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Linn County, Iowa

LINN COUNTY PUBLIC HEALTH DEPARTMENT
Air Quality Division

M E M O R A N D U M

DATE: **MARCH 13, 2009**
TO:
FROM: **TONY DAUGHERTY**
RE: **PM2.5 PREDICTED MODELING IMPACTS OF OUTDOOR WOOD BOILERS**
CC:

INTRODUCTION

Due to many factors outdoor hydronic heaters ((OHH) also known as outdoor wood boilers (OWB)) are increasingly becoming a primary method of heating homes and other buildings in the winter months and providing hot water year round. Due to the increasing prevalence of these units, Linn County Public Health has received a corresponding increase in nuisance complaints regarding the operation and siting of these emission sources.

At the direction of the Air Pollution Control Officer and the Linn County Board of Health, an air dispersion modeling analysis was conducted to determine what the predicted health impacts of air pollutants emitted from OWB units. The pollutant for which modeling was conducted for was particulate matter less than or equal to 2.5 microns in aerodynamic diameter ($PM_{2.5}$). Specifically, the Department reviewed what the appropriate setbacks should be for unqualified, Phase I and Phase II qualified OWB units based on the size of each unit and its associated stack height. $PM_{2.5}$ was evaluated in lieu of PM_{10} for several reasons. First, the Phase 1 and Phase 2 OWB's are certified to meet certain PM emission standards. Second, this approach is consistent with Northeast States Coordinated Air Use Management's (NESCAUM) approach in developing their model rule on OWB's. Lastly, $PM_{2.5}$ levels in Linn County vary from year-year, but remain between 80-95% of the National Ambient Air Quality Standard (NAAQS) of 35 $\mu g/m^3$. This memo summarizes the modeling procedures, emission rates used and results of the analysis.

REVIEW SUMMARY

MODELING METHODOLOGY and INPUTS

Air Quality Model Selection

The dispersion model chosen for this analysis is the American Meteorology Society / Environmental Protection Agency Regulatory Model (AERMOD), Version 07026. The AERMOD model is the preferred model by the U.S. Environmental Protection Agency (EPA) since it is capable of predicting short-term and annual concentrations for

single or multiple sources of air pollution. The AERMOD model is also preferred because of the capability to simulate building downwash and terrain effects.

Receptor Grid Development

The receptor grid consists of Discrete Cartesian receptors based on Universal Transverse Mercator (UTM) coordinates (North American Datum 1927 (NAD27)). Three different receptor grids were developed for each OWB modeled.

The OWB with a 10 feet tall stack contains 3,162 total receptors. The receptor grid consists of the following elements:

- A receptor grid with 50-meter (m) intervals in a 2500 x 2500m area.
- A receptor grid with 25 m intervals in a 500 x 500m area.
- A receptor grid with 12.5 m intervals in a 150 x 150m area.

The OWB with a 15 feet tall stack contains 5,082 total receptors. The receptor grid consists of the following elements:

- A receptor grid with 50 m intervals in a 2500 x 2500m area.
- A receptor grid with 25 m intervals in a 200 x 200m area.
- A receptor grid with 12.5m intervals in a 125 x 120m area.

The OWB with a 20 feet tall stack contains 4,065 total receptors. The receptor grid consists of the following elements:

- A receptor grid with 50m intervals in a 2500 x 2500m area.
- A receptor grid with 25m intervals in a 700 x 900m area.
- A receptor grid with 12.5m intervals in a 250 x 275m area.
- A receptor grid with 10m intervals in a 100 x 100m area.

The final grids were developed based on initial model runs in an attempt to pinpoint where predicted concentrations equivalent to 6 $\mu g/m^3$ (with a background of 29 $\mu g/m^3$) would occur. The final setback distances were based on predicted concentrations which ranged from 6.0-7.1 $\mu g/m^3$.

All elevations for receptors, the emission source and building have been interpolated from U.S. Geological Survey Digital Elevation Model (USGS DEM) data for the Cedar Rapids North, IA topographic quadrangle (NAD27). The stack of the OWB unit was located at UTM 611154E, 4660700N.

Terrain Option

All receptors were assigned a terrain height set by USGS DEM data. The elevations in the receptor grid range from 836 to 902 feet mean sea level (MSL). Hill heights were calculated using the AERMAP program from EPA and range from 836 to 902 feet. The model implements both simple and complex terrain algorithms and also applies intermediate terrain processing. The particular random placement of the OWB location was chosen due to the terrain being flat so as not to bias the dispersion modeling analysis results. The appropriate DEM data can be found on IDNR's website: http://www.iowadnr.gov/air/prof/tech/DEMData.html.

Modeling Domain

In accordance with IDNR's Air Dispersion Modeling Guidelines the modeling domain is required to encompass all significant terrain at or above a 10% slope. The BEELINE Software, Inc. dispersion modeling suite, BEEST for Windows, Version 9.77 was used to calculate the necessary domain which includes only the USGS quadrangle for Cedar Rapids North.

Rural/Urban

AERMOD allows the incorporation of increased surface heating from an urban area on pollutant dispersion under stable atmospheric conditions. Use of the URBANOPT keyword allows the user to define input parameters for an urban area. The URBANSRC keyword is used to identify which sources are to be modeled with urban effects. The URBANOPT and URBANSRC keywords were not utilized in this analysis. Rather, the rural land use option was used which is consistent with all locations within Linn County including the city of Cedar Rapids.

