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Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 42H

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EXECUTIVE SUMMARY

The Savannah River National Laboratory (SRNL) Atmospheric Technologies Group performed atmospheric dispersion modeling and analysis of mercury emissions from the H-Tank Farm - Tank 42 ventilation system exhaust to evaluate potential worker exposures to mercury vapor. This analysis was used to establish a minimum stack height at which ambient mercury concentration would not exceed any worker exposure limit. The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was used as the dispersion modeling tool for this analysis. Results indicate that the default 10-foot stack results in ground level concentrations that significantly exceed exposure standards for the mercury discharge scenarios evaluated. For a discharge of 25 mg/m^3, a 50-foot stack was necessary to raise the exhaust plume centerline from Tank 42H to a height that prevents mercury exposure problems for elevated receptors on buildings near the tank. If the discharge concentration is decreased to 10 mg/m^3, the minimum stack height required to comply with exposure limits is of 40 feet.

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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
AERSURFACE	AERMOD Surface Characteristics Preprocessor
ASL	Above Sea Level
AGL	Above Ground Level
ATG	Atmospheric Technologies Group
BPIP-Prime	Building Profile Input Program- Prime Algorithm
EPA	Environmental Protection Agency
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
SRR	Savannah River Remediation
SRS	Savannah River Site
STEL	Short Term Exposure Limit
TLV	8-hour Threshold Limit Value
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
cfm	Cubic feet per minute

1.0 Introduction

The Atmospheric Technologies Group (ATG) was asked to evaluate the exposure of workers to mercury vapor resulting from the H-Area Tank Farm Tank 42 purge exhaust systems emissions, and to ensure ambient air concentrations are within Savannah River Remediation (SRR) Industrial Hygiene program requirements (Ref. 1). The American Conference of Governmental Industrial Hygienists (ACGIH) short term exposure limit (STEL) for dimethyl mercury in the workplace is 0.030 mg/m^3 (30 µg/m^3) (Ref. 1). The STEL for dimethyl mercury is used to assess short term exposure because a STEL for elemental mercury has not been reported by the ACGIH. Additionally, average concentrations over a period of 8 hours were compared to the 8-hour Threshold Limit Value (TLV) for mercury (0.025 mg/m^3). Mercury concentrations were predicted for platform and ground-level breathing height receptors on and around Tank 42H.

To predict the mercury concentrations for Tank 42H, observed weather data for Savannah River Site (SRS) was taken from a five-year (2007-2011) quality assured record of hourly meteorological conditions and used to calculate the amount of atmospheric dispersion for 1-hour and 8-hour periods. Hourly-averaged modeled concentrations were adjusted to represent 15-minute values for comparison to the 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 worker exposure controls can be implemented, as needed.

2.0 Methodology

Modeling was conducted with the Environmental Protection Agency's (EPA) AMS/EPA Regulatory Model (AERMOD) dispersion model, which is recommended by the EPA for regulatory air quality analyses (Ref. 3). The model incorporates boundary layer scaling parameters to allow for vertical variability in wind, turbulence, and temperature, and to accommodate dispersion through the boundary layer in both stable and convective atmospheric situations (Refs. 4 and 5). 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 Above Ground Level) of the 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 8. For details on the processing of the most recent five-year quality assured dataset (2007-2011) see Reference 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.

Building information was included in AERMOD to account for downwash and re-circulation effects from nearby buildings. This 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. Of particular concern is the downwash of the plume over areas where workers will spend most of their time during operations. Small, ill-defined appurtenances in the vicinity of Tank 42H were not modeled for atmospheric downwash, therefore adding a level of conservatism (these features provide additional turbulence for dispersion which can lower atmospheric concentrations). The larger buildings and covered platforms need to be retained for AERMOD to enhance the vertical mixing of the plume centerline down to the ground level receptor heights, increasing the near surface ground concentrations. For this evaluation, four structures on Tank 42H were modeled: two small buildings near the stack (Valve House and Purge Exhaust Enclosure) and two covered platforms (Riser C3 and B4) as described in Reference 1. Additionally, two larger buildings located near Tank 42H: the 16H Evaporator Building and 82H Control Room were included in the modeling domain because downwash from these structures is likely to impact ground level concentrations (Ref. 12). Tank 42H itself was given a height of 0.3 meters (m) with a base height of 100 m Above Sea Level (ASL). BPIP-Prime was run for every change in stack height to determine the impact of the downwash from building wake on the stack effluent.

Terrain elevation was determined from SRS high resolution Light Detection and Ranging (LIDAR) dataset for SRS (Refs. 10 and 11). Tank 42H is located on the East Hill of H-area Tank Farm which has been graded to be approximately 100 m ASL (Fig. 2-1). The area surrounding the hill has been graded to be 89 and 91 m ASL. The terrain features surrounding Tank 42H were modeled by creating a terraced building (Figure 2-2) to model the impact of the East Hill on plume dispersion. The coordinate system used for this domain was a custom UTM grid, using the NAD27 datum.

The modeling domain is defined by a receptor grid of approximately 14,711 receptors covering the entire H-tank farm area. Receptor grid spacing of 6 m was used to identify any potential excessive concentrations that may occur near the ground level and elevated breathing zones. Elevated receptors were placed on various locations of concern as described in Ref 1. Each open platform on Tank 42H was modeled by placing several elevated receptors where these structures are located on the tank. The platform receptors varied in height for each platform and structure, from 2.7 m up to 6.4 m breathing level height. Elevated receptors were also placed on two containment huts (C3 and B4) at the respective breathing heights associated to each platform height. Several receptors were also added on both the 16H Evaporator building and the 82H Control Room building since elevated work areas can be found on these buildings (Ref. 12). A summary list of all elevated receptor locations and heights can be found on Table 2-1. Lastly, terrain was also considered for ground level receptor heights by changing the base height of these receptors as dictated by grade level changes on and around the East Hill (Figure 2-1).

The operating characteristics of the stack and source term are defined by the following parameters, also listed in Reference 1. Two discharge concentrations were evaluated: 10 mg/m^3, and 25 mg/m^3, with a flow rate of 300 cfm. The lower bound of the stack discharge temperature range (65°C) was used for conservatism. The inside diameter of the stack is 6 inches (in.) and the stack height is 10 ft (Ref. 1). For this evaluation the stack height was adjusted, as necessary, to various heights to determine the minimum height at which the estimated mercury concentrations around the stack both at ground and platform-level are within SRR Industrial Hygiene program requirements.

In order to have the correct units for input to AERMOD, the given concentration of mercury in the stack discharge was converted to a mass release rate by using the discharge flow rate given Reference 1:

Case 1:

$$\frac{10\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{300\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.001417\text{ g/s}$$

Case 2:

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

Once mercury concentration values were calculated by the model for each receptor on the grid, values were transformed to express results as percent of corresponding standard depicted in the figures included in this report (Figures 3-1 to 3-7). This was done by multiplying each value by a scaling factor of 4.3 for the STEL and 4.0 for the 8-hour TLV. These scaling factors were obtained using the following calculation:

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

$$\%\text{ of TLV} = \frac{1.0}{25\ \mu g/m^3} \times 100 = 4.0$$

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

Table 2-1. Summary of Elevated Receptor Locations and Heights

Elevated Structure/Platform (per Ref. 1)	Receptor Height* (ft, AGL)
Riser B3 Platform	11
Riser G Platform	21
Riser H Platform	21
Riser V1 Platform	9
Riser V2 Platform	9
Hopper Platform	9
Riser C3 Containment Hut	18
Riser B4 Containment Hut & Airlock	16 and 26
Building 241-82H (Control Room)	22 and 34
Building 241-16H (Evaporator Bldg.)	24 and 38

*Receptor heights listed include the platform height plus the breathing level height of 6 ft.

