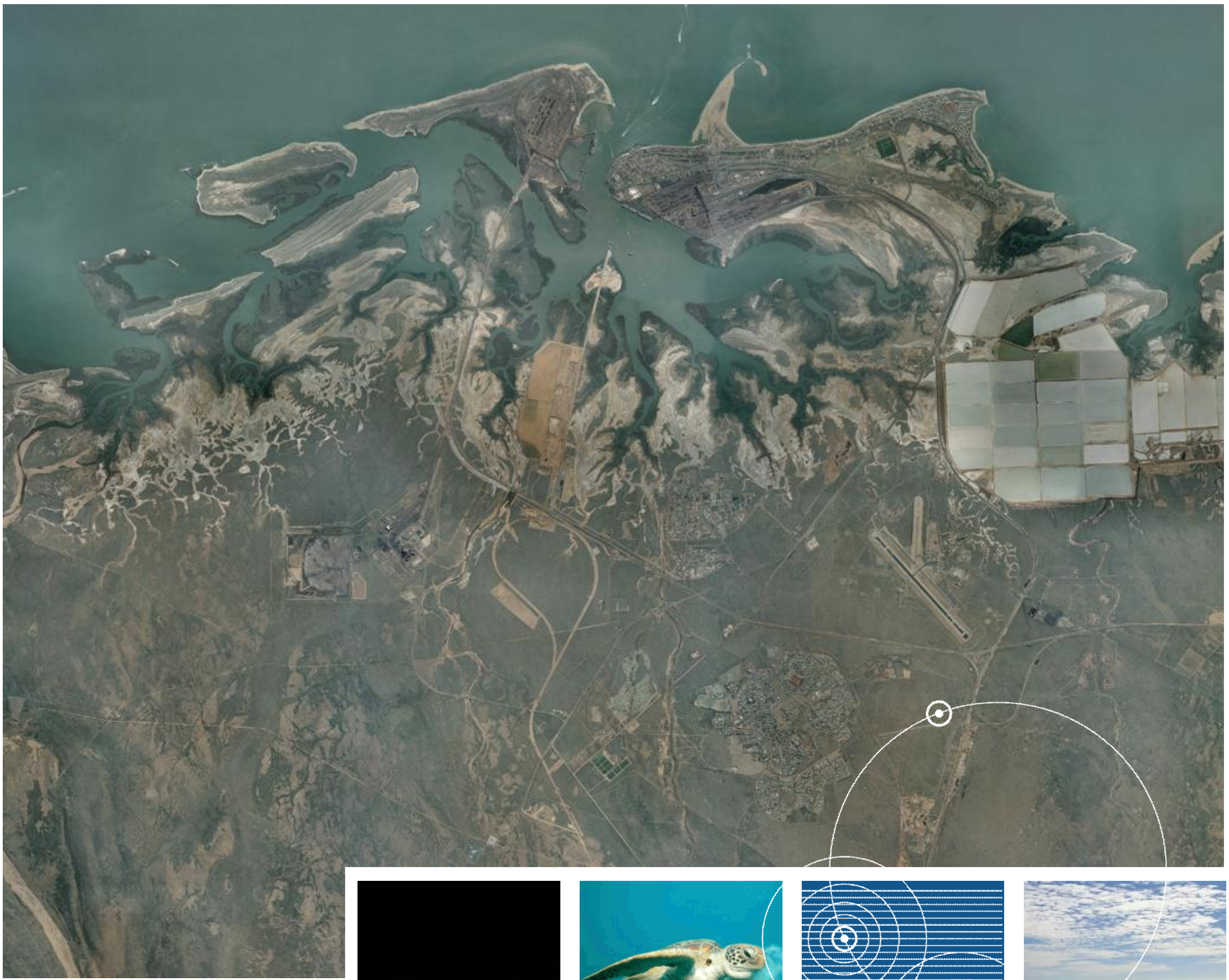

Port Hedland Outer Harbour Development Light Spill Assessment

BHP Billiton Iron Ore

Sinclair Knight Merz

15 September 2009

Port Hedland Outer Harbour Development Light Spill Assessment

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Executive Summary

BHP Billiton Iron Ore proposes to expand their iron ore operations in the Pilbara by developing a new port at Port Hedland. This proposed development is known as the proposed Outer Harbour Development. Bassett Consulting Engineers have been engaged by Sinclair Knight Merz to undertake an assessment of the lighting of the proposed Outer Harbour Development. A lighting assessment is required to determine potential additional light spill created by the proposed Outer Harbour Development at beaches which potentially support marine turtle nesting as well as the potential for obtrusive lighting effects to key areas of settlement.

As a part of this lighting assessment, a site visit was undertaken to establish a baseline understanding of existing lighting at beaches which potentially support marine turtle nesting, settlement areas and existing light spill from port developments at Port Hedland. The beaches investigated included Cemetery Beach, Cooke Point and Pretty Pool. The settlement areas investigated included residential sites within Port Hedland and South Hedland and the light industrial area of Wedgefield. Lighting details recorded at the above sites included illuminance and luminance measurements, visible light sources and existing sky glow where measureable.

Computer modelling was used to generate predicted light spill from the proposed Outer Harbour Development in Port Hedland, South Hedland and Wedgefield. Light spill from dominant light sources in Port Hedland, namely, existing port developments and the former Boodarie Hot Briquette Iron plant, was also generated using computer modelling for comparison with predicted light spill for the proposed Outer Harbour Development. Cumulative light spill was considered in terms of cumulative port development light spill (proposed Outer Harbour Development and existing port development light spill) and cumulative ambient light spill (proposed Outer Harbour Development light spill and existing ambient light levels at the sites).

Light spill from the proposed Outer Harbour Development is unlikely to be visible at the turtle nesting beaches Cooke Point and Pretty Pool due to the presence of high sand dunes at these sites and the large distance (greater than 7 km) of these sites from the proposed development. During the construction period, high pressure sodium vapour and metal halide and mercury vapour lighting on ships and dredge vessels will be visible at Cemetery Beach. The high pressure sodium vapour lighting present on the proposed Outer Harbour Development jetty, ship-loader area and transfer pad will also be visible from Cemetery Beach. Computer modelling results indicate illuminance values for direct light from the proposed Outer Harbour Development and cumulative ambient lighting levels is less than those associated with moonlight. The proposed Outer Harbour Development modelling results do not indicate a noticeable increase in existing port development lighting or ambient lighting at turtle nesting beaches.

Sites within settlement areas that were investigated in this light assessment will have varying views of the proposed Outer Harbour Development infrastructure and lighting. The proposed Outer Harbour Development jetty lighting will be visible at Point Laurentius, the Port Hedland Hospital and Seasons Hotel, all of which are located in or near residential areas. The lighting associated with the proposed Outer Harbour Development stockyards and overland conveyors will be visible at the western boundary of the light industrial area of Wedgefield and the residential area of South Hedland. Modelling results indicate that illuminance values for the proposed Outer Harbour Development do not represent a noticeable increase in existing port development lighting or ambient lighting, with exception of Wedgefield where there may be a slight change in illuminance. Cumulative ambient illuminance at all residential / light industrial sites does not exceed the limitations imposed by Australian Standard AS4282.

Modelling results suggest that lighting from the Boodarie Hot Briquette Iron plant when it was operating would have generated greater light spill at Wedgefield and South Hedland than the proposed Outer Harbour Development due to the original quantity of lighting on the site and the height of the main lit structure.

The lighting of the proposed Outer Harbour Development will marginally increase sky glow under some atmospheric conditions seen from residential sites (depending on observer position) and Cemetery Beach. The overall effect is not expected to be significantly brighter than existing sky glow.

The use of luminaires with asymmetric light distribution, that is those which focus light on a given area whilst allowing the front glass to remain horizontal will help minimise unnecessary light spill from the

proposed Outer Harbour Development both directly and also indirectly in the form of sky glow. It is anticipated that the proposed Outer Harbour Development lighting will have minimal impact on beaches supporting turtle nesting and areas of settlement as predicted light spill at these sites is considered to be minimal in comparison to light spill from existing port developments and local sources of lighting such as streetlights and sports oval floodlights.

1.0 Introduction

1.1 Background and Objectives

BHP Billiton Iron Ore proposes to expand their iron ore operations in the Pilbara through the development of a new port in Port Hedland. This proposed development is known as the Outer Harbour Development Project. Bassett Consulting Engineers have been engaged by Sinclair Knight Merz to undertake an assessment of the potential light spill from the proposed Outer Harbour Development.

The objectives of this lighting assessment were specifically to:

- assess existing luminaires and illuminance values at selected sites during a site visit;
- assess the proposed lighting associated with proposed Outer Harbour Development;
- predict light spill for the proposed Outer Harbour Development and cumulative light spill at selected sites using computer modelling;
- compare light spill levels for the proposed Outer Harbour Development with predicted light spill from other major light contributing sources, namely existing port developments and the Boodarie Hot Briquette Iron (HBI) plant using computer modelling; and
- compare cumulative light spill on beaches supporting turtle nesting and areas of settlement (residential / light industrial) with existing light spill.

1.2 Project Location

The proposed Outer Harbour Development is located to the west and south-west of the residential towns of Port Hedland and South Hedland, and covers an area from Finucane Island to the BHP Billiton Iron Ore Newman to Port Hedland rail line in the south-east (Figure 1). The proposed Outer Harbour Development is located approximately 2.5 km west of Port Hedland, 4.5 km west of the industrial suburb of Wedgefield and 6.5 km north-west of the residential suburb of South Hedland.

In the close vicinity of proposed Outer Harbour Development are the following existing port developments (Figure 1):

- Fortescue Metal Group's Anderson Point Port Facility - within 1.5 km of Port Hedland;
- BHP Billiton Iron Ore's Nelson Point Port Facility - within 1.5 km of Port Hedland;
- BHP Billiton Iron Ore's Rapid Growth Project 4 port facilities - within 1.5 km of Port Hedland, at Finucane island;
- BHP Billiton Iron Ore's Rapid Growth Project 5 port expansion – within 1.5km of Port Hedland at Finucane Island.

In addition to the above port developments, the following proposed port developments are in close vicinity to the proposed Outer Harbour Development:

- Port Hedland Port Authority's proposed Utah Point facility - within 1.5km of Port Hedland; and
- Port Hedland Port Authority's Nelson Point facilities; and

Also, the decommissioned Boodarie Hot Briquette Iron plant is located approximately 8.5 km south-west of Port Hedland.

1.3 Project Description

The major infrastructure components for the proposed Outer Harbour Development are summarised below.

Offshore Infrastructure:

- 4 km jetty with conveyors;
- 2 km wharf with conveyors;
- eight berth pockets; and
- four ship loaders (one per pair of berths).

Terrestrial Infrastructure:

- Western Spur Railway extending from the existing Newman to Port Hedland rail line to proposed stockyards at Boodarie;
- rail loop at Boodarie;

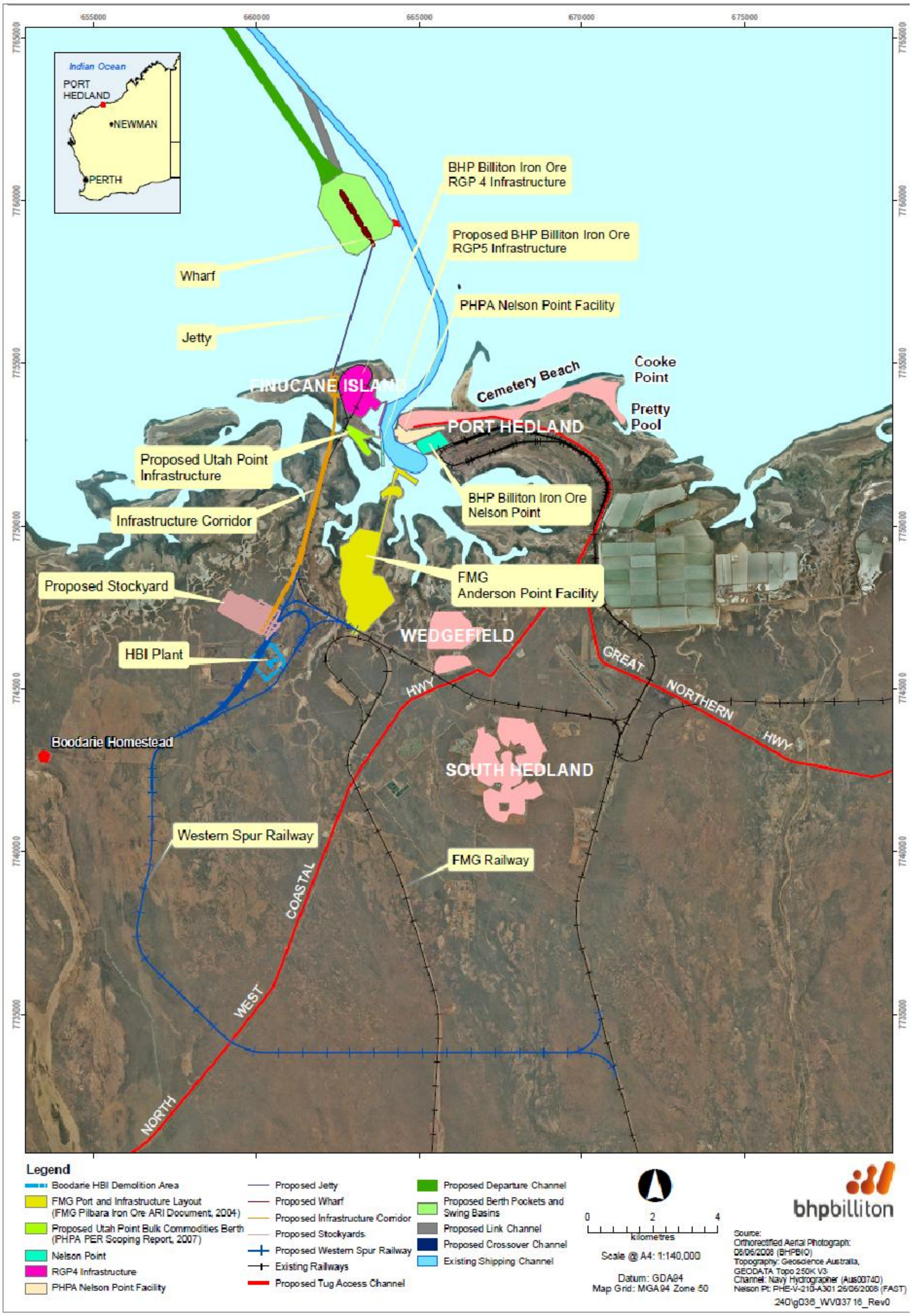


Figure 1: Project Location in Relation to Existing and Proposed Port Developments at Port Hedland

- stockyards at Boodarie; and
- infrastructure corridor (including conveyors, access roadway and utilities) from the stockyards to the proposed jetty offshore of Finucane Island.

1.4 Proposed Lighting

The proposed lighting for the project is detailed in Appendix A. The light sources associated with major components of the proposed Outer Harbour Development infrastructure and dealt with in this light impact assessment are summarised below.

Offshore Infrastructure:

- 4 km Jetty - high pressure sodium;
- 2 km wharf - high pressure sodium;
- eight berths with berthed ships - high pressure sodium; and
- four ship loaders- high pressure sodium.

Terrestrial Infrastructure:

- Transfer Station on Finucane Island - high pressure sodium;
- Infrastructure corridor/overland conveyor - high pressure sodium;
- Stockyards at Boodarie - high pressure sodium and metal halide;

Rail lighting is not considered in this assessment as only rail crossover points will be lit making this an insignificant source of light. Eight berthed ships have been included in this light spill assessment to represent worst case scenario.

1.5 Standards and Guidelines

The lighting is assessed for residential compliance against Australian Standard AS 4282 – 1997 "Control of the Obtrusive Effects of Outdoor Lighting" as referred to in Environmental Protection Authority (EPA) Guidance for Planning and Development No 33, Part C, Chapter 5.

In respect to AS4282 usually only the lighting that is subject to a particular development application is assessed. Street lighting is not subject to assessment under AS4282 and any comparisons to street lighting in this report are included for comparison with existing conditions only and to provide guidance as to whether or not the increase imposed by the proposed Outer Harbour Development Project and associated facilities is likely to be noticeable compared to existing ambient conditions. The AS4282 recommended values have been provided in Appendix B for reference.

1.6 Types of Light Sources

1.6.1 Low Pressure Sodium (LPS) Light

Lower pressure sodium (LPS) light is almost monochromatic with wavelengths at 589 and 589.6 nm which is close to the maximum human eye sensitivity at 555 nm. Night-time scenes will be experienced as tones of orange and grey to black as there are no other wavelengths of energy available to provide colour discrimination. In terms of electrical energy required to provide lighting for human vision it is energy efficient.

1.6.2 High Pressure Sodium (HPS) Light

High pressure sodium light has a completely different spectral composition to low pressure sodium light (refer to Appendix C). The operation of the high pressure sodium arc is kept electrically stable with the use of a small amount of mercury which acts as a buffer gas. High pressure sodium (HPS) light has a much broader distribution of spectral energy including in the blue green and ultraviolet range.

