Memorandum

To: *Chicago Department of Public Health*

From: *Robert Saikaly and Stephen Zemba*

Date: *December 8, 2014*

Subject: *Review of KCBX Dispersion Modeling used to Support Their Variance Request*

CDM Smith Inc. (CDM Smith) reviewed two air dispersion modeling studies developed by Sonoma Technologies Inc. (STi), to support KCBX's Petition for Variance from select provisions of the City of Chicago's Rules and Regulations for Control of Emissions from the Handling and Storage of Bulk Material Piles (Bulk Material Regulations). A brief summary of the first study, entitled "KCBX On-site Air Monitoring," is contained in a letter from STi dated April 25, 2014 and included by KCBX as Exhibit 3 of the Petition for Variance. STi based this modeling on air monitoring conducted over four days on which elevated concentrations of PM_{10} (particulate matter less than 10 microns in aerodynamic diameter) were observed at one or more monitors. The specific days were February 27 and April 12, 2014 for the North Terminal, and March 9 and March 31, 2014, for the South Terminal. In further follow-up material provided to the City (modeling inputs and related files), the accompanying STi narrative[1] describes the study as "Preliminary Modeling". This modeling used onsite meteorological data and 24-hour PM_{10} concentrations measured at the perimeter on-site meteorological stations.

The second modeling study was summarized in a letter entitled "Material Pile Heights and Associated Air Quality Impacts at the KCBX Terminals" dated September 9, 2014 that was submitted to support KCBX's request for variance on pile height limitations. Further details were provided in follow-up material, including a narrative text file[2] and modeling files. The material pile height modeling was conducted for pile heights at 30 and 45 feet and used 2013 meteorological data from the Chicago Midway Airport, Surface Station ID 14819. CDM Smith reviewed the original letters and the follow-up material, including modeling input and output files that were provided by STi/KCBX in response to the City's request for supplemental information.

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[1] The narrative is contained in a text file named "KCBX_PrelimAQModeling_README.txt" and is entitled "Description of AERMET and AERMOD Files Provided by Sonoma Technology, Inc. (STi) Air Quality Modeling Demonstration for PM10 at KCBX Terminals Company (KCBX)."

[2] The narrative text file "README.txt" describes this modeling as preliminary, also, and is entitled "(STi) 2013 Pile Heights and Air Quality Impacts Modeling for PM10 at KCBX Terminals Company (KCBX) South Terminal."

As a result of its review, CDM Smith generated the following general and specific comments.

Air Quality Modeling for April 25, 2014 "KCBX On-site Air Monitoring" Study

KCBX's study attempts to create the inputs for a dispersion model able to predict the PM_{10} concentrations measured at the downwind on-Site monitor, then extrapolate the modeling to predict PM_{10} concentrations at more distant, off-Site locations. To do so, STi constructed a source emission inventory and configuration and used on-site meteorological data to predict concentrations at the downwind on-Site monitoring station on specific days. STi's determination of the "most" downwind monitoring location is somewhat subjective and appears to be based only upon visual interpretation of the daily windrose – importantly, there is no demonstration of the specific emission sources that were upwind of the key monitor. In addition, STi uses the lowest measured PM_{10} concentration for an individual day across its North and South Terminal monitoring networks as background. Due to wind fluctuations and variability, it is possible that emissions from KCBX affected the 24-hour average PM_{10} measurements at all perimeter monitoring locations on a given day and that the true background is lower than the lowest monitored value. For example, winds can vary directions over short-periods of time, even swirling upwind, and non-diffusing eddies can carry emissions in all directions from a local dust source such as material loadout, despite an apparent hour-to-hour consistency in the resultant wind direction suggesting specific upwind and downwind locations.[3] Such effects are highly plausible given the proximity of on-site monitoring locations to KCBX's operations. It is also possible that some monitors are affected by other local dust sources (e.g., neighboring industrial concerns).

