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Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 41H

Steve Weinbeck

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Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Transfer Facility Tank 41H

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EXECUTIVE SUMMARY

The SRNL Atmospheric Technologies Group performed an analysis of mercury emissions from H-Tank Farm – Tank 41H ventilation system exhaust to assess worst case 15-minute and 8-hour average ground level concentrations and evaluate whether the Short-Term Exposure Limit (STEL), or Threshold Limit Value (TLV) levels for mercury will be exceeded during mixing operations. This analysis was also used to establish a minimum stack height at which ambient mercury concentration would not exceed the safety limits. The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was used as the dispersion modelling tool for this analysis. Results indicate that a stack height of 30-ft (for the 25 mg/m^3 emissions case) or 50-ft (for the 50 mg/m^3 emissions case) stacks results in ground level concentrations that do not exceed the STEL or TLV standards.

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AMS	American Meteorological Society
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AERMET	AERMOD Meteorological Preprocessor
AGL	Above Ground Level
ASL	Above Sea Level
ATG	Atmospheric Technologies Group
BPIP-Prime	Building Profile Input Program- Prime Algorithm
Cfm	Cubic feet per minute
DSA	Documented Safety Analysis
EPA	Environmental Protection Agency
ETP	Effluent Treatment Project
LIDAR	Light Detection and Ranging
NAD27	North American Datum, 1927
NLCD92	National Land Cover Database, 1992
NWS	National Weather Service
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

1.0 Introduction

The American Conference of Governmental Industrial Hygienists (ACGIH) short term exposure limit (STEL) for dimethyl mercury and 8–hour threshold limit value (TLV) for mercury in the workplace are 0.030 mg/m^3 (30 µg/m^3) and 0.025 mg/m^3 (25 µg/m^3), respectively (Ref. 1). Using these standards, the Atmospheric Technologies Group (ATG) has been asked to evaluate the exposure of workers to ambient mercury concentrations resulting from the H-Area tank farm Transfer Facility Tank 41H (hereafter referred to as Tank 41) ventilation stack emissions. The STEL for dimethyl mercury was used to assess short term exposure because a STEL for elemental mercury has not been reported by the ACGIH ambient concentrations standard. Mercury concentrations were predicted for ground-level breathing height and other specified work areas around Tank 41.

To predict the mercury concentrations for Tank 41, observed weather data for SRS was taken from a five-year (2007-2011) record of hourly meteorological conditions and used to calculate the amount of atmospheric dispersion for 1-hour and 8-hour time periods. Hourly-averaged modeled concentrations were adjusted to represent 15-minute values for comparison to the 15-minute STEL using the following equation (Ref. 2):

$$\boldsymbol{C_{15min} = C_{60min}\left(\frac{60}{15}\right)^{0.2} = 1.3\ C_{60min}} \qquad (1)$$

By multiplying the hourly concentrations by a factor of 1.3, the concentration is representative of concentrations sampled on a 15-minute time averaged period. Comparisons of the calculated concentrations can be made to the standards, and estimates of worker safety and potential mitigations methods can easily be made.

2.0 Methodology

Modeling was conducted with the Environmental Protection Agency (EPA) AMS/EPA Regulatory Model (AERMOD) dispersion model, which is recommended by the EPA for regulatory air quality analyses (Ref. 3). The model allows for variability in wind, turbulence, temperature and incorporates boundary layer parameters for dispersion through the boundary layer in both stable and convective atmospheric situations (Refs. 4 and 5). More information on ATG's software quality assurance plan for AERMOD can be found in C-SQP-G-00076 (Ref. 6). For this regulatory modeling, AERMOD was executed in default (regulatory) mode. AERMOD is routinely used for tank and multiple stack emissions, and has physics included to model building wake effects.

Meteorological data files used as input to AERMOD were prepared using EPA's AERMOD Meteorological preprocessor (AERMET, Ref. 7), which incorporates the National Weather Service's (NWS) hourly observations from Bush Field in Augusta, GA, twice-daily upper air soundings from the NWS Atlanta, GA radiosonde station and, quality assured 15-minute values of wind and temperature at four levels (4, 18, 36 and 61 meters) of the Savannah River Site (SRS) Central Climatology tower located near N-area.

For onsite data, values were extracted from the meteorological database and written to a text file only if there were no associated quality flags. When the data did not meet quality control criteria, a missing value code was assigned consistent with AERMET requirements. Quality assurance procedures for SRS meteorological data are described in Reference 10. For details on the processing of the most recent five-year quality assured dataset (2007-2011) see References 8 and 9.

Values used by AERMET for roughness length, Bowen ratio and albedo were determined from EPA's AERSURFACE algorithm. Input to the algorithm consisted of a (United States Geological Survey) USGS National Land Cover Data image for 1992 (NLCD92). This image was analyzed for the area around the Central Climatology tower. Monthly values of the three surface parameters were generated and imported into AERMET (Ref. 7).

Building information was included in AERMOD to account for downwash and re-circulation effects from nearby buildings and stacks. Building data was processed using the EPA utility Building Profile Input Program (BPIP-Prime) to determine how these obstacles affect airflow patterns and the transport of effluent discharge. Of concern is the downwash of the plume over areas where workers will spend most of their time during operations. The structures included in the ETP (effluent Treatment Project) model domain for the BPIP-Prime input are those specified in References 1. This modeling domain (including the terrain) was based on a domain previously used in SRNL-STI-2017-00669 (Ref. 13), and SRNL-2017-00298, Rev. 1 (Ref. 14) and in Reference 1.