1.6.3 Fluorescent Light

Fluorescent lamps are low pressure discharge mercury lamps with a fluorescent coating. Much of the fluorescent spectral characteristics of white light depends on the composition of the fluorescent powder matrix used to coat the inside of the glass tube. The older halophosphate (colour 33) fluorescent are now illegal for sale within Australia, being replaced with the more efficacious triphosphor technology. Appendix C contains the line spectra for two Philips lamps (Philips Lighting

1987, 9): one colour 33 and the other that appears as white but uses the higher light output triphosphor technology (colour 84).

1.6.4 Mercury Vapour and Metal Halide Light

Both of these white light source types are high intensity discharge (HID) lamps which have an arc tube that contains the mixture of metals and or metal halides that when vapourised emit characteristic line spectra. Mercury vapour is the simplest and cheapest HID lamp with metal halides having a much higher light output and a superior colour rendition. Appendix C contains the line spectra for two Philips mercury vapour lamps and four Philips metal halide lamps (Philips Lighting 1987, 10). There is a notable concentration of line spectra in the blue end for mercury vapour lamps and there are also line spectra in the blue end for metal halide lamps.

1.7 What is Natural Night Lighting?

1.7.1 Clear Night, Moon and Stars

Measuring illuminance from stars only on a clear night is beyond the practical limits of many commercially available illuminance meters and is at least 2 or more orders of magnitude below moonlight and remains in the province of astronomical observation. Moonlight is measurable and quite noticeable to the human visual system as well as affecting marine turtles with their sensitivity in the UVA and blue part of the spectrum plus sensitivity to brightness in the field of view (refer section 2.3.1).

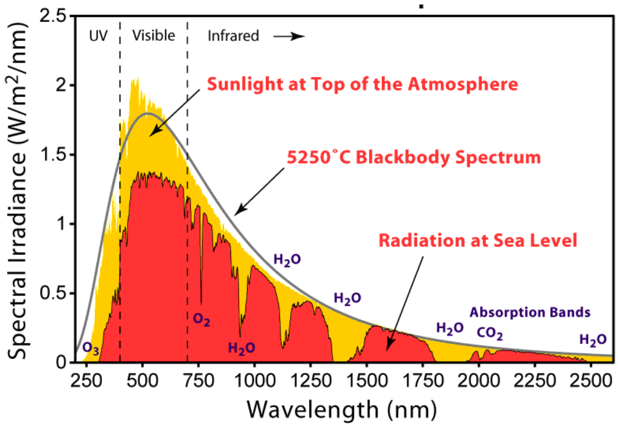


Figure 2 Spectral Distribution of Solar Radiation (Wikipedia, 2007)

1.7.2 Moonlight Spectral Distribution

Moonlight, which is reflected sunlight, is expected to have a similar spectral composition to sunlight. Sunlight in theory is similar to a black body at a specified temperature (in this case Figure 2 shows 5250 deg C for the sun) and emits a continuous spectrum of energy. However, sunlight received at the earth's surface is filtered by the atmosphere which creates absorption lines associated with water, oxygen, ozone and carbon dioxide hence spectral distribution of solar radiation is not smoothly continuous. In the visible region the spectrum is continuous with a substantial amount of energy in the blue end of the spectrum and includes radiation in the ultra-violet region. Moonlight is modified by reflection from the moon's surface and filtered by the atmosphere.

1.7.3 Typical Natural Lighting Values

The appearance of the moon is dependent on the relative position of the sun, moon, earth and observers' position on the earth. Moonlight will be screened more or less depending on the extent and density of cloud cover. Cloud cover varies on average from 6 days per month in October to 19 days per month for both January and February (Department of Agriculture, 2004). December to March is the high cyclone prone period.

Figure 3 shows typical illuminance values of natural light including night-time in the absence of any electric lighting. These values have been used as a comparison for the electric light illuminance values in this report (refer to Appendix D for terminology definitions).

Doubling the measureable illuminance (in absolute value) does not double the perceived effect. The human response to lighting is logarithmic not linear. As a rule of thumb, when the measureable value is tripled there is a "just noticeable" increase, when the measurable value is five times, there is a "noticeable difference". Hence for the purposes of easy understanding, the measured values are compared in their magnitudes. A noticeable difference in 'perceived light levels' is associated with an order of magnitude change in illuminance. e.g. 0.01 to 0.1 lux

Bright moonlight is commonly taken to be 0.2 lux.

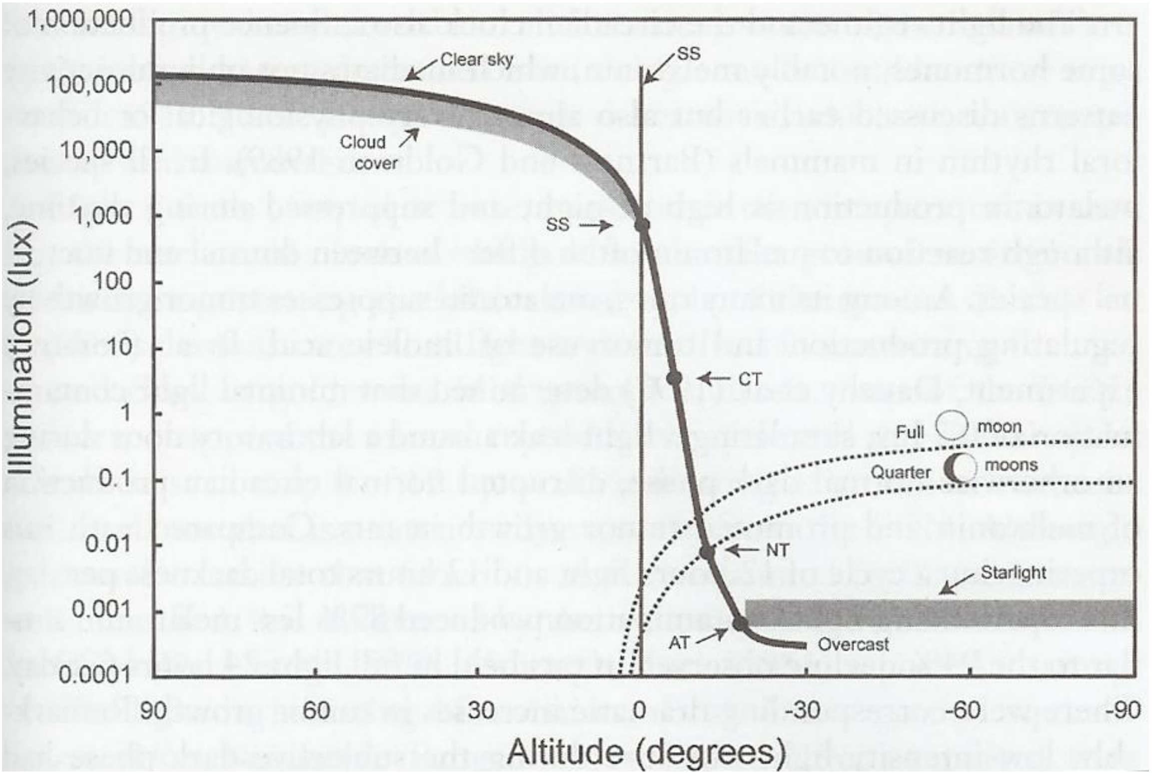


Figure 3 Natural Light Typical Illuminance Values.

Illuminance varies with respect to the position of the sun or moon above or below the horizon. The altitude of the moon is displayed on the negative (below the horizon) half of the x-axis so that it relates to sunset. SS is sunset; CT is civil twilight (i.e. sun 6 degrees below horizon); NT is nautical twilight (i.e. sun is 12 degrees below the horizon); AT is astronomical twilight (i.e. with sun 18 degrees below the horizon) (Rich and Longcore 2005).

2.0 Methods

2.1 Site Selection

Measurement locations were chosen to assess the impact on beaches which may potentially support turtle nesting, and at other locations specifically chosen to assess the potential impact to resident's under worst case scenarios. The suburb of Wedgefield, although primarily zoned as light industrial (Western Australian Planning Commission 2003), also contains scattered residences associated with caretaker dwellings and was therefore included in the assessment. The sites chosen were also those used in the visual impact assessment undertaken for the project (SKM 2009), refer Plate 1.

Beaches identified as potentially supporting turtle nesting at which the existing and predicted light spill are considered include:

- Cemetery Beach;
- Cooke Point; and
- Pretty Pools.

Settlement areas (residential and light industrial) at which the existing and predicted light spill are considered include:

- Public Gazebo at Port Laurentius (Port Hedland East);
- Port Hedland Hospital (Port Hedland East);
- Seasons Hotel (Port Hedland West);
- South Hedland; and
- Wedgefield.

Refer to Table 2 and Appendix E for locations of these areas and measuring point locations.

2.2 Fieldwork Methodology

The purpose of the field work was to measure the existing lighting conditions at the reference locations and to provide information required for modelling purposes. Full details of the measuring equipment used and the sensitivity of measuring equipment are provided in Appendix F.

Existing lighting for the formerly operated Boodarie Hot Briquette Iron plant, Nelson Point, Finucane Island and Anderson Point was observed both by day and by night. The daytime observations served the dual function of initial reconnaissance for potential night-time hazards, identifying where possible luminaire types and talking to staff at some of the facilities to ascertain additional information on lighting specifications that were used.

Night-time measurements were recorded at Cemetery Beach, Cooke Point, Pretty Pool Beach, adjacent to the Seasons Hotel, adjacent to Port Hedland Hospital, adjacent to the public gazebo at Richardson Point, and also at Wedgefield and South Hedland. The night-time measurements (illuminance and luminance) were timed to coincide with the new moon so that only the effect of electric lighting and star light would be measured. The effect of star light is several orders of magnitude below commercially available portable light measuring equipment capability and therefore was not expected to unduly affect any measurements.

Night-time measurements, both illuminance and luminance were made at a number of locations (refer Table 2 and Appendix E) and the positions of those measurements were recorded with a hand held GPS unit. The night-time measurements were taken on 2nd and 3rd of July 2008.

Illuminance is the quantity of light received at a given point but averaged per square metre (lumens/square metre). Illuminance is measured with an illuminance meter that is corrected to simulate the performance of the human eye. The unit of measurement is lux.

Luminance is the luminous intensity in a prescribed direction from an object that emits light divided by the projected area of that object towards that observation point. Unit of measurement is candela per square metre (cd/m^2).

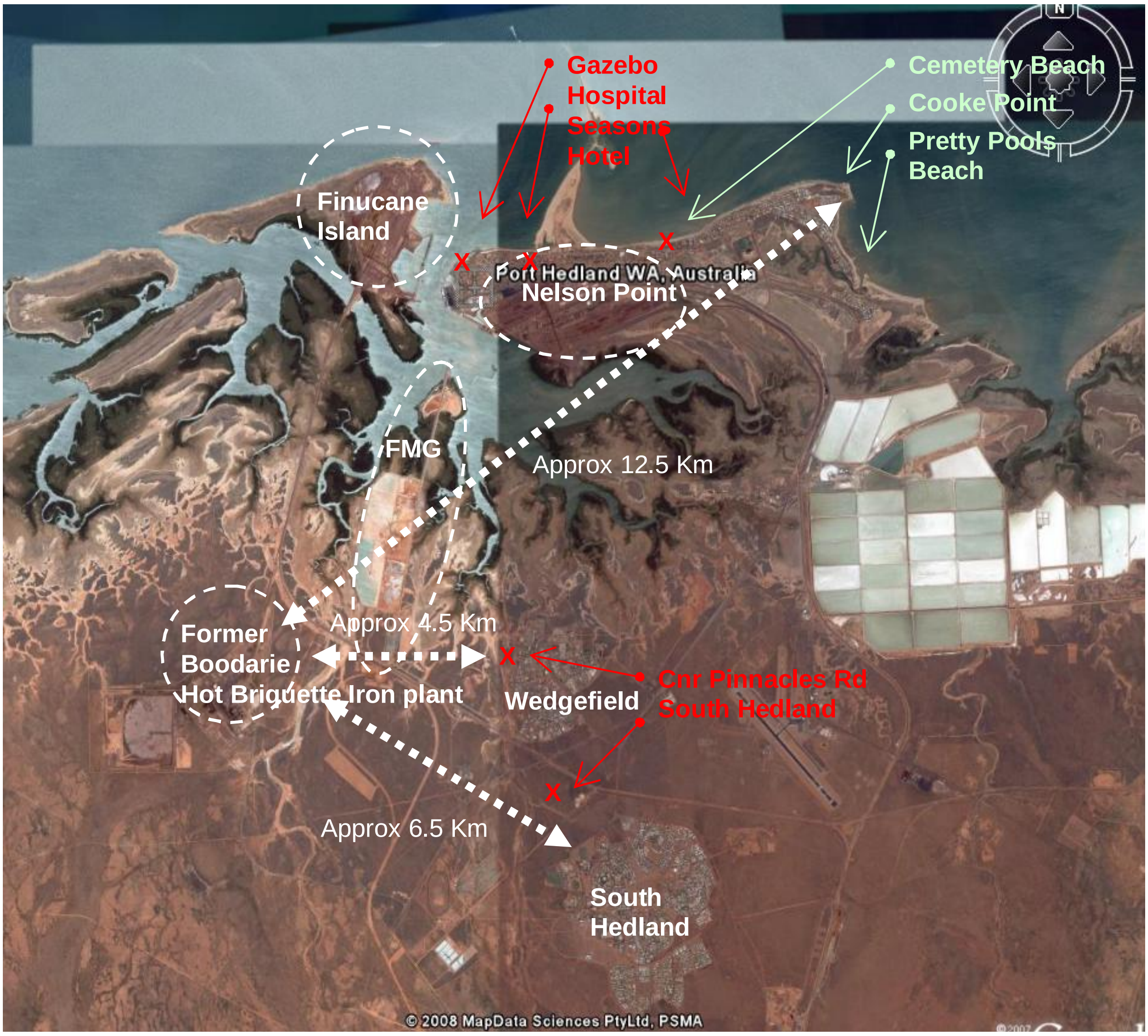


Plate 1. Project Visual Overview

2.3 Field Measurement Limitations

Field measurements are affected by various limitations of technology. Some of the factors which can have an influence on the measurements are:

2.3.1 Wavelength Sensitivity

Using the principle of best available technology (BAT), sensitive luminance and illuminance meters have been used to record measurements, however, such equipment is made to simulate the response of the human eye photopically to the different wavelengths of light in our visible spectrum and the results need to be interpreted carefully.

2.3.2 Luminance Measurement

The luminance results for various lights need to be interpreted with caution. Where the light source(s) did not fill the 1/3rd degree acceptance angle defined

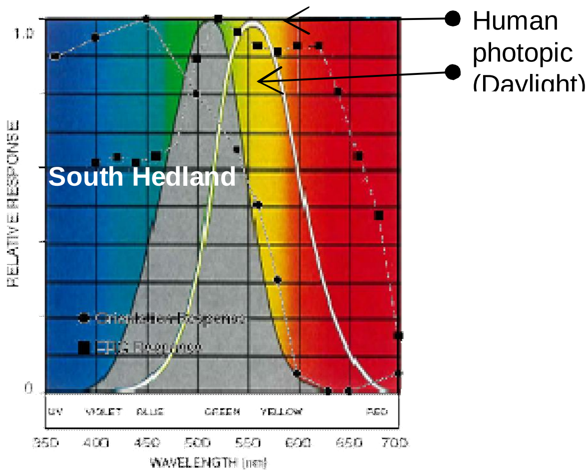


Figure 4 Human Visual Response Daylight (photopic) and Moonlight (scotopic) compared to Green Turtle Orientation and ERG Responses (Witherington and Martin, 2000, Philips Lighting, 1980's)

measuring area of the luminance meter deceptively low readings are recorded as the meter averages everything within the defined acceptance area. Where the distance is far too great to allow a complete filling of the luminance defined measurement area of the luminance meter the readings can only be an approximate guide to relative luminance's of similar clusters of luminaires at similar distances (refer Table 2 and Appendix G). The sky luminance measurements are accurate within the limits of the measuring equipment.

2.3.3 Illuminance Measurement

Illuminance is measured in two specific planes, viz, horizontal and vertical. Horizontal plane measurements (E_h) receive light from all directions and the larger the angle of light to the normal of the surface the less the value of illuminance (proportional to the cosine of the angle). Illuminance in a vertical plane (E_v) usually is higher in value than on the horizontal which makes vertical measurements important in light spill assessment. The added complication with a vertical plane is that it has to be in a specific direction. Light perpendicular to a surface will provide the highest illuminance values and therefore the E_v values shown in Table 2 have been measured on the basis that the illuminance meter faces vertically directly towards the brightest light sources.

At locations where there was more lighting than just iron ore related industrial infrastructure lighting in the field of view it was physically impossible to isolate the direct component of light reaching that measurement point from the industrial lighting from street lighting, sports lighting, other industry lighting, house lighting etc. Such illuminance measurements are a measure of ambient conditions.

The generally accepted average illuminance value for moonlight is 0.2 lux (see Fig 3) but that depends on the altitude of the moon and if it is a full moon. The maximum illuminance values permissible in AS4282-1997 vary according to the time of night, the darkness of the area and whether or not there is an adjoining commercial area and varies from 1 lux to 25 lux (refer to Appendix B). With respect to AS4282 usually only the lighting that is subject to a particular development application is assessed. Street lighting is not subject to assessment under AS4282 and any comparisons to street lighting in this report are included for comparison with existing conditions only and to provide guidance as to whether or not the increase imposed by the new port infrastructure is likely to be noticeable.

