is necessary, but remain off at other times.
No light source should be directly visible from the beach.	Any light that is directly visible to a person on a nesting beach will be visible to a nesting turtle or hatchling and should be modified to prevent it being seen.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 109 of 187
Signed:
MINISTER FOR PLANNING
Date: 9 May 2023

Management Action	Detail
Manage light from remote regional sources (up to 20km away).	Consider light sources up to 20 km away from the nesting beach, assess the relative visibility and scale of the night sky illuminated by the light e.g. is a regional city illuminating large area of the horizon and what management actions can be taken locally to reduce the effect i.e. protect or improve dune systems or plant vegetation screening in the direction of the light.

Table 6 Where all other mitigation options have been exhausted and there is a human safety need for artificial light, this table provides commercial luminaire types that are considered appropriate for use near important marine turtles nesting habitat and those to avoid.

Light type	Suitability for use near marine turtle habitat
Low Pressure Sodium Vapour	✓
High Pressure Sodium Vapour	✓
Filtered* LED	✓
Filtered* metal halide	✓
Filtered* white LED	✓
Amber LED	✓
PC Amber	✓
White LED	✗
Metal halide	✗
White fluorescent	✗
Halogen	✗
Mercury vapour	✗

* ‘Filtered’ means LEDs can be used *only* if a filter is applied to remove the short wavelength (400 – 500 nm) light.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 110 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix G - Seabirds

Seabirds spend most of their lives at sea, only coming ashore to nest. All species are vulnerable to the effects of lighting. Seabirds active at night while migrating, foraging or returning to colonies are most at risk.

Fledglings are more affected by artificial lighting than adults due to the synchronised mass exodus of fledglings from their nesting sites. They can be affected by lights up to 15 km away.

The physical aspects of light that have the greatest impact on seabirds include intensity and colour (wavelength). Consequently, management of these aspects of artificial light will have the most effective result.

Seabirds are birds that are adapted to life in the marine environment (Figure 28). They can be highly pelagic, coastal, or in some cases spend a part of the year away from the sea entirely. They feed from the ocean either at or near the sea surface. In general, seabirds live longer, breed later and have fewer young than other birds and invest a great deal of energy in their young. Most species nest in colonies, which can vary in size from a few dozen birds to millions. Many species undertake long annual migrations, crossing the equator or circumnavigating the Earth in some cases[88].

Artificial light can disorient seabirds and potentially cause injury and/or death through collision with infrastructure. Birds may starve as a result of disruption to foraging, hampering their ability to prepare for breeding or migration. High mortality of seabirds occurs through grounding of fledglings as a result of attraction to lights[4] and through interaction with vessels at sea.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 111 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 28 Flesh-footed Shearwater at sunset. Photo: Richard Freeman.

Conservation Status

Migratory seabird species in Australia are protected under international treaties and agreements including the *Convention on the Conservation of Migratory Species of Wild Animals* (CMS, Bonn Convention), the *Ramsar Convention on Wetlands*, the *Agreement on the Conservation of Albatrosses and Petrels* (ACAP), and through the East Asian - Australasian Flyway Partnership (the Flyway Partnership). The Australian Government has bilateral migratory bird agreements with Japan (Japan-Australia Migratory Bird Agreement, JAMBA), China (China-Australia Migratory Bird Agreement, CAMBA), and the Republic of Korea (Republic of Korea-Australia Migratory Bird Agreement, ROKAMBA). In Australia the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) gives effect to these international obligations. Many seabirds are also protected under state and territory environmental legislation.

An estimated 15.5 million pairs of seabirds, from 43 species, breed at mainland and island rookeries[4]. Of the 43 species, 35 are listed as threatened and/or migratory under the EPBC Act. Of the 35 EPBC Act listed species, 90 per cent are Procellariiformes (petrels, shearwaters, storm petrels, gadfly petrels and diving petrels) that breed in burrows, only attend breeding colonies at night[89], and are consequently most at risk from the effects of artificial light. Short-tailed Shearwaters comprise 77 per cent (11.9 million pairs) of the total breeding seabird pairs.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 112 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Distribution

Seabirds in Australia belong to both migratory and residential breeding species. Most breeding species include both temperate and tropical shearwaters and terns that undergo extensive migrations to wintering areas outside Australia's Exclusive Economic Zone (EEZ). However, there are significant numbers of residential species that remain within the EEZ throughout the year and undergo shorter migrations to non-breeding foraging grounds within the EEZ.

Timing of habitat use

Most seabird breeding occurs during the austral spring/summer (September-January), but may extend in some species to April/May. The exceptions are the austral winter breeders, a handful of species largely comprised of petrels that may commence nesting in June. Breeding occurs almost exclusively on many of the offshore continental islands that surround Australia. Seabirds spend most of their time flying, at sea, and so are usually found on breeding islands only during the breeding season, or along mainland coastal sand bars and spits or island shorelines when roosting during their non-breeding period.

Important habitat for seabirds

Seabirds may be affected by artificial light at breeding areas, while foraging and migrating. For the purposes of these Guidelines, Important Habitat for seabirds includes all areas that have been designated as Habitat Critical to the Survival of Seabirds and Biologically Important Areas (BIAs) and those areas designated as important habitat in wildlife conservation plans and in species specific conservation advice.

- The *National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016*[*] provides designated Habitat Critical to the Survival of these species. Where a recovery plan is not in force for a listed threatened species, please see relevant approved conservation advice.
- Actions in Antarctica should consider Important Bird Areas in Antarctica[90].
- Biologically Important Areas (BIAs) are areas where listed threatened and migratory species display biologically important behaviour, such as breeding, foraging, resting and migration. Seabird BIAs can be explored through the Department of the Environment and Energy's National Conservation Values Atlas.
  - The presence of a BIA recognises that biologically important behaviours are known to occur, but the absence of such a designation does not preclude the area from being a BIA. Where field surveys identify biologically important behaviour occurring, the habitat should be managed accordingly.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 113 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

Effects of Artificial Light on Seabirds

Seabirds have been affected by artificial light sources for centuries. Humans used fire to attract seabirds to hunt them for food[91] and reports of collisions with lighthouses date back to 1880[92]. More recently artificial light associated with the rapid urbanisation of coastal areas has been linked to increased seabird mortality[93] and today, 56 petrel species worldwide are known to be affected by artificial lighting[4,31]. Artificial light can disorient seabirds causing collision, entrapment, stranding, grounding, and interference with navigation (being drawn off course from usual migration route). These behavioural responses may cause injury and/or death.

All species active at night are vulnerable as artificial light can disrupt their ability to orient towards the sea. Problematic sources of artificial light include coastal residential and hotel developments, street lighting, vehicle lights, sporting facility floodlights, vessel deck and search lights, cruise ships, fishing vessels, gas flares, commercial squid vessels, security lighting, navigation aids and lighthouses[31,93-99]. Seabirds, particularly petrel species in the Southern Ocean, can be disoriented by vessel lighting and may land on the deck, from which they are unable to take off. The effect of artificial light may be exacerbated by moon phase[96], wind direction and strength[28,100], precipitation, cloud cover and the proximity of nesting sites or migrating sites to artificial light sources[101-103]. The degree of disruption is determined by a combination of physical, biological and environmental factors including the location, visibility, colour and intensity of the light, its proximity to other infrastructure, landscape topography, moon phase, atmospheric and weather conditions and species present.

[*] This legislative instrument is in force until 2021.

Seabirds that are active at night while migrating, foraging or returning to colonies and are directly affected include petrels, shearwaters, albatross, noddies, terns and some penguin species. Less studied are the effects of light on the colony attendance of nocturnal Procellariiformes, which could lead to higher predation risks by gulls, skuas or other diurnal predators, and the effects on species that are active during the day, including extending their activities into the night as artificial light increases perceived daylight hours.

High rates of fallout, or the collision of birds with structures, has been reported in seabirds nesting adjacent to urban or developed areas[4,104,105] and at sea where seabirds interact with offshore oil and gas platforms[106,107]. A report on interactions with oil and gas platforms in the North Sea identified light as the likely cause of hundreds of thousands of bird deaths annually. It noted that this could be a site specific impact[108].

Gas flares also affect seabirds. One anecdote describes 24 burnt carcasses of seabirds (wedge-tailed shearwaters) in and around an open pit gas flare. The birds were likely to have been attracted to the light and noise of the flare and as they circled the source, became engulfed, combusting in the super-heated air above the flame (pers. obs. K Pendoley, 1992).

Mechanisms by which light affects seabirds

Most seabirds are diurnal. They rest during dark hours and have less exposure to artificial light. Among species with a nocturnal component to their life cycle, artificial light affects the adult and fledgling differently.

Adults are less affected by artificial light. Many Procellariiformes species (i.e. shearwaters, storm petrels, gadfly petrels) are vulnerable during nocturnal activities, which make up part of the annual breeding cycle. Adult Procellariiformes species are vulnerable when returning to and leaving the nesting colony. They may leave or enter to re-establish their pair bonds with breeding partners, repair nesting burrows, defend nesting sites or to forage. Adults feed their chick by regurgitating partially digested food[109]. A recent study shows artificial light disrupts adult nest attendance and thus affects weight gain in chicks[110].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Condition 7 & 9
ENDORSED PLAN
Sheet 114 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Fledglings are more vulnerable due to the naivety of their first flight, the immature development of ganglions in the eye at fledging and the potential connection between light and food[104,111]. Burrow-nesting seabirds are typically exposed to light streaming in from the burrow entrance during the day. The young are fed by parents who enter the burrow from the entrance creating an association between light and food in newly fledged birds[31]. Much of the literature concerning the effect of lighting upon seabirds relates to the synchronised mass exodus of fledglings from their nesting sites[96,98,101,102,112,113]. Fledging Procellariiformes leave the nesting colony for the sea at night[89], returning to breed several years later. In Australia, the main fledgling period of shearwaters occurs in April/May[114].

Emergence during darkness is believed to be a predator-avoidance strategy[115] and artificial lighting may make the fledglings more vulnerable to predation[113]. Artificial lights are thought to override the sea-finding cues provided by the moon and star light at the horizon[116] and fledglings can be attracted back to onshore lights after reaching the sea[28,105]. It is possible that fledglings that survive their offshore migration cannot imprint their natal colony, preventing them from returning to nest when they mature[98]. The consequences of exposure to artificial light on the viability of a breeding population of seabirds is unknown[117].

Eye structure and sensitivities

Seabirds, like most vertebrates, have an eye that is well adapted to see colour. Typically, diurnal birds have six photoreceptor cells which are sensitive to different regions of the visible spectrum[118]. All seabirds are sensitive to the violet – blue region of the visible spectrum (380 - 440 nm)[119]. The eyes of the Black Noddy (*Anous minutus*) and Wedge-tailed Shearwaters (*Puffinus pacificus*) are characterised by a high proportion of cones sensitive to shorter wavelengths[120]. This adaptation is likely due to the need to see underwater, and the optimum wavelength for vision in clear blue oceanic water is between 425 and 500 nm. There is no ecological advantage to having many long-wavelength-sensitive photoreceptors in species foraging in this habitat[120].

Many diurnal birds can see in the UV range (less than 380 nm[121]), however, of the 300 seabird species, only 17 have UV sensitive vision[119]. In all seabirds, their photopic vision (daylight adapted) is most sensitive in the long wavelength range of the visible spectrum (590 – 740 nm, orange to red) while their scotopic (dark adapted) vision is more sensitive to short wavelengths of light (380 – 485 nm, violet to blue).

Petrel vision is most sensitive to light in the short wavelength blue (400 – 500 nm), region of the visible spectrum. Relative to diurnal seabirds, such as gulls and terns, petrels have a higher number of short wavelength sensitive cones. This is thought to be an adaptation that increases prey visibility against a blue-water foraging field favoured by petrels[120].

Little has been published on vision in penguins. Penguins are visual foragers with the success of fish capture linked directly to the amount of light present[122]. The eyes of the Humbolt Penguin (*Spheniscus humboldti*) are adapted to the aquatic environment, seeing well in the violet to blue to green region of the spectrum, but poorly in the long wavelengths (red)[123].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 115 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Wavelength, intensity and direction

The intensity of light may be a more important cue than colour for seabirds. Very bright light will attract them, regardless of colour[98]. There are numerous, although sometimes conflicting, reports of the attractiveness of different wavelengths of artificial light to seabirds. White light has the greatest effect on seabirds as it contains all wavelengths of light[7,96,124]. Seabirds have reportedly been attracted to the yellow/orange colour of fire[91], while white Mercury Vapour and broad-spectrum LED is more attractive to Barau's Petrel (*Pterodroma baraui*) and Hutton's Shearwater (*Puffinus huttoni*) than either Low or High-Pressure Sodium Vapour lights[96]. Bright white deck lights and spot lights on fishing vessels attract seabirds at night, particularly on nights with little moon light or low visibility[95,97,104].

A controlled field experiment on Short-tailed Shearwaters at Phillip Island tested the effect of metal halide, LED and HPS lights on fledging groundings[32]. The results suggested the shearwaters were more sensitive to the wider emission spectrum and higher blue content of metal halide and LED lights relative than to HPS light. The authors strongly recommended using HPS, or filtered LED and metal halide lights with purpose designed LED filtered to remove short wavelength light for use in the vicinity of shearwater colonies[32].

The first studies of penguins exposed to artificial light at a naturally dark site found they preferred lit paths over dark paths to reach their nests[125]. While artificial light might enhance penguin vision at night, reducing predation risk and making it easier for them to find their way, the proven attraction to light could attract them to undesirable lit areas. This study concluded that the penguins were habituated to artificial lights and were unaffected by a 15 lux increase in artificial illumination[125]. However, the authors were unable to rule out an effect of artificial light on penguin behaviour due natural differences between the sites; potential complexity of penguin response to the interaction between artificial light and moonlight; and probable habituation of penguins to artificial lights.

Environmental Impact Assessment of Artificial Light on Seabirds

As a minimum, infrastructure with artificial lighting that is externally visible should have Best Practice Lighting Design implemented. Where there is important habitat for seabirds within 20 km of a project, an EIA should be undertaken. The following sections step through the EIA process with specific consideration for seabirds.

The 20 km buffer for considering important seabird habitat is based on the observed grounding of seabirds in response to a light source at least 15 km away[28].

The spatial and temporal characteristics of migratory corridors are important for some seabird species. Species typically use established migratory pathways at predictable times and artificial light intersecting with an overhead migratory pathway should be assessed in the same way as ground-based populations.

Where artificial light is likely to affect seabirds, consideration should be given to mitigation measures at the earliest point in a project development and used to inform the design phase.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 116 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Associated guidance

- National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016†
- EPBC Act Policy Statement 3.21—Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species

Qualified personnel

Lighting design/management and the EIA process should be undertaken by appropriately qualified personnel. Light management plans should be developed and reviewed by appropriately qualified lighting practitioners who should consult with appropriately trained marine ornithologists and/or ecologists. People advising on the development of a lighting management plan, or the preparation of reports assessing the effect of artificial light on seabirds, should have relevant qualifications equivalent to a tertiary education in ornithology, or equivalent experience as evidenced by peer reviewed publications in the last five years on a relevant topic, or other relevant experience.

† Please note that this legislative instrument is in force until 2021.

Step 1: Describe the project lighting

The type of information collated during this step should consider the biological Impact of Light on Seabirds. Seabirds are susceptible when active at night while migrating, foraging or returning to colonies. The location and light source (both direct and sky glow) in relation to breeding and feeding areas should be considered. Seabirds are sensitive to both short wavelength (blue/violet) and long (orange/red)[9] light with some species able to detect UV light. However, the intensity of lights may be more important than colour.

Step 2: Describe seabird population and behaviour

The species, life stage and behaviour of seabirds in the area of interest should be described. This should include the conservation status of the species; abundance of birds; how widespread/localised is the population; regional importance of the population; and seasonality of seabirds utilising the area.

Relevant seabird information can be found in the, *National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016*; Protected Matters Search Tool; National Conservation Values Atlas; relevant conservation advice; relevant wildlife conservation plans; state and territory listed species information; scientific literature; and local/Indigenous knowledge.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 117 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Where there are insufficient data available to understand the population importance or demographics, or where it is necessary to document existing seabird behaviour, field surveys and biological monitoring may be necessary.

Biological monitoring of seabirds

Any biological monitoring associated with a project should be developed, overseen and results interpreted by an appropriately qualified biologist or ornithologist to ensure reliability of the data.

The objectives of monitoring in an area likely to be affected by light are to:

- understand the habitat use and behaviour of the population (e.g. migrating, foraging, breeding)
- understand the size and importance of the population
- describe seabird behaviour prior to the introduction/upgrade of light.

The data will be used to inform the EIA process and assess whether mitigation measures are successful. Suggested minimum monitoring parameters (what is measured) and techniques (how to measure them) are summarised in Table 7.

Table 7 Recommended minimum biological information necessary to assess the importance of a seabird population. Note: the information in this table is not prescriptive and should be assessed on a case-by-case basis.

Target Age Class	Survey Effort	Duration	Reference
Adult Nesting	In colonial nesting burrow or surface nesting species with fixed or transient nesting sites, a single survey timed to coincide with predicted peak laying period. • A minimum of three sampling areas (transects/quadrats) appropriate for nest density to capture ~100 nests per transect. Status of nests recorded (used/unused- chick stage). Transient surface nesting species estimate of chicks in creches using aerial or drone footage. • A minimum of three sampling areas (transects/quadrats) appropriate for nest density to capture ~100 nests per transect. Status of nests recorded (used/unused- egg or chick).	Minimum of two breeding seasons	Henderson and Southwood (2016)[126] Surman and Nicholson (2014)[127] Survey Guidelines for Australia's Threatened Birds[128]
Fledging	In colonial nesting burrow or surface nesting species with fixed nesting sites, a single survey timed to coincide with predicted max fledging period.	Minimum of two breeding seasons	Henderson and Southwood (2016)[126] Surman and Nicholson (2014)[129]

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 118 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Additional seabird monitoring

- Monitor fledging behaviour before a project begins to establish a benchmark for assessing changes in fledging behaviour during construction and operations.
- Monitor fallout by assessing breeding colonies prior to fledging to assess annual breeding output/effort and measure against fallout (expecting greater fallout in years with higher reproductive output).
- Install camera traps at key locations to monitor fallout.
- Conduct nightly assessments of target lighting/areas to identify and collect grounded birds.
- Conduct observations post-dusk and pre-dawn with night vision goggles to assess activity/interactions.
- Track movement using land-based radar to determine existing flightpaths[98].

As a minimum, qualitative descriptive data on visible light types, location and directivity should also be collected at the same time as the biological data. Handheld camera images can help to describe the light. Quantitative data on existing sky glow should be collected, if possible, in a biologically meaningful way, recognising the technical difficulties in obtaining these data. See Measuring Biologically Relevant Light for a review.

Step 3: Risk assessment

The objective is that light should be managed in a way that seabirds are not disrupted within, or displaced from, important habitat, and they are able to undertake critical behaviours, such as foraging, reproduction and dispersal. These consequences should be considered in the risk assessment process. The aim of the process is to ensure that at important seabird rookeries, burrow usage remains constant, adults and fledglings are not grounded, and fledglings launch successfully from the rookery.

In considering the likely effect of light on seabirds, the assessment should consider the existing light environment, the proposed lighting design and mitigation/management, and behaviour of seabirds at the location. Consideration should be given to how the birds perceive light. This should include both wavelength and intensity information and perspective. To discern how/whether seabirds are likely to see light, a site visit should be made at night and the area viewed from the seabird rookery. Similarly, consideration should be given to how seabirds will see light when in flight.

Using this perspective, the type and number of lights should be considered/modelled to determine whether seabirds are likely to perceive light and what the consequence of the light on their behaviour is likely to be.

Step 4: Light management plan

This should include all relevant project information (Step 1) and biological information (Step 2). It should outline proposed mitigation. For a range of seabird specific mitigation measures please see the Seabird Mitigation Toolbox below. The plan should also outline the type and schedule for biological and light monitoring to ensure mitigation is meeting the objectives of the plan and triggers for revisiting the risk assessment phase of the EIA. The plan should outline contingency options if biological and light monitoring or compliance audits indicate that mitigation is not meeting objectives (e.g. light is visible in seabird rookeries or fallout rates increase).