There are numerous, ill-defined, small appurtenances in the vicinity of Tank 41; however, these were not modeled for atmospheric wake, therefore adding a level of conservatism (wake area adds additional turbulence for dispersion which can lower atmospheric concentrations). The larger buildings need to be retained for AERMOD to enhance the vertical mixing of the plume centerline down to the receptor heights, increasing the near surface ground concentrations.

Terrain elevation was determined from the Savannah River Site (SRS) high resolution Light Detection and Ranging (LIDAR) dataset for SRS Reference 13 and accessed through the site GIS application (Ref. 14). The area surrounding Tank 41 has been graded to be 101 meters (m) ASL (Fig. 2-1).

The modeling domain was defined with a receptor grid of almost 9000 receptors. The majority of these are ground level receptors placed every 5 m to identify any potential excessive concentrations that may occur near the ground. The pattern selected was that of a "L-shape", which was selected to provide a receptor grid encompassing both the East Hill and ETP facility. These receptors oriented roughly in a north-south direction, with an offset of the ETP to the right (plant East direction) relative to the East Hill. The flagpole height of these receptors is nominally 1.85 m (6 feet, Ref. 1), which represents the breathing zone of a tall worker standing at ground level.

Two overpass platforms were modeled by adding four receptors placed at 12-ft (3.66m); 6-ft for the platform plus 6-ft for the breathing height. The B5 riser has 16 receptors on a 4 by 4 grid, all at a height of 13-ft (3.96 m); which is 7-ft (2.13 m) riser height and 6-ft breathing level height. A small 13 by 12 receptor grid was placed on top of the 2H evaporator building. The Plant Northeast corner of the grid (5 by 10 receptors) covers the top tier. The remainder of the 13 by 12 grid covers the lower tier of the building. All receptors at these locations are placed at 3-ft [0.67m] above the roof height (Ref. 1).

Additionally, 12 receptors were placed on the top of 241-84H building to model potential elevated roofing workers. that could be located anywhere along the roof. As with the ground level receptors, the rooftop receptors are determined based on the roof elevation (6.63 m [21.7 ft]) plus 1.85 m (6.0

ft), giving a total height of 27.8 ft (8.48 m). This receptor grid closely resembles the receptor grid previously used in References 10 and 11.

The stack discharge temperature range is estimated to be 80°C, for conservatism 65°C was used in modeling. The inside diameter of the stack is 6 inches (Ref. 1). The current stack height is 20 feet (Ref. 1). To have the correct units for input to AERMOD, the concentration of mercury in the stack discharge was converted to a mass release rate by using the flow rate (300 cfm) containing mercury at a 10, 25, and 50 mg/m^3 mercury discharge concentrations (Ref. 1). The emission rate for the Tank 41H stack (in g/s) was determined using the following calculation based on inputs from Reference 1:

$$\frac{10\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{300\ \text{ft}^3}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 0.00142\ \text{g/s}$$

$$\frac{25\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{300\ \text{ft}^3}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 0.00354\ \text{g/s}$$

$$\frac{50\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{300\ \text{ft}^3}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 0.00708\ \text{g/s}$$

Finally, once mercury concentration values were calculated for each receptor on the grid, values were transformed to percent of corresponding standard. This was done by multiplying each value by a scaling factor of 4.3 and 4.0, to obtain a percent of the STEL or TLV for the 15-minute and 8-hour period, respectively. These scaling factors were obtained using the following calculation:

$$\%\ \text{of STEL} = \frac{1.3}{30\ \mu g/m^3} \times 100 = 4.3$$

$$\%\ \text{of TLV} = \frac{1}{25\ \mu g/m^3} \times 100 = 4.0$$

where the value 1.3 in the first equation is incorporated from Eq. 1 to obtain a value representative of a 15-minute period.

To determine the final stack height, the current stack height of 20-ft will be used as an initial input for the AERMOD model, and the three (3) different emissions scenarios will be run, using the described or calculated inputs (see inputs described in this section). If there is an exceedance of either the STEL or TLV standards, the stack height input will be increased to reflect a hypothetical 10-foot increase, and the model is run again. Once the model output indicates a given stack input will not produce an exceedance, the stack height was gradually decreased to examine if a smaller increment could be used to refine the necessary stack height.

