CN Milton Logistics Hub Ambient Lighting Follow-up Program

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Abbreviations

CIE	Commission Internationale de L'Éclairage
CN	Canadian National Railway Company
IAAC	Impact Assessment Agency of Canada
SP-Meter	Solar Light Model SL-3101 SP-Meter™, PMA 2130D sensor
SQM-L	Sky Quality Meter with lens

1.0 INTRODUCTION

This document outlines the follow-up program for light monitoring and adaptative management in relation to construction and operation of the Milton Logistics Hub.

The light monitoring program presented below, and the associated monitoring details have been developed to comply with the conditions of approval in the Minister of the Environment's Decision Statement issued January 21, 2021. This program has been developed to comply with Condition 4.5 of the Decision Statement and has been developed in consultation with Transport Canada the Town of Milton. Draft versions of this document were sent to Transport Canada on September 2, 2021, and the Town of Milton on July 27, 2021. Comments were received from Transport Canada and have been considered in the finalizing this document. Any revisions and manner by which comments were addressed, including corresponding rationale, were communicated to those who responded to CN's request for input.

2.0 PROGRAM DESIGN CONSIDERATIONS

A follow-up program for light monitoring and adaptive management program will be implemented during construction and operation to verify the accuracy of the environmental assessment and determine the effectiveness of proposed mitigation measures.

The program will consist of three components:

1. Pre-construction measurement of baseline light trespass and glare and additional measurement of sky quality for environmental zone classification.
2. Measurement, during construction of light trespass and glare attributed to the Designated Project and additional measurement of sky quality for environmental zone classification.
3. Measurement, of light trespass and glare at the end of the first year at which the Designated Project operates at full operational capacity and additional measurement of sky quality for environmental zone classification.

3.0 LIGHT PRE-CONSTRUCTION BASELINE UPDATE

An update of the light baseline data prior to construction is proposed to confirm the light baseline information and to reflect any changes since the baseline monitoring program conducted in 2014.

This program will measure nighttime sky quality as well as incident light levels in the photopic range to evaluate brightness as it relates to light trespass and glare. This work is proposed in accordance with Condition 4.1 of the Decision Statement.

3.1 CRITERIA

The lighting criteria assessed for all three program components will be the same as the Technical Data Report Light (Appendix E.8) (Canadian Impact Assessment Registry Reference Number 80100, Document Number 57). That is, classification of Environmental Zone based on measured sky quality and review of metered lighting levels against recommended maximum values for light trespass (illumination) and glare (intensity of the luminaires) based on the Commission Internationale de L'Éclairage (CIE), also known as the International Commission on Illumination document 'Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations' (CIE 150:2003) and 'Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, 2nd Edition' (CIE 150:2017), for environmental zones E2 rural (low distinct brightness) and E3 suburban (medium distinct brightness) (see **Table 3.1** below).

3.1.1 Environmental Zone

The CIE has established five environmental zones as a basis for outdoor lighting guidance in their Document, CIE 150:2017. These five zones are listed in **Table 3.1**.

Table 3.1: Environmental Zones

Zone	Surrounding[1]	Lighting Environment	Examples
E0	-	Intrinsically dark	UNESCO Starlight Reserves, IDA Dark Sky Parks, Major optical observatories
E1	Natural	Dark	Relatively uninhabited rural areas
E2	Rural	Low distinct brightness	Sparsely inhabited rural areas
E3	Suburban	Medium distinct brightness	Well inhabited rural and urban settlements
E4	Urban	High distinct brightness	Town and city centres and other commercial areas

Source: CIE 150:2017

1 – Surrounding description is from CIE 150:2003, Zone E0 was not listed in CIE 15;2003 thus, no description for "Surrounding" is provided

The Technical Data Report Light (Appendix E.8) (Canadian Impact Assessment Registry Reference Number 80100, Document Number 57) concluded that the baseline condition at the time of measurement during the summer of 2014 was Suburban, E3 based on sky quality measurements.

3.1.2 Sky Quality

Sky quality will be measured at all sample locations. Sky quality is a useful surrogate to evaluate any changes in local sky quality levels to original baseline sky quality data collected in 2014. The terms of sky glow and sky quality are often used interchangeably. Updated sky quality measurements will be used to classify the areas Environmental Zone during each program component: pre-construction, construction, and operation by comparing measured sky quality to reference levels from Berry (1976), presented in **Table 3.2**. The higher the number, the more the sky is dominated by the natural background; the lower the number, the greater the degree of sky quality caused by the reflection of lighting from the atmosphere.

