Environmental Protection Authority

Environmental Assessment Guidelines

No.5

Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts

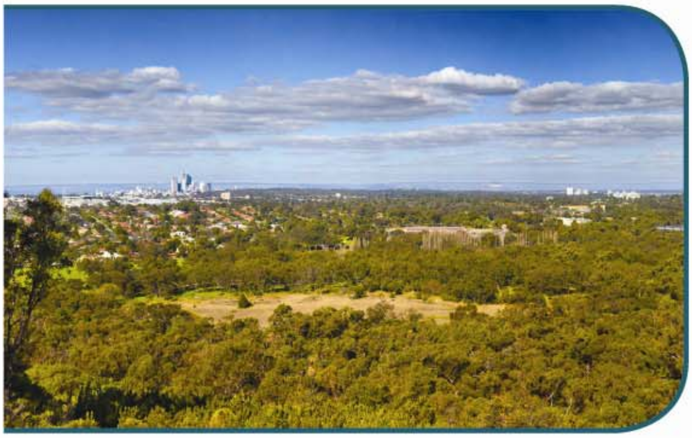

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Table of Contents

1. INTRODUCTION AND BACKGROUND 1
2. OBJECTIVES 3
3. SCIENTIFIC, POLICY AND LEGISLATIVE CONTEXT 3
4. METHODOLOGY 13
5. DEFINITIONS 19
6. BIBLIOGRAPHY 21

Tables

Table 1: Details for Western Australian populations of marine turtles 6

Table 2: Illustrative list of known locations in WA where significant lighting occurs or is planned near significant turtle nesting beaches 8

Figure

Geographic locations in the Kimberley, Pilbara and Gascoyne regions referred to in Environmental Assessment Guideline No.5. 5

Appendix:

Generic Flow Diagram for the Environmental Assessment Guideline Process 27

Environmental Assessment Guideline No. 5

Protecting Marine Turtles from Light Impacts

1. INTRODUCTION AND BACKGROUND

Environmental Assessment Guidelines (EAGs) are developed by the Environmental Protection Authority (EPA) under Section 16(k) of the *Environmental Protection Act 1986*.

Environmental Assessment Guidelines are used to provide advice to proponents, consultants and the public generally about specific procedures, methodologies and the minimum requirements for environmental management which the EPA would expect to be met by proposals or schemes it considers during the environmental impact assessment (EIA) process. EAGs are not statutory documents. Proponents are encouraged to consider their proposals in the light of the guidance given. A proponent should show that the intent of the relevant Guideline has been understood and given serious consideration. An argument to deviate from the position in an EAG should demonstrate that all practicable endeavours have been made to meet the intent of the Guideline. The generic process for developing EAGs is set out in Appendix 1.

This EAG specifically addresses approaches to proposal design and implementation to protect marine turtles from the adverse impacts of light. This EAG sets out:

(a) guidance on an array of approaches available for avoiding, reducing, managing and mitigating light impacts on marine turtles to be considered when preparing documentation relevant to the EIA process and during the implementation of proposals or planning schemes; and

(b) alternative methods for the avoidance and management of light impacts that can be applied using a risk-based approach and by applying best practice methods.

Marine turtles are listed as threatened fauna deserving of special protection worldwide. They live for many decades and can take 20 to 30 years or more to reach breeding age (e.g. Chaloupka et al, 2001). Important populations of these animals live offshore and breed on the beaches of northern Western Australia. Six of the seven species of marine turtles in the world occur in Western Australian waters. These are the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), flatback (*Natator depressus*), leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*) turtle. Marine turtles have existed for some 110 million years but all species are now declining globally as a result of human activity (Lutcavage et al, 1996).

Past and ongoing impacts on turtle populations have depleted numbers to the extent that all species are now listed as threatened. Commercial scale hunting of turtles has occurred in Western Australia in the past (Cox, 1977; Halkyard, 2009). Direct threats to hatchlings or eggs include predation by feral animals (Stancyk, 1979). Driving on beaches poses a significant threat by crushing marine turtle nests and the creation of wheel ruts that can trap hatchings. Ingestion of plastic, tar balls and other debris can kill hatchlings and adults (Guinea, 1990). Traditional hunting still occurs in Australia (NAILSMA, 2006; 2009), including in the Gascoyne, Pilbara and Kimberley (Prince, pers. comm., Pendoley, 2005). Atomic testing in the Montebello Islands in the 1950s caused widespread turtle deaths there (Kendrick, 2003) and boat strikes, dredging, oil spills, marine seismic, pile driving and underwater blasting all comprise industrial threats to marine turtles (Lutcavage et al 1996). By-catch during trawling operations has also historically been responsible for many turtle deaths (NRC, 1990; DEWHA, 2005).

Commercial hunting ceased in 1973 (Halkyard, 2009) and fishing by-catch threats have been minimised via industry management in Western Australia. Western Australia's marine turtle populations are significant for global conservation because their breeding populations are estimated to be among the largest in the world (Shanker, 2004).

It is important to consider and manage all the cumulative threats to marine turtles. Cumulative threats are particularly detrimental to these animals because of their extensive migrations, which often take them into other jurisdictions including international waters and foreign countries. All nesting populations are therefore considered significant because of their contribution to the conservation of the species, particularly where there are pressures on other nesting sites.

This guideline focuses on steps to avoid, reduce, manage and mitigate light impacts on marine turtles, particularly where new developments are planned. While development in proximity to turtle breeding sites in Western Australia is currently limited to a few locations, considerable future coastal development is anticipated.

Provision of this guideline now will enable light impacts to be largely designed out of new developments or otherwise managed in ways that provide the best practicable environmental outcome. The business case for applying the approaches advocated in this guideline now is that they are likely to be more cost-effective than retro-fitting controls later if mandated standards become necessary because voluntary action has not occurred.

2. OBJECTIVES

The objectives of this Guideline are to:

- Improve the scientific understanding of the effects of light on marine turtles;
- Demonstrate how the deleterious effects of light can be avoided and minimised to the fullest extent possible during project design; and
- Improve understanding about the EPA's expectations of proponents where light emissions are a relevant factor for proposals assessed by the EPA.