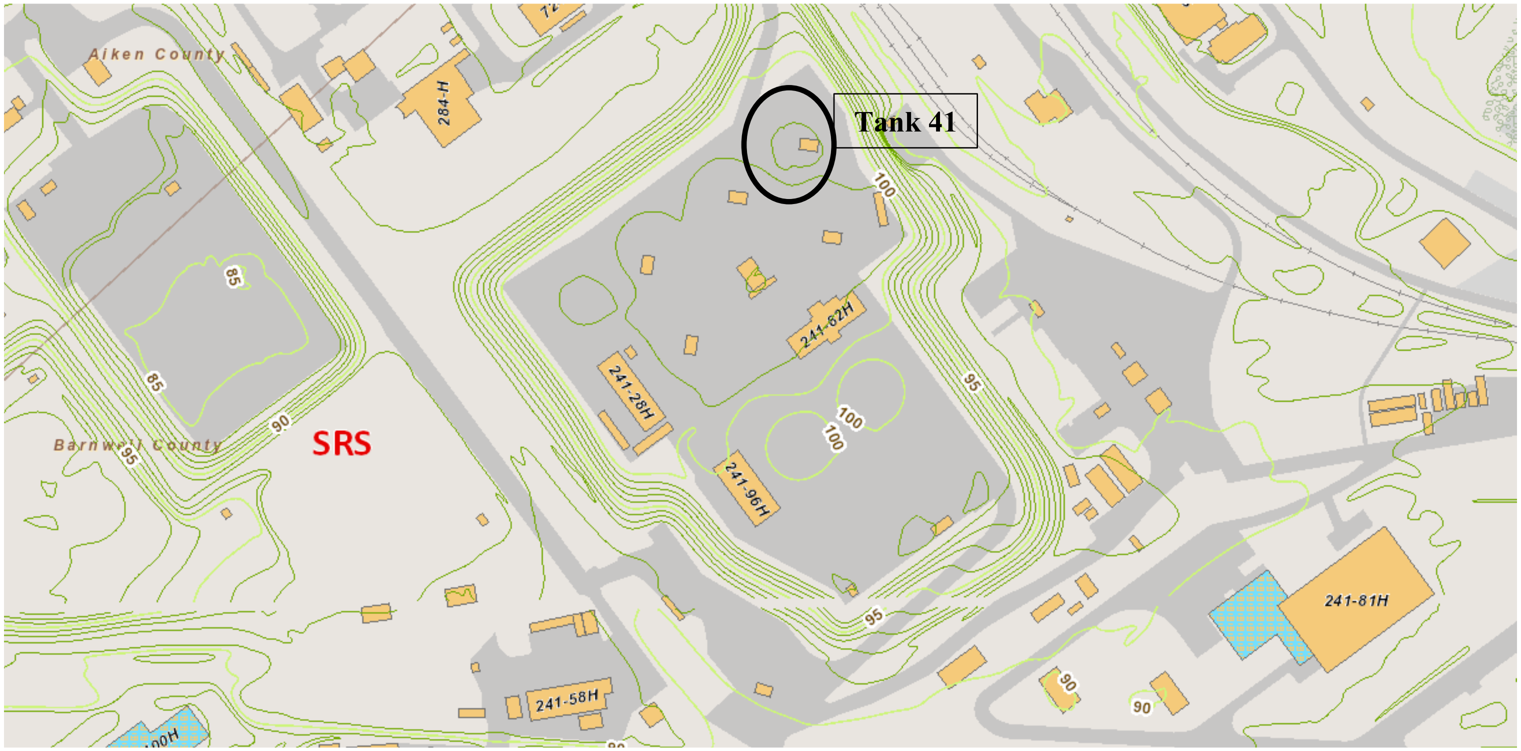

Figure 2-1. Topography around the East Hill as displayed via SRS Explorer web application. Small, rectangular shapes indicate buildings are other permanent structures and huts**.** Contours are in meters above sea level. True North is oriented to the top of the page. Area around Tank 41 in black circle. The cluster of Buildings around 241-81H (southwest corner of insert) are collective referred to as ETP (Ref. 14).

