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MEMORANDUM

DATE:	2022-01-24	**RWDI REFERENCE #:** 2201247
TO:	[redacted]	**EMAIL:** [redacted]
FROM:	[redacted]	**Email:** [redacted]
RE:	**College Farm, Shortstown**	
RE:	**Met Office Meteorological Research Unit Cardington - Impact Assessment of subdivision on near surface temperature & humidity measurements**	

[redacted],

Introduction

1. This Technical Note below has been prepared by [redacted]. [redacted] holds a MSc in Atmospheric Science from the University of British Columbia. I specialise in boundary layer (i.e. near-surface) meteorology and have over 20 years of experience in environmental assessment, building design and land use induced local climate change.

2. RWDI has prepared a separate report showing that the changes to measurements of wind will be negligible.

Methodology

3. In general terms, development (or densification) will alter the earth surface in a manner that will tend to increase surface roughness and alter the surface radiation budget in a manner that will increase the amount of incoming solar radiation that is absorbed as heat. This is not universally true; for example, removing a stand of mature forest to build a low-rise school and surrounding grassed playing fields would likely reduce the bulk roughness of the land parcel - but it is generally true in most cases where new built form is introduced.

4. The increased surface roughness of new development increases surface momentum drag. This will reduce near surface wind speeds and increase near surface shear generated turbulence. However, the effect will be localised and limited.

5. The change in surface characteristics will also affect the surface radiation balance. In general, for example, development or densification will tend to increase the surface albedo, which means more incoming solar radiation is retained as heat. Other changes

might be increasing the surface thermal mass (the ability to retain and store heat) through the use of materials such as concrete, and an increase in anthropogenic surface heat from energy use. Such changes will tend to increase near surface temperatures.

6. While there can be a notable difference in surface and near surface temperatures due to development and/or densification – such as a paved street versus nearby irrigated grass – as with roughness, the effect is localised and any one development will have a minimal effect on temperatures over a wider area.

7. Humidity will tend not be significantly affected. In the absence of a large surface source (lake an ocean or lake or irrigated field) or cloud/dew formation, water vapor behaves as a conserved passive tracer and is fairly well mixed. Increased mixing from urban roughness mixing will not matter if humidity is already well mixed. The slightly warmer urban temperatures will reduce *relative* humidity (which depends on temperature as well as the absolute amount of water present), and there will tend to be less surface evaporation from urban surfaces, but there may also be less dew or frost formation versus undeveloped areas.

8. Overall, changes to absolute and/or relative humidity will be minimal.

9. When an air parcel crosses from one surface to another, the layer that is adjusted to the new surface is termed an Internal Boundary Layer or (IBL) or Equilibrium Boundary layer (EBL). The depth of the IBL/EBL grows as distance from the change in the surface increases. The process is described by Bou-Zeid et. al. (2020):

   "*Following a change in properties of the underlying surface under moderate to strong winds, the mean wind field and the turbulence begin to adjust to the new boundary conditions. Very close to the surface, an internal equilibrium layer (IEL) [sometimes also referred to as the equilibrium boundary layer, EBL, develops in which the flow (mean and higher moments) is in complete equilibrium with the new surface and the effect of upstream conditions is negligible. The depth of this layer typically scales with the distance from the surface change x, and a rough estimate under near-neutral conditions is de ~ x/100. Further aloft, the flow has responded to the new surface but equilibrium has not been attained; this region is referred to as the internal boundary layer (IBL) and its depth db ~ x/10, again under near-neutral conditions. Above the IBL, the flow is unchanged from the upstream inflow.*

10. The rate of growth depends on many factors, including the new roughness, the heat flux and the atmospheric stability. A summary of the equations that have been developed and samples IBL profiles are given in Savelyev and Taylor (2005). A schematic from this document demonstrating the IBL/EBL is shown in Figure 1.

Assessment of Effects & Mitigation

11. The nearest approach of the current built-up area to the Cardington Met Office Station is approximately 500m to the north. After development (as currently proposed) it will be approximately 350m away to the north-northwest. The Cardington Studios are located approximately 500m to the north-northeast. There will also be surrounding green spaces. The surface characteristics of these green spaces should be similar enough to existing rural areas to be considered 'undeveloped' for purposes of assessment.

