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EXTERNAL MEMORANDUM

TO: Mr. Allan Cagnoli, Hearth, Patio & Barbecue Association

FROM: Dr. Rick Reiss, Exponent

DATE: December 3, 2009

PROJECT: 1307839.000

SUBJECT: Review of NESCAUM wood smoke monitoring proposal

NESCAUM has proposed to conduct a study to identify local areas in upstate New York with potentially high wood smoke levels. Two studies were cited (Naeher et al. 2007 and Bennett et al. 2002) to show that (1) wood smoke is an important contributor to $PM_{2.5}$, and (2) close proximity between wood burning appliances and people leads to wood smoke exposure. NESCAUM hopes that the study results can lead to effective management programs to limit public exposure to $PM_{2.5}$ in non-urban settings.

NESCAUM believes that there are localized gradients of high $PM_{2.5}$ concentrations that are caused by wood smoke. However, New York State ambient air monitoring networks are not dense enough to capture the spatial variability in wood smoke. NESCAUM therefore proposed to use a GIS-based mapping approach coupled with a low-cost air monitoring field campaign to characterize wood smoke emissions. NESCAUM considers this as a cost-effective approach in non-urban areas to identify local areas with high wood smoke levels.

NESCAUM relied on two prior studies in the proposal: (1) spatial modeling and monitoring in the Pacific Northwest/British Columbia (Su et al. 2007 and Larson et al. 2007), and (2) pilot study fixed point air monitoring at Rutland, VT (Allen et al 2004). NESCAUM attempted to adapt the two study protocols, but left out important steps necessary to verify the methodology. Therefore, results from the study cannot be validated and would not be reliable to serve its purpose of guiding $PM_{2.5}$ management programs.

Specific comments to each task of NESCAUM proposed statement of work are described below.

Tasks 1–3–Develop initial emission surface

NESCAUM proposed to use U.S. Census data and a Mid-Atlantic Regional Air Management Association (MARAMA) survey to estimate wood smoke emissions. NESCAUM believed that it is a low cost substitute for the telephone survey conducted by Su et al. (2007), which was the model for the NESCAUM proposal. However, the U.S. Census only provides the number of households that use wood as home heating fuel in a census block group. It does not describe the type and age of the wood burning unit, or usage data such as the quantity of wood burned. The MARAMA survey provides more information on wood stove usage, but was limited in coverage–there were only 79 responses from households in New York State with a residential wood combustion unit (Broderick et al. 2005). Su et al. (2007) had significantly more detailed data regarding residential wood burning to develop the emission estimates for the greater Vancouver area, which is Step 1 of the GIS mapping design. NESCAUM will need to verify the wood burning activity data, as well as the emission factors for different wood burning appliances, in order to improve the emission estimates.

Task 4–Emission surface enhancements

In this task, NESCAUM proposes to "enhance" the initial emissions surface by incorporating information about meteorological flow. The task assumes that drainage flow is the most important atmospheric process that determines wood smoke concentrations at the surface. NESCAUM planned to follow the exact methodology used by Su et al. (2007) for the greater Vancouver area. This drainage flow or "flow accumulation" model is a simplified way to describe complex meteorological dispersion of wood smoke during cold nights when inversion occurs. Even though Su et al. (2007) used the method in their emission surface enhancement step, it is not a general method that is applicable everywhere. In particular, the greater Vancouver area modeled by Su et al. (2007) is relatively small, roughly 40 miles east-west and 30 miles north-south, compared to the NESCAUM proposed modeled domain, which is 75 miles east-west and 150 miles north-south. Within an almost 10 times larger model domain, other atmospheric dispersion processes might be more important to consider. The greater Vancouver area is surrounded by mountains and faces the Pacific Ocean. This is vastly different from the topography and background sources of the New York counties to be modeled by NESCAUM.

Task 5–Fixed-site wood smoke samples

Su et al. (2007) developed a four-step method to characterize spatial distribution of wood smoke. The first two steps are explained above: (1) creation of an initial emission surface, and (2) emission surface enhancements. Following these two steps, Su et al. (2007) uses the enhanced emission surface created in GIS to allocate fixed-site wood smoke samplers. There are benefits of using spatial analytic techniques to design an air monitoring network, such as increasing the chance of sampling from locations with high and low wood smoke. Su et al. (2007) selected seven air monitoring locations. $PM_{2.5}$ gravimetric analysis was performed at each location for seven months (October 2004–April 2005) to determine mass concentration using impactor samplers. Filters were subsequently analyzed for levoglucosan, which is generally recognized as a tracer for wood smoke. At one of the sites, there was also additional monitoring by a nephelometer.

NESCAUM did not mention roughly how many fixed-site air monitors will be placed based on the enhanced emission surface created for the New York counties. It did not explain how the enhanced emission surface would be used to guide the placement of fixed-site air monitors.

NESCAUM also did not explain any plans to incorporate existing $PM_{2.5}$ air monitoring data with the new data collection effort.

NESCAUM planned to use optical instruments only, one Aethalometer and one nephelometer, to quantify wood smoke PM levels. It is clear from Su et al. (2007) that optical instruments are insufficient to quantify wood smoke PM. Instead, the researchers used gravimetric analysis coupled with chemical analysis of levogulucosan.