This uncertainty compounds with the potential importance of the distribution of emissions across the KCBX sites, which are not described or explicitly specified by STi. STi essentially calibrated its model inputs to predict the observed incremental impacts of KCBX dust emissions at the key downwind perimeter monitoring location, and then used the same model inputs to predict PM_{10} concentrations at more distant downwind residential locations. To do so, STi was required to make specific assumptions about the size and configuration of the KCBX dust emission source(s). The very simple assumption was made that dust emissions occurred uniformly over a portion of the KCBX property. The dimensions of the assumed emission sources are not described in STi's documentation, and differed between simulations. Model calibration requires intimate knowledge of the spatial and temporal distributions of emissions. As an example, an intense, localized emission source near a monitor can cause the same PM_{10} concentration as a larger, more distant source, and the predictions from each source can show different sensitivities to shifts in wind directions. More importantly, the two different emission configurations can lead to very different

[3] For this reason, the dispersion model AERMOD adds a plume meander component to the concentration predictions in all directions from an emission source, despite the specification of a resultant model wind direction (see http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_mfd.pdf).

predictions of PM_{10} concentrations at alternate receptor locations (such as downwind neighborhoods).

One important information gap is STi's translation of impacts from the AERMOD modeling system to the figures presented in Exhibit 3 of the KCBX Petition for Variance. The narrative[1] that accompanies the "Air Quality Modeling Demonstration For PM_{10} at KCBX Terminals Company (KCBX)" (termed "preliminary air quality modeling demonstration") states that modeling results were scaled to produce peak 24-hour average PM_{10} concentrations measured at the KCBX North and South Terminals, but the input files do not indicate that the scaling was accomplished within the model. The scaling procedure, if external to the model, should have been described in detail and calculations provided.

STi stated in its air quality modeling demonstration narrative that the modeled source was not aligned with the monitor showing the highest measured PM_{10} concentration along the prevailing wind direction. It is evident that the piles (i.e., sources) used for the March 9 and March 31, 2014 modeling runs have different areas, geometries, and orientations. Other than mentioning monitoring station alignment, STi does not provide the rationale for these variations in pile geometries. Since these factors affect modeling predictions, the purpose for this variability should have been explained and all associated calculations and emission rates included.

Because KCBX noted in their fugitive dust monitoring plan that pile geometries are subject to change, the sensitivity of pile geometry on predicted impacts should have been assessed in this modeling.

March 9, 2014 Modeling Simulation for the South Terminal

STi conducted preliminary modeling for March 9, 2014 to evaluate the rate at which PM_{10} concentrations decrease with distance from the facility. The emission rate flux of 1.33E-5 lb/hr-ft^2 was used in the modeling along with an assumed and arbitrary rectangular source of area 495,098 square feet located at the nominal center of the facility and oriented with edges parallel to the principal compass points. The flux rate is relatively low, equating to approximately one bulldozer operating 50 percent of the time over the given area with uncontrolled emissions.[4] If the emission flux is derived empirically to "match" the monitored PM_{10} levels, the low emission rate suggests that KCBX's dust control efforts are effective at reducing emissions to levels below those associated with no controls. Regardless, neither the emission rate nor the size of the emission source are documented. KCBX/STi should have provided a source/equipment inventory used to model emissions for each of the scenarios examined to justify the size, shape, and location of the source(s).

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[4] This emission rate was estimated from AP42 (11.9 Western Surface Coal Mining) using an uncontrolled emission factor for bulldozing of coal and is based upon a geometric mean moisture and silt content of 10.4% and 8.6%, respectively.

