Milton CN Intermodal Logistics Hub Development Project
Review of Environmental Impact Statement (EIS)
and Supporting Documents

Impacts of Outdoor Lighting

Submitted to:
Region of Halton

Prepared by:
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1. INTRODUCTION

1.1 Summary of Findings

Dark Sky Partners, LLC ("DSP") has reviewed the Environmental Impact Assessment provided by CN in support of the proposed Milton Logistics Hub and associated documentation (the "EIS") and MILTON LOGISTICS HUB - Technical Data Report Light (Appendix E.8) (the "CN Light Report")[1] which provides an assessment of the environmental impacts of the nighttime lighting due to the proposed CN Milton Logistics Hub (the Project).

The CN Light Report provides a first step toward a comprehensive evaluation of the Project's lighting impact on the local environment, however more evaluation is required. Accordingly, we recommend 12 information requests in the report below that we suggest be made to CN in respect of its work on light impacts.

Purpose of Review and Scope of Report

Dark Sky Partners, LLC was retained by the Regional Municipality of Halton, the Corporation of the City of Burlington, the Corporation of the Town of Halton Hills, the Corporation of the Town of Milton and the Corporation of the Town of Oakville (collectively, the "Halton Municipalities") to conduct a review of the EIS to determine whether the project meets the requirements of the EIS Guidelines dated July 2015, as well as the standards set out in the Halton Brief. As directed by the Joint Panel, we have considered sufficiency in the context of whether adequate information has been provided to allow a proper assessment of the technical validity of the information, methods, analysis, and conclusions regarding the significance of any environmental effects, mitigation, and proposed follow-up programs.

Expert Qualifications

Donald R. Davis has a Ph.D. in Physics and over 25 years' experience in the field of dark sky preservation. He is the Past President of the International Dark-Sky Association and a former Chair of the City of Tucson/Pima County Outdoor Lighting Code Committee. He is the author or co-author of over 100 publications in the refereed literature including many in the field of the impacts of nighttime outdoor lighting. He is a co-founder of Dark Sky Partners LLC and is the Managing Partner of that organization.

Christian B. Luginbuhl has a B.S. in Physics and over 30 years' experience in the field of light pollution assessment and mitigation. He is the author or co-author of over 60 publications in the refereed literature including many in the field of the impacts of nighttime outdoor lighting. He is a co-founder of Dark Sky Partners LLC.

1.2 Documents Reviewed

Please see Appendix **A** for a list of the documents we reviewed in preparing this report.

[1] Note: all references in this review preceded by § refer to sections within the document MILTON LOGISTICS HUB – Technical Data Report Light (Appendix E.8) ("CN Light Report").

2. ASSESSMENT OF CN EIS AND TECHNICAL APPENDICES ANALYSIS AND CONCLUSIONS

2.1 Review of Methodology, Data Used, Standard Reference, Results and Conclusions regarding Significance and Mitigation of Adverse Environmental Effects

This section discusses and summarizes principal deficiencies in the CN Light Report and includes requests for additional information.

In the CN Light Report, three areas of potential impact were assessed: light trespass, glare and sky glow and criteria were identified to establish acceptable levels for the first two parameters. Current levels of these quantities were then measured at selected locations and times in order to provide a baseline against which to judge future impacts due to the Project. Calculations were next carried out based on the Project's proposed lighting plan to determine the impact of the lighting on the surrounding environment.

a) Selection of the Area to Be Assessed for Potential Impact:

Setting the Local Assessment Area ("LAA") boundary at 1 km distance from the Project Development Area ("PDA") boundary is not justified quantitatively in relation to environmental impact, consistent with the CEAA guidelines. An assessment of quantitative lighting impacts (such as line-of-sight light fixture visibility or predicted glare level or sky glow impact, or all three) should underlie the determination of the LAA and Regional Assessment Area ("RAA").