Table 3.2: Reference Levels of Sky Quality

Sky Quality (mag/arcsec^2)	Corresponding Appearance of the Sky
21.7 (Rural)	The sky is crowded with stars that appear large and close. In the absence of haze, the Milky Way can be seen to the horizon. The clouds appear as black silhouettes against the sky.
21.6	The above with a glow in the direction of one or more cities is seen on the horizon. Clouds are bright near the city glow.
21.1	The Milky Way is brilliant overhead but cannot be seen near the horizon. Clouds have a greyish glow at the zenith and appear bright in the direction of one or more prominent city glows.
20.4	The contrast to the Milky Way is reduced and detail is lost. Clouds are bright against the zenith sky. Stars no longer appear large and near.
19.5	Milky Way is marginally visible, only near the zenith. Sky is bright and discoloured near the horizon in the direction of cities. The sky looks dull grey.
18.5 (Urban)	Stars are weak and washed out and reduced to a few hundred. The sky is bright and discoloured everywhere.

Source: Berry (1976)

3.1.3 Light Trespass and Glare

The maximum values recommended by CIE for light trespass (illuminance) on properties by environmental zone and time of day are presented in **Table 3.3**.

Table 3.3: Recommended Maximum Values of Light Trespass (Illumination) per Environmental Zones

Time of Day	Environmental Zones				
	E0	**E1**	**E2**	**E3**	**E4**
19:00 – 23:00	n/a	2 lux	5 lux	10 lux	25 lux
23:00 – 6:00	n/a	< 0, 1 lux*	1 lux	2 lux	5 lux

NOTES:

* If for public (road) lighting value may be up to 1 lux

Source: CIE 150:2017

The maximum values recommended by CIE for glare (intensity of luminaires) in designated directions by environmental zone and time of day are presented in **Table 3.4**.

Table 3.4: Recommended Maximum Values for Glare (Intensity of Luminaires) in Designated Directions

Light Technical Parameter	Application Conditions	Luminaire group (projected area A_p in m^2)				
		$0<A_p\leq0.002$	**$0.002<A_p\leq0.01$**	**$0.01<A_p\leq0.03$**	**$0.03<A_p\leq0.13$**	**$0.13A_p\leq0.50$**
Maximum luminous intensity emitted by luminaire (I in cd)	Environmental Zone E0 Pre-curfew: Post-curfew:	 0 0	 0 0	 0 0	 0 0	 0 0
	Environmental Zone E1 Pre-curfew: Post-curfew:	 0.29*d 0	 0.63*d 0	 1.3*d 0	 2.5*d 0	 5.1*d 0
	Environmental Zone E2 Pre-curfew: Post-curfew:	 0.57*d 0.29*d	 1.3*d 0.63*d	 2.5*d 1.3*d	 5.0*d 2.5*d	 10*d 5.1*d
	Environmental Zone E3 Pre-curfew: Post-curfew:	 0.86*d 0.29*d	 1.9*d 0.63*d	 3.8*d 1.3*d	 7.5*d 2.5*d	 15*d 5.1*d
	Environmental Zone E4 Pre-curfew: Post-curfew:	 1.4*d 0.29*d	 3.1*d 0.63*d	 6.3*d 1.3*d	 13*d 2.5*d	 26*d 5.1*d

NOTES:

d is the distance between the observer and the glare source in meters

A luminous intensity of 0 cd can only be realized by a luminaire with a complete cut-off in the designated directions

Source: CIE 150:2017

3.2 LOCATIONS

Light metering for sky quality, trespass and glare will be taken at minimum at the eight sites listed in **Table 3.5**. These locations correspond with the eight sites used in the 2014 baseline sample survey and identified in Table 4.5 of the document entitled Technical Data Report Light (Appendix E.8) (Canadian Impact Assessment Registry Reference Number 80100, Document Number 57). Exceptions which may result in measurements being taken from alternate locations during program components 1 (pre-construction), 2 (construction) or 3 (operation) are identified as a note in **Table 3.5**. Measurements will be made at locations away from streetlights and shading from trees, buildings, or other objects. Some measurements will also be recorded at additional sites to provide further information for the glare evaluation aspect of the program.