The March 9, 2014 modeling predictions are depicted graphically in Figure 1, as reproduced in the Lakes Environmental AERMOD View™ program using the input files provided by STi. The modeling predicts an incremental PM_{10} concentration of 27 µg/m^3 at the NE monitoring station (the station located in the predominant downwind monitoring location). The lowest measured concentration of PM_{10} at any of the South Terminal monitors was 29 µg/m^3 on April 9, 2014 (at the NW monitor). Per KCBX's method of selecting the lowest measured PM_{10} value as background, the total expected concentration at the NE monitor is 56 µg/m^3, comparable to the measured value of 48 µg/m^3. Similarly, the STi modeling predicts an incremental PM_{10} concentration of 21 µg/m^3 at the N monitor due to KCBX activities, which when added to a background of 29 µg/m^3 yields a total PM_{10} concentration of 50 µg/m^3, reasonably comparable to the measured level of 58 µg/m^3.

The modeling predicts incremental PM_{10} concentrations of essentially zero at all locations outside of the color-coded plume depicted on Figure 1. Notably, the concentration of 71 µg/m^3 measured at the SW monitor is not sufficiently explained by the modeling, as this value is 42 µg/m^3 above the background level, it is upwind of the site on the specific day, and the STi modeling predicts no contribution from KCBX. This monitor was thus either impacted by an off-site dust source or by localized activities at KCBX that are not adequately accounted for in hourly average meteorological monitoring and the model's assumed emission rate and source.

The most significant factor, however, is STi's depiction of impacts at the nearest neighborhood location. STi Figure 4 in Exhibit 3 of the Petition for Variance indicates the level at the nearest neighborhood location to be the background level of 29 µg/m^3, with an incremental PM_{10} concentration from KCBX of zero. This is consistent with STi selecting a neighborhood location directly to the east of the South Terminal, as indicated in Figure 1. However, this is misleading, because the contour diagram depicts incremental concentrations of PM_{10} due to KCBX at levels of 27 µg/m^3 and greater at more distant residences to the northeast of the terminal. In fact, the reduction in incremental impacts is quite gradual, suggesting that impacts measured at the perimeter monitoring locations may attenuate only a small amount by the time neighborhood locations are reached.

Implications of STi's incomplete presentation of the results of the March 9, 2014 preliminary model simulation are two-fold. First, the notion that KCBX impacts decrease rapidly from monitoring locations to residences is contradicted by the model predictions (Figure 1), which suggest an incremental PM_{10} concentration at a neighborhood equal to that predicted at the NE monitor. Second, given that the neighborhood to the east of KCBX South Terminal is sparsely monitored, KCBX impacts in the neighborhood east of the South Terminal could be greater than those measured at the KCBX monitoring network under some meteorological conditions. For example, emissions from a localized emission source on the eastern side of the South Terminal, coincident with westerly winds, could lead to a situation in which the release is detected by neither the NE nor Central-East PM_{10}, monitors, but nevertheless leads to increased PM_{10} concentrations in the neighborhood to the east.

Figure 1 also shows the location of the Washington High School (WHS) air monitoring station relative to the South Terminal. On March 9, 2014, a 24-hour PM_{10} concentration of 28 μg/m^3 was measured at the WHS air monitor. This value is slightly lower than (but comparable to) the assumed background concentration of 29 μg/m^3, suggesting that PM_{10} even at the NW monitoring station was influenced by KCBX activities or other local sources on the March 9th date (given that PM_{10} at the WHS site was likely affected to some degree by local sources, possibly including KCBX). For modeling purposes, EPA posits that background air quality includes pollutant concentrations due to nearby sources other than the ones currently under consideration.[5] Furthermore, the mean background concentration should be determined at a monitor or monitors when the source in question is not impacting the monitors. That means that the 24-hour PM_{10} concentrations measured at the WHS are potentially more applicable to representing background than the lowest PM_{10} concentration measured on site, and that the site's contribution of PM_{10} to the local ambient air would be estimated as slightly greater if the WHS's monitoring data were used as background.