2.3.4 Sky Glow

Sky glow is reflected light off particulates in the atmosphere back towards an observer. For any given quantity of upwards directed light the amount of sky glow will be directly proportional to the quantity of particulates in the atmosphere. The particulates include moisture vapour, salt and dust. With sufficient intensity of light combined with sufficient particulates on any one evening there may be adequate reflected light to produce a measureable result. Only the atmosphere in close proximity to a light may produce a glow on most nights whereas on a misty or overcast evening there may be a much more noticeable glow. When only the atmosphere in close proximity to the light sources of concern was visible and the direct light from light source(s) was not able to be shielded from view, a luminance measurement only was taken and recorded in Table 2. Where the effect of sky glow was separable from direct views of any light source then an illuminance measurement is shown in Table 2 if the effect was within the measurement range of the illuminance meter.

2.3.5 Dazzle and Distance

When a relatively bright light source is at some distance and forms an angular diameter of less than 2 minutes of arc, the human visual system has difficulty resolving the detail and it is seen as dazzle rather than glare and the bright spot seems much larger than its actual physical dimensions.

2.4 Computer Modelling

2.4.1 Calculation Methodology

Table 1 provides a summary of the four light spill scenarios that were modelled. Existing port developments in the Port Hedland area (refer section 1.2) are a major source of light, as was the Boodarie Hot Briquette Iron plant when it was operational (see Plates 22, 31, 32, and 36 refer Appendix I). As a result light spill from these sources was modelled for comparison with light spill generated from the proposed Outer Harbour Development.

3D modelling was carried out using light calculation software AGI32 version 2.03, an industry accepted 3D light modelling software and the most current version at the time of modelling. Modelling of the sites is based on drawings of existing infrastructure where available, observations of types and locations of luminaires on site, discussions with staff on site and previous experience in lighting for the iron ore industry. The topography was also modelled in 3D using iso-contours provided by SKM. AGI32 algorithms provide values for direct light but do not include sky glow from particulates in the atmosphere nor the influence of a gas flare.

The topographical layout of the site, dunes and the existing port developments were modelled in 3D which consisted of a series of three dimensional objects, of irregular shape stacked on top of each other in accordance with the topographical map provided by SKM. The luminaire positions were then overlayed and vertical calculation points (E_v) were created along the receptor sites with the light meter facing the iron ore facilities. The computer model is then run to predict illuminance values.

The existing port development light spill scenario (scenario A) includes both currently existing port developments and those currently planned which will be operational when the proposed Outer Harbour Development construction commences, for example Port Harbour Port Authority's proposed Utah Point Facility and BHP Billiton Iron Ore's proposed Rapid Growth Project 5 facility. Information on proposed infrastructure for planned developments was sourced from Port Harbour Port Authority (2008) and BHP Billiton Iron Ore (2008).

Modelling of the light spill from the proposed Outer Harbour Development infrastructure (Scenario B) is based on the visual impressions provided by SKM and shown in Appendix H plus proposed locations and luminaire selection as noted in the assumptions stated in Appendix A. Computer modelling of the proposed jetty infrastructure includes two 1000 watt Jet1000N floodlights mounted back-to-back on 10 m poles at 40 m spacing on the proposed jetty. The floodlights are directed along the length of the jetty, not across the jetty. The floodlights are aimed with the front glass horizontal to minimise light spill and brightness of the floodlights when seen from a distance. Eight berthed ships were also included in the proposed Outer Harbour Development modelling scenario to represent worst case scenario, although it is acknowledged that it is unlikely that eight ships would be berthed at any one time. Lighting on the ships is unique to each ship and not controlled by BHP Billiton Iron Ore. The lighting can be a mixture of high pressure sodium, metal halide and mercury vapour. Typically there are four to six floodlights mounted above the bridge and three to four floodlights mounted on the foremast. The computer simulations include eight ore carriers with ten high pressure sodium floodlights on each.

2.4.2 Modelling Output

Illuminance values obtained in modelling for the proposed Outer Harbour Development were represented visually as:

1) isolux contours overlaid on aerial photography; and

2) pseudo-colour rendered imagery.

Pseudo-colour rendering provides a colour rendered image that represents specified criteria. It is a technique that can provide an easier to interpret visual impression than the more detailed iso-lux contour plots. Interpretation requires a scale to indicate the value each colour represents; red is usually the highest value for the range chosen and blue is the lowest value in the range chosen. In this instance red is greater than or equal to 5 lux and blue is equal to 0 lux.

2.4.3 Cumulative Light Spill

For the purposes of this report 'cumulative light spill' is considered in two ways:

1) Cumulative port development lighting: This includes the calculated illuminance values for the existing port development scenario (Scenario A) and the proposed Outer Harbour Development scenario (Scenario B). This does not reflect sky glow, lighting from street lights, residential lighting, sports lighting and offshore lighting.

2) Cumulative ambient lighting: This includes the measured values for ambient lighting at all sites during the site visit and the modelled output under the proposed Outer Harbour Development lighting scenario (Scenario B). This includes street lighting, residential lighting, sports lighting and offshore lighting. For this reason, cumulative ambient light spill will always be greater than that for cumulative port development lighting.

Table 1 Lighting Scenarios Modelled with Computer Software AGI32		
MODELLED LIGHTING SCENARIO	DESCRIPTION OF THE AREA	LIGHTING USED IN COMPUTER MODELLING
A) Existing port development light spill	Light spill from Fortescue Metals Group's Anderson Point facility, BHP Billiton Iron Ore's Nelson Point and Rapid Growth Project 4 facilities (Finucane Island), the Port Hedland Port Authority's Nelson Point facilities. Modelled light spill from the Port Hedland Port Authority's proposed Utah Point facility and BHP Billiton Iron Ore's proposed Rapid Growth Project 5 facility are also included.	Finucane Island: Stackers and reclaimers lighting → 400W HPS lighting Wharf lighting → 70W HPS lighting Conveyor lighting → 70W, 150W HPS lighting Rapid Growth Project 4 250W HPS lighting and 1000W MH lighting Other areas: Stackers and reclaimers lighting → 400W HPS lighting Wharf lighting → 70W HPS lighting Conveyor lighting → 70W HPS lighting
B) Outer Harbour Development light spill	Outer Harbour Development light spill only	Includes stockyard lighting, transfer station, over land conveyor lighting, jetty lighting, wharf lighting, ship-loader lighting and berthed ships. Refer material provided by SKM in Appendix A
C) Cumulative port development light spill	Outer Harbour Development light spill and light spill from existing port developments	Scenario A & B
D) Boodarie Hot Briquette Iron plant light spill	Light spill from the Hot Briquette Iron plant when fully operational (pre-existing facility prior to decommissioning)	2 x 36 W fluorescent lighting in the inner perimeter of the Hot Briquette Iron plant tower, 400W, 250W, 70W HPS along the perimeter of the building for area lighting

2.5 Photography

The human visual system has a much greater capacity to adapt to lighting and the range of brightness's in the field of view than any camera. This is particularly important for night-time photography. Images were recorded with digital cameras at settings that ultimately produced images that provided as realistic as possible representations of each particular aspect (refer Appendix I).

3.0 Existing Lighting

3.1 Beaches Potentially Supporting Turtle Nesting

3.1.1 Light Sources

Four main varieties of existing light sources are present at the three beaches: existing port development lighting, offshore lighting, local street lighting and sports lighting (refer Appendix I).

Lighting from existing port developments e.g. Finucane Island, Rapid Growth Project 4 is visible from Cemetery Beach. This lighting is located on ship loaders, conveyors and conveyor transfer structures, stackers and reclaimers. The lighting comprises a mixture of metal halide, high pressure sodium and mercury vapour. Lighting from existing port developments cannot be seen at Cooke Point or Pretty Pool Beach due to the presence of sand dunes which block direct views of these light sources.

Navigational lights, ship lighting comprising mercury vapour, metal halide and high pressure sodium are visible from Cemetery Beach. These light sources are not visible at Cooke Point and Pretty Pool for reasons stated above.

A white inverted cone-shaped water tower located east of the Seasons Hotel is lit up with metal halide lights making this a visually prominent feature at Cemetery Beach. This lighting is switched off during the turtle nesting season.

Metal halide floodlights at Matheson Oval (behind Tinder Street) are a visually prominent feature at Cooke Point and Pretty Pool. These lights are turned off during the turtle nesting season.

Street lighting comprising of mercury vapour and high pressure sodium are present at all three beaches.

3.1.2 Illuminance

Full moon provides illuminance values to approximately 0.2 lux and it can be seen from Table 2 that the majority of illuminance measurements (in the vertical plane) at turtle nesting beaches are one order of magnitude below this value. This means the light is noticeably less than full moonlight. At Cemetery beach illuminance measurements taken in the direction of the water tower (MP3), the proposed jetty (MP4) and dune (MP4) are the same order of magnitude as full moonlight. Dominant light sources contributing to this include the well-lit water tower and street lights (see Plates 20 and 23, Appendix I).

3.1.3 Luminance

Luminance measurements recorded at the turtle nesting beaches are far less than the luminance of the full moon (3500 cd/m^2) (Table 2).

3.1.4 Sky Glow

Sky glow from Finucane Island (Rapid Growth Project 4) and Nelson Point is visible at Cemetery Beach (MP 1, 3, 5) and Pretty Pool (MP1) as atmosphere in the proximity of lights is visible. Illuminance values for this sky glow are one order of magnitude less than full moonlight (Table 2). The dunes at Cooke Point beach shield much of the view of the sky towards the proposed development and therefore shield views of sky glow under most circumstances. The sports floodlights of Matheson Oval when switched on will dominate any sky glow effects as seen from Pretty Pool or Cooke Point beaches.

3.2 Settlement Areas

3.2.1 Light Sources

Four main varieties of existing light sources may be present at settlement areas: existing port development lighting, offshore lighting, local street lighting and sports lighting (refer Appendix I).

Lighting from existing port developments are visible at all sites to varying degrees. The visible light sources vary depending on the location and the infrastructure visible to that observation point and can at any one time be a mixture of or only one of metal halide, high pressure sodium, mercury vapour or fluorescent lighting. The existing port development lighting is most prominent at the Gazebo site at Point Laurentius which overlooks the Rapid Growth Project 4 ship loading facilities, followed by the Hospital and Seasons Hotel. Lighting from Fortescue Metals Group's development at Anderson Point and the decommissioned Hot Briquette Iron plant are visible at Wedgefield and South Hedland. This lighting comprises roadway and general area lighting, infrastructure lighting, conveyor and conveyor transfer station lighting and is a mixture of light sources as noted above.

Navigational lights (blinking red, and green plus static blue), ship lighting comprising mercury vapour, metal halide and high pressure sodium area visible at the Hospital, Gazebo and Seasons Hotel.

Metal halide sports floodlights, at the sports oval on Hudson Way in South Hedland is a visually prominent feature.

Street lighting comprising of mercury vapour and high pressure sodium is present at the Hospital (MP1), Gazebo, Seasons Hotel, Wedgefield and South Hedland.

Table 2: Illuminance and Luminance Measurements at Port Hedland (refer to Glossary, Appendix D for definition of lighting terminology)

Measurement Point		Description	Measured Values		Notes: Measurements intentionally taken during no moon
No	**Location**		**cd/m^2**	**lux**	
Pretty Pool Beach					
MP1	20^O 18.812' S 118^O 38.643' E	Luminance of main sports floodlights	98.9		Measurements started 1715 hrs local time 2/07/2008. Slightly overcast sky. Main sports stadium metal halide floodlights (Matheson Oval) switched on.
		Luminance of sky glow adjacent sports lights	0.04		
		Illuminance E_v towards sports lighting		0.04	
		Illuminance E_v towards sea		0.02	
		Illuminance E_v from sky glow (towards 240 deg)		0.01	
Cooke Point Beach					
MP1	20^O 18.099' S 118^O 38.380' E	Illuminance E_v towards house on corner		0.04	Under the dune there is no view of lights towards Rapid Growth Project 4. Some mercury vapour street lights visible towards pretty ponds direction. At low tide walking towards sea the sports lighting is visible. Sports lighting switched off a 1945 hrs before measurements taken
MP2	20^O 18.085' S 118^O 38.356' E	Luminance of sports floodlights (Matheson oval)	850		Moving away from dune at low tide. Sports floodlights switched back on 2000 hrs
		Luminance of street light	895		
		Illuminance E_v towards sports flood lights		0.05	
Cemetery Beach					
MP1	20^O 18.514' S 118^O 36.561' E	Luminance of water tower, up-lit with metal halide	57		Near Seasons Hotel. 10 ships visible waiting out to sea with all floodlights blazing
		Illuminance @ 240 deg towards new jetty		0.03	
		Illuminance E_v towards Rapid Growth Project 4		0.04	
MP2	20^O 18.428' S 118^O 36.669' E	Illuminance E_v towards tower at 150 deg		0.08	Adjacent Seasons Hotel and water tower
		Illuminance E_v towards sea (ship with floodlights switched on)		0.01	
		Illuminance E_v Rapid Growth Project 4 at 100 deg		0.01	
		Illuminance E_h		0.01	
MP3	20^O 18.441' S 118^O 36.531' E	Illuminance E_v towards Rapid Growth Project 4 at 100 deg		0.05	From streetlights mainly
		Illuminance E_v towards tower at 260 deg		0.30	
		Illuminance E_v towards ocean		0.01	
		Illuminance E_v towards dune		0.02	
		Illuminance E_h			Too low for meter
MP4	20^O 18.448' S 118^O 36.434' E	Illuminance E_v towards new jetty at 160 deg		0.18	From streetlights mainly
		Illuminance E_v towards water tower		0.04	
		Illuminance E_v towards ocean		0.01	
		Illuminance E_v towards dune		0.10	
		Illuminance E_h			Too low for meter

Table 2: Illuminance and Luminance Measurements at Port Hedland (refer to Glossary, Appendix D for definition of lighting terminology)					
Measurement Point		**Description**	**Measured Values**		**Notes: Measurements intentionally taken during no moon**
No	**Location**		**cd/m²**	**lux**	
MP5	20° 18.500' S 118° 35.908' E	Illuminance E_v towards tower at 70 deg		0.02	Sand bar excludes new jetty from view Extensive length of rock next to sand bar
		Illuminance E_v towards new jetty at 270 deg			
		Illuminance E_v from sky glow towards Rapid Growth Project 4		0.03	
		Illuminance E_h		0.04	
		Sky glow towards dune	0.01		
		Sky glow towards Rapid Growth Project 4	0.03		
Hospital					
MP1	20° 18.551' S 118° 35.351' E	Illuminance E_v towards 260 deg		0.16	Red and green blinking navigation lights in random sequences. Also blue lights. 10 Ships visible at sea with all floodlights blazing. Angular size 1/3rd degree (note 1)
		Illuminance E_v towards new jetty		0.10	
		Illuminance E_v towards HPS streetlight		0.55	
		Luminance of HPS streetlight	6540		
Gazebo at Point Laurentius					
MP1	20° 18.645' S 118° 34.482E	Illuminance E_v towards Rapid Growth Project 4 at 270 deg		0.66	Mostly high pressure sodium lamps but also some metal halide and mercury vapour
House Opposite Gazebo					
MP1	20° 18.669' S 118° 34.552' E	Illuminance E_v towards Rapid Growth Project 4		1.10	2345hrs 2/07/08
		Illuminance E_v behind streetlight		1.32	
Wedgefield, Pinnacle Road					
MP1	Corner of road	Illuminance E_v towards Fortescue Metals Group site		0.04	Virtually no sky glow. Nothing measureable.
		Illuminance E_h		0.00	
South Hedland					
MP1	Adjacent round-about	Sky glow towards Fortescue Metals Group site	0.2 to 0.08		Softball field floodlights do not fill 1/3rd degree target zone (note 1)
		Luminance of softball sports fields floodlights	396		
		Illuminance E_v towards Boodarie		0.09	
		Illuminance E_v towards softball sports fields		1.41	

Note 1: Luminance measurements are accurate where the bright source of concern fills the 1/3rd degree target zone of the luminance meter as indicated in the notes column in Table 2. The notes column also indicates where the value can only be used as a guide rather than an absolute measurement as the target zone was not completely occupied (for more detail refer section 2.3.2).

3.2.2 Illuminance

Illumination values recorded at all sites are generally below the values recommended in AS4282 (refer to Table 2 and Appendix E).

3.2.3 Luminance

Most luminance measurements of port facility lighting from the residential location measuring points would be totally inaccurate for the reasons explained in Section 2.3.2. The light sources would occupy only a small fraction of the luminance meter's angle of acceptance and therefore provide inaccurate results. Where valid, the information is provided in Table 2.

3.2.4 Sky Glow

Sky glow towards the Fortescue Metals Group operations and beyond towards Nelson Point was noticeable at South Hedland and measureable (0.2 to 0.08 cd/m^2 for Fortescue Metals Group). It varied depending on proximity of the measurement point to the actual luminaire locations, that is, adjacent intense light sources such as floodlights there was a brighter glow than a few degrees further above the horizon where the effect rapidly diminished.

On the night of measurement the atmosphere may have been quite clear of particulates as in a number of locations there was no noticeable sky glow from that observation point. Only those observation positions with a measureable quantity in specific directions are listed in Table 2.

