CDM

Memorandum

To: *William Cundiff - Town Engineer*

From: *Robert Burkard*

Date: *August 19, 2010*

Subject: *Review of Shadow Flicker Analysis Douglas Woods Wind Farm Report Dated August 9, 2010*

Camp Dresser & McKee Inc. (CDM) has completed our review of the most recent Shadow/Flicker Report dated August 9, 2010 prepared by Atlantic Design Engineers Inc. (ADE). CDM received the report on the morning of August 10, 2010 the same day of the scheduled planning board meeting and performed an initial review within the time available. Our initial review on August 10th amongst other items noted a discrepancy in the interpretation of the referenced German standard noted in the report for allowable hours/year of shadow/flicker vs. common practice and the manner in which the standard was being applied. This issue was conveyed to the developer on August 10 and noting this, the developer decided not to submit the report until this issue could be resolved and CDM had the chance to perform a more complete review of the report.

CDM's comments on the August 9, 2010 report are discussed below and organized to correspond with the various sections of the report:

I . Scope of Work/Introduction

- CDM's comments on the previous version of the report Addendum 2 dated July 12, 2010 included a comment that the report should describe in greater detail the methodology that was used in selection of the four representative shadow/flicker receptors that are modeled in the study. A sentence has been added to the report to explain that these receptors were chosen to be representative of the surrounding neighborhoods. We feel that more explanation and analysis is needed in the report especially given that the latest results show the calculated worst case and real shadow/flicker at all four receptors exceeds 30 experienced hours/year. We suggest that the following additional analysis be performed:
    - Prepare a Windpro zone of visual influence map (ZVI) that shows the complete areas surrounding the site where the turbines can be seen. Include concentric

circles of 1000 and 1500 meters in diameter from each turbine to show the maximum potential areas of shadow/flicker.

- We note that the report initially considered a distance of 1000 meters in the shadow/flicker analysis however, given that the results now show exceedances at all four representative receptors, a more conservative approach should be taken to fully evaluate the potential impacts and ensure that all surrounding areas are looked at. This same approach was also taken by UMass in their initial review of the preliminary studies as noted in their April 30, 2009 memorandum (contained on page 138 of the zoning application document and attached herein as attachment 2 for reference)

- For the 4 receptors identified in the report (Neighbors A thru D) indicate how many nearby residences are also represented by each neighbor. For example, Neighbor A is considered in the report as the most representative residence within this neighborhood/area because of its highest elevation, proximity and direct line of sight to turbine(s) and represents a neighborhood consisting of (a certain number of) residences. Since the latest analysis indicates exceedance of the 30 hour /year criteria, ADE may wish to re-run the Windpro analysis including additional receptors within each affected area/neighborhood such that all affected residences are identified and/or certain residents with less than 30 hours/year can be eliminated. We call attention to condition 7 of the ZBA decision (attachment 3) which requires identification of all affected property owners. ADE must therefore provide a complete listing and mitigation plan for all residential locations where shadow/flicker will exceed 30 experienced hours/year.

- The specific residences identified as Neighbors B,C & D shown in the table are not included in the Appendix D photographs. (see further comments under section V)

II. Introduction to Shadow Flicker

- To avoid confusion, CDM recommends that the reference distance of 1000 meters be also stated as 3280 feet. The reason being is the distances shown on Figure 2 are stated in feet and are coincidentally in the order of 1000 – 1400 feet and one may confuse the text being stated in meters at 1000 as being of the same order of magnitude. Both the text and figures should be shown in the same (or both) units.

III. Zoning Bylaws and Legislation

Discussion on Shadow/Flicker Standards

The reference to the German court decision and the application of 30 hour/year standard requires clarification in the report as there are two distinctly different interpretations of how the 30 hour/year of shadow flicker is to be calculated as either a "worst case" or "expected or real case" calculation. Presumably this information was discussed and agreed upon as part of the ZDA decision process. Since a standard has been set for the project by the ZBA decision, CDM recommends that the criteria stated in condition 7 of the ZBA decision be used when discussing the shadow/flicker impact criteria and that the calculation method be clarified with the Board. However, for the benefit of the Board, CDM did some research on the issue and offer the following background and summary:

- As stated in the report, there are no formal shadow/flicker standards in the US. As such, consultants performing shadow flicker studies have relied upon the German standards or a referenced German court decision. Based on our limited research[1], these two German references specify the calculation of shadow flicker in two different ways.

