Royal Astronomical Society of Canada

Guidelines for Outdoor Lighting
in
Urban Star Parks
(RASC-USP-GOL)

Adopted by the RASC

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Written by
Robert Dick

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1.0 SCOPE

This document presents Guidelines for Outdoor Lighting (GOL) in Urban Star Parks (USPs, and herein after referred to as Parks) and describes the types of equipment required to satisfy these guidelines.

The goal of the USP Program is to promote the reduction in light pollution, demonstrate good night-time lighting practices, improve the nocturnal environment of urban wildlife, protect and expand accessible observing sites for astronomy, and provide accessible locations for the general public to experience the night sky.

This USP-GOL has three objectives: to limit glare across the USP, provide a guide for adequate lighting used for navigation within the Park, and presents lighting policies that may be applied to urban areas beyond the Park boundaries. These will protect the USP from deterioration by surrounding light pollution.

We present in Section 3.0 the rationale for an USP and the protection of the nighttime environment from the excessive use of artificial lighting. To support these guidelines, this document provides references to useful web sites and to general research into the effects of nocturnal lighting on humans, human activity and wildlife.

The general guidelines for outdoor lighting within the Urban Star Park is presented in Section 4. Lighting hardware and signage are described in Section 5 to assist Park managers minimize the impact of artificial lighting on the nighttime environment while maintaining a degree of safety for visitors.

A bibliography in Section 6 provides a set of references and useful websites. Supplementary technical information is provided in the appendices to this document.

2.0 GLOSSARY

2.1 Acronyms

CARS Canadian Aviation Regulations
CF Compact Fluorescent lamps
CO Cut-off luminaires (>0% and <2% up-light)

DSP Dark-sky Preserve

FCO Full Cut-Off luminaires (0% up-light or fully shielded)

GOL Guidelines for Outdoor Lighting

HID High Intensity Discharge lamps (LPS, HPS, MH lamps)
HPS High Pressure Sodium lamps (“yellow” coloured lamps)

IESNA Illumination Engineering Society of North America

LEDs Light Emitting Diodes
LPS Low Pressure Sodium lamps (monochromatic, single colour lamps)

MH Metal Halide lamps (“white” coloured lamps)

SCO Semi Cut-off luminaires (<2% up-light)
SAD Seasonal Affective Disorder

USP Urban Star Park

2.2 Definitions

Amber – A colour of light. Light that does not have any emissions at wavelengths shorter than 500 nm. Typically associated with the emitted colour of "true amber" light emitting diodes. Generally has a yellowish colour and has less impact on night vision and circadian rhythm than other colours.

Dark Time – a period after which scheduled outdoor activity has ended and visitors are expected to minimize their activity to permit other visitors to sleep. In this document, Dark Time is further assumed as being 2-hours after sunset. Appendix D contains a reference table with the approximate times of sunset for parks in southern Canada. Park managers may define a Dark Time that is suitable for their facility.

Foot-candles (fc) - an English unit measure of the amount of light that falls on a defined area[1]. Examples of levels are provided in Appendix A and C.

Lux – a metric unit measure of the amount of light that falls on a defined area[2]. Examples of levels are provided in Appendix A and C.

Photobiology – the study of the effects of light on biological systems

Photopic Vision – vision that uses the lower sensitivity photoreceptors (cones) that have evolved for daytime vision and high illumination levels

Scotobiology – the study of the effects of darkness on biological systems

Scotopic Vision - vision that uses the higher sensitivity photoreceptors (rods) that have evolved for nighttime vision and low illumination levels.

USP Buffer - Region within USP surrounding the Core area under control of the park manager, or others. The Buffer is to prevent glare and light trespass from shining into the Core area.

USP Core - Region within USP surrounded by a Buffer area.

[1] www.physlink.com/Education/AskExperts/ae409.cfm
[2] www.physlink.com/Education/AskExperts/ae409.cfm

3.0 RATIONALE

Most people take artificial nighttime lighting for granted. In cities it is considered to be an acceptable component of our society, and indeed they think it is a necessity for safety and security. Specifications and guidelines for street and roadway lighting[3] address these urban assumptions. This has lead to lighting policies that encourage the illumination of all urban areas to allow the use of human photopic (daytime) vision. (Figure 3.0.1).

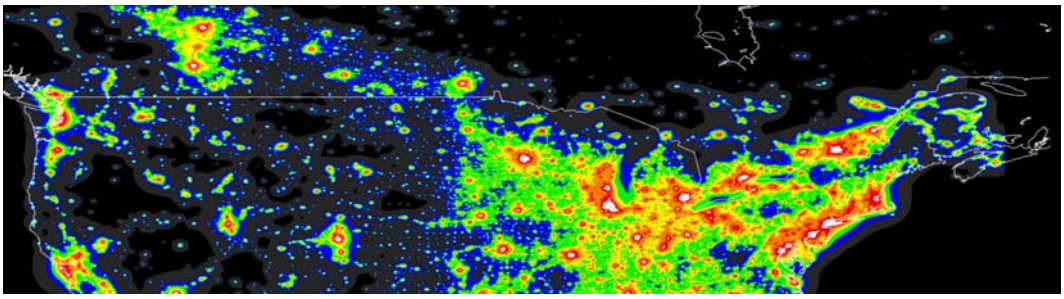
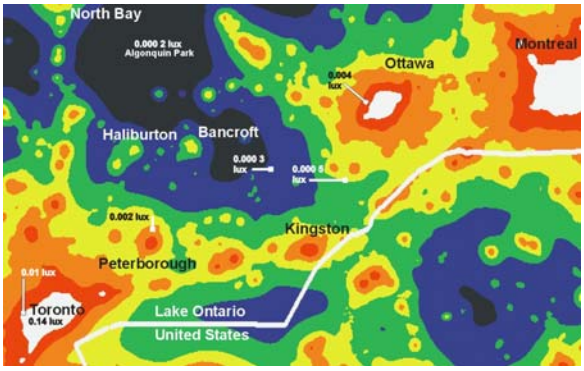


Figure 3.0.1 Mid Latitudes at Night[4]

The availability of electrical energy and efficient lighting fixtures have enabled the current urban lifestyle of non-stop "24-7" activity. Further, the advances in lighting technology have permitted illumination levels to increase over the last 50 years by a factor 10, with the use of the same amount of electrical energy. The result is most commercial luminaires are designed for high levels of illumination. Low intensity fixtures are primarily limited to decorative lighting such as Christmas lights.

It is now common in a city to be able to read a newspaper at night under the city's artificial sky glow. In Figure 3.0.2, the light polluted skies of Toronto are compared to relatively good skies southwest of Ottawa on the Rideau Canal system leading to Kingston. Bright red corresponds to high levels of sky glow (0.010 lux) and green is an intermediate amount (0.000 4 lux). The area of Algonquin Park appears black with very dark skies.