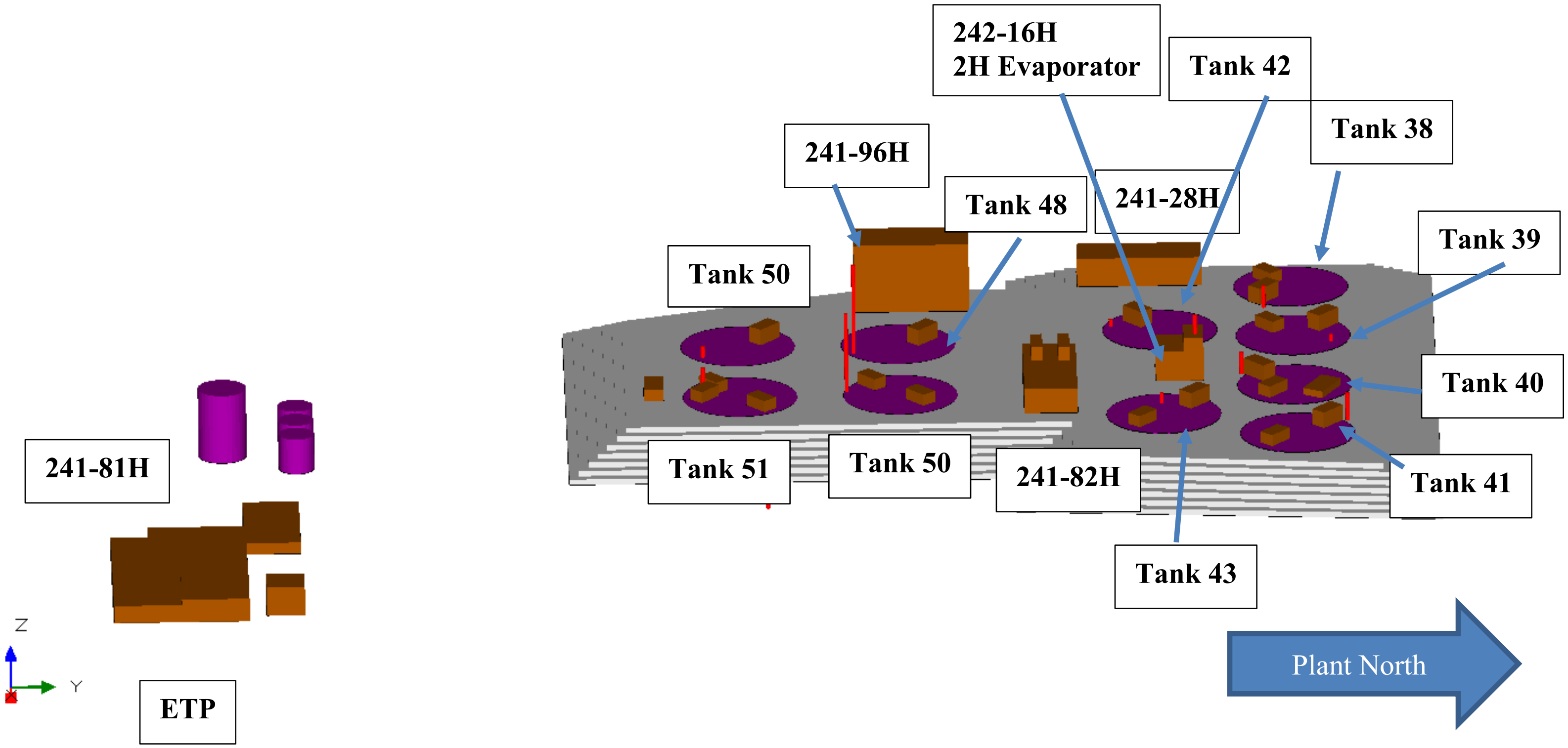

Figure 2-2. Three-dimensional view of the buildings around Tank 41H for the 25-foot stack height from AERMOD modeling domain. The tanks are represented by purple circles, hills by grey, buildings in brown, and the stacks are in red. Thick blue arrow shows the direction of the Plant North. View is to the Plant West and slightly above scene.

3.0 Results and Discussion

The results from the three (3) emissions scenarios run are presented in Table 3-1. For all three scenarios, there are no exceedances of the TLV standard, regardless of the stack height. For the 10 mg/m^3 release scenario, there are no exceedances of the STEL standard (Table 3-1). Figures 3-1 to 3-4 show the postulated stack heights that resulted in STEL exceedances.

Table 3-1. Maximum ambient concentrations (µg/m^3) associated to Tank 41 emissions for 15-minute and 8-hour periods for all receptors.

Ht (ft)	10 mg/m^3	
	15-min	8-hr
20	18.4	4.0
30	11.4	3.2
40	9.5	2.6
50	5.5	1.7
60	4.1	1.6

Ht (ft)	25 mg/m^3	
	15-min	8-hr
20	**45.8**	9.9
25	**37.0**	8.9
28	**32.2**	8.4
30	28.5	8.0
40	23.7	6.5
50	13.8	4.3
60	10.2	3.9

Ht (ft)	50 mg/m^3	
	15-min	8-hr
20	**91.5**	19.9
30	**56.9**	16.0
40	**47.5**	12.9
45	**33.9**	12.3
48	**30.7**	10.1
50	27.7	8.6
60	20.4	7.8

Values in bold exceed exposure limits for respective time periods (0.030 mg/m^3 or 30 µg/m^3 for 15-min STEL and 0.025 mg/m^3 or 25 µg/m^3 for 8-hour TLV).

For the 25 mg/m^3 scenario, a 30-ft. stack height is required to produce mercury concentrations below STEL (Table 3-1). With the 25-ft stack height, downwash from the nearby 2H Evaporator building and the wake downwind of the East Hill cause the mercury plume to mix down both on top of the East Hill between Tank 40 and Tank 41, as well as off the Hill to the Plant Northeast direction (Fig. 3-1). With a stack height of 28-ft, the stack is just above the wake caused by the ventilation building, and the mercury plume is only directed to the receptors in the areas on top of and below the Plant Northeast corner of the hill (caused by the East Hill wake) (Fig. 3-2). Mercury concentrations on top of the 2H Evaporator building are close to the STEL standard for both the 25- and 28-ft, but do not exceed it.

For the 50 mg/m^3 scenario, a 50-ft. stack height is required (Table 3-1). Downwash from the nearby buildings and the wake downwind of the East Hill cause the mercury plume to be mixed down on top of the East Hill between Tank 40 and Tank 41, as well as off the Hill to the Plant Northeast direction (Fig. 3-3a). A stack height of 48-ft (Fig 3-4), still has a relatively small area (about 15-meters/50-ft long) along the the side and below the Hill with exceedances of the standard (located in the Plant North directions from Tank 41). Mercury concentrations on top of the 2H Evaporator building also exceeds the STEL for a 45-ft stack (Fig 3-3b), but disappear when the stack is raised to 48-ft (Fig 3-4).