Building Downwash Option

Section 123 of the Clean Air Act requires that regulations be promulgated (40 CFR §51) to ensure that the degree of emission limitation required for the control of any air pollutant is not affected by:

- That portion of any stack height, which exceeds good engineering practice (GEP).
- Any other dispersion technique

Section 123 defines GEP, with respect to stack heights, as the height necessary to ensure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of the source, as a result of atmospheric downwash, eddies, or wakes which may be created by the source itself, nearby structures, or nearby terrain obstacles. Section 123 of the CAA further provides that GEP stack height shall not exceed 2 ½ times the height of the source unless a demonstration is performed justifying a higher stack.

Although there are exceptions for stacks in existence prior to 1979, for most stacks, GEP stack height is the greater of a height of 65m (approximately 213.25 feet) that is considered de minimis stack height measured from the ground-level elevation at the base of the stack or according to the formula:

$GEP = H_b + 1.5(L)$

Where:

H_b = Height of nearby structures measured from the elevation of the base of the stack.

L = Lesser dimension, height, or projected width of nearby structure.

40 CFR §51 defines a nearby structure as being within 5L of a stack. For purpose of this modeling analysis, only the OWB unit was considered. It is important to note that this is not the most conservative approach, since residential homes and other out buildings are not included in this analysis which could potentially negatively affect the downwash characteristics of the plume. Based on the variability of number and distance of structures to an OWB unit, it was decided to conduct the analysis without these considerations. NESCAUM modeled scenarios with a house or a barn to demonstrate downwash effects. The house characteristics were 15m x 20m with a 6m height. The barn characteristics were 25m x 30 m with a 13m height. Each structure located approximately 20 feet from the OWB unit. NESCAUM noted that general GEP guidance suggest that in order to minimize structure influence on the unit's plume, these units have to be at least 5 times the height of the nearby structure, or about 100 and 200 feet away from the house and barn, respectively.

The BEELINE Software, Inc. dispersion modeling suite, BEEST for Windows, Version 9.77, was used to calculate wind direction-specific building dimensions. The OWB building dimension of 4' feet by 6 feet and 7 feet tall with the stack location on the shorter side of the unit was used in the analysis. The dimensions were derived from review of NESCAUM's Dispersion Modeling Report and observations from nuisance complaint investigations. The dimensions do vary based on manufacturer and size of the OWB.

Model Averaging Period Options

National Ambient Air Quality Standards (NAAQS) have been established for 24-hour and annual averaging periods for $PM_{2.5}$. This modeling analysis only investigated short-term concentrations or the 24-hour averaging period of $PM_{2.5}$ emitted from OWB units operating between the months of October 1 – April 30. The 24-hour primary and secondary $PM_{2.5}$ standards are met when the 98^{th} percentile 24-hour concentration, as determined in accordance with appendix N of 40 CFR §50, is less than or equal to 35 micrograms per cubic meter ($\mu g/m^3$). Current background $PM_{2.5}$ levels for Linn County are 29 $\mu g/m^3$. This value is based on the 98^{th} percentile of $PM_{2.5}$ measurements at the Army Reserve Center for years 2005-2007.

Meteorological Data

Local meteorological data from the Cedar Rapids, Iowa, National Weather Service (NWS) station (WBAN 14990) were chosen for the modeling input requirements. Five years of surface observations from Cedar Rapids encompassing the years 2000-2004 were selected for analysis. The surface observations from Cedar Rapids were combined with upper air observations from Davenport, Iowa, (WBAN 94982) to generate turbulence flux values for the modeling analysis. Surface observations at Cedar Rapids are located on a 6.1m (20 foot) tower. The profile base elevation used is 256.032m (840 feet), which is the base elevation of the Cedar Rapids meteorological tower. The default values in the AERMOD model were used for the upper bound of the wind speed categories. Since these units are predominantly used during the winter months to provide heat to building(s), this analysis only includes the results from October 1 – April 30. The appropriate meteorological data can be found on IDNR's website: http://www.iowadnr.gov/air/prof/tech/AERMODMetData.html.

EMISSION RATES

Currently, there are three types of outdoor wood boilers which potentially could be installed and operated in Linn County. EPA has launched a voluntary program to make cleaner more efficient outdoor wood boilers available to consumers. There is Phase I qualified units which are 70% less polluting than "unqualified" units. EPA's emission level for Phase I units is 0.6 lb/mmBTU for fine particulate matter. More recently, EPA has moved to Phase II qualified units which are 90% less polluting than "unqualified" units. EPA's emission level for Phase II units is 0.32 lb/mmBTU for fine particulate matter which manufacturers must certify that no single test run exceeds 18 grams/hour. Units rated at 250,000 and 125,000 BTU/hr were the only sizes modeled at 18 grams/hour (0.005 g/s). The results for units sized at 350,000 BTU/hr and larger are irrelevant since there are no Phase 2 qualified units currently on the market which can meet 0.005 g/s. Outdoor wood boilers which have not been certified by EPA as meeting Phase I or II are deemed "unqualified" (most polluting) which emit 2 lb/mmBTU according to EPA. See http://www.epa.gov/woodheaters/pdfs/FAQs10-22-08VT.pdf. The summary of the hourly emission rates used in the model are summarized below in Table 1. Thus, the three types of OWBs are unqualified (EP description in model is "uncertified"), Phase I or Phase II qualified. The Department modeled each type of OWB with capacities of 1.0, 0.75, 0.50, 0.35, 0.25 and 0.125 mmBTU/hr heat input. The corresponding setback distances were based on these results. See Table 2 for the summary of EP characteristics. The OWB units were evaluated using the parameters listed in Table 2. The OWB units were modeled as operating 24 hours/day between the months of October and April.

Table 1Summary of Hourly Emission Rates used described above.