[3] Illumination Engineering Society of North American (IESNA) Handbook
[4] P. Cinzano, et. al. 2001

In Toronto only the brightest stars are visible. On the Rideau Lake, the Milky Way is easy to see but the glow from Ottawa extends half way up the sky in the northeast and with sky glow from Kingston on the southwestern horizon. From Algonquin Park, there is virtually no visible sky glow and the Milky Way dominates the skyscape after dark.

3.1 Crime

The most prevalent reason given for nighttime lighting is to reduce crime in cities. This is generally based on the notion that more light improves visibility, and that this visibility discourages criminals. Based on before and after studies of crime statistics, there is no clear evidence that outdoor lighting reduces crime[5]. Although there are anecdotal reports that "improved lighting" (i.e. improved visibility) reduces crime[6], there is no evidence that crime is reduced with "more or brighter lighting"[7]. In some cases crime was simply displaced, or the altered lighting was prompted or caused by a change in use of the streets by "…strengthening informal social control and community cohesion"[8] and this may have affected the pattern of crime.

There are different types of crime. Theft is more prevalent during daytime hours, whereas violent crime occurs more often in the evening and after midnight.[9] Anecdotal studies report that most property crime occurs during the day and violent crime is usually between persons that know each other. The public's belief in the prevalence of random violence is not supported by the research.

There was an unconfirmed report that the brightly lit City of Manila found violent crime was more prevalent after dark and the presence of police was effective at reducing nighttime crime. The city lights were not the deterrent to crime. In a comprehensive report to Congress, by the National Institute of Justice[10] it is stated that there is no evidence that artificial lighting deters crime. It reports that most studies are poorly designed, without controls, which undermines any conclusions to the contrary. The report states that: "We can have very little confidence that improved lighting prevents crime". Furthermore, lighting can assist in the crime by putting the victim on display. The feeling of safety provided by the light may have the opposite effect.

Vandalism provides an example of the opposite effect of security lighting than is generally accepted. Studies conclude that lit areas are subject to more vandalism and graffiti. Anecdotal evidence[11] and more focused studies[12] support the policy of turning

[5] The Influence of Street Lighting on Crime and Fear of Crime, Prevention Unit Paper No. 28, Stephen Atkins, Sohail Husain and Angele Storey, 1991, ISBN 0 86252 668 X
[6] Effects of Improved Street Lighting on Crime: A Systematic Review, Home Office Research Study 251, by David P. Farrington and Brandon C. Welsh, August 2002
[7] The Indiana Council on Outdoor Lighting Education (ICOLE), P.O. Box 17351, Indianapolis, IN 46217
[8] ibid, page 2.
[9] www.bpap.org/bpap/research/DCA_briefing_dtd.pdf
[10] National Institute of Justice Grant Number 96MUMU0019 (www.ncjrs.gov/works/)
[11] "Darkened Streetlights Fail to Raise Crime Rate", DesMoines Register, T. Alex and T. Paluch, May 6, 2004 www.dmregister.com
[12] Effects of improved street lighting on crime: a systematic review, Home Office Research Study 251, August 2002

lights off when security staff is not around. Apparently, vandals want to see the results of the damage and for others to see it. When lights are off, there is less gratification in vandalising an area or painting graffiti.

3.2 Urban Lighting Needs

Humans are a daytime species. Although we can see at night, our vision is significantly reduced compared to the daytime. In the past, starlight provided sufficient levels of illumination for most activities. However our modern fast paced and mechanized activity requires better visual acuity for driving cars, bicycles and avoiding urban hazards.

The human reaction time to a stimulus is a function of the illumination level[13]. For our photopic vision it is les than 0.2 seconds whereas with our scotopic (night) vision it is about 0.5 seconds, which is sufficient for a walking pace.

Some level of artificial lighting is required for nighttime activities. But this lighting must be designed to increase visibility. Paradoxically, more light can reduce visibility, especially for persons over 40 years of age[14].

The average age of our population is getting older and our sensitivity to glare increases with age, as does our chances of developing cataracts. In the face of a bright light, our iris closes down letting light into the eye only through the centre of our lens. Since cataracts begin in the centre of the lens, the vision of adults can be severely degraded by glare. With the aging of our population, it is becoming more important to reduce glare in the urban environment.

3.3 Human Health

The proliferation of outdoor lighting has a significant impact on the health and behaviour of humans[15]. “Biological clocks control our sleep patterns, alertness, mood, physical strength, blood pressure, and other aspects of our physiology”[16]. The dominant mechanism for synchronizing this biological clock to our activity (the circadian rhythm) is the day-night contrast and the timely release of the hormone melatonin. This hormone regulates the ebb and flow of other hormones in our bodies. These “repair the damage” we do to our bodies each day. Without the proper release of these hormones, healing takes longer and our bodies are less able to fend off disease[17].

The timing of the circadian rhythm also affects our behaviour. For example, Seasonal Affective Disorder (SAD) is an emotional condition experienced by travellers and others. The symptoms can be reduced with exposure to bright light[18] in the morning as it shifts

[13] A.L. Robert - Simple Time Reaction as a Function of Luminance for Various Wavelengths, Perception & Psychophysics, 1971, Vol.10(6)
[14] Work, Aging, and Vision: Report of a Conference, ISBN-10: 0-309-07793-1
[15] Light Research Organization, Electric Power Research Institute, (www.epri.com/LRO/index.html)
[16] WebMD, March 06, 2007, www.webmd.com/cancer/news/20040908/light-at-night-may-be-linked-to-cancer
[17] [17] “Light at night and cancer risk”, Schernhammer E, et.al., Photochem Photobiol. 2004 Apr;79(4):316-8.
[18] “Shutting Off the Night”, H. Marano, Psychology Today, Sep/Oct 2002

(or entrains) and resets our biological clock. If this entrainment occurs during the late evening or at night due to artificial outdoor lighting, the biochemistry that controls our physiological well-being will also be shifted away from the proper daytime hours.

3.4 Environmental Health

Although many people are familiar with the activity of the natural world during the day (i.e., photobiology), few people are as familiar with similar activity at night. Humans are not the only species whose biological clock is controlled by day-night contrasts and the release of melatonin. It is found in plants and animals wherein it plays a similar role[19]. Wildlife depends on the darkness of the night and the study of this dependence is called "scotobiology".

Research into the nocturnal environment is relatively recent compared to research into the daytime environment. Consequently there is far less published literature documenting the sensitivity of the general nighttime ecology to artificial lighting. Most of the research is on specific species in the wild or laboratory studies. However, mounting scientific evidence is documenting the profound impact of artificial light on the ecology of the night.

Plants are affected by the colour and duration of lighting. Whether the effects are considered beneficial or not depends on the desired outcome. Generally, artificial lighting will change the natural growth patterns and may affect the resistance of plants to infestations and disease. Many plants respond to the length of the day and normally recognize it as an indication of the season. By extending light past the evening, may slow the plant's biochemistry from changing to prepare for winter[20]. The various affects of colour, duration, type of plant, etc. makes sweeping conclusions impossible however, they indicate that changing the lighting environment will change the natural ecology of the area.