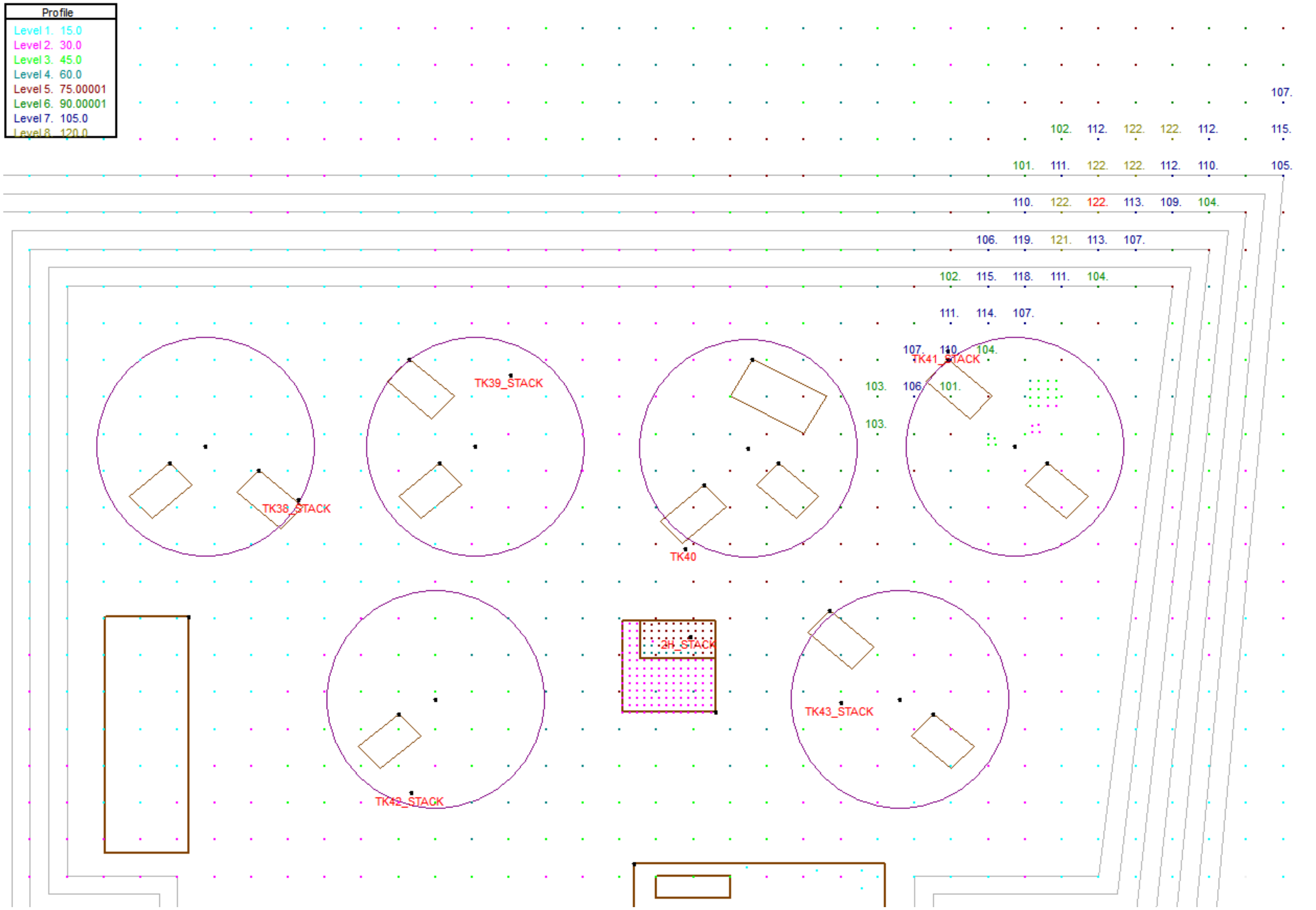

Figure 3-1. STEL Exceedances for Tank 41H with a 25-foot stack and 25 mg/m^3 release concentration scenario. Receptor values shown as percent of STEL (>30 μg/m^3) for values that exceed 100%.