3. SCIENTIFIC, POLICY AND LEGISLATIVE CONTEXT

Policy and legislative context

Australia is a signatory to international agreements for the protection of marine turtles known as CITES, CMS and IOSEA. All six marine turtle species occurring off Western Australia are listed in Appendix I of the *Convention on International Trade in Endangered Species of Flora and Fauna* (CITES, Washington 1973) which prohibits trade in endangered species amongst the 166 CITES member nations. The *Convention on the Conservation of Migratory Species of Wild Animals* (CMS, Bonn 1979) protects endangered migratory marine turtles by prohibiting their taking, protecting their habitat and controlling exotic invasive species and other activities that may interfere with migratory species. The *Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-east Asia* (IOSEA, 2005) is an agreement that aims to protect, conserve, replenish and recover marine turtles and their habitats in the Indian Ocean and South-East Asian region.

The International Union for the Conservation of Nature (IUCN, 2010) red list of species that require protection lists leatherback and hawksbill turtles as 'critically endangered'. Green and loggerhead turtles are listed as 'endangered', olive ridley turtles are listed as 'vulnerable' and flatback turtles are listed as 'data deficient'.

All six species of marine turtles found in Western Australia are listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* as threatened species. Marine turtles are also listed as threatened (species that are rare or likely to become extinct) under Schedule 1 of the Western Australian *Wildlife Conservation Act 1950*. It is illegal to 'take' any threatened species without lawful authority.

Responsibility for the implementation of these Acts rests with the Commonwealth Department of Sustainability, Environment, Water, Population and Communities and the Western Australian Department of Environment and Conservation respectively. The National Recovery plan for marine turtles in Australia requires that action is taken to reduce detrimental impacts on Australian populations of marine turtles and promote their recovery in the wild (Environment Australia, 2003). A draft Marine Turtle Recovery Plan for Western Australia is also under development (DEC, in prep.). It will be complementary to the National Plan and contains specific recovery strategies for Western Australia.

The northwest of Western Australia represents an outstanding opportunity to protect marine turtle populations on a globally significant scale, not least because there has been limited development across the region as a whole so far, compared to other parts of the world where turtles nest. The area also comprises a global stronghold of several species (Limpus, 2002). For flatback, hawksbill and green turtles, at least some proportion of their populations nest or forage wholly in Western Australian or Australian waters. All life history stages of these populations are thus protected by State and Australian Government legislation, unlike other populations that migrate across international boundaries and are exposed to varying levels of protection and threat. It is important, therefore, to develop mechanisms that avoid, reduce and mitigate impacts at the design stage of future developments in Western Australia.

Scientific context

Genetically distinct stocks of each marine turtle species nest in different parts of Australia. If one stock is seriously depleted or lost, turtles from other genetically distinct stocks will not replace them in the foreseeable future (Limpus, pers. comm.; DEC, in prep.).

Turtle nesting is known to occur in Western Australia from Shark Bay to the Northern Territory border (Figure 1). Globally significant nesting beaches have been indentified on offshore islands like Dirk Hartog Island and on the mainland in the Kimberley and Pilbara regions (Prince, 1994, 1997). As more research is undertaken the number of known nesting locations in the Kimberley is likely to increase and augment what is already known about important nesting sites (Environment Australia, 2003; DEWHA, 2005; Whiting et al, 2009).

Details of the estimated nesting population size and period of nesting for marine turtles in Western Australia are listed in Table 1 below.

