16. TURTLES AND LIGHTING

This chapter summarises the findings of the marine ecology (turtles) technical study written by Pendoley Environmental Pty Ltd (Appendix 9) for the Arrow LNG Plant SREIS.

The technical study was undertaken to further investigate the impacts of project lighting (and flaring) on the behaviour of marine turtles and to validate the mitigation measures proposed in the Arrow LNG Plant EIS (Coffey Environments, 2012).

Further information relating to other aspects of marine and estuarine ecology can be found in Chapter 15, Marine Ecology and Chapter 17, Estuarine Ecology (Calliope River) of this SREIS.

16.1 Studies and Assessments Completed for the EIS

Coffey Environments carried out the marine and estuarine ecology impact assessment for the EIS. The technical report is attached to the EIS as Appendix 12.

The Arrow LNG Plant will be located within the Great Barrier Reef World Heritage Area and adjacent to the Great Barrier Reef Marine Park. The marine park extends around the Port of Gladstone, which encompasses Port Curtis and part of The Narrows, the narrow waterway between Curtis Island and the mainland.

Port Curtis is included in the list of nationally important wetlands in Queensland, and areas in and around Port Curtis provide important habitat for a range of species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) and the IUCN red list of threatened species (IUCN, 2010).

The marine and estuarine ecology impact assessment found that marine turtles listed as vulnerable or endangered under the EPBC Act are present in the waters of Port Curtis and along the east coast of Curtis Island, Facing Island and the mainland south of Port Curtis.

A range of physical environments and habitat types within Port Curtis provide and support a diverse biodiversity, including several turtle species. These include seagrass beds, known to be important feeding grounds for some species of turtles. Seagrass beds of Port Curtis are protected under the *Queensland Fisheries Act 1994*.

Port Curtis and its surrounding waters support a large marine fauna population, including six of the seven known species of marine turtles in the world. The three marine turtle species most commonly found in and known to nest on beaches adjacent to the project area are:

- Flatback turtle (*Natator depressus*): EPBC Act–listed as ‘Vulnerable’.
- Green turtle (*Chelonia mydas*): EPBC Act–listed as ‘Vulnerable’.
- Loggerhead turtle (*Caretta caretta*): EPBC Act–listed as ‘Endangered’.

The study assessed the impact of the project on these marine turtle species, in addition to other marine and estuarine species and habitats, and proposed mitigation measures to reduce the identified impacts.

Potential impacts of the project to marine turtles include:

- Loss and disturbance of marine and estuarine habitat, in particular to seagrass beds, from project infrastructure.

- Injury or mortality from shipping activity or accidents, including boat strike.
- Displacement or mortality from the effects of underwater noise and lighting.

Impacts relating to the loss and disturbance to marine habitats and vessel activity and underwater noise on marine fauna and flora were assessed in the EIS (Chapter 19, Marine and Estuarine Ecology) and are further discussed in Chapter 15, Marine Ecology.

Lighting at the LNG plant and associated marine facilities on Curtis Island (principally the LNG jetty and materials offloading facility (MOF)) and particularly lighting from the flare were identified as potential impacts on marine turtles for which further investigation was required. The aim of further studies was to verify the adequacy of management measures proposed in the EIS to reduce the impacts of lighting on turtles.

Arrow Energy made a number of commitments in the EIS to implement measures aimed at managing light sources and reducing the impacts of light from the LNG plant and ancillary facilities. These commitments include:

- Shield/direct the light source onto work areas where practical. (C17.16)
- Use long-wavelength lights, where practical, including use of red, orange or yellow lights. (C17.17)
- Lower the height of the light sources as far as practical. (C17.18)
- Avoid routine planned maintenance flaring at night during sensitive turtle-reproductive periods (where practical). (C17.19)
- Develop a construction management plan that contains specific mitigation measures, performance indicators and management action required to reduce impacts to the marine and estuarine ecological values. (C19.01)

16.2 Study Purpose

Pendoley Environmental Pty Ltd (Pendoley) was commissioned to complete a technical study on marine turtles to further assess the impact of project lighting on turtles that nest on the islands of Port Curtis, to address changes in the project description, and to validate the management measures proposed in the EIS. Pendoley was selected due to their previous experience with similar projects in both Western Australia and in Port Curtis.

16.2.1 Study Objectives

As part of the study, a number of specific questions have been addressed, and they are detailed below:

- Are marine turtle species found in Port Curtis and along the east coast of Curtis Island likely to be affected by project lighting?
- What background lighting conditions exist at the turtle nesting sites north of Southend and at the northern end of Facing Island, i.e., prior to any project development?
- What specific intensity (luminosity) and wavelength or spectrum of light are the nominated marine turtle species most sensitive to? Do the light sources at the LNG plant fit within the spectrum, wavelength and intensity of light to which the nominated marine turtle species are susceptible?

- Will marine turtles utilising beaches north of Southend and on Facing Island have line of sight to the flare?
- Will marine turtles utilising beaches north of Southend and on Facing Island have line of sight to the glow created by LNG plant lighting?
- What specific behaviour – breeding, nesting or hatching – is affected by light?
- What time of year is the most sensitive for the species that nest on the east coast of Curtis Island and Facing Island?
- What are the potential risks to marine turtles if flaring occurs during the sensitive periods for the nominated species, e.g., during hatching?
- Are the management measures expressed as commitments adequate to address potential impacts on marine turtles?
- Is additional mitigation required to address potential impacts on marine turtles?
- How effective are the mitigation and management measures likely to be; specifically, will the proposed flaring strategy reduce impacts on the nominated marine turtle species?
- Will there be any residual impacts to turtles following adoption of the mitigation and management measures; and if so, how significant will they be?

16.2.2 Project Description Changes

Project description changes relevant to the marine ecology (turtles) technical study are described below. Additional information supporting these changes is contained in Chapter 4, Project Description: LNG Plant.

The main changes to the project as described in the EIS relevant to the study are changes to both the location and operation of the flare on the LNG plant site. No changes have been made to the design of the LNG plant that would significantly change other (non-flare) light emitted from the site.

The flare stack has moved from the north (in the EIS) to the south of the LNG trains. The original design has been revised with the 110-m stack now increased to 115 m. However, the overall height of the flare has not changed as the bench relative level on which the flare will sit has been lowered.

The operational flare (as described in the EIS) has been discontinued. Scheduled routine maintenance of the LNG plant will generally be conducted when the plant is operational and without the need for flaring.

Unscheduled plant upsets could result in a requirement to flare. During operations, up to 20 plant upsets are anticipated each year, of which four upsets are assumed to require flaring for up to two hours.

Once every six years, each individual LNG train will be taken out of service for a shutdown. Intermittent flaring will occur over approximately a two-day period in preparation for a shutdown. Intermittent flaring will also occur again for approximately three days during start up. Consequently, when all four LNG trains are in operation flaring will occur for approximately five days every year and a half. Scheduled shutdowns (where possible) will be planned during the southern hemisphere winter months to align with the period of lowest global demand for LNG.

16.3 Desktop Study

Pendoley conducted a comprehensive desktop study of available data and information relevant to the study objectives. The method and findings of the desktop study are described below.

16.3.1 Desktop Study Method

The desktop study looked at available information worldwide on the impacts and effects of industrial and other coastal lighting on the behaviour of marine turtles. The study drew on both published literature and Pendoley's experience in working on the impacts of artificial lighting on turtles in Australia.

The desktop study focused on marine turtle sensitivity to light, including sensitivity to different wavelengths, intensity, and directivity, and on the impacts of light on both hatchling and adult marine turtle behaviour. The study focused particularly on sea-finding behaviour of hatchlings and nesting-beach selection of adult females.