4.0 Proposed Outer Harbour Development Project Infrastructure and Predicted Light Spill

4.1 General

The pseudo colour representation of proposed Outer Harbour Development light spill shows that the major emitting sources of light (as indicated by colours other than dark blue) include the jetty and stockyards area (see Figures 7 and 8). The light spill from pole mounted floodlights along the jetty will be contained to a band in close proximity to the jetty due to the choice of luminaires. On the sea surface the horizontal illuminance will be one order of magnitude below moonlight (that is 0.02 lux) 250 m from the edge of the jetty and vertical illuminance values will attenuate to the same value, 600 m from the edge of the jetty. This is based on the jetty lighting being in accordance with the details in Appendix A. The floodlights chosen have an asymmetric light distribution which allows them to be positioned as per the design with the front glass horizontal thereby minimising the extent of light spill. If the floodlights were aimed such that the front glass was above the horizontal, then as the angle above the horizontal increased so would the area of influence.

For the wharf and ship loading area, on the sea surface the horizontal illuminance will be one order of magnitude below moonlight (that is 0.02 lux) 1300 m from the edge of the jetty and vertical illuminance values will attenuate to the same value, 3200 m from the edge of the jetty.

Light spill from the jetty dissipates to a value close to 0.00 lux at all residential areas and turtle nesting beaches (see Figures 6, 9, 10 and 11). The lighting on the stackers and reclaimers will provide potentially provide the highest light spill as indicated by the fading red area in Figure 7. For the jetty, light spill will dissipate to a value close to 0.00 lux at all residential areas (Figures 5 and 6).

4.2 Beaches Potentially Supporting Turtle Nesting

4.2.1 New Light Sources

Lighting from the proposed Outer Harbour Development is highly unlikely to be seen from Pretty Pool or Cooke Point due to the large distance separating the proposed Outer Harbour Development and these areas (greater than 7 km) and that the project's lighting will be blocked by the surrounding topography (such as dunes). The existing sports floodlights from Matheson Oval will remain visually dominant at these locations in addition to street lighting (refer Appendices E and **I**).

During the construction period, high pressure sodium, metal halide and mercury vapour lighting on ships and dredge vessels will be visible. Light sources along the jetty, the wharf ship loaders and ships plus the overland conveyors will be visible to different locations depending on the luminaire in which the lamp is housed and the installed aiming. The new light sources will be high pressure sodium on the jetty plus navigation lighting (red, green, and blue) associated with the jetty and loading wharf facility. Navigation lighting may be either coloured light blinking red or green separate lights plus static blue separate lights with wavelengths in those regions of the spectrum regardless of whether the lamp is incandescent, tungsten halogen or LED. Lighting from the ships will be as previously described in Section 3

It is expected that more luminaires than existing will be visible based on visual impression in Plates 11, 12, 14, 15 and 16 (Appendix H).

4.2.2 Predicted Illuminance

Computer modelling of the direct cumulative port development scenario revealed that there will be no light spill from the proposed Outer Harbour Development at Cook Point or Pretty Pool (as indicated by the calculated value of 0 lux) (refer to Table 3, and Figure 9).

As the predicted direct light spill from the proposed Outer Harbour Development and cumulative light spill at Cemetery Beach is two orders of magnitude less than bright moonlight (0.2 lux) it is considered insignificant (Table 3, Figures 9 and 11). Cumulative port development light spill at Cemetery Beach is dominated by the contribution of light spill from existing port developments which are located in closer proximity (0.024 lux).

The light spill from the proposed Outer Harbour Development contributes minimally to the cumulative ambient lighting (total light from all possible sources) present at Cemetery Beach (0.301-0.011 lux) and represents no noticeable change in light spill as it is at least one order of magnitude less than cumulative ambient lighting (Table 4).

4.2.3 Sky Glow

The sports lighting of Matheson Oval visible at Cooke Point and Pretty Pool will dominate any sky glow at these locations when those lights are switched on. Depending on the installation of the luminaires used on the proposed Outer Harbour Development and the number of ships docked, there may be an increase in sky glow in the direction of Finucane Island and the wharf, which as previously mentioned, will depend on particulates in the atmosphere at that time. Use of the luminaires recommended in Appendix A generally on the proposed Outer Harbour Development project will reduce sky glow effects.

The lighting of the proposed jetty and ship loading facilities will increase sky glow seen from Cemetery Beach. Any open face type floodlights, bulkhead style luminaires and other omni-directional light distribution type luminaires used on Finucane Island, even though out of any direct line of sight to Cemetery Beach, will contribute to increased sky glow. The overall effect is not expected to be significantly brighter than existing sky glow as horizontal front glass floodlights are being used.

4.3 Settlement Areas

4.3.1 New Light Sources

The proposed jetty and ship loading facilities will be visible from the Gazebo, Hospital and Seasons Hotel. Visible light sources will be high pressure sodium. With the use of low glare luminaires with horizontal front glass (see Appendix A) the lighting from the jetty will virtually disappear from view.
Ship lighting from additional ships will be visible. The new light sources that will be visible are considered to be insignificant compared to the existing local lighting present, including street lighting which dominates these sites. In the case of the Gazebo site, existing port development facilities on Finucane Island are already a dominant source of lighting.

The proposed Outer Harbour Development stockyards (including stackers and reclaimers) and part of the overland conveyors will be visible from Wedgefield and South Hedland, although less noticeable at South Hedland due to increased distance from the development. Visible light sources will include metal halide area lighting and lighting on stackers and reclaimers, high pressure sodium lighting on overland conveyor areas.

4.3.2 Predicted Illumination

Computer modelling of the direct cumulative port development scenario revealed that there will be no predicted light spill at South Hedland resulting from the proposed Outer Harbour Development (as indicated by the calculated value of 0 lux) (Table 3, Figure 6).

Cumulative port development light spill (note this does not include any lighting other than port development lighting) at the gazebo, hospital and Seasons Hotel is the same order of magnitude as that modelled for the existing port developments scenario (Table 3). This suggests no noticeable change in existing port development lighting received at these locations.

The direct light spill from the proposed Outer Harbour Development is the dominant contributor (0.09 lux) to cumulative port light spill at Wedgefield (Table 3, Figure 9), but this light spill is lower than that likely to have resulted from the Boodarie Hot Briquette Iron plant infrastructure when it was fully operational (0.001 to 0.014 lux).

The light spill from the proposed Outer Harbour Development contributes minimally, if any, to the cumulative ambient lighting (total light from all possible sources) present at all residential areas other than Wedgefield and represents no noticeable change in light spill as it is at least one order of magnitude less than ambient lighting (Table 4). Light spill from the proposed Outer Harbour Development at Wedgefield (0.009 lux) is close to contributing a measurable change in ambient lighting (Table 4).

Predicted values of illumination at all residential locations are less than that stipulated under AS4282.

4.3.3 Sky Glow

The lighting of the proposed development will increase sky glow under some atmospheric conditions marginally as seen from residential sites and that will depend on observer location and view. Any open face type floodlights, bulkhead style luminaires and other omni-directional light distribution type luminaires used on Finucane Island even though they may be out of any direct line of sight to residential areas, will contribute to increased sky glow. The overall effect is not expected to be significantly brighter than existing sky glow as horizontal front glass floodlights are being used.

Table 3 Modelling Scenario Calculation Summary – Cumulative Port Development Lighting				
Location Towards Which Calculated Vertical Illuminances are Directed	Locations Where Luminaires Have Been Placed Based on Best Available Information. The Results Showing the Maximum Illuminance Value Contributions Anticipated. Refer to Notes for the Different Scenarios			
	Existing port facilities[1]*	Proposed Outer Harbour Development[2] *	Cumulative: Exist port facilities & Proposed Outer Harbour Development[3]*	Only Boodarie Hot Briquette Iron plant[4*]
	Max	Max	Max	
Beaches				
Cemetery Beach	0.024	0.001	0.025	0
Cooke Point	0	0	0	0
Pretty Pool Beach	0	0	0	0
Settlement l Areas				
Public Gazebo	1.679	0.01	1.689	0
Hospital	0.036 to 0.064	0.001	0.037 to 0.065	0
Seasons Hotel	0.001 to 0.002	0.001	0.001 to 0.003	0
Wedgefield	0	0.009	0.009	0.001 to 0.014
South Hedland	0	0	0	0

Notes:

* [1]Existing port facilities – BHP Billiton Iron Ore's existing Rapid Growth Project 4 and Nelson Point facilities and planned Rapid Growth Project 5 facility, Port Harbour Port Authority's Nelson Point facility and planned Utah Point facility, Fortescue Metals Group's Anderson point facility.
* [2]Proposed Outer Harbour Development lighting - Proposed Outer Harbour Development stockyard, conveyors and jetty facilities.
* [3]Existing port facilities and Proposed Outer Harbour Development – Cumulative; that is, existing port facilities lighting and the proposed Outer Harbour Development lighting combined.
* [4]Boodarie Hot Briquette Iron plant – Simulation of pre-existing lighting at the Boodarie site

Refer Appendix G for calculation diagrams.

Table 4 Modelling Scenario Calculation Summary - Cumulative Ambient Lighting			
Location Towards Which Vertical Illuminances are Directed	Ambient lighting measurements taken from Table 2	Proposed Outer Harbour Development calculated	Combined ambient lighting & Proposed Outer Harbour Development calculated
	Max	Max	Max
Beaches			
Cemetery Beach	0.30 – 0.01	0.001	0.301 – 0.011
Cooke Point	0.05 – 0.04	0	0.05 – 0.04
Pretty Pool Beach	0.04 – 0.01	0	0.04 – 0.01
SettlementAreas			
Hospital	0.55 – 0.10	0.001	0.551 – 0.101
Seasons Hotel	0.04 – 0.03	0.001	0.041 – 0.031
Wedgefield	0.04	0.009	0.049
South Hedland	1.41 – 0.09	0	1.41 – 0.09

Key:
Green lines: Topographical contours modelled in 3D
Grey area: Calculation grid points
Blue and red lines: ore processing and delivery facilities modelled

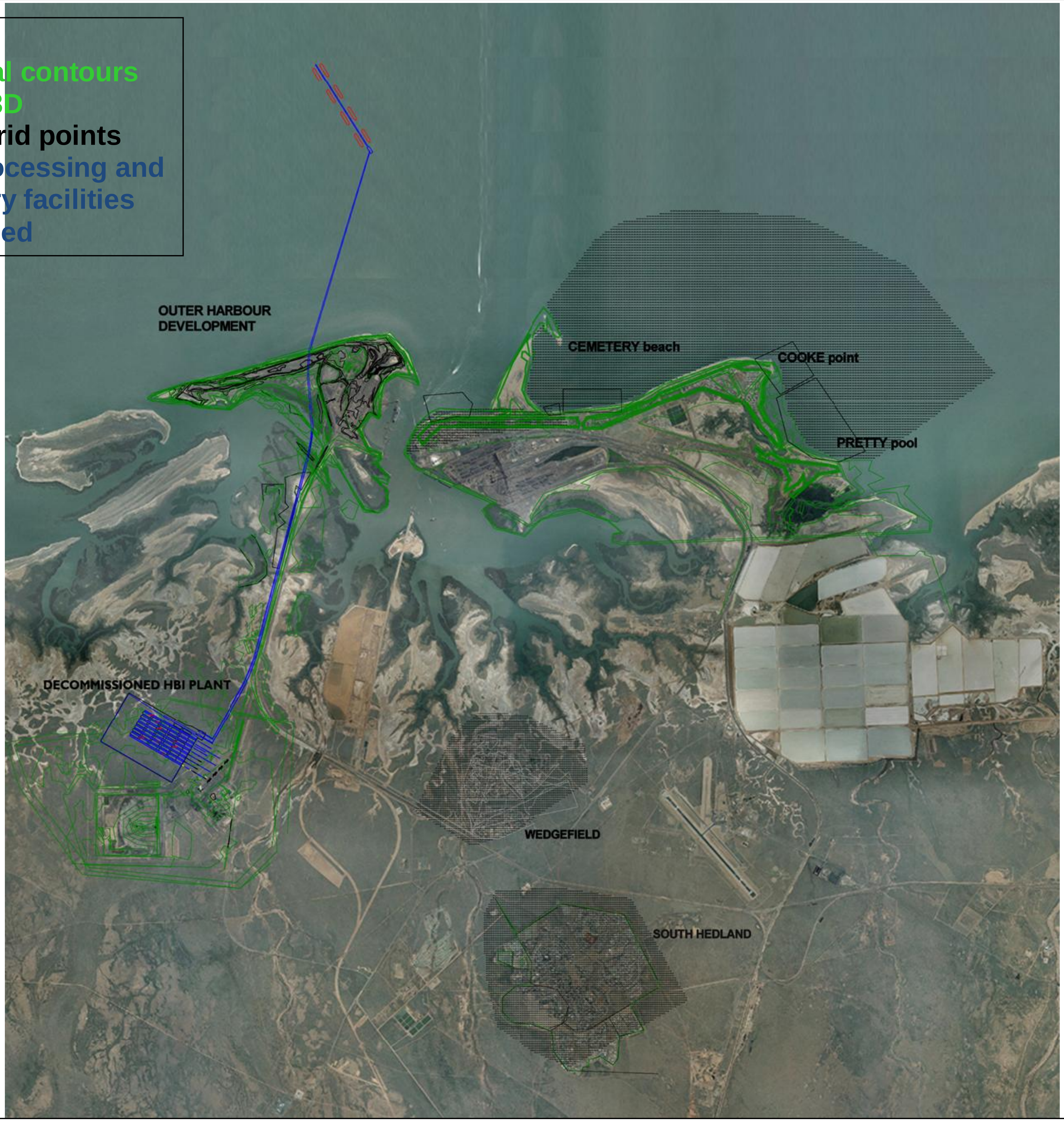


Figure 5 Modelling Scenario B: OHD LIGHTING EFFECT ON SOUTH HEDLAND, WEDGEFIELD, PORT HEDLAND & TURTLE BEACHES MODELLING CALCULATION FIELDS AND TOPOGRAPHICAL CONTOURS INCLUDED (refer Fig 6 for detailed isolux results).

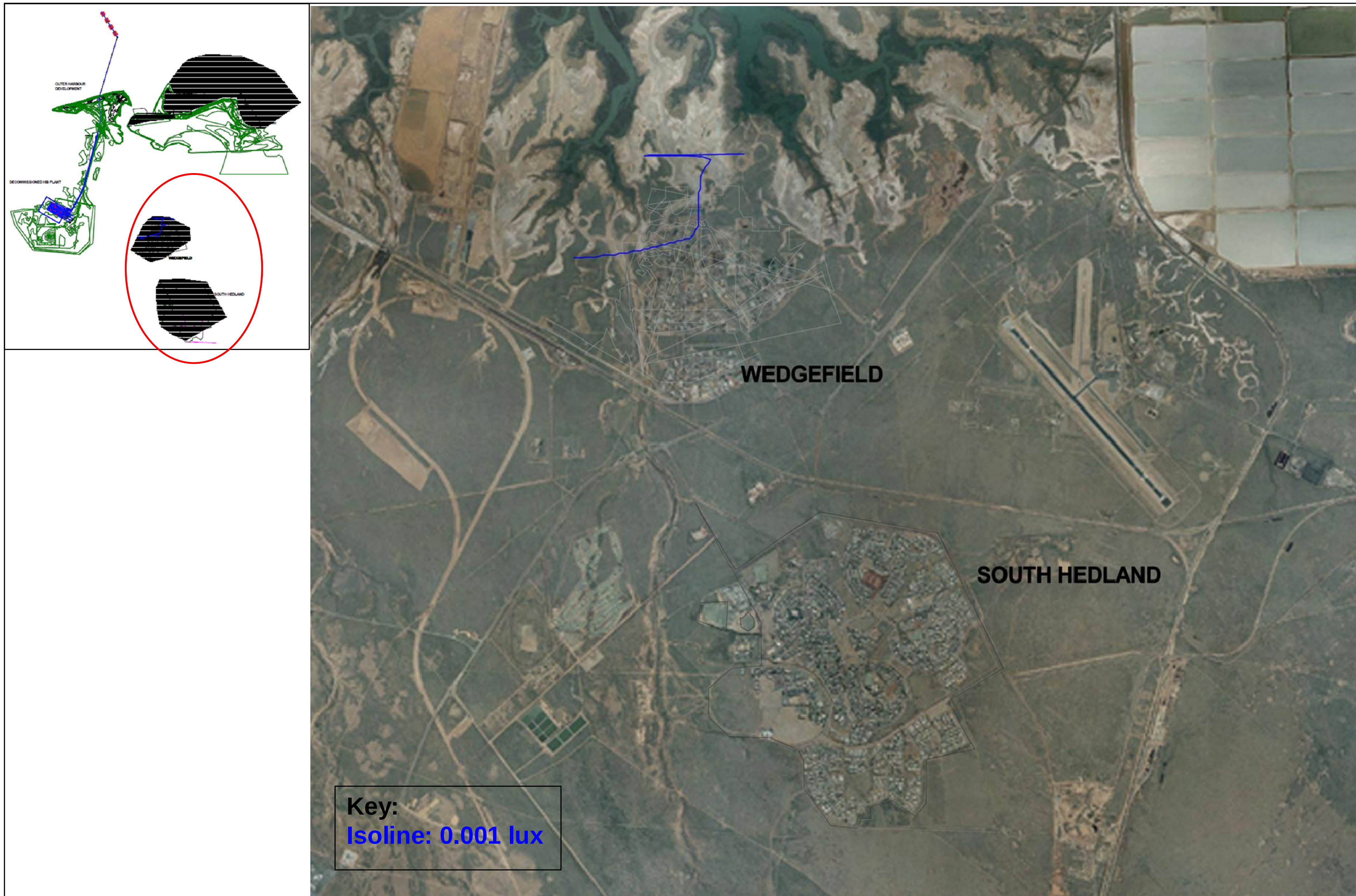


Figure 6 Modelling Scenario B: OHD LIGHTING EFFECT ON SOUTH HEDLAND, WEDGEFIELD (detail)