Table 3.5: Light Metering Locations

Site[1]	Site Location (UTM Zone 17T)		Site Description
	Easting (m)	Northing (m)	
1	595464	4810448	2nd Sideroad, approximately 50 m southwest of Tremaine Road
2	593900	4811995	Tremaine Road, along property line of proposed Terminal
3	592962	4812846	Tremaine Road, along property line of proposed Terminal
4	595072	4812796	First Line, along property line of proposed Terminal
5	595179	4811749	Lower Base Line, along property line of proposed Terminal
6	589967	4815070	Derry Road West, approximately 400 m west of Tremaine Road
7	588525	4815147	Bell School Line, approximately 1.2 km north of Derry Road West
8	591259	4808849	Walkers Line, Indian Wells Golf Club Parking Lot

NOTE:

1 – For the follow-up monitoring program, light measurements will be taken to be generally consistent with the above eight sites as best possible. Locations used will consider current roadside development or other factors that make the original site from 2014 no longer accessible or not safe to conduct nighttime field work measurements at those locations. Any new or differing sample locations will be within 200 m of the original locations from the 2014 baseline. The new locations will be marked and identified in summary reports generated by each follow-up program component.

3.3 METHOD

The methodology to be used for the light follow-up program in terms of equipment used, measurement procedures and sampling date conditions will be consistent for all three components.

3.3.1 Light Metering Equipment

Light measurements will be taken using two types of light metering equipment:

- **A Unihedron Sky Quality Meter with lens (SQM-L)** will be used to measure sky quality. This meter was developed for astronomical applications to document the level of sky brightness, with the measurement consisting of light within an approximate 60 degree solid angle of sky. The SQM-L provides sky quality measurements in units of mag/arcsec^2 and has a resolution of ±0.10 mag/arcsec^2. The SQM-L displays the internal temperature of the unit after each measurement, the temperature will be recorded as well.
- **A Solar Light Model SL-3101 SP-Meter™ (SP-Meter)** will be used for the characterization of light trespass and glare. The photopic sensor PMA2130D measures light down to a level of 0.001 Lux.

3.3.2 Interpretation of Measured Light Levels

3.3.2.1 Sky Quality

Sky quality measurements obtained from the SQM-L will be used to classify the Environmental Zone of the area at the time of each measurement. Classification will be based on measurements taken during the period of no snow cover on the ground and compared to the range of sky quality conditions from Berry (1976) listed in **Table 3.1**.

3.3.2.2 Light Trespass

Light trespass will be evaluated and quantified based on the photopic light level measurements obtained from the SP-Meter in units of Lux. The measured values, representing the light intensity at the measurement location will be compared to the maximum recommended levels for light trespass (illuminance) outlined in **Table 3.3**.

3.3.2.3 Glare

The means to measure glare practically and realistically in an outdoor environment is limited. There are currently about 12 glare metrics used for assessment of discomfort glare, these date from 1950 to 2011 (Miller, 2019) only a couple of which have had some exterior applications. These glare metrics, however, do not work very well, especially in outdoor environments. The reasons for this are that the metrics typically use average luminance over luminaire aperture which is an inaccurate assumption for LEDS with visible arrays, they assume that the person does not look above the horizontal (about 55° above the axis of view), it is difficult to determine or define what can or should be considered the background luminance, and the spectral power distribution is not considered in how it might impact the discomfort glare response (Miller, 2019 and Davis, 2019). The CIE and Illuminating Engineering Society (IES) are both actively working on glare metrics for outdoor environments through the CIE Joint Technical Committee 7 (CIE JTC7) and the IES Discomfort Glare in Outdoor Nighttime Environments (DGONE) and Lighting for Outdoor Pedestrian Spaces (LOPS) Committees (Miller, 2019 and Davis, 2019). A study by Tyukhova,

2015, summarized six glare metrics developed for outdoor nighttime environments and stated that use of the metrics to predict discomfort glare is questionable due to limitations these metrics have.

Depending on the start-up time of the Designated Project there may be an accepted method to follow for measurement of glare based on work by the CIE JTC7, or IES DGONE and LOPS Committees, however, there is none at this time. Therefore, for purposes of the light follow-up program, glare will be assessed by CIE calculation methods which are an extension of the Unified Glare Ratio (UGR) metric (one of the 12 glare metrics used for discomfort glare). The UGR, developed in 1995 is a tool primarily developed for indoor glare applications but has been used in outdoor applications. Tyukhova, 2015, tested four glare metrics and compared to subjective responses finding that the UGR small source extension had the highest correlation with subjective responses.