Step 5: Biological and light monitoring and auditing

The success of the impact mitigation and light management should be confirmed through monitoring and compliance auditing and the results used to facilitate an adaptive management approach for continuous improvement.

Relevant biological monitoring is described in Step 2: Describe the Seabird Population above. Concurrent light monitoring should be undertaken and interpreted in the context of how seabirds perceive light and within the limitations of monitoring techniques described in Measuring Biologically Relevant Light. Auditing, as described in the light management plan, should be undertaken.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 119 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Review

The EIA should incorporate a continuous improvement review process that allows for upgraded mitigations, changes to procedures and renewal of the light management plan.

Seabird Light Mitigation Toolbox

Appropriate lighting design/lighting controls and mitigating the effect of light will be site/project and species specific. Table 8 provides a toolbox of management options relevant to seabirds. These options should be implemented in addition to the six Best Practice Light Design principles. Not all mitigation options will be practicable for every project. Table 9 provides a suggested list of light types appropriate for use near seabird rookeries and those to avoid.

A comprehensive review of the effect of land based artificial lights on seabirds and mitigation techniques found the most effective measures were:

- turning lights off during the fledgling periods
- modification of light wavelengths
- removing external lights and closing window blinds to shield internal lights
- shielding the light source and preventing upward light spill
- reducing traffic speed limits and display of warning signs
- implementing a rescue program for grounded birds[4].

Additional mitigation measures listed, but not assessed for effectiveness were:

- using rotating or flashing lights because research suggests that seabirds are less attracted to flashing lights than constant light
- keeping light intensity as low as possible. Most bird groundings are observed in very brightly lit areas[4].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 120 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 8 Light management options for seabirds.

Management Action	Detail
Implement management actions during the breeding season.	Most seabird species nest during the Austral spring and summer. Light management should be implemented during the nesting and fledgling periods.
Maintain a dark zone between the rookery and the light sources.	Avoid installing lights or manage all outdoor lighting within three kilometres of a seabird rookery[102]. This is the median distance between nest locations and grounding locations. Avoiding the installation of lights in this zone would reduce the number of grounding birds by 50 per cent.
Turn off lights during fledgling season.	If not possible to extinguish lights, consider curfews, dimming options, or changes on light spectra (preferably towards lights with low blue emissions). Fledglings can be attracted back towards lights on land as they fly out to sea.
Use curfews to manage lighting.	Extinguish lights around the rookery during the fledgling period by 7 pm as fledglings leave their nest early in the evening.
Aim lights downwards and direct them away from nesting areas.	Aim light onto only the surface area requiring illumination. Use shielding to prevent light spill into the atmosphere and outside the footprint of the target area. This action can reduce fallout by 40 per cent[4].
Use flashing/intermittent lights instead of fixed beam.	For example, small red flashing lights can be used to identify an entrance or delineate a pathway.
Use motion sensors to turn lights on only when needed.	Use motion sensors for pedestrian or street lighting within three kilometres of a seabird rookery.
Prevent indoor lighting reaching outdoor environment.	Use fixed window screens or window tinting on fixed windows and skylights to contain light inside buildings.
Manage artificial light on jetties, wharves, marinas, etc.	Fledglings and adults may be attracted to lights on marine facilities and become grounded or collide with infrastructure.
Reduce unnecessary outdoor, deck lighting on all vessels and permanent and floating oil and gas installations in known seabird foraging areas at sea.	Extinguishing outdoor/deck lights when not necessary for human safety and restrict lighting at night to navigation lights. Use block-out blinds on all portholes and windows.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 121 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Management Action	Detail
Night fishing should only occur with minimum deck lighting. Avoid shining light directly onto fishing gear in the water. Ensure lighting enables recording of any incidental catch, including by electronic monitoring systems.	Night is between nautical dusk and nautical dawn (as defined in the Nautical Almanac tables for relevant latitude, local time and date). Light on the water at night can attract seabirds to deployed fishing gear increasing the risk of seabird bycatch (i.e. killing or injuring birds). Minimum deck lighting should not breach minimum standards for safety and navigation. Record bird strike or incidental catch and report these data to regulatory authorities.
Avoid shining light directly onto longlines and/or illuminating baits in the water.	Light on the water can attract birds and facilitate the detection and consumption of baits, increasing bycatch in fisheries (i.e. killing or injuring birds). Record bird strike or incidental catch and report these data to regulatory authorities.
Vessels working in seabird foraging areas during breeding season should implement a seabird management plan to prevent seabird landings on the ship, manage birds appropriately and report the interaction.	For example, see the International Association of Antarctica Tour Operators (IAATO) Seabirds Landing on Ships information page.
Use luminaires with spectral content appropriate for the species present.	Consideration should be given to avoid specific wavelengths that are problematic for the species of interest. In general this would include avoiding lights rich in blue light, however, some birds are sensitive to yellow light and other mitigation may be required.
Avoid high intensity light of any colour.	Keep light intensity as low as possible in the vicinity of seabird rookeries and known foraging areas.
Shield gas flares and locate inland and away from seabird rookeries.	Manage gas flare light emissions by: reducing gas flow rates to minimise light emissions; shielding the flame behind a containment structure; containing the pilot flame for flare within shielding; and scheduling maintenance activity requiring flaring outside of shearwater breeding season or during the day.
Minimise flaring on offshore oil and gas production facilities.	Consider reinjecting excess gas instead of flaring, particularly on installations on migratory pathways.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 122 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Management Action	Detail
In facilities requiring intermittent night-time inspections, turn on lights only during the time operators are moving around the facility.	Use appropriate wavelength explosion proof LEDs with smart lighting controls. LEDs have no warmup or cool down limitations so can remain off until needed and provide instant light when required for routine nightly inspections or in the event of an emergency.
Ensure industrial site/plant operators use head torches.	Consider providing plant operators with white head torches (explosion proof torches are available) for situations where white light is needed to detect colour correctly or in an emergency.
Supplement facility perimeter security lighting with computer monitored infrared detection systems.	Perimeter lighting can be operated when night-time illumination is necessary but otherwise remain off.
Tourism operations around seabird colonies should manage torch usage so birds are not disturbed.	Consideration should be given to educational signage around seabird colonies where tourism visitation is generally unsupervised.
Design and implement a rescue program for grounded birds.	This will not prevent birds grounding, but it is an important management action in the absence of appropriate light design. Rescue programs have proven useful to reducing mortality of seabirds. The program should include documentation and reporting of data about the number and location of rescued birds to regulatory authorities.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 123 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 9 Where all other mitigation options have been exhausted and there is a human safety need for artificial light, this table provides commercial luminaires recommended for use near seabird habitat and those to avoid.

Light type	Suitability for use near seabird habitat
Low Pressure Sodium Vapour	✓
High Pressure Sodium Vapour	✓
Filtered* LED	✓
Filtered* metal halide	✓
Filtered* white LED	✓
LED with appropriate spectral properties for species present	✓
White LED	✗
Metal halide	✗
White fluorescent	✗
Halogen	✗
Mercury vapour	✗

* 'Filtered' means this type of luminaire can be used *only* if a filter is applied to remove the problematic wavelength light.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 124 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix H - Migratory Shorebirds

There is evidence that night-time lighting of migratory shorebird foraging areas may benefit the birds by allowing greater visual foraging opportunities. However, where nocturnal roosts are artificially illuminated, shorebirds may be displaced, potentially reducing their local abundance if the energetic cost to travel between suitable nocturnal roosts and foraging sites is too great.

Artificial lighting could also act as an ecological trap by drawing migratory shorebirds to foraging areas with increased predation risk. Overall the effect of artificial light on migratory shorebirds remains understudied and consequently any assessment should adopt the precautionary principle and manage potential effects from light unless demonstrated otherwise.

Shorebirds, also known as waders, inhabit the shorelines of coasts and inland water bodies for most of their lives. Most are from two taxonomic families, the Sandpipers (*Scolopacidae*) and the Plovers (*Charadriidae*). They are generally distinguished by their relatively long legs, often long bills, and most importantly, their associations with wetlands at some stages of their annual cycles[130].

At least 215 shorebird species have been described[131] and their characteristics include long life-spans, but low reproductive output and they are highly migratory[132]. Many species have special bills for feeding on different prey in wetlands. Their bills contain sensory organs to detect the vibrations of prey inside the substrate. Shorebirds are often gregarious during the non-breeding season, which is perhaps a mechanism to reduce individual predation risk[133] and increase the chance of locating profitable feeding patches[132]. About 62 per cent of shorebird species migrate. Some are transoceanic and transcontinental long-distance migrants capable of flying up to eight days non-stop, with examples of individuals covering distances up to 11,500 km[134].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 125 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 29 Curlew Sandpipers. Photo: Brian Furby.

Conservation Status

Migratory shorebird species in Australia are protected under international treaties and agreements including the *Convention on the Conservation of Migratory Species of Wild Animals* (CMS, Bonn Convention), the Ramsar Convention on Wetlands, and through the East Asian - Australasian Flyway Partnership (the Flyway Partnership). The Australian Government has bilateral migratory bird agreements with Japan (Japan-Australia Migratory Bird Agreement, JAMBA), China (China-Australia Migratory Bird Agreement, CAMBA), and the Republic of Korea (Republic of Korea-Australia Migratory Bird Agreement, ROKAMBA). In Australia, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) gives effect to these international obligations. Many species are also protected under state and territory environmental legislation.

There are 37 species listed as threatened and/or migratory species under the EPBC Act and are hence Matters of National Environmental Significance (MNES) in Australia. At least 56 trans-equatorial species belonging to three families: Pratincoles (*Glareolidae*), Plovers (*Charadriidae*) and Sandpipers (*Scolopacidae*) have been recorded in Australia[135]. Of these, 36 species and one non-trans-equatorial species are listed under the EPBC Act. Three species (and one subspecies) of migratory shorebird are listed as "Critically Endangered", two species as "Endangered" and one species (and one subspecies) as "Vulnerable" under the EPBC Act.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 126 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

These Guidelines should be read in conjunction with EPBC Act *Policy Statement 3.21 Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species*[136].

Distribution

Migratory shorebirds are found in all states and territories, and are found in Australia throughout the year. Peak abundance occurs between August and April, however, sexually immature birds defer their northward migration for several years and can be found in Australia during the Austral winter months.

They are predominantly associated with wetland habitats including estuaries and intertidal wetlands, coastal beaches, saltmarsh, mangrove fringes, wet grasslands, and ephemeral freshwater and salt lakes in inland Australia. Shorebirds are also opportunists and exploit artificial habitats such as pastures, tilled land, sewage treatment plants, irrigation canals, sports fields and golf courses. Of 397 internationally recognised sites considered important for migratory shorebirds along the East Asian–Australasian Flyway, 118 are found in Australia[137].

Important habitat for migratory shorebirds

For the purposes of these Guidelines, Important Habitat for migratory shorebirds includes all areas that are recognised, or eligible for recognition as nationally or internationally important habitat. These habitats are defined in *EPBC Act* *Policy Statement 3.21 Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species*[136] and the *Wildlife Conservation Plan for Migratory Shorebirds (2015)*[138].

- **Internationally important** habitat are those wetlands that support one per cent of the individuals in a population of one species or subspecies; or a total abundance of at least 20 000 waterbirds.
- **Nationally important** habitat are those wetlands that support 0.1 per cent of the flyway population of a single species; 2000 migratory shorebirds; or 15 migratory shorebird species.

Effects of Artificial Light on Migratory Shorebirds

Artificial light can disorient flying birds, affect stopover selection, and cause their death through collision with infrastructure[139]. Birds may starve as a result of disruption to foraging, hampering their ability to prepare for breeding or migration. However, artificial light may help some species, particularly nocturnally foraging shorebirds as they may have greater access to food[140,141].

Annual cycle and habitat use in migratory shorebirds

Migratory shorebird species listed on the EPBC Act breed in the northern hemisphere, except the Double-banded Plover (*Charadrius bicinctus*), which breeds in New Zealand. Many of the northern hemisphere breeders nest in the arctic or sub-arctic tundra during the boreal summer (May – July) and spend the non-breeding season (August – April) in Australia or New Zealand. They usually spend five to six months on the non-breeding grounds, where they complete their basic (non-breeding plumage) moult, and later commence a pre-alternate (breeding plumage) moult prior to their northward migration. While undergoing their pre-alternate moult, shorebirds also consume an increased amount of prey to increase their fat storages, permitting them to travel greater distances between refuelling sites. Shorebirds refuel in East Asia during their northward migration, but during southward migration, some individuals travel across the Pacific, briefly stopping on islands to refuel. Shorebirds migrating across the Pacific typically have non-breeding grounds in Eastern Australia and New Zealand. Shorebirds returning to non-breeding grounds in Western and Northern Australia, once again pass through East Asia on their southward journey.

A common feature for many birds is their reliance on inland or coastal wetland habitats at some stages in their annual life-histories. In many migratory shorebirds, despite the vast distances they cover every year, they spend most of their time on coastal wetlands except for the two months of nesting when they use the tundra or taiga habitats. However, productive coastal wetland is localised, which means large proportions, or even entire populations, gather at a single site during stopover or non-breeding season. The Great Knot and Greater Sand Plover, is an example, with 40 per cent and 57 per cent respectively of their entire flyway population spends their non-breeding season at Eighty-Mile Beach in Western Australia[137]. Wetlands commonly used include coastal mudflats and sandflats, sandy beaches, saltmarsh and mangrove fringes, ephemeral freshwater wetlands and damp grasslands.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 127 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The coastal intertidal wetlands favoured by many migratory shorebirds are a dynamic ecosystem strongly influenced by the tidal cycle. This is part of the critical transition zones between land, freshwater habitats, and the sea. Throughout the East Asian-Australasian Flyway, intertidal wetlands have been susceptible to heavy modification for the development of farmlands, aquaculture, salt mining, ports and industry.

Daily activity pattern and habitat use of migratory shorebirds

The daily activity pattern of shorebirds at coastal wetlands is not only determined by daylight, but also tidal cycle[131]. They feed on the exposed tidal wetland during low tide and roost during high tide as their feeding areas are inundated. The birds feed during both the day and night, especially in the lead-up to migration[142,143].

Roost site selection can vary between day and night. Shorebirds often use diurnal roosts nearest to the intertidal feeding area and may travel further to use safer nocturnal roosts – but at greater energetic cost[144,145]. Roosting habitat can also vary between day and night.
For example, the Dunlin (*Calidris alpina*), in California, had a greater use of pasture at night (which tended to be less affected by artificial light and disturbances) and relied less on their diurnal roosts of islands and artificial structures such as riprap and water pipes[146].

Foraging behaviours differ between day and night, and between seasons[143,147]. Shorebirds typically show a preference for daytime foraging, which occurs over a greater area, and at a faster rate, than nocturnal foraging[143]. Increased prey availability, avoidance of daytime predation and disturbance are some reasons for nocturnal foraging[147]. Two basic types of foraging strategies have been described: visual and tactile (touch-based) foraging, with some species switching between these strategies. Tactile feeders such as sandpipers can use sensory organs in their bills to detect prey inside the substrate in the dark and can switch to visual foraging strategy during moonlit nights to take advantage of the moonlight[147]. Visual feeders such as plovers, have high densities of photo receptors, especially the dark adapted rods, which allow foraging under low light conditions[147,148]. Plovers have been shown to employ a visual foraging strategy during both the day and night, whereas sandpipers can shift from visual foraging during the day, to tactile foraging at night, likely due to less efficient night vision[143].

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 128 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

Vision in migratory shorebirds

There is a dearth of literature on light perception in migratory shorebirds with most studies confined to the role of vision in foraging and nothing on the physiology of shorebirds' eyes or their response to different wavelengths of light.

Birds in general are known to be attracted to, and disoriented by, artificial lights. This could be a result of being blinded by the intensity of light that bleaches visual pigments and therefore failing to see visual details[149] or interference with the magnetic compass used by the birds during migration[150]. An attraction to conventional artificial night lightings may lead to other adverse consequences such as reducing fuel stores, delaying migration, increasing the chance of collision and thereby, injury and death[151].

Gulls and terns (*Anous minutus, Anous tenuirostris* and *Gygis alba*) share visual pigments that give them vision in the short wavelength ultraviolet region of the spectrum in addition to the violet (blue) region of the spectrum. However, this sensitivity to very short wavelength light is rare in seabirds, which are characterised by photopic vision (daylight adapted) sensitivity in the mid to long wavelength range of the visible spectrum (590 – 740 nm, orange to red) while their scotopic (low light, dark adapted) vision is more sensitive to short wavelengths of light (380 - 485 nm, violet – blue)[119].

Biological impacts on migratory shorebirds

The exponential increase in the use of artificial light over the past decade means ecological light pollution has become a global issue[60]. Although the extent to which intertidal ecosystems are being affected is unclear[152], several studies have assessed both the positive and negative aspects of light pollution on migratory shorebirds.

Artificial lighting has been shown to influence the nocturnal foraging behaviour in shorebirds[141,153]. Santos et al (2010) demonstrated three species of plover (Common Ringed Plover *Charadrius hiaticula*, Kentish Plover *Charadrius alexandrina* and Grey Plover *Pluvialis squatarola*) and two species of sandpiper (Dunlin *Calidris alpina* and Common Redshank *Tringa totantus*) improved foraging success by exploiting sites where streetlights provided extra illumination[153].

Similarly, Dwyer et al (2013) showed artificial light generated from a large industrial site significantly altered the foraging strategy of Common Redshanks within an estuary. The greater nocturnal illumination of the estuary from the industrial site allowed the birds to forage for extended periods using a visual foraging strategy, which was deemed a more effective foraging behaviour when compared to tactile foraging[141].

Although shorebirds may be attracted to foraging areas with greater nocturnal illumination, artificial light near nocturnal roosting sites may displace the birds. Rogers et al (2006) studied the nocturnal roosting habits of shorebirds in north-western Australia, and suggested nocturnal roost sites with low exposure to artificial lighting (e.g. streetlights and traffic) were selected, and where the risk of predation was perceived to be low[140]. The study also found nocturnal roosts spatially differed from diurnal roosts and required increased energetic cost to access as the distance between nocturnal roosts and foraging areas was greater than the distance between diurnal roost sites and the same foraging areas[145]. The overall density of shorebirds in suitable foraging areas is expected to decline with increased distance to the nearest roost, due to the greater energetic cost travelling between areas[144,145]. The artificial illumination (or lack thereof) of nocturnal roost sites is therefore likely to significantly influence the abundance of shorebirds in nearby foraging areas.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 129 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Intermittent or flashing lights could flush out the shorebirds and force them to leave the area, especially if the light is persistent (Choi pers. obs. 2018, Straw pers. comm. 2018).

Artificial light can affect birds in flight. Not only can bright light attract airborne migrants[154], but artificial light can also affect stop-over selection in long distance migrators which can impact on successful migration and decrease fitness[139]. Similarly, Roncini et al (2015) reported on interactions between offshore oil and gas platforms and birds in the North Sea and found these were likely to include migratory shorebirds. The review estimated that hundreds of thousands of birds were killed each year in these interactions and light was the likely cause. The review recognised the gaps in monitoring and concluded that impacts are likely to be region, species and platform specific[108].

Environmental Impact Assessment of Artificial Light on Migratory Shorebirds

As a minimum, Best Practice Lighting Design should be implemented on infrastructure with externally visible artificial lighting. Where there is important habitat for migratory shorebirds within 20 km of a project, consideration should be given as to whether that light is likely to have an effect on those birds. The following sections step through the framework for managing artificial light, with specific consideration for migratory shorebirds. The 20 km buffer is based on a precautionary approach that sky glow can cause a change in behaviour in other species up to 15 km away[28].

Where artificial light is likely to affect migratory shorebirds, consideration should be given to mitigation measures at the earliest point in a project and used to inform the design phase.

It is important to recognise the spatial and temporal characteristics of migratory corridors for some migratory shorebird species. Species typically use established migratory pathways at predictable times and artificial light intersecting with an overhead migratory pathway should be assessed in the same way as for ground-based populations.