There are no previous scientific studies available on the behaviour of marine turtle hatchlings on Curtis and Facing islands in relation to light from existing sources. The significance of the existing night sky illumination and its impact on marine turtle hatchlings were therefore assessed using known behaviours observed elsewhere and specialist knowledge and expertise in marine turtle response to light.

The design of the LNG plant flare is still in progress and thus Pendoley based their study on an emissions light spectra from what is considered to be a typical LNG plant flare (in this case, for an LNG plant in Western Australia). The Arrow Energy LNG plant's flare is expected to have a higher methane content than the Western Australian example. As such, it will burn cleaner and will be characterised by shorter wavelength light (in the UV region of the spectrum) compared to the longer wavelength enrichment of the Western Australia flare (in the infra-red region of the spectrum).

16.3.2 Desktop Study Findings

The desktop study found that project lighting would mostly impact marine turtles by modifying their natural behaviour, particularly the behaviour of nesting females and newly hatched turtles. As these behaviours are distinctly seasonal, it was possible to define specific 'sensitive periods' during a year when marine turtles were more susceptible to the impacts of project lighting.

Adult turtles are thought to use a range of cues when navigating the ocean, as well as in sea-finding. The cues include a magnetic compass, windborne odours, visual landmarks, chemical cues, and celestial or solar navigation. While light is considered to be one of the cues used for sea-finding in adult turtles, it does not appear to be important in ocean navigation outside the breeding season.

Adult Nesting Behaviour

Studies have indicated that artificial lighting may disrupt the normal nesting behaviour in female marine turtles (Salmon et al., 1995; Salmon, 2005), and beaches with high levels of light exposure can typically support lower densities of nests. Studies in Florida found the green and loggerhead turtles tended to nest significantly less near beach exposed to mercury vapour (high pressure sodium) light and in higher numbers in darker sections of beach (Witherington, 1992). Similar experiments conducted with low pressure sodium lighting found that nesting turtles did not show the same beach aversion. Insufficient data is available to indicate whether exposure to lighting is the primary cause for nesting beach selection.

Pendoley suggests that, while well-lit beaches may deter young first time (novice) nesting females from selecting that beach for nesting, the older and more experienced nesting females will continue to return to a beach they had selected as a first time nester, despite an increase in lighting. This is thought to explain why marine turtles continue to nest along developed coastlines around the world. This same trend can be seen in Port Curtis, where industry has been present for over 30 years and yet turtles still nest on nearby beaches.

Beach fidelity in green turtles, as seen in studies by Limpus et al. (2006), does not equate to all nesting turtles returning to the exact beach from which they hatched. Instead, they are found to return to the same rookery area. Pendoley has observed similar behaviour in flatback turtles. Thus, nesting females with site fidelity to Curtis Island or Facing Island may return to a variety of beaches considered in the 'mainland and mainland islands' region that incorporates Fraser Island, Agnes Waters, Wreck Rock, Rules Beach, Moore Park and Woongarra Coast (Norman et al., 1994a, 1994b). Pendoley suggests that it is possible that novice nesting females may choose to avoid nesting on well-lit beaches near Port Curtis, preferring instead to find darker beaches within the area. The newly selected site may not be as suitable for nesting, although the impacts of this behaviour on turtles have not been assessed in this region.

Hatchling Behaviour

Normal hatchling behaviour is to emerge from the nest and crawl toward the sea. Ideally, this process should occur as quickly and efficiently as possible, as newly hatched turtles are at risk of predation, dehydration, exhaustion, energy depletion and exposure to the elements (particularly if they hatch during the day). Once it has reached the ocean, a hatchling must still have enough energy to swim away from the shallow water where predation is still a high risk.

This process of crawling in the correct direction toward the ocean is called sea-finding. The natural sea-finding instinct is maintained by hatchlings regardless of such environmental factors as time of day, weather conditions and location of the nest. Thus, it has been found that sea-finding in hatchling marine turtles relies on several environmental cues. In addition to visual cues, these include:

- Light intensity.
- Light wavelength.
- Light directivity.
- Horizon elevation.
- Beach and dune environment (silhouettes).

Marine turtle hatchlings are more attracted to high-intensity light than to low-intensity light. This is seen when hatchlings are found to crawl toward bright bands of lighting and away from dimmer bands. Horizon elevation is also a factor, seen when hatchlings distinguish and move away from high, dark silhouettes, i.e., moving away from tall, vegetated dunes (silhouettes) toward the lower lighter horizon of the ocean.

Pendoley suggests that short-wavelength light (450 to 550 nm) is more attractive to hatchlings and that long-wavelength (600 to 700 nm) light is relatively less attractive. High-intensity, *long*-wavelength light may be more attractive to hatchlings than low-intensity, *short*-wavelength light and could indicate that intensity is more important than wavelength in sea-finding behaviour.

Hatchlings are thought to orient themselves by detecting wide, horizontal, vertically narrow bands of light (over 180 degrees) and are less influenced by single points of light. This orientation behaviour could assist hatchlings in distinguishing between the horizon and a moon, sun or star light. Thus small intense single-point light sources may not impact strongly on hatchling behaviour.

Illumination of the sky by moonlight is thought to override the visibility of artificial light to hatchlings. During full-moon events the high levels of sky illumination reduce the visibility of individual artificial light sources while increasing the visibility of the low light horizon over the ocean. Similarly, during nights with thick cloud cover, artificial light is reflected and creates a highly lit sky. In these events, research has found (Tuxbury & Salmon, 2005) that horizon elevation becomes the most important cue for sea-finding.

Artificial light can affect hatchling sea-finding behaviour by either causing disorientation or misorientation. Disorientation is seen when hatchlings crawl in circuitous paths in the beach, confused by conflicting cues. Misorientation is seen when hatchlings crawl landwards away from the water, towards bright artificial lighting (Witherington and Martin, 1996; Salmon, 2005). Both misorientation and disorientation can increase the time a hatchling spends in seafinding, exposing them to increased stress and predation risk.

Lorne and Salmon (2007) found that the attraction of hatchlings to artificial light is so strong that it can negate the hatchlings' response to other sea-finding and orientation cues.

Sensitive Periods

Marine turtles are most sensitive to artificial light during two periods: as hatchlings during sea-finding, followed by female adults during nesting beach selection.

The two species of marine turtle that most commonly utilise the beaches of Curtis Island and Facing Island are the green and flatback turtles. Table 16.1 shows the regional nesting and hatching seasons for green and flatback turtles.

Table 16.1 Nesting and hatching seasons for green and flatback turtles in the Port Curtis region

Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Green Turtle									
Nesting									
Hatching									
Flatback Turtle									
Nesting									
Hatching									

	Peak activity. Presence reliable and predictable each year.
	Low level of abundance, activity or presence. May vary from year to year.
	Activity typically not occurring in the area. Note that low levels may occur.

Green turtles are known nest in the Port Curtis region between mid-October to April, with a peak nesting period from mid-December to mid-January. Green turtle hatching season begins in mid-December and continues to mid-May, with a peak hatching period during February and March.

Flatback turtles nesting in the Port Curtis region have a shorter nesting period that spans from November to February, with a peak from mid-November to mid-December. Flatback hatchlings emerge between December and April, with a peak in February.

The peak periods are when the majority of marine turtles will be nesting and hatching. The 4.5-month period (from mid-November to April) is therefore when most marine turtles in the Port Curtis region are likely to be at risk from the impacts of project lighting.

16.4 Field Study

Pendoley undertook a field study to collect baseline data to establish the existing light environment on the turtle nesting beaches on both Curtis and Facing islands. Future light emissions associated with the LNG plant could be measured against this baseline to assess the plant's contribution to light pollution at these beaches.

The method and findings of the field study are described below.