Figure 2-1. **Aerial photo of East Hill at the H-Tank farm with LIDAR elevations (green contours) around Tank 42H (Ref. 11)**

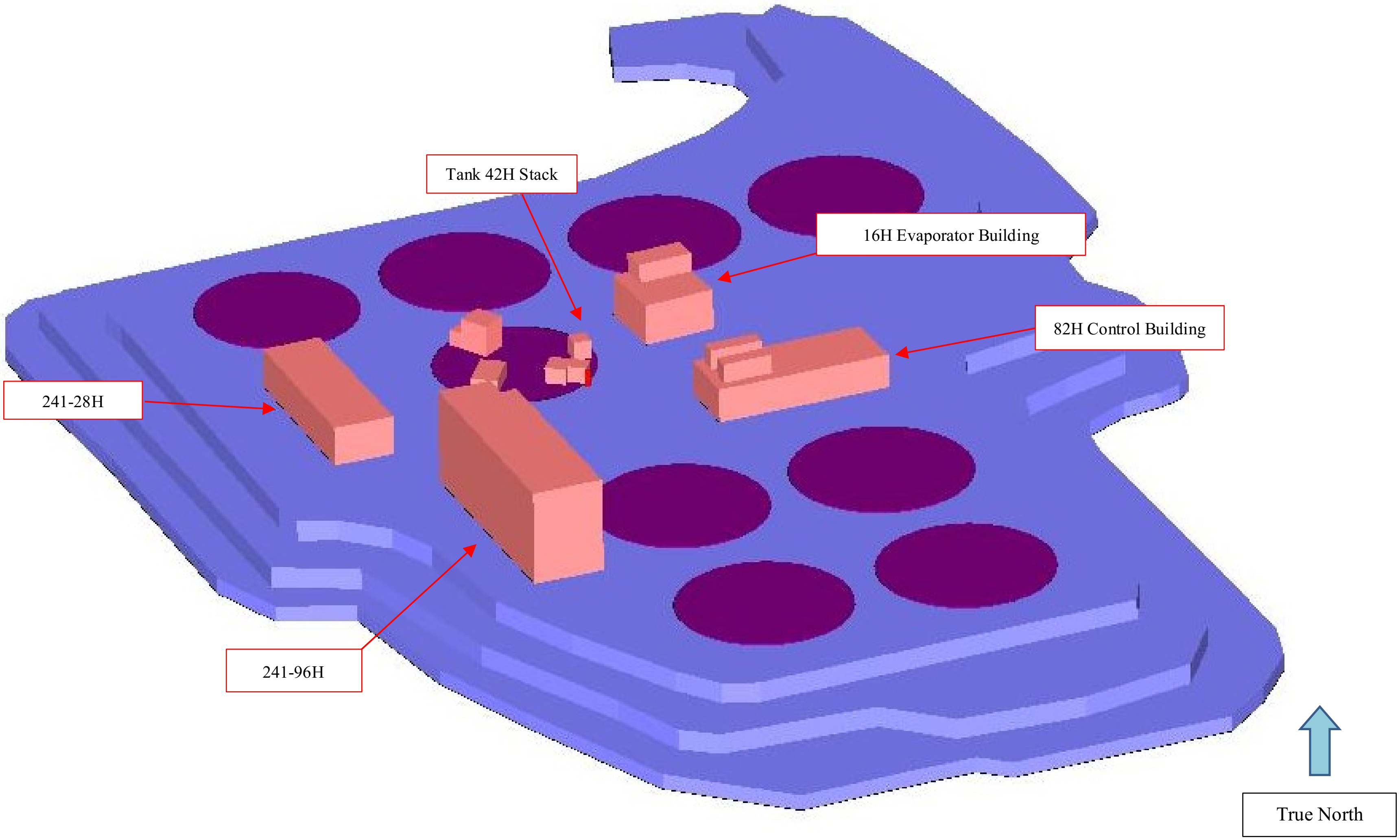

Figure 2-2. Three-dimensional view of Tank 42H for a 10-foot stack. The tank is represented by a purple circle, buildings and enclosed platforms in pink, and the 10-ft stack is in red. Blue arrow shows the direction of the true north.

3.0 Results and Discussion

Modeling was conducted based on the release characteristics previously summarized to assess compliance with the STEL for dimethyl mercury (0.030 mg/m^3 or 30 $\mu g/m^3$), which as identified previously is used as a surrogate for elemental mercury, and 8-hour TLV for mercury (0.025 mg/m^3 or 25 $\mu g/m^3$). AERMOD provides output of a 1-hour time weighted average which was adjusted to a 15-minute averaging period using the multiplier from Equation 1 to assess compliance with the STEL. The stack discharge concentrations modeled were 10 mg/m^3 and 25 mg/m^3 (Ref. 1). The stack height was initially set to 10 ft, which is the current height of the stack, and increased by 10 ft increments until the concentration at all receptor locations was below the exposure limits. Then the minimum stack height is found by refining the modeled stack heights in increments of 5 ft.

Table 3-1 summarizes the maximum mercury concentrations predicted by the model over the entire domain for each modeled stack height and flow rate. A graphical depiction of model results showing the location of receptors exceeding the worker exposure limits for selected stack heights can be found on Figures 3-1 to 3-10. Values at each receptor are expressed as a percent of the standard and only the values over 100% of the standard are depicted in each figure, i.e. values that exceed the standard.

For a 10-ft stack, and a 10 mg/m^3 release concentration, the STEL is exceeded at numerous ground level and elevated receptors near the tank and on the 16H Evaporator building (Figure 3-1). However, the 8-hour TLV is only exceeded on elevated receptors located on the Riser C3 Containment Hut on Tank 42H (Figure 3-2). With a 10-ft stack and increasing the discharge rate to 25 mg/m^3, the extent of ground level receptors exceeding STEL includes most of the northern portion of the East Hill, as well as a small region to the south of Tank 42H (Figure 3-3). For this scenario, significantly high concentration values above the STEL are estimated for elevated receptors on the Tank 42H platforms (particularly for Riser C3 Containment Hut), as well as on elevated receptors located on the top of the 16H Evaporator Building (Figure 3-3). Similarly, for this discharge and stack height combination, the 8-hour TLV is only exceeded on elevated receptors located on the Riser C3 Hut and on the 16H Evaporator Building (Figure 3-4).

With each incremental stack height increase the number of receptors with concentrations above exposure limits decreased, and so did the maximum mercury concentration values (Table 3-1). Beyond the 20-ft height and a 10 mg/m^3, *ground level* receptor concentrations do not exceed STEL and 8-hour TLV. However, *elevated* receptors on Riser C3 and the 16H Evaporator Building continue to exhibit concentrations well above the STEL for both the 10 mg/m^3 and 25 mg/m^3 release scenarios (Figures 3-5 to 3-7). With a discharge of 10 mg/m^3, a minimum stack height of 40 ft was needed to ensure elevated receptor concentrations were below limit exposure. In turn, for a discharge of 25 mg/m^3, the modeled stack must reach a minimum height of 50 ft to ensure concentrations at the elevated receptors in 16H Evaporator are below STEL. Therefore, it is these elevated receptors that drive the minimum stack height for the Tank 42H stack to 50 ft (Figures 3-8 to 3-10).