Associated guidance

- *Wildlife Conservation Plan for Migratory Shorebirds* (2015)
- Approved conservation advice

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 130 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Qualified personnel

Lighting design/management and the EIA process should be undertaken by appropriately qualified personnel. Plans should be developed and reviewed by appropriately qualified lighting practitioners who should consult with an appropriately trained marine ornithologist or ecologist. People advising on the development of a lighting management plan, or the preparation of reports assessing the effect of artificial light on migratory shorebirds, should have relevant qualifications equivalent to a tertiary education in ornithology, or equivalent experience as evidenced by peer reviewed publications in the last five years on a relevant topic, or other relevant experience.

Step 1: Describe the project lighting

The information collated during this step should consider the biological impact of light on migratory shorebirds. They can be affected by light when foraging or migrating at night. Artificial light at night may also affect their selection of roost site. The location and light source (both direct and sky glow) in relation to feeding and resting areas should be considered, depending on whether the birds are active or resting at night. Shorebirds are sensitive to short wavelength (blue/violet) light with some species able to detect UV light. However, the intensity of lights may be more important than colour.

Step 2: Describe the migratory shorebird population and behaviour

The species, and behaviour of shorebirds in the area of interest should be described. This should include the conservation status of the species; abundance of birds; how widespread/localised is the population; the migratory corridor location and timing or usage; the regional importance of the population; the number of birds in the area in different seasons; and their night-time behaviour (resting or foraging).

Relevant shorebird information can be found in the *EPBC Act* *Policy Statement 3.21 Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species*[136], *Wildlife Conservation Plan for Migratory Shorebirds (2015)*[138], the Protected Matters Search Tool, the National Conservation Values Atlas, state and territory listed species information, scientific literature, and local/Indigenous knowledge.

Where there is insufficient data to understand the population importance or demographics, or where it is necessary to document existing shorebird behaviour, field surveys and biological monitoring may be necessary.

Biological monitoring of migratory shorebirds

Monitoring associated with a project should be developed, overseen and results interpreted by appropriately qualified biologists to ensure reliability of the data.

The objective is to collect data on the abundance of birds and their normal behaviour. Please see Survey guidelines for Australia's threatened birds[128].

The data will be used to inform the EIA and assess whether mitigation measures are successful. Suggested minimum monitoring parameters (what is measured) and techniques (how to measure them) are summarised in Table 10.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101152-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 131 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 10 Recommended minimum biological information necessary to assess the importance of a migratory shorebird population. Note: the information in this table is not prescriptive and should be assessed on a case-by-case basis.

Target Age Class	Survey Effort	Duration	Reference
Adult	Four surveys of roosting birds (one in December, two in January and one in February), with an additional three to four surveys within the same neap-spring tide cycle is recommended.	Two hours before and after predicted high tide.	*Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species*[136]
Immature	One to two surveys on roosting birds between mid-May and mid-July.	Two hours before and after predicted high tide.	

Monitoring migratory shorebird populations

- Monitor the population (during different seasons) to establish a benchmark for assessing abundance before, during and after construction, and during operations to detect project-related change.
- Quantify the diurnal and nocturnal habitat use and movement in relation to tidal cycle (both high and low tides during the neap and spring tide cycles) in the area under baseline conditions to compare with light-affected conditions during construction and operations.
- Measure nocturnal light levels at foraging sites and nocturnal roost sites before and after the construction period of a project.
- Monitor nocturnal roost sites using acoustic recording devices and/or infrared cameras to determine nocturnal roost site use following the introduction of artificial light.

As a minimum, qualitative descriptive data on visible light types, location and directivity should also be collected at the same time as the biological data. Handheld camera images can help to describe the light. Quantitative data on existing sky glow should be collected, if possible, in a biologically meaningful way, recognising the technical difficulties in obtaining these data. See Measuring Biologically Relevant Light for a review.

Step 3: Risk assessment

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 132 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The objective of these Guidelines is that light should be managed so that shorebirds are not disrupted within or displaced from important habitat and are able to undertake critical behaviours such as foraging, roosting and dispersal. These consequences should be considered in the risk assessment process. At important shorebird habitats, roosting and foraging numbers should remain constant and foraging birds should not be startled or at increased risk from predators as a result of increased illumination.

The assessment should consider the existing light environment, the proposed lighting design and mitigation/management, the behaviour of shorebirds at the location, and how the birds perceive light. This should include wavelength and intensity information and perspective. To understand how/whether shorebirds are likely to see light, a site visit should be made at night and the area viewed from the intertidal flats and roosting areas. Similarly, consideration should be given to how shorebirds will see light when in flight and along flyways during migration periods.

The type and number of artificial lights should then be considered to assess whether the birds are likely to perceive the light, and the possible consequences of light on their behaviour.

Step 4: Light management plan

This plan should include all relevant project information (Step 1) and biological information (Step 2). It should outline proposed mitigation. For a range of shorebird specific mitigation measures see the Migratory Shorebird Light Mitigation Toolbox below. The plan should also outline the type and schedule for biological and light monitoring to ensure mitigation is meeting the objectives of the plan and triggers for revisiting the risk assessment phase of the EIA. The plan should outline contingency options if biological and light monitoring or compliance audits indicate that mitigation is not meeting the objectives of the plan (e.g. light is visible on intertidal flats, shorebirds cease using resting areas, or birds are grounding or colliding with fixed or floating infrastructure, or migrating birds cease using a migratory corridor).

Step 5: Biological and light monitoring and auditing

The success of the plan should be confirmed through monitoring and compliance auditing. The results should be used to facilitate an adaptive management approach for continuous improvement.

Biological monitoring is described in Step 2: Describe the Migratory Shorebird Population. Concurrent light monitoring should be undertaken and interpreted in the context of how the birds perceive light and within the limitations of monitoring techniques described in Measuring Biologically Relevant Light. Auditing, as described in the plan, should be undertaken.

Review

The EIA should incorporate a continuous improvement review process that allows for upgraded mitigations, changes to procedures and renewal of the light management plan.

Migratory Shorebird Light Mitigation Toolbox

All projects should incorporate the Best Practice Light Design Principles. Appropriate lighting controls and light impact mitigation will be site/project and species specific. Table 11 provides a toolbox of options that would be implemented in addition to the six Best Practice Light Design principles. Not all mitigation options will be relevant for all situations. Table 12 provides a suggested list of light types appropriate for use near rookeries or roosting sites and those to avoid.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 133 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 11 Light management actions specific to migratory shorebirds.

Management Action	Detail
Implement actions when birds are likely to be present. This includes peak migration periods (flyway locations).	Birds are found in Australia year-round. Major movements along coastlines take place between March and April, and August and November. Between August and April, shorebird abundance peaks. Smaller numbers are found from April to August.
No light source should be directly visible from foraging or nocturnal roost habitats, or from migratory pathways.	Any light that is directly visible to a person standing in foraging or nocturnal roost habitats will potentially be visible to a shorebird and should be modified to prevent it being seen. Similarly, lights should be shielded such that they are not visible from the sky.
Do not install fixed light sources in nocturnal foraging or roost areas.	Installing light sources (e.g. light poles) within shorebird habitat may permanently reduce the available area for foraging or roosting and provide vantage points for predators (e.g. raptors) during the day.

Management Action	Detail
Prevent mobile light sources shining into nocturnal foraging and roost habitat.	The light from mobile sources such as mobile lighting towers, head torches or vehicle headlights should be prevented from aiming into nocturnal foraging or roost areas, as this can cause immediate disturbance.
Maintain a natural barrier (e.g. dune and/or vegetation screen) between nocturnal foraging and roost areas, and sources of artificial light.	Reducing the exposure of shorebirds to artificial light will reduce the risk of predation and disturbance.
Maintain a dark zone between nocturnal foraging and roost habitats and sources of artificial lights.	Creating a dark zone between artificial lights and shorebird habitat will reduce disturbances to shorebirds.
Use curfews to manage lighting near nocturnal foraging and roosting areas in coastal habitats. For example, manage artificial lights using motion sensors and timers from 7pm until dawn.	Curfews should also consider the tidal cycle if the artificial lighting is located coastally, e.g. extinguish lighting from two hours before high tide, until two hours after high tide, while shorebirds are potentially roosting.
Use of flashing/intermittent lights instead of fixed beam.	For example, small red flashing lights can be used to identify an entrance or delineate a pathway. The timing of when lights flash must follow a predictable, well-spaced pattern.
Use motion sensors to turn lights on only when needed.	For example, installing motion-activated pedestrian lighting within 500 m of nocturnal foraging or roost areas may reduce the amount of time the habitat is exposed to artificial light.
Manage artificial light on jetties and marinas.	Shorebirds will often roost on breakwaters and jetties, so allowing dark areas in such places may provide a safe area for shorebirds to roost.
Reduce deck lighting to minimum required for human safety on vessels moored near nocturnal foraging and roost areas, and those operating offshore.	Extinguish deck lights when not necessary and restrict lighting at night to navigation lights only. Offshore vessels should direct light inwards, particularly during the migration periods when shorebirds are potentially overhead. Record bird strike or incidental capture and report these interactions to regulatory authorities.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 134 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Management Action	Detail
Minimise night-time flaring on offshore oil and gas production facilities.	Consider reinjecting excess gas instead of flaring. Schedule maintenance flaring during daylight hours. Record bird strike or incidental capture and report these interactions to regulatory authorities.
Use luminaires with spectral content appropriate for the species present.	Consideration should be given to avoid specific wavelengths that are problematic for the species of interest. In general this would include avoiding lights rich in blue light, however, some birds are sensitive to yellow light and other mitigation may be required.
Avoid high intensity light of any colour.	Keeping light intensity as low as possible in the vicinity of nocturnal foraging and roost areas will minimise impact.
Prevent indoor lighting reaching migratory shorebird habitat.	Use fixed window screens or window tinting on fixed windows and skylights to contain light inside buildings.
In facilities requiring intermittent night inspections, turn lights on only during the time operators are moving around the facility.	Use appropriate wavelength, explosion proof LEDs with smart lighting controls and/or motions sensors. LEDs have no warmup or cool down limitations so can remain off until needed and provide instant light when required for routine nightly inspections or in the event of an emergency.
Industrial site/plant operators to use personal head torches.	Consider providing plant operators with white head torches (explosion proof torches are available) for situations where white light is needed to detect colour correctly, or in the event of an emergency. Operators should avoid shining light across nocturnal foraging or roost areas as this can cause disturbance.
Supplement facility perimeter security lighting with computer monitored infrared detection systems.	Perimeter lighting can be operated when night-time illumination is necessary but remain off at other times.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 135 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 12 Where all other mitigation options have been exhausted and there is a human safety need for artificial light, the following table provides commercial luminaires recommended for use near migratory shorebird habitat and those to avoid.

Light type	Suitability for use near migratory shorebird habitat
Low Pressure Sodium Vapour	✓
High Pressure Sodium Vapour	✓
Filtered* LED	✓
Filtered* metal halide	✓
Filtered* white LED	✓
LED with appropriate spectral properties for species present	✓
White LED	✗
Metal halide	✗
White fluorescent	✗
Halogen	✗
Mercury vapour	✗

* 'Filtered' means this type of luminaire can be used *only* if a filter is applied to remove the problematic wavelength light.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 136 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Glossary

ACAP is the *Agreement on the Conservation of Albatrosses and Petrels*.

ALAN is Artificial Light At Night and refers to artificial light outside that is visible at night.

Artificial light is composed of visible light as well as some ultraviolet (UV) and infrared (IR) radiation that is derived from an anthropogenic source.

Artificial sky glow is the part of the sky glow that is attributable to human-made sources of light (see also **sky glow**).

Baffle is an opaque or translucent element to shield a light source from direct view, or to prevent light reflecting from a surface like a wall.

Biologically Important Area (BIA) is a spatially defined area where aggregations of individuals of a species are known to display biologically important behaviour, such as breeding, feeding, resting or migration.

Biologically relevant is an approach, interpretation or outcome that considers either the species to which it refers, or factors in biological considerations in its approach.

Brightness is the strength of the visual sensation on the naked eye when lit surfaces are viewed.

Bulb is the source of electric light and is a component of a luminaire.

CAMBA is the *China-Australia Migratory Bird Agreement*.

Candela (cd) (**photometric term**) is a photometric unit of illumination that measures the amount of light emitted in the range of a (three-dimensional) angular span. Luminance is typically measured in candela per square meter (cd/m2).

Charge Coupled Device (CCD) is the sensor technology used in digital cameras. It converts captured light into digital data (images) which can be processed to produce quantifiable data.

CIE is the Commission Internationale de l'Eclairage (International Light Commission), which sets most international lighting standards.

CMS is the *Convention on the Conservation of Migratory Species of Wild Animals* or the Bonn Convention.

Colour temperature is the perceived colour of a light source ranging from cool (blue) to warm (yellow), measured in Kelvin (K). A low correlated colour temperature such as 2500K will have a warm appearance while 6500K will appear cold.

Correlated Colour Temperature (CCT) is a simplified way to characterize the spectral properties of a light source and is correlated to the response of the human eye. Colour temperature is expressed in Kelvin (K).

Cumulative light refers to increased sky brightness due to light emissions contributions from multiple light producers. Measured as **sky glow**.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 137 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

Disorientation refers to any species moving in a confused manner e.g. a turtle hatchling circling and unable to find the ocean.

EEZ is the Australian Exclusive Economic Zone.

EIA is an environmental impact assessment process.

Electromagnetic radiation is a kind of radiation including visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously.

EPBC Act is the Commonwealth *Environment Protection and Biodiversity Act 1999*.

Fallout refers to birds that collide with structures when disoriented.

Footcandle (fc or ftc) (photometric term) is a unit of light intensity used in America, it is based on the brightness of one candle at a distance of one foot. Measured in lumens per square foot, one ftc is equal to approximately 10.7639 lux. This is not an appropriate measure for understanding how animals perceive light.

FMP refers to the Field Management Program.

Genetic stock is a discrete grouping of a species by genetic relatedness. Management of the species may be undertaken on a genetic stock basis because each genetic stock represents a unique evolutionary history, which if lost cannot be replaced.

Grounding refers to events where birds fail to take their first flight from the nest or collide with a structure (adults and juveniles) and are unable to launch back into the air.

Habitat critical to the survival of the species is an area defined in a Recovery Plan for a listed threatened species that provides for the recovery of the species.

Horizontal plane, in relation to the light fitting, means the horizontal plane passing through the centre of the light source (for example the bulb) of the light fitting.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 138 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

HPS is a high-pressure sodium lamp that produces a characteristic wavelength near 589 nm.

IAATO is the International Association of Antarctica Tour Operators.

Illuminance is a **photometric** measure of the total luminous flux incident on a surface, per unit area. It is a measure of how much the incident light illuminates the surface, wavelength-weighted to correlate with human brightness perception. Illuminance is measured in **lux** (lx) or equivalently in **lumens** per square metre (lm/m^2).

Important habitats are those areas that are necessary for an ecologically significant proportion of a listed species to undertake important activities such as foraging, breeding, roosting or dispersal. Important habitats will be species specific and will depend on their listing status. It will include areas that have been designated as **Habitat Critical to Survival** of a threatened species.

Incandescent bulb is a bulb that provides light by a filament heated to a high temperature by electric current.

Intensity is the amount of energy or light in a given direction.

Internationally important refers to wetland habitat for migratory shorebirds that support one per cent of the individuals in a population of one species or subspecies; or a total abundance of at least 20 000 waterbirds.

IR is infrared radiation and represents a band of the electromagnetic spectrum with wavelength from 700 nm to 1 mm.

Irradiance (**radiometric term**) is a measurement of radiant flux at or on a known surface area, W/m^2. This measure is appropriate for understanding animal perception of light.

IUCN is the International Union for the Conservation of Nature.

JAMBA is the *Japan-Australia Migratory Bird Agreement*.

Kelvin (K) is the absolute unit for temperature and is equal in magnitude to one degree Celsius. Kelvin is typically used to describe **Correlated Colour Temperature (CCT)**.

Lamp is a generic term for a source of optical radiation (light), often called a “bulb” or “tube”. Examples include incandescent, fluorescent, high-intensity discharge (HID) lamps, and low-pressure sodium (LPS) lamps, as well as light-emitting diode (LED) modules and arrays.

LED is a light-emitting diode, or a semiconductor light source that emits light when current flows through it.

Light fitting (**luminaire**) is the complete lighting unit. It includes the bulb, reflector (mirror) or refractor (lens), the ballast, housing and the attached parts.

Light is the radiant energy that is visible to humans and animals. Light stimulates receptors in the visual system and those signals are interpreted by the brain making things visible.

Light pollution is the brightening of the night sky caused by **artificial light**.

Light spill is the light that falls outside the boundaries of the object or area intended to be lit. Spill light serves no purpose and if directed above the horizontal plane, contributes directly to **artificial sky glow**. Also called spill light, obtrusive light or light trespass.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101133-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 139 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Lighting controls are devices used for either turning lights on and off, or for dimming.

Listed species are those species listed under the **EPBC Act,** or under relevant state or territory environment/conservation legislation. Species may be listed as threatened, migratory or part of a listed threatened ecological community.

LNG is liquefied natural gas.

LPS is a low pressure sodium lamp that produces a characteristic wavelength near 589 nm.

Luminaire refers to the complete lighting unit (fixture or light fitting), consisting of a lamp, or lamps and ballast(s) (when applicable), together with the parts designed to distribute the light (reflector, lens, diffuser), to position and protect the lamps, and to connect the lamps to the power supply.

Luminous flux is the total light emitted by a bulb in all directions which is measured in **lumen**.

Lumen (lm) (photometric term) is the unit of **luminous flux**, a measure of the total quantity of visible light emitted by a source per unit of time. This is a **photometric** unit, weighted to the sensitivity of the human eye. If a light source emits one **candela** of luminous intensity uniformly across a solid angle of one steradian, the total **luminous flux** emitted into that angle is one lumen.

Luminance (cd/m^2) is a **photometric** measure of the luminous intensity per unit area of light travelling in a given direction, wavelength-weighted to correlate with human brightness perception. Luminance is measured in candela per square metre (cd/m^2). Luminance and **illuminance** ("**Lux**") are related, in the sense that luminance is a measure of light emitted from a surface (either because of reflection or because it's a light-emitting surface), and illuminance is a measure for light hitting a surface.

Lux (lx) is a **photometric** measure of illumination of a surface. The difference between lux and **candela** is that lux measures the illumination of a surface, instead of that of an angle. This is not an appropriate measure for understanding how animals perceive light.

Magnitudes per square arc second (**magnitudes/arcsec^2**) (**radiometric term**) is a term used in astronomy to measure sky brightness within an area of the sky that has an angular area of one second by one second. The term magnitudes per square arc second means that the brightness in magnitudes is spread out over a square arcsecond of the sky. Each magnitude lower (numerically) means just over 2.5 times more light is coming from a given patch of sky. A change of 5 magnitudes/arcsec^2 means the sky is 100x brighter.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 140 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Misorientation occurs when a species moves in the wrong direction, e.g. when a turtle hatchling moves toward a light and away from the ocean.

MNES are Matters of National Environmental Significance as defined by the **EPBC Act** and include listed threatened and listed migratory species.

Mounting height is the height of the fitting or bulb above the ground.

Nationally important habitat are those wetlands that support 0.1 per cent of the flyway population of a single species of migratory shorebird; or 2 000 migratory shorebirds; or 15 migratory shorebird species.

Natural sky glow is that part of the **sky glow** that is attributable to radiation from celestial sources and luminescent processes in the Earth's upper atmosphere.

Outdoor lighting is the night-time illumination of an area by any form of outside light fitting (luminaire).

Outside light fitting means a light fitting (luminaire) that is attached or fixed outside or on the exterior of a building or structure, whether temporary or permanent.

Photocells are sensors that turn lights on and off in response to natural light levels. Some advanced mode can slowly dim or increase the lighting (see also **smart controls**).

