Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 31H

Steve Weinbeck

March 2019

SRNL-STI-2018-00654, Rev.0

SRNL.DOE.GOV

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Printed in the United States of America

Prepared for
U.S. Department of Energy

Keywords: *Mercury Emissions; H Tank Farm; Tank 31H.*

Retention: *Permanent*

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EXECUTIVE SUMMARY

The SRNL Atmospheric Technologies Group performed an analysis of mercury emissions from the H-Tank Farm Tank 31-H to assess worst case 15-minute, 1-hour and 8-hour average concentrations and evaluate whether the ACIGH Short-Term Exposure Limit (STEL), PAC (Protection Action Criteria), or Threshold Limit Value (TLV) levels for mercury are exceeded. This analysis was also used to establish a minimum stack height at which ambient mercury concentration would not exceed the regulatory limits. The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was used as the dispersion modeling tool for this analysis. The PAC standard is not exceeded for any of the stack heights, or release scenario. A 92 ft stack for the 25 mg/m^3 modeling scenario and 95 ft for the 50 mg/m^3 are necessary to prevent all exceedances at all receptors. If the highest receptor on the Evaporator West Stack Platform is excluded from the domain, then the maximum heights are 35 ft and 52 ft for the 25 mg/m^3 and the 50 mg/m^3 modeling scenarios, respectively.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AMS	American Meteorological Society
AEGLs	Acute Exposure Guideline Levels
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
EPA	Environmental Protection Agency
LIDAR	Light Detection and Ranging
NAD27	North American Datum 1927
NLCD92	National Land Cover Database 1992
NWS	National Weather Service
PAC	Protection Action Criteria
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

Using established thresholds, 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 Tank 31H purge ventilation stack emissions, against three different exposure criteria. 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). 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. The Protective Action Criteria (PAC) for mercury (vapor) exposure, which is 8.9 mg/m^3 (8900 µg/m^3) for a 1-hour averaging period, representing an acute exposure guideline levels (AEGLs) that describe the human health effect from once-in-a-lifetime, or rare (extreme) exposure to airborne chemicals (Ref. 2). Mercury concentrations were predicted for ground-level breathing height and other specified work areas around Tank 31H.

To predict mercury concentrations from the Tank 31H emissions, 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. 3):

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

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 mitigation 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. 4). The model allows for vertical variability in wind, turbulence, temperature and incorporates boundary layer parameters for dispersion in both stable and convective atmospheric situations (Refs. 5 and 6). More information on ATG's software quality assurance plan for AERMOD can be found in C-SQP-G-00076 (Ref. 7). 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. 8), 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 9. For details on the processing of the most recent five-year quality assured dataset (2007-2011) see References 10 and 11.

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 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 around the Tank 31H were added to the model domain for inclusion in the BPIP-Prime input (wake) and are specified in Ref. 1. This modeling domain was based on a domain previously generated for use in SRNL-STI-2016-00119 (Tank 35H, Ref. 12), SRNL-STI-2016-00453 (Tank 22H, Ref. 13) and SRNL-STI-2017-00745 (HPP-7 Ref. 14), SRNL-STI-2018-00409 (Ref. 15) and was updated with revised base heights and building information (Ref 1). The East and West Hills were also modeled as a building to ensure that wake impacts from the hills could be evaluated.

There are other ill-defined appurtenances around the Tank 31H area; 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 (Refs. 16 and 17). The area surrounding Tank 31H and the 3H Evaporator building have been graded to be 98 meters (m) ASL (Fig. 2-1). The areas on top of the east and west hills are about 98 m and 100 m, respectively. To match the elevations taken from drawings it was decided to input the graded elevation at the top of the West Hill as 98.33 m (322.625 ft, Ref. 1 pg3).

The modeling domain was defined by a receptor grid of about 13,600 receptors. Receptor grid spacing of 6 m was used to identify any potential excessive concentrations that may occur near the ground. The height of ground level receptors is nominally 1.83 m (6 feet) AGL to represent the breathing zone of a tall worker standing at ground level. The coordinate system used for this domain was a UTM grid, using the NAD27 datum. Several other additional receptors were included in addition to the ground level breathing receptors. These locations were selected to pick particularly exposed locations where the plume would have a chance to impact workers. These additional receptors were placed at two levels in the Huts, 13 ft (3.96m) and 26 ft (7.93m), catwalks at 20 and 47 ft, the 3H Evaporator stairs 14, 20 and 23 ft (4.26, 6.10 and 7.01 m), 23ft (7.01 m) at the PVV platform and the 5^{th} floor breathing zone at 63 ft (19.2m) AGL. A single receptor was added at the

96 ft height for the platform (29.26 m), known as the West Stack Platform. Each height for the receptor is at the nominal height, plus an additional 6 ft to represent a worker breathing height (Ref. 1).