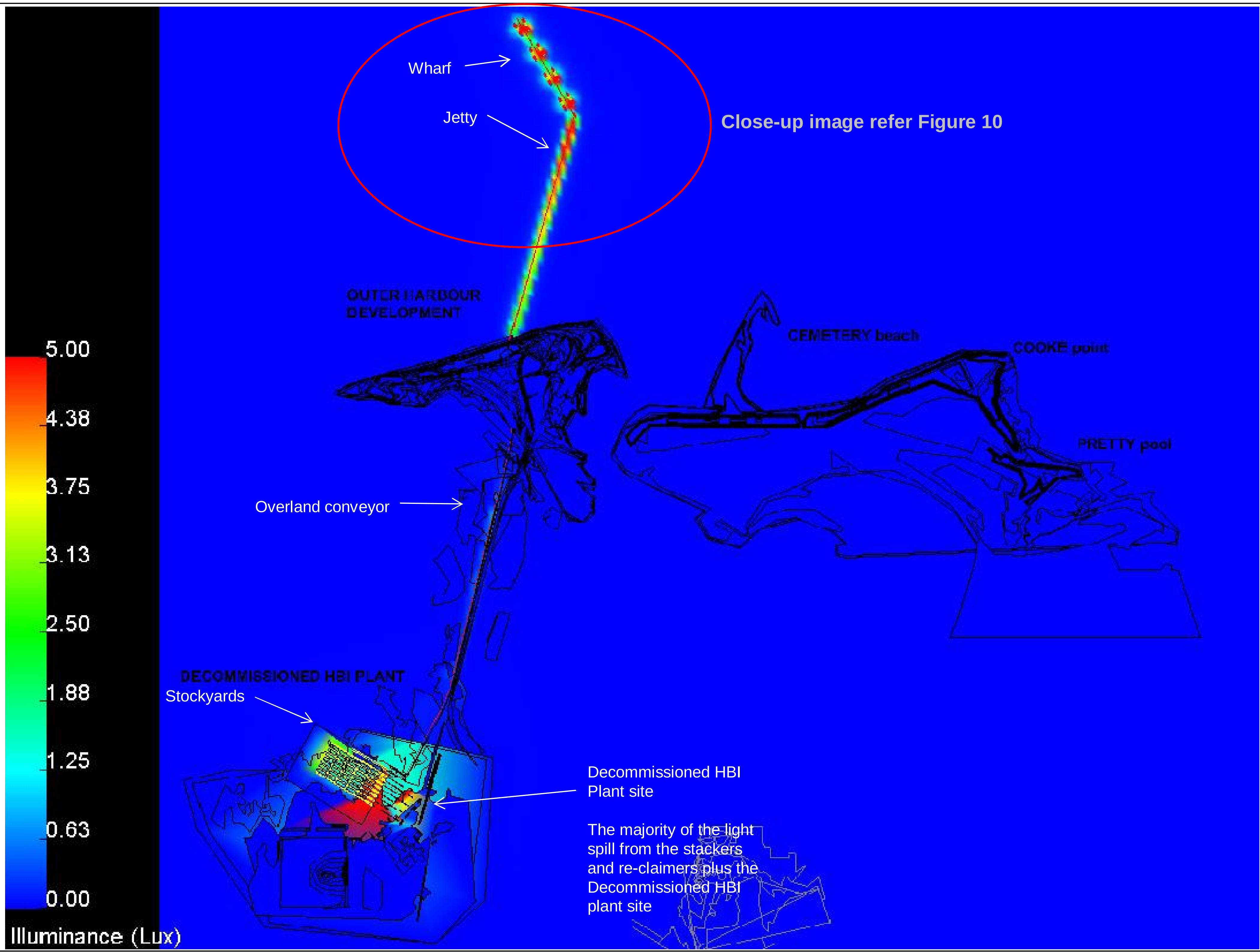


Figure 7 Modelling Scenario B: PSEUDO COLOUR REPRESENTATION OF OHD LIGHTING

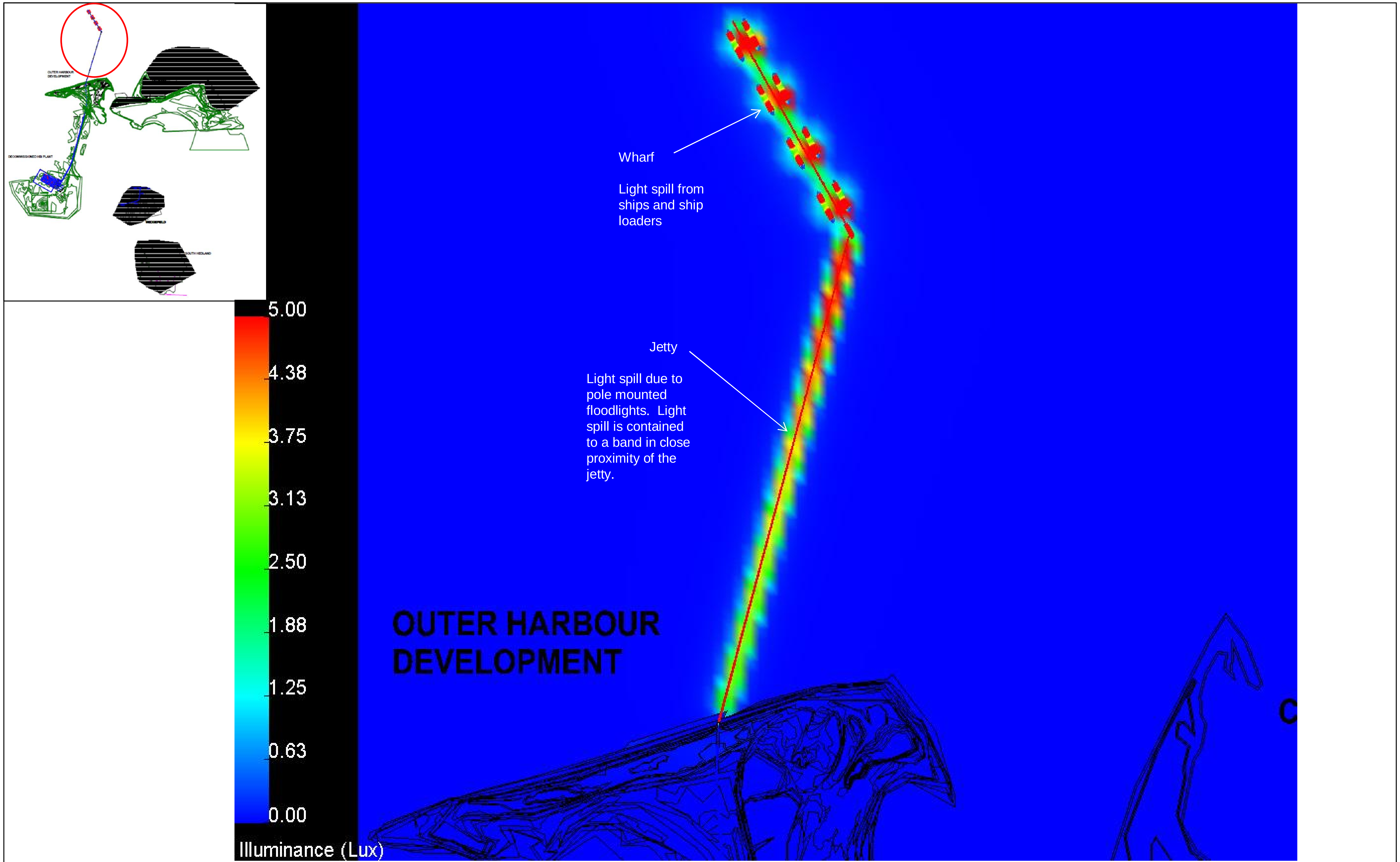


Figure 8a Modelling Scenario B: PSEUDO COLOUR REPRESENTATION OF THE JETTY, WHARF AND SHIP LOADER LIGHTING

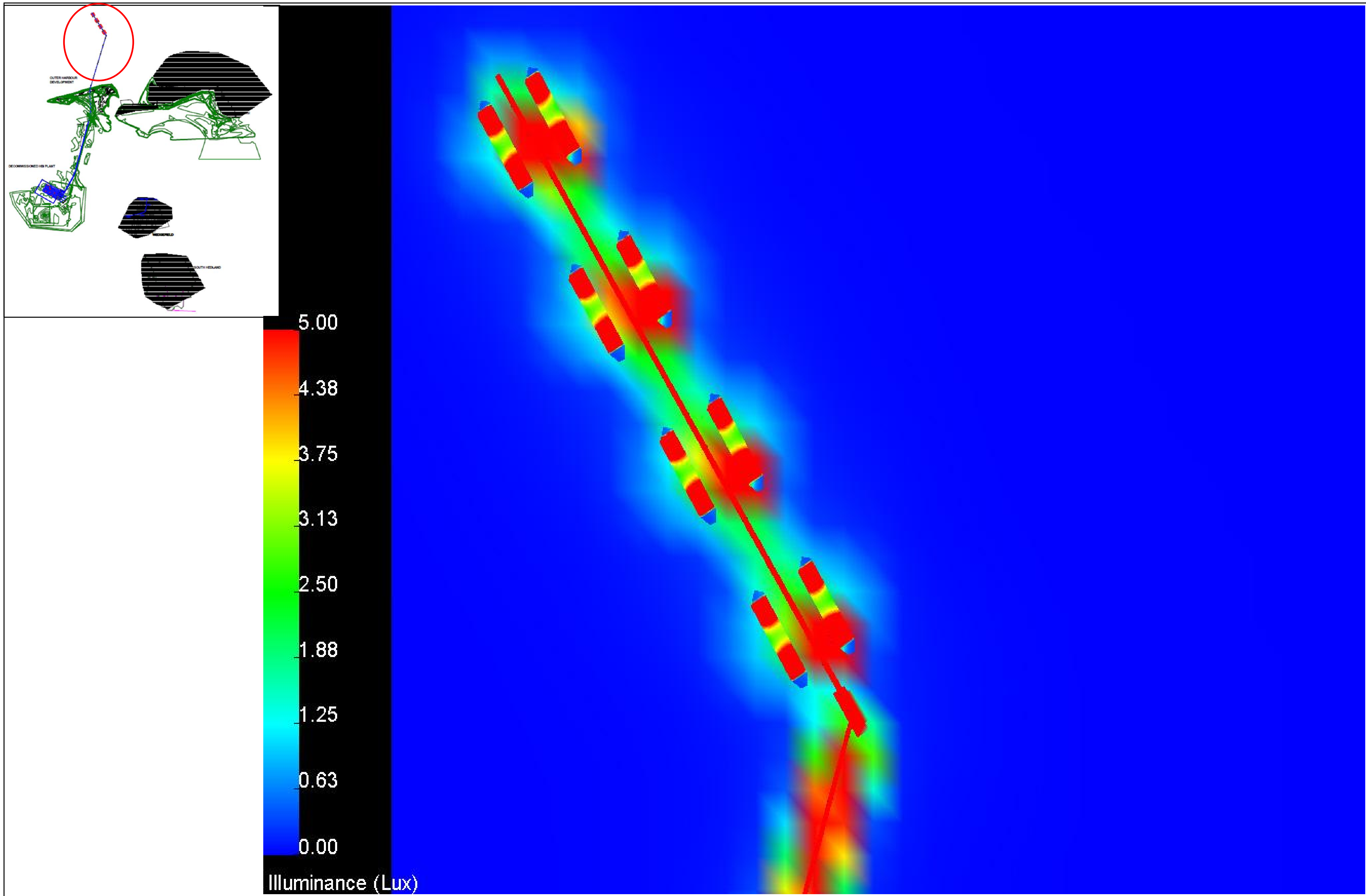


Figure 8b Modelling Scenario B: PSEUDO COLOUR REPRESENTATION OF THE WHARF AND SHIP LOADER LIGHTING

Key:
Green lines: Topographical contours modelled in 3D
Grey area: Calculation grid points
Blue and red lines: ore processing and delivery facilities modelled

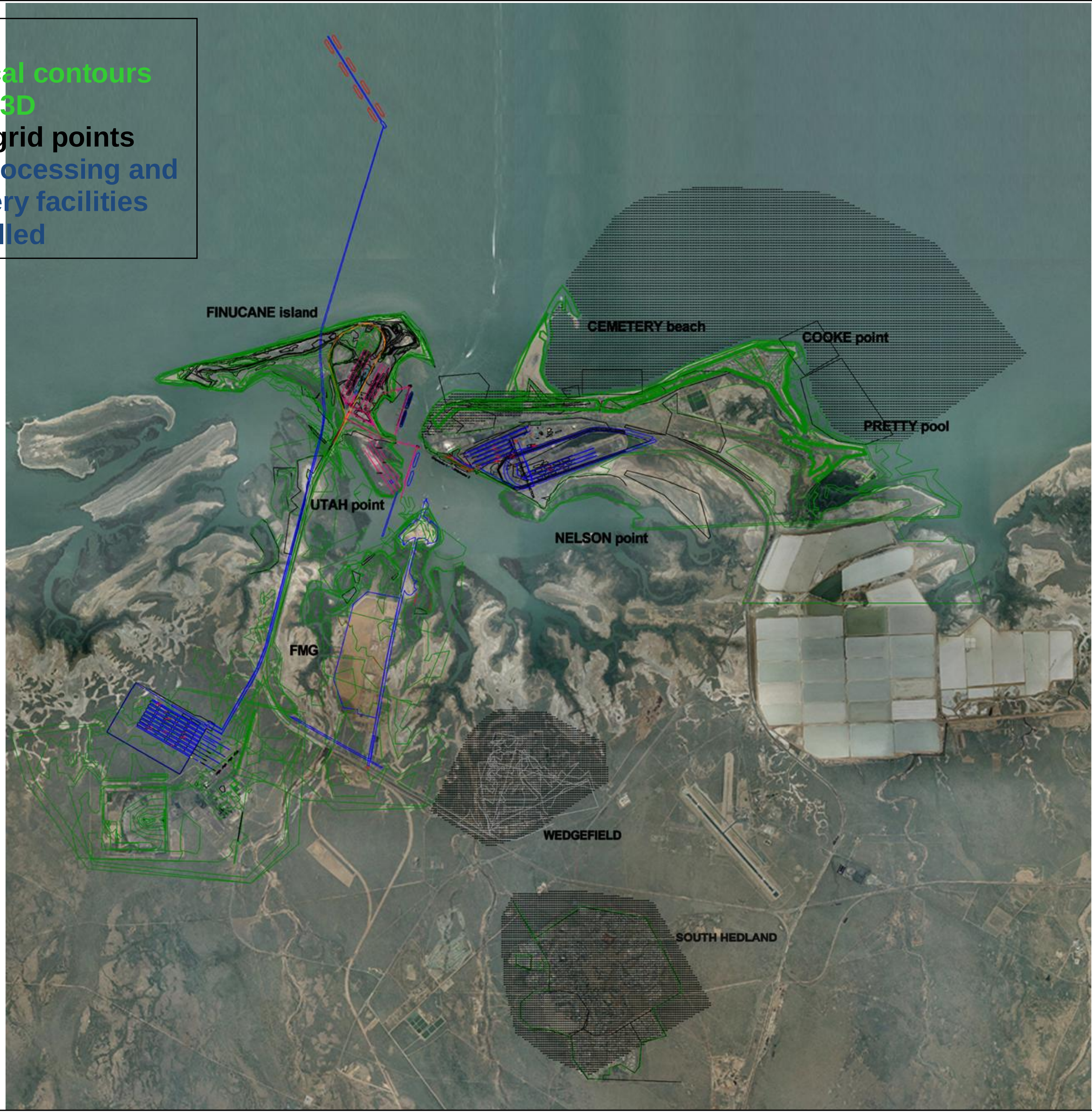


Figure 9 Modelling Scenario C: CUMULATIVE LIGHTING EFFECT ON SOUTH HEDLAND, WEDGEFIELD, PORT HEDLAND & BEACHES (refer Figures 10 and 11 for detailed isolux results and Figure 1 for location of proposed and existing developments)