16.4.1 Field Study Method

In July 2012, Pendoley completed field work to collect data on existing night sky conditions and dune elevations from four known marine turtle nesting beaches. Study locations were Southend Beach and Connor Bluff on Curtis Island and Settlement Beach and North Beach on Facing Island. Figure 16.1 shows the study locations in relation to known turtle nesting sites along the east coast of Curtis Island, Facing Island and the mainland. It also provides the number of nesting females returning annually to each site.

Four locations across Curtis and Facing islands were identified as suitable to conduct the study. However, inclement weather during the second day of surveying made it necessary to revisit North Beach a second time as the data collected was insufficient. Thus, the study has five study locations, which include North Beach 1 and North Beach 2.

Innovative Sky Cam and Sky 42 light monitoring equipment was used overnight to obtain photographic images and data between sunset and dawn of night-time ambient light levels and changes to the night-time horizon as perceived from sea and beach level on turtle nesting beaches.

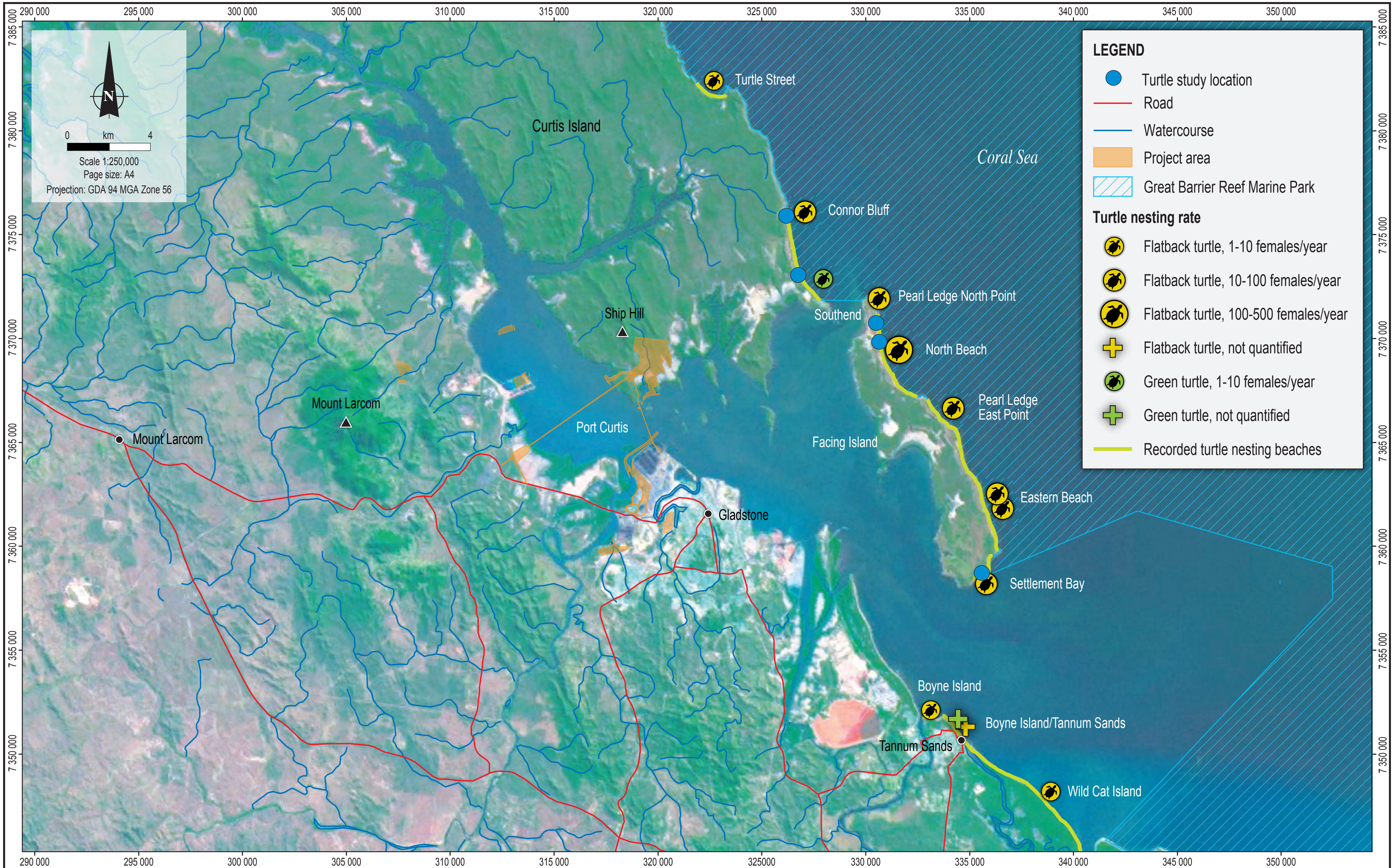
The Sky Cam and Sky 42 light monitoring equipment relies on locating specific stars in the sky, analysing their light emissions with relative to deep space (background) sky, thereby providing a reference against which to calibrate anthropogenic light sources. The new-moon phase was selected for the study as data collected in this phase avoids ambient light generated by the full moon, which can cause variability in the data.

Further information on the Sky Cam and Sky 42 light monitoring equipment techniques and image processing can be found in Appendix 9, Marine Ecology (Turtles) Technical Study.

Several other environmental factors can influence the amount of visible light in the sky, including cloud cover, pollutants and airborne particulates in the air column, humidity and precipitation. These factors can redirect and scatter the available light (i.e., show the apparent sky as brighter and reflect glow). For this survey, cloud cover (100%) at North Beach 1 meant a second visit (North Beach 2) was required.

Information was also collected at each beach on the elevation (in degrees) of the primary dune. Dune elevation is an important factor in the visibility of light sources from a beach and also provides a cue for hatchlings sea-finding behaviour.

Table 16.2 describes the GPS location, dune elevation and percentage cloud cover at the survey locations.



Source:
Place names and roads from DME. Watercourses from Alluvium. Project area from Coffey Environments.
Great Barrier Reef Marine Park from GBRMPA. Imagery from Nearmap (captured 7 August 2012).
Turtle nesting sites digitised by Coffey Environments from EPA figure 'Shorebirds and Turtles'.
Turtle nesting rates courtesy Col Limpus QPWS Senior Principal Conservation Officer Parks and Wildlife Strategy Research Coordination Unit.
Nesting rates recorded between 1968 - 1999, not all records shown. Study locations from Pendoley Environmental (August 2012).

coffey environments

Date: 10.12.2012
MXD: 7033CC_16_GIS03_v1_5
File Name: 7033_16_F16.01_GIS_GL

Arrow Energy
Arrow LNG Plant

arrow energy go further

Study locations and turtle nesting sites in the Gladstone region

Figure No: 16.1

Table 16.2 GPS location, dune elevation angles and dominant weather conditions at the survey sites

Date	Location (island, beach)	Latitude (South)	Longitude (East)	Primary dune elevation (degrees) from sand	Percentage of images affected by cloud
16 July 2012	Facing Island, Settlement Beach	-23.874425	151.385441	7° to 12° (from base of dune)	Greater than 50%
17 July 2012	Facing Island, North Beach 1	-23.765498	151.337483	20° (from base of dune)	100%
18 July 2012	Curtis Island, Southend	-23.744566	151.300873	25° (2.7 m behind camera) 6° (15 m south of camera)	Greater than 50%
19 July 2012	Facing Island, North Beach 2	-23.774023	151.338485	19° (8 m behind camera) 5° (10 m south of camera)	0%
20 July 2012	Curtis Island, Connor Bluff	-23.718631	151.295626	No data	0%

The data collected at the beaches was analysed and interpreted to visually represent the light that marine turtles would view from each beach. The visualisations were prepared as processed isophote images, which allow the visible light to be distinguished into ‘magnitude bands’.