Photometric terms refer to measurements of light that are weighted to the sensitivity of the human eye. They are not include the shortest or the longest wavelengths of the visible spectrum and so are not appropriate for understanding the full extent of how animals perceive light.

Photometry is a subset of radiometry that is the measurement of light as it is weighted to the sensitivity of the human eye.

Point source is light from an unshielded lamp (i.e. directly visible).

Radiance (**radiometric term**) is a measure of radiant intensity emitted from a unit area of a source, measured in W/m^2.

Radiant flux/power (**radiometric term**) is expressed in watts (W). It is the total optical power of a light source. It is the radiant energy emitted, reflected, transmitted or received, per unit time. Sometimes called radiant power, and it can also be defined as the rate of flow of radiant energy.

Radiant intensity (**radiometric term**) is the amount of flux emitted through a known solid angle, W/steradian, and has a directional quantity.

Radiometric terms refer to light measured across the entire visible spectrum (not weighted to the human eye). These are appropriate for understanding how animals perceive light.

Radiometry is the measurement of all wavelengths across the entire visible spectrum (not weighted to the human eye).

Reflected light is light that bounces off a surface. Light coloured surfaces reflect more light than darker coloured surfaces.

ROKAMBA is the *Republic of Korea-Australia Migratory Bird Agreement*.

Sensitive receptor is any living organism that has increased sensitivity or exposure to environmental contaminants that may have adverse effects.

Shielded light fitting is a physical barrier used to limit or modify the light paths from a luminaire.

Sky glow is the brightness of the night sky caused by the cumulative impact of reflected radiation (usually visible light), scattered from the constituents of the atmosphere in the direction of observation. Sky glow comprises two separate components: natural sky glow and artificial sky glow (see also **natural sky glow** and **artificial sky glow**).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 141 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Smart controls are devices to vary the intensity or duration of operation of lighting, such as motion sensors, timers and dimmers used in concert with outdoor lighting equipment.

Spectral power curve provides a representation of the relative presence of each wavelength emitted from a light source.

Task lighting is used to provide direct light for specific activities without illuminating the entire area or object.

Upward Light Ratio (ULR) is the proportion of the light (flux) emitted from a **luminaire** or installation that is emitted at and above the horizontal, excluding reflected light when the luminaire is mounted in its parallel position. ULR is the upward flux/total flux from the luminaire.

UV is ultraviolet light and represents a band of the electromagnetic spectrum with wavelength from 10 nm to 400 nm.

Visible light transmittance is the proportion of light transmitted by window glass which is recorded as either TVw (visible transmittance of the window) and is reported as a dimensionless value between 0 and 1, or 0 and 100%. A low TVw (e.g. < 30%) indicates little light is transmitted through the glass while higher TVw values are associated with increasing light transmittance. While the VLT/Tvw rating varies between 0 and 1, most double glazed windows rate between 0.3 and 0.7, which means that between 30% and 70% of the available light passes through the window.

W/m^2 is a measure of radiance, the radiant intensity emitted from a unit area of a source (see **radiance**). This is an appropriate measure for understanding how animals perceive light.

Wattage is the amount of electricity needed to light a bulb. Generally, the higher the wattage, the more **lumens** are produced. Higher wattage and more lumens give a brighter light.

Wavelength as light travels through space it turns a wave with evenly spaces peaks and troughs. The distance between the peaks (or the troughs) is called the wavelength of the light. Ultraviolet and blue light are examples of short wavelength light while red and infrared light is long wavelength light. The energy of light is linked to the wavelength; short wavelength light has much higher energy than long wavelength light.

Zenith is an imaginary point directly above a location, on the imaginary celestial sphere.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 142 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

References

1. Kyba CCM, Kuester T, Sánchez de Miguel A, Baugh K, Jechow A, Hölker F, Bennie J, Elvidge CD, Gaston KJ & Guanter L (2017) Artificially lit surface of Earth at night increasing in radiance and extent. *Science Advances* 3:e1701528.
2. Russart KLG & Nelson RJ (2018) Artificial light at night alters behavior in laboratory and wild animals. *JEZ-A Ecological and Intergrative Physiology* 329(8-9):401-408.
3. Witherington B & Martin RE (2003) *Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches* Florida Fish and Wildlife Conservation Commission FMRI Technical Report TR-2: Jensen Beach, Florida. 84p.
4. Rodríguez A, Holmes ND, Ryan PG, Wilson K-J, Faulquier L, Murillo Y, Raine AF, Penniman J, Neves V, Rodríguez B, Negro JJ, Chiaradia A, Dann P, Anderson T, Metzger B, Shirai M, Deppe L, Wheeler J, Hodum P, Gouveia C, Carmo V, Carreira GP, Delgado-Alburqueque L, Guerra-Correa C, Couzi F-X, Travers M & Le Corre M (2017) A global review of seabird mortality caused by land-based artificial lights. *Conservation Biology* 31:986-1001.
5. Robert KA, Lesku JA, Partecke J & Chambers B (2015) Artificial light at night desynchronizes strictly seasonal reproduction in a wild mammal. *Proceedings of the Royal Society B* 282:20151745.
6. Fobert EK, Burke da Silva K & Swearer SE (2019) Artificial light at night causes reproductive failure in clownfish. *Biology Letters* 15:e20190272.
7. Rich C & Longcore T, eds. (2006) *Ecological consequences of artificial night lighting*. Island Press: Washington DC. 480p.
8. Campos SMC (2017) The impact of artificial lighting on nature. In *6th SENAC MEETING of Integrated Knowledge Senac Sorocaba*.
9. Reed JR (1986) *Seabird vision: Spectral sensitivity and light-attraction behavior* University of Wisconsin. Madison, Wisconsin. 190p.
10. Newman EA & Hartline PH (1981) Integration of visual and infrared information to biomodal neurons in the rattlesnake optic tectum. *Science* 213(4509):789-91.
11. Gaston KJ, Visser ME & Holker F (2018) The biological impacts of artificial light at night: the research challenge. *Philosophical Transactions of the Royal Society B* 370:e20140133.
12. Sanders D & Gaston KJ (2018) How ecological communities respond to artificial light at night. *Journal of Experimental Zoology* 329(8-9):394-400.
13. Bennie J, Davies TW, Cruse D & Gaston J (2016) Ecological effects of artificial light at night on wild plants. *Journal of Ecology* 104(3):611-620.
14. Price JT, Drye B, Domangue RJ & Paladino FV (2018) Exploring the role of artificial light in Loggerhead turtle (*Caretta caretta*) nest-site selection and hatchling disorientation. *Herpetological Conservation and Biology* 13(2):415-422.
15. Witherington BE (1992) Behavioural response of nesting sea turtles to artificial lighting. *Herpetologica* 48:31-39.
16. Thums M, Whiting SD, Reisser JW, Pendoley KL, Pattiaratchi CB, Proietti M, Hetzel Y, Fisher R & Meekan M (2016) Artificial light on water attracts turtle hatchlings during their near shore transit. *Royal Society Open Science* 3:e160142.
17. Cabrera-Cruz SA, Smolinsky JA & Buler JJ (2018) Light pollution is greatest within migration passage areas for nocturnally-migrating birds around the world. *Nature Scientific Reports* 8:e3261.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101133-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 143 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

18. Ouyang JQ, de Jong M, Hau M, Visser ME, van Grusven RHA & Spoelstra K (2015) Stressful colours: Corticosterone concentrations in a free-living songbird vary with the spectral composition of experimental illumination. *Biology Letters* 11:20150517.

19. Warrant EJ, Frost B, Green K, Mouritsen H, Dreyer D, Adden A, Brauburger K & Heinze S (2016) The Australian Bogong moth *Agrotis infusa*: A long-distance nocturnal navigator. *Frontiers in Behavioural Neuroscience* doi: 10.3389/fnbeh.2016.00077.

20. Commonwealth of Australia (2016) *National Recovery Plan for the Mountain Pygmy-possum Burramys parvus* Prepared by the Victorian Department of Environment, Land, Water and Planning: Canberra, Australia. 43p.

21. Haddock JK, Threlfall CG, Law B & Hochuli DF (2019) Responses of insectivorous bats and nocturnal insects to local changes in street light technology. *Austral Ecology* 44(6):doi.org/10.1111?aec.12772.

22. Bolton D, Mayer-Pinto M, Clark GF, Dafforn KA, Brassil WA, Becker A & Johnston EL (2017) Coastal urban lighting has ecological consequences for multiple trophic levels under the sea. *Science of the Total Environment* 576:1-9.

23. Gonza´lez-Bernal E, Brown G & Shine R (2014) Invasive cane toads: Social facilitation depends upon an individual's personality. *PLoS ONE* 9(7):e102880.

24. Wilson P, Thums M, Pattiaratchi CB, Whiting S, Pendoley K, Ferreira L & Meekan M (2019) High predation of marine turtle hatchlings near a coastal jetty. *Biological Conservation* 236(2019):571-579.

25. Commonwealth of Australia (2013) *Matters of National Environmental Significance Significant Impact Guidelines 1.1 Environmental Protection and Biodiversity Conservation Act 1999*: Canberra, Australia. 39p.

26. Kamrowski RL, CJ L, Pendoley K & Hamann M (2014) Influence of industrial light pollution on the sea-finding behaviour of flatback turtle hatchlings. *Wildlife Research* 41:421-434.

27. Hodge W, Limpus CJ & Smissen P (2007) *Queensland turtle conservation project: Hummock Hill Island Nesting Turtle Study December 2006 Conservation Technical and Data Report* Environmental Protection Agency Queensland. p:1-10.

28. Rodríguez A, Burgan G, Dann P, Jessop R, Negro JJ & Chiaradia A (2014) Fatal attraction of short-tailed shearwaters to artificial lights. *PLoS ONE* 9(10):e110114.

29. Moro D, van de Merwe J, Thomas M, Smith A & Lagdon R (2018) Integrating resource development with island conservation: Barrow Island as a model for conservation and development. In: *Australian Island Arks: Conservation, Management and Opportunities*, Moro D, Ball D & Bryant S, Editors. CSIRO Publishing: Melbourne, p:131-146.

30. Chevron Australia (2018) *Gorgon Gas Development and Jansz Feed Gas Pipeline Long-term Marine Turtle Management Plan*. 83p.

31. Rodrıguez A, Moffet J, Revoltos A, Wasiak P, McIntosh RR, Sutherland DR, Renwick L, Dann P & Chiaradia A (2017) Light pollution and seabird fledglings: Targeting efforts in rescue programs. *Journal of Wildlife Management* 81:734-741.

32. Rodríguez A, Dann P & Chiaradia A (2017) Reducing light-induced mortality of seabirds: High pressure sodium lights decrease the fatal attraction of shearwaters. *Journal for Nature Conservation* 39:68-72.

33. Limpus CJ, Miller JD, Parmenter CJ & Limpus DJ (2003) The green turtle, *Chelonia mydas*, population of Raine Island and the Northern Great Barrier Reef: 1843-2001. *Memoirs of the Queensland Museum* 49:349-440.

34. Irsitech (2018) https://iristech.co/how-iris-reduces-blue-light/visible-spectrum. 2018 [cited Accessed 1stOctober 2018.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 144 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

35. Algvere PV, Marshall J & Seregard S (2006) Age-related maculopathy and the impact of blue light hazard. *Acta Ophthalmologica Scandinavica* 84(1):4-15.

36. West KE, Jablonski MR, Warfield B, Cecil KS, James M, Ayers MA, Maida J, Bowen C, Sliney DH, Rollag MD & Hanifin JP (2010) Blue light from light-emitting diodes elicits a dose-dependent suppression of melatonin in humans. *Journal of applied physiology* 110(3):619-626.

37. Pendoley K & Kamrowski RL (2015) Influence of horizon elevation on the sea-finding behaviour of hatchling flatback turtles exposed to artificial light glow. *Marine Ecology Progress Series* 529:279-288.

38. Bird BL, Branch LC & Miller DL (2004) Effects of coastal lighting on foraging behaviour on beach mice. *Conservation Biology* 18:1435-1439.

39. Salmon M (2006) Protecting sea turtles from artificial night lighting at Florida's oceanic beaches. In: *Ecological Consequences of Artificial Night Lighting*, Rich C & Longcore T, Editors. Island Press: Washinton DC p:141-168.

40. Tosini G, Ferguson I & Tsubota K (2016) Effects of blue light on the circadian system and eye physiology. *Molecular Vision* 22:61-72.

41. Ecker JL, Dumitrescu ON, Wong KY, Alam NM, Chen S, LeGates T, Renna JM, Prusky GT, Berson DM & Hattar S (2010) Melanopsin-expressing retinal ganglion-cell photoreceptors: Cellular diversity and role in pattern vision. *Neuron* 67(1):49-60.

42. Berson DM (2007) Phototransduction in ganglion-cell photoreceptors. *Pflügers Archiv* 454(5):849-855.

43. de Jong M, Ouyang JQ, Da Silva A, Van Grunsven RHA, Kempenaers B, Visser ME & Spoelstra K (2015) Effects of nocturnal illumination on life-history decisions and fitness in two wild songbird species. *Philosophical Transactions of the Royal Society of London. Series B Biological Sciences* 370:20140128–20140128.

44. Angers K, Haddad N, Selmaoui B & Thibault L (2003) Effect of melatonin on total food intake and macronutrient choice in rats. *Physiology & Behavior* 80:9-18.

45. Benenson W, Harris JW, Stocker H & Lutz H, eds. (2006) *Handbook of Physics*. Springer Science & Business Media.

46. Kyba CCM, Ruhtz T, Fischer J & Holker F (2011) Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems. *PLoS ONE* 6(e17307).

47. Longcore T, Rodríguez A, Witherington B, Penniman JF, Herf L & Herf M (2018) Rapid assessment of lamp spectrum to quantify ecological effects of light at night. *Journal of Experimental Zoology Part A Ecological and Integrative Physiology* 2018:1-11.

48. Lohmann KJ, Witherington B, Lohmann CMF & Salmon M (1997) Orientation, navigation, and natal beach homing in sea turtles. In: *The Biology of Sea Turtles. Volume I*, Lutz PL & Musick JA, Editors. CRC Press: Washington D.C. p:107-135.

49. Barentine JC (2019) Methods for assessment and monitoring of light pollution around ecologically sensitive sites. *Journal of Imaging* 5(54):e5050054.

50. Hänel A, Posch T, Ribas SJ, Aubé M, Duriscoe D, Jechow A, Kollath Z, Lolkema D, Moore C, Schmidt N, Spoelstra H, Wuchterl G & Kyba CCM (2018) Measuring night sky brightness: Methods and challenges. *Journal of Quantitative Spectroscopy and Radiative Transfer* doi: 10.1016/j.jqsrt.2017.09.008

51. Levin N, Kyba CCM, Zhang Q, Sánchez de Miguel A, Román MO, Li X, Portnov BA, Moltman AL, Jechow A, Miller SD, Wang Z, Shrestha RM & Elvidge CD (2020) Remote sensing of night lights: A review and an outlook for the future. *Remote Sensing of the Environment* 237:111443.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 145 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

52. den Outer P, Lolkema D, Haaima M, Hoff RVD, Spoelstra H & Schmidt W (2011) Intercomparisons of nine sky brightness detectors. *Sensors* 11(10):9603.

53. Duriscoe DM (2013) Measuring anthropogenic skyglow using a natural sky brightness model. *Publications of the astronomical society of the Pacific* 125:1370-1382.

54. Jechow A, Kyba CCM & Hölker F (2019) Beyond all-sky: Assessing ecological light pollution using multi-spectral full-sphere fisheye lens imaging *Journal of Imaging* 5(46):doi:10.3390/jimaging5040046.

55. Kolláth Z (2010) Measuring and modelling light pollution at the Zselic Starry Sky Park. *Journal of Physics: Conference Series* 2018 (5th Workshop of Young Researchers in Astronomy & Astrophysics) e012001.

56. Jechow A, Ribas SJ, Domingo RC, Hölker F, Kolláth Z & Kyba CC (2018) Tracking the dynamics of skyglow with differential photometry using a digital camera with fisheye lens. *Journal of Quantitative Spectroscopy and Radiative Transfer* 209:212-223.

57. Commonwealth of Australia (2017) *The Recovery Plan for Marine Turtles in Australia* Department of the Environment and Energy: Canberra, Australia. 146p.

58. Hooker D (1911) Certain reactions to color in the young loggerhead turtle. *Papers from the Tortugas Laboratory - Carnegie Institute* 13:71-76.

59. Salmon M (2003) Artificial night lighting and sea turtles. *Biologist* 50:163-168.

60. Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA & Furgoni R (2016) The new world atlas of artificial night sky brightness. *Science Advances* 2(6):e1600377.

61. Kamrowski RL, Limpus CJ, Moloney J & Hamann M (2012) Coastal light pollution and marine turtles: Assessing the magnitude of the problem. *Endangered Species Research* 19:85-98.

62. Pendoley K (2000) *The influence of gas flares on the orientation of Green Turtle hatchlings at Thevenard Island, Western Australia* in Pilcher NJ & Ismail G, Editors, *Second ASEAN Symposium and Workshop on Sea Turtle biology and Conservation* ASEAN Academic Press: Kota Kinabalu, Borneo. p.130-142.

63. Pendoley KL (2005) *Sea Turtles and the Environmental Management of Industrial Activities in North Western Australia* Murdoch University. 330p.

64. Hu Z, Hu H & Huang Y (2018) Association between nighttime artificial light pollution and sea turtle nest density along Florida coast: A geospatial study using VIIRS remote sensing data. *Environmental Pollution* 239:30-42.

65. Pennell JP (2000) *The Effect of Filtered Roadway Lighting on Nesting by Loggerehad Sea Turtles (Caretta caretta) and Green Turtle (Chelonia mydas) Hatchlings* Florida Atlantic University: Boca Raton.

66. Salmon M, Reiners R, Lavin C & Wyneken J (1995) Behavior of loggerhead sea turtles on an urban beach. I. Correlates of nest placement. *Journal of Herpetology* 29(4):560-567.

67. Campbell C (1994) The effects of flash photography on nesting behavior of green turtles (*Chelonia mydas*) at Tortuguero, Costa Rica. In *Proceeding of the fourteenth annual symposium on sea turtle biology and conservation*. 1994. NOAA Technical Memorandum - NMFS-SEFSC.

68. Mrosovsky N (1968) Nocturnal emergence of hatchling sea turtles: Control by thermal inhibition of activity. *Nature* 220:1338-1339.

69. Erb V & Wyneken J (2019) Nest-to-Surf Mortality of Loggerhead Sea Turtle (*Caretta caretta*) Hatchlings on Florida's East Coast. *Frontiers in Marine Science* 6(271):doi: 10.3389/fmars.2019.00271.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 146 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

70. Limpus CJ & Kamrowski RL (2013) Ocean-finding in marine turtles: The importance of low horizon elevation as an orientation cue. *Behaviour* 150:863-893.

71. Horch KW, Gocke JP, Salmon M & Forward RB (2008) Visual spectral sensitivity of hatchling loggerhead (*Caretta caretta* L.) and leatherback (*Dermochelys coriacea* L.) sea turtles, as determined by single-flash electroretinography. *Marine and Freshwater Behaviour and Physiology* 41(2):107-119.

72. Witherington BE & Bjorndal KA (1991) Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta. Biological Conservation* 55(2):139-149.

73. Fritches KA (2012) Australian loggerhead sea turtle hatchlings do not avoid yellow. *Marine and Freshwater Behaviour and Physiology* 45(2):79-89.

74. Levenson DH, Eckert SA, Crognale MA, Deegan II JF & Jacobs GH (2004) Photopic spectral sensitivity of green and loggerhead sea turtles. *Copeia* 2004(2):908-914.

75. Robertson K, Booth DT & Limpus CJ (2016) An assessment of 'turtle-friendly' lights on the sea-finding behaviour of loggerhead turtle hatchlings (*Caretta caretta*). *Wildlife Research* 43:27-37.

76. Mrosovsky N (1972) The water finding ability of sea turtles. *Brain Behaviour and Evolution* 5:202-225.

77. Mrosovsky N & Shettleworth SJ (1968) Wavelength preferences and brightness cues in the water finding behaviour of sea turtles. *Behaviour* 32:211-257.