PM_{10} is ubiquitous in ambient air. In the context of evaluating KCBX's PM_{10} impacts, background represents the concentration of PM_{10} that would be present in ambient air in the absence of the KCBX facilities. Background is difficult to determine, as PM_{10} is released to the atmosphere by innumerous local and distant sources. Once released to air, the standard monitoring methods cannot distinguish PM_{10} contributions of different sources. It is thus possible that other neighboring or proximate industries could be contributing to the PM_{10} concentrations measured across the KCBX monitoring network. In some cases, there are techniques that can be used to identify and apportion PM_{10} sources. KCBX collects PM_{10} on filters at the NE monitors at both the South and North Terminals at three-day intervals, and the chemical speciation data provide information that could potentially help to differentiate petcoke impacts from those of other sources.[6] Routine (everyday) collection of filter-based data at all of the KCBX monitoring sites, along with subsequent speciation analysis of components, might provide additional information useful in identifying petcoke contributions to ambient PM_{10}.

April 12, 2014 Modeling Simulation for the North Terminal

STi modeled PM_{10} emissions from an unspecified generic source using an emission rate of 31.3 pounds per hour. That emission rate for the month of April 2014 equates to approximately 11.3 tons per month based on 720 potential hours. It is not clear what activities the emissions estimate for this modeling includes but the overall emission is equivalent to the uncontrolled emissions from five bulldozers operating at a 50% usage factor for a month, and thus must assume some combination of limited hours of operation/activity and effective dust control.[4] The emission rate should be justified by specifying the specific sources, such as conveyors, stackers, haul trucks,

[5] http://www.epa.gov/scram001/guidance/guide/appw_05.pdf
[6] Even in this case, source attribution could be difficult, as some impacts of diesel particulate sources will be due to KCBX operations, and likely impossible to distinguish from other diesel exhaust emissions.

bulldozers and other equipment, and windblown fugitive emissions.[7] In addition, the geometry of the source used in the modeling is an elongated trapezoid that runs north-south and is located along the east perimeter. The April 12, 2014 modeling predictions are depicted graphically in Figure 2, as reproduced in the Lakes Environmental AERMOD View™ program using the input files provided by STi. On April 12, 2014, a 24-hour PM_{10} concentration of 49 μg/m^3 was measured at the WHS air monitor. This value is much lower than the assumed background concentration of 86 μg/m^3 measured at the *South* Terminal SW monitoring station, suggesting that all PM_{10} North Terminal monitoring stations were influenced by KCBX activities or other local sources on April 12th.[8] No explanation is provided by STi for the shape or orientation of the assumed area source, which differs markedly from that assumed for the March 9, 2014 modeling simulation, and possibly reflects some knowledge of emission sources active that day. The source orientation and location could favor the model predicting low concentrations for receptors west of the site. The sensitivity to assumed pile geometry, and the effect of specific PM_{10} sources, should have been evaluated by STi.

CDM Smith's reproduction of the April 12, 2014 modeling also indicates greater worst-case impacts at off-site monitoring locations than indicated by STi in Figure 2 of Exhibit 3 of the KCBX Petition for Variance. Therein, STi indicates the incremental PM_{10} at the residential location to be 8 μg/m^3 (94 μg/m^3 less the assumed background of 86 μg/m^3). The isocontours of Figure 2, generated using the input files supplied by KCBX in response to the City's data request, indicate KCBX emissions contribute an incremental PM_{10} concentration as high as 18 μg/m^3 at a residential location to the northeast of the terminal – a value more than double that presented by STi in Exhibit 3 of the KCBX Petition for Variance.

In summary, CDM Smith's reproduction of the April 12 modeling simulation indicates higher KCBX-related PM_{10} impacts at residential locations than portrayed by STi in Exhibit 3 of the Petition for Variance. In addition to the inaccurate portrayal of worst-case KCBX impacts, STi may also overestimate background PM_{10} from sources, leading to under-prediction of KCBX impacts. For the April 12th simulation date, there is a large disparity between the PM_{10} concentration measured at the WHS (49 μg/m^3) and the *lowest* KCBX monitor (86 μg/m^3), suggesting that all of KCBX's monitors were affected by local PM_{10} emissions (either from KCBX, or other nearby sources). As STi attempts to model only the incremental PM_{10} due to KCBX emissions, an overestimation of the PM_{10} background concentration in ambient air would lead to an underestimation of KCBX emissions.