Table 3-0-1. Maximum estimated ambient concentrations (µg/m^3) associated to Tank 42H emissions.

Tank Discharge	Averaging Time	Tank 42H Stack Height						
		10-ft	*20-ft*	*30-ft*	*35-ft*	*40-ft*	*45-ft*	*50-ft*
10 mg/m^3	15-minutes	**123.5**	**44.4**	**39.4**	**35.3**	27.3		
	8-hours	**34.9**	11.6	8.6	7.2	6.7		
25 mg/m^3	15-minutes	**308.5**	**110.9**	**98.4**	**88.2**	**68.3**	**38.2**	24.9
	8-hours	**87.3**	**28.9**	21.5	17.9	16.7	12.1	9.4

Values in red exceed exposure limits (0.030 mg/m^3 or 30 µg/m^3 for STEL, and 0.025 mg/m^3 or 25 µg/m^3 for 8-hr TLV)

4.0 Conclusions

The focus of this report was to assess the worst-case 15-min and 8-hour average mercury concentrations at ground level and elevated breathing zones on and around Tank 42H for the current stack height of 10 ft. Emissions from this height were found to result in significant exceedances of the STEL and 8-hour TLV exposure limits. Receptors with the concentrations above exposure limits were those located on platforms and on top of nearby buildings.

Results show that the minimum stack height to ensure concentrations below STEL and 8-hour TLV for both discharge scenarios evaluated is 50 ft. A stack of 40 ft would provide concentrations below exposure limits for a discharge rate of 10 mg/m^3, however a 50-ft stack is necessary with a discharge rate of 25 mg/m^3.

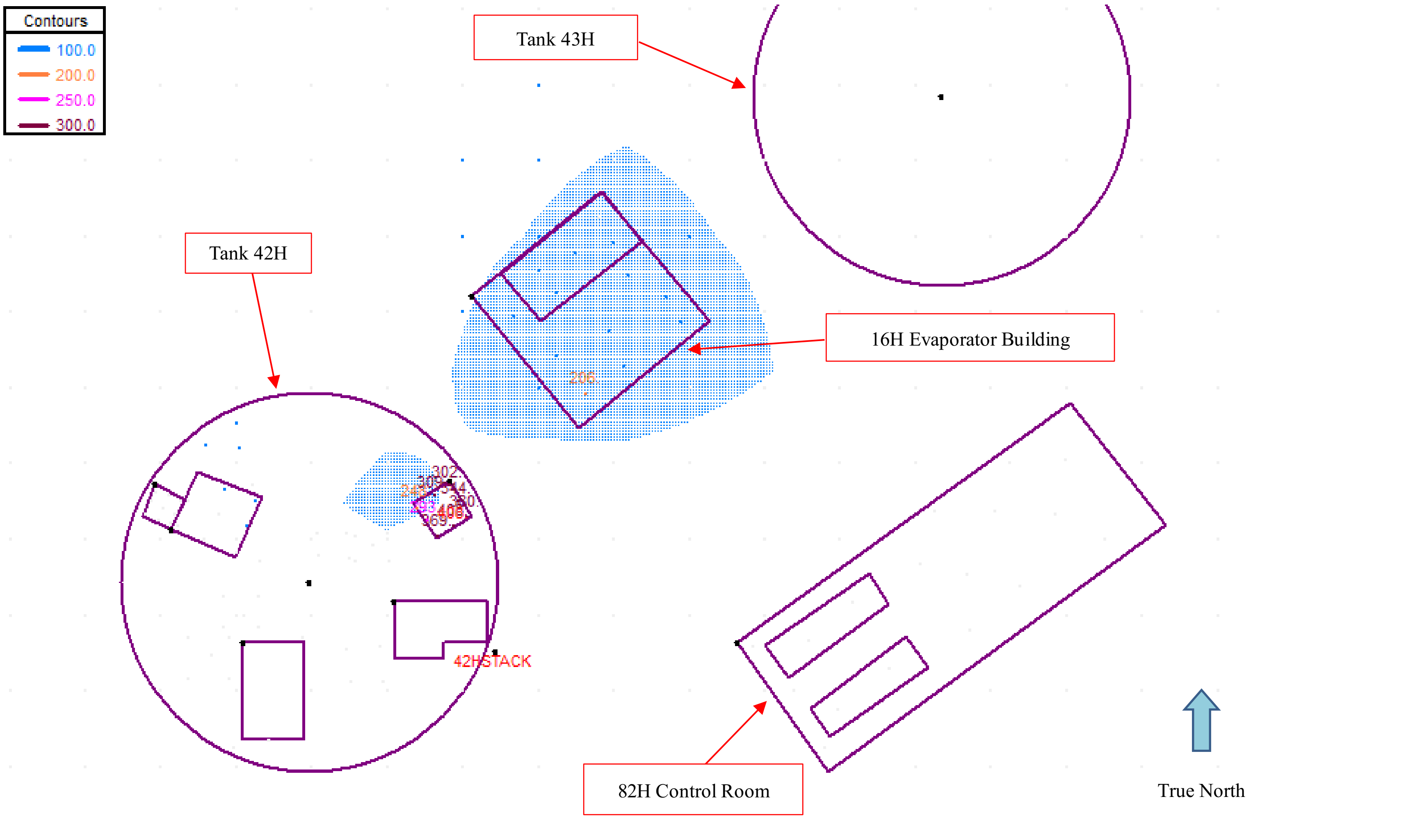

Figure 3-1. STEL Exceedances for Tank 42H with a 10-foot stack and a 10 mg/m^3 discharge. Exceedances expressed as a percentage of the STEL standard (30 µg/m^3). Filled contours display areas with concentration values above 100% of standard while numeric values display concentrations above 200% of standard. Buildings and tanks are shown in purple.