In previous studies, when plume centerlines are close to the receptors predicted concentration can be sensitive to small changes in heights. To account for potential uncertainty in the heights relative to one another, additional receptors were added 2 ft above and 2 ft below the nominal receptor heights for the receptors on the PVV platform, the 5th Floor breathing zone, the catwalks and the 3H Evaporator stairs. The stack heights were increased until 60 ft was reached to ensure that the plume would not impact these additional receptors.

The stack discharge temperature range is estimated to be 25°C to 60°C, for conservatism 25ºC was used in modelling. The inside diameter of the stack is 6 inches (Ref. 1). The initial stack height was 20-ft to examine the areas being impacted by mercury emissions (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 of 200 cfm, (maximum flow rate, see Ref. 1). While two stack flow rates were given, the larger of the two was selected to use for the modeling since the maximum flow will give the largest source term for mercury and is therefore conservative. The emission rate for the Tank 31H stack (in g/s) was determined using the following calculation based on inputs from Reference 1:

$$\frac{25\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{200\ \text{ft}^3}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 0.00236\ \text{g/s}$$

$$\frac{50\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{200\ \text{ft}^3}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 0.00472\ \text{g/s}$$

For the figures in this report, once mercury concentration values were calculated for each receptor, the value was 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:

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

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

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

$$\%\ \text{of PAC} = \frac{1.0}{8900\ \mu g/m^3} \times 100 = 0.01124$$

The third factor is shown for the PAC standard. Since the modeled values in this report were significantly below the PAC threshold, these were not displayed.