[7] Because several of the emission sources have source strengths that vary with wind speed, such variation should also be incorporated in the modeling.

[8] CDM Smith's analysis indicates that the WHS monitoring station recorded 24-hour PM_{10} levels lower than all of the KCBX monitors on 11% of the days from February 18, 2014 to July 31, 2014. On ten days over this period, the lowest PM_{10} concentration measured across the nine KCBX monitors was 10% or more greater than the PM_{10} concentration measured at WHS.

Selection of an appropriate PM_{10} background concentration is thus a key factor in gauging the emission source strength in the modeling simulation. It is possible that chemical speciation data could be used as an additional line of evidence in estimating background, especially the PM_{10} contributions of other industrial sources located close to KCBX's terminals. More sophisticated determinations incorporating both off-Site monitoring (*e.g.*, at the WHS site) and PM_{10} chemical speciation data may yield improved estimates of background. However, at present, CDM Smith believes that the most appropriate method to conservatively estimate background is to take the lowest PM_{10} concentration measured among all KCBX monitoring locations and the WHS monitoring site.

Modeling to Determine Impact of Pile Height on Ambient PM_{10} Concentrations

The purpose of this study was to evaluate the effect of pile height on fugitive dust impacts to ambient air. STi performed two modeling runs which differed only by the height assumed for the area source emissions. STi found that the model predicted essentially the same PM_{10} concentrations in ambient air for the two emission height scenarios, with slightly lower impacts predicted for the higher pile height scenario.

- STi assumed the same emission rates for both pile heights. As is discussed in a separate memorandum on the effects of pile height on emission rates, CDM Smith expects that emission rates, and hence impacts, will be higher as the pile height is increased, principally because a number of emission processes depend on wind speed, which increases with height in the atmosphere.

- The AERMOD dispersion model used by STi treats area sources as hypothetical planes, and does not account for the effects of flow over terrain. Hence, the pile shape and size does not affect dispersion predictions — the emissions are assumed to be released into an air flow that is not affected by the pile. In reality, large piles can be expected to induce plume downwash that will bring the elevated plume down to the ground more quickly than predicted by AERMOD. Adequate consideration of terrain effects requires sophisticated approaches such as wind tunnel studies or Computational Fluid Dynamics (CFD) modeling.

- Other than stating that October 2013 was the month with the highest estimated PM_{10} emission rate, STi's modeling does not adequately explain the origin of the worst-case monthly emission rate of 3.2 tons. Such an explanation would require details of the emission factor equations used and the individual calculations for each emission source. Lacking any technical narrative to explain the assumptions used to derive the emission estimate and lacking any specific information on the design of the modeling study, the basis for STi's modeling is not clear.

- The AERMOD input files used for the pile height modeling appear to incorporate truck traffic as line volume sources; however, non-road earth moving equipment does not appear to be accounted for in any way. Similarly, drop emissions from conveyor transfers and material loading and unloading do not seem to be represented in the input files. On September 9, 2014, CDM smith visited the South Terminal perimeter and observed loader, bulldozer and conveyor operations. In addition, the KCBX Variance Request (June 9, 2014, KCBX Terminals Company's Petition for Variance, page 18) identifies for the South Terminal 7 of 12 conveyors that are partially open to allow for maintenance and inspection and 4 uncovered conveyors. Since these PM_{10} emission sources do not appear to be accounted for in the input files for the pile height modeling, it is unclear whether the emissions from these sources were also included or excluded from the October 2013 site-wide emissions inventory (3.2 tons per month) that was used as an input to the pile height modeling. The sources of these emissions should have been included and clearly represented. The dimensions of these sources and the calculations of release heights and other parameters should have been clearly documented.