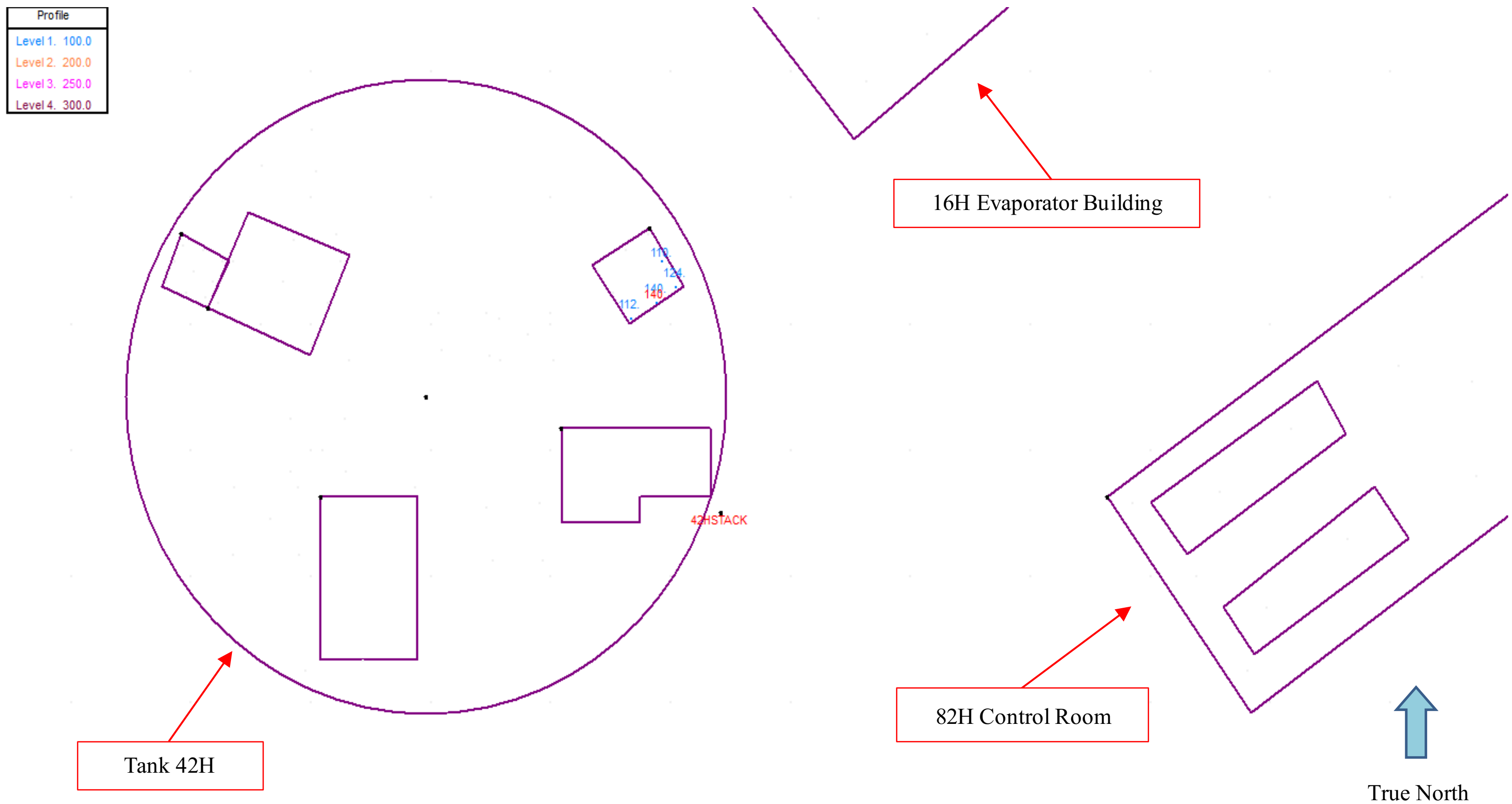

Figure 3-2. 8-hour TLV Exceedances for Tank 42H with a 10-foot stack and 10 mg/m^3 discharge. Exceedances expressed as a percentage of the 8-hour TLV standard (25 µg/m^3). Numeric values display areas with concentration values above 100% of standard. Buildings and tanks are shown purple.

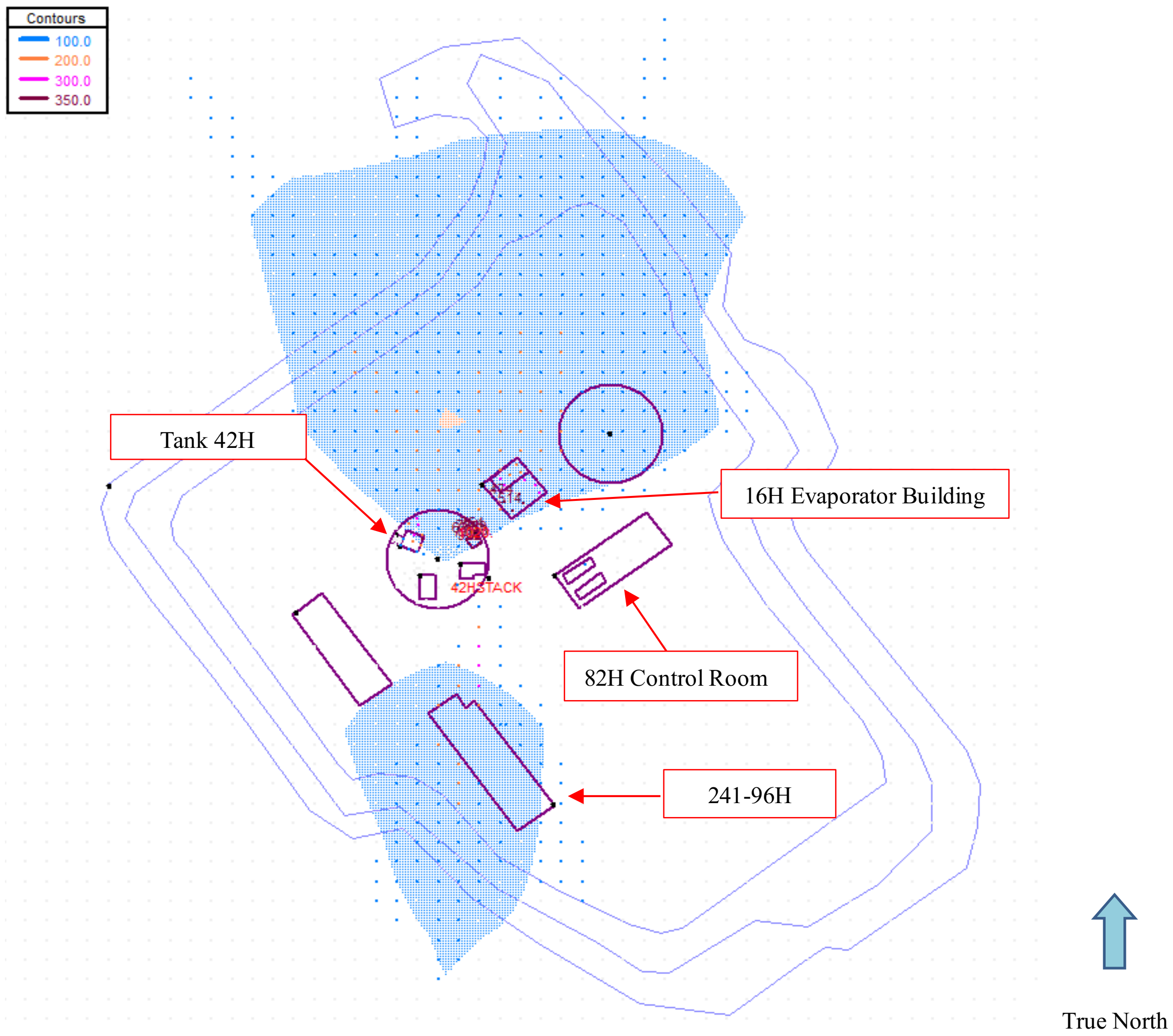

Figure 3-3. STEL Exceedances for Tank 42H with a 10-foot stack and a 25 mg/m^3 discharge. Exceedances expressed as a percentage of the STEL standard (30 μg/m^3). Filled contours display areas with values above 100% of the standard. Numeric values display areas with concentration values above 300% of the standard. Terrain, buildings and tanks are shown in blue and purple, respectively.