DSP suggests that a quantitative estimation of total all-sky or zenith sky glow increase of 10% above current (measured) conditions, arising from Project lighting, be used to set the LAA, and that the RAA be extended to all areas from which the proposed Project lighting fixtures could be directly visible.

The following information is required in order to assess the impact of project lighting:

Information Requests:

Topic	Reference to CN EIS and Information Responses	Requested Information	Rationale
Selection of Assessment Area: LAA and RAA Boundaries EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS Appendix E.8. Lighting Report, Section 3.2	**RL.1** **Re-evaluate LAA and RAA Boundaries** Please provide a re-evaluation of LAA and RAA boundaries based on estimations of the geographical extent of significant lighting impacts. We suggest a quantitative estimation of total all-sky or zenith sky glow increase of 10% above current (measured) conditions, arising from Project lighting, be used to set the LAA, and that the RAA be extended to all areas from which the proposed Project lighting fixtures could be directly visible.	Definition of LAA and RAA at 1 km beyond PDA is arbitrary and not based on lighting impacts. An assessment of quantitative lighting impacts (such as line-of-sight light fixture visibility or predicted glare level or sky glow impact, or all three) should underlie the determination of the LAA and RAA.

b) Selection of Criteria to Measure Project Impact

There have been no legally binding criteria, thresholds or standards widely established for assessing or limiting the impact of outdoor lighting impacts. The International Commission on Illumination ("CIE"), and other organizations such as the International Dark-Sky Association ("IDA"), note three principal aspects of outdoor lighting that can be used to gauge "obtrusive" or "off-site" impacts: light trespass, glare, and sky glow. These are appropriate for the analysis of Project lighting impacts, and have been employed in the CN Light Report (§4.1.3). The CIE, in Technical Report 150:2003, suggests recommended limits to the first two of these (light trespass and glare): CN's analysis has partially employed these measures.

Regarding the basis of its recommendations, CIE Technical Report 150:2003 (pg. 8) notes:

> *The limiting values recommended for the control of obtrusive effects have been developed taking account of the following:*
>
> *a) the level of brightness existing in the area;*
>
> *b) the times that the proposed lighting is to operate;*

c) *the type of lighting technology available to light the activity; and*
d) *the use of readily available and easily understood technical data on the lighting installations that can easily be verified the design and assessment stages.*

Thus, while the CIE provides "recommended limits" for light trespass and glare (there are no recommended limits for sky glow), it is important to note that these 1) are not based on a quantitative understanding of aesthetic, biological, health or other effects of the lighting; 2) are influenced by the "level of brightness in the area" (not necessarily characterized by sky glow brightness), and 3) are based on the capabilities of lighting technologies available in 2003.

The implications of this for evaluating Project impacts are:

1) Other reference values should be considered when assessing the levels of impact. An important reference value is the current condition. Thus, beyond noting that all light trespass levels are below the maximum CIE E3 recommendation of 2 lux[2] (or 1 lux, see below), it should be noted that the impacts represent a dramatic increase above the current values.

2) The most appropriate CIE recommendations should be those appropriate to currently existing local conditions in the Project area, which DSP feels are more accurately considered as "Rural" (E2).

[2] 1 lux = 1 lumen per square meter

Information Requests:

Topic	Reference to CN EIS, EIS Guidelines and Information Responses	Requested Information	Rationale
Assessment of Light Trespass and Glare EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS Appendix E.8. Lighting Report, Section 4.1	**RL.2 Characterization of Project Area** Please expand rationale and assessment to include assessment of impacts relative to CIE E2, in addition to E3 assessment already performed	Though the region is affected by significant sky glow arising primarily from distant light sources in the Toronto region, the local environment near the Project is much darker than would be indicated by the "suburban" "medium district brightness" classification, and if continued to be developed for residential uses can be expected to stay so. The Project area may more appropriately be characterized as "rural" and "low district brightness," or CIE E2.