Heat Input (mmBTU/hr)	Exhaust Flow (ACFM)	Unqualified Unit ER (lb/hr)	Phase 1 Qualified Unit ER (lb/hr)	Phase 2 Qualified Unit ER (lb/hr)
1.00	248	2	0.6	NA
0.75	186	1.5	0.45	NA
0.50	124	1	0.3	NA
0.35	87	0.7	0.21	NA
0.25	62	0.5	0.15	0.04
0.125	31	0.25	0.075	0.04

The model was run using EPA's regulatory default settings. For PM2.5 the control option "PM25" was used and the highest-eighth-high receptor evaluated over the concatenated five-year meteorological data set in accordance with EPA's addendum to the User's Guide for the AMS/EPA Regulatory Model - AERMOD. This document can be located here: http://www.epa.gov/scram001/dispersion_prefrec.htm.

RESULTS SUMMARY

According to the results from the AMS/EPA Regulatory Model (AERMOD, dated 07026), the $PM_{2.5}$ emissions from OWB units will cause predicted concentrations that are greater than the 24-hr $PM_{2.5}$ NAAQS. How significant the predicted exceedance of the NAAQS is dependent on three factors: type of unit (e.g. unqualified, Phase 1 or Phase 2), stack height, exhaust flow rate and distance of the unit to ambient air. EPA defines "ambient air" as that portion of the atmosphere, external to buildings, to which the general public has access. Therefore, in order to be protective of public health, setbacks are necessary to be established to protect individuals who reside, work or play surrounding properties which operate an OWB. The setback distances determined as a result of the dispersion modeling analysis were rounded to the nearest 25 feet. These proposed setbacks are identified in Table 3.

From the results graphs were developed that only highlights the receptors of which a predicted $PM_{2.5}$ level of 35 $\mu g/m^3$ or more. This is so one can visualize that with the added background of 29 $\mu g/m^3$ how far the necessary setbacks would need to be if a 1 mmBTU/hr boiler were installed. These graphs are represented after Table 3.

The predicted $PM_{2.5}$ concentrations from the operation of one OWB unit are in Tables 3a-3c.

Table 2. Modeled Emission Rates and Stack Parameters

Emission Point	$PM_{2.5}$	Stack Height	Stack Gas Exit Temperature	Stack Tip Diameter	Stack Gas Flow Rate
Heat Input (mmbtu/hr)	(lb/hr)	(ft)	(°F)	(in)	(acfm)*
Uncertified (1)	2.0	10, 15 & 20	300	6	248
Phase 1 (1)	0.6	10, 15 & 20	300	6	248
Phase 2 (1)	0.32**	10, 15 & 20	300	6	248
Uncertified (0.75)	1.5	10, 15 & 20	300	6	186
Phase 1 (0.75)	0.45	10, 15 & 20	300	6	186
Phase 2 (0.75)	0.24**	10, 15 & 20	300	6	186
Uncertified (0.50)	1	10, 15 & 20	300	6	124
Phase 1 (0.50)	0.3	10, 15 & 20	300	6	124
Phase 2 (0.50)	0.16**	10, 15 & 20	300	6	124
Uncertified (0.35)	0.7	10, 15 & 20	300	6	87
Phase 1 (0.35)	0.21	10, 15 & 20	300	6	87
Phase 2 (0.35)	0.112**	10, 15 & 20	300	6	87
Uncertified (0.25)	0.5	10, 15 & 20	300	6	62
Phase 1 (0.25)	0.15	10, 15 & 20	300	6	62
Phase 2 (0.25)	0.08	10, 15 & 20	300	6	62
Phase 2 (0.25)**	0.04	10, 15 & 20	300	6	62
Uncertified (0.125)	0.25	10, 15 & 20	300	6	31
Phase 1 (0.125)	0.075	10, 15 & 20	300	6	31
Phase 2 (0.125)	0.04	10, 15 & 20	300	6	31
Phase 2 (0.125)**	0.04	10, 15 & 20	300	6	31

* Emission point modeled with a vertical, unobstructed exhaust.
** An emission rate equal to this value would not be considered a Phase 2 qualified unit.
*** Modeled at 0.005 grams/second

Table 3a. Modeling Results (1.0 mmBTU/hr OWB w/ 10' stack)

Pollutant	Averaging Period	OWB Type	Distance from OWB to H8H Receptor	Predicted Concentration*	Background Concentration	Total Concentration	NAAQS
			(m)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
$PM_{2.5}$	24-hour	Uncertified	24	209.8	29	238.8	35
		Phase 1	24	62.9	29	91.9	35
		Phase 2	24	33.5	29	62.5	35

* The short-term concentrations are the highest-eighth-highest predicted values.

Table 3b. Modeling Results (1.0 mmBTU/hr OWB w/ 15'stack)

Pollutant	Averaging Period	OWB Type	Distance from OWB to H8H Receptor (m)	Predicted Concentration* ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Total Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
$PM_{2.5}$	24-hour	Uncertified	40	78.8	29	107.8	35
		Phase 1	40	23.6	29	52.6	35
		Phase 2	40	12.6	29	41.6	35

* The short-term concentrations are the highest-eighth-highest predicted values.

Table 3c. Modeling Results (1.0 mmBTU/hr OWB w/ 20' stack)

Pollutant	Averaging Period	OWB Type	Distance from OWB to H8H Receptor (m)	Predicted Concentration* ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Total Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
$PM_{2.5}$	24-hour	Uncertified	50	40.2	29	69.2	35
		Phase 1	50	12.0	29	41	35
		Phase 2	50	6.4	29	35.4	35

* The short-term concentrations are the highest-eighth-highest predicted values.
** Concentrations for a Phase 2 unit emitting 0.08 lb/hr.