78. Pendoley K & Kamrowski RL (2015) Sea-finding in marine turtle hatchlings: What is an appropriate exclusion zone to limit disruptive impacts of industrial light at night? *Journal for Nature Conservation* 30:1-11.

79. Salmon M, Wyneken J, Fritz E & Lucas M (1992) Sea finding by hatchling sea turtles: Role of brightness, silhouette and beach slope as orientation cues. *Behaviour* 122:56-77.

80. Harewood A & Horrocks J (2008) Impacts of coastal development on hawksbill hatchling survival and swimming success during the initial offshore migration. *Biological Conservation* 141:394-401.

81. Truscott Z, Booth DT & Limpus CJ (2017) The effect of on-shore light pollution on sea-turtle hatchlings commencing their off-shore swim. *Wildlife Research* 3(5):127-134.

82. White D & Gill J (2007) A "lost years" flatback turtle *Natator depressus* (Garman, 1858) found. *Northern Territory Naturalist* 19:51-53.

83. Salmon M & Wyneken J (1990) Do swimming loggerhead turtles (*Caretta caretta* L.) use light cues for offshore orientation? *Marine Behavioural Physiology* 17:233-246.

84. Wilson P, Thums M, Pattiaratchi CB, Meekan M, Pendoley K, Fisher R & Whiting S (2018) Artificial light disrupts the nearshore dispersal of neonate flatback turtles *Natator depressus. Marine Ecology Progress Series* 600:179-192.

85. Eckert KL, Bjorndal KA, Abreu-Grobois FA & Donnelly M, eds. (1999) *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication No. 4. Washington, DC. 235.

86. Pendoley KL, Whittock PA, Vitenbergs A & Bell CD (2016) Twenty years of turtle tracks: marine turtle nesting activity at remote locations in the Pilbara, Western Australia. *Australian Journal of Zoology* 64:217-226.

87. Witherington B (1997) The problem of photopollution for sea turtles and other nocturnal animals. In: *Behavioral Approaches to Conservation in the Wild*, Clemmons JR & Buchholz R, Editors. Cambridge University Press: Cambridge. p:303-328.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101133-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 147 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

88. Ross GJB, Burbidge AA, Canty P, Dann P, Fuller PJ, Kerry KR, Norman FI, Menkhorst PW, Shaughnessy G, Shaughnessy PD & Smith GC (1996) Status of Australia's Seabirds. In: *State of the Environment Report*. CSIRO Sustainable Ecosystems: Perth, p:167-182.

89. Warham J (1990) *The Behaviour, Population Biology and Physiology of the Petrels*. London: Academic Press. 440p.

90. Harris CM, Lorenz K, Fishpool LDC, Lascelles B, Cooper J, Croxall JP, Emmerson LM, Fraser WR, Fijn R, Jouventin P, LaRue MA, Le Maho Y, Lynch HJ, Naveen R, Patterson-Fraser DL, Peter H-U, Poncet S, Phillips RA, Southwell CJ, van Franeker JA, Weimerskirch H, Wienecke B & Woehler EJ (2015) *Important Bird Areas in Antarctica 2015 Summary*. Cambridge: BirdLife International and Environmental Research & Assessment Ltd. p:45.

91. Murphy RC (1936) *Oceanic birds of South America*. New York: Macmillan.

92. Allen JA (1880) Destruction of birds by light-houses. *Bulletin of the Nuttall Ornithological Club* 5:131-138.

93. Gineste B, Souquet M, Couzi F-X, Giloux Y, Philippe J-S, Hoarau C, Tourmetz J, Potin G & Le Corre M (2016) Tropical shearwater population stability at Reunion Island, despite light pollution. *Journal of Ornithology* 158:385-394.

94. Ainley DG, Podolsky R, Nur N, Deforest L & Spencer GA (2001) Status and population trends of the Newell's shearwater on Kaua'i: A model for threatened petrels on urbanized tropical oceanic islands. *Studies in Avian Biology* 22:108-123.

95. Black A (2005) Light induced seabird mortality on vessels operating in the Southern Ocean: Incidents and mitigation measures. *Antarctic Science* 17:67-68.

96. Deppe L, Rowley O, Rowe LK, Shi N, McArthur N, Gooday O & Goldstien SJ (2017) Investigation of fallout events in Hutton's shearwaters (*Puffinus huttoni*) associated with artificial lighting. *Notornis* 64(4):181-191.

97. Merkel FR & Johansen KL (2011) Light-induced bird strikes on vessels in Southwest Greenland. *Marine Pollution Bulletin* 62:2330-2336.

98. Raine H, Borg JJ, Raine A, Bariner S & Cardona MB (2007) *Light Pollution and Its Effect on Yelkouan Shearwaters in Malta; Causes and Solutions* BirdLife Malta: Malta: Life Project Yelkouan Shearwater. p:1-54.

99. Rodríguez A, Rodríguez B & Lucas MP (2012) Trends in numbers of petrels attracted to artificial lights suggest population declines in Tenerife, Canary Islands. *Ibis* 154:167-172.

100. Syposz M, Goncalves F, Carty M, Hoppitt W & Manco F (2018) Factors influencing Manx Shearwater grounding on the west coast of Scotland. *Ibis* 160:846-854.

101. Rodrıguez A, García D, Rodríguez B, Cardona EP, L. & Pons P (2015) Artificial lights and seabirds: Is light pollution a threat for the threatened Balearic petrels? *Journal of Ornithology* 156:893-902.

102. Rodríguez A, Rodríguez B & Negro JJ (2015) GPS tracking for mapping seabird mortality induced by light pollution. *Scientific Reports* 5:10670.

103. Troy J, Holmes N, Veech J & Green M (2013) Using observed seabird fallout records to infer patterns of attraction to artificial light. *Endangered Species Research* 22:225-234.

104. Montevecchi WA (2006) Influences of Artificial Light on Marine Birds. In: *Ecological consequences of artificial night lighting*, Rich C & Longcore T, Editors. Island Press: Washington D.C. 480p.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 148 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

105. Podolsky R, Ainley D, Spencer G, Deforest L & Nur N (1998) Mortality of Newell's shearwaters caused by collisions with urban structures on Kauai. *Colonial Waterbirds* 21:20-34.

106. Bourne WRP (1979) Birds and gas flares. *Marine Pollution Bulletin* 10:124-125.

107. Burke CM, Davoren GK, Montevecchi WA & Wiese FK (2005) Seasonal and spatial trends of marine birds along offshore support vessel transects and at oil platforms on the Grand Banks. In: *Offshore oil and gas environmental effects monitoring: approaches and technologies*, Armsworthy SL, Cranford PJ & Lee K, Editors. Battelle Press: Columbus, Ohio. p:587–614

108. Ronconi RA, Allard KA & Taylor PD (2015) Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. *Journal of Environmental Management* 147:34-45.

109. Imber MJ (1975) Behaviour of petrels in relation to the moon and artificial lights. *Notornis* 22:302-306.

110. Cianchetti-Benedetti M, Becciu P, Massa B & Dell'Omo G (2018) Conflicts between touristic recreational activities and breeding shearwaters: short-term effect of artificial light and sound on chick weight. *European Journal of Wildlife Research* 64:19.

111. Mitkus M, Nevitt GA, Danielsen J & Kelber A (2016) Vision on the high seas: spatial resolution and optical sensitivity in two procellariform seabirds with different foraging strategies. *Journal of Experimental Biology* 219:3329-3338.

112. Le Corre M, Ollivier A, Ribes S & Jouventin P (2002) Light-induced mortality of petrels: a 4-year study from Réunion Island (Indian Ocean). *Biological Conservation* 105:93-102.

113. Reed JR, Sincock JL & Hailman JP (1985) Light attraction in endangered procellariform birds: Reduction by shielding upward radiation. *Auk* 102:377-383.

114. Serventy DL, Serventy VN & Warham J (1971) *The Handbook of Australian Sea-birds*. Sydney. 255p.

115. Watanuki Y (1986) Moonlight avoidance behavior in leach's storm-petrels as a defense against slaty-backed gulls. *The Auk* 103(1):14-22.

116. Telfer TC, Sincock JL, Byrd GV & Reed JR (1987) Attraction of Hawaiian seabirds to lights: Conservation efforts and effects of moon phase. *Wildlife Society Bulletin* 15:406-413.

117. Griesemer AM & Holmes ND (2011) *Newell's shearwater population modeling for Habitat Conservation Plan and Recovery Planning Technical Report No. 176. The Hawai`i-Pacific Islands Cooperative Ecosystem Studies Unit & Pacific Cooperative Studies Unit* University of Hawai`i: Honolulu, Hawai`i. 68.

118. Vorobyev M (2003) Coloured oil droplets enhance colour discrimination. *Proceedings Biological Sciences* 270:1255–1261.

119. Capuska GEM, Huynen L, Lambert D & Raubenheimer D (2011) UVS is rare in seabirds. *Vision research* 51(12):1333-1337.

120. Hart NS (2001) The visual ecology of avian photoreceptors. *Progress in Retinal and Eye Research* 20:675-703.

121. Bowmaker JK, Heath LA, Wilkie SE & Hunt DM (1997) Visual pigments and oil droplets from six classes of photoreceptor in the retinas of birds. *Vision Research* 37:2183-2194.

122. Cannell BL & Cullen JM (1998) The foraging behaviour of little penguins *Eudyptula minor* at different light levels. *Ibis* 140(3):467-471.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 149 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

123. Bowmaker JK & Martin GR (1985) Visual pigments and oil droplets in the penguin, *Spheniscus humboldti. Journal of Comparative Physiology A* 156(1):71-77.

124. Wiltschko W & Wiltschko R (1999) The effect of yellow and blue light on magnetic compass orientation in European robins, *Erithacus rubecula. Journal of Comparative Physiology A* 184:295-299.

125. Rodríguez A, Holmberg R, Dann P & Chiaradia A (2018) Penguin colony attendance under artificial lights for ecotourism*. JEZ-A Ecological and Intergrative Physiology* 329(8-9):457-464.

126. Henderson PA & Southwood TRE (2016) *Ecological Methods 4th Edition.* Wiley-Blackwell. 656p.

127. Surman CA & Nicholson LW (2014) *The Integrated Shearwater Monitoring Project (ISMP): Annual Report for the 2013/14 Season. Unpublished report prepared for Apache Energy Ltd.* Halfmoon Biosciences. 47p.

128. Commonwealth of Australia (2010) *Survey guidelines for Australia's threatened birds Guidelines for detecting birds listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999* Australian Government: Canberra, Australia. 278p.

129. Surman CA & Nicholson LW (2014) *Monitoring of annual variation in seabird breeding colonies throughout the Lowendal Group of islands: 2014 Annual Report. Lowendal Island Seabird Monitoring Program (LISMP).* Unpublished report prepared for Apache Energy Ltd. by Halfmoon Biosciences. 55p.

130. van de Kam J, Ens B, Piersma T & Zwarts L (2004) *Shorebirds: An illustrated behavioural ecology*. KNNV Publishers: Utrecht, the Netherlands. p. 368.

131. Colwell MA (2010) *Shorebird ecology, conservation, and management*. Berkeley, California: University of California Press. 344p.

132. Piersma T & Baker AJ (2000) Life history characteristics and the conservation of migratory shorebirds. In: *Behaviour and conservation*, Gosling LM & Sutherland WJ, Editors. Cambridge University Press: Cambridge, United Kingdom. p:105-124.

133. Cresswell W (1994) Flocking is an effective anti-predation strategy in redshanks, *Tringa tetanus. Animal Behaviour* 47(2):433-442.

134. Battley PF, Warnock N, Tibbitts TL, Gill RE, Piersma T, Hassell CJ, Douglas DC, Mulcahy DM, Gartrell BD, Schuckard R, Melville DS & Riegen AC (2012) Contrasting extreme long-distance migration patterns in bar-tailed godwits *Limosa lapponica. Journal of Avain Biology* 43(1):21-32.

135. Menkhorst P, Rogers D, Clarke R, Davies J, Marsack P & K. F (2017) *The Australian bird guide*. Clayton South, Victoria: CSIRO Publishing. 576p.

136. Commonwealth of Australia (2017) *EPBC Act Policy Statement 3.21—Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* Australian Government: Canberra, Australia. 24p.

137. Bamford M, Watkins D, Bancroft W, Tischler G & J. W (2008) *Migratory Shorebirds of the East Asian-Australasian Flyway; Population Estimates and Internationally Important Sites: Wetlands International - Oceania*: Canberra, Australia. 249p.

138. Commonwealth of Australia (2015) *Wildlife Conservation Plan for Migratory Shorebirds*. Australian Government: Canberra, Australia. 32p.

139. McLaren JD, Buler JJ, Schreckengost T, Smolinsky JA, Boone M, van Loon E, Dawson DK & Walters EL (2018) Artificial light at night confounds broad-scale habitat use by migrating birds. *Ecology Letters* 21(3):356-364.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 150 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

140. Rogers DI, Battley PF, Piersma T, Van Gils JA & Rogers KG (2006) High-tide habitat choice: Insights from modelling roost selection by shorebirds around a tropical bay. *Animal Behaviour* 72(3):563-575.

141. Dwyer RG, Bearhop S, Campbell HA & Bryant DM (2013) Shedding light on light: benefits of anthropogenic illumination to a nocturnally foraging shorebird. *Journal of Animal Ecology* 82:478-485.

142. Santiago-Quesada F, Estrella SM, Sanchez-Guzman JM & Masero JA (2014) Why water birds forage at night: A test using black-tailed godwits *Limosa limosa* during migratory periods. *Journal of Avian Biology* 45(4):406-409.

143. Lourenço PM, Silva A, Santos CD, Miranda AC, Granadeiro JP & Palmeirim JM (2008) The energetic importance of night foraging for waders wintering in a temperate estuary. *Acta Oecologica* 34:122-139.

144. Dias MP, Granadeiro JP, Lecoq M, Santos CD & Palmeirim JM (2006) Distance to high-tide roosts constrains the use of foraging areas by dunlins: Implications for the management of estuarine wetlands. *Biological Conservation* 131:446-452.

145. Rogers DI, Piersma T & Hassell CJ (2006) Roost availability may constrain shorebird distribution: Exploring the energetic costs of roosting and disturbance around a tropical bay. *Biological Conservation* 133(2):225-235.

146. Conklin JR & Colwell MA (2007) Diurnal and nocturnal roost site fidelity of Dunlin (*Calidris alpina pacifica*) at Humboldt Bay, California. *The Auk* 124(2):677-689.

147. McNeil R, Drapeau P & Pierotti R (1993) Nocturnality in Colonial Waterbirds: Occurrence, Special Adaptations, and Suspected Benefits. In: *Current Ornithology*, Power DM, Editor. Springer US: Boston, MA. p:187-246.

148. Rojas LM, McNeil R, Cabana T & Lachapelle P (1999) Diurnal and nocturnal visual capabilities in shorebirds as a function of their feeding strategies. *Brain Behavior and Evolution* 53(1):29-43.

149. Verheijen FJ (1985) Photopollution - artificial light optic spatial control systems fail to cope with incidents, causations, remedies. *Experimental Biology* 44(1):1-18.

150. Poot H, Ens B, Vries H, Donners MAH, Wernand MR & Marquenie JM (2008) Green light for nocturnally migrating birds. *Ecology and Society* 13(2):47.

151. Gauthreaux SA & Belser CG (2006) Effects of artificial night lighting on migrating birds. In: *Ecological Consequences of Artificial Night Lighting*, Rich C & Longcore T, Editors. Island Press: Washington, D.C., USA. p:67-93.

152. Depledge MH, Godard-Codding CAJ & Bowen RE (2010) Light pollution in the sea. *Marine Pollution Bulletin* 60(9):1383-1385.

153. Santos CD, Miranda AC, Granadeiro JP, Lourenço PM, Saraiva S & Palmeirim JM (2010) Effects of artificial illumination on the nocturnal foraging of waders. *Acta Oecologica* 36:166-172.

154. Longcore T, Rich C, Mineau P, MacDonald B, Bert DG, Sullivan LM, Mutrie E, Gauthreaux SA, Avery ML, Crawford RL, Manville AM, Travis ER & Drake D (2013) Avian mortality at communication towers in the United States and Canada: Which species, how many, and where? *Biological Conservation* 158:410-419.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 151 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix D: Reduction of Obtrusive Light

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 152 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

ILP INSTITUTION OF LIGHTING PROFESSIONALS

GUIDANCE NOTE 01/21

THE REDUCTION OF OBTRUSIVE LIGHT

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 153 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Guidance Note

GN01/21

The Reduction of Obtrusive Light

Copyright © 2021 ILP

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic tape, mechanical, photocopying, recording or otherwise, without permission in writing from the Institution of Lighting Professionals.

Institution of Lighting Professionals
Regent House
Regent Place
Rugby
Warwickshire
CV21 2PN

Tel: (01788) 576492
Email: info@theilp.org.uk
Website: www.theilp.org.uk
Registered Charity Number 268547

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 154 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

The Reduction of Obtrusive Light

This Guidance Note supersedes GN01/20 to reflect the changes in international guidance regarding obtrusive light as detailed in *CIE 150: 2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations*[1]. It also considers industry comment regarding the assessment and definition of obtrusive lighting.

Good lighting practice is the provision of the right light, at the right time, in the right place, controlled by the right system.

The invention of artificial light and its application in the external environment has done much to safeguard and enhance our night-time environment but, if not properly controlled, **obtrusive light** (sometimes referred to as light pollution) can present serious physiological and ecological problems.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 155 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Obtrusive light, whether it keeps you awake through a bedroom window, impedes your view of the night sky or adversely affects the performance of an adjacent lighting installation, is a form of pollution. It may also be a nuisance in law and can be substantially mitigated without detriment to the requirements of the task.

Sky glow, the brightening of the night sky, **Glare** the uncomfortable brightness of a light source when viewed against a darker background, **Light spill** the spilling of light beyond the boundary of the area being lit and **Light intrusion ('Nuisance')**[2] are all forms of obtrusive light which may cause nuisance to others, or adversely affect fauna & flora as well as waste money and energy.

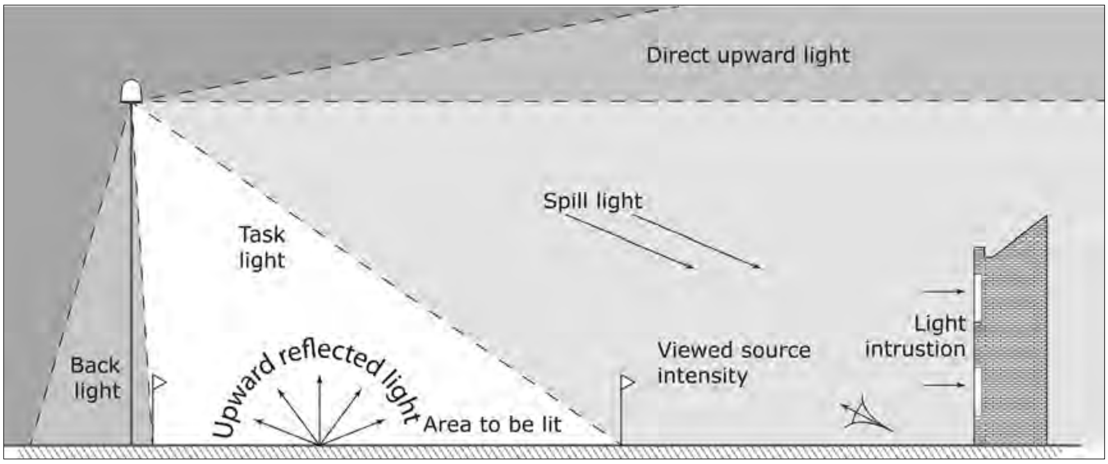


Figure 1: Types of obtrusive light

[1] The copyright of the data detailed within this guide belongs to CIE, email ciecb@cie.co.at
This document should be used in conjunction with CIE 150:2017 and CIE 126:1997 and not as a replacement for the procedures contained therein. These documents can be obtained from http://cie.co.at/publications and members of a National Committee of the CIE can purchase them with a discount of 66.7 %.