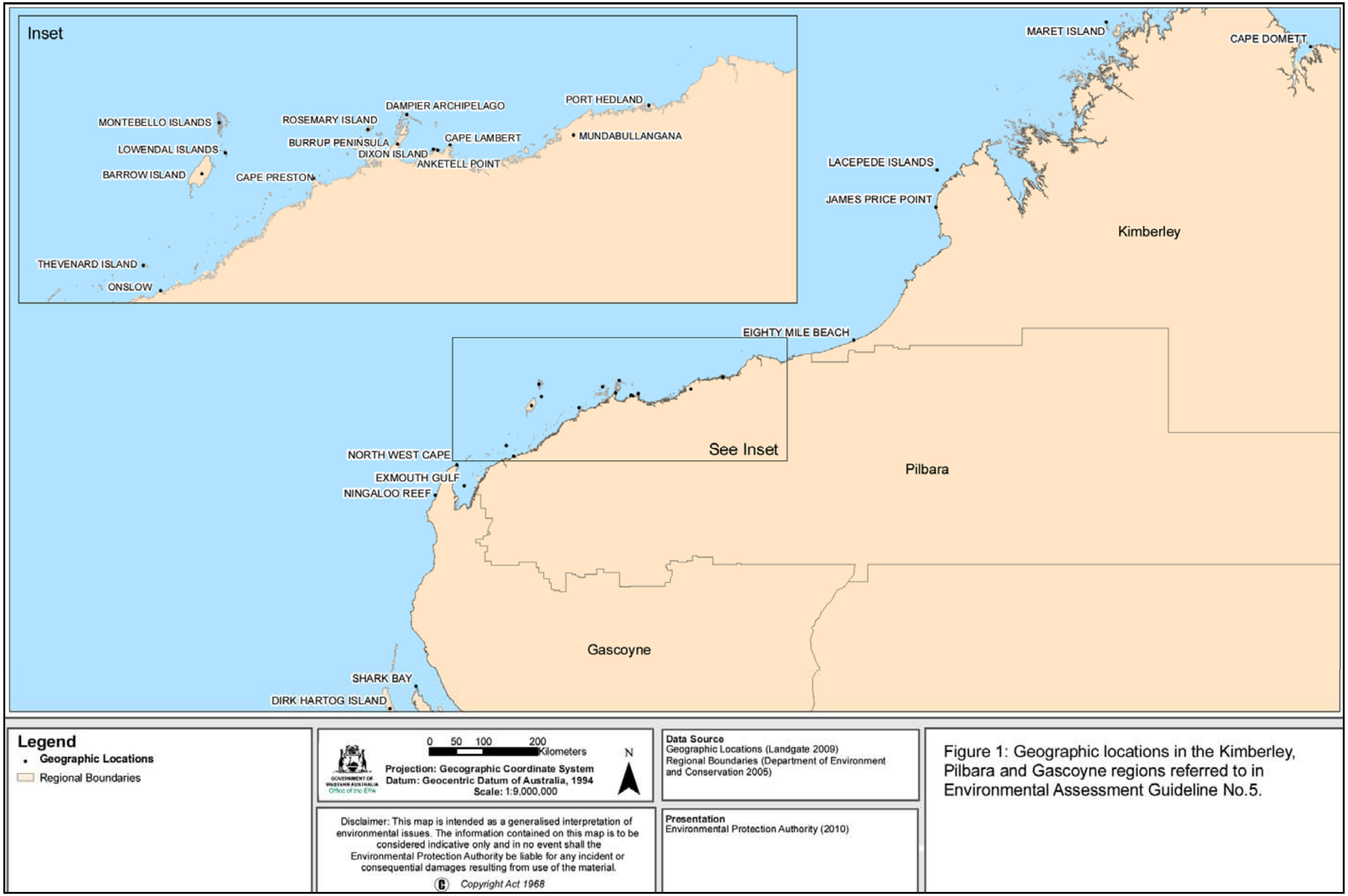

Figure 1: Geographic locations in the Kimberley, Pilbara and Gascoyne regions referred to in Environmental Assessment Guideline No.5.

Table 1. Details for Western Australian populations of marine turtles

Common name	Estimated annual population of nesting females in WA	Nesting period	Hatchling emergence period	Known nesting locations/ comments
Loggerhead	1000s	November – March. December – February peak	January – April	Dirk Hartog Island rookery is largest in Australia, 3rd largest in world, Murion Islands, Ningaloo coast
Olive Ridley	Unknown, low	Year round with July – September peak	Year round	Nests on Kimberley islands; mainly in NT
Green	10,000 to 30,000[1]	October to March; December – January peak. Low level year round	November to May; January-April peak. Low level year round	Ningaloo, Barrow Is, Montebellos, Lacepedes, Kimberley
Hawksbill	1000s	August to December; October – November peak	Year round; November-December peak	Ningaloo, Lowendal Islands, Rosemary Island, Dampier Archipelago to Montebello Islands, possibly Kimberley
Flatback	1000s to 10,000	November to March; December – January peak	December to April	Nest only in Australia; in WA from, Exmouth Gulf to NT border
Leatherback	Not known to nest in WA	Not known to nest in WA	Not known to nest in WA	Forage off WA coast

Sources – DEWHA, 2005; Pendoley, 2005; Pendoley pers. comm.; Prince, 1994; DEC, in prep; DEC, unpublished data; Waayers, pers. comm.; Waayers, 2010.

[1] May be up to 125,000 individuals; Dethmers et al, 2006; Limpus, 2009.

Turtle Nesting

To nest successfully, marine turtles require sandy beaches with access to the ocean. Different species prefer different combinations of sand depth, sand composition, shore approach and offshore habitat, but sandy beaches beyond the reach of high tides are universally required for successful nesting. Examples of important nesting sites include Cape Domett, the Maret Islands, the Lacepede Islands, Mundabullangana on the Pilbara mainland coast, Barrow Island, the Montebello Islands, the islands of the Dampier Archipelago and Dirk Hartog Island in Shark Bay. Lower density nesting occurs along undeveloped sections of the Gascoyne coast, North West Cape and adjacent islands, along the Onslow coast and offshore islands, along Eighty Mile Beach and at suitably sandy locations throughout the Kimberley and its offshore islands. Nests are also known from areas close to developed sites on Barrow, Thevenard and Varanus Islands, at Pretty Pool and Cemetery Beach in Port Hedland and at Cape Lambert.

Most species forage far afield, with turtles from Barrow Island known to feed in Exmouth Gulf, the Kimberley and Indonesia. Males and females aggregate off nesting beaches to mate and then female turtles come ashore, usually at night, to nest. In Western Australia this generally occurs in summer. An individual turtle will generally only nest about every two to five years, thought to be due to the need to accumulate sufficient energy reserves to produce several clutches of eggs during a breeding year. A female turtle will usually lay about five clutches of eggs about two weeks apart when she does nest.

Nests are constructed by digging into the sand at the top of the beach above the tide line or in the foredunes (Witherington and Martin, 2000; Salmon, 2003; Pendoley, 2005). The female turtle uses all four flippers to excavate a body pit and then digs an egg chamber with her rear flippers. The eggs are laid, and the nest is then filled and covered with sand.

Nesting in Western Australia occurs predominantly from August to March, with a peak from September to February, depending on the species. Incubation takes 6 to 8 weeks. Hatchlings usually emerge at night. Some species emerge in Western Australia year round, although more generally from November to May, with a peak from November to February (Table 1). One exception is the flatback turtle population in the far north of the state at Cape Domett which has a nesting peak in winter. This population is thought to be genetically linked to the turtles that nest in the Northern Territory but distinct from the summer breeding population off the Northwest Shelf (DEC, pers. comm.).

Lighting Threats to Marine Turtles

Lighting is an important threat to marine turtles that could become significant if left unmitigated in Western Australia. Lighting from coastal development can disrupt the behaviour of nesting adult turtles and hatchlings, as well as other animals (Rich and Longcore, 2006). Significant decreases in turtle nesting have been recorded in places like Florida (USA) and Queensland as development has resulted in the lighting of more and more turtle nesting beaches (Limpus, 1995; Rich and Longcore, 2006).

Pendoley (2005) estimated that 42% of flatback turtles and 12% of hawksbill turtles nesting in the Barrow-Lowendal-Montebello Islands complex were potentially subject to effects from industrial lighting on nesting beaches when a potentially conservative radius of 1.5km was assumed for the area of influence of lighting on turtles. Significant lighting also occurs, or is planned, at a number of other locations near turtle nesting beaches or foraging locations in Western Australia (Table 2).