Table 3. Recommended Setback Requirements

Uncertified Units with a Minimum Stack Height of 10 feet

If the heat input rating of your OHH is no greater than	and your stack height, measured from ground level, is no less than	then the minimum distance of your OHH to the property line is:
125,000 Btu/hour	10 feet	700 feet
250,000 Btu/hour	10 feet	1050 feet
350,000 Btu/hour	10 feet	1400 feet
500,000 Btu/hour	10 feet	1725 feet
750,000 Btu/hour	10 feet	2250feet
1,000,000 Btu/hour	10 feet	2550 feet

Uncertified Units with a Minimum Stack Height of 15 feet

If the heat input rating of your OHH is no greater than	and your stack height, measured from ground level, is no less than	then the minimum distance of your OHH to the property line is:
125,000 Btu/hour	15 feet	425 feet
250,000 Btu/hour	15 feet	825 feet
350,000 Btu/hour	15 feet	1075 feet
500,000 Btu/hour	15 feet	1400 feet
750,000 Btu/hour	15 feet	2000 feet
1,000,000 Btu/hour	15 feet	2250 feet

Uncertified Units with a Minimum Stack Height of 20 feet

If the heat input rating of your OHH is no greater than	and your stack height, measured from ground level, is no less than	then the minimum distance of your OHH to the property line is:
125,000 Btu/hour	20 feet	275 feet
250,000 Btu/hour	20 feet	600 feet
350,000 Btu/hour	20 feet	850 feet
500,000 Btu/hour	20 feet	1125 feet
750,000 Btu/hour	20 feet	1500 feet
1,000,000 Btu/hour	20 feet	1775 feet

Phase 1 Certified Units with a Minimum Stack Height of 10 feet

If the heat input rating of your OHH is no greater than	and your stack height, measured from ground level, is no less than	then the minimum distance of your OHH to the property line is
125,000 Btu/hour	10 feet	200 feet
250,000 Btu/hour	10 feet	300 feet
350,000 Btu/hour	10 feet	425 feet
500,000 Btu/hour	10 feet	600 feet
750,000 Btu/hour	10 feet	750 feet
1,000,000 Btu/hour	10 feet	875 feet

Phase 1 Certified Units with a Minimum Stack Height of 15 feet

If the heat input rating of your OHH is no greater than	and your stack height, measured from ground level, is no less than	then the minimum distance of your OHH to the property line is
125,000 Btu/hour	15 feet	100 feet
250,000 Btu/hour	15 feet	200 feet
350,000 Btu/hour	15 feet	275 feet
500,000 Btu/hour	15 feet	375 feet
750,000 Btu/hour	15 feet	550 feet
1,000,000 Btu/hour	15 feet	675 feet

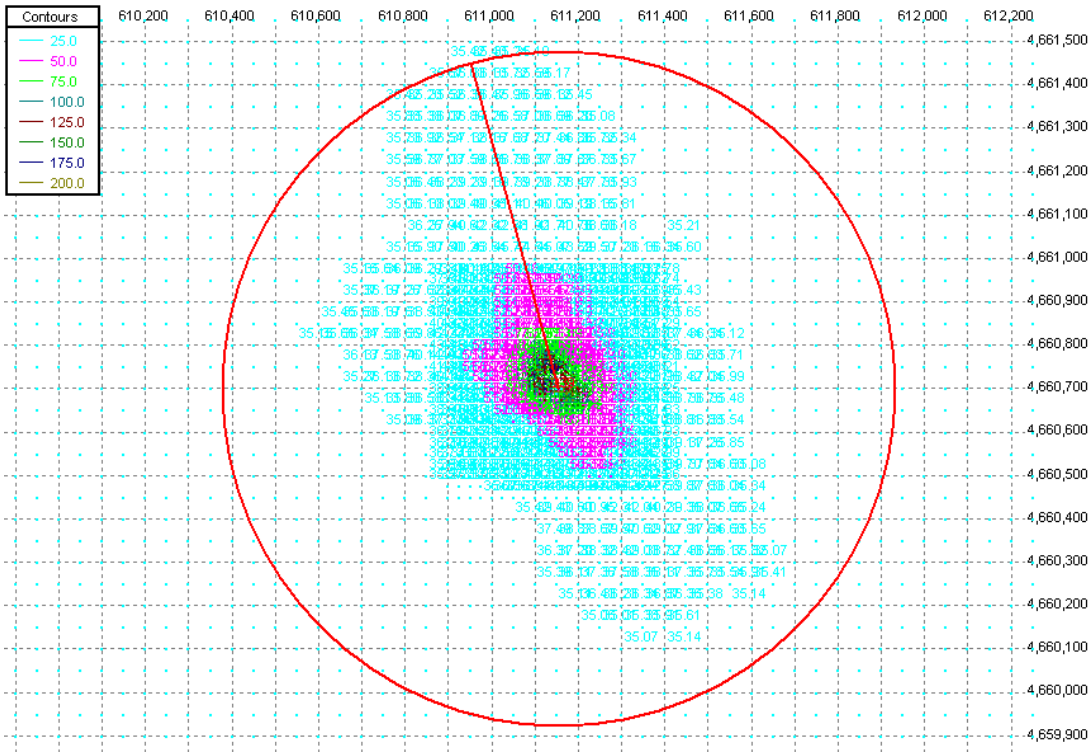
Phase 1 Certified Units with a Minimum Stack Height of 20 feet