The magnitude bands in themselves cannot be related directly to turtle sensitivity or vision. Rather they represent variations in the intensity of light glow in the sky, with dark sky unaffected by artificial light falling in the darkest (highest magnitude number band; in this study, band 12). The use of magnitude bands allowed Pendoley to quantify the light so that light emissions can be compared both spatially and temporally. Within a given isophote image, it is possible to see and quantify the spatial extent of glow and represent it as a proportion of the night sky (%).

Existing light glow from industry, urban areas and even vessels moored offshore is distinguishable and identifiable on isophote images. As a result, it is possible to predict for each nesting beach whether light glow from the project would add to the existing horizon glow or would create a new area of glow on the horizon, depending on the location of the Arrow Energy LNG plant in relation to each beach.

16.4.2 Field Study Findings

The field study looked at the existing visible light environment from the turtle nesting beaches on Curtis and Facing islands and evaluated whether turtles utilising these beaches would have direct line of site to either the LNG plant flare, flare glow or the light glow emitted from the plant. The findings are discussed below.

Background Lighting Conditions

The study found that the current night sky as seen from Curtis and Facing islands’ east-facing beaches is illuminated by a range of light sources. The current sky glow is dominated by light emitted from existing industrial and commercial facilities in the Gladstone area and from the city of Gladstone. This region is highly industrialised, with many of the industrial sites having been in operation for over 30 years. The major industrial light sources around the Gladstone region (and the year in which they began operation) include:

- Boyne Island Aluminium Smelter (c. 1975 to 1976).
- Queensland Alumina (c. 1967).
- Barney Point Wharf and Coal Terminal (c. 1967 to 1968).

- Auckland Point Wharves (c. 1930).
- RG Tanna Coal Terminal (c 1977 to 1980).
- Yarwun Alumina (c. 2004).
- Orica Chemical Plant (c. 1990).
- Cement Australia (c. 1981).

Different light sources produce glow that consists of a range of magnitude bands. Using the isophote imagery, Pendoley was able to differentiate and resolve the different light sources, distinguishing, for example, the white glow of Gladstone city from the orange glow of the Queensland Alumina site. The isophote images for the five beach locations are illustrated in Figures 16.2 to 16.4. Table 16.3 outlines the percentage of sky characterised by magnitude bands 7 (lightest sky) to 12 (darkest sky) for each nesting beach.

Table 16.3 Percentage of sky occupied by magnitude bands 7 to 12 at each nesting beach

Isophote Image Location	Percentage of Sky in Each Magnitude Band (%)					
	Band 7	Band 8	Band 9	Band 10	Band 11	Band 12
Settlement Beach	0.38	3.08	11.43	27.58	38.81	18.72
Southend	–	0.95	6.47	24.34	50.47	14.35
North Beach 1	0.78	4.73	14.62	45.99	30.63	6.77
North Beach 2	–	0.03	0.09	7.67	78.61	13.60
Connor Bluff	–	0.02	0.25	6.00	61.53	32.21

The existing glow from Gladstone urban lighting and industry is expected to be most visible from the beaches on Curtis and Facing islands during new-moon conditions or when there is a significant amount of low cloud cover. Low cloud cover reflects more light than high cloud cover.

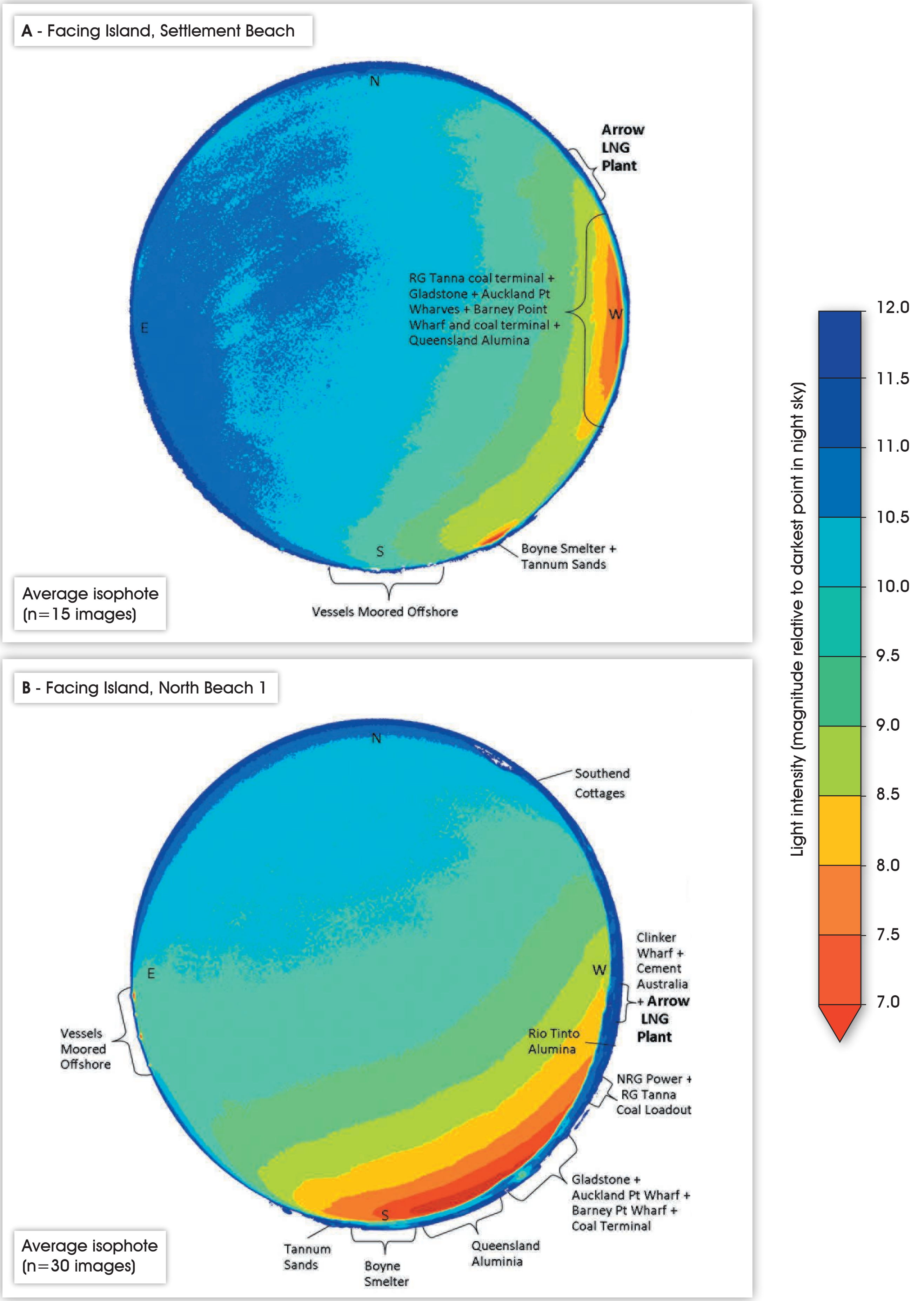
The study found the beaches with the most exposure to sky glow were Settlement Beach and North Beach 1 on Facing Island. However, over 50% cloud cover was present on the evening Settlement Beach was surveyed, and North Beach had 100% cloud cover. When North Beach was revisited (North Beach 2), it was found to have the least amount of visible sky glow. This is a good example of how cloud cover can amplify any existing light.

Data showed that, of the beaches on Curtis Island, Southend was exposed to glow that was characterised by a higher percentage of lower magnitude bands (i.e., more intense light) than was Connor Bluff. However, as there was over 50% cloud cover present at Southend, these results do not necessarily show that Connor Bluff has less light exposure than Southend.