[2] The term light trespass has been used in the past and should no longer be referenced, trespass is to physically encroach on land and light can't do that, so the term nuisance or spill light should always be used.

Considerations to be made

Think before you light. Is it necessary? What effect could it have on others? Has it the potential to cause a nuisance? How can you mitigate and manage and potential adverse effects from your lighting installation?

There are published standards and guidance for most lighting tasks adherence to these will help mitigate obtrusive lighting aspects. Organisations from which full details of these standards can be obtained are given later in this Guidance Note.

For the purpose of this Guidance Note, the following two Commission Internationale De L'Eclairage (CIE) documents are specifically referenced, which provide guidance to the mitigation of obtrusive light from exterior lighting installations:

- CIE 150: 2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations
- CIE 126: 1997 Guidelines for Minimizing Sky Glow

When considering any lighting installation then these two documents should be referenced and referred to.

Whilst this guidance Note examines the effects of external lighting installations, other factors should also be considered. Office buildings, residences and shop fronts, with extensive use of glass without blinds, screens or curtains, could become a source of illumination to the exterior environment.

"Good Design Equals Good Lighting"

It cannot be stressed sufficiently that, by employing a competent lighting designer with proven experience in the relevant application, will result in a suitable lighting installation where all obtrusive lighting aspects are mitigated[3].

Any lighting scheme consists of three basic elements: a light source, a luminaire (incorporating the optical control system) and a method of installation / mounting.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 156 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

[3] Competency can be determined through membership of a professional lighting body supported by the appropriate qualifications and experience in the application of lighting required.

Light sources (Lamps / LEDs)

The light source output in lumens is not the same as the wattage. It is the former that is important in combating the problems of obtrusive light.

Most night-time visual tasks are only dependent on light radiated within the visual spectrum. It is therefore not necessary for light sources to emit either ultra-violet or infra-red radiation unless specifically designed to do so. The majority of light sources used in external lighting do not contain these wavelengths or where they are present their spectral power is very low.

Research indicates that light from the blue end of the spectrum could have important adverse effects on fauna and flora. The lighting designer should consider the blue light spectral power of the light source and try to balance the needs of the task to be lit with any impact on fauna and flora within the environment.

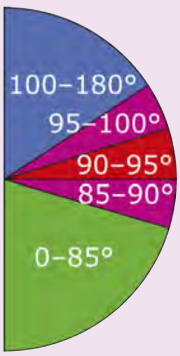
Luminaires

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 157 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

The choice of luminaire with the right optical distribution at the right mounting height is critical to minimising light spill and obtrusive light effects, yet providing the right lighting performance on the task area.

Sky glow is the general diffused sheen that is visible in the direction of large cities, airports, and industrial complexes. It occurs from both natural and artificial light sources and does not depend exclusively on the lighting design. It also depends on the atmospheric conditions (humidity, aerosols, clouds, haze, atmospheric pollution, etc.). Light propagating into the atmosphere either directly from upward directed or incompletely shielded sources, or after reflection from the ground or other surfaces, is partially scattered back towards observers on the ground; the impact being shown in table 1.

Table 1: The effect on the ability to view the night sky at various angles



Indicative diagram

Angle of light emitted (degrees)	Sky glow effect	Glare effect
100 - 180	Local	Little
95 - 100	Significant	Some
90 - 95	High	High
85 - 90	Significant	High
0 - 85	Minimum	Some

It is therefore important to consider the luminaire, its light distribution, how it is installed and how it is set up.

For most general sports and area lighting installations the use of luminaires with asymmetric optics is preferred. This type of optic should be designed and installed so that the front glazing is kept at or near horizontal; parallel to the surface to be lit or ground. if correctly designed, installed and aimed correctly should ensure minimising obtrusive light.

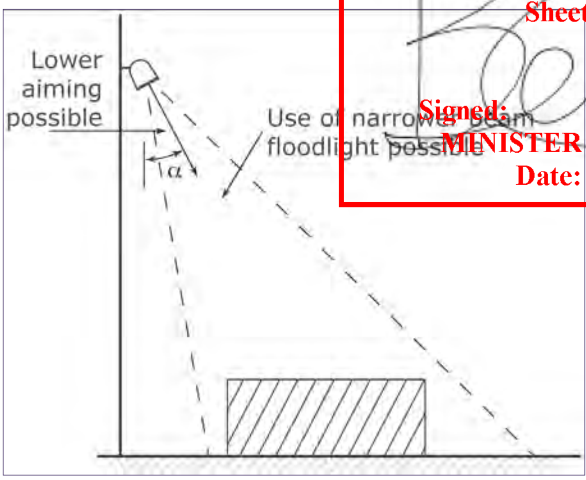
Appendices 1 and 2 give more details of how to choose, and if necessary, through the use of louvres and shields, modify luminaires.

Installation

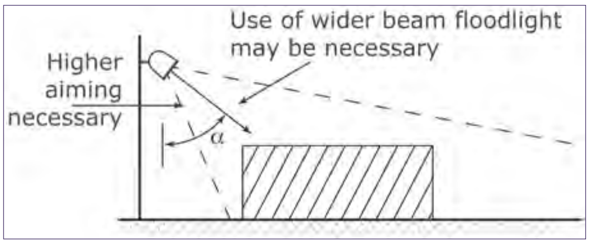
In most cases it will be beneficial to use as high a mounting height as possible, giving due regard to the daytime appearance of the installation.

It should be noted that a lower mounting height can be worse as can be seen from figures 2 and 3 from CIE 150. A lower mounting height can create a higher level of light spill and require additional lighting points.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 158 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023



✔ *Figure 2a: Higher mounting height – less spill light and glare*



✖ *Figure 2b: Lower mounting height – more spill light and glare*

Keep glare to a minimum by ensuring that the main beam angle of all luminaires directed towards any potential observer is no greater than 70°. Higher mounting heights allow lower main beam angles, which can assist in reducing glare.

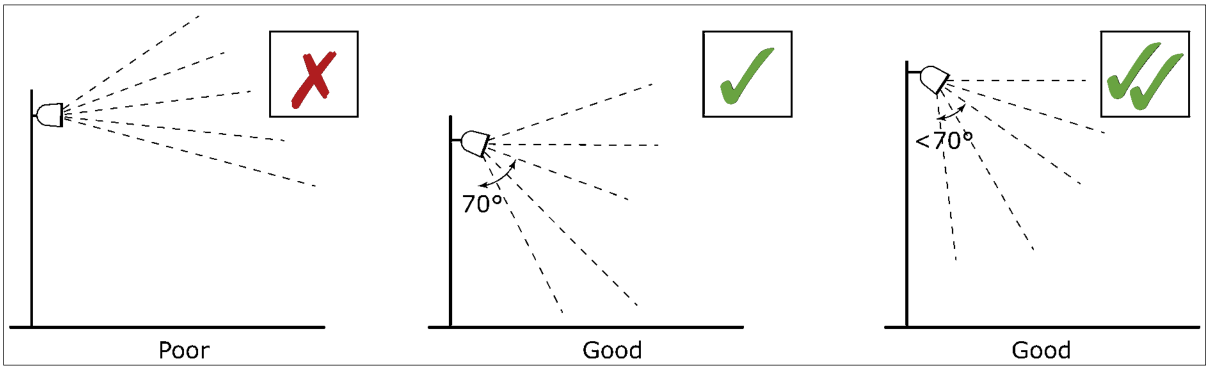


Figure 3: Luminaire aiming angles

In areas with low ambient lighting levels, glare can be very obtrusive and extra care should be taken when positioning and aiming lighting equipment. With regard to domestic security lighting, the ILP produces an information leaflet GN09:2019 “Domestic exterior lighting, getting it right!” that is freely available from its website.

When lighting vertical structures such as advertising signs, direct light downwards wherever possible. If there is no alternative to up-lighting, as with much decorative lighting of buildings, then the use of luminaires with the correct optical distribution coupled where required with shields, baffles and louvres will help reduce spill light around and over the structure to a minimum.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 159 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Figure 4: Façade illumination

For road and amenity lighting installations light near to and above the horizontal should normally be minimised to reduce glare and sky glow (Note the Upward Lighting Ratios (ULR’s) advised in Tables 5 and 6). In rural areas the use of full horizontal cut off luminaires installed at 0° uplift will, in addition to reducing skyglow, also help to minimise visual intrusion within the open landscape. However, in some urban locations, luminaires fitted with a more decorative bowl and good optical control of light should be acceptable and may be more appropriate.

Clean Neighbourhoods and Environment Act (CNEA) 2005

The Clean Neighbourhoods and Environment Act (CNEA) 2005 gives Local Authorities and the Environment Agency additional powers to deal with a wide range of issues by classifying artificial light emitted from defined premises as a statutory nuisance.

The CNEA 2005 amended section 79(1) of the Environmental Protection Act 1990 to extend the statutory nuisance regime to include light nuisance stating the following:

> *'(fb) artificial light emitted from premises so as to be prejudicial to health or a nuisance'.*

Guidance produced on Sections 101 to 103 of the CNEA 2005 by DEFRA (DEFRA, April 2006) extends the duty on local authorities to ensure their areas are checked periodically for existing and potential sources of statutory nuisances, including nuisances arising from artificial lighting. Local authorities must take reasonable steps to investigate complaints of such nuisances from artificial light. Once satisfied that a statutory nuisance exists or may occur or recur, local authorities must issue an abatement notice (in accordance with section 80(2) of the Environmental Protection Act 1990), requiring that the nuisance cease or be abated within a set timescale.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 160 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

National Planning Policy Framework (NPPF)

The NPPF was introduced as a more concise and useable planning document to aid developers and designers in the design and construction of developments within the UK.

The National Planning Policy Framework 2019 makes little reference to lighting with regard to the control of obtrusive light, the only reference states:

> *c) limit the impact of light pollution from artificial light on local amenity, intrinsically dark landscapes and nature conservation.*

Many Local Planning Authorities (LPAs) have already produced, or are producing, policies that within the planning system will become part of their local development framework. For new developments there is an opportunity for LPAs to impose planning conditions related to external lighting, including curfew* hours.

* Curfew: The time after which stricter requirements (for the control of obtrusive light) will apply; often a condition of use of lighting applied the local planning department. Depending upon application curfew times often commence between 21:00 to 23:00 and may run until 07:00. However, exact curfew hours should be carefully applied to ensure the reduction of obtrusive light is prioritised within the immediate environment and towards sensitive human as well as fauna and flora receptors.

National Planning Policy

The national on-line planning guidance resource looks at when lighting pollution concerns should be considered;

The guidance provides a high level overview for planners with links to a few appropriate documents to give planners an overview of the subject through seven discussion points as follows:

- When is light pollution relevant to planning
- What factors should be considered when assessing whether a development proposal might have implications for light pollution
- What factors are relevant when considering where light shines
- What factors are relevant when considering when light shines
- What factors are relevant when considering how much the light shines
- What factors are relevant when considering possible ecological impact
- What other information is available that could inform approaches to lighting and help reduce light pollution

Artificial light requires consideration at the planning stage. To ensure that any proposed lighting installation conforms to the requirements of an area and its intended task, planners should consult with a competent lighting professional. The appropriate planning conditions for the project can then be established, the application reviewed, and the final performance of the installation confirmed.

The Scottish Executive has published a design methodology document (March 2007) entitled *"Controlling Light Pollution and Reducing Energy Consumption",* to further assist in mitigating obtrusive light elements at the design stage.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 161 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Environmental Zones

It is recommended that Local Planning Authorities specify the following environmental zones for exterior lighting control within their Development Plans.

Table 2: Environmental zones

Zone	Surrounding	Lighting environment	Examples
E0	Protected	Dark (SQM 20.5+)	Astronomical Observable dark skies, UNESCO starlight reserves, IDA dark sky places
E1	Natural	Dark (SQM 20 to 20.5)	Relatively uninhabited rural areas, National Parks, Areas of Outstanding Natural Beauty, IDA buffer zones etc.
E2	Rural	Low district brightness (SQM ~15 to 20)	Sparsely inhabited rural areas, village or relatively dark outer suburban locations
E3	Suburban	Medium district brightness	Well inhabited rural and urban settlements, small town centres of suburban locations
E4	Urban	High district brightness	Town / City centres with high levels of night-time activity

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 162 of 187
Signed for
MINISTER FOR PLANNING
Date: 9 May 2023

Note 1 Where an area to be lit lies close to the boundary of two zones the obtrusive light limitation values used should be those applicable to the most rigorous zone (see comment below)

Note 2 Rural zones under protected designations should use a higher standard of policy

Note 3 Zone E0 must always be surrounded by an E1 Zone

Note 4 Zoning should be agreed with the local planning authority. Due to local requirements a more stringent zone classification may be applied to protect special / specific areas

Note 5 SQM (Sky Quality Meter) is referenced by the International Dark Skies Association (IDA). SQM is an instrument used to measure the luminance of the night sky. It is typically used by astronomers to quantify skyglow, using units of magnitudes per square arcsecond. the scale is between 16:00 (a bright night sky) and 22:00 (the least light pollution). The criteria for zone E0 was revised in mid 2019, with the new requirements not being made retrospective

Note 6 Astronomical Observable Dark Skies will offer clearer views of the Milky Way and of other objects such as the Andromeda Galaxy and the Orion Nebula

Note 7 Although values of SQM 20 to 20.5 may not offer clear views of astronomical dark sky objects such as the Milky Way, these skies will have their own relative intrinsic value in the UK

Adjacent Zone Considerations

As advised in Note 1 to Table 2, where an area to be lit lies within visual distance of the boundary between two zones then the obtrusive light values applicable to the most rigorous zone shall apply. Figure 5 demonstrates this. For an observer located within or at the boundary of a more rigorous zone (E(X-1)) compared to the adjacent less rigorous zone (E(X)) then when the observer faces the less rigorous zone they will only be exposed to obtrusive lighting level pertinent to the zone within which they are located.

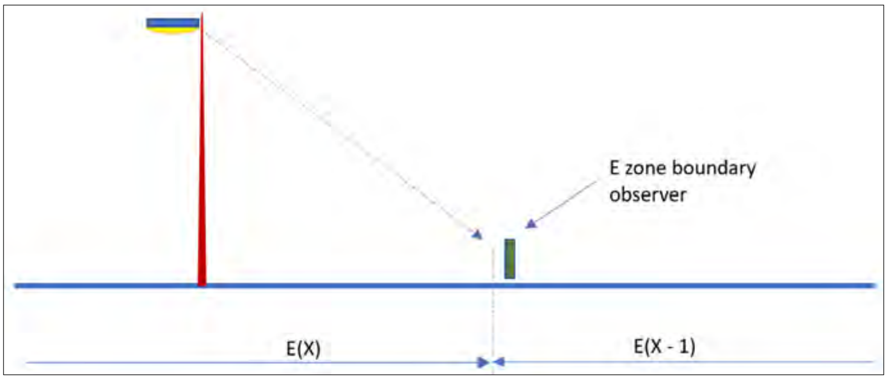


Figure 5: boundary zone considerations

Design Guidance

The following limitations based upon CIE150 may be supplemented or replaced by an LPA's own planning guidance for exterior lighting installations. As lighting design is not as simple as it may seem, you are advised to consult and/or work with a competent professional lighting designer when considering any exterior lighting.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 163 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Recommended Maximum Values of Light Parameters for the Control of Obtrusive Light

Limitation of illumination on surrounding premises

Light intrusion / nuisance

Table 3 (CIE 150 table 2): Maximum values of vertical illuminance on premises

Light technical parameter	Application conditions	Environmental zone				
		E0	E1	E2	E3	E4
Illuminance in the vertical plane (E_v)	Pre-curfew	n/a	2 lx	5 lx	10 lx	25 lx
	Post-curfew	n/a	<0.1 lx*	1 lx	2 lx	5 lx

* If the installation is for public (road) lighting then this may be up to 1 lx.

Limits apply to nearby dwellings / premises or potential dwellings / premises and specifically windows. The values are the summation of all lighting installations.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO: PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 164 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Spill light

Table 3 can also be considered for the management of spill light; however, designers must consider the task performance requirements of any adjacent lit areas and ensure that any spill light does not adversely affect these performance parameters as this could affect their safe use. This may result in a need to minimise spill and intrusive lighting values to less than might be expected for the environmental zone within which the installation lies.

Limitation of bright luminaires in the field of view

The limits for the luminous intensity of bright luminaires are dependent on the viewing distance *d*, (between the observer and the bright luminaire(s)) and the projected area A_p, of the bright part of the luminaire in the direction of the observer.

Table 4 shows the maximum values for the luminous intensity of luminaires in designated directions where views of bright surfaces of luminaires are likely to be a nuisance to occupants of premises, or from positions where such views are likely to be maintained, i.e. not for momentary or short-term viewing.

Table 4 (CIE 150 table 3): Limits for the luminous intensity of bright luminaires[4]

Light technical parameter	Application conditions	Luminaire group (projected area A_p in m²)					
		$0<A_p \leq 0.002$	$0.002<A_p \leq 0.01$	$0.01<A_p \leq 0.03$	$0.03<A_p \leq 0.13$	$0.13<A_p \leq 0.50$	$A_p > 0.5$
Maximum luminous intensity emitted by luminaire (*I* in cd)[5]	E0 Pre-curfew Post-curfew	0 0	0 0	0 0	0 0	0 0	0 0
	E1 Pre-curfew Post-curfew	0.29 *d* 0	0.63 *d* 0	1.3 *d* 0	2.5 *d* 0	5.1 *d* 0	2,500 0
	E2 Pre-curfew Post-curfew	0.57 *d* 0.29 *d*	1.3 *d* 0.63 *d*	2.5 *d* 1.3 *d*	5.0 *d* 2.5 *d*	10 *d* 5.1 *d*	7,500 500
	E3 Pre-curfew Post-curfew	0.86 *d* 0.29 *d*	1.9 *d* 0.63 *d*	3.8 *d* 1.3 *d*	7.5 *d* 2.5 *d*	15 *d* 5.1 *d*	10.000 1,000
	E4 Pre-curfew Post-curfew	1.4 *d* 0.29 *d*	3.1 *d* 0.63 *d*	6.3 *d* 1.3 *d*	13 *d* 2.5 *d*	26 *d* 5.1 *d*	25,000 2,500

Note 1 *d* is the distance between the observer and the glare source in metres;

Note 2 A luminous intensity of 0 cd can only be realised by a luminaire with a complete cut-off in the designated directions;

Note 3 A_p is the apparent surface of the light source seen from the observer position

Note 4 For further information refer to Annex C of CIE 150

Note 5 Upper limits for each zone shall be taken as those with column A_p>0.5

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 165 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Considerations to aid the application of Table 4 and the assessment process.

- The assessment of A_p for observers can prove difficult and will vary for all observer positions and distances.
- The above information is applicable for the consideration of a single luminaire, but where two or more luminaires are located in close proximity to each other that to the observer they appear as a single light source, then the assessment shall be undertaken based upon the combined bright surfaces of luminaires (A_p) in the direction of the observer or, from positions where such views are likely to be maintained.
- In installations that involve lighting poles, towers or columns, the luminaires will often be viewed against the night sky. The contrast between the background sky and the bright surface areas of the luminaires can be considerable. In such installations the curfew levels

[4] Amended based upon the approach taken by NSVV Nederlandse Stichting Voor Verlichtingskunde (Dutch: Dutch Foundation for Illumination; The Netherlands) and to consider CIE150 Annex C Table C.2

set for each environmental zone shall be applied, with the exception that such installations within an E4 zone will be designed to suit the curfew requirements of an E3 zone.

Appendix 3 provides a supplementary guidance to aid the application and use of Table 4.

Limitation of the effects on transport systems

Limits apply where users of road networks are subject to a reduction in the ability to see essential information. CIE 150 2017; Table 4 gives values that are for relevant positions and for viewing directions in the path of travel.

This assessment does not just apply to road lighting installations, but to any installation where luminaires' positioning falls under the above definition i.e. luminaires visible from the road network.