If the heat input rating of your OHH is no greater than	and your stack height, measured from ground level, is no less than	then the minimum distance of your OHH to the property line is
125,000 Btu/hour	20 feet	100 feet
250,000 Btu/hour	20 feet	100 feet
350,000 Btu/hour	20 feet	150 feet
500,000 Btu/hour	20 feet	275 feet
750,000 Btu/hour	20 feet	425 feet
1,000,000 Btu/hour	20 feet	525 feet

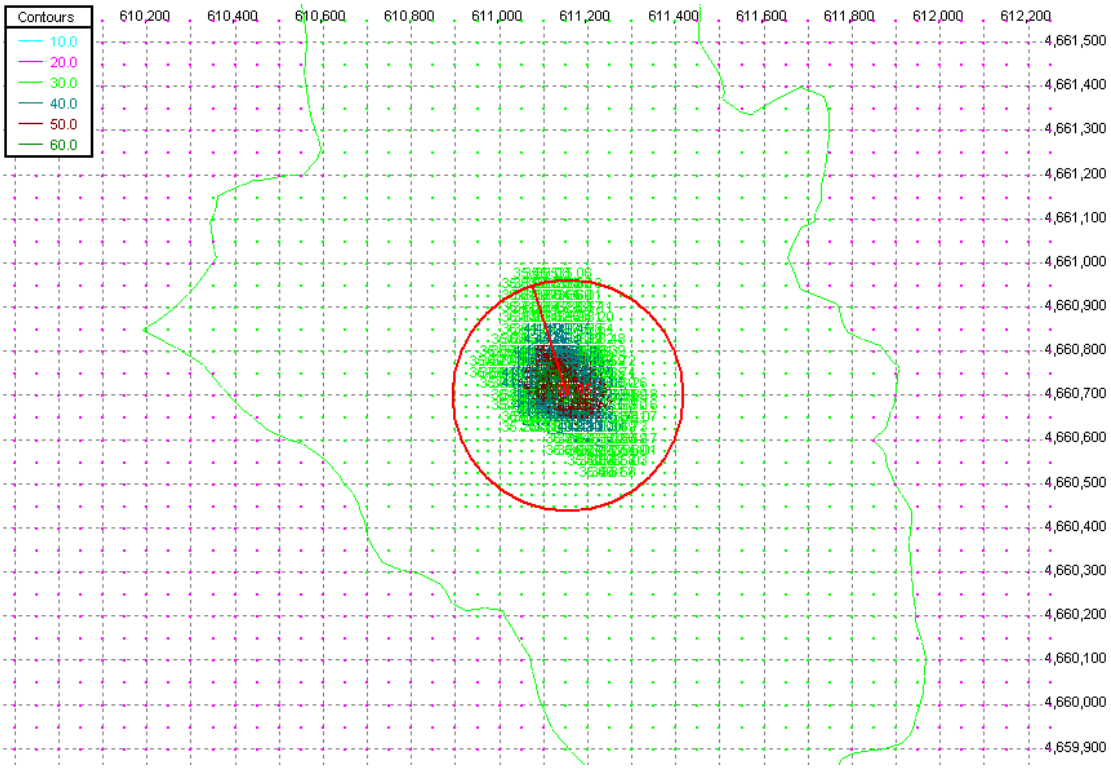
1) Setback and stack height requirements for Outdoor Hydronic Heaters that are Phase 2 emission level qualified models. Outdoor hydronic heater that meet the applicable, "Phase 2 emission level qualified model" as set forth in Paragraph B and purchased after [insert rule promulgation date] must be installed at a minimum distance from the property line and stack height, measured from ground level to the top of stack:
   a. OHH with a heat input rating no greater then 1,000,000 Btu/hour and a stack height no less than 15 feet must installed at least 100 feet from the property line
   b. An OHH with a heat input rating no greater then 1,000,000 Btu/hour and a stack height of at least 10 feet but not greater than 15 feet must installed at least 150 feet from the property line.

Illustrative Graphs – Note that the “snap-shot” of the impacts were magnified to illustrate how much smaller the impacts are based on the type of unit installed for each stack height.

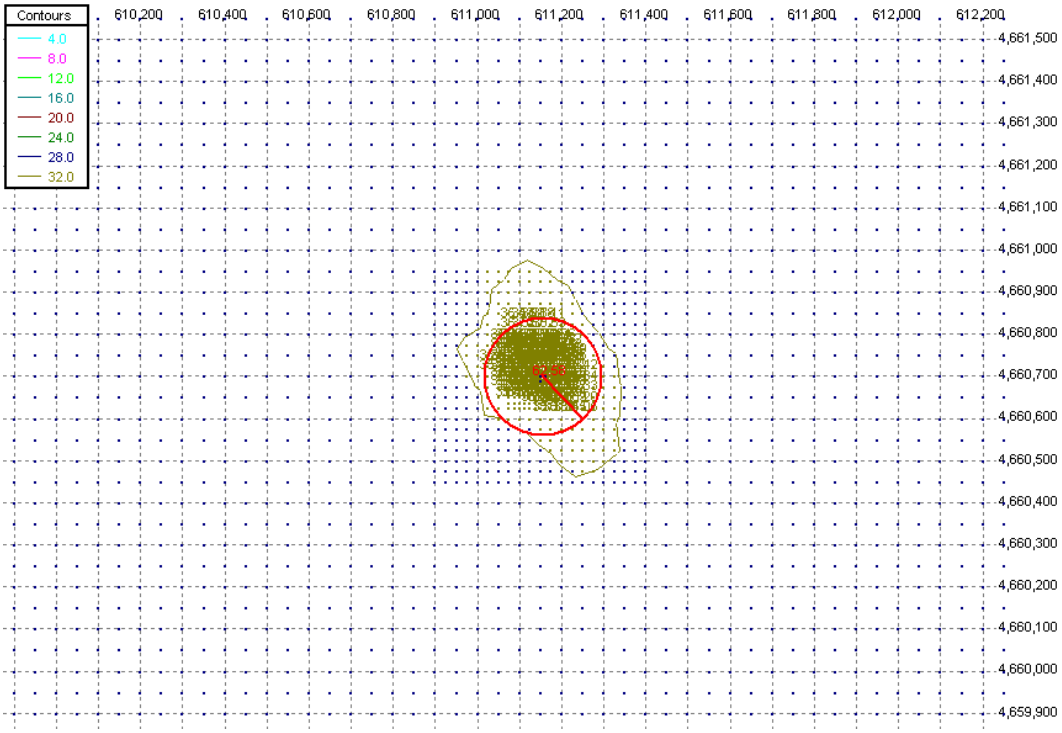
Radius-of-Impact Uncertified OWB – 10’ stack