  German Guidelines referred as *"**Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windnergianlagen**"* state that:

  "A receptor should be subjected to shadow flicker a maximum of 30 hours per calendar and a maximum of 30 minutes per day. These maximum limits are based upon a calculation of the astronomically maximum shadow, which is defined as the time sunrise and sunset during which theoretically, the sun will shine continuously cloudless sky."

  In other words shadow/flicker is calculated based on the worst case condition that the sun is always shining, that the wind is always blowing at sufficient velocity to spin the blades and in a direction which results in the blades being perpendicular to the receptor (maximum shadow flicker or worst case). The manufacturer's information from Nordex on shadow flicker that is included in the report Appendix G also references this German regulation or guideline and also indicates that in addition to the 30 hours per year, there is also a maximum 30 minute/day criteria.

  The 2nd reference to Germany includes a court decision in which shadow flicker is defined as:
  "Maximum of 30 hours per year based upon actual/real predicted values."

[1] See attachment 1 Shadow Flicker Assessment- Honeywood, page 5

In other words, the German court ruled that the criteria to apply should be actual or real case, not worst case shadow/flicker values. This calculation takes into account the probability of sunshine as well as site specific wind direction and speed data. As such, the real or calculated shadow flicker is significantly less than the worst case.

CDM also found a reference to a Denmark standard that limits shadow flicker to a maximum of 10 hours per year or real or expected case.[2]

- The Windpro software used to generate the results presented in the report actually calculates both the worst case (astronomically maximum value) and the real or expected case (reduced for sunshine probability, wind speed and direction). Both worst case and real case values are useful in evaluating potential shadow/flicker impact and both values are typically presented in studies.

- Condition 7 of the ZBA decision does not specifically state the methodology (either worst or real case) for comparing to the 30 hour/year criteria. However, the term "experienced hours per year" used in the language of the decision implies the real or expected case. The calculation method should be clarified with the Board before finalizing the report and evaluating compliance with the condition with respect to each affected receptor. We also recommend that the final report simply reference the ZBA decision rather than the German standard to avoid any confusion as to which criteria (worst or real case) applies to this project.

- It should be noted that similar studies conducted in the US and particularly in Massachusetts by various consultants including UMass have followed the maximum of 30 hours per year of "real case" shadow flicker criteria. CDM found one example of a county in Ontario Canada that adopted the German regulation using worst case but this seems to be the exception rather than the rule in North America[3]. As noted above, both numbers are typically presented but precedence seems to be that the real case values are used in evaluating shadow/flicker impact. Attachment 5 is an example similar shadow flicker study prepared by UMass for the Town of Scituate. In this study the criteria of 30 real hours/year of shadow flicker has been adopted. Both the worst case and real case values have also been presented in the report.

Additional Comments on Section III

The last paragraph in section III discusses *"Common practice is to a) site the wind energy facility in a manner that minimizes significant shadowing or flicker impacts and b) perform an analysis to*

[2] See attachment 4 Borsih Wind Farm Assessment, page 2
[3] See attachment 4 Borish Wind Farm Assessment, page 2

show that the effect of shadow flicker does not have significant adverse impact on neighboring, on-site, or adjacent uses either through siting or mitigation."

- The report does not provide a discussion on how the specific locations of the turbines were sited with respect to minimizing the impact of shadow flicker on nearby residences nor any iterative process that may have been used to evaluate various locations such that it can be confirmed that the most optimum siting configuration with respect to shadow flicker impacts has been achieved. If initial analysis were performed that resulted in less favorable results and the turbines were subsequently moved, then this analysis should be noted in the report to demonstrate that the developer has taken all reasonable steps to reduce shadow flicker impacts prior to applying further mitigation measures.

- Given that the revised analysis shows shadow flicker in excess of 30 hours/year at all four receptors, and assuming that the siting of the turbines has already been optimized, mitigation measures may need to be expanded beyond what is presented in the report.

IV. Shadow flicker Modeling & Analysis

- The first sentence in the 2nd paragraph states that "*The calculations performed by Atlantic estimate both the "worst case" and" expected" shadow hours per year*". Both of these methods are then described consistent with the comments on the standards noted above. However, in the results section of the report the calculated worst case values are not presented. This information is typically provided in a shadow flicker study for comparison to the expected or real case. In addition, the maximum minutes per day should also be presented in the report for each receptor.

- The shadow flicker impact plan referenced in the 2nd to last paragraph (Appendix B) based on the revised analysis shows isolines with potentially more receptors that would experience shadow flicker in excess of 30 hours/year. As noted above, condition 7 of the ZBA decision requires that all of these residences be identified. We recommend that further analysis be done to identify each residence where shadow flicker exceeds 30 hours/year and include this listing in the report.