For non-road lighting installations where Threshold Increment (TI) cannot be established look to GN01 Table 4 source intensity limitations.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 166 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 5 (CIE 150; table 4): Maximum values of Threshold Increment and viewing direction in the path of travel

Light technical parameter	Road classification[1]			
	No road lighting	M6 / M5	M4 / M3	M2 / M1
Veiling luminance[2] (L_v)	0.037 cd/m^2	0.23 cd/m^2	0.40 cd/m^2	0.84 cd/m^2
Threshold Increment	15% based on adaption luminance of 0.1 cd/m^2	15% based on adaption luminance of 1.0 cd/m^2	15% based on adaption luminance of 2.0 cd/m^2	15% based on adaption luminance of 5 cd/m^2

Note 1 Road classifications as given in CIE 115:2010

Note 2 The veiling luminance values specified in this table are based upon on a permissible TI value of 15%

Definitions:

TI The measure of disability glare expressed as the percentage increase in contrast required between an object and its background for it to be seen equally well with a source of glare present. Note: Higher values of TI correspond to greater disability glare, the reduction in visibility caused by intense light sources in the field of view.

L_v The luminance that would need to be superimposed on a scene in object space to reduce the scene's contrast by an amount equal to the added retinal illuminance from scattered light on the scene's retinal image. It is most commonly used to describe the contrast-reducing effect of a glare source in the field of view.

Limitation of skyglow

Table 6 (CIE 150 table 5): Maximum values of upward light ratio (ULR) of luminaires

Light technical parameter	Environmental zones				
	E0	E1	E2	E3	E4
Upward light ratio (ULR) / %	0	0	2.5	5	15

Note 1 This is the primary approach to limit skyglow and is suitable to compare different single luminaires and mitigate the contribution of each luminaire within an installation.

Note 2 This does not take into account the effect of light reflected upwards from ground that also contributes to skyglow.

Note 3 Some lighting schemes will require the deliberate and careful use of upward light, e.g. ground recessed luminaires, ground mounted floodlights and festive lighting, to which these limits cannot apply. However, care should always be taken to minimise any upward waste light by the proper application of suitably directional luminaires and light controlling attachments.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 167 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 7 (CIE 150 table 6): Maximum values of upward flux ratio of installation (of four or more luminaires)

Light technical parameter	Type of installation	Environmental zones				
		E0	E1	E2	E3	E4
Upward flux ratio (UFR) / %	Road	n/a	2	5	8	12
	Amenity	n/a	n/a	6	12	35
	Sports	n/a	n/a	2	6	15

Table 7 allows the effect of both direct and reflected upward components of a whole installation to be considered. The factor being the upward flux ratio (UFR).

Note n/a within table 7 denotes that lighting of this type is not usually expected within these zones

This should only be considered where an installation consists of four or more luminaires that form an installation with a defined performance requirement or specialised fauna growth lighting systems (such as those use to promote grass growth in sports stadia) and is in proximity to:

- Optical observatories
- Lies within dark (E1) zones which abuts a protected (E0) dark sky zone

Note 1 The effect of distance must be considered which is a factor of the artificial lighting installation size. A small lighting installation will have an effect on an optical observatory 30km away whereas a large lighting installation of many luminaires will have an effect from a greater distance up to 100km. Specific guidance is given in CIE126 and CIE150.

Note 2 All external surfaces will have varying reflectances depending upon their condition and climatic conditions (wet, dry, frost etc,) as well as their varying angles, therefore the level of uncertainty in any assessment may be considerable.

Clauses 6.4.2 and 6.4.3 of CIE 150: 2017 describe the calculation methods for both ULR and UFR.

As discussed in Table 1, light emitted just above the horizontal in a zone between 80° and 110° is extra critical for skyglow in large open areas around observatories. An additional measure in these areas limits the luminous intensities (I_{80} – I_{110}) as follows:

- Between 80° and 90°   < 2.0 cd/ 1000lm
- Between 90° and 100°   < 0.5 cd/1000lm
- Between 100° and 110°   0 cd (0.5% of total luminaire lumens for bollard luminaires)

Note All proposed luminaires must have been photometrically measured so that results can be verified for Gamma angles 0 to 180°.

Limitations of the effect of over-lit building facades and signs

Table 8 provides recommendations regarding luminance values that provide visibility in order that a balanced urban lighting master plan can be considered. This lighting does not cause negative impacts such as a continuous increase in the lighting levels (or ratcheting) between buildings and within areas creating light pollution.

Illuminated advertising signage should be assessed as advised in the Institutions Professional Lighting Guide 05 (PLG05); The Brightness of Illuminated Advertisements.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 168 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Table 8 (CIE 150 table 7): Maximum permitted values of average surface luminance

Light technical parameter	Application conditions	Environmental zones				
		E0	E1	E2	E3	E4
Building façade luminance (L_b)	Taken as the product of the design average illuminance and reflectance divided by π	< 0.1 cd/m^2	< 0.1 cd/m^2	5 cd/m^2	10 cd/m^2	25 cd/m^2
Sign luminance (L_s)	Taken as the product of the design average illuminance and reflectance divided by π (pi), or for self-luminous signs, its average luminance	< 0.1 cd/m^2	50 cd/m^2	400 cd/m^2	800 cd/m^2	1.000 cd/m^2

Note The values apply to both pre- and post-curfew, except that in Zones 0 and 1 the values shall be zero post-curfew. The values for signs do not apply to signs for traffic control purposes.

For illuminated advertising signs the aim should be to achieve the limits advised in PLG05.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 169 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Relevant Publications and Standards

British Standards

BS 5489-1:2020 Code of practice for the design of road lighting – Part 1 Lighting of roads and public amenity areas

BS EN 13201-2:2015 Road lighting; Part 2: Performance requirements

BS EN 13201-3:2015 Road lighting; Part 3: Calculation of performance

BS EN 13201-4:2015 Road lighting; Part 4: Methods of measuring lighting performance

BS EN 12193:2018 Light and lighting; Sports lighting

BS EN 12464-2:2014 Lighting of work places; Outdoor work places

PD CEN TR 13201-1:2014 Road lighting; Guidelines on selection of lighting classes

BS EN 12464-2:2014 Light and lighting; Lighting of work places; Part 2 Outdoor work places

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 170 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

CIE publications

001 Guidelines for minimizing urban skyglow near astronomical observatories

CIE 094-1993 Guide for flood lighting

CIE 112-1994 Glare evaluation system for use within outdoor sport and area lighting

CIE 115:2010 Lighting of roads for motor and pedestrian traffic

CIE 126:1997 Guidelines for Minimising Sky Glow

CIE 129:1998 Guide for lighting exterior working areas

CIE 136:2000 Guide to the lighting of urban areas

CIE 150:2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations

CIE 169:2005 Practical design guidelines for the lighting of sport events for colour

ILP publications

PLG 04 Guidance on undertaking environmental lighting impact assessments

PLG 05 The brightness of illuminated advertisements

PLG 06 Guidance on seasonal decorations and lighting column attachments

GN 09 Domestic Security Lighting: Getting it right!

SLL / CIBSE Publications

LG 01: The industrial environment (2018)

LG 04: Sports lighting

LG 06/16: The exterior environment

LGLOL Guide to limiting obtrusive light

NB: These notes are intended as guidance only. The application of the values given in the various tables should be given due consideration along with all other factors in the lighting design. Lighting is a complex subject with both objective and subjective criteria to be considered. The notes are therefore no substitute for professionally assessed and designed lighting undertaken and assessed by a competent lighting professional, where the various and maybe conflicting visual requirements need to be balanced.

© 2021 **The Institution of Lighting Professionals.** Permission is granted to reproduce and distribute this document, subject to the restriction that the *complete* document must be copied, without alteration, addition or deletion.

Acknowledgements

Allan Howard	*WSP (Chair)*
Peter Raynham	*UCL*
Dan Oakley	*South Downs National Park*
Appendix 2 images	*acdc*
Cover image	*Allan Howard*

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 171 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

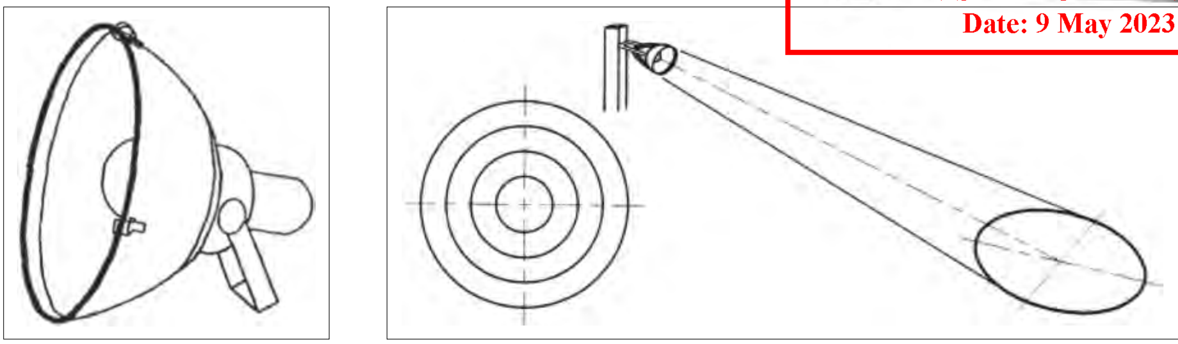
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 172 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

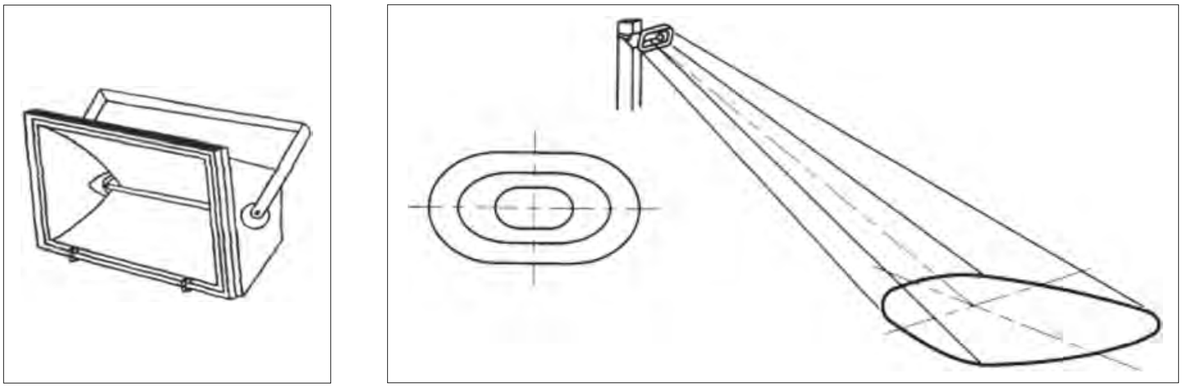
Appendix 1

Outdoor luminaire classification system

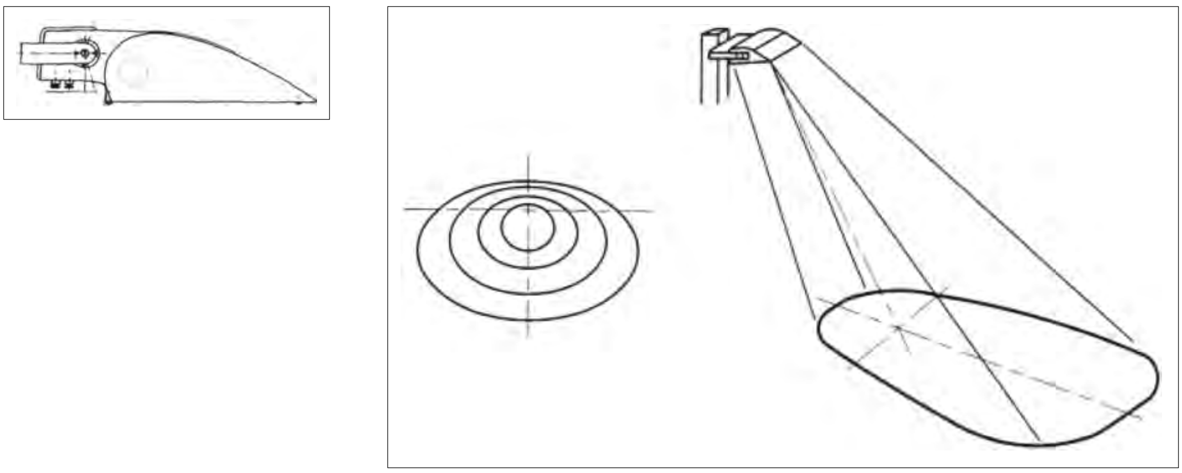
Based upon CIE 150:2017 and for the purpose of this and associated documents the following figures illustrate the luminaire classification (CIE 150:2017).



Type A flood light / projector producing a symmetrical beam



Type B flood light / projector producing a fan-shaped beam



Type C flood light / projector producing a double asymmetric distribution in the vertical plane

Appendix 2

Illustrations of luminaire accessories for limiting obtrusive light

Luminaire with cowl, hood & shield

With louvre

With cowl

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 173 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix 3

Supplementary guidance

Limits for the luminous intensity of bright luminaires

The ILP's Guidance notes for the reduction of obtrusive light 2011 and CIE 150:2003 only advised of a single limiting luminaire intensity based upon an environmental zone and pre / post curfew assessment. This approach did not take into consideration the fact that intensity is a factor of illuminance at the observer multiplied by the square of the distance to the source. As we know, the illuminance received is a factor of the inverse square law, as well as the size of the source.

GN01/20 superseded by GN01/21, as well as CIE150:2017 now take this into consideration, but with few exceptions lighting design software has yet to catch up with the requirements.

The assessment of intensity as advised within Table 4 has been developed to assist the competent professional lighting designer in making the considerations necessary. At this time, and until software is available to assist the designer, they must make their best professional judgement and undertake some manual assessments, calculations and reviews, based upon software that is currently available to determine compliance or otherwise with intensity limits and values.

This should be considered as follows:

1. Observer position (d)

The closest observer position will be the most onerous, so for any given installation determine where the most realistic closest maintained observer position will be. This is where the luminous intensity will be greatest, and should therefore set the limiting assessment value.

2. Determine the luminaire group (projected area A_p)

As can be seen in Image 1, whilst all the luminaires are of the same size, their apparent projected area A_p is different for each one from a single observer position.

Image 1: Change in projected area based upon observer position

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 174 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

In general, for the same observer distance (d) a luminaire with a smaller A_p will cause the greater concern regarding luminous intensity.

Where the designer knows the expected A_p of the installed luminaire, then this figure can be used to determine the luminaire group in Table 4. Where this factor is unknown then the bottom three rows of table 4 (amended below) are provided as an aid to gauging A_p and are based upon CIE150:2017 Annex C. This approach groups ranges of luminaires by diameter, extracts a geometric mean diameter for each group and provides a corresponding A_p for application (if your luminaire is square then you will need to do a calculation based upon area), so this can be used to assign the luminaire group. Whilst this is for circular luminaires the designer will need to make their best professional judgement for all shapes of luminaires and the expected A_p towards each observer.

Table 4 (CIE150 Table 3 (amended)), limits for the luminous intensity of bright luminaires[5]

Light technical parameter	Application conditions	Luminaire group (projected area A_p in m²)					
		0<A_p ≤0.002	0.002<A_p ≤0.01	0.01<A_p ≤0.03	0.03<A_p ≤0.13	0.13<A_p ≤0.50	A_p > 0.5
Maximum luminous intensity emitted by luminaire (*I* in cd)[5]	E0 Pre-curfew Post-curfew	0 0	0 0	0 0	0 0	0 0	0 0
	E1 Pre-curfew Post-curfew	0.29 *d* 0	0.63 *d* 0	1.3 *d* 0	2.5 *d* 0	5.1 *d* 0	2,500 0
	E2 Pre-curfew Post-curfew	0.57 *d* 0.29 *d*	1.3 *d* 0.63 *d*	2.5 *d* 1.3 *d*	5.0 *d* 2.5 *d*	10 *d* 5.1 *d*	7,500 500
	E3 Pre-curfew Post-curfew	0.86 *d* 0.29 *d*	1.9 *d* 0.63 *d*	3.8 *d* 1.3 *d*	7.5 *d* 2.5 *d*	15 *d* 5.1 *d*	10.000 1,000
	E4 Pre-curfew Post-curfew	1.4 *d* 0.29 *d*	3.1 *d* 0.63 *d*	6.3 *d* 1.3 *d*	13 *d* 2.5 *d*	26 *d* 5.1 *d*	25,000 2,500
Aid to gauging A_p Luminaire diameter		**2 to 5 cm**	**5 to 10 cm**	**10 to 20 cm**	**30 to 40 cm**	**40 to 80 cm**	**>80 cm**
Geometric mean of diameter (cm)		3.2	7.1	14.1	26.3	56.6	>80
Corresponding A_p representative area (m²)		0.0008	0.004	0.016	0.063	0.251	>0.5

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 175 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Note 6 *d* is the distance between the observer and the glare source in metres

Note 7 A luminous intensity of 0 cd can only be realised by a luminaire with a complete cut-off in the designated directions

[5] Amended based upon the approach taken by NSVV Nederlandse Stichting Voor Verlichtingskunde (Dutch: Dutch Foundation for Illumination; The Netherlands) and to consider CIE150 Annex C Table C.2

Note 8 A_p is the apparent surface of the light source seen from the observer position

Note 9 For further information refer to Annex C of CIE 150

Note 10 Upper limits for each zone shall be taken as those with column A_p>0.5

To aid this assessment, values of A_p corresponding to the geometric mean diameter of each circular luminaire group have been extracted from CIE150 Annex C and included within Table 3. These areas can be considered for an assessment of likely A_p in the observer direction to calculate a maximum luminous intensity value.

3. Determining the maximum luminous intensity emitted

This is just a matter of looking down the luminaire group and to the appropriate environmental zone, and determining the calculation required for pre and post curfew levels. This will advise the designer / assessor of the maximum permitted luminous intensity for that observer position and luminaire. Existing software can then be used based upon observer position and the value of intensity advised by the programme manually compared to the limited value determined from Table 4.

The additional notes b) multiple luminaires and c) luminaires viewed against the night sky within GN01/20 for the consideration of the limitation of bright luminaires in the field of view should also be considered.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 176 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Example:

1. 15 cm luminaire

We are working in an E2 zone, the luminaire has a diameter of 15cm and the realistic expected maintained nearest observer position is 100m away.

Based upon Table 4, this advises that the geometric mean of diameter is 14.1cm, and the corresponding representative A_p is 0.016. This places it within the luminaire group $0.01 < A_p \leq 0.03\ m^2$ grouping. Reading down this column to E2, the pre-curfew maximum luminous intensity calculation is 2.5d where d from our case is 100m.

The limiting intensity to the identified observer is therefore 2.5 x 100 = 250 cd

2 44 cm luminaire

We are working in an E3 zone, the luminaire has a diameter of 44 cm and the realistic expected maintained nearest observer is 80m away.

Based upon Table 4, this advises that the geometric mean of diameter is 56.6cm, and the corresponding representative A_p is 0.251. This places it within the luminaire group $0.13 < A_p \leq 0.50\ m^2$ grouping. Reading down this column to E3, the pre-curfew maximum luminous intensity calculation is 15d where d from our case is 80m.

The limiting intensity to the identified observer is therefore 15 x 80 = 1,200 cd

Assessment

In both cases these are the values the competent lighting designer needs to use within the assessment calculations. If the lighting design software is CIE150:2017 compliant it will do this, however this may require the designer to make manual assessments between intensity values advised through existing software, and the limitation required for each observer, and adjust their design until it is compliant.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 177 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Appendix E: Industrial Waste Resource Guidelines

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 178 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

INDUSTRIAL WASTE RESOURCE GUIDELINES

WASTE CATEGORISATION

CONTENTS

INTRODUCTION

This document provides an overview of waste types and hazard categorisation for both solid industrial waste and soils.

Specific categorisation requirements for soil and solid industrial waste can be found in the Industrial Waste Resource Guidelines (IWRG):

- *Soil hazard categorisation and management*
- *Solid industrial waste hazard categorisation and management*.