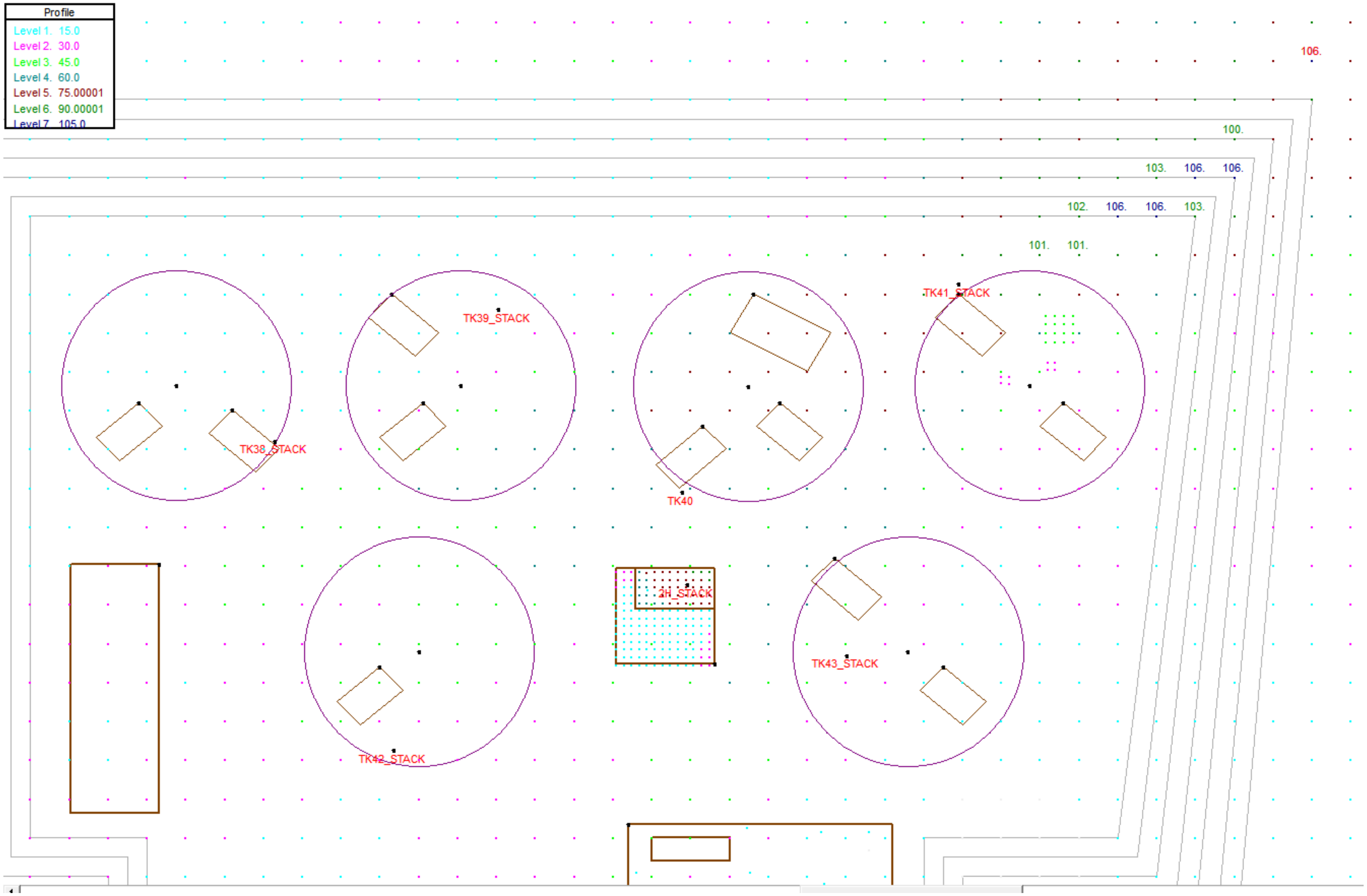

Figure 3-2. STEL Exceedances for Tank 41H with a 28-foot stack and 25 mg/m^3 release concentration scenario. Receptor values shown as percent of STEL (>30 µg/m^3) for values that exceed 100%. Plant North is at the top of the page.