- STi set the release height for the stockpiles at one half of the height of each pile, apparently in an effort to account for the release of emissions across the entire face of the pile, but no vertical dimension was input for the initial plume release height. Fugitive emissions from the pile itself would come from the entire freshly exposed surface exposed to high wind velocities. Stacker emissions would be spread over the drop distance from the stacker to the pile. Emissions from bulldozers on top of the pile would be initially emitted at the height of the pile, but turbulent mixing would likely spread the effective emission height over an appreciable fraction of the pile height. If the entire site emission rate was used to estimate the emission flux (as may have been done, rather than modeling individual sources), it would therefore be appropriate to include an initial vertical dimension in the modeling to account for plume generation for mechanically generated and wind-blown emission from the stockpiles.

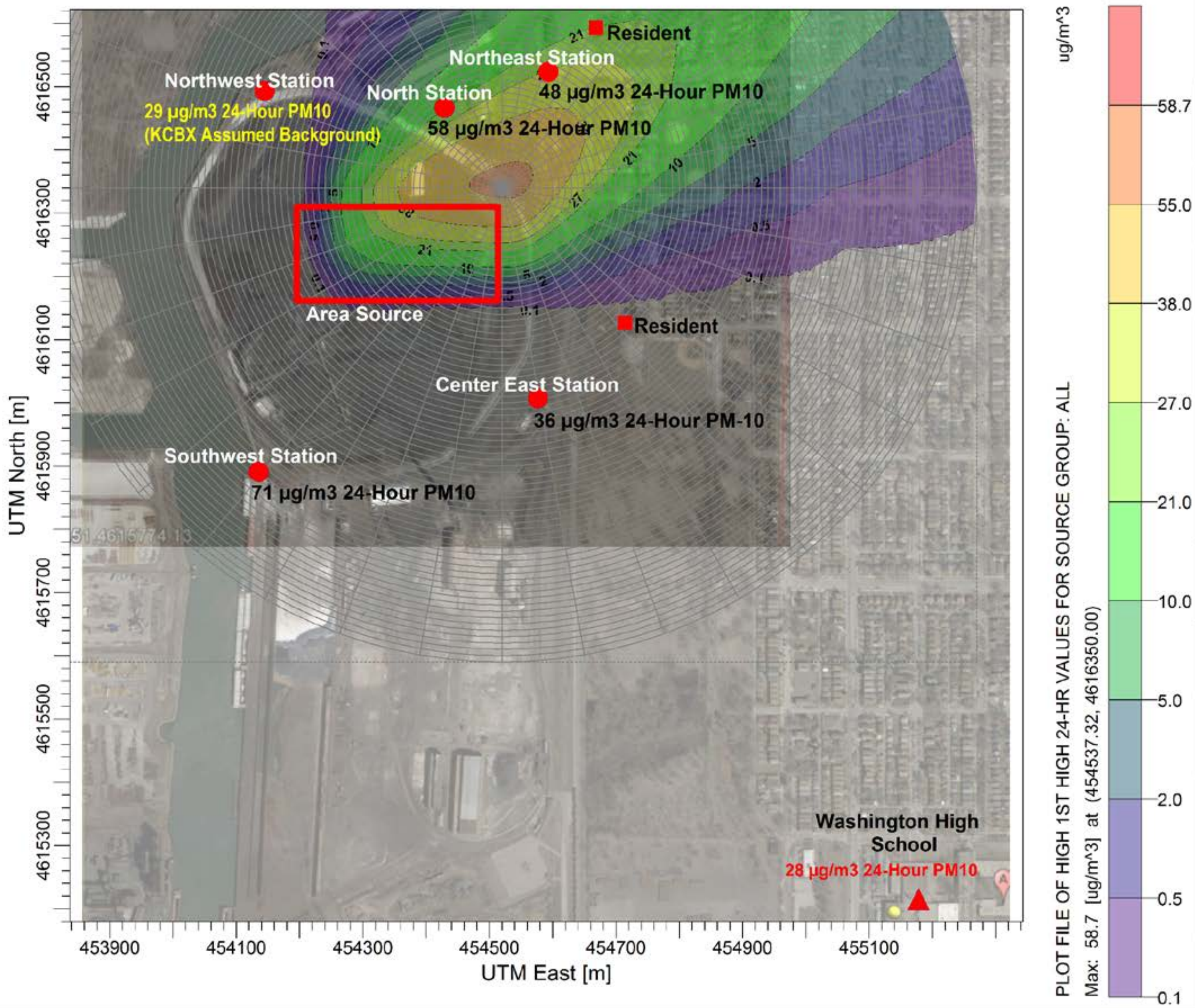
- Plume depletion was selected as a modeling option and the method used to simulate the depletion assumes that 90% of the particulate matter by mass is greater than 10 microns in diameter. Such a high percentage is inconsistent with the EPA AP42 *k* factors used in emission factor calculations. Per our March 2014 Fugitive Dust Study, the particle fraction greater than 10 microns should range from 25% to 80%, but not be as high as 90%. Consequently, STi likely overestimates the rate of deposition and plume depletion (as larger particles settle/deposit faster). Although the deposition rate and plume depletion rate for larger particles do not (or at least, should not) affect PM_{10} air concentration estimates, the initial estimate of 90% greater than 10 microns means that only 10% of the emission is assumed to contribute to PM_{10}. We also note that STi fails to provide any reference for its particle size distribution, and it is therefore unclear whether the assumed particle size distribution correctly accounts for the particle density. This point is especially confusing, since the particle density used for this analysis (1.35 g/cm^3) differs from the particle density used for the "Air Quality Modeling Demonstration for PM_{10}" (2.33 g/cm^3).[9] Model runs should have also been performed assuming no deposition (i.e. no plume depletion) to test the sensitivity of the modeling to deposition assumptions.