Table 2. Illustrative list of known locations in WA where significant lighting occurs or is planned near significant turtle nesting beaches.

Location	Activity	Predominant turtle species present
Thevenard Island	Existing oil industry	Flatback, green, hawksbill
Barrow Island	Existing oil industry; LNG under construction	Flatback, green, hawksbill
Varanus Island (Lowendal group)	Existing oil industry	Flatback, green, hawksbill
Port Hedland Cemetery Beach/ Pretty Pool	Existing and planned residential development and iron ore shipping	Flatback
Cape Preston	Planned iron ore shipping	Flatback
Cape Lambert	Existing and expanded iron ore shipping	Flatback
Burrup Peninsula/ Dampier Archipelago	Existing and planned iron ore shipping ; LNG industry; salt export	Flatback, green, hawksbill, loggerhead
Onslow	Existing residential, saltworks, planned LNG industry	Flatback
Anketell Point area	Planned iron ore shipping and port	Flatback

Sources – DEWHA, 2005; Pendoley, 2005; EPA, 2008; 2009.

It is timely therefore to look at what can be done to manage lighting before more development occurs at sensitive locations along Western Australia's north and north-western coast.

This document focuses on the management of light impacts, however other human-induced disturbances, including predation by feral animals, pollution and impacts from dredging, pile driving, seismic operations and boat strike should all be avoided or properly managed to control the negative impacts that these events may also have on marine turtles.

Light Impacts on Marine Turtles

While turtles tend to prefer dark beaches, they do also nest in lit areas. When they do, however, the survival of their hatchlings is jeopardised (Witherington and Martin, 2000). As hatchlings emerge from nests they can be disoriented[2] or mis-oriented by artificial lights. Artificial lighting may also deter mature turtles from emerging from the water to nest (Mortimer, 1982; Raymond, 1984; Witherington, 1992; Mattison et al, 1993). In particular, a female laying eggs for the first time in her life is more likely to avoid beaches affected by light. Witherington (1992) showed in field experiments that loggerhead and green turtles displayed a significant tendency to avoid brightly illuminated stretches of beach. In areas where glow from artificial lights is present behind the dunes, loggerhead turtles have been shown to prefer to nest in the darker area shaded by tall buildings or dune vegetation (Salmon et al., 1995). Avoidance of lighted beaches may lead to a gradual decline in the number of turtles using a beach, with changes not evident for decades because of the long life cycles involved.

Hatchling turtles primarily rely on vision to find the sea by orienting towards the brightest direction (Salmon et al, 1992). Sea finding occurs when hatchlings orient away from dark, elevated horizons (Limpus, 1971; Salmon et al, 1992) towards the low, light horizon over the sea and make a frenzied dash for the water *en masse* once they emerge from the nest. Under natural conditions, the brightest direction is almost always away from elevated horizons (e.g. dunes, vegetation) towards the horizon over the sea due to the reflection of celestial light off the water. Artificial lighting can disrupt this pattern (Tuxbury and Salmon, 2005).

Turtles which are disoriented or mis-oriented by artificial lights often do not find the sea promptly and may die due to dehydration, predation or exhaustion (Witherington and Martin, 2000). Two hours of crawling towards a landward light source temporarily impairs the subsequent ability of loggerhead hatchlings to crawl seaward, by interfering with their ability to respond appropriately to the cues normally used to locate the ocean (Lorne and Salmon, 2007). Hatchlings may also waste part of the limited energy stored in the egg yolk, reducing their capacity to swim offshore away from coastal predators (see Lorne and Salmon, 2007). Reports also exist of turtle hatchlings perishing by walking into an abandoned fire (Mortimer, 1979).

[2] Disorientation means that hatchlings wander aimlessly, often in circles. Mis-orientation means that turtles move purposefully in the wrong direction.

Hatchlings can be badly mis-oriented if bright lights or atmospheric glow occur away from the sea (Witherington and Martin, 2000; Hodge et al, 2007). This is frequently the case where buildings, roadways, marine infrastructure or other developments occur near the coast. For example, hatchlings can be misdirected towards streetlights and crushed by vehicles (Witherington and Martin, 2000) or, once in the sea, thousands of hatchlings may be attracted to lights over the ocean where they become trapped and readily predated by gulls, sharks or fish (Limpus et al, 2003).

Wavelength

The wavelength a light emits influences its colour and its impact on turtles. Human perceptions of light and means of measuring it are not necessarily relevant to the way turtles perceive the colour and brightness of light. The term ‘brightness’ is often used to describe the combination of wavelength and intensity that affects turtle behaviour (Witherington and Martin, 2000). Turtles are most sensitive to short wavelengths of light, probably because they live in a marine environment that filters out long wavelengths. Green and loggerhead turtles are least attracted to longer wavelength light in the yellow-orange to red end of the spectrum (630 to 700 nm) (Witherinton and Martin, 2000; Ecological Associates, 2002). Hatchling loggerhead and leatherback turtle eyes have been shown to be more sensitive to shorter (including ultraviolet) than longer light wavelengths (Horch et al, 2008). In the absence of other light sources, however, turtles may still be attracted to long wavelength light.

Filters designed to exclude transmission of short wavelengths (<570nm) can be fitted to high pressure sodium (HPS) vapour lights. Such filters have been found to be effective at avoiding disruption of nesting females (Salmon, 2006) but even filtered HPS light has been found to attract hatchlings, although not as strongly as unfiltered HPS lights (Sella et al, 2006). Filtering alone is thus not sufficient to avoid attraction and disruption of hatchling orientation. Attraction of hatchlings can be mitigated by imposing a high, dark silhouette between the turtles and the lights (Salmon, 2006).

Species-dependent differences in light perception are also evident. Green and hawksbill hatchlings from the Pilbara region respond preferentially to short wavelength light, much like hatchlings tested in North America (Pendoley, 2005). Flatback hatchlings showed a similar preference for light of short wavelengths, although they may not be able to discriminate well between wavelengths between 450 and 550nm (Pendoley, 2005).