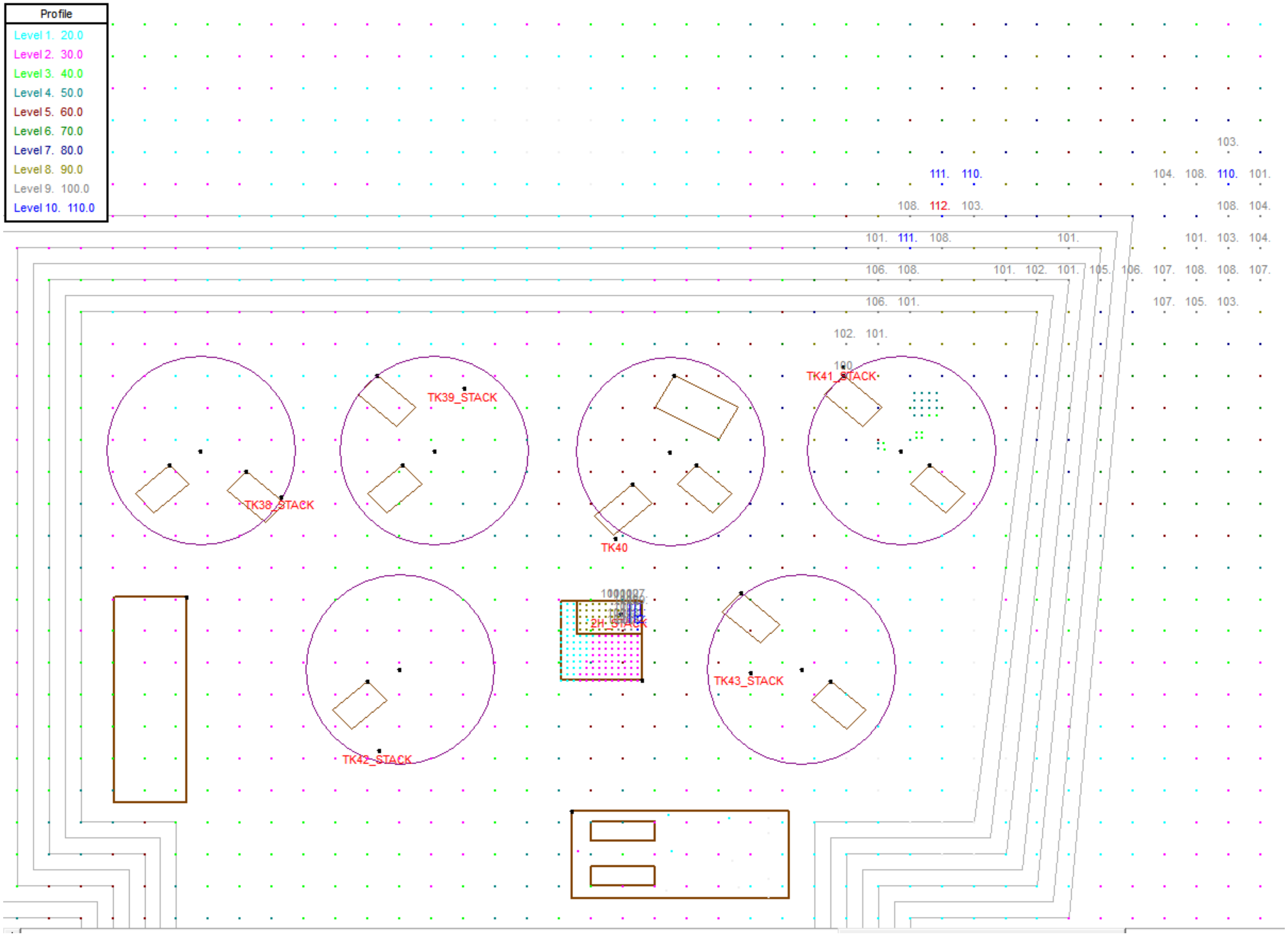

Figure 3-3a. STEL Exceedances for Tank 41H with a 45-foot stack and 50 mg/m^3 release concentration scenario. Receptor values shown as percent of STEL (>30 µg/m^3) for values that exceed 100%. Plant North is at the top of the page.