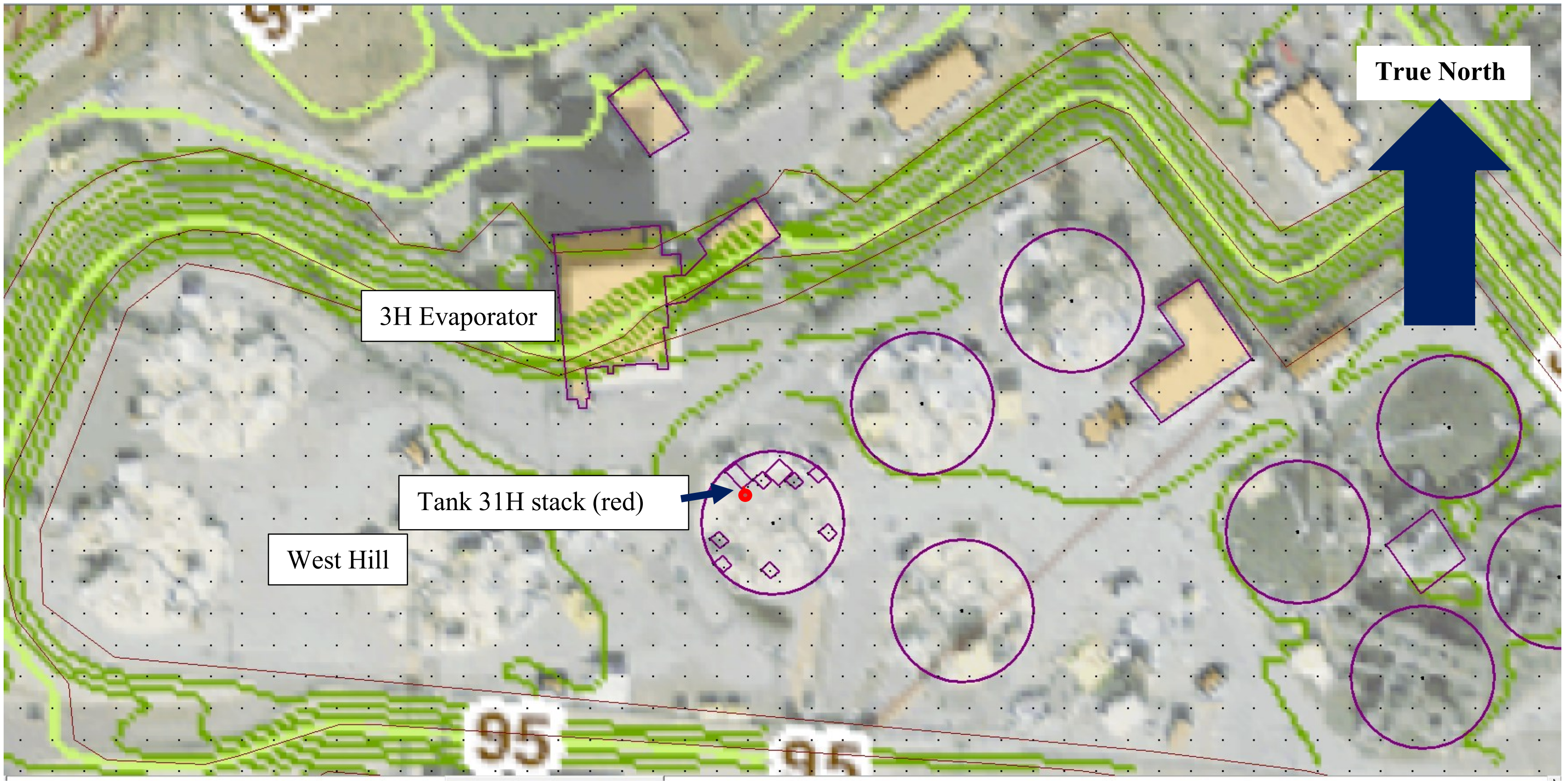

Figure 2-1. Aerial photo of H-Tank farm with LIDAR elevation (green contours) with receptors (dots) around H-tank Farm (Ref. 3).

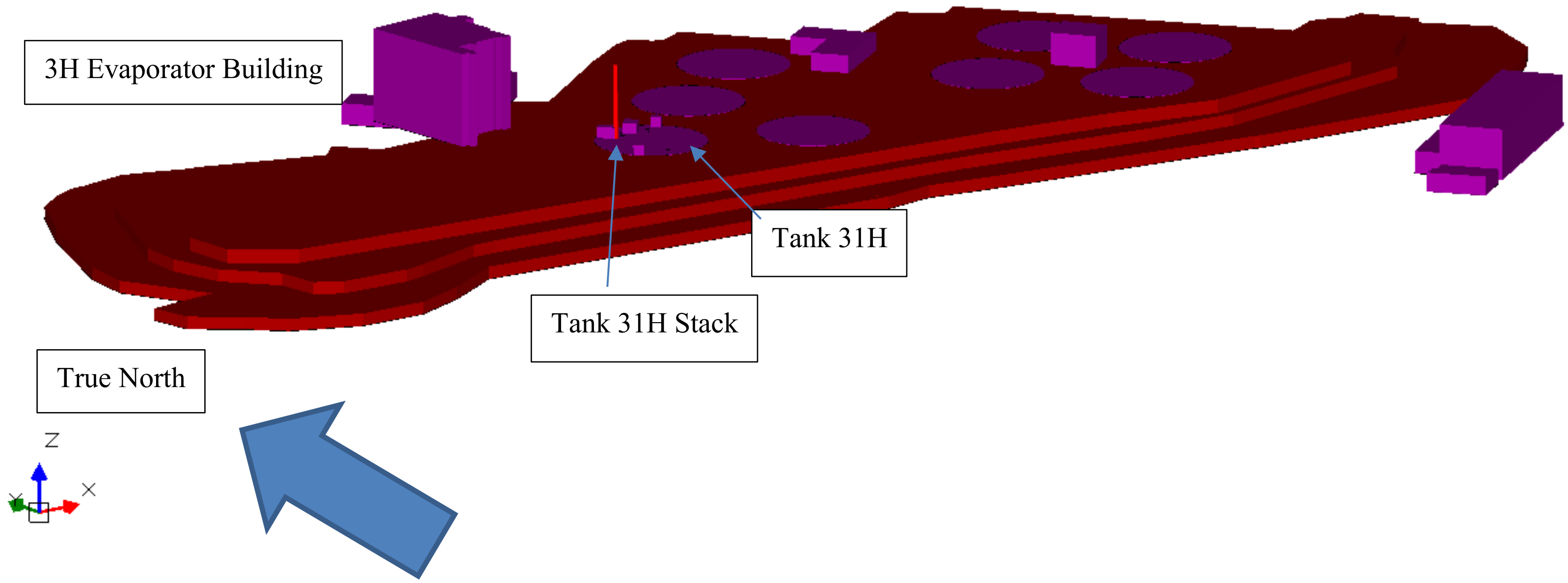

Figure 2-2. Three-dimensional view of the buildings around Tank 31H facility for the 60-foot stack height from AERMOD modeling domain. The tanks are represented by purple circles, hills by brown, buildings in purple, and the stack is in red. Blue arrow shows the direction of the True North. View is from the True Southeast direction and down.

3.0 Results and Discussion

Results of the modeling scenarios are listed in Table 3-1. Each of the two emissions scenarios were modeled starting with a stack height of 20-ft and increased in 5-ft increments until the modeled concentration no longer exceeded the applicable standard at any receptor in the modeling domain. When an increase in the stack height caused the receptor locations to no longer exceed the PAC, STEL, or TLV standards, then an intermediate height was run to further refine the allowable stack height.

The PAC standard is not exceeded for any of the stack heights, or release scenarios. If the 3H Evaporator Building Stack receptor is included (Tables 3-1a and 3-1b), the stack height necessary to avoid an exceedance is 92 ft for the 25 mg/m^3 modeling scenario and 95 ft for the 50 mg/m^3. Without the receptor on the top of the 3H Evaporator Building platform (labeled Evaporator West Stack Platform breathing level in Ref. 1), a 35 ft stack for the 25 mg/m^3 modeling scenario and 52 ft for the 50 mg/m^3 are necessary to prevent all exceedances (Tables 3-2a and 3-2b).