3.5 Animal Behaviour

Artificial sky glow extends well beyond the city boundaries. Therefore in considering urban outdoor lighting, we must also consider its impact on rural areas in the region.

Exposure to short periods of bright illumination (less than a minute) does not seem to affect the biological rhythm in animals[21]. However, longer exposures to light can shift (or entrain) their circadian rhythm and modify their behavioural patterns. Minimizing the duration of exposure to artificial light is necessary to limit its impact.

Seasonal variations will shift the time of sunset by over four hours (from roughly 16:30 in winter to 21:00 in summer). During the peak of Park activities in summer, the time of sunset can vary by two hours (see Appendix D). In addition to this, dusk can extend the daylight by as much as an hour.

[19] "Lighting for the Human Circadian Clock", S. M. Pauley, Medical Hypotheses (2004) 63,588–596
[20] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Pg. 405
[21] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Pg. 24

Artificial lighting changes the nighttime behaviour of species[22]. Over a month, the changing phases of the Moon affect the ground illumination at night. Nocturnal mammals adapt their behaviour over the month in sympathy to moonlight to avoid predators. This behaviour includes, in part, limiting the foraging area and carrying food back to their shelters instead of eating it in the field. This latter adaptation limits how much they can eat[23].

Predator and prey behaviour depends on the darkness of the night[24]. Illumination levels that significantly affect wildlife are believed to be at the level of the full Moon, although the effect begins to be evident at lower light levels[25]. To put this in context, it is generally recommended by the IESNA that an urban parking lot be lighted to more than 100X this level (see Appendix A).

It is well documented that some insects are drawn towards light sources. This interrupts their normal mating and foraging activities and it concentrates them within a small area thus enhancing predation[26]. They may swarm the light fixture until they are exhausted. The resulting pile of insects must then be cleaned up.

Animals separated from their normal foraging grounds by an illuminated road cannot see the area beyond the lights. They can be temporarily blinded by headlights from passing cars. Their natural instinct is to wait until they can see where they are going. This can leave them in the open and vulnerable to predation. They may abandon their established foraging patterns for new ones, which will impact other species as they compete for resources[27].

3.6 Shorelines

Historically, waterways have been used for transportation and recreation. However, they are also important ecosystems that support wildlife in the water and on the lands adjacent to the shoreline. Shoreline property is valued by our society and this is causing human developments along rivers and around lakes. An increasing number of properties have shoreline lighting that illuminates the waterway. This impacts the river and lakes in two ways.

From the human stand point; bright lights along the shoreline make it very difficult to navigate the channel. Glare from unshielded shoreline lighting prevents our eyes from becoming adapted to the darkness. At night, a boater will only be able to see the points of light along the shore rendering the channel markers and out-of-channel hazards very difficult to see. Clearly, glare along the shoreline results in a safety hazard that should be corrected.

[22] The Urban Wildlands Group (www.urbanwildlands.org/abstracts.html)
[23] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Pg. 28
[24] ibid., Chapter 2
[25] ibid., Chapter 11
[26] ibid., Chapter 13
[27] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006

The second impact is on the fish and aquatic plants[28]. The effect of light on fish is not clear. Fish are attracted to the light from their natural feeding depths. The increase in the concentration of fish changes the hunting efficiency of predators. Although the behaviour of the nocturnal predator may not be compromised by artificial light, the ability of its prey to recognize the danger and to escape will affect their survival.

3.7 Cultural Impact

There is a cultural imperative to protect the darkness of the night sky. Throughout recorded history (about 6,000 years) astronomy has been a focus of stories and mythologies. Those who have seen a dark sky are impressed by the serene majesty of the celestial sphere. It comes as no surprise that all civilizations have the constellations and asterisms woven into their culture.

After stepping outside from a lighted room and under a dark rural sky, our initial count of a few stars with photopic vision increases a hundred fold after only 10 minutes. This may increase by another order of magnitude after less than an hour as our eyes become fully dark-adapted. However, urban sky glow overwhelms the faint stars, and the glare from discrete light fixtures prevents our eyes from becoming dark-adapted. These limit the number of stars we can see from many thousands to only a few hundred. Our current generation is the first for whom much less than half the population has seen a star-filled night sky. Most children have never seen the Milky Way.

3.8 Summary

Generally there is limited research on the environmental benefits and costs of artificial lighting. In the absence of clear conclusions, the best policy is to minimize its effects on the ecosystem.

The cost of lighting an area may cause funds to be redirected away from other more effective safety and security measures.

There is growing medical evidence for the degradation of human health with the illumination of the night. The reduction in day-night contrast can uncouple the circadian rhythm from our normal daytime activities that may cause an increase in chronic diseases.

It is clearly shown in published research, that artificial outdoor lighting affects ecology by disrupting food webs. Although the actual mechanism for this disruption is not always clear, this does not weaken the evidence for the damaging impact of artificial light on the ecosystem and the need to minimize it.

Education is the key to correcting this degradation of the nocturnal environment by artificial light at night. As the main source of light pollution, cities are key components in

[28] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Part V

education and solving this problem. Establishing Dark-sky Preserves an obvious way to help inform the public about the virtues of a dark night.

Artificial lighting that is installed for human activity is altering the natural environment. This environmental degradation continues without resistance, and is indeed supported by human nighttime culture. Primarily due to ignorance, civic policies and the legal system are strongly biased in favour of human demands at the expense of the natural environment. New research is revealing how artificial lighting degrades both human health and the health of wildlife within and well outside our cities. Wildlife has no voice and cannot control their environment. We must act on their behalf. Cities must take action and advocate against change in their environment.

4.0 GENERAL GUIDELINES

A RASC Urban Star Park (USP) is defined as an area within or near an urban area from which artificial lighting outside the Park is not directly visible. An USP may be a relatively confined enclave inside a city, or beyond city limits but close enough for its night sky to be impacted by artificial sky glow.

In order to prevent light of the adjacent neighbourhoods from shining directly into the USP, coniferous trees, buildings, berms and bushes may be used to as natural light shields (Figure 4.1 USP Layout). These form a Buffer Zone around the USP Core.