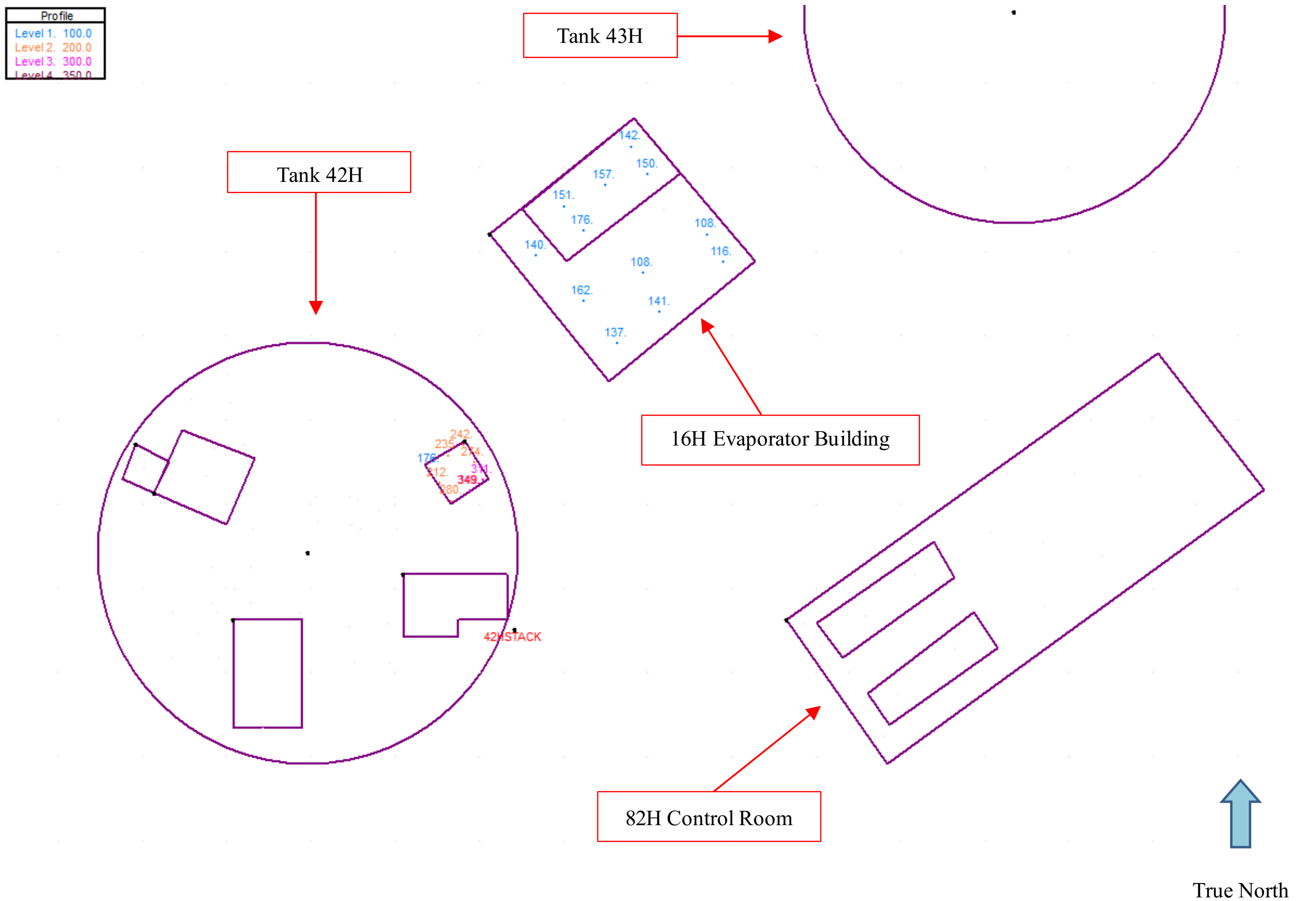

Figure 3-4. 8-hour TLV Exceedances for Tank 42H with a 10-foot stack and 25 mg/m^3 discharge. Exceedances expressed as a percentage of the 8-hour TLV standard (25 µg/m^3). Numeric values display areas with concentration above 100% of standard. Buildings and tanks are shown in purple.

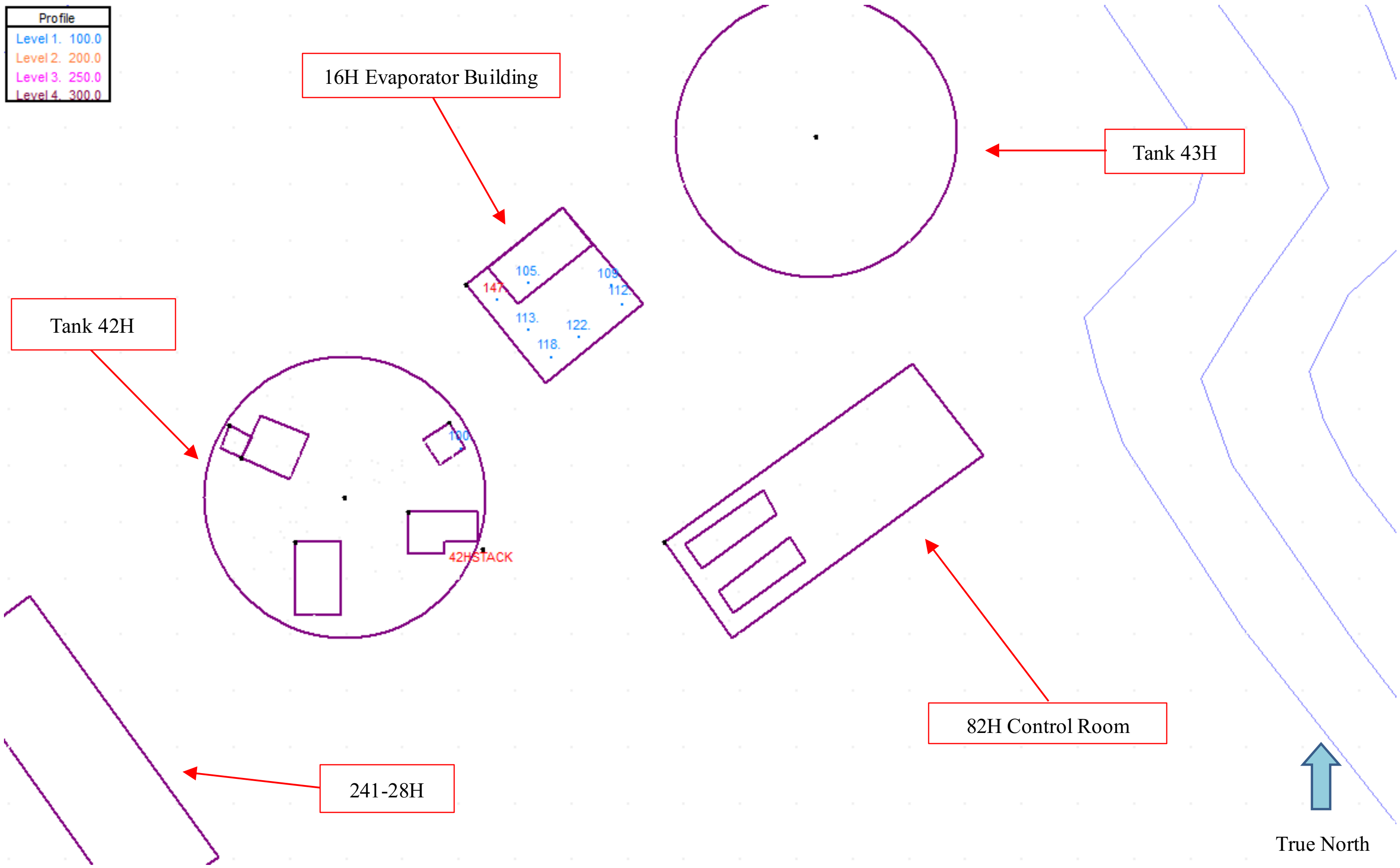

Figure 3-5. STEL Exceedances for Tank 42H with a 20-foot stack and 10 mg/m^3 discharge. Exceedances expressed as a percentage of the STEL standard (30 µg/m^3). Numeric values display areas with concentration above 100% of standard. Buildings and tanks are shown in purple.