Pilot study by Allen et al. (2004)

The proposed "delta-C" Aethalometer measurements by NESCAUM as a tracer for wood smoke is based on a pilot study in a Rutland, VT by Allen et al. (2004). Rutland is a small city with a total area of about 10 square miles. Between February and July 2004, Aethalometer measurements were taken at a fixed air monitoring location, collocated with continuous $PM_{2.5}$, SO_2, CO, and NO_x measurements. "Delta-C" is the difference in optical absorption of PM at 880 nm and 370 nm wavelength. "Delta-C" is not a direct quantitative mass measurement of PM or any chemical component of it. Rather, Allen et al. (2004) calculated the source contribution of wood smoke based on "delta-C" measurements and the use of a receptor model. The authors showed that the calculated wood smoke contributions were correlated with expected wood burning on cold nights. Allen et al. (2004) then concluded that the "delta-C" signal is a "specific indicator of wood smoke-related PM" and incorrectly describe the Aethalometer as a "wood smoke sampler."

NESCAUM assumed that the Rutland pilot study is directly applicable to its model domain that includes many New York counties. The mix of other air pollutants, difference in topography, proximity to upwind sources are some of the reasons why the Rutland study may not apply to all of the study domain. The Rutland study used a receptor model to determine source contribution in a novel way with unknown reliability. The proven receptor modeling methodology requires chemical analysis of the composition of PM in order to determine the wood smoke source contribution. Allen et al. (2004) did not follow this proven approach. The authors were not able to determine the reliability of using "delta-C" measurements as indicators for PM wood smoke. NESCAUM's statement that the "delta-C" method provides "reasonably quantitative wood smoke PM levels" is not valid, especially when it is applied to a vastly different model domain.

Allen et al. also refer to a factor of 15 as a "semi-quantitative" method to convert "delta-C" to wood smoke PM. However, this value is only based on the single study in Rutland and would clearly be unreliable to apply elsewhere without significantly more data.

Task 6–Mobile monitoring network

NESCAUM planned to use the same pair of optical instruments, an Aethalometer and a nephelometer, at the fixed monitoring sites. Without proper validation of the "delta-C" method, the mobile monitoring will suffer from the same deficiency as the fixed site monitoring.

The greater Vancouver area study used a nephelometer placed in the back seat of a passenger vehicle to collected mobile measurements. It did not use an Aethalometer. NESCAUM will need to test the sensitivity of the Aethalometer to vehicle emissions before using it for sampling.

Larson et al. (2007) described the need to select sampling routes to maximize spatial variability of wood smoke concentrations. They also performed monitoring for a substantial number of methods from November 2004 to March 2005 on one route, and January–March 2005 on second route. NESCAUM assumed that feasible sampling routes would adequately capture spatial variability within the large model domain incorporating many New York counties. The proposed statement of work did not address if sufficient number of mobile sampling would be conducted to quantify spatial distribution of wood smoke.

Tasks 7 to 9–Spatial models to predict regions of high wood smoke levels

NESACUM proposed to follow the spatial regression model described in Larson et al. (2007) to predict regions of high wood smoke levels. Larson et al. (2007) defined a parameter Y_x that was calculated using optical measurements made by nephelometer and $PM_{2.5}$ TEOM measurements. The parameter Y_x was calculated and averaged for each "catchment" area, similar to the idea of drainage flow explained earlier. Finally, a spatial regression model was used to correlate the parameter Y_x with factors such as woodstove use, socio-economic status, etc.

NESACUM did not explain how it planned to use "delta-C" measurements to calculate Y_x or other parameters. Apart from the "delta-C" sampling issue and applicability of the "catchment" or drainage flow concept, the described methodology requires data that NESACUM did not plan to collect in its proposal. The first is reliable $PM_{2.5}$ mass concentration either by TEOM or other proven regulatory method. The calculation of Y_x requires this data be collected from a sufficient number of fixed air monitors. For a large model domain that includes many New York counties, NESACUM needs to determine if the existing monitoring network is enough for the calculation. The second is levoglucosan concentrations used to verify Y_x. Larson et al. (2007) proposed two formulations of Y_x and decided to use one over the other because of its higher correlation with the measured levoglucoscan concentrations. This means that NESACUM must also conduct filter samples and analyze for levoglucosan to follow this methodology. However, there appear to be no plans to do so.

The outcome of the spatial regression is a number of explanatory variables that correlates to wood smoke levels. Larson et al. (2007) found that the best-fitted model considered all variables: average number of families, average number of bedrooms, average population, average number of households, % low income population, number of building by age, and total number of buildings. The spatial regression fit using data collected from one mobile sampling route had a R^2 of 0.58. The other mobile sampling route has a R^2 of 0.84. NESACUM did not explain in the proposed work how the spatial regression model may be applied in $PM_{2.5}$ management program. Uncertainty of the spatial regression model will be high from the multi-step processes and use of different measurement sets. The resulted spatial resolution will depend on the "catchment" identification, and might not be as fine as the 100–500 m proposed by NESACUM.

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