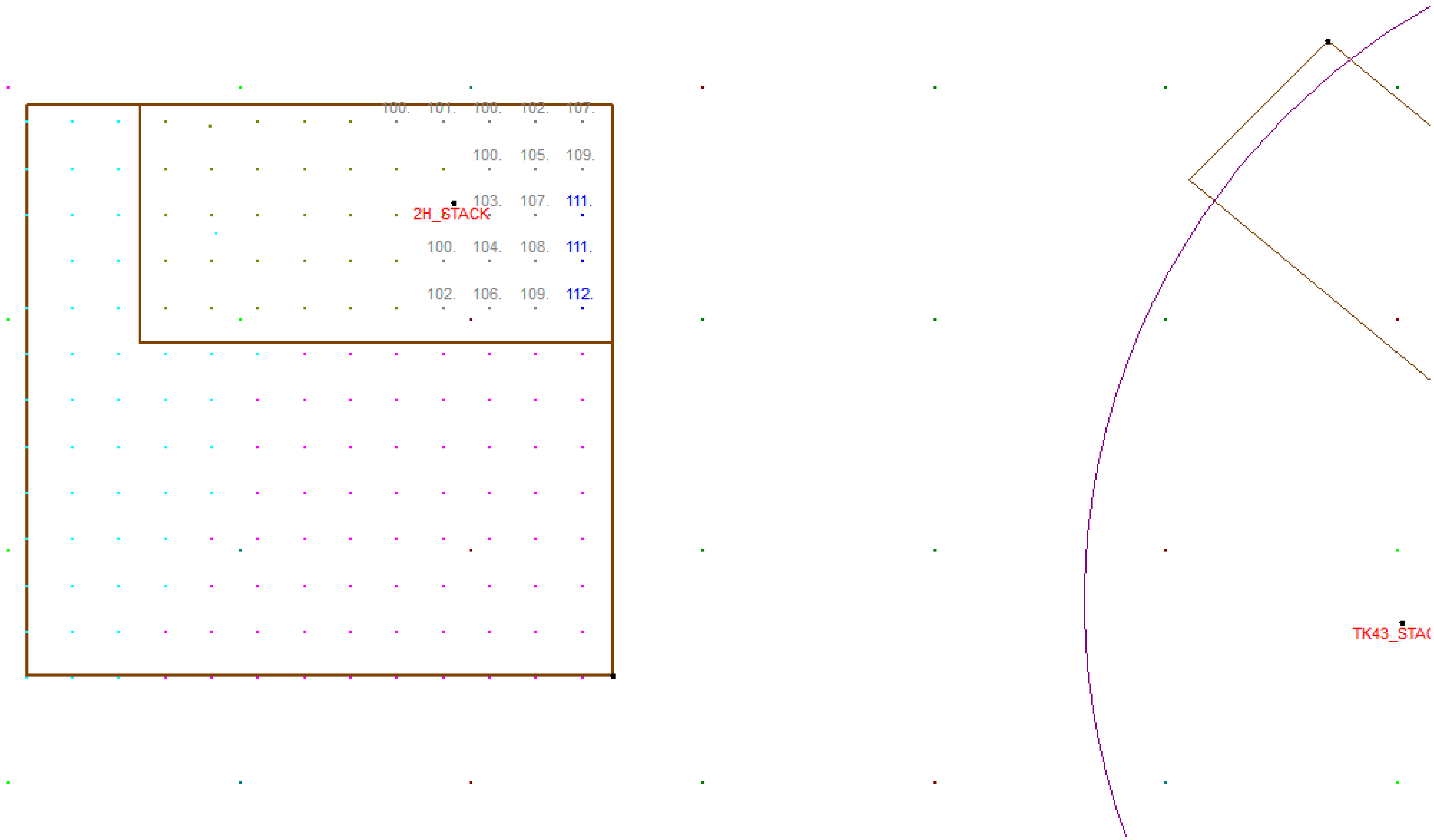

Figure 3-3b. Closeup of the 2H Evaporator roof showing the STEL Exceedances for Tank 41H with a 45-foot stack and 50 mg/m^3 release concentration scenario. Receptor values shown as percent of STEL (>30 µg/m^3) for values that exceed 100%. Plant North is at the top of the page.

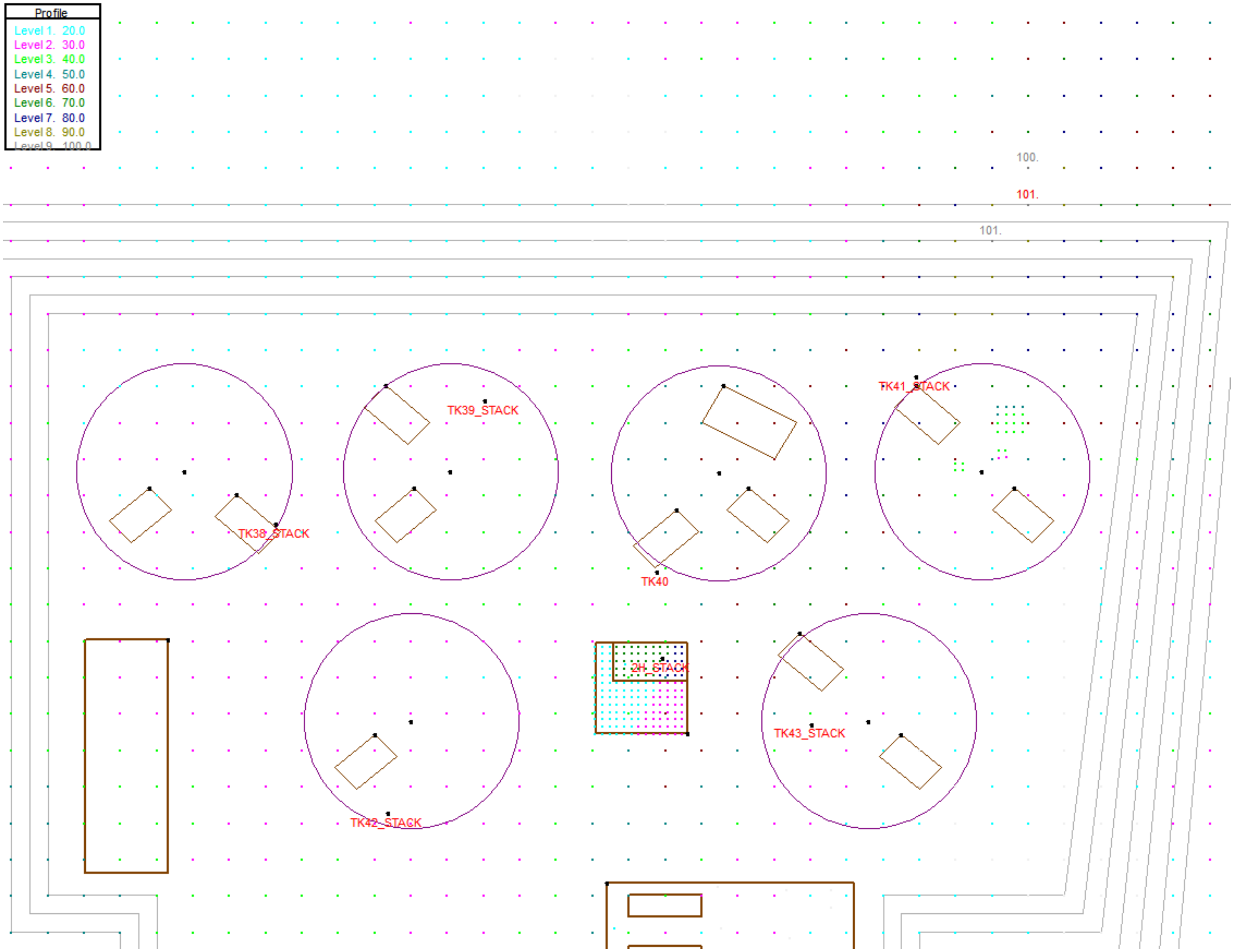

Figure 3-4. STEL Exceedances for Tank 41H with a 48-foot stack and 50 mg/m^3 release concentration scenario. Receptor values shown as percent of STEL (>30 µg/m^3) for values that exceed 100%. Plant North is at the top of the page.

4.0 Conclusions

The EPA's AERMOD dispersion analysis tool was used to calculate the ground-level concentration of mercury due to emissions from the Tank 41 stack. Results show that the STEL and TLV standards are not exceeded for mercury emissions up to 25 mg/m^3 and a stack height of at least 30-ft. For emissions up to 50 mg/m^3 a 50-ft stack is required.

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