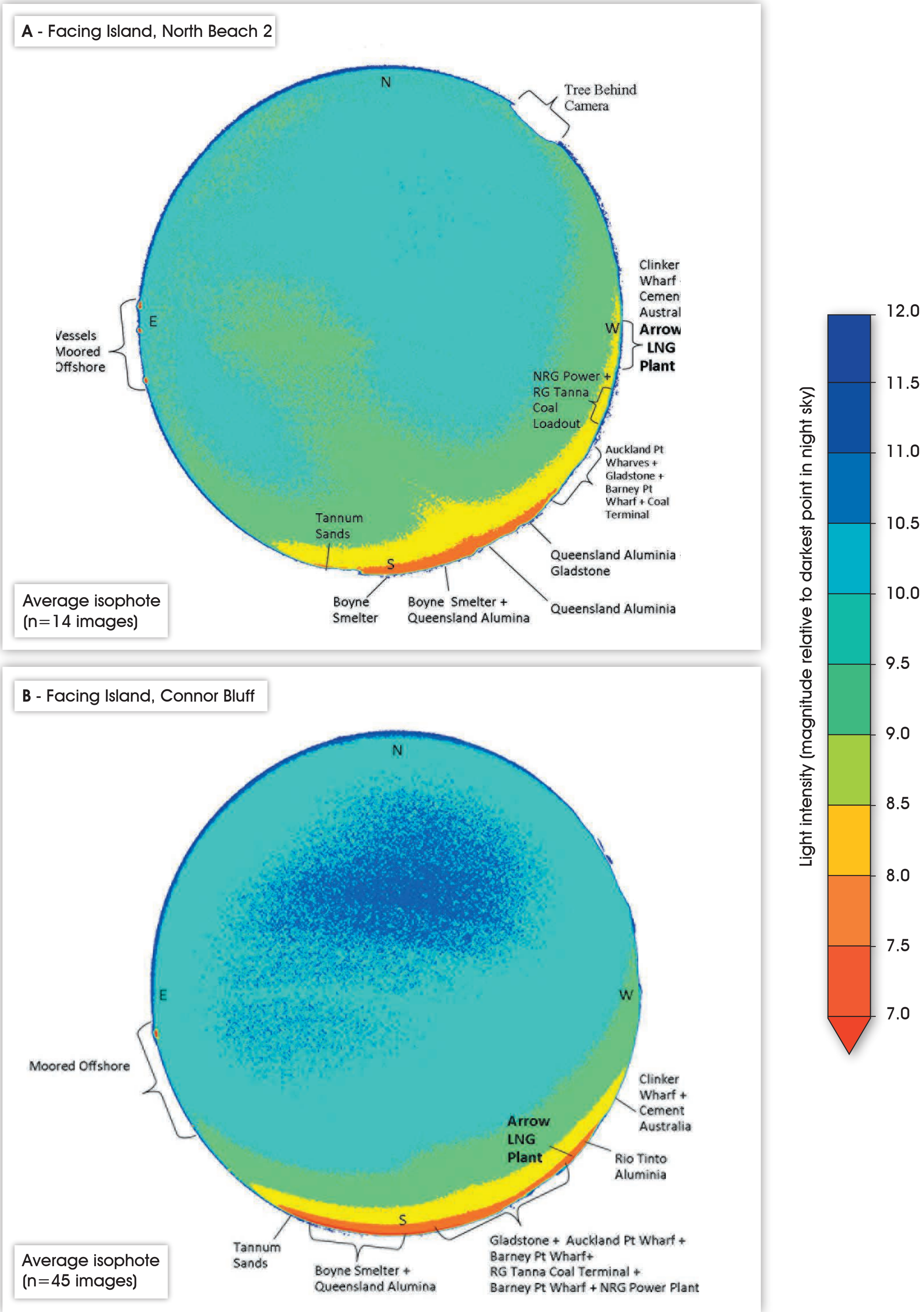
Beach Topography and Line of Sight

The topography of Curtis and Facing islands plays an important role in providing both a physical barrier between anthropogenic light sources and the nesting beaches and as a cue for hatchling sea-finding behaviour (see Section 16.3.2).

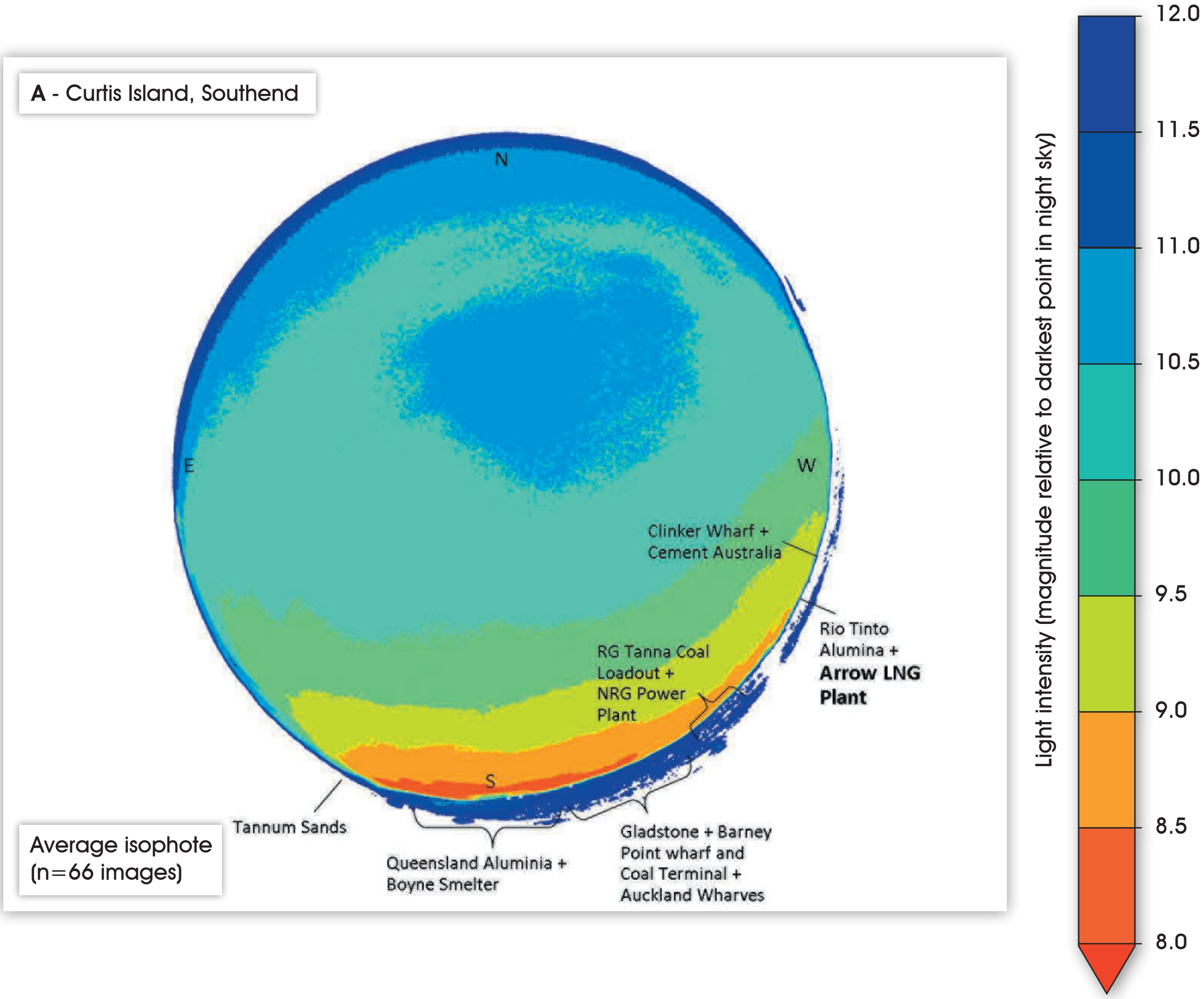
The topography of the beaches of Curtis and Facing islands is varied. While some beaches are characterised by high, vegetated back dunes (2 to 3 m high), others are characterised by sections of low dunes with very little or no vegetation. Pendoley found that the dune elevation across the surveyed beaches ranged from flat dunes of 5° at North Beach 2 to 25° dune elevation at Southend beach. Figure 16.5 illustrates the effect of different dune elevations on the potential visibility of light sources on marine turtle beaches (in this case, from an LNG plant and flare).