Conclusions

CDM Smith's review of two modeling studies, conducted by STi on behalf of KCBX, indicates a limited ability of modeling to predict reliable estimates of PM_{10} concentrations due to the general difficulty in specifying spatial and temporal emission patterns from KCBX's operations. The dispersion modeling is sensitive to emission source configuration, which based on STi's lack of documentation and CDM Smith's experience, is difficult (if not impossible) to know with confidence. Attempts to "calibrate" modeling to match on-site measurements for the sake of extrapolating to off-site predictions are at best uncertain. Notwithstanding, CDM Smith's reproduction of STi's model simulations indicates that PM_{10} impacts at residential locations are substantially greater than portrayed in figures in Exhibit 3 of the Petition for Variance. Additionally, STi's conclusion that PM_{10} impacts were not substantially affected by pile height did not account for the potentially greater PM_{10} emissions associated with higher piles.

[9] Particle size distributions that derive from empirical measurements sometimes assume a unit particle density (1 g/cm^3). If the method used to establish the particle size distribution assumes a particle density value, this value should be used in the modeling study.

Figure 1 KCBX South Terminal Air Dispersion Modeling 24-Hour PM10 Concentrations March 9, 2014



COMMENTS:

Revised November 25, 2014

SOURCES:

1

RECEPTORS:

2705

OUTPUT TYPE:

Concentration

MAX:

58.7 ug/m^3

CDM Smith

MODELER:

Robert Saikaly

DATE:

11/25/2014

SCALE: 1:9,821

0 — 0.3 km

CDM Smith

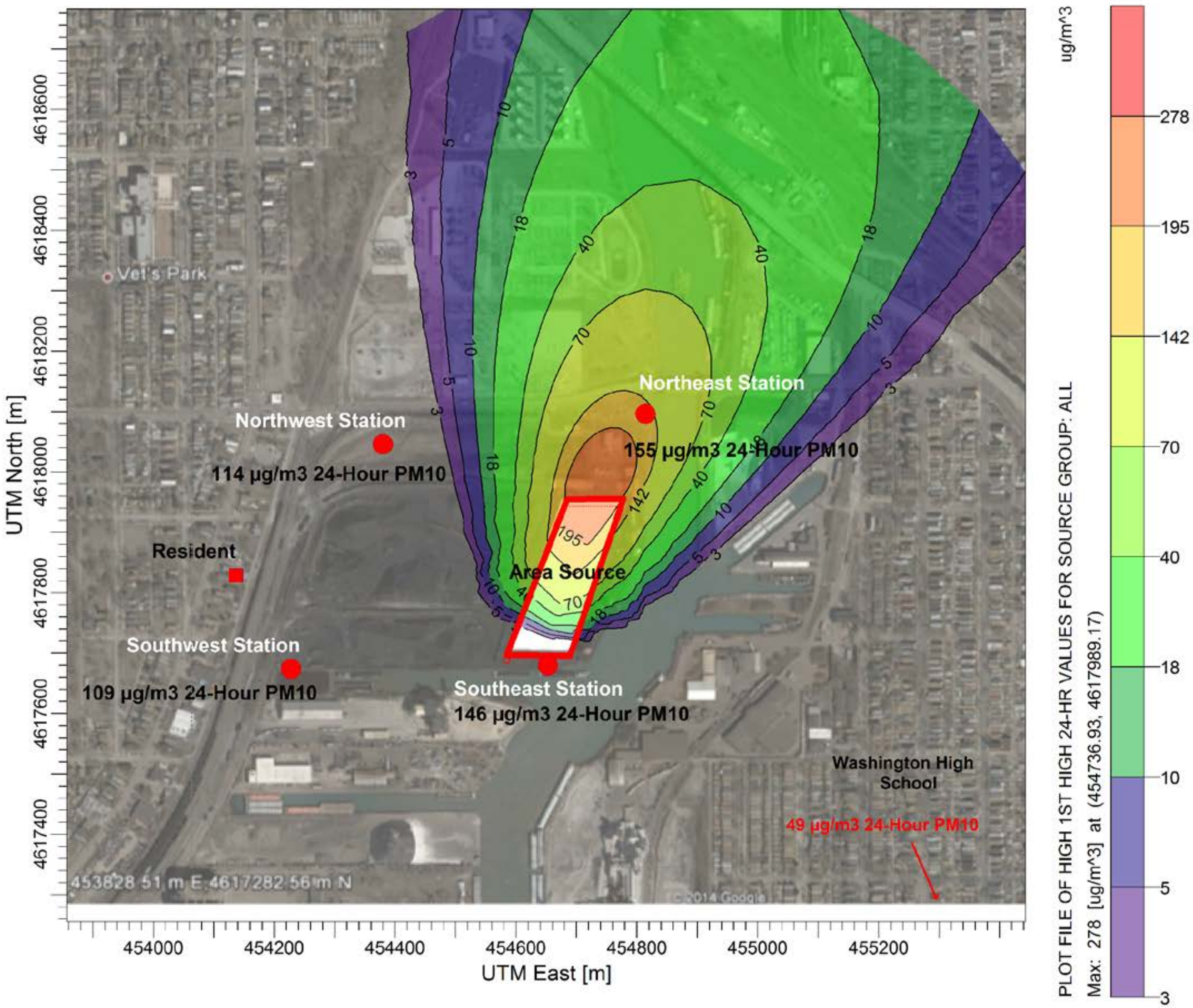
PROJECT NO.:

105998

AERMOD View - Lakes Environmental Software

C:\Users\saikalym\Documents\Rob\city of chicago\petcoke air study\KCBX_Modeling\0309radpol_223\0309radpol_223.isc

Figure 2 KCBX North Terminal Air Dispersion Modeling 24-Hour PM10 Concentrations April 12, 2014



COMMENTS:

SOURCES:
1

RECEPTORS:
2254

OUTPUT TYPE:
Concentration

MAX:
278 ug/m^3

CDM Smith

MODELER:
Robert Saikaly

DATE:
11/25/2014

SCALE: 1:10,285
0 0.3 km

CDM Smith

PROJECT NO.:
105998

AERMOD View - Lakes Environmental Software

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