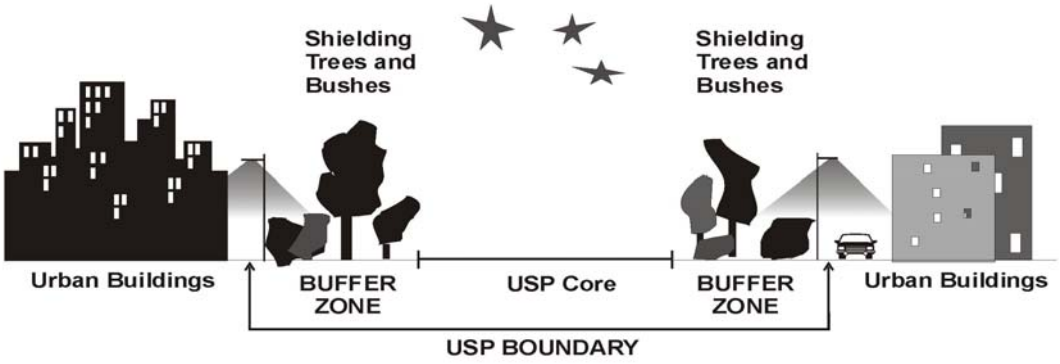


Figure 4.1 USP Layout

This section provides guidelines that should be followed to minimize light pollution within a Park. Similar fixture hardware is recommended to minimize the inventory for repairs or replacement.

Where necessary for basic safety and navigation:

1. Illumination should be to the minimum practical level,
2. The affected area of illumination should be as small as practical,
3. The duration of the illumination should be as short as practical, and
4. Illumination should minimize the amount of blue colour in the light (avoid white),

What is “practical” depends upon the specific facilities and their use, and the technology available at the time.

These guidelines address the typical use of an urban park and expected pedestrian and vehicle traffic. Park managers have the discretion to assess what levels are most appropriate for their facility within the limits outlined in Section 3 of this document.

Illumination levels specified in this document are lower than urban areas for which most luminaires have been designed. This restricts the type of light sources that may be used. Although High Intensity Discharge (HID) lamps are very efficient, they may emit more light than is recommended in these guidelines. To address this, relatively inefficient,

incandescent lights may be used for short periods of time or more advanced Light Emitting Diode (LED) luminaires may be installed.

4.1 Illumination Levels

Visitors should expect the Park environment to be as natural as possible. Therefore, they should not expect urban roadway lighting standards to apply within the USP.

In this document, illumination levels for all Park facilities should be designed to minimize the impact of artificial lighting on the natural environment. This runs counter to standard practice of urban lighting specified by the IESNA. Artificial lighting should be used only where it has been justified to be critical for the safety of visitors and where other safety systems are not practical. To the extent practical, personal flashlights should be used as an alternative to permanent lighting fixtures.

In order to minimize the disruption to plants and wildlife by artificial lights, maximum illumination levels should be comparable to that of the full Moon. Placing these levels in context, in the absence of glare people have reported seeing “fine” at full Moon illumination levels[29] (maximum 0.27-lux and more typically 0.1-lux when the Moon lis low in the sky). Although the Moon produces a degree of glare, it is above our horizontal field of view. For example, about two hours after sunset the full Moon will be approximately 20 degrees above the horizon.

The following illumination levels are suggested as a guide to limit the impact of artificial lighting within the Park.

1. No artificial illumination should be installed unless there are buildings, roads and pathways in the vicinity.

2. Artificial illumination levels from artificial lights should be no greater than the full Moon (less than 0.3 lux[30], maximum) except in areas specified by the Park Manager.

3. Where vehicle and pedestrian traffic volume is known to be high after dark, illumination levels should be no more than about 2 lux maximum.

4. A lighting curfew after “Dark Time” should be imposed in all areas except where specifically identified by the Park manager.

[29] Preliminary Recommendations: Outdoor Lighting at Highlands Center, Cape Cod National Seashore, Chad Moore, March 25, 2006
[30] www.stjarnhimlen.se/comp/radfaq.html#10

Table 4.1 Illumination Level Guidelines (Maximum Values)					
4.1 Area	Type	Light*	Illumination Level (lux)	Height	Curfew
Buildings.	FCO	Incandescent, Amber CFL or LED	~2 lux	2.5 m	Yes
Pathways.	FCO	Incandescent, Amber CFL or LED	~2 lux	2.5 m	Yes
Pathways at Parking Lots	FCO	Incandescent, Amber CFL or LED	~3 lux	2.5 m	Yes
Parking Lots	FCO	Incandescent, Amber CFL or LED	~3 lux	6 m	Yes
Entrance	Marker (FCO)	Incandescent, Amber CFL or LED	~3 lux	2.5 m	No

* The wattage for individual lamp type are not specified due to differences in efficacy, Park Managers should consult Appendix C for guidance in meeting the recommended illumination level in all tables in Section 4.

Note: 2 lux = illumination of dusk about 20 minutes after sunset

4.2 Extent of Illumination

Where illumination is required, its impact on the nocturnal environment should be minimized by limiting the extent of the affected area.

The light from non-shielded fixtures can be seen, literally, as far as the eye can see. Tall trees around an illuminated area will significantly restrict the extent of the impact, however it is more effective to use light fixtures that are engineered to limit the extent of the illumination.

Full Cut-off (FCO) fixtures (also called fully shielded fixtures) prevent light from shining beyond the immediate area and up into the sky (see Figure 4.2). Since no light shines horizontally, the amount of glare at a distance from the fixture is significantly reduced from that of semi cut-off or unshielded luminaires. This increases visibility. By reducing glare, eyes of both animals and people can become more accustomed to the darkness allowing them to see into areas with lower illumination levels farther from the fixture.

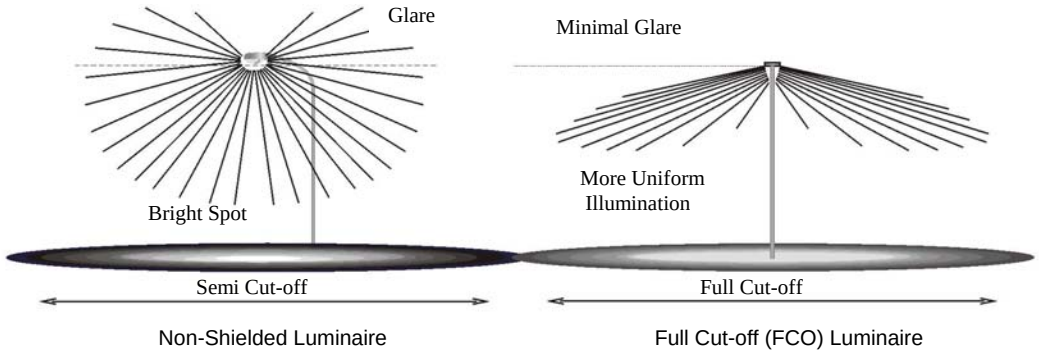


Figure 4.2 Luminaires

The IESNA BUG Designation System (Back-light, Up-light and Glare) that defines this shielding is in Table 4.1. Appendix F has the definitions for the BUG lighting zones.

Table 4.2.1 BUG System Designation for USP Compliant Luminaires

BVH	<1%	FVH	<2%	UH, UL	0%
BH, BM, BL	<10%, or as required	FH, FM, FL	As required		

The improvement in visibility with FCO fixtures permits the use of lower wattage bulbs due to the reduction in glare, which in turn reduces energy consumption. By lowering the illumination levels, less light will reflect off the ground into the surrounding trees, and into the sky. This also reduces the extent, and impact, of the artificial light on the night environment.