3) Lighting technologies have dramatically changed since 2003, and what is possible and practical in light pollution mitigation today should not be limited by lighting technologies available in 2003.
Regarding the most appropriate CIE environmental zone, the CN Light Report uses sky glow measurements along with descriptions of the environment used by CIE and Berry to assign the CIE "suburban" and "medium district brightness" environmental zone (E3) to the Project area. The CIE identifies recommended limits for light trespass (2 lux) and glare (1000 candela[3]) for this zone.

DSP believes that, considering all aspects of the lighting environment in the LAA, as well as expected characteristics under future (residential) development, that the Project area would be more appropriately characterized as "rural" and "low district brightness," or CIE E2. Though the region is affected by significant sky glow arising primarily from distant light sources in the Toronto region, the local environment near the Project is much darker than would be indicated by the "suburban" "medium district brightness" classification, and if continued to be developed for residential uses can be expected to stay so. We note that CIE does not propose a quantified relation between sky glow measurements

[3] 1 candela (cd) = 1 lumen per steradian

and environmental zone classification. Thus, a more comprehensive assessment of "district brightness" is needed.

The consequences of utilizing CIE E2 versus E3 recommended limits will not affect the light trespass analysis, since all predicted light trespass levels fall substantially below both recommended limits. It can be expected however that the differing glare recommended limits will have some consequence when the needed glare evaluations are performed (see below).

c) Adequacy of Field Survey Data Characterizing the Current Lighting Environment

The characterization of current lighting conditions is inadequate for all measures of impact.

- Light Trespass: The light meter used is insufficiently sensitive to detect low illumination levels that may be significant, particularly after the Project lighting is constructed.
  The CIE recommended glare limit for E3 is 1000 cd (500 cd in E2) per luminaire; this luminous intensity will produce an illuminance at 500m distance of 0.004 lux. Though the Extech EA33 meter will show this as 0.00 lux, a single source at this brightness and distance will illuminate surfaces more brightly than a quarter moon, and appear 40 times brighter than the planet Venus at its brightest. DSP estimates that the proposed high-mast fixtures may exceed 1000 cd when viewed from off-site; there are 300 such fixtures shown in Appendix C of the CN Light Report.
- Glare: The photographs (§5.1.1) show glare sources, but provide no measures.
- Sky Glow: Measures are reported from eight sites for only one sky position (that is not adequately described). The meter employed for these measurements, the Unihedron Sky Quality Meter with lens ("SQM-L"), while sufficiently sensitive to measure the low brightness of the night sky, has a field of view characterized by a "full width to half maximum sensitivity" (FWHM) of 20°. It remains significantly sensitive however to much larger angles, making it important to ascertain that no glare sources exist even to angles as large as 60° to 80° from the pointing direction. We presume that the reported measures are with the meter pointed toward the zenith (though this is not stated in the report), but the meter pointing direction and presence of nearby glare sources is not described. Nonetheless, sky glow conditions and predictions for other parts of the sky are important. Early measures by Berry in the Toronto region (the same paper referenced in the CN Light Report) show the significant variation in sky brightness:

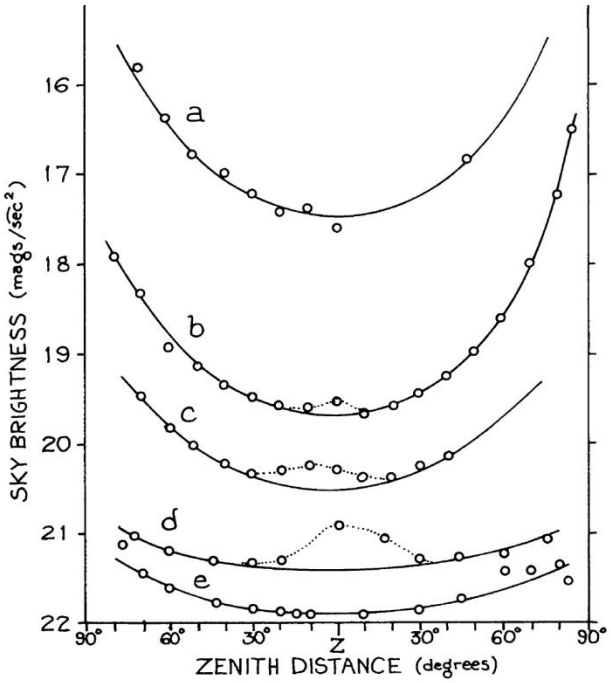
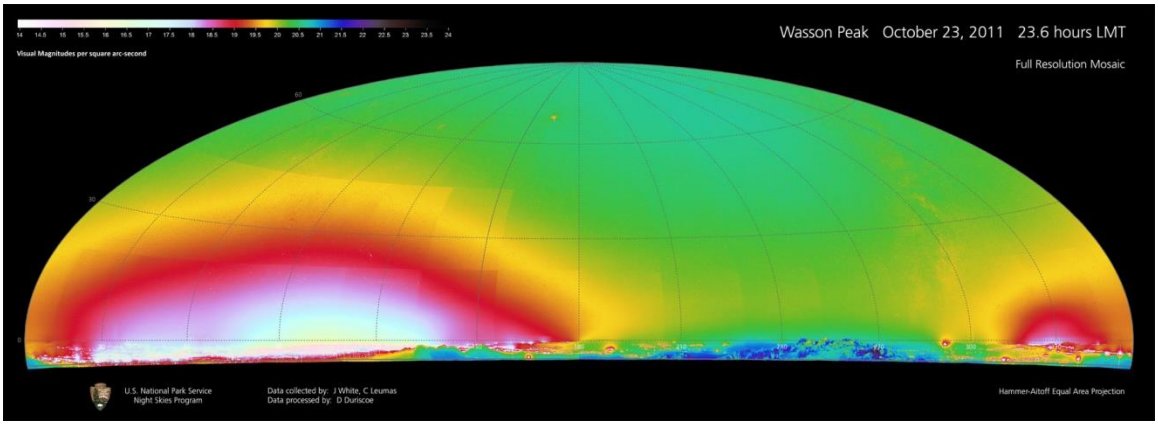


FIG. 2—Horizon-zenith-horizon scans, on the meridian, of five night skies: a) downtown Toronto, March 20, 1975; b) Palermo, Ontario, September 16, 1974; c) Lynden, Ontario, September 14, 1974; d) Cyprus Lake Provincial Park, September 6, 1975; e) Junipero-Serra Peak, California, from Walker (1973).

These measures were made along a great circle crossing the sky from horizon to horizon, passing through the zenith. Particularly in regions like that under consideration here (cf. profile b), the contribution of artificial lighting to the sky glow is dramatically greater toward the horizon. All-sky panoramic measures made with modern instrumentation show the effect even more dramatically, as shown by this map made by the US National Park Service near Tucson Arizona:



The impacts of the Project lighting can be expected to be much more significant away from the zenith in the direction toward the Project. The SQM-L meter is not suitable for measuring sky glow away from the zenith, as its large field of view means that it will begin to include portions

of the landscape in the measurement which will bias the measures low. Any directly visible (glare) sources will also contaminate the measures.

Finally, sky glow arising from artificial sources is known to vary not only seasonally (as noted in the CN Light Report), but also by time of night. Studies have shown that variations of as much as 30% or more are observed. It is therefore important that time of night information be included with the measures in the CN Light Report.