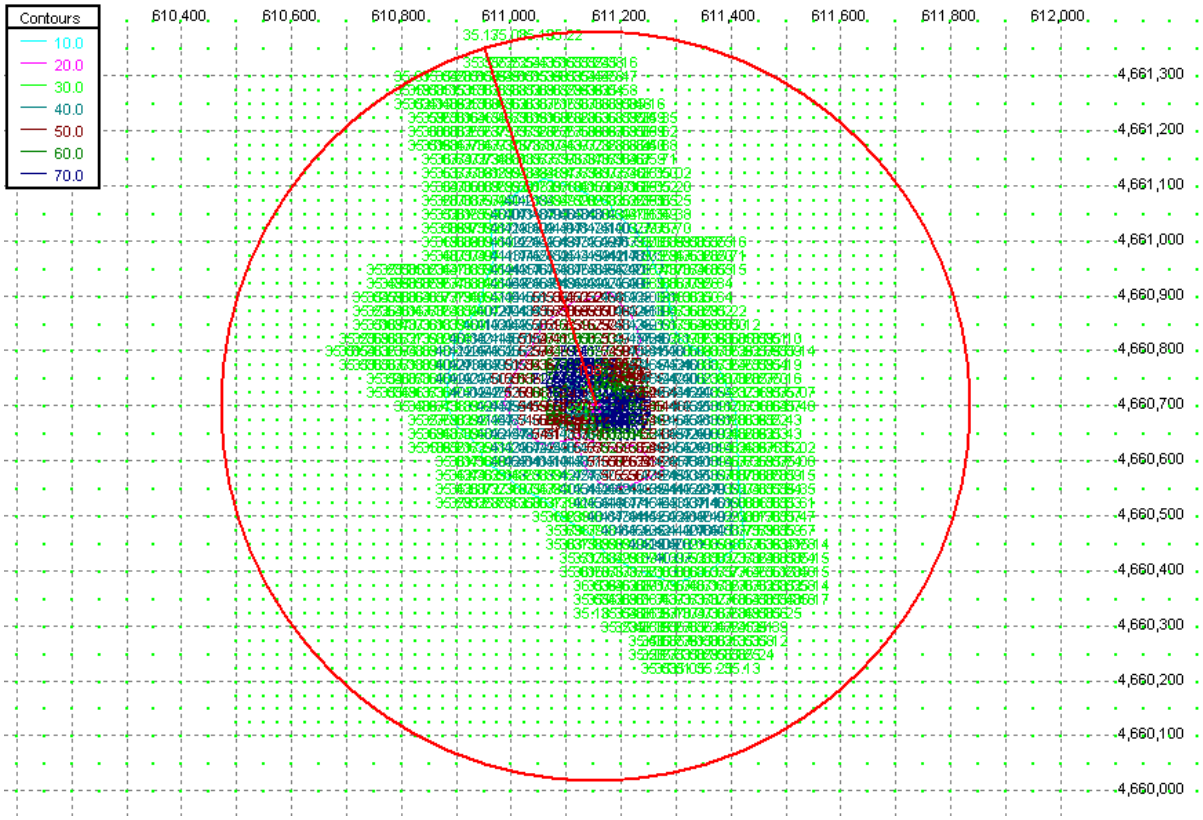
Radius-of-Impact Phase 1 Qualified OWB – 10’ stack