A two-step approach will be taken to estimate a glare score or UGR small source extension rating during each phase of the light follow-up program. First field measurements will be collected of background ambient luminance (based on the illuminance measurements collected for light trespass) and luminance from existing luminaires (street lights) in the area around the designated project area, such as existing streetlighting on Tremaine Rd. north of Britannia Rd. W. Measurements of luminance from the street lighting will also include measurement and recording of luminaire type, height and distance of measurement from the measurement locations to the luminaire. This assessment will characterize background luminance and estimate glare from existing streetlighting sources. Measurements during the construction and operations phases of the project from lighting sources on the site of the Designated project can then be compared to current streetlighting sources.

Glare prediction calculations for the Project operation case will be carried out with typical lighting design prediction software (such as AGi32), and those values can be compared to criteria established in CIE 150 (2107) considering the individual luminaires.

3.3.3 Measurement Procedures

Light trespass and glare have two sets of maximum recommended levels based on time of day (**Table 3.3** and **Table 3.4**), therefore, measurements will be taken between 11:00 pm and 6:00 am corresponding with the period with more stringent maximum recommended light levels. The procedures for measuring light are described here for each piece of equipment.

3.3.3.1 Unihedron Sky Quality Meter

At each site the SQM-L will be held with the sensor pointed at the zenith (the point in the sky directly overhead) and eight (8) readings will be recorded, along with the displayed internal temperature of the SQM-L after each reading. The average of the eight sky quality measurements will be used for characterization of the Environmental Zone.

3.3.3.2 Solar Light Model SL-3101 SP-Meter™

At each site the sensor head of the SP-Meter will first be zeroed following the unit's operations manual procedure. The sensor head will be held and pointed at 90° to the zenith (eye view direction while standing upright and facing forward) and measurements will be taken from the sample location in the direction towards the Designated Project area. A two person team will deploy the meter and record readings to enable stable and safe data collection. The light meter is able to measure the following light parameter:

- Photopic reading (lux, metered value)

3.3.3.3 Sky Condition Observations

At each sample location notes will be recorded on the field sheet about sky, weather, and ground conditions. These observations will be used to provide context for the measured sky quality, light trespass, and glare measurements.

3.3.4 Dates and Timing of Measurements

Light measurements for each component phase will take place with consistent environmental/ground conditions. This will be during the spring, summer or autumn when there is no snow accumulation on the ground, this is expected to be a conservative assessment of the existing condition with least surface reflectivity – the same criteria applied during the initial baseline measurements during the summer of 2014.

Prior to conducting each light measurement survey night sky condition forecasts which provide information on cloud cover, transparency, seeing and darkness will be reviewed. Field surveys will be conducted on clear cloudless nights whenever possible, with a forecast for a dark sky, after astronomical twilight and when the moon is not present in the sky. The light meters are designed and specified to operate at temperatures at or above 0°C, therefore, measurement plans will target nights where the ambient temperature is at or around 0°C.

3.4 REPORTING

The results of the pre-construction baseline monitoring proposed as part of the follow-up program will be reviewed and analyzed to document any changes in baseline conditions for these specific criteria since the measurements in 2014. These results will also be used to compare monitoring data collected during the construction and operational light monitoring follow-up programs.

4.0 LIGHTING FOLLOW-UP PROGRAM – CONSTRUCTION

During construction, light trespass and glare attributed to the Designated Project will be measured, for comparison against the light trespass and glare levels outlined in **Table 3.3** and **Table 3.4** respectively. Measured results will be assessed against conditions 4.2.1 and 4.2.2 of the Decision Statement.

4.1 CRITERIA

The same criteria will be used as the light pre-construction baseline update, see Section 3.1 for information on light criteria.

4.2 LOCATIONS

The same locations will be used as the light pre-construction baseline update, see Section 3.2 for information on locations.

4.3 METHOD

The same methods will be used as the light pre-construction baseline update, see Section 3.3 for information on methods.

The construction period is expected to be two years, during this period light measurements will be taken once as per ground cover conditions outlined in Section 3.3.4. Should 24/7 site paving operations be utilized, a light measurement plan will be co-ordinated with the activity if other measurement requirements can also be aligned (i.e., after astronomical twilight, moon not present, dark cloudless sky).