12. The Cardington Met Office Station measures temperature and humidity at 2m, 10m, 25m and 50m. If we use the simplified estimates given by Bou-Zeid (2020), then for measurement heights to be within the EBL or IBL that is adjusted to the immediate rural area, the distance to the nearest development should be no less than 10 times the measurement heights. For the tallest height of 50m, this means development should be located greater than 500m from this tower.

13. For current conditions, where development area is approximately 500m distant, under neutral conditions for winds from this direction, the EBL would be in the order of 5m deep and the IBL on the order of 50m deep. Therefore, under most conditions, the tower is unaffected by the surrounding development areas up to the 50m measurement level.

14. With the development as currently proposed, the distance to the change in surface characteristics would be decreased to approximately 350m. Accordingly, the depths of the EBL and IBL would be in the order of 3.5m and 35m, respectively. Measurements at the 2m would still be in the fully equilibrated layer while measurements at 10m and 25m would be in the IBL, which is the same as present.

15. Thus, for these lower measurement heights, the proposed development should have no effect on measurements.

16. However, at 50m, this would potentially be below the measurement height thus there would be some potential for the development to affect measurements at this level.

17. This would likely be a factor for wind directly from the closest approach. As the wind angle moves away, the upwind distance will increase, the EBL and IBL will deepen and any potential effect on measurements will be reduced.

18. It can be concluded therefore that any proposed development areas further than 500m (the recommended mitigation) will have a negligible effect on even the 50m measurement height.

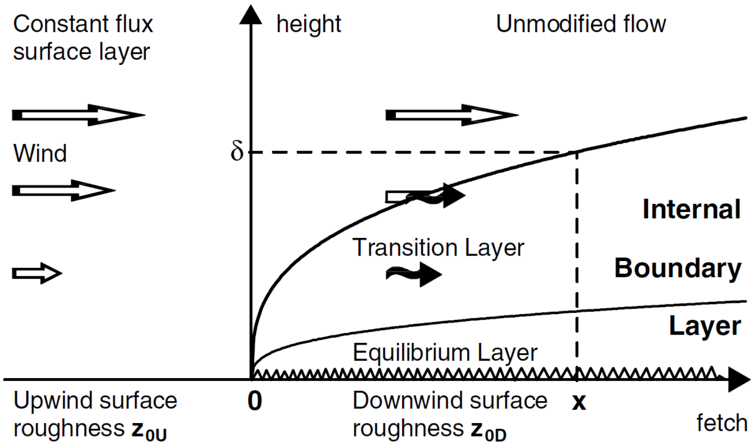

Figure 1. Sketch of a two-dimensional internal boundary layer developing within a constant flux surface layer after a change in surface conditions. d is the height of the interface at distance x from a leading edge. Taken from Savelyev and Taylor (2005).

<u>Summary</u>

19. In my opinion, this development will not result in significant wider changes in near surface meteorology. Effects due to the development will be minimal and localised to the immediate area of development. I can therefore summarise as follows:

   - The proposed development should have no measured effect on temperature or humidity measurements at the tower for the 2m, 10m 25m measurements heights.
   - As a worst case, the nearest edge of the proposed development may have the potential to have limited impacts on tower measurements at 50m.
   - To mitigate the possibility of affecting tower measurements up to the 50m level, the proposed development edge should be kept to 500m away from the tower in all directions.

20. The likely minimal potential effects identified could therefore be mitigated through appropriate design by locating built form outside of the 500m radius of the 50m tower, which would result in any potential impact being reduced to negligible.

Yours truly,

[redacted]

[redacted]

Senior Project Manager, Associate

References

Elie Bou-Zeid, E., Anderson, W., Katul, G., and Mahrt, L. (2020) The Persistent Challenge of Surface Heterogeneity in Boundary-Layer Meteorology: A Review, *Boundary-Layer Meteorology*, https://doi.org/10.1007/s10546-020-00551-8. Retrieved from https://nicholas.duke.edu/people/faculty/katul/BLM_Bouzeid_2020.pdf January 2022.

EPA (1987). On-Site Meteorological Program Guidance for Regulatory Modeling Applications, EPA-450/4-87-013. Office of Air Quality Planning and Standards, Research Triangle Parks, North Carolina 27711.

Savelyev, S.A. and Taylor, P.A. (2005) Internal Boundary Layers: I. Height Formulae for Neutral and Diabatic Flows, Boundary-Layer Meteorology (2005) 115: 1–25. Retrieved from http://www.yorku.ca/pat/ESS5203/Savelyev2005.pdf January 2022.