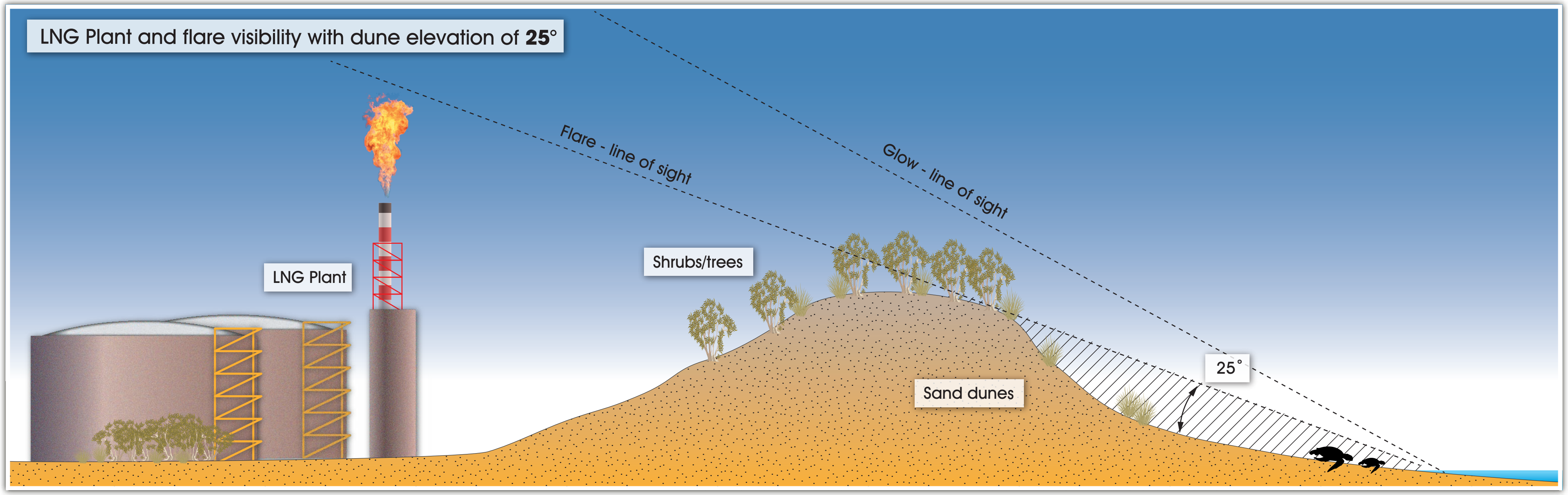
coffey environments	Date: 22.10.2012	Arrow Energy	arrow energy go further	Isophote Image: Settlement Beach and North Beach 1	Figure No: 16.2
	File Name: 7033_16_F16.02_VS	Arrow LNG Plant			

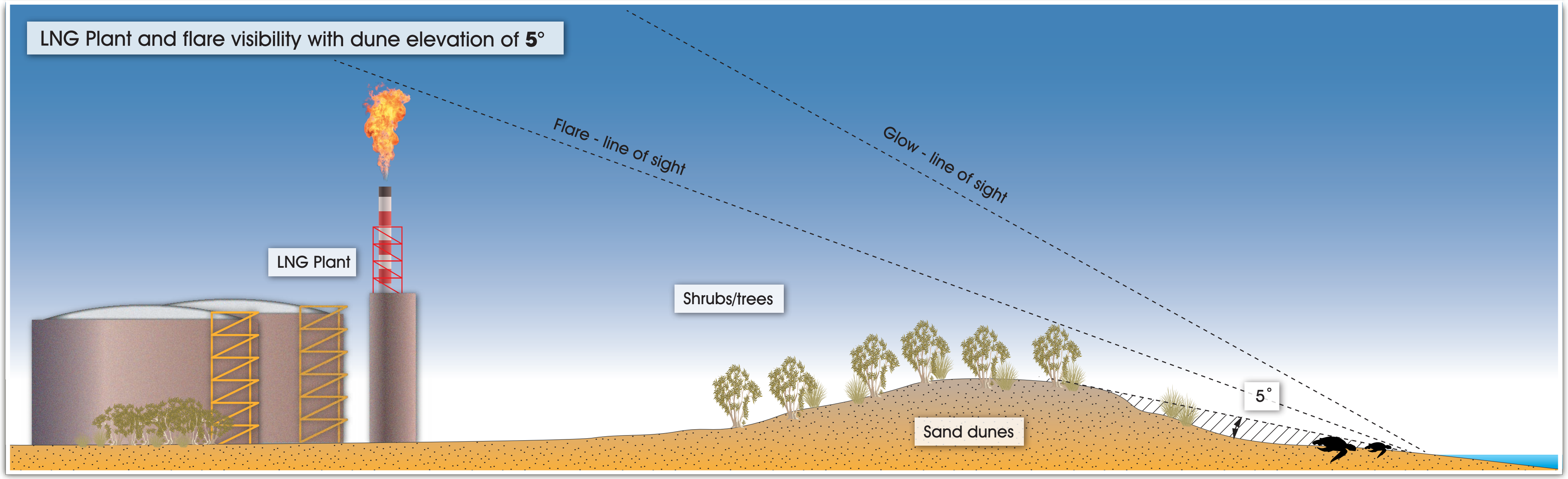


coffey environments	Date: 22.10.2012	Arrow Energy	arrow energy go further	Isophote image: North Beach 2 and Connor Bluff	Figure No: 16.3
	File Name: 7033_16_F16.03_GL	Arrow LNG Plant			



coffey environments	Date: 04.12.2012	Arrow Energy	arrow energy go further	Isophote image: Southend	Figure No: 16.4
	File Name: 7033_16_F16.04_GL	Arrow LNG Plant			





Source: Coffey	coffey environments	Date: 16.10.2012	Arrow Energy	arrow energy go further	Light visibility on turtle nesting beaches	Figure No: 16.5
		File Name: 7033_16_F16.05_GL	Arrow LNG Plant			

There will be no line of sight to the actual plant lighting from any of the beaches. Two lighting source types from the project may be visible to marine turtles utilising the beaches on Curtis and Facing islands. These include the flare and its glow and the glow from general LNG plant site lighting. Line of sight of both types of project lighting depends on the onshore topography and dune layout between the nesting beaches and the plant.

During clear conditions, Pendoley found that the beaches at Southend and North Beach may potentially have line of sight of the flare. The remaining beaches (Settlement Beach and Connor Bluff) are unlikely to have line of sight due to established dunes, vegetation and hills providing a shielding mechanism from the light.

During cloudy conditions or if there is a high level of aerosols or particulate matter in the air, the flare will produce a more visible glow. Pendoley suggest that in these conditions, this resultant glow will be visible to all surveyed beaches.

Analysis of the isophote images (see Figures 16.2 to 16.4) show that, excluding the beaches at Settlement Beach and Connor Bluff, the LNG plant lighting (when in operation) although visible from the nesting beaches, will add to the existing Gladstone City urban and industrial light glow but will not be distinguishable. From Settlement Beach and Connor Bluff, light glow from LNG plant lighting will potentially introduce a new area of visible horizon glow.