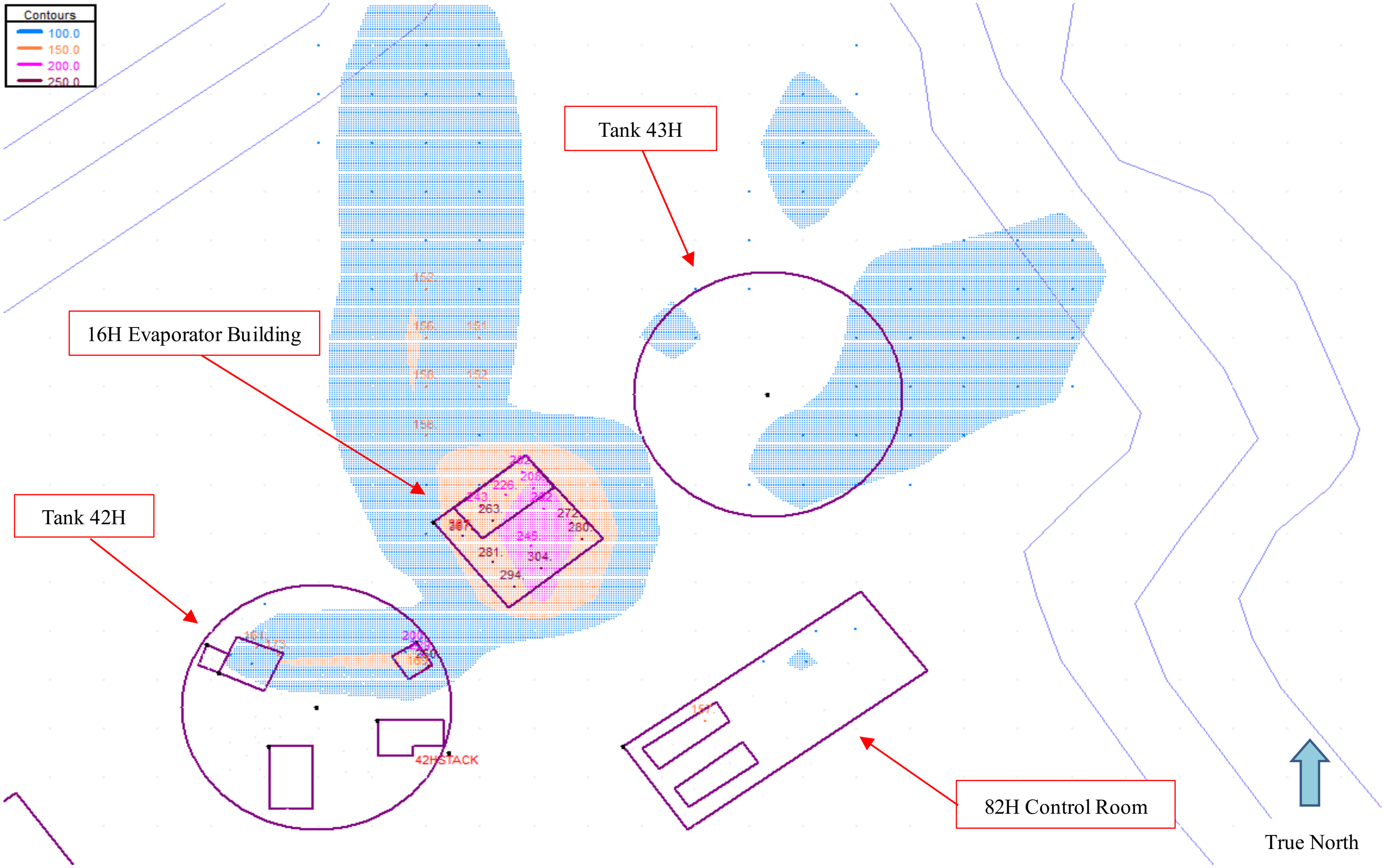

Figure 3-6. STEL Exceedances for Tank 42H with a 20-foot stack and a 25 mg/m^3 discharge. Exceedances expressed as a percentage of the STEL standard (30 µg/m^3). Filled contours display areas with values above 100% of the standard. Numeric values display areas with concentration values above 200% of the standard. Terrain, buildings and tanks are shown in blue and purple, respectively.