Table 4.2.2 Extent of Illumination

Buildings	2x Mtg Ht.	Parking Lot	Parking Area
Pathways	1.5 x Width	Entrance	2 x Mtg. Ht.

To further limit the extent of the illuminated area, mounting heights (Mtg. Ht.) should be limited to below the surrounding trees (typically 6-meters or less) or berms so that the stray light will be contained.

4.3 Duration of the Illumination

Artificial illumination should not persist past a reasonable time after dark to avoid the need for plants and animals to over extend their natural accommodation period, or to compromise the park's usefulness as an Urban Star Park.

Park activity is significantly reduced in urban parks and campgrounds during dusk. Just after sunset, natural illumination levels are approximately 0.1% that of full sunlight (100 lux) or less than 100X that of a full Moon (see Appendix A). At that time, indoor illumination (approximately 200 lux) is higher than the outdoor levels. After about 30 minutes, the natural illumination level of dusk is about that of a full Moon (0.3 lux).

If indoor lighting shines through windows beyond 30-minutes after sunset, it will have a considerable impact on the non-lighted areas outside. It will also produce glare that will prevent visual dark adaptation. Window coverings should be used 30-minutes after sunset to prevent continued spillage of the indoor light through the windows.

Park managers may define a "dark time" after which illuminated activity and noise is discouraged. This recognizes that low-level activity may occasionally continue after sunset and dusk. Exterior Park lighting may remain on during this time, after which there should be a lighting curfew. The time of this curfew will depend on the nature of the Park and type of permitted activity. Park managers should determine a reasonable lighting

curfew time (such as 2 hours after sunset). To reduce the effort and cost of exterior lighting and its controls:

1. No lighting should be installed for areas with minimal pedestrian traffic. Pedestrians should be expected to use their own flashlights.

2. There should be a lighting curfew within 2 hours of sunset.

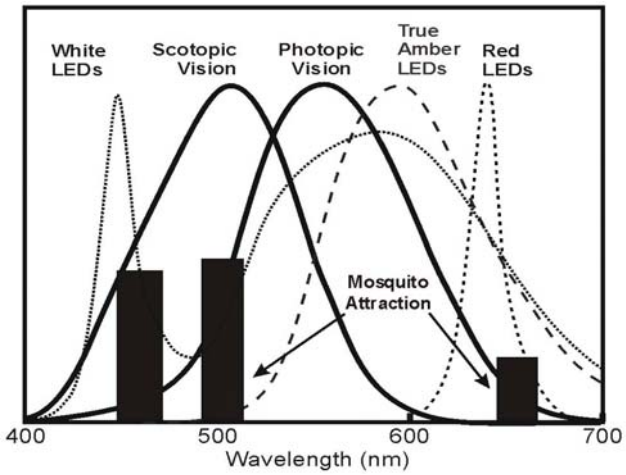
3. Timing circuits should turn off all exterior lighting fixtures within the Park at the beginning of the lighting curfew except where identified in this document. A post-sunset timer should control the light fixtures. Manually activated switches should also be available to turn off exterior lighting if on a separate circuit.

4. In areas with high volume of pedestrian traffic and where limited activity continues after dark that requires illumination, motion detectors should control light fixtures. Automatic timers should be used to turn them off after a reasonable period of time.

On a technical note, only Light Emitting Diodes (LEDs), compact fluorescent and incandescent lamps can be switched on for short periods of time. High Intensity Discharge (HID) lamps (Low Pressure Sodium and High Pressure Sodium) require several minutes to heat up before they will reach full brightness.

4.4 Colour of Illumination

Various light sources (lamps) have different colour content. These are discussed in Appendix B.



Humans, plants and animals are affected by the colour of light. Blue light (short wavelengths <500 nm) affects animal low-level scotopic vision whereas yellow, orange and red light (long wavelengths) is seen well by our photopic vision (see Figure 4.4). The use of long wavelength light allows many animals to see without significantly degrading their sensitive scotopic vision.

For example, insects and birds[31] are affected more by white than red lights. Longer wavelengths are less likely to attract disease-bearing insects to public places. The effect of lighting on birds has been documented in studies of bird mortality around

[31] Ecological Consequences of Artificial Night Lighting, Rich, Longcore, Island Press, 2006, Part II, V

communication towers that have navigation avoidance beacons[32], and further documented by members of the Fatal Light Awareness Program (FLAP)[33].

The colour and type of light that is used may vary depending on the extent and use of the illuminated area. The colour content of light (spectral content) assists in identifying cars or persons by the colour of their clothing. When artificial lighting is deemed necessary due to high pedestrian or vehicle traffic, the colour content of the light source should provide sufficient colour content to allow fair colour recognition (CR>50). Higher CR may be required on occasion when television equipment is being used. However high CR lamps should not be used at other times.

1. Low illumination levels are necessary (pathways and buildings), lighting may only be possible with incandescent bulbs, red or amber LEDs. Florescent lamps may not be available with low enough light output.

2. Where there is high volume pedestrian and vehicle traffic, FCO luminaires should be used. Illumination levels may be higher than for non-vehicle locations. Incandescent, High Pressure Sodium (HPS), amber florescent or amber LED lamps may be used. The level of required illumination, and motion detector controls should determine the specific type of lamp.

[32] Gehring,J. Aviation Collision Study for the Michigan Public Safety Communications System (MPSCS): Summary of Spring 2005 Field Season, Central Michigan University, August 12, 2005
[33] www.flap.org

5.0 LIMITATIONS

No assurance is made regarding the accuracy and completeness of these data. The RASC disclaims responsibility for consequential financial effects on transactions or property values, or requirements for follow-up actions and costs.

This document is based on data and information collected during work undertaken by the RASC. The RASC will not be held responsible for the errors and omissions of work carried out by third parties.

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6.2 Web Sites

International Dark Sky Association
www.darksky.org

Royal Astronomical Society of Canada (RASC) Light Pollution Abatement Program
www.rasc.ca/lpa/index.shtml

National Crime Prevention Council
www.ncpc.org/ncpc/ncpc/?pg=2088-10802

National Institute of Justice Grant Number 96MUMU0019
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BC Hydro Power Smart Program – 42 watt LED sufficient for urban pathway
http://dmdeng.com/pdf/learning/Power_Smart_Roadway_Lighting,_BCH.pdf

Light Research Organization, Electric Power Research Institute,
www.epri.com/LRO/index.html

The Indiana Council on Outdoor Lighting Education (ICOLE),
P.O. Box 17351, Indianapolis, IN 46217, USA
http://home.att.net/~icole/crime_ref_guide.html

Fatal Light Awareness Program
www.flap.org/new/nestegg_3.htm/

Florida Fish and Wildlife Conservation Commission
www.floridamarine.org/publications/default.asp

Web Sites (continued)

The Urban Wildlands Group
www.urbanwildlands.org/abstracts.html

Sample of Luminaire Product Sources
http://store.starrynightlights.com/depali.html

LED Landscape Lighting
www.superbrightleds.com/malibu.htm

Astronomy Outreach and Education Materials
www.starlight-thatre.ca

Wildlife Lighting
www.state.hi.us/dlnr/dofaw/fbrp/sos.htm

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APPENDIX A - Reference Illumination Levels

Condition	Illumination Levels* (lux)**
Clear night sky (no Moon)	0.000 05
Clear Urban Sky with Light Pollution	0.015
Twilight	0.1
Overcast Urban Sky with Light Pollution	0.15
Full Moon	0.26 max. (0.1 typical)
Urban Road Artificial Illumination	2
Open Parking Lot	11-22
Car Dealership Lot	200
Full Sunlight	130,000

* Clarity of the atmosphere is highly variable over hours and days. These values are presented to provide only a rough guide to approximate illumination levels.