- The last paragraph in this section with respect to ZVI was added in response to earlier comments made by CDM. CDM had requested a ZVI map discussed above to be able to show broadly all areas where the turbines would be visible which has not been provided. CDM also suggested using the model to input trees and obstructions to check results rather than applying the reduction factors used in the report and discussed further in section V. The additional text added to the report does not adequately explain the revised Windpro analysis and the input assumptions. The

model results for this condition contained in Appendix E also show zero shadow flicker impact which is probably not representative of actual conditions once the wind farm is constructed. Further discussion with ADE is needed to understand the assumptions used in this model run. Attachment 6 is an example ZVI map prepared by CDM using Windpro in which both the topography and vegetation were input to the model to generate the ZVI map. Areas in yellow indicate locations where the turbine would be visible. We recommend that a similar map be prepared for the Douglas Wind Farm project that can be used in identification of areas for further shadow flicker analysis.

V. Results and Conclusions

- The table of calculated shadow/flicker results should present both the worst case and expected or real case results for comparison in both hours per year and minutes per day. Based on the comments above, additional receptors may also need to be added or at a minimum all residences represented by neighbor A, B, C & D identified in the report. It should be noted that under both calculation methods the model does not take into account trees, buildings fences and other obstructions that may exist in the line of site between the residence and the turbines and subsequently would reduce the amount of shadow flicker. This conservative approach is typically used in shadow flicker studies as if the criteria is met under this condition then there is greater confidence that once the turbines are installed that shadow flicker impacts will not be a concern. Worst case shadow/flicker results for each receptor as included in the Windpro output in Appendix A are as follows:

Receptor	Worst case (hr/yr)	Expected (hr/yr)
Neighbor A	122:59	34:03
Neighbor B	101:08	32:25
Neighbor C	153:28	54:02
Neighbor D	97:49	37:20

- Paragraph 5 that discusses the impacts to neighbors C and A should be revised to clearly indicate that these receptors represent a complete neighborhood or area containing multiple residences. The text as written, may be interpreted that only 4 locations are impacted when in fact significantly more residences may be impacted. This text may also need to be revised to include additional receptors based on the comments noted above and to comply with condition 7 of the ZBA decision.

- Paragraph 6 provides a discussion on further reduction factors that ADE applied to the expected results that further reduce the estimated shadow flicker to below the 30 hours/year criteria for all but one of the receptors. CDM had previously commented that this approach was not fully justified or explained in the report. Our further comments on this issue are noted below:

    - The field sketches and photographs included in Appendix D are not explained and as is do not further justify the assumed reduction factors of 30 and 75 percent. Specific photographs and sketches for three of the receptors B, C and D are also not included. This information would be more useful if the turbine(s) were superimposed within the photos or these locations cross referenced with the photo simulation report.

    - We have not found an example of a shadow flicker study that used Windpro or a similar model to calculate shadow flicker hours and then further applied assumed reduction factors to generate desired results. Given the sensitivity and valid concerns of nearby residents, there needs to be a sound and defensible analysis performed to put concerns at ease. CDM recommends that the results of the model be used as the benchmark for comparison to the criteria and if there are exceedances that these be mitigated either through an iterative process of evaluating alternate turbine locations or a comprehensive mitigation plan that is prepared in consultation with the affected residences.

    - Paragraph 6 makes reference to "*These* (reduction factors 30 & 75% respectively) *were previously reviewed by the UMass Wind Energy Center, as part of the ZBA process and were found to be appropriate*". We believe that ADE has misinterpreted UMass' Comments as contained in their April 30, 2009 memorandum[4] and as excerpted below. Please note that UMass comments were based on the 13 turbine configuration which has now changed. Nevertheless, CDM believes the same general comments apply. Where appropriate CDM has inserted additional commentary within the UMass memo as indicated in **[brackets]**.

      "These results reflect no obstructions of any kind, as noted by ADE in their conclusions. The discounts ADE applied 75% for neighbors A and B and 30% for neighbors C and D, are dependent on how close trees are to the houses, how many trees there are, and how tall they are, In addition, the type of tree is important as evergreens will provide a greater obstruction throughout the year. ***[CDM commentary: there is no discussion in the report with respect to the size, location, proximity or type of trees present at each of the receptors to begin to justify these reduction***

[4] See attachment 2

factors. The information in Appendix D is simply a compilation of photographs and limited sketches with no explanation or analysis nor an indication of where the turbines would be visible. Further this type of analysis would need to be performed for each residence in the neighborhood as residences farther away from the adjacent tree line may actually be impacted greater than the selected receptor depending on line of sight to the turbine(s)]