The Arrow LNG Plant is one of four LNG plants proposed to be built on the southeastern coast of Curtis Island. All projects, both pre- or post-mitigation- will produce some amount of light glow. The Arrow Energy LNG plant has the highest risk of impacting marine turtles utilising these beaches due to its location relative to the other plants and Curtis Island topography.

Ship Hill on Curtis Island may provide some natural shielding of the light glow from the other three LNG plants, as it is located between the LNG plants and the nesting beaches on Curtis Island (Connor Bluff and Southend) and at North Beach. Settlement Beach will not benefit from this shielding by Ship Hill. When viewed from this beach, other LNG plants will sit directly behind the Arrow Energy LNG plant, and any light from these three plants will cumulatively add to the night sky glow and it will not be possible to distinguish between the sources of this glow in the sky.

16.5 Conclusions

The marine ecology (turtles) technical study was framed around answering specific questions relating to the impact of project lighting on the local populations of marine turtles in and adjacent to Port Curtis. The answers to these questions are detailed below.

Are marine turtle species found in Port Curtis and along the east coast of Curtis Island likely to be affected by project lighting?

Marine turtles utilising the nesting beaches of Curtis Island and Facing Island in Port Curtis are likely to be exposed to some project lighting, in addition to the light exposure that currently exists from existing urban and industrial sources. The impact of this exposure depends on many factors, including intensity, wavelength and directionality of light; time of year; beach topography; weather conditions; and the presence or absence of aerosols within the atmosphere.

What background lighting conditions exist at the turtle nesting sites north of Southend and at the northern end of Facing Island, i.e., prior to any project development?

The beaches of Facing Island and Curtis Island are used as successful nesting beaches by green and flatback turtles. Currently, the night sky as seen from these beaches is dominated by a glow from existing industry and Gladstone city urban lighting.

The light study results indicated that beaches at Settlement Bay, located at the south end of Facing Island were exposed to the greatest amount of light due to their relative closeness to Gladstone city, Tannum Sands residential area, and the Boyne Island smelter. North Beach, in the north of Facing Island, was exposed to the least amount of light glow, due to its location and the island's topography.

What specific intensity (luminosity) and wavelength or spectrum of light are the nominated marine turtle species most sensitive to? Do the light sources at the LNG plant fit within the spectrum, wavelength and intensity of light to which the nominated marine turtle species are susceptible?

Any artificial lighting at the LNG plant and associated facilities on Curtis Island will also emit a glow that, in the absence of other competing light sources, is likely to be attractive to hatchlings. It is this glow that must be managed to prevent it impacting marine turtles on the nearby nesting beaches.

Adult turtles rely on a range of cues to navigate both in the ocean and when sea-finding. Light is one of the cues adults use for sea-finding, but it does not appear to be the most prominent as adult turtles are able to orient seaward regardless of the visibility of light.

Hatchling turtles rely more heavily on light cues when sea-finding. They are thought to use horizon elevation, light intensity, light wavelength, light directivity and beach and dune environment as cues.

Hatchlings appear to be more attracted to high-intensity (more luminous) light than to low-intensity light and to short-wavelength light (seen as blue-green) than to long-wavelength light (red-yellow). Low pressure sodium vapour and high pressure sodium vapour lights spectra are concentrated in the longer wavelength region (around 650 nm) while halogen, fluorescent, metal halide and LED lighting produce a much greater proportion of shorter wavelength light.

The detailed lighting specifications for the LNG plant, including the flare, are not yet available. Arrow Energy's LNG plant flare is expected to be enriched in short wavelength light in the UV region of the spectrum (400 nm) which is more attractive to hatchlings than longer wavelengths.

Will marine turtles utilising beaches north of Southend and on Facing Island have line of sight to the flare?

Of the nesting beaches studied, the beaches at Southend and North Beach are most likely to have line of sight to the flare at the LNG plant site. This is due to the location and height of the flare relative to the beaches, in conjunction with the specific beach topography (i.e., lower primary dune elevation). Marine turtles are less sensitive to single visible light sources which can be confused with a bright star. The physical dimensions and appearance of the flare flame will depend on flow rates with small flow rates producing a flame that may be indistinguishable from the moon while large flow rates will produce a large and highly visible flame that will potentially impact on turtle orientation.

The flare is likely to produce a glow in the sky, particularly during new moon conditions or when there is low-lying cloud cover or high levels of aerosols or particulate matter in the air column. All beaches are likely to have line of sight to this glow. This glow is more likely to impact marine turtles than the single light source visible at beaches that have line of sight to the flare.

Will marine turtles utilising beaches north of Southend and on Facing Island have line of sight to the glow created by LNG plant lighting?

Light glow is reflected and enhanced due to environmental conditions (both natural and anthropogenic), including aerosols in the air column (sea-spray, precipitation, smoke, etc.) and cloud cover. Thus, light glow is potentially visible from beaches, regardless of beach topography and dune structure. All turtle nesting beaches on Curtis and Facing Island could be exposed to line of sight to lighting glow generated by the LNG plant (including glow from the flare).

The analysed isophote images (see Figures 16.2 to 16.4) show that project lighting associated with the LNG plant (and flare) will add to the existing light glow from Gladstone city and local industry when seen from beaches near Southend and North Beach. This extra glow will be indistinguishable by turtles from the existing glow from Cement Australia and the Yarwun Alumina. The light glow will add a new area of horizon glow to the view from Settlement Beach and Connor Buff. This is due to the location of each beach in relation to existing industry. This new glow will be distinguishable from the mainland sources of glow. Glow from the other three LNG plants on Curtis Island will cumulatively add to the night sky glow, particularly when viewed from Settlement Beach. It will not be possible to distinguish the sources of this glow.

What specific behaviour – breeding, nesting or hatching – is affected by light?

Sea-finding behaviour in hatchling turtles and nesting beach selection in adult (novice) females are the behaviours most impacted by artificial light.

Hatchling turtles use light as one of the primary cues in sea-finding behaviour. While other cues are known to be used by hatchlings, exposure to specific types of artificial light may override these other cues. Misorientation and disorientation can occur and can impede hatchlings' ability to find the ocean safely.

Misorientation and disorientation can cause increased mortality in hatchlings, due to increased predation, dehydration, exhaustion and depleted energy reserves and exposure to the elements (particularly if they hatch during the day).

Nesting females tend to rely on many other cues (in addition to lighting) for navigation and sea-finding and are less at risk of misorientation and disorientation than are newly hatched individuals. Novice nesting females may select nesting beaches with minimal exposure to light glow.

What time of year is the most sensitive for the species that nest on the east coast of Curtis Island and Facing Island?

The majority of marine turtles will be nesting and hatching over a 4.5-month period from mid-November to April. This period is when most marine turtles in the Port Curtis area are most likely to be at risk from the impacts from project lighting.

This sensitive period occurs between November and April, which is Queensland's 'wet season'. This season is characterised by regular cloud cover and high aerosol content within the air column (due to rain and humidity). These conditions increase the light reflection in the sky and may increase the impacts to hatchling behaviour. Isophote imagery of North Beach 1 (see Figure 16.2) demonstrates this increased reflection when there is more that 50% cloud cover.

Impacts from light glow emitted by flaring would be exacerbated during these 'wet season' conditions.

What are the potential risks to marine turtles if flaring occurs during the sensitive periods for the nominated species, e.g., during hatching?

Glow arising from extended flaring during the nesting season may cause a light glow that could deter novice females from nesting on beaches exposed to the glow.

Extended flaring during the turtle hatchling season may increase mortality rates in hatchlings by interrupting sea-finding by causing misorientation and disorientation. This impact is predicted to be more likely on beaches with less established, flatter dunes as this low light horizon behind the beach can be mistaken for the low light horizon over the ocean. This impact is considered to be less likely on beaches with high dune elevation where the hatchling are able to respond to the tall dark dune horizon by moving away from it and can more easily distinguish the lower ocean horizon light.