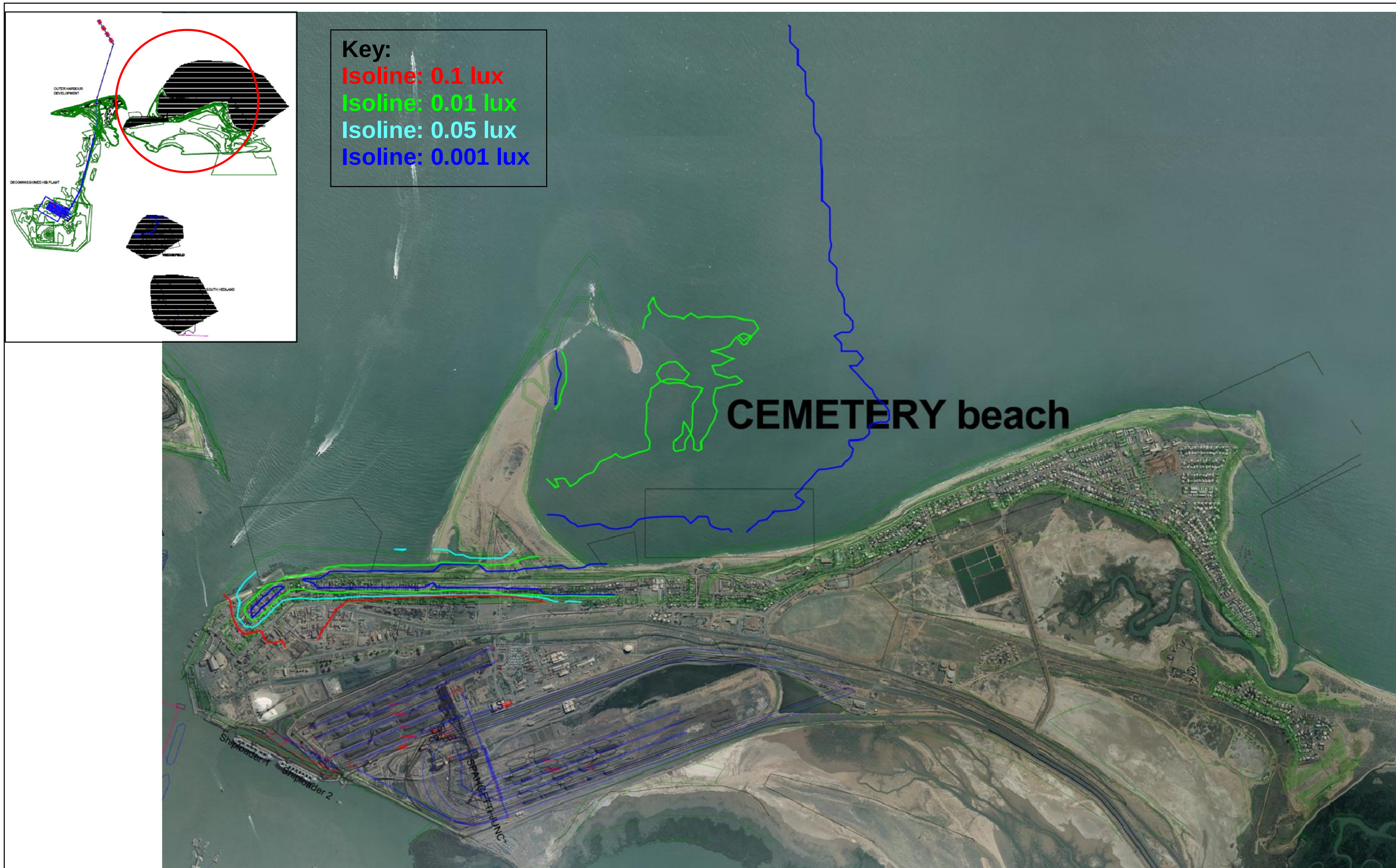


Figure 11 Modelling Scenario C:
CUMULATIVE LIGHTING EFFECT ON SOUTH HEDLAND, WEDGEFIELD, PORT HEDLAND & BEACHES

5.0 Summary

5.1 Beaches Potentially Supporting Turtle Nesting

Key findings from this assessment for effects of the proposed Outer Harbour Development lighting on beaches potentially supporting turtle nesting are summarised below.

- Lighting from the proposed Outer Harbour Development jetty rather than land-based infrastructure will have the greatest potential to effect Cemetery Beach.
- The light spill from the proposed jetty will not be visible at either Cooke Point or Pretty Pool Beach due to topographical barriers and the large distance separating these sites from the proposed Outer Harbour Development.
- The light spill from the proposed jetty will be visible at Cemetery Beach, albeit, modelling results indicate Outer Harbour Development direct illuminance levels and cumulative ambient lighting levels are less than moonlight.
- The modelling results for the proposed Outer Harbour Development do not represent a noticeable increase in existing port development lighting or ambient lighting.
- During the construction period, high pressure sodium, metal halide and mercury vapour lighting on ships and dredge vessels will be visible at Cemetery Beach.
- Sky Glow from the proposed Outer Harbour Development is unlikely to be evident at Cooke Point as the presence of large sand dunes at this site will block the majority of any sky where such an effect would be visible. With the topography, views from Pretty Pools Beach are closer to the horizon and therefore may under conditions of heavy moisture or dust provide a minimal increase close to the horizon but this will be insignificant in comparison to any sky glow effect from the sports lighting of Matheson Oval. Depending on the weather conditions, if there is a lot of moisture or particulates in the atmosphere, there may be a marginal increase in sky glow as seen from Cemetery Beach. The overall effect is not expected to be significantly brighter than existing sky glow under any one set of atmospheric conditions.

5.2 Settlement Areas

Key findings from this assessment for effects of lighting from the proposed Outer Harbour Development on specific locations in areas of settlement are summarised below.

- The chosen residential sites will have varying views of the proposed Outer Harbour Development infrastructure and lighting.
- The proposed Outer Harbour Development jetty lighting will be visible at the gazebo, hospital and Seasons Hotel.
- The lighting associated with the proposed infrastructure corridor, specifically the overland conveyor, may be visible at the gazebo site.
- The lighting associated with the proposed Outer Harbour Development stockyards and overland conveyors will be visible at Wedgefield and South Hedland.
- Modelling results indicate that the illuminance values from the proposed Outer Harbour Development do not represent a noticeable increase in existing port development lighting or ambient lighting, with exception of Wedgefield where there may be a slight change in illuminance values.
- The lighting from the Boodarie Hot Briquette Iron plant, when operational, would have had greater impact than the proposed Outer Harbour Development with respect to residents in Wedgefield and South Hedland due to the original quantity of lighting on the site, the height of the lit stack and the gas flare burning off volatile gases produced by processing the ore into briquettes.
- Cumulative ambient illuminance levels at all residential sites do not exceed the limitations imposed by Australian Standard AS4282.
- Inappropriately aimed or selected types of floodlights have the potential to exceed the luminance limits stated in AS4282, particularly for those residents at the Gazebo (Port Hedland east) and Wedgefield. Selection of the right type of luminaire, usually of appropriate asymmetric distribution will control any light spill (providing it is installed and aimed as intended).
- Depending on the weather conditions, if there is a lot of moisture or particulates in the atmosphere, there may be a marginal increase in sky glow depending on location of the observer and the field of view. The overall effect is not expected to be significantly brighter than existing sky glow.

5.3 Conclusion

The light spill assessment indicates the direct lighting associated with the proposed Outer Harbour Development will have minimal impact on the beaches which may potentially support turtle nesting and areas of settlement. The modelling results for the proposed Outer Harbour Development do not represent a noticeable increase in existing port development lighting or ambient lighting at beaches or areas of settlement with the exception of Wedgefield where a slight change is predicted. However, light spill from the former Boodarie Hot Briquette Iron plant lighting would have been greater at Wedgefield than light spill from the proposed Outer Harbour Development. The use of asymmetric distribution floodlights aimed with front glass close to horizontal along the jetty will reduce light spill and potential sky glow significantly and reduce the visual impact of the luminaires. This approach along the jetty is environmentally responsible and good practice.

Any lighting in stockyards if aimed away from residential areas will minimise any unnecessary light spill in those directions.

The lighting impacts to turtles are addressed in a separate report.

6.0 Bibliography

BHP Billiton Iron Ore (2008) Port Hedland Finucane Island Dredging, Environmental Referral Document

Department of Agriculture, Western Australia
Technical Bulletin No 92, December 2004
An inventory and condition survey of the Pilbara region, Western Australia

Environment Protection Authority
Environmental Guidance for Planning and Development No 33
Part C Pollution Management, Chapter 5 Light, Radiation and Electromagnetic Fields.

Google Earth Pro,2008
Port Hedland

PHPDA (2008) Utah Point Berth Project, Port Hedland, Public Environment Review

Philips Lighting International BV, 1987
Correspondence Course
No 9 Fluorescent Lamps.

Philips Lighting International BV, 1987
Correspondence Course
No 10 High-pressure Mercury and Metal Halide Lamps

Philips Lighting International BV, 1987
Correspondence Course
No 11 Low and High Pressure Sodium Lamps.

Philips (no publication date but known to be early 1980's)
LIGHT, Sight, Science, Sources,
8 page information pamphlet included in LIGHTING: Basic Concepts, Department of Architectural Science, University of Sydney, Reprinted 1985.

Rich, C, Longcore, T (Editors)
Ecological Consequences of Artificial Night Lighting, Island Press 2005

Standards Australia
AS 4282-1997 Control of the obtrusive effects of outdoor lighting.

SKM (2009) Port Hedland Outer Harbour Development Project Visual impact Assessment unpublished report for BHP Billiton Iron Ore

Western Australian Planning Commission, 2003. Port Hedland Area Planning Study.

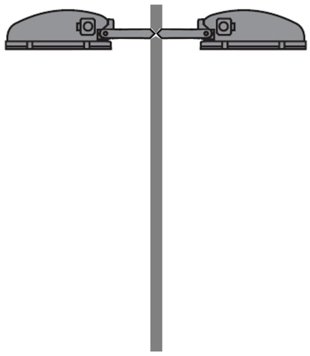
Wikipedia, Solar Spectrum, 2007
http://en.wikipedia.org/wiki/Image:Solar_Spectrum.png

APPENDIX A: Proposed Outer Harbour Development Lighting

Table 5 Summary of Proposed Lighting at the Outer Harbour Development Project	
Proposed Outer Harbour Development Infrastructure	**Proposed Lighting**
Stockyards	
Raised conveyor	1000 watt metal halide fittings mounted on 10 m poles spaced at approximately 40 m intervals.
Stackers (x 4) and Reclaimers (x 4)	Up to four mercury vapour floodlights with 2000 watt fittings per stacker/reclaimer with70 watt mercury vapour lights where necessary.
Transfer Stations (x 13)	10 m poles with 1000 watt metal halide fittings spaced at approximately 30 m intervals.
Car Dumpers (x 4)	Floodlights mounted at 10-15 m height with 1000 watt metal halide fittings.
LRP(x 2)	2 x 10m poles with 1000 watt metal halide fittings.
	70 watt mercury vapour lamps.
General Area Lighting	Approximately 14 x 30m towers with 6 x 2000 watt metal halide fittings. Approximately 9 x10 m poles with 1000 watt metal halide fittings spaced at approximately 50 m intervals.
Infrastructure Corridor	
Overland Conveyor	70 watt high pressure sodium vapour luminaires mounted on 2 m poles spaced at approximately 40 m intervals.
Transfer Pad	
General Area Lighting	Approximately 8 x 250 watt sodium vapour floodlights mounted on 10 m poles.
Offshore Infrastructure	
Jetty	2 x 1000 watt sodium vapour fittings mounted on 10 m poles spaced at approximately 40 m intervals. Front glass horizontal. 70 watt high pressure sodium vapour luminaires mounted on 2 m poles spaced at approximately 10m intervals on each side of the 2 km wharf.
Wharf	70 watt high pressure sodium vapour luminaires mounted on 2 m poles spaced at approximately 10m intervals on each side of the 2 km wharf.
Ship Loaders (x 4)	Each ship loader has a 1000 watt high pressure sodium vapour floodlight mounted on the front of the boom (horizontal front glass)and two off 400W symmetric distribution floodlights on each side of the boom (a total 4 off)
Ships (x 8)	Each ship has been provided with ten off 400W high pressure sodium vapour fully symmetric distribution floodlights: six above the bridge and four on the foremast.

**Note 1 Rail lighting is not considered in this light spill assessment as only rail crossover points will be lit with 70 watt sodium vapour light fittings mounted on 2m poles which is considered an insignificant source of lighting. Lighting design is still in preliminary stages and hence design details provided are approximate only.*

An important aspect in determination of light spill is the aiming of adjustable tilt floodlights. Minimum light spill and minimum glare is achieved when floodlights are installed with the front glass horizontal which can be achieved with the proposed asymmetric light distribution jetty floodlights. The calculations in this report assume that the floodlights are installed and commissioned with the front glass horizontal.



Jet1000 Asymmetrical

Reference drawings used for light modelling in AGI32 software (provided by SKM).

- DS03333_1210_G_00188_A.pdf
- DS03333_1210_G_00189_A.pdf
- DS03333_1210_G_00190_A.pdf
- SOW-1210-G-000211-10.07.08.pdf

The computer simulated lighting scenarios were based on the details provided in Table 5, the drawings and assumptions listed above. Also assumptions were made based on the observations on site and photographs of the night time lighting scenarios as there was no available information detailing lamp types, wattages, locations and precise aiming.

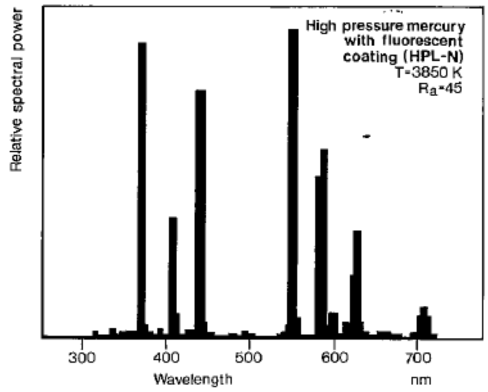
APPENDIX B: AS4282-1997 Recommendations

Table 6 Light Technical Parameters from AS4282-1997

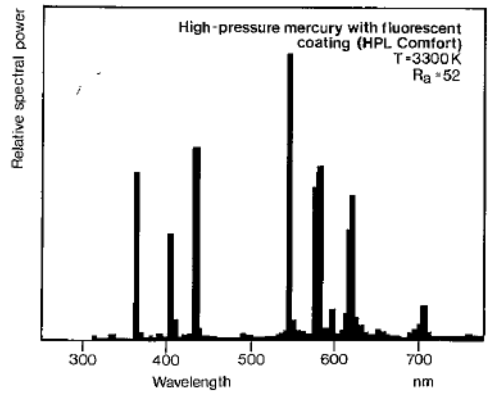
Light technical parameter	Application or calculation conditions	In commercial areas or at boundary of commercial and residential areas*	Residential areas	
			Light surrounds	Dark surrounds
Illuminance in vertical plane (Ev)	Pre-curfew: Limits apply at relevant boundaries of nearby residential properties, in a vertical plane parallel to the relevant boundary, to a height commensurate with the height of the potentially affected dwellings. Values given are for the direct component of illuminance.	25 lx	10 lx	10 lx
	Curfew hours: Limits apply in the plane of the windows of habitable rooms of dwellings on nearby residential properties. In the absence of development (i.e. vacant allotment), the limits apply on the potentially affected property, in a vertical plane parallel to the relevant boundary, at the minimum setback permitted for a dwelling, to a height commensurate with land use zoning provisions. Values given are for the direct component of illuminance.	4lx	2 lx	1lx

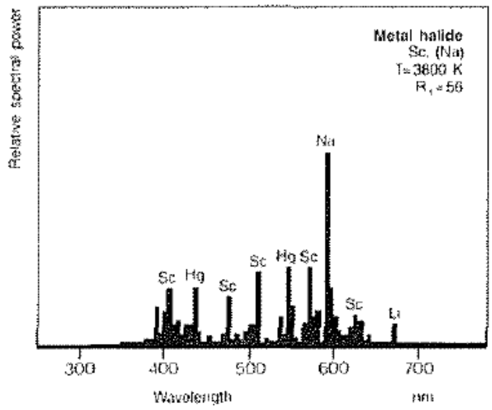
APPENDIX C: Light Source Line Spectra

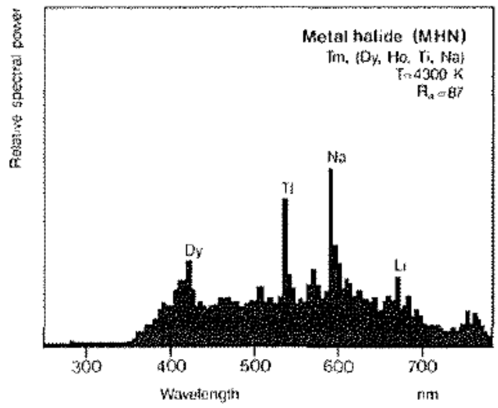
Some mercury vapour lamps typically used on industrial sites – showing spectral composition of some Philips Lighting lamps. Each manufacturer's lamp spectral footprint may vary slightly depending on the fluorescent coating applied. Note concentration of line spectra in the blue (400nm and below) and UVA ends of the spectrum (Philips Lighting, 1987, 10).