Intensity

Both the wavelength of light (which determines its colour) and its relative intensity are important to sea finding by hatchlings (Witherington and Martin, 2000). Intensity determines the relative attractiveness of different colours to hatchling turtles. Lower intensities of short wavelength ultraviolet to green light elicit an orientation response in loggerhead hatchlings, while much higher intensities of long wavelength light are required to elicit a similar response (Witherington and Martin, 2000). For green turtles, red light must be approximately 100 times more intense than blue light to elicit a similar degree of response at the retina (Granda and O'Shea, 1972).

Lights filtered to avoid emission of wavelengths less than 570nm are less attractive to hatchlings than unfiltered high pressure sodium lights, up to the point where high pressure sodium lights are up to three log units less intense than filtered lights of the same type (Salmon, 2006). This shows that intensity, as well as wavelength, affects turtle responses to light. Even long wavelength light can be attractive at very high intensities. High intensity lights are typically used on industrial and other infrastructure installations. It is therefore important to consider light intensity, as well as wavelength, when planning the location and lighting design of new facilities.

Glow

Glow reflected off clouds or other aerosols above the beach can also be disruptive to turtle hatchlings. This can be because celestial light is largely blocked by the cloud cover, rendering the artificial glow the brightest visible source from the hatchling's perspective. Large gas flares used at hydrocarbon production facilities also emit light that is disruptive to turtles. Green turtle hatchlings at Thevenard Island clearly showed mis-orientation when exposed to the glow from flares situated immediately behind the beach. While the flares were not directly visible from the beach, the glow above the flares was sufficient to cause mis-orientation (Pendoley, 2000). Glow reflected off salt spray over a shopping centre 5km distant from a nesting beach has also been reported to mis-orient turtles on moonless nights (Limpus, pers comm.).

Perception of Light

Turtles do not see light in the same way as humans. White lights are commonly used because they suit human needs for illumination. White light is in fact made up of many wavelengths, so the actual mix of wavelengths present can be important in regard to the relative effect a light source can have on turtles. Bright, white metal halide lights are particularly problematic for turtles (Pendoley, 2005). A light source emitting both green (525nm) and red (645nm) light is highly attractive to hatchlings but appears to humans as yellow light comparable to a 588 nm source (Witherington and Martin, 2000).

Typical light meters are designed to measure light as perceived by humans and do not necessarily provide a good representation of the colour, intensity, elevation and directivity of light that is important to turtles. It is possible that specialist astronomical light meters that are used to measure celestial light may be more useful, but further research is needed in this area. While modelling can be useful to compare the relative effects of different lighting designs, the actual behaviour of hatchlings is a much more reliable guide to the impact of light on turtles than measurements and modelling based on standard light meter readings. Arena arrays[3] (Limpus, 1971; Salmon, 2003; Pendoley, 2005) can be used by authorised personnel to test the response of hatchlings to lights, while mapping hatchling tracks on the beach is a useful way to document mis-orientation or disorientation of hatchlings. Further research on the actual effects of lights on marine turtles is needed.

Direction and Elevation

The directional component of lights is also important to hatchlings (Lohmann et al., 1997; Witherington and Martin, 2000). For loggerhead turtles, bright light from 10^{o} to 30^{o} above the horizon plays the greatest role in determining orientation and hatchlings appear to integrate all light across a 180^{o} wide field of view (Witherington, 1992).

The term ‘directivity’ has been used to describe the brightness of one direction over others. As the directivity of the light field a hatchling sees increases, the brightest direction becomes more pronounced and provides a greater orientation stimulus (Witherington and Martin, 2000). Directivity helps explain why bright lights that are nearby cause mis-orientation but celestial light, including full moonlight, does not. Celestial light is less directed because it is scattered by the atmosphere and reflected by objects on land so that differences in irradiance between celestial sources and other directions are relatively small compared to those between a nearby artificial source and other directions. From a hatchling’s perspective, celestial light does not make one direction significantly brighter to the exclusion of others. Hatchlings appear more influenced by the celestial light reflected off the ocean at low elevation rather than the moon itself. While the direction towards the moon is brightest, it is not greatly brighter than the surroundings and it illuminates the entire beach area.

Bright, low, short wavelength sources by contrast can be very disruptive because the bright, highly directed nature of a source near ground level can overwhelm celestial sources and strongly disrupt the orientation of a hatchling. A bright light close to the horizon appears intense to an observer but does not significantly illuminate the surroundings at a distance. Disruption is particularly problematic around a new moon, before moon rise,

[3] A circular arena divided into equal radial segments is used on a beach to determine which direction hatchling turtles travel after being released in the centre of the array.

and after moon set, when the reduced celestial light available makes competing artificial sources even more attractive.

The directivity effect results in an important outcome. Just because the intensity of an artificial light source, measured with a light meter, is less than that of the full moon does not mean that those lights will not be disruptive. The artificial light source is relatively directive, whereas celestial light is not. A single, bright light can lead to mis-orientation and death of hundreds of turtle hatchlings has been reported (Witherington and Martin, 2000) whereas a bright, moonlit night will not. Equally, horizon elevation is important and hatchlings will orient away from a tall, dark horizon regardless of the location of the ocean or the moon (Salmon, 2003).

Integrated Effects
In practical terms, bright light that has high directivity causes the greatest disruption. Broadly speaking, bright, highly directive white lights containing short (blue-green) wavelengths create the greatest problems for turtle hatchling orientation but even long wavelength lights (orange-red) that are intense enough and directive enough will disrupt hatchling orientation, especially in the absence of sun or moon light. As far as lighting design is concerned, the combination of intensity, colour, elevation and reflectivity of the surroundings appear to act together to influence turtle behaviour. Glow from an artificial light field reflected off overhead cloud is also problematic.

The effects of colour, intensity, proximity and direction of a light source thus combine to determine its attractiveness to a turtle hatchling. These factors, combined with the tendency to move away from dark horizons, determine the orientation adopted by a hatchling turtle.

4. METHODOLOGY

This section describes planning, design, management, monitoring and audit measures that can be used to avoid, reduce, mitigate and manage the negative impacts of light on marine turtles. The application of the principles in this Guideline will also benefit other animals (eg. birds like shearwaters) whose behaviours can also be disrupted by artificial light (Rich and Longcore, 2006).