Short-term flaring (i.e., hours) is unlikely to have a detectable impact on the marine turtle behaviours of nesting or hatchling sea-finding.

Are the management measures expressed as commitments adequate to address potential impacts on marine turtles?

Pendoley reviewed the management measures committed to in the marine and estuarine ecology chapter in the EIS (see Chapter 19 in the EIS) and commented on their adequacy in addressing the impacts of project lighting on marine turtles.

Pendoley assessed the existing commitments outlined in Chapter 19 of the EIS as adequate and recommended adding further detail to the following commitments as set out below:

- C17.17: Use long-wavelength lights, where practical, including use of red, orange or yellow lights.
  - Low-pressure sodium light has least impact on turtles, followed by high-pressure sodium light.
  - The LNG plant should avoid using metal halide, halogen, incandescent and fluorescent lights; and if used, they should be carefully managed so as to prevent light escaping into the overhead sky.
  - The additional impact on marine turtles from using well-managed (i.e., shielded and directed) short-wavelength light is likely to be minor and undetectable over existing light impacts.
- C17.19: Avoid routine planned maintenance flaring at night during sensitive turtle-reproductive periods (where practical).
  - Give highest priority to avoiding flaring during the peak flatback and green turtle hatching period (February to March).
  - Give second highest priority to avoiding flaring during the shoulder hatching periods (December to January and April to mid-May) and peak adult nesting period (mid-November to mid-January).
- C19.01: Develop a construction management plan that contains specific mitigation measures, performance indicators and management action required to reduce impacts to the marine and estuarine ecological values.

  - Develop a light mitigation plan for construction and operation. Include specific light management measures, commitment to routine light audits, and hatchling monitoring to assess the impact of current and future light impacts on hatchlings emerging on both Curtis Island and Facing Island beaches.

Is additional mitigation required to address potential impacts on marine turtles?

Pendoley recommended adopting additional management practices to address impacts of project lighting on marine turtles. These measures incorporate and expand on the above listed recommendations by Pendoley on the existing EIS commitments. Similar measures have been implemented nationally for similar projects and are accepted as industry best practice by the Western Australian Environmental Protection Authority (EPA, 2010).

Arrow Energy will consider measures to minimise light emitted from the LNG plant during the detailed design of the LNG plant (C17.47) including:

- Assess the necessity and choice of lighting in the LNG plant area:
  - Use low-pressure sodium (LPS) lights as a first-choice light source and high-pressure sodium (HPS) lights where LPS is not practical.
  - Replace short-wavelength light with long-wavelength light and exclude short-wavelength light with the use of filters.
  - Avoid using halogen, metal halide or fluorescent lights (white lights) where possible, and only use white lights in contained areas where colour rendition is required.
  - Minimise the number and wattage of lights, and recess lighting into structures where possible.
- Use timers and motion-activated light switches.
- Use reflective materials to delineate equipment or pathways and use embedded lighting for roads.
- Position doors and windows on the sides of buildings facing away from marine turtle nesting beaches and install and use window coverings to reduce light emissions.
- Maintain elevated horizons (such as topographic features, vegetation or barriers) to screen rookery beaches from light sources

A light mitigation plan for construction and operation will be developed and will include specific light management and reduction measures and a commitment to routine light audits. (C19.14)

Arrow Energy will participate in monitoring programs established to assess the impact of current and future industrial lighting in the Gladstone region on hatchlings emerging on the beaches of Curtis and Facing islands. (C19.15)

How effective are the mitigation and management measures likely to be; specifically, will the proposed flaring strategy reduce impacts on the nominated marine turtle species?

The proposed flaring strategy refers to commitment C17.19, which states that Arrow Energy will avoid routine planned maintenance flaring at night during sensitive turtle-reproductive periods (where practical). Scheduling shutdowns (which require flaring) to only occur during the non-breeding season and minimising necessary flaring during the breeding season will effectively minimise the impact of flaring on marine turtles in the Port Curtis region.

Unscheduled flaring (train trips) will be short in duration (four times a year for up to two hours). These trips are unlikely to have a detectable impact upon hatchling behaviour should these events occur during the sensitive periods.

Will there be any residual impacts to turtles following adoption of the mitigation and management measures; and if so, how significant will they be?

Quantifying the impact of light on hatchlings and adults is difficult for several reasons, including variable environmental conditions. During the wet season, for example, light reflected off clouds will increase the light reflection in the sky and may increase the impacts to hatchling behaviour.

Overall, however, the residual impacts of project lighting on marine turtles using beaches on Curtis and Facing islands will be reduced to a minimum with the implementation of a detailed lighting mitigation plan for the Arrow LNG Plant that incorporates the measures identified above. Results from any monitoring program developed to assess the impact on hatchlings of current and planned industrial lighting in the Gladstone region (including from other LNG plants) will assist in establishing the effectiveness of mitigation, and the review of management measures as required.

Residual impacts from the project lighting following implementation of the lighting mitigation plan are likely to include an increased extent of horizon illumination at some locations on Facing Island and Curtis Island beaches due to the additional light glow from the LNG plant lighting and an marginal increase in sky glow due the LNG plant lighting, which will add to the existing artificial illumination in Port Curtis. This includes an increase in the amount of glow seen on turtle nesting beaches, which could increase the degree of misorientation and disorientation in hatchlings. The proposed flaring strategy will effectively minimise the impact of flaring on marine turtles in the Port Curtis region.

16.6 Commitments Update

Three new commitments have been added in response to the findings of the marine ecology (turtles) technical study.

Commitment C17.16.A was revised in accordance with the findings of the terrestrial ecology studies. Aspects of this commitment are also of benefit to minimising impacts of lighting on marine turtles. Commitment C19.01A has been revised to improve clarity.

The new and revised commitments relevant to marine turtles and lighting are set out in Table 16.4. Other measures are unchanged and are included in Attachment 7 (Commitments Update).

Table 16.4 Commitments update: turtles and lighting

No.	Commitment	Comment
C17.16A	Shield/direct the light source onto work areas where practical, and avoid light spill on to habitat areas (such as mangroves and Clinton ash ponds), where practical.	Common with terrestrial ecology - changed to expand on intent of commitment.

Table 16.4 Commitments update: turtles and lighting (cont'd)

No.	Commitment	Comment
C17.47	Consider measures to minimise light emitted from the LNG plant during the detailed design of the LNG plant including: • Assess the necessity and choice of lighting in the plant area: – Use low-pressure sodium (LPS) lights as a first-choice light source and high-pressure sodium (HPS) lights where LPS is not practical. – Replace short-wavelength light with long-wavelength light and exclude short-wavelength light with the use of filters. – Avoid using halogen, metal halide or fluorescent lights (white lights) where possible, and only use white lights in contained areas where colour rendition is required. – Minimise the number and wattage of lights, and recess lighting into structures where possible. • Use timers and motion-activated light switches. • Use reflective materials to delineate equipment or pathways and use embedded lighting for roads. • Position doors and windows on the sides of buildings facing away from marine turtle nesting beaches and install and use window coverings to reduce light emissions. • Maintain elevated horizons (such as topographical features, vegetation or barriers) to screen rookery beaches from light sources.	New commitment
C19.01A	Develop a construction environmental management plan that contains specific mitigation measures, performance indicators and management action required to reduce impacts to the marine and estuarine ecological values.	Changed for improved definition.
C19.14	A light mitigation plan for construction and operation will be developed and will include specific light management and reduction measures and a commitment to routine light audits.	New commitment
C19.15	Arrow Energy will participate in monitoring programs established to assess the impact of current and future industrial lighting in the Gladstone region on hatchlings emerging on the beaches of Curtis and Facing islands.	New commitment