** "lux" is a Système internationale (SI) unit of illumination equal to 1 candela/m^2 (cd/m^2) = 0.093 foot-candles (fc)

To place these levels in context, people have reported seeing "fine" at full Moon illumination levels in the absence of glare[34].

[34] Preliminary Recommendations: Outdoor Lighting at Highlands Center, Cape Cod National Seashore, Chad Moore, March 25, 2006

APPENDIX B - Colour from Various Light Sources

There six lights that convey "colour" from bright white to deep yellow. The last light source, LEDs can be designed to provide a range of colour. The accompanying table lists these sources in order from white to yellow.

MH – Metal Halide	It is a "High Intensity Discharge' (HID) lamp that must be warmed up before it can reach full brightness. The white light gives very good colour recognition. MH has high blue spectral content, produces a significant amount of UV and therefore its use should be avoided in all DSPs.
Incandescent bulbs	These emit a warm white light and have very low energy efficiency. Two characteristics make them desirable for some applications. They can be turned off and on very quickly so they can be used for motion detection systems. Incandescent should only be considered if amber LED or amber CFL lamps are not available with low enough brightness.
HPS - High Pressure Sodium	These are bright yellow and allow fair colour recognition. A HPS bulb has a small light-emitting region for very good control over where the light is focused. As a HID source, they require a few minutes to heat up before they reach their design brightness.
Amber CF – Compact Fluorescent Lamps	These produce filtered light and are commercially sold as bug and party lights. They may be identified as yellow and orange but their colour and quality vary greatly. Choose darker yellow and orange whenever possible to avoid flying insect attraction. They typically do not perform as well in cold temperatures and may take several minutes to warm up in sub-zero temperatures.
LPS - Low Pressure Sodium	Deep yellow light is virtually a single colour offering very poor colour recognition. It is the most energy efficient of the above lamps. They are so efficient that even low wattages may produce too much light for use in DSPs. The light-emitting region in the lamp is quite large compared to other HID lamps.
Amber and Red Light Emitting Diodes	These are available in a range of colours, amber and red LEDs minimizes their impact on the environment. They can produce very focused illumination, which is very desirable for DSP applications. For DSP purposes "Amber" is defined as light in the wavelength of 500 – 650 nm and "Red" is 600 - 660nm. White LEDs emit short wavelength blue light and are not recommended.

APPENDIX C - Light Output from Typical Bulbs for Comparison Purposes

Bulb Types	Lumens†	Lux†† at 6 m	Lux†† at 2 m	Lux†† at 1 m
Incandescent*				
7 watt	60	0.13	1.2	4.8
15 watt	128	0.28	2.6	10.2
40 watt	342	0.8	6.8	27.2
60 watt	513	1.1	10.2	40.8
100 watt	855	1.9	17.0	68.0
Metal Halide (MH)				
70 watt	3,000	6.6	59.7	238.7
100 watt	5,800	12.8	115.4	461.6
High Pressure Sodium (HPS)				
35 watts	2025	4.5	40.3	161.1
50 watts	3600	8.0	71.6	286.5
70 watts	5450	12.1	108.4	433.7
100 watts	8550	18.9	170.1	680.4
Low Pressure Sodium (LPS)				
18 watts	1570	3.5	31.2	124.9
35 watts	4000	8.8	79.6	318.3
55 watts	6655	14.7	132.4	529.6
Compact Florescent (CF)				
9 watt (40 w equivalent)	550	1.2	10.9	43.8
13 watt (60 w equivalent)	850	1.9	17.9	71.6
LED**				
1 watt (White) ***	100	2.8	25	100
1 watt (amber) ***	75	2.	19	75
3 watt amber A19	90	0.5	4.0	12
3 watt amber PAR16	90	1.8	16	50
7 watt amber PAR30	200	5.5	50	200
13 watt amber PAR38	400	11	100	400

Note: Fixture and bulb degradation before cleaning or replacement may decrease these to as low as 50%.

* The luminous efficiency of incandescent light is approximated as 1/10 that of HPS for photopic vision

** Supplied by IDA

*** Assumes a 1 steradian illumination angle and no external optics, typical for 2011

† Lumens is the total amount of light emitted in all directions (over 4π steradians)

†† Lux is the amount of light illuminating a surface of one metre square

1 lux = 1 Lumen / (4π dist^2) where distance is in metres

References:

IDA Information Sheet 4, Operating Data and Economics of Different Lamps, (08/96)
CAN/CSA-C653-94 (2000) - Performance Standard for Roadway Lighting Luminaires
Mesopic Street Lighting Demonstration, Lighting Research Centre, Jan. 31, 2008, (Rensseaer), Table 2, 5

APPENDIX D - Approximate Times of Sunset for Areas in Southern Canada

The time of sunset depends on the time of year and the latitude for a site. The following table lists the approximate time of sunset (DST) for latitude of about +50 degrees from May to the end of September.

May 1	8:17
8	8:29
15	8:38
22	8:48
29	8:57
June 1	9:00
8	9:08
15	9:11
22	9:13
29	9:13
July 1	9:13
8	9:09
15	9:04
22	8:57
29	8:48
August 1	8:42
8	8:31
15	8:19
22	8:06
29	7:50
September 1	7:45
8	7:30
15	7:15
22	6:59
29	6:44

From the Royal Astronomical Society of Canada
Observers Handbook

APPENDIX E - Navigation Light Photometric Distribution[35]

			Minimum Intensity (candelas) **(a)**				Intensity (candelas) at given elevation angles when the light is levelled **(c)**				
Light Type	Colour	Signal type	day	twilight	night	Vert. beam spread **(b)**	- 10deg **(d)**	- 1deg **(e)**	± 0deg **(e)**	+ 2.5deg	+12.5deg
CL810	red	fixed	N/A	32min	32min	10deg	-----	-----	-----	32 min	32 min
CL864	red	flashing 20-40fpm	N/A	N/A	2,000 ±25%	3 deg min	-----	50% min 75% max	100% min	-----	-----
CL865 **(f)**	white **(f)**	flashing 40fpm	20,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----
CL866	white	flashing 60fpm	20,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----
CL885 Catenary	red	flashing 60fpm	N/A	N/A	2,000 ±25%	3 deg min	-----	50% min 75% max	100% min	-----	-----
CL856	white	flashing 40fpm	270,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----
CL857 Catenary	white	flashing 60fpm	140,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----