While the impact of light has been considered by regulatory authorities in Western Australia over about the last decade, there are currently no specific regulations or codes for the management of light impacts on wildlife in this state. A generic set of regulations that apply in Florida can be found in Witherington and Martin (2000) as an example of the sort of requirements that are imposed elsewhere.

The EPA has provided guidance on the principles and practices that should be applied to ensure that the impacts of light on turtles are carefully taken into account and managed to the fullest extent possible when proposals are submitted to and assessed by the EPA. The EPA will use the principles in this document to evaluate the effectiveness of light management solutions applied to all stages of new proposals under assessment.

The advice provided here can be considered by proponents for application to existing developments, particularly when redesign or replacement occurs, but is not intended to be applied retrospectively to a development that has already been assessed by the EPA. Developers are, however, encouraged to consider improvements whenever possible.

Solutions - Planning and Design to Avoid Light Impacts

In the absence of long term biological datasets on the location of all turtle nesting habitat in WA, and with the potential for climate change to impact nesting beach usage in the long term, these principles should be applied to all coastal projects from Shark Bay northwards. The same principles are also applicable to offshore facilities.

Wherever possible, the starting point for design should be to locate developments sufficiently far from the coast to ensure that lights (or light glow) are not visible from nesting beaches or the adjacent sea. Initial design of a new project which is visible from habitats used by nesting or hatchling turtles should start with zero artificial lights as the base case. Only essential lighting should be added to the design where absolutely necessary. This means that facilities near habitats used by nesting or hatchling turtles should not simply be based on designs acceptable elsewhere. The real need for each and every light source should be carefully evaluated and only added to the design if absolutely necessary for safe operations.
Lighting plans should consider the best control measures for the circumstances and consider interactions between them. Engaging an appropriate array of people from the range of disciplines involved in designing a new operation will help find light management solutions that achieve necessary design outcomes in ways which will not have significant effects on marine turtles.

A simple way to think about lighting is:
- Keep it **OFF** (keep light off the beach and lights off when not needed)
- Keep it **LOW** (mount lights low down with lowest intensity for the job)
- Keep it **SHIELDED** (stop all light escaping upwards and outwards), and
- Keep it **LONG** (use long wavelength lights).

Satisfactory resolution of lighting designs near turtle nesting beaches requires the accommodation of public and employee safety and utility needs in a way that does not significantly disrupt turtle behaviour. The best way to avoid impacts on nesting and hatching turtles is to avoid artificial light spill onto turtle nesting beaches and adjacent waters in the first place. Careful location and design of infrastructure at the planning stage is the most important action that can be taken to avoid light impacts. Cape Canaveral Air Force Station in Florida has demonstrated the effectiveness of diligent attention to planning and management of lighting. The US Air Force has now adopted a limit of 2% or less for the 'take' (losses) of hatchlings from all nests (Salmon, 2006).

The potential impacts of light glow above the local horizon also require attention when planning a development.

Before Construction
Close analysis and judicious use of terrain and vegetation before commencing the design of a facility can significantly reduce the potential for light spill onto the beach and sea. Locating a development out of sight of the coast is the most effective solution to manage light impacts on marine turtles. Facilities should be located away from the coast wherever possible. Where facilities already exist, baseline data on the existing light levels in the area should be obtained.

Where developments require access to the coast, attention to structural layout at the early design stage can significantly reduce adverse lighting impacts. A 'light impact avoidance' approach should be taken at the time that the layout of a new facility is being considered. A turtle sensitive design should identify sensitive sites, locate facilities away from those sites and avoid light spill from the facilities onto sensitive sites. Industrial light sources (e.g. flares) and operational areas needing bright illumination should be located as far inland as possible and large structures needing little lighting (e.g. storage tanks) used to shield light sensitive habitats wherever possible.

A site specific 'illumination plan' should be developed at the detailed design stage of a new project. Each light source should be described in terms of its purpose, location, footprint, intensity and spectral composition. Light spill modelling based on the sources expected to be used should be undertaken to determine any potential impacts on turtle nesting beaches or the marine approaches to them.

Steps to avoid, mitigate and manage the impacts of each source should then be documented. Careful choices of light wavelength, intensity (often strongly determined by management of wattage) and design, directing lights downwards onto target areas and effective light shielding will be important considerations at the detailed design stage.

A three-stage approach is considered most effective to manage lighting near turtle nesting beaches. The three stages below can be considered in a step-wise approach. Physically managing the light sources to ensure lights are not visible to turtles is always the best option for their protection. Filters and other means of managing spectral qualities that still permit light spill onto the beach or sea are always less effective and should be avoided wherever possible. The greatest benefit may accrue by using the best available combination of measures to achieve the lighting objective while also avoiding significant disruption of turtles. The amount of effort required to avoid or resolve a lighting problem is directly related to the amount of light reaching the beach (Ecological Associates, 2002) and to the regional importance of the nesting location.

Step 1. Keep Light Off the Beach and the Sea Surface

a. Adopt as an objective the joint achievement of the minimum light level required for human safety and avoidance of turtle disruption.
b. Start with darkness and add light only as absolutely necessary for safety and operational requirements.
c. Design facilities to avoid light spill onto the beach and sea surface.
d. Do not use decorative lighting; confine lighting to essential purposes only.
e. Maintain a darkness zone within at least 1.5km of significant rookeries[4].
f. Avoid over the horizon glow in line of sight of significant rookeries[5].
g. Use natural topography and vegetation or structures to shield the beach from light at turtle eye level.
h. Design in light screens using topography, vegetation or structures.
i. Design activities to avoid turtle nesting season[6] with a suitable buffer since nesting can vary between years.
j. Avoid night-time activity in turtle nesting season, including turning off non-essential lights completely during the season.
k. Locate light sources such as gas flares at or below ground level, well inland and behind screening buildings, topography or vegetation.
l. Design for the minimum number and intensity of lights necessary.
m. Consider redesigning activities that require lighting so that they can be done elsewhere (e.g. fabrication, maintenance), in daylight, automated, out of turtle nesting season or with task lighting only (e.g. head-torches).
n. Design light fixtures that are mounted low down, shielded and aligned to direct light onto the target area only – e.g. embedded LED