4.4 ADAPTIVE MANAGEMENT

The conditions to be met in terms of light trespass and glare during the construction phase of the Designated Project are outlined in Section 4.2 of the Decision Statement, and its sub-conditions 4.2.1 and 4.2.2. If the pre-construction baseline measurements (Section 3.0) for light trespass and glare meet or surpass E2 rural guidelines (light levels are below the maximum recommended values) then light trespass and glare levels are to remain below these values during the construction phase. If pre-construction baseline measurements exceed E2 rural guidelines, then light trespass and glare shall not exceed maximum recommended values for E3 suburban environmental zone during the construction phase.

As per condition 4.5.2 of the Decision Statement, should light trespass and glare during construction exceed maximum recommended values, CN shall develop and implement modified or additional mitigation measures to ensure that light trespass and glare attributed to the Designated Project meet or surpass the applicable guidelines referred to in conditions 4.2.1 or 4.2.2.

4.5 REPORTING

The results of the light measurements during construction as part of the follow-up program will be reviewed, analyzed and presented in a report to document (a) the results of the program, (b) comparison to applicable CIE guidelines for light trespass and glare outlined in **Table 3.3** and **Table 3.4** and (c) any adaptive management measures (i.e., additional mitigation) employed during construction to reduce light trespass and glare attributed to the Designated Project.

A summary of the results will be provided to the Town of Milton and included as a component of the annual report IAAC.

5.0 LIGHTING FOLLOW-UP PROGRAM – OPERATIONS

During operations and until the end of the first year at which the Designated Project operates at its full operational capacity, light trespass and glare attributed to the Designated Project will be measured, along with sky quality. Measured light levels will be compared against the light trespass and glare levels outlined in **Table 3.3** and **Table 3.4** for light trespass and glare respectively. Measured results will be assessed against conditions 4.2.1 and 4.2.2 of the Decision Statement.

5.1 CRITERIA

The same criteria will be used as the light pre-construction baseline update, see Section 3.1 for information on light criteria.

5.2 LOCATIONS

The same locations will be used as the light pre-construction baseline update, see Section 3.2 for information on locations.

5.3 METHOD

The same methods will be used as the light pre-construction baseline update, see Section 3.3 for information on methods.

The sampling period for this portion of the follow-up program will be contingent on how many years it is before the Designated Project is operating at full capacity. The program will end after the Designated Project has been operational at full capacity for one complete calendar year. During this phase of the follow-up program, light measurements will be taken once operating at full capacity as per the ground cover conditions outlined in Section 3.3.4.

5.4 ADAPTIVE MANAGEMENT

The condition to be met in terms of light trespass and glare during full operational capacity of the Designated Project is outlined in Section 4.2 of the Decision Statement, and its sub-conditions 4.2.1 and 4.2.2. If the pre-construction baseline measurements (Section 3.0) for light trespass and glare meet or surpass E2 rural guidelines (light levels are below the maximum recommended values) then light trespass and glare levels associated with the Project are to remain below these values during full operational capacity as well. If pre-construction baseline measurements exceed E2 rural guidelines, then light trespass and glare levels associated with the Project shall not exceed maximum recommended values for E3 suburban environmental zone during full operational capacity.

As per condition 4.5.2 of the Decision Statement, should light trespass and glare during full operational capacity exceed maximum recommended values, CN shall develop and implement modified or additional mitigation measures to ensure that light trespass and glare attributed to the Designated Project meet or surpass the applicable guidelines referred to in condition 4.2.1 or 4.2.2.

5.5 REPORTING

The results of the light measurements taken during operations and up to a full year after full operational capacity of the Designated project will be reviewed, analyzed and presented in a report to document (a) the results of the program, (b) comparison to applicable CIE guidelines for light trespass and glare outlined in **Table 3.3** and **Table 3.4**, (c) the effectiveness of the mitigation measures implemented and (d) any adaptive management measures (i.e., additional mitigation) employed during operations to reduce light trespass and glare attributed to the Designated Project. The report will also discuss any complaints logged and recorded on lighting concerns, and address investigation or possible mitigations deployed in response.

A summary of the results will be provided to IAAC, the Town of Milton, the Community Consultation Committee and made public through the CN website.

6.0 REFERENCES

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