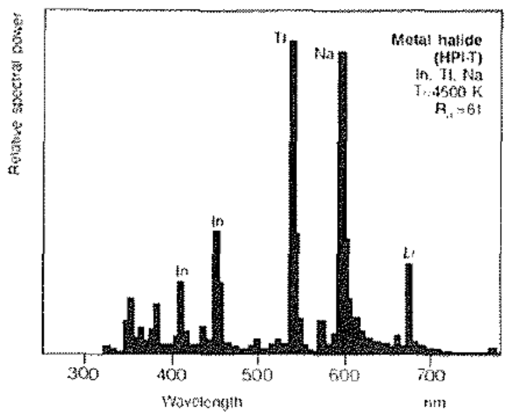


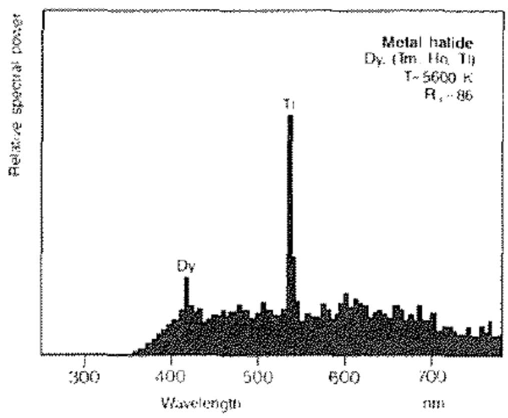
There are many different types of metal halide lamp in the market place and they vary between manufacturers. The spectral footprint depends on the composition of halides mixed in the arc tube (Philips Lighting, 1987, 10). The four spectral compositions shown below are some typical Philips lamp line spectra.



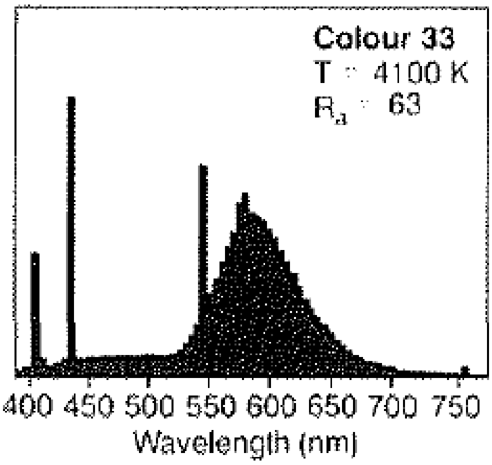


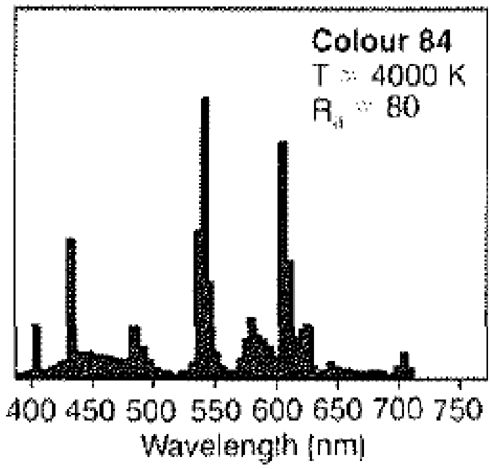


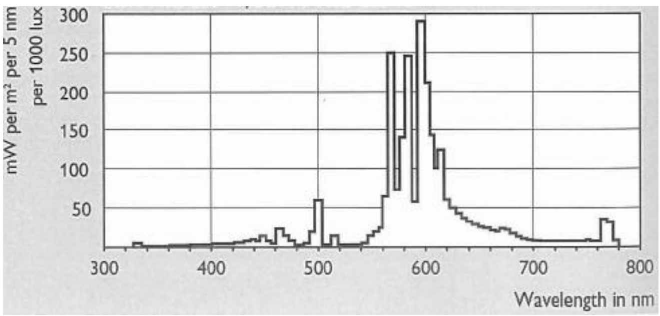




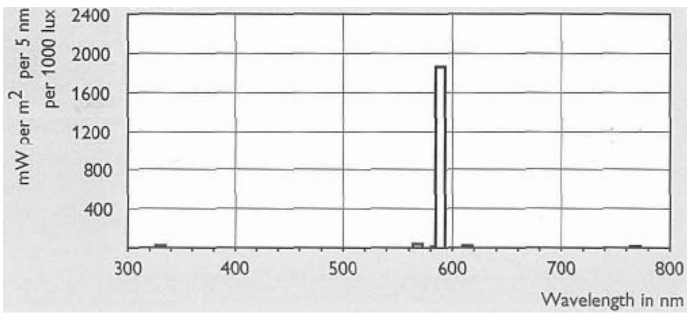
Some typical fluorescent spectral footprints for the older halophosphate (colour 33) fluorescent lamps (Philips Lighting, 1987, 9) and the more recent triphosphour (colour 84) fluorescent lamp which appears approximately the same whiteness but has superior colour rendition and produces more light for the same power consumption. The spectral footprint may vary between different manufacturers; the footprints shown are Philips Lighting spectral footprints. Note the line spike in the blue end of the spectrum for the older halophosphate type fluorescent coated lamps.







Typical high pressure sodium spectral distribution



Typical low pressure sodium spectral distribution

APPENDIX D: Glossary

Table 7 Lighting Terminology	
Term	**Definition**
Brightness	Brightness is a perception and not a measureable quantity. The perceived brightness depends on the state of adaptation of the observer's visual system (i.e. what has been seen previously and also what is currently in the total field of view) as well as the health and age of the observer.
Dazzle	A non technical term used to describe the brightness of the appearance of lights in the field of view which do not necessarily produce glare. Glare is a technical term relating to the brightness of lights and the resultant discomfort or reduction in the ability to perform visual tasks.
Efficacy	Luminous efficacy is the quantity of light (in lumens) produced per watt of energy of the light source.
Illuminance	The quantity of light received at a given point but averaged per square metre (lumens/square metre). It is measured with an illuminance meter that is corrected to simulate the performance of the human eye. Illuminance at any point is inversely proportional to the square of the distance from the light source. Unit of measurement: lux.
Iso-lux	Iso-lux curves are a locus of points on or in a plane where the illuminance has the same value
Lumen	A lighting unit of measurement. The quantity of light emitted from a light source (lamp).
Luminaire	A technical term for the complete assemblage of apparatus that distributes, filters or transforms the light given by a lamp or lamps and consists of lamp, control gear, housing, reflector system, glass or refractor and mounting arrangement commonly referred to as a *"light fitting"* or *"lighting fixture"* or a *"light".*
Luminance	Luminous intensity in a prescribed direction from an object that emits light divided by the projected area of that object towards that observation point. Units candelas per square metre (cd/m^2). Luminance is independent of distance.
Luminous intensity	The intensity of light in a specific direction measured in candelas (cd)
Nadir	The lowest point; the point opposite the zenith on the celestial sphere. In practical terms it is vertically downwards towards the centre of the Earth.

APPENDIX E: Measuring Point Locations

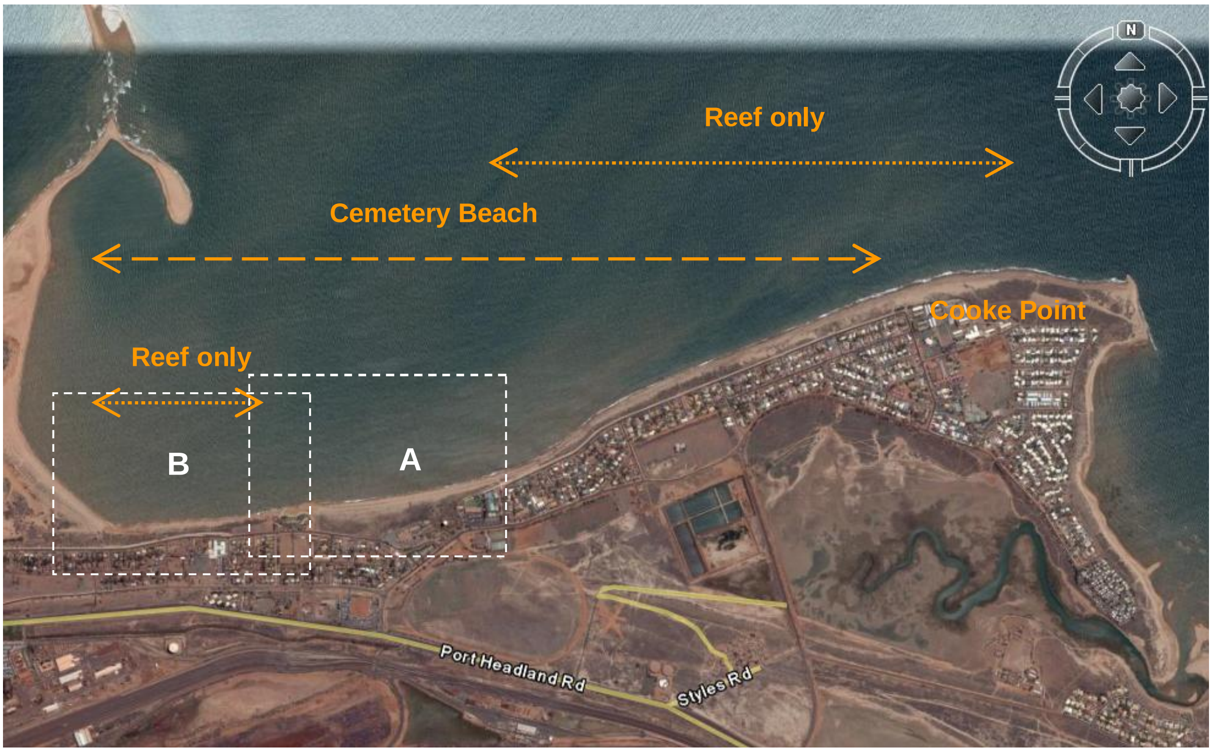


Plate 2 Cemetery Beach Overview

Plate 3. Cemetery Beach Measurement Points (A)

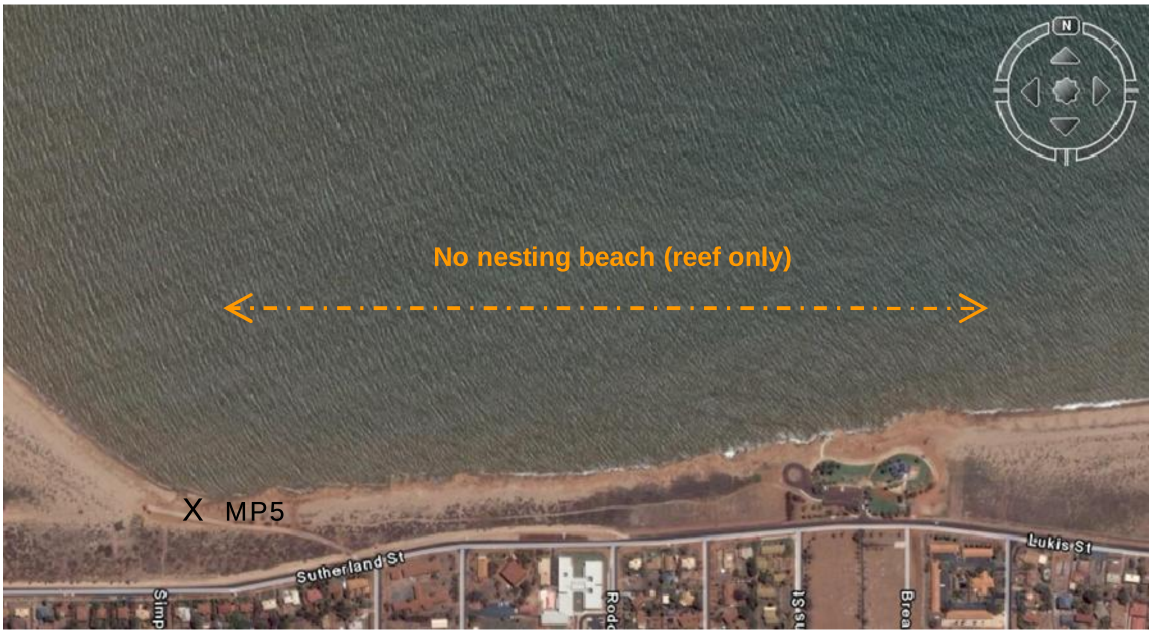


Plate 4: Cemetery Beach Measurement Points (B)

Plate 5: Cooke Point Beach and Measurement Points

Plate 6: Pretty Pools Beach Measurement Points

Plate 7: Hospital Measurement Point

Plate 8: Gazebo and Opposite Residence Measurement Points

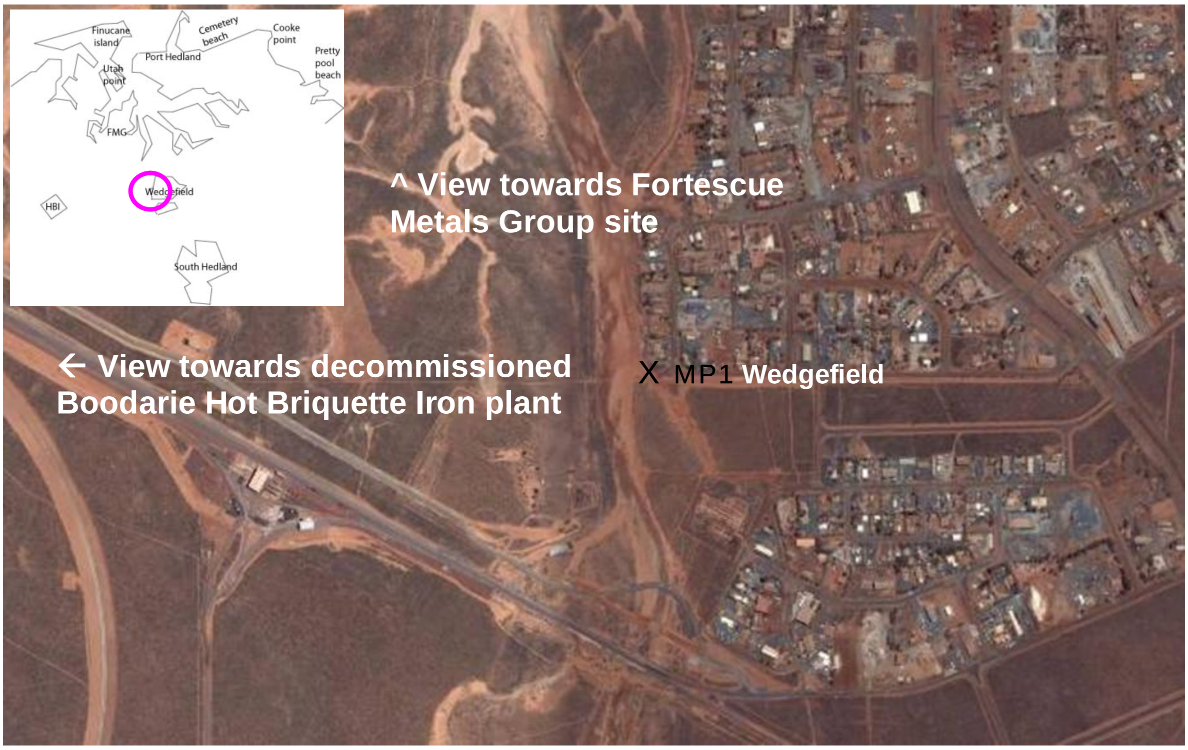


Plate 9: Pinnacle Road, Wedgefield - Measurement Point

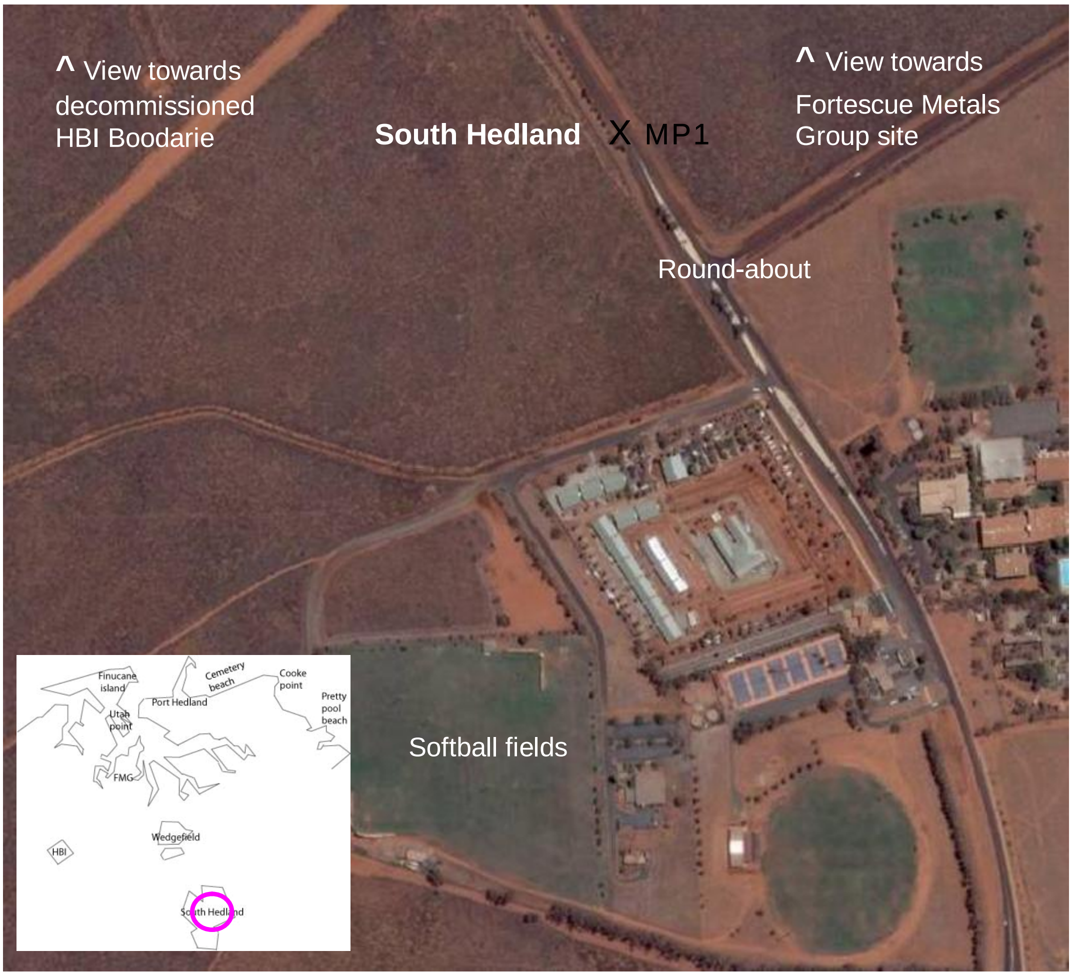
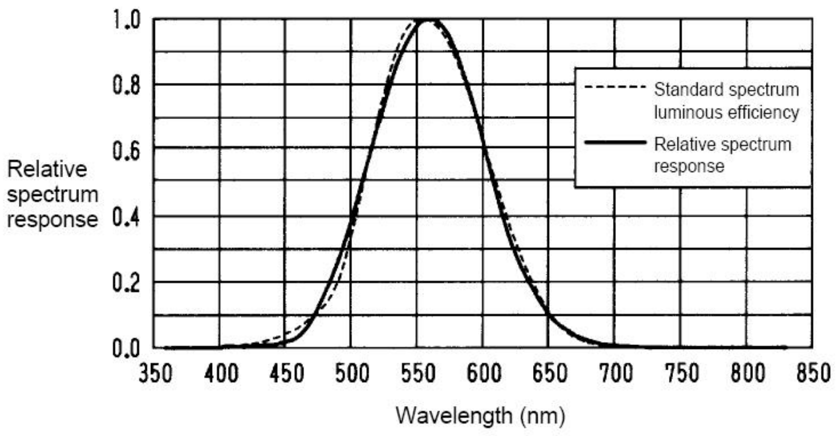


Plate 10: South Hedland Measurement Point

APPENDIX F: Details of Measuring Equipment

Illuminance meter. Yokogawa 510 02 auto ranging illuminance meter. Auto ranging from 0.01 lux to 100,000 lux. Last calibrated by a NATA registered laboratory 06/06/08.