[4] A darkness zone means a zone where artificial lighting is not visible to nesting or hatchling turtles.
[5] The terms ‘nesting beaches’ and ‘rookeries’ are used interchangeably here.
[6] Turtle nesting season refers to both the period of nesting and the period when hatchlings emerge from nests.

stud lights or recessed lighting can be used to illuminate roads and paths.

o. Direct lights downward and shield them to avoid overhead glow on cloudy nights.
p. Direct shielded jetty and vessel deck lighting onto work surfaces and ensure it does not spill over the vessel deck onto the water.
q. Reduce the light footprint by using light distribution types that illuminate along rather than across roadways.
r. Turn lights on only when they are needed (use motion sensors).
s. Turn lights off after 2100 hours or when not needed (use timers) including search lights and deck lights at sea.
t. Use long period flashing lights for navigation beacons or safety marking.
u. Design in ground level path lighting for use when task lighting is not required on jetties and ships.
v. Design surfaces of structures and ground coverings to avoid reflection so light is not reflected towards beaches or upwards (to reduce glow).
w. Screen interior lights with blinds, window tinting or light traps at doorways.
x. Design buildings with windows and doors facing away from the beach.
y. Plan construction and maintenance activities for daylight hours only or avoid the turtle nesting season wherever possible if 24 hour operations are required.

Step 2. Reduce Intensity

a. Use the minimum number of lights required.
b. Reduce the wattage and brightness of individual lights as low as possible; security lighting need only be a fraction of the light needed for detailed work.
c. Use light emitting diodes (LEDs) for lighting wherever possible.
d. Reduce directivity by avoiding intense lights or clusters of lights.

Step 3. Select Wavelengths with Appropriate Spectral Qualities

a. Use long wavelength (550-700 nanometers, orange to red) lights wherever possible. While light responses in turtles are likely to be species specific, low pressure sodium (LPS) lights are considered more desirable than HPS sources. HPS lights are, however, a better choice than short wavelength (blue) and broad spectrum sources such as metal halide, mercury vapour, fluorescent or halogen lights.
b. Use amber filters on HPS lights if their use cannot be avoided, but remember that filtering is not as effective as avoiding light spill.

c. Do not use white lights that emit ultraviolet light.
d. Limit strong blue or green spectral elements (eg. mercury vapour lights) as far as possible.
e. Remember that even long wavelength lights can be disruptive if there is no moon or the light source is very intense.

A detailed alternative selection process for street and similar lighting is included in Table 7 of Ecological Associates (2002) at www.myfwc.com/docs/WildlifeHabitats/Seaturtle_CoastalRoadwayLightingManual.pdf

After Construction

A number of additional steps can be taken after construction to ensure that actions taken to avoid, manage and mitigate light impacts on marine turtles are working successfully.

Monitoring and Audit

Once a plant or other infrastructure is built, an "as built" audit of where lights are actually visible from nesting beaches or the sea surface should be performed at the first available opportunity, before the next turtle nesting season. Where lights illuminate nesting beaches or the sea, the approaches listed above should be used to correct problem lights. A desirable hierarchy of action is:

- remove the light source;
- turn the light off throughout the nesting season;
- screen the affected habitat from the light source;
- use a combination of shielding, footprint reduction, lowering, filtering, dimming, flashing and increasing the wavelength of the light source; and
- turn the light on only when needed, using motion sensors and automatic timers to turn it on and off.

A subsequent audit should be conducted during the next nesting season. The focus of this audit should be to look for evidence of mis-orientation or disorientation of turtle hatchlings. If such signs are found, further investigation into the possible causes should be undertaken and additional remedial action taken.

Periodic inspection, audit and corrective management of light sources should then be conducted on an ongoing basis. This should occur annually, in time for corrective action to be taken before the turtle nesting season starts. Useful information on assessing lighting problems and monitoring turtle behaviour at established facilities is contained in Witherington and Martin (2000) and in Ecological Associates (2002).

Biological Monitoring of Hatchling Behaviour
Should hatchlings be found mis-oriented or disoriented during the hatching season steps should be taken immediately to identify the cause of the impact on the hatchlings and remedial action taken to prevent the impact from occurring. Where engineering or physical management of lighting fails to reduce the disruption to hatchling behaviour, alternative intervention measures should be considered as a last resort. Interventions such as collection of hatchlings for release at dark beaches should only be undertaken with appropriate regulatory approval.

Education and Legislation
Ongoing education of decision makers, plant operators, infrastructure users, home owners, beach users etc should be undertaken to continuously reinforce the message that individual performance will make a difference to lighting impacts on turtles.

Most marine turtle nesting in the mainland US occurs in Florida, where beaches are of regional, national and in some cases global significance as nesting habitat. Most coastal communities adjacent to marine turtle nesting beaches in Florida have adopted beachfront lighting regulations. Regulation at local council level may be appropriate in circumstances where building is likely to occur adjacent to turtle nesting beaches. Model legislation can be found in Appendix H of Witherington and Martin (2000) and found at www.myfwc.com/docs/Conservation/technical_report_english.pdf