The following information is required in order to assess the impact of the project lighting:

Information Requests:

Topic	Reference to CN EIS, EIS Guidelines and Information Responses	Requested Information	Rationale
Sky Glow Levels EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS Appendix E.8, Lighting Report, Section 4.2.1	**RL.3** **Assessment of Baseline Sky Glow over Entire Sky** Please execute measures documenting sky brightness of the whole sky, from zenith to horizon.	The Unihedron Sky Quality Meter with lens ("SQM-L") is not adequate for total sky assessment. An evaluation of the entire night sky is needed to determine current sky glow levels, not just measurements in a limited portion of the sky.
Glare Sources EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	CN EIS, s. 4.2.1	**RL.4** **Measure Current Glare Conditions** Please document pertinent camera exposure/sensitivity information for photographs; employ High Dynamic Range (HDR) techniques to quantify current glare conditions.	Though photographs are qualitatively useful to document baseline, specific exposure/sensitivity information must be recorded, as well as potentially High Dynamic Range (HDR) techniques employed to quantify glare.

Topic	Reference to CN EIS, EIS Guidelines and Information Responses	Requested Information	Rationale
Light Trespass (Illuminance) EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	CN EIS, s. 5.1.1	**RL.5** **Use All-Sky Brightness Measures To Evaluate Baseline Light Trespass.** Please measure horizontal illuminance (light trespass) through all-sky sky brightness measurements. The measurements requested under IR.6 will provide these data.	Measurement of 0.00 lux is not the same as "no incident light is shining within the area." The meter employed is insufficiently sensitive to measure the impacts, having been designed for use in different circumstances.

d) Assessment of the Project Lighting Plan

Details of the project lighting plan (overall site lighting design criteria; fixture photometric characteristics; fixture spectral characteristics; mounting geometry; etc.) should be examined to assess potential for specification changes that can reduce impacts while still meeting design criteria. For example, narrower photometric lighting distributions of the high-mast lighting may provide needed illumination while reducing impacts in the region. Further, the potential for headlights from truck operations during evening or night hours to cause off-site glare and light trespass must be assessed.

Information Requests:

Topic	Reference to CN EIS and Information Responses	Requested Information	Rationale
Design Criteria and Lighting Plans EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS Appendix E.8. Lighting Report, Section 4.4 Predictive Modeling	**RL.6** **Design Criteria and Lighting Plans** Please provide design criteria and lighting plan details including position coordinates of each individual fixture, lamp type, and manufacturer cut sheets, needed to evaluate the proposed lighting from the perspective of environmental protection. Vehicular movement patterns must be evaluated to assess potential off-site impacts of headlights.	This information is needed to assess the impact of the project lighting on future light trespass, glare and sky glow, and the potential to mitigate these impacts through changes in the lighting design.
Roadway Lighting EIS Guidelines Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS Appendix E.8. Lighting Report, Section 3.2 Local Assessment Area	**RL.7** **Design Criteria for Roadway Lighting** Please provide design criteria for roadway lighting in the Region Official Plan and the locations of planned future lighting.	This information is needed to assess the impact of the Project lighting on future sky glow, and potential changes to the reference (background) condition.

e) Adequacy of the Predictive Assessment of Project Impacts

- Sky Glow: There is no quantitative assessment of the magnitude of the sky glow increase due to Project lighting.
- Glare: There is no quantitative prediction of glare resulting from Project lighting.
- Light Trespass: The trespass assessment is insufficient.
  The predictive light trespass assessment should include reflections from ground surfaces within the Project, as well as contributions from line-of-sight emissions from the luminaires, and must be executed with instrumentation capable of detecting light trespass levels below 0.005 lux.

The following information is required in order to assess the impact of project lighting:

Information Requests:

Topic	Reference to CN EIS, EIS Guidelines and Information Responses	Requested Information	Rationale
Sky Glow EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	CN EIS, s. 5.2.2	**RL.8 Future Sky Glow Assessment** Please include at a minimum: change to sky glow over entire sky from Project lighting. This assessment should include ground reflection (both summer and winter conditions) together with the berm mitigation.	Assessment is missing. Assessment should include at a minimum: change to sky glow over entire sky from Project lighting.
Glare EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS, s. 4.1.4.1	**RL.9 Future Glare Assessment** Please provide an assessment of the predicted future glare resulting from Project lighting. This assessment should include number and brightness of directly visible light sources due to Project lighting, ground reflectance (both summer and winter conditions) together with the berm mitigation.	A glare assessment is a required in order to understand potential impacts.