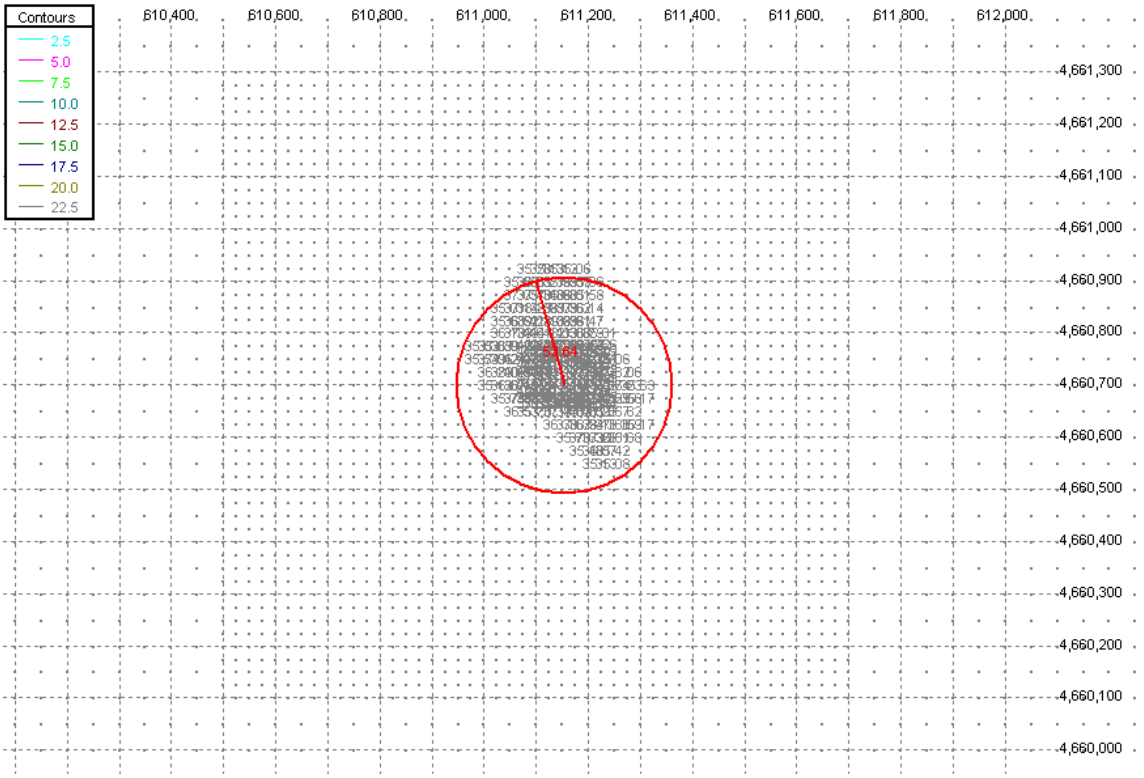
Radius-of-Impact Phase 2 Qualified OWB – 10’ stack



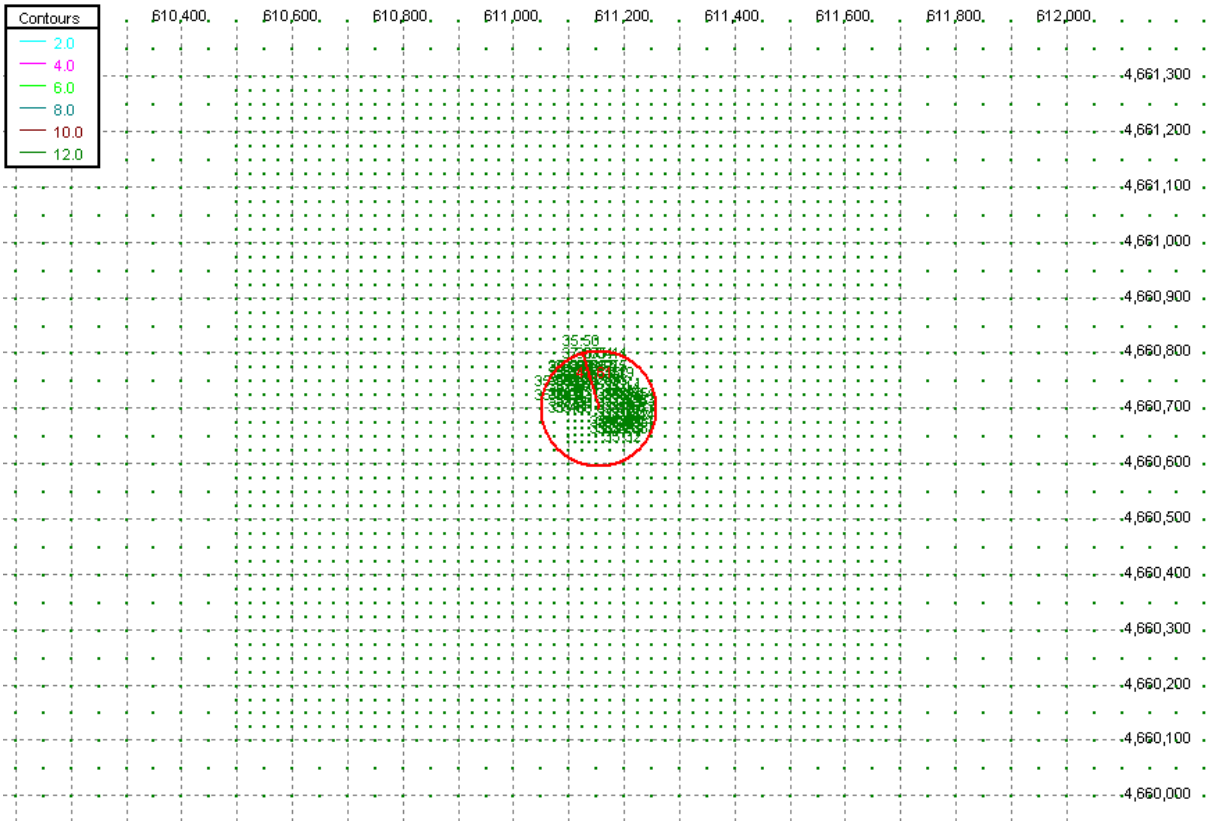
Radius-of-Impact Uncertified OWB – 15’ stack