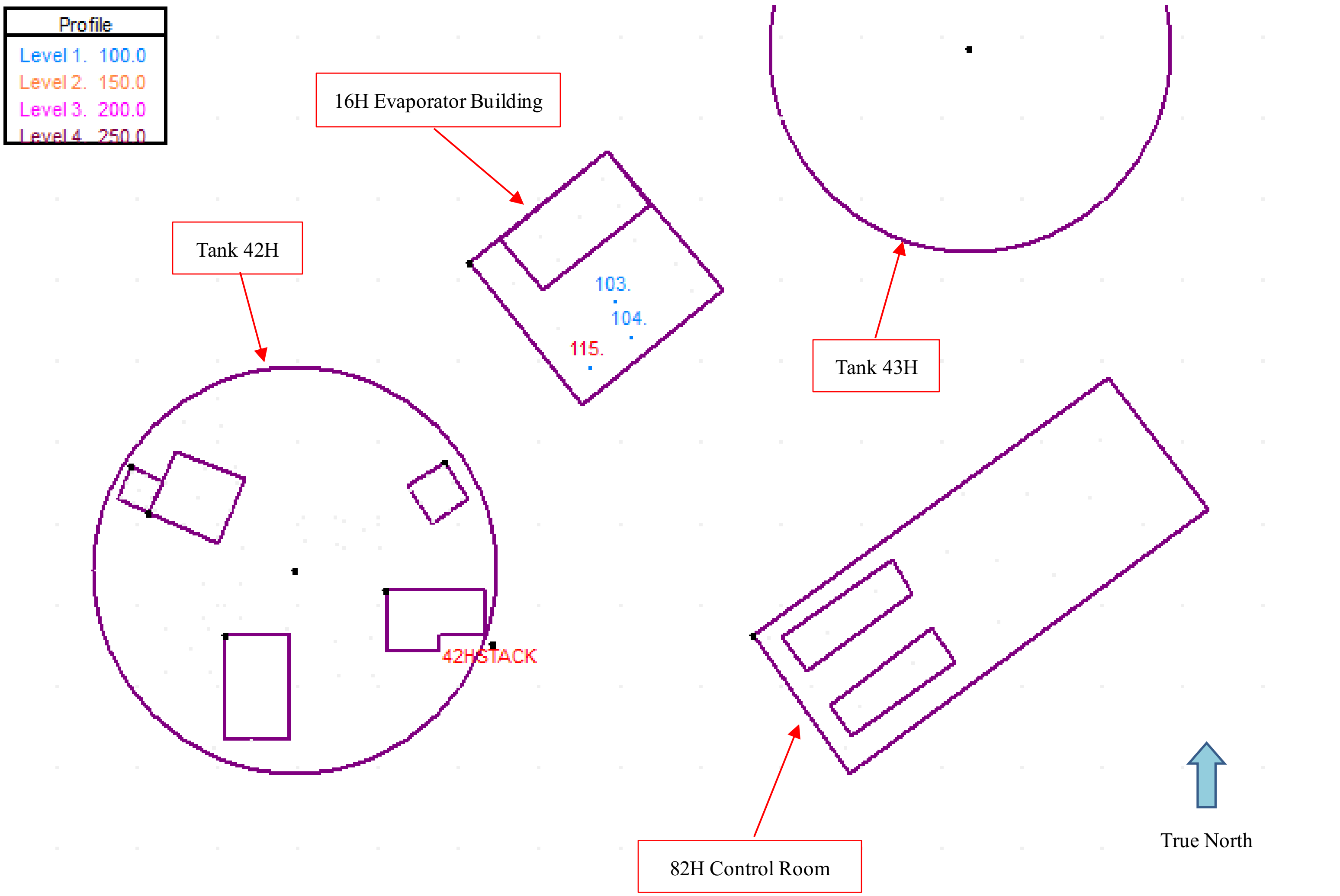

Figure 3-7. 8-hour TLV Exceedances for Tank 42H with a 20-foot stack and 25 mg/m^3 discharge. Exceedances expressed as a percentage of the 8-hour TLV standard (25 µg/m^3). Numeric values display areas with concentration above 100% of standard. Buildings and tanks are shown in purple.

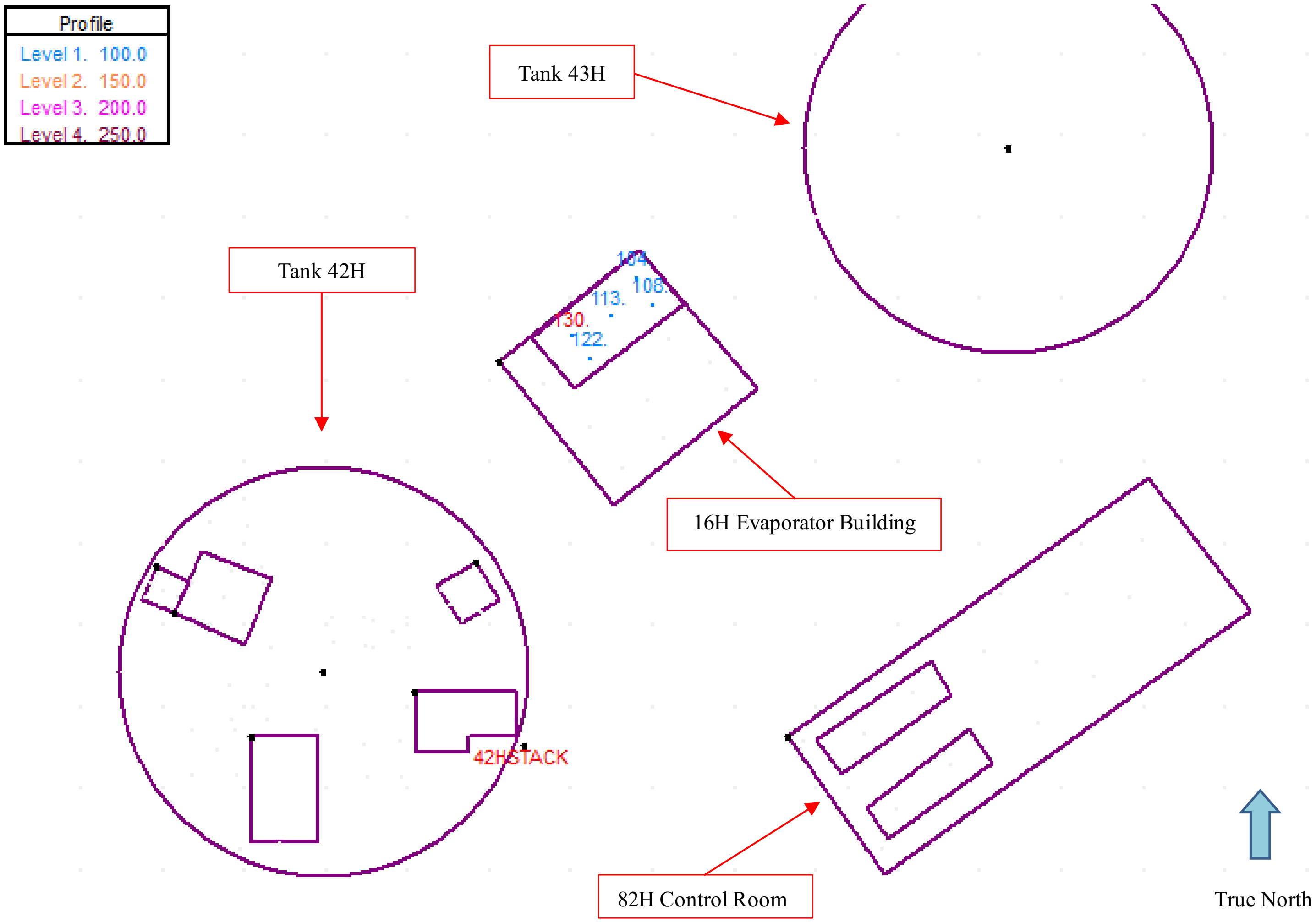

Figure 3-8. STEL Exceedances for Tank 42H with a 30-foot stack and 10 mg/m^3 discharge. Exceedances expressed as a percentage of the STEL standard (30 µg/m^3). Numeric values display areas with concentrations above 100% of standard. Buildings and tanks are shown in purple.