Topic	Reference to CN EIS, EIS Guidelines and Information Responses	Requested Information	Rationale
Predicted Trespass (Illuminance) EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	CN EIS, s. 5.2.1	**RL.10 Predicted Light Trespass** Please compare predicted illuminance to existing condition as well as CIE maximum. This assessment should include ground reflectance (both summer and winter conditions) together with the berm mitigation.	Predicted light trespass is compared only to CIE maximum recommended limits.
Sky Glow EIS Guidelines, s. 6.1.1, 6.2.1 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS, s. 4.1.4.1	**RL.11 Spectral Impacts on Sky Glow** Please assess sky glow brightness arising from proposed Project lighting using both photopic and scotopic metrics.	Low levels of illumination and sky glow indicate an assessment of human scotopic impacts should be assessed. All measures/predictions in the current analysis have used only standard luminance/illuminance (i.e. photopic) responses.

f) Mitigation

The CN proposed mitigation is vaguely described and not quantified.

Information Requests:

Topic	Reference to CN EIS, EIS Guidelines and Information Responses	Requested Information	Rationale
Mitigation EIS Guidelines, s.6.4 Halton Brief, Table D.7, Night-Time Light on Residential Receptors	EIS, s.6.4	**RL.12** **Mitigation Strategies** Please provide quantitatively assessed mitigation strategies for the Project lighting plan.	Mitigation strategies are not quantitatively assessed. The proposed Project lighting plan should be reviewed to minimize environmental impact consistent with the lighting design criteria. The effectiveness of berms should be explicitly evaluated.

3. CONCLUSIONS

The EIS Appendix E.8 Light Report contains a number of deficiencies that preclude a quantitative assessment of the effects of the outdoor lighting for the proposed CN Project on light trespass, glare and sky glow. The most significant of these are:

1) the boundaries of the LAA and RAA are arbitrarily set, and not based on any quantitative assessment of realistic impacts;
2) there is no or insufficient quantitative assessment of the existing or glare or sky glow baseline condition – the photographic documentation and the SQM-L measurements are inadequately documented, and the wide-field nature of the SQM-L precludes accurate assessment over the entire sky – a quantitative all-sky assessment using modern instrumentation is needed;
3) there is no quantitative assessment of the predicted future glare or sky glow impact;
4) assessment criteria for light trespass and glare are based upon old technology and were devised before modern lighting technologies, including the LED fixtures proposed for this project, became available;
5) mitigation strategies suggested (lighting equipment specification and berms) must be quantitatively assessed for their ability to reduce impacts; and
6) an assertion in the CN Light Report that impacts from future roadway lighting in the region will greatly exceed the expected impacts from Project lighting is not substantiated – quantitative impacts from future roadway lighting in the area should be included in the assessment.

We request that the Joint Panel ask CN to remedy the sufficiency issues we have identified in this report by providing the requested information.

Signed this 9th day of March, 2017

Donald R. Davis

Donald Davis, Dark Sky Partners, LLC

Signed this 9th day of March, 2017

Christian B. Luginbuhl

Christian Luginbuhl, Dark Sky Partners, LLC

APPENDIX A – DOCUMENTS REVIEWED

1) Canadian Environmental Assessment Act 2012

2) Guidelines for the Preparation of an Environmental Impact Statement, July 2015

3) The Halton Brief

4) The CN EIS (including the cover letter from CN dated December 7, 2015, the summary and the report); and, technical appendices:
    a) Appendix A (Final EIS Guidelines)
    b) Appendix B (Figures)
    c) Appendix C (Renderings)
    d) Appendix E.8 - Milton Logistics Hub Technical Data Report – Light
    e) Appendix G - Mitigation Measures and Commitments

5) CEAA Additional Information Requirements (March 15, 2016)

6) CN Response to CEAA on Information Requirements (May 18, 2016)