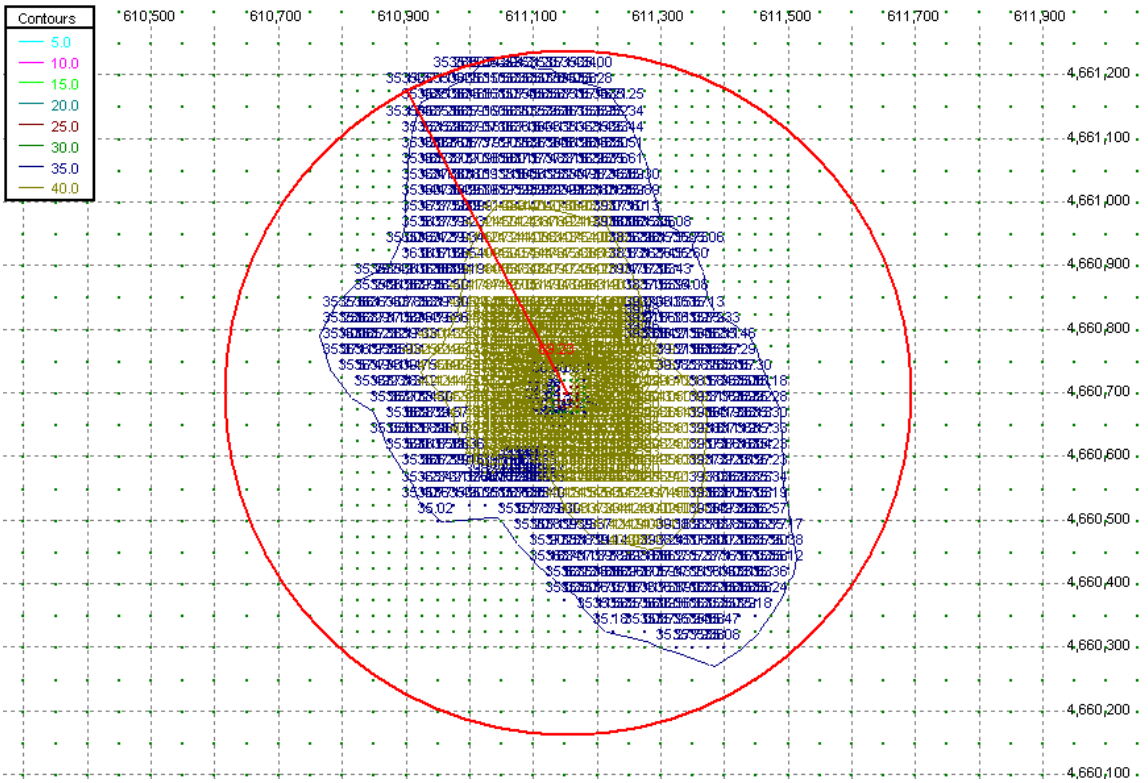
Radius-of-Impact Phase 1 Qualified OWB – 15’ stack



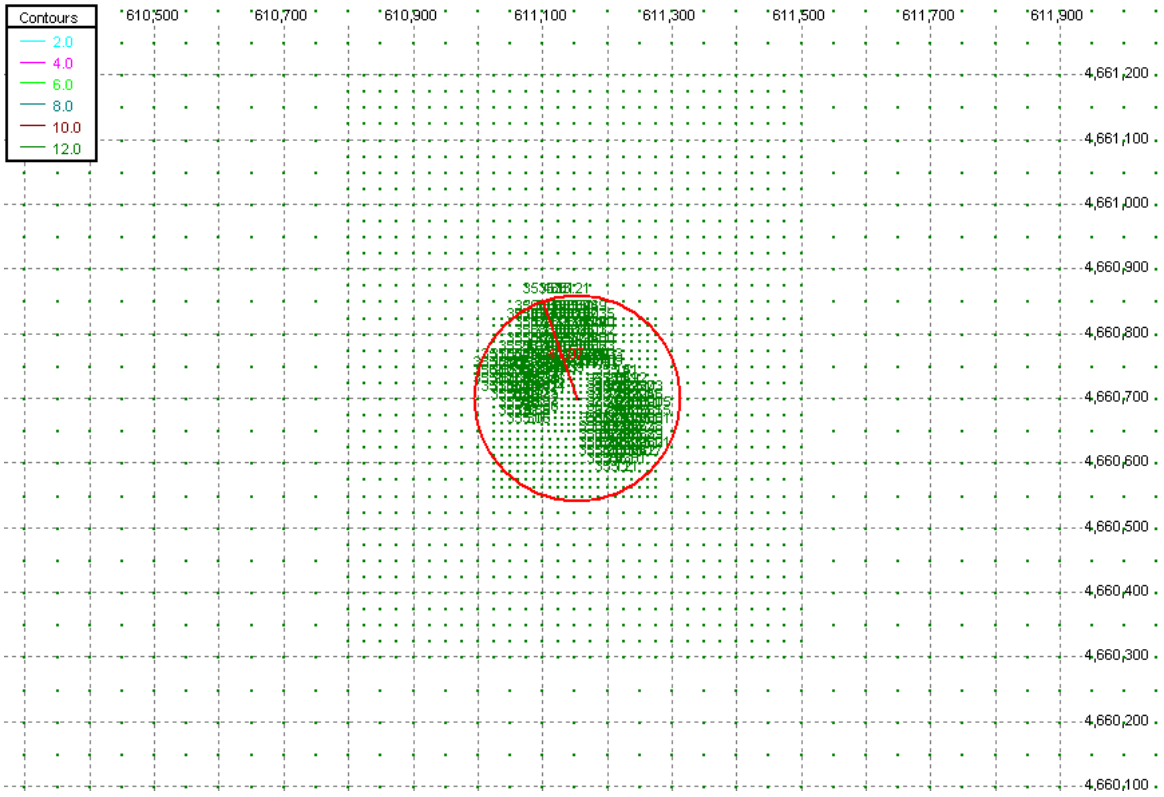
Radius-of-Impact Phase 2 Qualified OWB – 15’ stack



Radius-of-Impact Uncertified OWB – 20’ stack



Radius-of-Impact Phase 1 Qualified OWB – 20’ stack



Radius-of-Impact Phase 2 Qualified OWB – 20’ stack