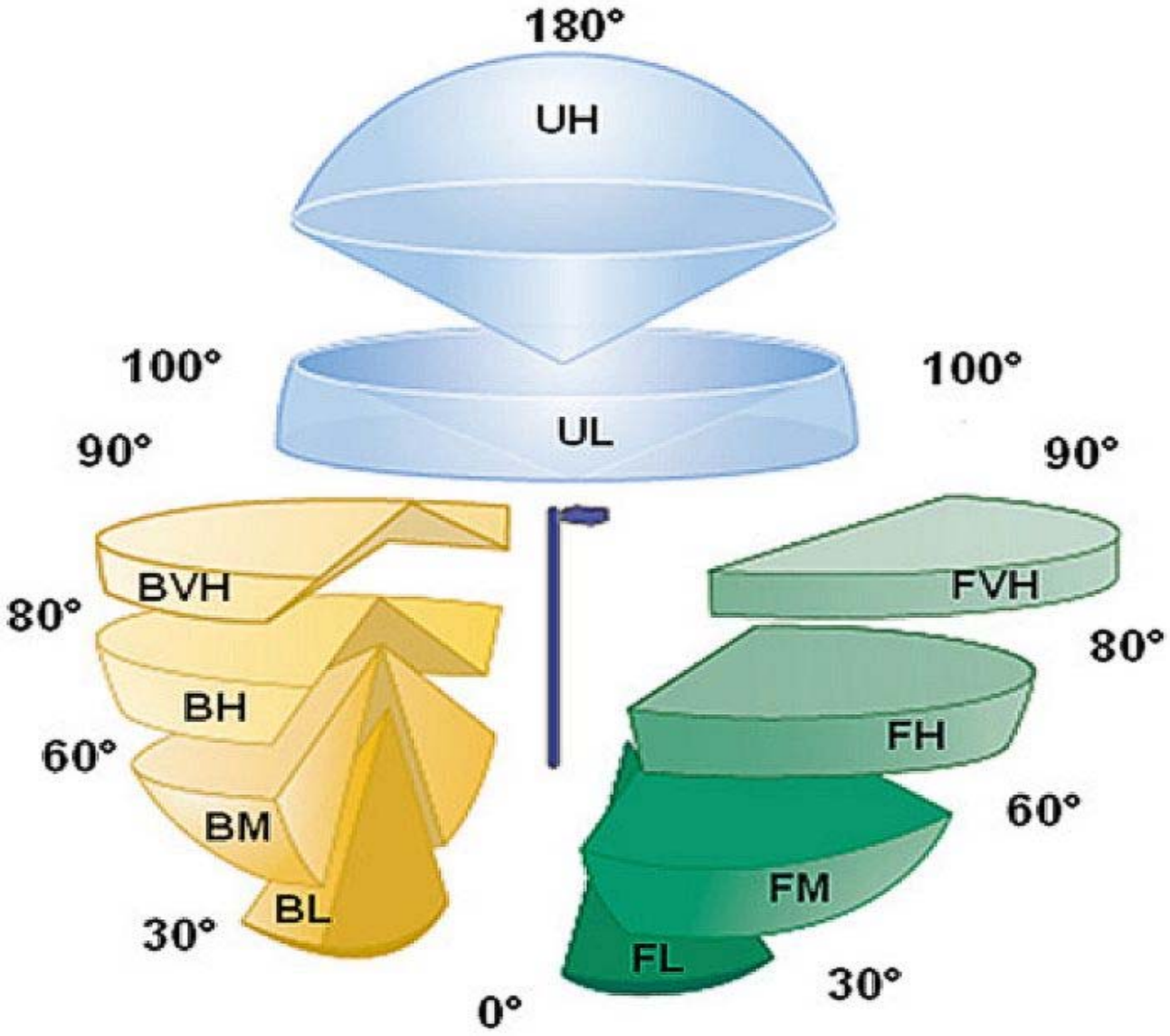
(a) Effective intensity, as determined in accordance with External Transport Canada Document
(b) Beam spread is defined as the angle between two directions in a plane for which the intensity is equal to 50% of the lower tolerance value of the intensity shown in columns 4, 5 and 6. The beam pattern is not necessarily symmetrical about the elevation angle at which the peak intensity occurs.
(c) Elevation (vertical) angles are referenced to the horizontal.
(d) Intensity at any specified horizontal radial as a percentage of the actual peak intensity at the same radial when operated at each of the intensities shown in columns 4, 5 and 6.
(e) Intensity at any specified horizontal radial as a percentage of the lower tolerance value of the intensity shown in columns 4, 5 and 6.
(f) In the case of rotating type CL865 one third of the flash display should be red in colour. e.g. WWR

[35]Wind Turbine and Windfarm Lighting, CAR621.19 Advisory Circular 1/06 - DRAFT 9, Transport Canada

APPENDIX F – IESNA BUG Designation System

The IESNA BUG System has been developed to more specifically define the illumination from a luminaire. Ten zones have been defined that affect the shielding and glare from a light fixture.

The Addendum A for IESNA TM-15-07 provides examples of this system for a given luminaire. The diagram below[36] visually defines the different zones.



FCO luminaire preclude any up light (UH and UL = 0% of total emitted light). To minimize glare and light trespass that increases the impact area of the illumination should have BVH and FVH as close to 0% as possible. FCO fixtures allow 10%. However the preferred Sharp Cut-off designation only permits 1%.

[36] IDA Specifier Bulletin for Dark Sky Applications, Vol. 2(1), 2009

APPENDIX G – Summary of RASC Lighting Protocol Dark Sky Preserve / Urban Star Park

This summary applies to all property and structures within the Dark Sky Preserve.

1. No additional light fixtures should be installed.

If additional light fixtures are considered necessary by the park manager, and with approval by the DSP nominators, additional fixtures may be installed. All new fixtures should conform to the requirements of Items 3-8 below.

2. Signage should not use active lighting.

Signage should use retro reflective materials. Pedestrian signs should be mounted at a height suitable for illumination with flashlights (<1 metre from the ground).

3. Only full cut-off (FCO) fixtures should be used.

All existing light fixtures should be replaced with FCO fixtures or shielded to prevent light from shining above the horizon or beyond the immediate area requiring illumination.