As set out in the *Environment Protection Act 1970* (the Act), all wastes should be managed in accordance with the waste hierarchy, which states the following order of preference:

- avoidance
- reuse
- recycling
- recovery of energy
- treatment
- containment
- disposal.

The wastes hierarchy is one of eleven principles of environment protection contained in the Act.* The principles provide a framework for EPA's decision-making and are intended to benefit the Victorian environment and community. In making decisions, EPA takes all of the principles into account and applies them in an integrated manner.

* The other environmental protection principles are: the principle of integration of economic, social and environmental considerations; the precautionary principle; the principle of intergenerational equity; the principle of conservation of biological diversity and ecological integrity; the principle of improved valuation, pricing and incentive mechanisms; the principle of shared responsibility; the principle of product stewardship; the principle of integrated environmental management; the principle of enforcement; and the principle of accountability.

WHAT THIS MEANS FOR YOU

All prescribed industrial wastes (PIWs) require contaminant analysis to determine the appropriate hazard category prior to being accepted at landfills.

Landfill operators may require a copy of the analytical results to demonstrate that the material meets the relevant criteria set out in their licence.

From 1 July 2009, the Regulations allow for solid industrial waste, that has contaminant levels below those specified, to be categorised and managed as Industrial Waste. Refer to Table 3 in IWRG *Solid industrial waste hazard categorisation and management*.

HOW THE CATEGORISATION SYSTEM WORKS

Once it has been determined that there is no available opportunity for a waste stream to be avoided, reduced, reused, recycled, treated or reprocessed, it must be appropriately characterised prior to disposal.

The final outcome of a characterisation study will be an understanding of the contaminants, their concentrations and leachability for the entire waste stream. The waste must be assessed for all chemical substances known and/or reasonably expected to be present in the waste.

Once each of the potential contaminants have been identified, a set of samples should be taken and sent for analysis. For more information on sampling of solid industrial waste, please refer to the IWRG Waste Sampling for Solid Industrial Waste or IWRG Soil Sampling Guidelines for contaminated soils.

These samples must be submitted to an analytical laboratory accredited by the National Association of Testing Authorities (NATA) to undertake the analyses. It is recommended that a total concentration screen be completed first to confirm the presence of certain contaminants. Once this is known, leachability testing may be required.

These results can then be used to determine the hazard category based on the upper limits for each category of waste. The industrial waste threshold values can be found in the IWRG for both soil and solid waste under:

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 179 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

This guidance forms part of the Industrial Waste Resource Guidelines, which offer guidance for wastes and resources regulated under the *Environment Protection (Industrial Waste Resource) Regulations 2009*.
Publication IWRG600.2 – December 2010. This replaces publication IWRG600.1, published September 2010.

- *Soil hazard categorisation and management*
- *Solid industrial waste hazard categorisation and management*.

These guidelines also provide greater detail on how to determine the category of the waste and what management options are available for each category.

WASTE TYPES

Wastes can be included into one of four types (Table 1 provides a summary) to determine EPA requirements for off-site disposal and to choose an appropriate management option. If doubt exists as to which waste type applies, seek advice from EPA.

Fill material

This waste type consists of soil (being clay, silt and/or sand), gravel and rock of naturally occurring materials. Fill material, often referred to as 'clean fill' by industry, may be suitable for site filling or levelling depending on an assessment of contaminant levels and intended use†. Local councils may have requirements and advice should be sought from them.

An assessment of soil, including site history‡, will determine whether the material has been potentially contaminated as a result of industrial, commercial, construction or agricultural activities, or contaminated with manufactured chemicals; and/or where material has been placed as fill or has been mechanically disturbed.

Soil may be classified as fill, when:

- an assessment (as discussed above) will demonstrate that the material is not contaminated

or

- contaminant levels are below those specified in IWRG *Soil hazard categorisation and management*

or

- any elevated level of metals (such as arsenic) or other constituents can be demonstrated to be of natural origin. Where it can be demonstrated that the constituents of concern are naturally elevated, EPA does not consider these soils to be 'contaminated' and therefore can be classified as fill material.

EPA does not regulate the use of fill material. However, the *Environment Protection Act 1970* places general obligations to prevent adverse impacts on the environment and human health. Where there is potential for adverse impacts from the deposit of fill material, advice should be sought from EPA. EPA may require information such as the origin of the soil, site history, sampling and analytical results of contaminants or other constituents, the nature of the elevated contaminants and the location of sites where the soil is to be reused.

Solid inert waste

Solid inert waste is hard waste that has a negligible activity or effect on the environment. The waste may be either a municipal or industrial waste.

Industrial waste

Industrial waste is defined under Section 4(1) of the *Environment Protection Act 1970* as:

a) any waste arising from commercial, industrial, or trade activities or from laboratories

or

b) any waste containing substances or materials which are potentially harmful to human beings or equipment.

Industrial waste includes waste arising from all commercial, industrial, building and demolition activities, including:

- manufacturing activities
- wholesale/retail trade
- commercial services including those provided to households (e.g. gardening, skip/bin hire etc)
- accommodation, cafes, restaurants
- building/demolition waste from building construction, renovations or repairs, and road construction and maintenance
- waste from primary industries including agricultural, forestry and fishing.

Reuse and recycling options should be investigated for this type of waste, as in many cases industrial waste, such as building materials, can be reused or recycled. Proponents should seek advice from EPA if in doubt about the appropriateness of the reuse and recycling options.

Putrescible waste

Putrescible waste is 'waste able to be decomposed by bacterial action'. It may be suitable for composting or recycled for stockfeed (which includes food wastes from residential, industrial or commercial sources, such as restaurants, food markets, supermarkets, and butchers).

Problems associated with putrescible waste landfills or reprocessing facilities (e.g. composting facilities) often include vermin, seagulls, dust, odour, flies and other insects, fires, litter, as well as surface and groundwater contamination by leachate. Accordingly, the design and operating requirements for facilities accepting putrescible waste are generally more stringent than for sites accepting solid inert waste only.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 180 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

† The Victorian Department of Primary Industries can provide advice on organochlorine pesticide thresholds in soil for cattle grazing.

‡ Australian Standard 4482.1, published by Standards Australia, provides information on conducting preliminary site investigations.

EPA VICTORIA

The source of the waste determines whether it is putrescible waste of municipal or industrial origin.

Prescribed industrial waste

PIWs have the potential to adversely impact human health and the environment. They may either be from a manufacturing source or be contaminated soils.

The only prescribed waste of domestic origin is grease interceptor trap waste arising from domestic premises. All others are of industrial origin, or arise from trade or commercial activity.

Solid prescribed industrial wastes must be categorised by hazard before disposal. Guidance, for waste generators and treaters, in determining the hazard category (A, B or C) of their solid prescribed industrial wastes can be found in IWRG *Solid industrial waste hazard categorisation and management* or IWRG *Soil hazard categorisation and management*.

All PIWs must be transported in accordance with the *Environment Protection (Industrial Waste Resource) Regulations 2009*.

Table 1: Summary of waste types

Category	Description	Management option	EPA requirements for off-site disposal
Fill material	Soil where: • the site assessment demonstrates the soil is not contaminated or • contamination concentrations do not exceed those specified in IWRG Soil – Hazard Categorisation and Management or • any elevated levels of metals or other constituents can be demonstrated to be of natural origin	Use as fill material, e.g. site filling/levelling.	No licence required. However, reuse must not give rise to environmental or health impacts.
Solid inert waste from an industrial source	Waste arising from all commercial, industrial, building and demolition activities. Contaminant concentrations do not exceed those specified in IWRG *Solid Industrial waste hazard categorisation and management* Building/demolition material, e.g. concrete, bricks, dry timber, plastic, glass, metals, bitumen; and shredded tyres.	– Reuse – Recycling – Landfill	– Non-municipal landfills must be licensed. – When disposing to municipal landfill serving >5000 persons site must be licensed.[4]
Putrescible waste from an industrial source	Wastes from commercial or industrial sources, e.g. vegetable processing, butchers and domestic garbage.	– Composting – Stockfood[5] – Recovery of energy – Landfill	– Non-municipal landfills must be licensed. – When disposing to municipal landfill serving >5000 persons site must be licensed.1
Prescribed industrial waste	Has the potential to adversely impact human health and the environment. Manufacturing sources or contaminated soils.	Various treatment and disposal methods depending on waste type and hazard category.	– No disposal of Category A waste to landfill. – Disposal of hazard category B or C waste to a licensed site.1 – EPA transport certificates must be used. – Vehicles must hold EPA permit (unless exemption issued).

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME
PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 181 of 187
Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

4 Facilities must be licensed to receive the specific waste type, and for prescribed industrial waste, the specific hazard category.
5 The Victorian Department of Primary Industries can provide advice on the suitability of commercial waste as stockfeed.

Other waste types

There are certain other waste types which warrant mention here.

Municipal waste is defined under the *Environment Protection Act 1970* as 'any waste arising from municipal or residential activities, and includes waste collected by, or on behalf of, a municipal council, but does not include any industrial waste'.

Therefore municipal waste is associated with the day-to-day activities of households and the maintenance of a clean municipality, and includes:

- garbage and domestic household waste
- residential kerbside collections
- residential hard waste collections
- residential self-haul waste
- residential garden waste
- municipal litter collections
- municipal street sweepings
- park waste.

Waste asbestos: the transport and disposal of asbestos wastes needs to be carried out under strictly controlled conditions. EPA has produced a separate guideline, IWRG *Asbestos transport and disposal* regarding these wastes.

Mining and extractive industry wastes include a range of wastes (overburden, rock, tailings) with varying contamination levels. Sites used for the deposit of waste, not in accordance with the Extractive Industries Development Act or Mineral Resources Development Act, require a licence. Tailings, sand or waste rock deposits resulting from the extraction and processing of gold-bearing ore containing arsenic must be managed in accordance with the Notifiable Chemical Order for arsenic and arsenic compounds. IWRG *Arsenic in mine tailings, sand and rock*, provides further information.

Scheduled wastes are wastes that are difficult to safely dispose of without special technologies and facilities. Australian governments have agreed to implement a national approach for the management of scheduled wastes. Examples of these are polychlorinated biphenyls (PCBs), organochlorine pesticides and hexachlorobenzene. There are some facilities available for these wastes and further information is available. Contact EPA for further advice.

Acid sulfate soils includes any soil, sediment, unconsolidated geological material or disturbed consolidated rock mass containing metal sulfides exceeding criteria published in EPA publication 655, *Acid sulfate soil and rock*. If managed inappropriately, waste acid sulfate soils may oxidise to produce acid which poses a risk to human health and the environment.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 182 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

EPA VICTORIA

Appendix F: Construction Waste and Fire Water Storage Area Locations

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 183 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

Latrobe Valley BESS Project
Indicative Constuction Waste and Water Storage Areas

Legend

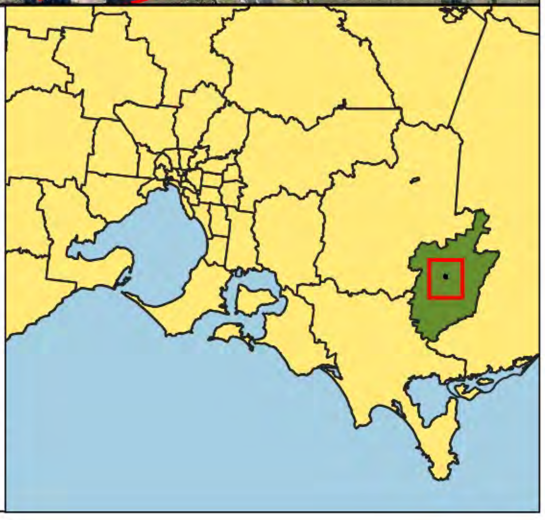
- Construciton Setdown and Waste Storage Area
- Fire Water Runoff and Detention Basin
- 15000L Water Tank
- Stock Exclusion Fencing
- Construction Footprint

0 50 100 m

N

Job No.: G013
Date: 15/02/2023
Drawn By: Tim Gamble
Coordinate System: GDA 1994 MGA Zone 55

DATA SOURCES: Vicmap Data 2023, Nearmap 2023, Acacia Environmental 2023. Acacia Environmental Management does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Acacia Environmental Management is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

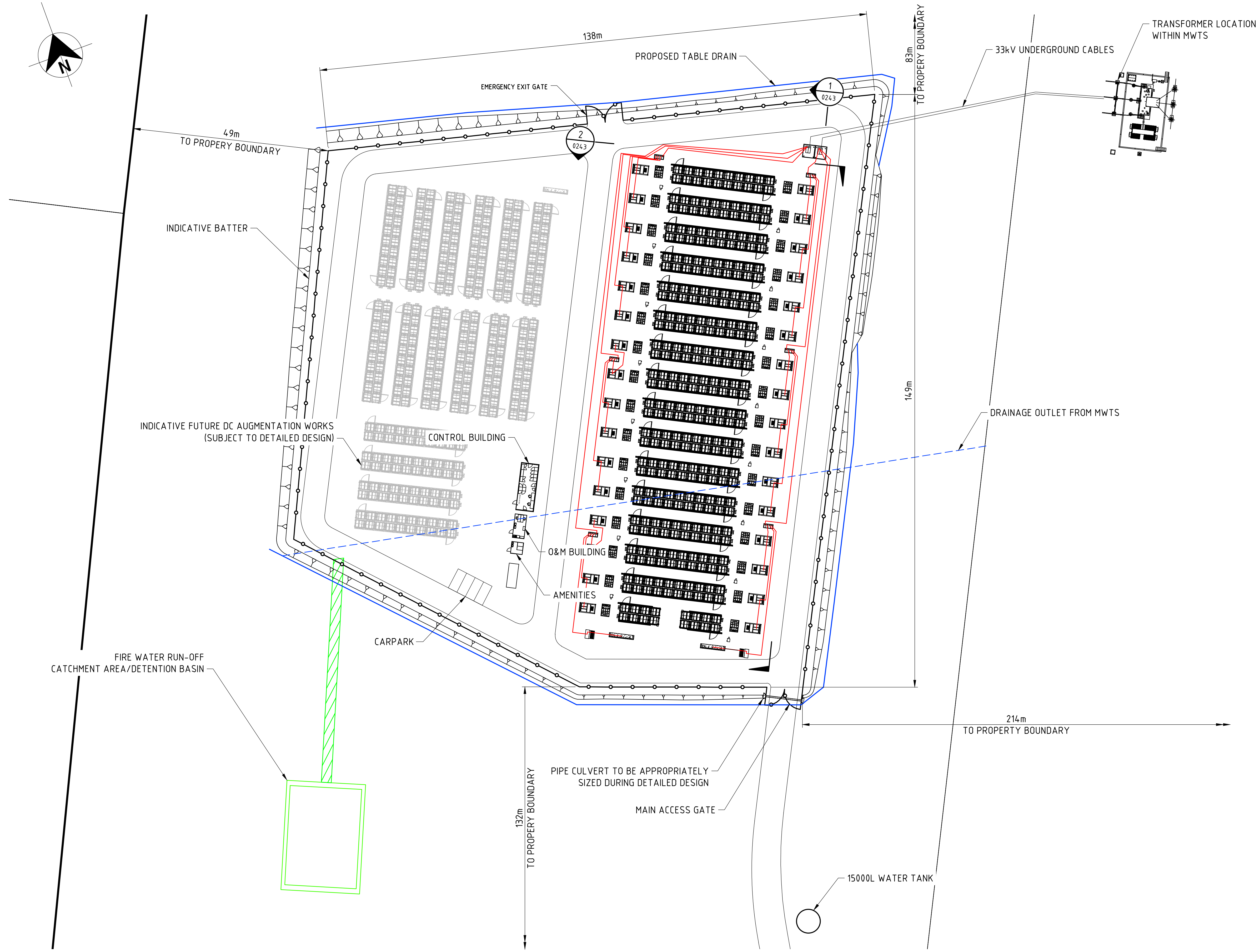


Appendix G: Latrobe Valley BESS Project Overall Site Electrical Layout

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 185 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023



NOTES:

1. THIS DRAWING IS INDICATIVE ONLY AND IS NOT FOR CONSTRUCTION. DIMENSIONS, RATINGS AND ALL INFRASTRUCTURE SHOWN IS SUBJECT TO DETAILED DESIGN AND EQUIPMENT SELECTION.
2. BATTERY ENERGY STORAGE SYSTEM INFRASTRUCTURE INCLUDING BATTERIES, MV TRANSFORMERS, INVERTERS, MV SWITCHGEAR AND CONTROL BUILDING ARE INDICATIVE ONLY, ACTUAL SIZE AND FOUNDATIONS ARE DIFFERENT AND ARE TO BE CONFIRMED.
3. DIMENSIONS ARE APPROXIMATE ONLY.
4. THE LAND RESERVED FOR THE PROJECT AUGMENTATION (STAGE 1B) WILL BE USED AS A TEMPORARY LAYDOWN AREA AND CONSTRUCTION COMPOUND FOR THE CONSTRUCTION OF STAGE 1A.
5. THE PROVISION OF FOUR CAR PARKING SPACES ADEQUATELY MEETS THE NEEDS OF THE OPERATIONAL PHASE OF THE PROJECT IN ACCORDANCE WITH CLAUSE 52.06 OF THE LATROBE PLANNING SCHEME.
6. THE COLOURS AND MATERIALS WILL BE NON-REFLECTIVE, AND MATCHED WHERE POSSIBLE TO COLOURS PRESENT WITHIN THE SURROUNDING LANDSCAPE.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 186 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

SCALE 1:1000 (10 0 10 20 30 40 50m)

No	DESCRIPTION	DES	DRN	CHK	APP	DATE
D	CONCEPT ONLY	MB	MB	JH	KA	10/01/2023
C	CONCEPT ONLY	JH	MB	BR	KA	03/01/2023
B	CONCEPT ONLY	JH	MB	BR	KA	20/12/2022
A	CONCEPT ONLY	MW	MB	BR	KA	15/12/2022

REVISION HISTORY

FLUENCE — A Siemens and AES Company

Zenviron

SIZE	A3
SCALE	1:1000
STATUS	CONCEPT ONLY — NOT FOR CONSTRUCTION
PROJECT	LATROBE VALLEY BESS
TITLE	PROJECT OVERALL SITE ELECTRICAL LAYOUT
DRAWING No.	8135-DWG-0242
REV	D

COPYRIGHT © ZENVIRON PTY. LTD. ANY UNAUTHORISED USE, DUPLICATION, DISTRIBUTION, LICENSING OR ALTERATION IS STRICTLY PROHIBITED.

PLANNING and ENVIRONMENT ACT
LATROBE PLANNING SCHEME

PERMIT NO. PA2101132-2
Conditions 7 & 9
ENDORSED PLAN
Sheet 187 of 187

Signed: for
MINISTER FOR PLANNING
Date: 9 May 2023

NOTES:

1. THIS DRAWING IS FOR PLANNING PURPOSES ONLY AND IS NOT FOR CONSTRUCTION. FINAL ARRANGEMENT AND DETAILS SUBJECT TO DETAIL DESIGN.
2. ALL SET-OUT DIMENSIONS ARE APPROXIMATE ONLY. ACCURATE SET-OUT DIMENSIONS TO BE CONFIRMED BY SURVEYORS.

16 12 8 4 0 20 40 60 80 100m
SCALE 1:1000

REFERENCE DRAWINGS		REVISION					
			12/10/22	A	ISSUED FOR PLANNING	DKB	AURECON
DRAWING TITLE	DRAWING No.		DATE	REV	DESCRIPTION	BY	CONTRACTOR

AusNet services

MORWELL TERMINAL STATION (MWTS)
LATROBE VALLEY BESS PROJECT
SITE PLAN

DRAWN
ENDORSED REV A
ENDORSED DATE
ISSUED
Spec No. Order No.
Contractors No.
AusNet services No
522063-0000-DRG-JJ-0001 A

FOR PLANNING

AusNet Services STD A1
561 X 801 A1

This drawing and any information or descriptive matter set out hereon are the confidential and copyright property of AusNet Services and must not be disclosed, loaned, copied or used for manufacturing, tendering or for any other purpose without written permission © 2014

AutoCAD [A1]