5. DEFINITIONS

aerosols	fine solid or liquid particles suspended in a gas
arena arrays	a fenced, circular area divided into equal radial segments used on a beach to determine which direction hatchling turtles travel after being released in the centre of the array
artificial light	source of light created by humans; industrial, commercial, municipal and domestic lighting; includes fires, gas flares, furnaces and other sources of illumination from industrial or other processes
brightness	the perception elicited by the luminance of a visual target; often attributed to the combination of wavelength and intensity of light that determines how readily light is seen
celestial light	light from the moon, stars etc that are lit at night

colour	the sensation produced on the eye corresponding in humans to the categories red, yellow, blue etc; determined in part by wavelength of light
directivity	brightness of one direction over another
disorientation	to wander aimlessly, often in circles
elevation	height or angle above reference level, often mean sea level
genetically distinct stock	discrete breeding population of animals; genetically distinct stocks of marine turtles use breeding beaches separated by large distances and may breed in different seasons. Distinct stocks do not normally interbreed, even though individuals of each stock may forage in a similar area
glow	light from a source that is not directly visible but where the light is reflected off clouds or other aerosols overhead
hatchlings	newly hatched turtles
intensity	luminous flux emitted from a point per unit solid angle in a particular direction, regardless of distance. The candela is the basic unit of luminous intensity in SI units
irradiance	power of electromagnetic radiation incident on a surface, commonly expressed as Watts.m^{-2}
log units	short for logarithmic units, in this case measurements where each unit corresponds to ten times the previous unit, i.e. 1, 2, 3, etc log units correspond to the numbers 10, 100, 1000, etc
mis-orientation	move purposefully in the wrong direction
nanometre	one billionth of a metre; 1 x 10^{-9}m
nesting season	turtle nesting season refers to both the period of nesting and the period when hatchlings emerge from nests

new moon	phase of the moon when the dark (unilluminated) portion of the moon faces toward earth, so that the moon is not visible to the naked eye
reflectivity	the fraction of incident radiation (light) reflected by a surface
rookery	a colony of breeding animals; in this sense, a beach occupied by marine turtle nests
significant lighting	lighting likely to have a significant effect on the behaviour of nesting or hatchling marine turtles
take	to kill, capture, disturb or molest fauna by any means
threatened species	in this context, species listed as threatened under the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the Western Australian *Wildlife Conservation Act 1950.*

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Web Pages

The following web pages have some of the best readily available information on turtle biology in relation to light, means of managing light and model light regulations.

www.myfwc.com/docs/Conservation/technical_report_english.pdf

www.myfwc.com/docs/WildlifeHabitats/Seaturtle_CoastalRoadwayLightingManual.pdf

http://myfwc.com/CONSERVATION/Conservation_LivingWith_WildlifeLighting_resources.htm

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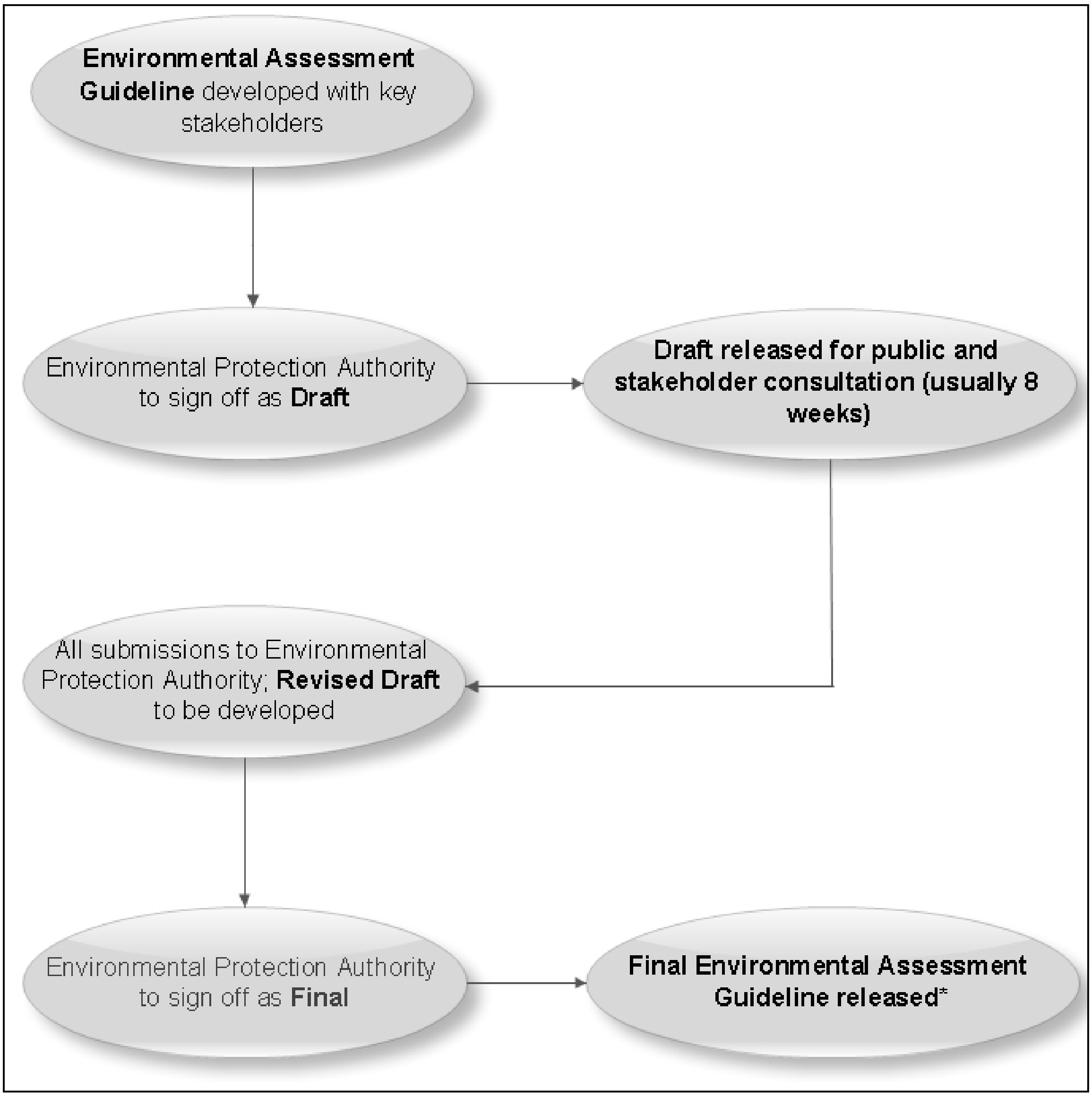
Appendix 1 – Generic Flow Diagram for the Environmental Assessment Guideline Process



*** The Environmental Protection Authority may update the Guideline as necessary.**