Under the most conservative approach, the turbines that can be seen from a location where they are clearly well above the tree line should not have a reduction in the values shown above. In those cases, foliage will not block the view of the turbines and therefore shadow flicker will be fully seen during the hours estimated above. ***[CDM commentary: For this reason (and provided this type of reduction factor analysis ultimately is accepted by the Board and affected residences) each affected residence as represented by neighbors A thru D in the report would need to be independently evaluated and separate reduction factors applied on an individual basis. The report as presented does not justify lumping all residences in a single area into a single reduction factor. We believe that ultimately this type of approach will be extremely difficult to defend by the developer.]***

From location#9 in the visualization study, turbines #7, #8, #9 and #12 are all visible from Blueberry Hill near Shadow Receptor (or neighbor) C. From these locations, turbines #12 and #13 appear to be close to or below the tree line. However turbines #7, #8, and #9 are above the tree line. At visualization location #16, the view is close to Shadow Receptor A and shows that turbine #1 is clearly visible over the parking lot. For locations where trees will not provide cover, a reduction factor of 75% or even 30% could be considered excessive" ***[CDM commentary: while UMass comments are based on the previous 13 turbine configuration, the locations of turbines 1 thru 5 and 7 thru 9 are essentially in the same location. Further, the type of analysis and basic observations UMass made in their comments was not carried forward by ADE in subsequent versions of the report. UMass also clearly states that the reduction factors as applied could be considered excessive where there is no tree cover. This statement is not consistent with ADE's statement in the report text that UMass found with respect to the reduction factors that "****These were previously reviewed by the UMass Wind Energy Center, as part of the ZBA process and were found to be appropriate****". Based on our review of the UMass memorandum CDM believes that the report is not justified in making this statement.***

- While the analysis focuses on shadow flicker as experienced from a person within the residence at a 2nd story window, affected residences may also be concerned with general shadow flicker effects across their entire property. A shadow cast on the

general property footprint may be more prevalent than a window and would likely not be reduced should reduction factors for trees and obstructions be applied. This is a further case to approach the analysis more conservatively by solely relying on the output from the Windpro model itself with no further reduction factor applied. It should be noted that the 30 hours/year of shadow flicker is considered a maximum and that the results of most wind farm studies strive to reduce the shadow flicker to significantly below this maximum value.

VI. Flicker Mitigation Plan

As noted above, CDM does not concur that the application of the 30 and 75 percent reduction factors beyond the calculated real case values generated by the Windpro model have been adequately justified and we question whether this is the most prudent approach to analyze the potential impacts. As such, we recommend that each effected receptor should be addressed with respect to mitigation which may include a combination of relocation of select turbine(s), proposed screening for effected residences and as noted in the report, installation of light sensor switch-off modules to limit turbine operation in times of peak shadow flicker periods. We further recommend that the project developer consider consultation with effected residents in developing the mitigation plan prior to submitting it under condition 7 of the ZBA decision.

Recommendations to the Board

Based on CDMs review of the latest draft of the shadow flicker study dated August 9, 2010, CDM recommends the following:

- That the Board clarify the intent of condition 7 of the ZBA decision to interpret the "experienced hours" of shadow flicker as being calculated as the "worst" or "real" case as discussed above. In general, CDM has found that the accepted standard on similar studies has been to interpret the accepted limit of shadow flicker to be a maximum of 30 hours per year as the "real" (i.e. taking into account sun probability, wind speed and direction) case.

- That the report be revised to reference only the criteria outlined in condition 7 of the ZBA decision so as to not introduce confusion over the interpretation of the German regulations/court decision.

- In our opinion, the information presented in the report with regard to reduction factors is not based on well presented or sound analysis and opens the project up to valid concerns by effected residents. We recommend that all information be presented openly including the estimates of both the worst case and real or expected case and that further refinement of the turbine layout and/or mitigation measures to reduce shadow flicker below a maximum of 30 hours per year be based on the output of the Windpro model alone with no further reduction applied that may be subject to interpretation, debate or subjective opinion.

- That any flicker mitigation plan that may be necessary include an evaluation of alternative siting of the turbines, potential screening measures and/or limitation of operating hours and that such plans be developed in consultation with the affected residents.

- That the subsequent revisions to the report identify all effected receptors (those exceeding 30 hours/year) be individually listed in the report and those effected residences notified together with a flicker mitigation plan as per the requirements of condition 7 of the ZBA decision.

cc: Bruce Haskell – CDM
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