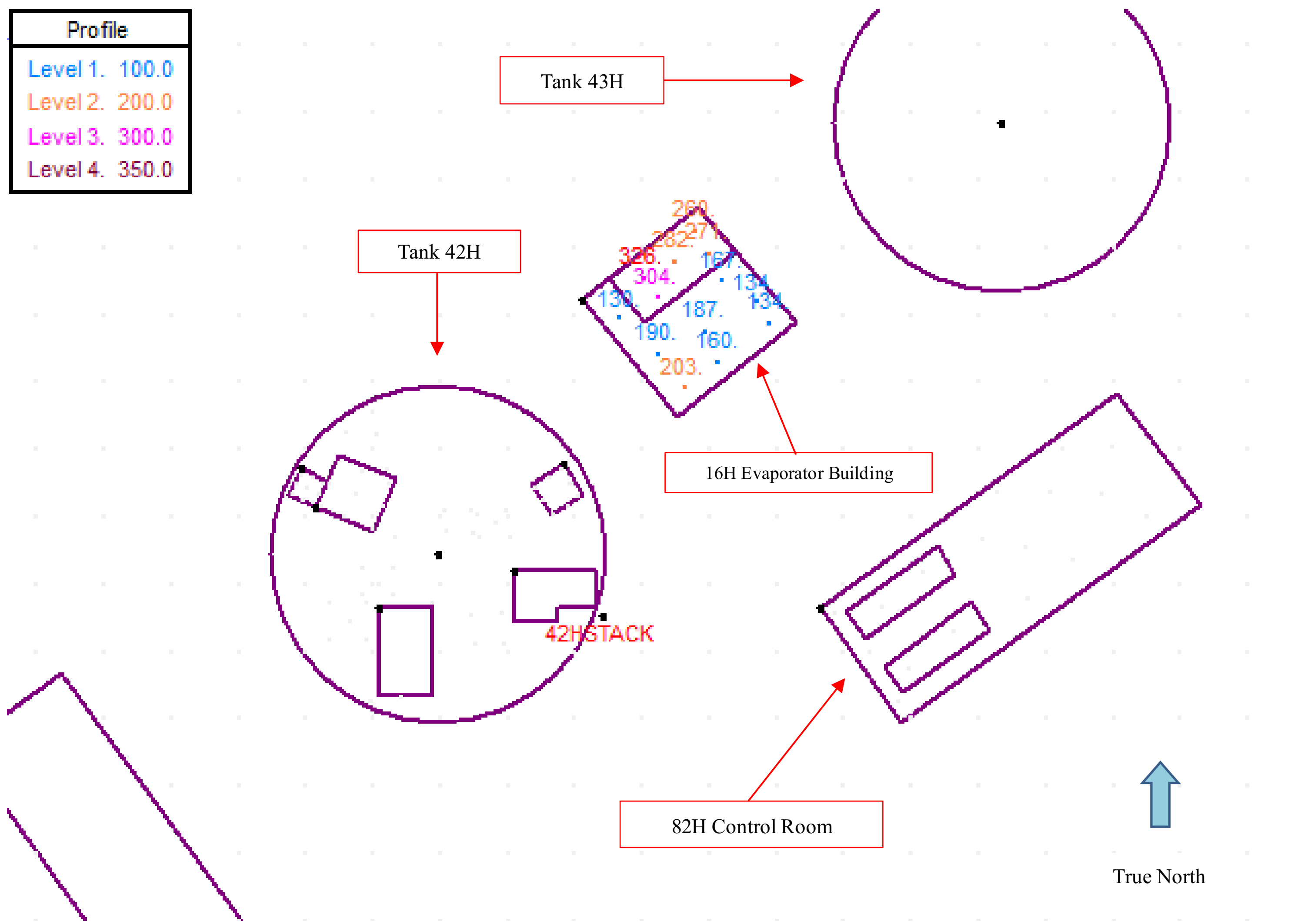

Figure 3-9. STEL Exceedances for Tank 42H with a 30-foot stack and 25 mg/m^3 discharge. Exceedances expressed as a percentage of the STEL standard (30 μg/m^3). Numeric values display areas with concentration above 100% of standard. Buildings and tanks are shown in purple.

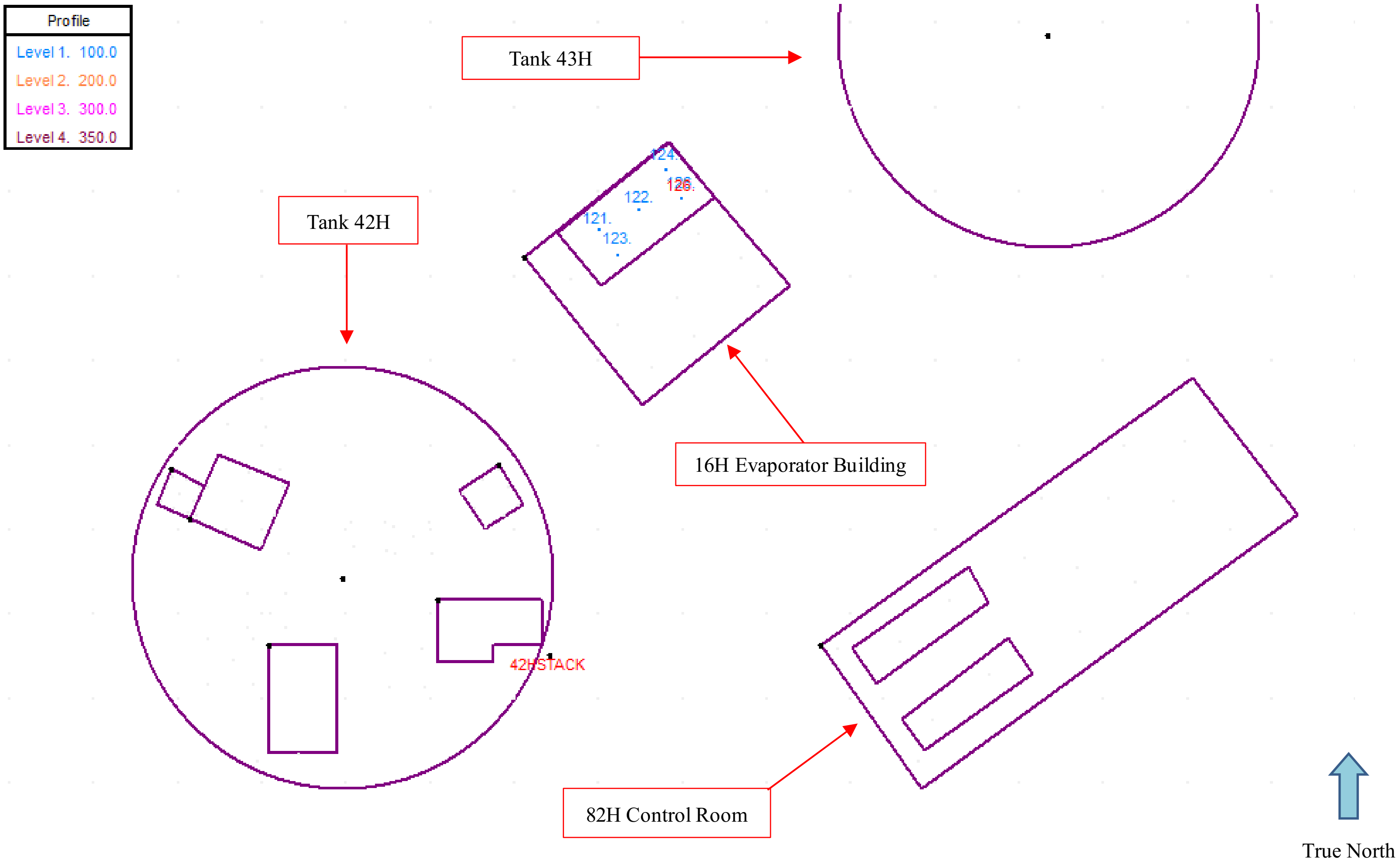

Figure 3-10. STEL Exceedances for Tank 42H with a 45-foot stack and 25 mg/m³ discharge. Exceedances expressed as a percentage of the STEL standard (30 µg/m³). Numeric values display areas with concentration above 100% of standard. Buildings and tanks are shown in purple.

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