4. The illumination level produced by all light fixtures should be as low as practical.

Dusk and nighttime pedestrian and vehicle traffic densities should be used in assessing the level of illumination. For vehicles, typically <70 watt HPS is sufficient (3 lux) for large parking lots and high traffic density areas where low speed limits are in effect. Major pedestrian routes may be illuminated by typically <5 watt incandescent light or <1 watt LED (1 lux). Due to the use of vehicle headlights and pedestrian flashlights, lower light wattages can be used with the understanding that they are used only as marker lights. Phosphorescent markers may be used.

5. Structures and barriers should be used to confine illumination to the immediate area.

Illuminated areas should be bordered by trees and bushes or other barriers to prevent the light from shinning and scattering beyond the area being illuminated.

6. All light sources should be turned off within 2-hours of sunset

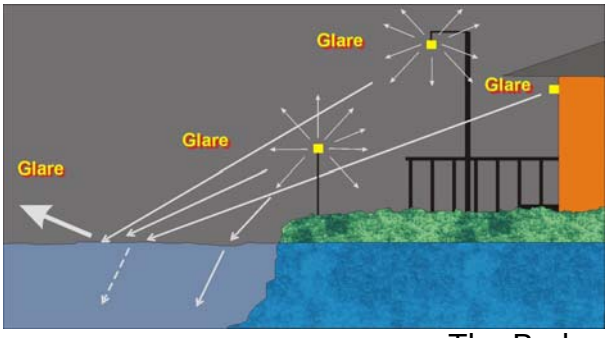
Automatic timers should be used to avoid the need for staff to turn off the lights. The timers should detect nightfall and should turn the lights off within 2-hours. If the park manager considers lights will occasionally be required after this time, the timer should be capable of being reset by staff.

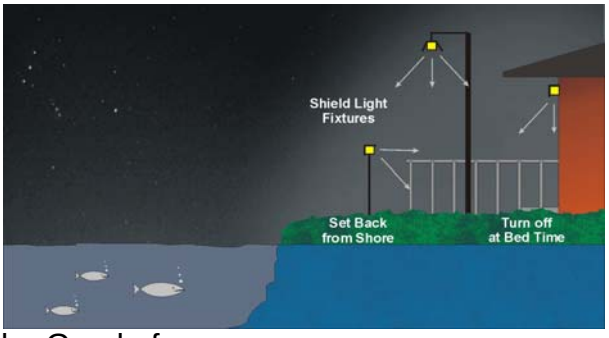
7. Indoor lighting should be prevented from shining through exterior windows.

If interior lights must be used after sunset, window curtains should be closed within 30-minutes of sunset.

8. The colour of all light fixtures should emit a minimum of blue in their spectrum.

“White” light sources such as metal halide lamps and white LEDs should not be used. High-pressure, and low-pressure sodium lamps, incandescent bulbs and “yellow” LEDs may be used.

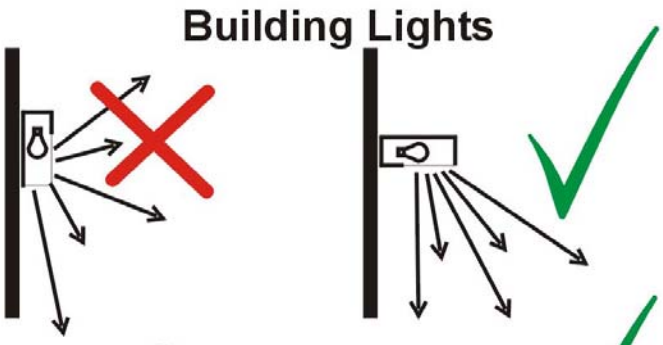




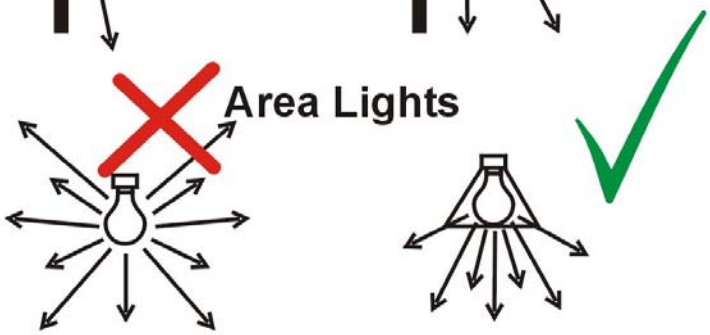
The Bad and the Good of
Shoreline Lighting

Shielded Bollard and White Stone
for Parkland Pathways

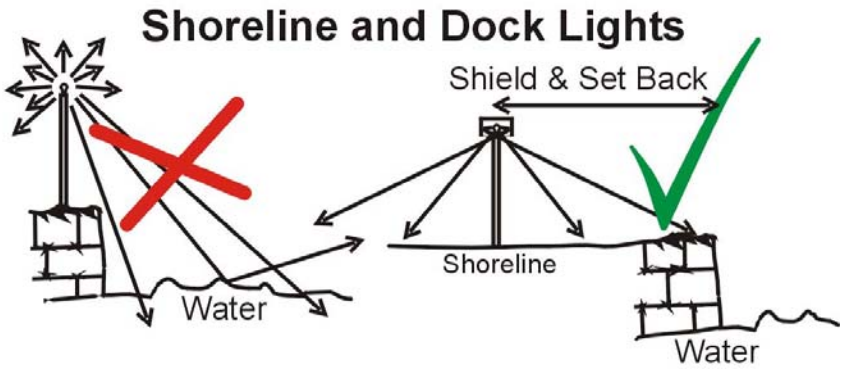
Use Timers
- on at sunset
- off 2-hours later



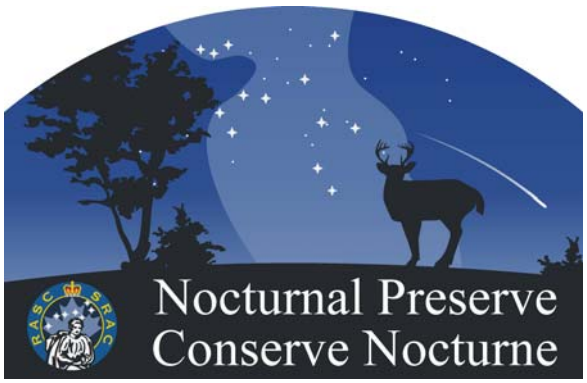
Use Motion Sensors
- lights on only
  when needed



Use "Warm Light"
- not blue white light



RASC Dark-sky Protection Programs



Nocturnal Preserve
Limited use of artificial light at night
May have visitor facilities
May have visitor access at night
Limiting artificial sky glow
Promotion of nocturnal environment

Dark-sky Preserves
Limited use of artificial light at night
Visitor facilities
Visitor access at night
Limiting artificial sky glow
Stargazing and astronomy outreach programs
Promotion of light pollution Abatement

Urban Star Park
Limited use of artificial light at night
Visitor facilities
Visitor access at night
Noticeable impact of artificial sky glow
Stargazing and astronomy outreach programs
Promotion of light pollution Abatement