51002 Digital Luxmeter

- Wide measurement range, high accuracy
- Spectral response characteristics for visible range
- Good oblique incident light characteristics
- Recorder output, digital output, comparator output
- Color correction coefficient setting
- Light source brightness measurement
- Mean brightness calculation

CE

Specifications

- Phototelectric element : Silicon photodiode
- Measuring range : 0.00 to 9.99/99.9/999/9,990/99,900/999,000 lx
- Response time : 5 sec (auto rang)
  2 sec (manual range)
- Accuracy : ±2% rdg ±1 dgt

General Specifications

- External dimensions : Approx. 67 (W) × 177 (H) × 38(D) mm
- Weight : Approx. 260 g
- Power : One 6F22 (S-006P) 9 V dry battery or AC adapter (Option)

Luminance meter. Minolta LS110. Last calibrated by a NATA registered laboratory 03/06/08.

SPECIFICATIONS

Type:	Spot luminance meter
Receptor:	*Sillicon photocell filtered to closely match the CIE Relative Photopic* Luminosity Response
Calibration:	PRESET for Minolta standard calibration VARI. for user-selected calibration standard
Measuring modes:	ABS. for measuring absolute luminance % for determining percent luminance in relation to a reference luminance in memory
Other measuring functions:	PEAK function to display highest value of absolute or percent luminance measured while measuring trigger held in; C.C.F. (color-correction factor) to correct meter response when measuring colored subjects or using close-up lenses
Optical system:	85mm f/2.8 lens; TTL (through-the-lens) viewing system; influence of flare on measurement less than 1.5%
Acceptance angle:	*LS-100:* 1° LS-110: 1/3°
Field of view:	9° (with circular measurement-area indication)
Focusing distance:	1014mm to infinity (205mm minimum using close-up lens)
Minimum target area:	LS-100: φ14.4mm at 1014mm (φ1.3mm at 205mm using close-up lens LS-110: φ4.8mm at 1014mm (φ0.4mm at 203mm using close-up lens
Luminance units:	cd/m^2 or fL selectable; calibration and reference luminance values in memory automatically converted
Measuring range:	LS-100: FAST: 0.001 to 299900 cd/m^2 (0.001 to 87530 fL) SLOW: 0.001 to 49990 cd/m^2 (0.001 to 14590 fL) LS-110: FAST: 0.01 to 999900 cd/m^2 (0.01 to 191800 fL) SLOW: 0.01 to 499900 cd/m^2 (0.01 to 145900 fL)
Accuracy:	LS-100: 0.001 to 0.999 cd/m^2 (or fL): ±2% ±2 digits of measured value 1.000 cd/m^2 (or fL) or more: ±2% ±1 digit of measured value LS-110: 0.01 to 9.99 cd/m^2 (or fL): ±2% ±2 digits of measured value 10.00 cd/m^2 (or fL) or more: ±2% ±1 digit of measured value (Measuring conditions: Subject: Standard Illuminant A; ambient temperature: 20 to 30°C/68 to 86°F)
Short-term repeatability:	LS-100: 0.001 to 0.999 cd/m^2 (or fL): ±0.2% ±2 digits of measured value 1.000 cd/m^2 (or fL) or more: ±0.2% ±1 digit of measured value LS-110: 0.01 to 9.99 cd/m^2 (or fL): ±0.2% ±2 digits of measured value 10.00 cd/m^2 (or fL) or more: ±0.2% ±1 digit of measured value (Measuring subject: Standard Illuminant A)
Displays:	*External* LCD *panel shows measured value plus operation and error* indications; viewfinder LCD panel shows measured value
Data output:	1-bit serial, ASCII code, ± 5V, 4800 baud; output via Hirose RP17-13RA-12SD connector; remote control possible

APPENDIX G: Additional Natural Lighting Information

Moon Reference Field Measurements

Typical values for moonlight vary depending on location (latitude) and filtering by the atmosphere. The typical value used worldwide as an average is noted in (i), however, for accuracy some measurements at similar latitude and also time of year as the nesting season provides a valuable field reference. Some measurements of moonlight were taken at Binnaway in New South Wales during late December. Binnaway is approx 30 km from the Siding Spring Observatory and therefore in a fairly clear environment.

i. The generally accepted horizontal illuminance from literature for a full moon is 0.2 lux.

ii. Measurements were recorded of various aspects of the night sky from December 22nd to 25th as full moon was late 23rd to early 24th December. The results are shown in Table B1. The results are based on human eye performance and given that there is a large quantity of blue and UV radiation in moonlight that our eyes do not register, it could well appear much brighter for turtles.

iii. The angular size of the moon is 31’ 27.5” and the focal diameter of the luminance meter focus zone is 20’ 0”, the measurements are reasonably representative.

iv. When the moon was close to the horizon the luminance was less than when the moon was higher in the sky.

v. Full moon luminance was in excess of 3,500 cd/m^2. The results are based on human eye performance and given that there is a large quantity of blue and UV radiation in moonlight that our eyes do not register, it could well appear much brighter for turtles.

vi. The sky luminance immediately adjacent the moon varied from 1 to 5 cd/m^2 depending on the moisture in the atmosphere. The results are based on human eye performance and given that there is a large quantity of blue and UV radiation in moonlight that our eyes do not register, it could well appear much brighter for turtles.

vii. When the moon was high in the sky the sky luminance at the horizon directly below the moon was 0.03 cd/m^2 and varied down to 0.01 cd/m^2 on the opposite horizon.

viii. Cloud conditions varied, however, at the time the cumulus cloud in the vicinity of the moon averaged 0.4 cd/m^2.

Table 8 Moonlight Measurements Taken at Binnaway, NSW. -31°33' S, 149° 23' E

Date	Time Australian Eastern Standard Time (excludes any daylight savings).	Moon Luminance cd/m^2	Sky Luminance Adjacent Moon cd/m^2	Horizon Luminance Below Moon cd/m^2	Opposite Horizon Luminance cd/m^2	Cloud Luminance Adjacent cd/m^2	Moon altitude	Notes: Moon angular diameter 31' 27.5"
22/12/2007	2050	1783					27°06'44"	Clear night after day of heavy rain
	2145	2260	3.77	0.03	0.01		30°14'35"	
		2358	5.63		0.02			
23/12/2007	2130	3413	1.3	0.03	0.02	0.4	23°35'50"	Clear night. Full moon.
		3405						
	2210	3704					26°53'06"	
24/12/2007	2330	3586					28°40'52"	Clear night
		3666						
25/12/2007	2120	907					7°36'47"	Becoming cloudy
	2310	2100					23°46'50"	

APPENDIX H: Proposed Outer Harbour Development Visual Impressions

Plate 11: Daytime Visual Impression of the OHD Jetty Extending into the Sea from Seasons Hotel for the purpose of comparison with Plate 12 (Source: SKM 2009)

Plate 12: Typical Lighting on a Wharf of an Iron Ore Facility (location confidential)

Plate 13: Northerly View from Pretty Pool Beach

Plate 14: Visual Impression of Proposed Jetty from Port Hedland Hospital (Source: SKM

Plate 15: Visual Impression of Proposed Jetty from Gazebo before (image above) and after Jetty is Constructed. (Source: SKM 2009)

Plate 16: Visual Impression of the Proposed Jetty from Seasons Hotel before (image above) and after Jetty is Constructed (image below) (Source: SKM 2009)

Plate 17: Decommissioned Boodarie Hot Briquette Iron Plant as Seen from Pinnacle Road Wedgefield.

Plate 18: Visual Impression of the Proposed Outer Harbour Development Stockyards from Wedgefield (Source: SKM 2009)

Plate 19: Visual Impression of the Proposed Outer Harbour Development Stockyards from Wedgefield (Source: SKM 2009)

APPENDIX I: Photographs of Existing Lighting

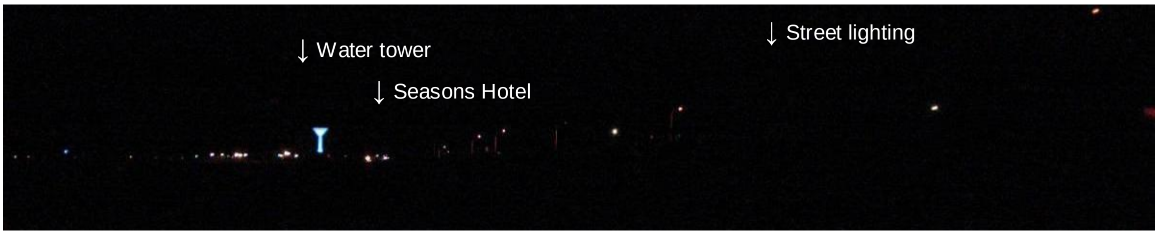


Plate 20: Night View from the Cemetery Beach Towards Seasons Hotel with Floodlit Water Tower Visible.

Plate 21: Day-time View of Cemetery Beach Adjacent Seasons Hotel Seasons (looking towards the East)

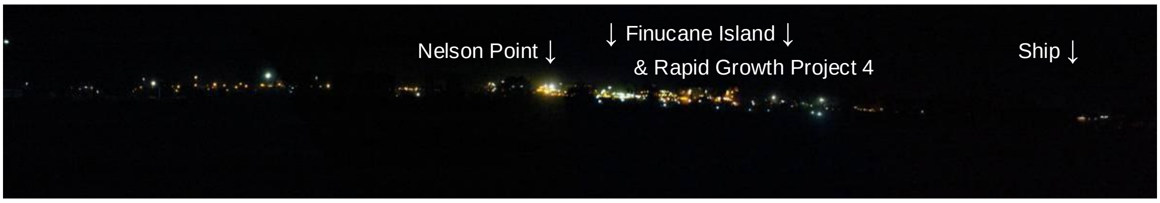


Plate 22: Night View Adjacent Seasons Hotel Towards the Harbour (looking Westerly)

Plate 23: Existing Lighting at Cemetery Beach Showing Water Tower and Street Lighting in the Foreground in the public car park off Sutherland Street adjacent Brearley Street.

Plate 24: Day View of Beach and Dunes Near Cooke Point at Low Tide (looking north towards Cooke Point)

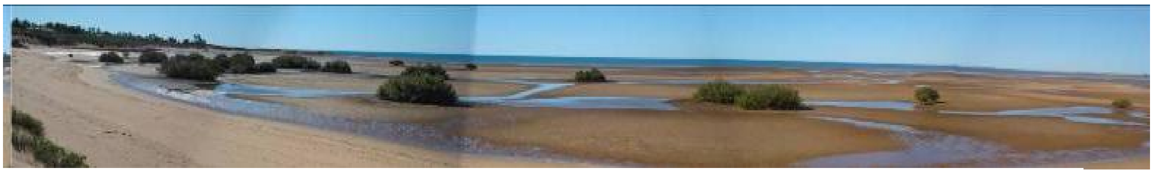


Plate 25: Day View from Cooke Point Beach (looking north)

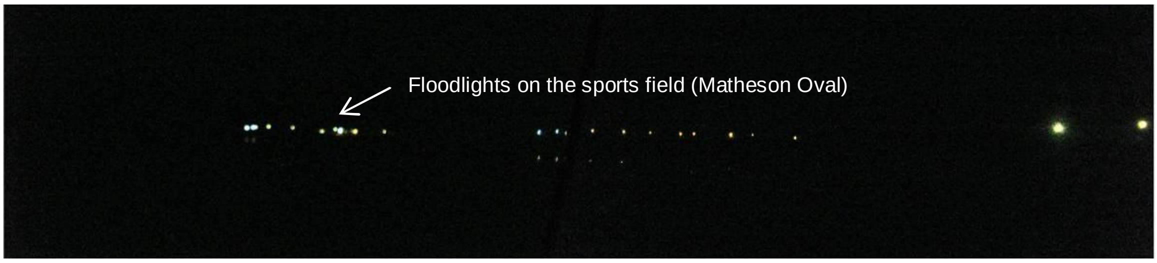


Plate 26: Night View from Cooke Point Beach at Nigh (looking west)

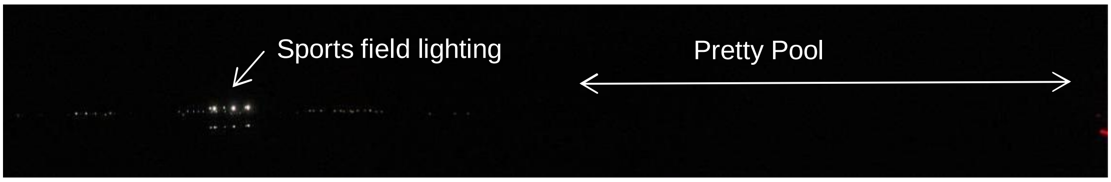


Plate 27: Day and Night Views of Pretty Pool Beach (looking north)

Plate 28: Day View from the Road in Front of Port Hedland Hospital

Plate 29: Night View from the Road in Front of the Port Hedland Hospital

Plate 30: Day View from the Gazebo, Richardson Point Towards Existing Rapid Growth Project 4 Operations on Finucane Island.

Plate 31: Night View from the Gazebo, Richardson Point Towards Existing Rapid Growth Project 4 Operations on Finucane Island.

Plate 32: Boodarie Hot Briquette Iron Plant Prior to Decommissioning (photograph taken from north-east looking south-west)

Plate 33: Day View from Wedgefield towards Boodarie Hot Briquette Iron Plant

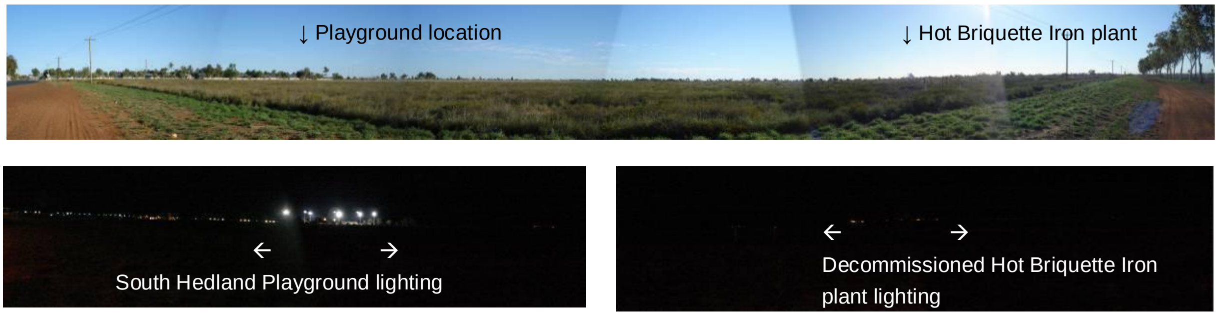


Plate 34: views from South Hedland towards Boodarie Hot Briquette Iron Plant (day & night) respectively)

Plate 35: Night View towards Fortescue Metals Group Site and Nelson Point from South Hedland

Plate 36: Fortescue Metals Group Operations as Seen from Finucane Road (looking north-east)

Plate 37: Day and Night Views of Fortescue Metals Group from Nelson Point Road