Ht	25 mg/m^3 (with 3H Evaporator Building Platform Receptor)		
	15-min	1-hr	8-hr
20	**1,356.7**	1,043.6	**262.6**
25	**229.8**	176.7	**97.1**
30	**56.0**	43.1	9.9
35	27.1	20.9	5.6
40	**45.4**	34.9	4.7
45	**66.9**	51.4	7.5
50	**81.1**	62.4	10.9
55	**92.8**	71.4	14.7
60	**103.2**	79.4	16.1
65	**80.4**	61.8	12.8
70	**53.6**	41.2	11.2
75	**48.4**	37.3	10.1
80	**54.6**	42.0	8.9
85	**120.4**	92.6	11.9
90	**48.4**	37.2	4.7
92	16.1	12.4	1.7
95	5.9	4.6	1.6
97	5.7	4.4	1.6
100	5.3	4.1	1.5

Table 3-1a. Maximum ambient concentrations (µg/m^3) associated to Tank 31H emissions for 15-minute, 1-hour and 8-hour periods for all receptors with a 25mg/m^3 tank concentration. Includes platform receptor at the top of 3H Evaporator Building.

Values in bold text and yellow highlights exceed exposure limits for respective time periods (0.030 mg/m^3 or 30 µg/m^3 for 15-min STEL, 8.9 mg/m^3 or 8,900 µg/m^3 for 1-hour PAC and 0.025 mg/m^3 or 25 µg/m^3 for 8-hour TLV).

Ht	50 mg/m³ (with 3H Evaporator Building Platform Receptor)		
	15-min	1-hr	8-hr
20	**2,713.5**	2,087.3	**525.2**
25	**459.5**	353.5	**194.2**
30	**112.0**	86.1	19.7
35	**54.2**	41.7	11.1
40	**90.7**	69.8	9.3
45	**133.8**	102.9	14.9
50	**162.2**	124.8	21.8
55	**185.7**	142.8	**29.4**
60	**206.4**	158.8	**32.3**
65	**160.8**	123.7	**25.5**
70	**107.2**	82.4	22.4
75	**96.9**	74.5	20.2
80	**109.3**	84.1	17.8
85	**240.7**	185.2	23.7
90	**96.8**	74.5	9.3
92	**32.2**	24.8	3.4
95	11.9	9.1	3.2
97	11.4	8.8	3.1
100	10.7	8.2	2.9

Table 3-1b. Maximum ambient concentrations (µg/m³) associated to Tank 31H emissions for 15-minute, 1-hour and 8-hour periods for all receptors with a 50 mg/m³ tank concentration. Includes platform receptor at the top of 3H Evaporator Building.

Values in bold text and yellow highlights exceed exposure limits for respective time periods (0.030 mg/m³ or 30 µg/m³ for 15-min STEL, 8.9 mg/m³ or 8,900 µg/m³ for 1-hour PAC and 0.025 mg/m³ or 25 µg/m³ for 8-hour TLV).

Ht	25 mg/m³ (without 3H Evaporator Building Platform Receptor)		
	15-min	1-hr	8-hr
20	**1,356.7**	1,043.6	**262.6**
25	**229.8**	176.7	**97.1**
30	**56.0**	43.0	9.9
32	**35.8**	27.5	7.7
35	27.1	20.9	5.6
40	22.1	17.0	4.7
45	18.8	14.4	4.1
50	16.5	12.7	4.4
55	12.3	9.5	4.0
60	11.2	8.6	2.8

Table 3-2a. Maximum ambient concentrations (µg/m³) associated to Tank 31H emissions for 15-minute, 1-hour and 8-hour periods for all receptors with a 25mg/m³ tank concentration. Does not include platform receptor at the top of 3H evaporator building.

Ht	50 mg/m³ (without 3H Evaporator Building Platform Receptor)		
	15-min	1-hr	8-hr
20	**2,713.5**	2,087.3	**525.2**
25	**459.5**	353.5	**194.2**
30	**111.9**	86.1	19.7
35	**54.3**	41.8	11.1
40	**44.2**	34.0	9.3
45	**37.5**	28.9	8.2
50	**33.0**	25.4	8.8
52	26.7	20.6	9.5
55	24.6	19.0	8.0
60	22.3	17.2	5.6

Table 3-2b. Maximum ambient concentrations (µg/m³) associated to Tank 31H emissions for 15-minute, 1-hour and 8-hour periods for all receptors with a 50 mg/m³ tank concentration. Does not include platform receptor at the top of 3H evaporator building.

Values in bold text and yellow highlights exceed exposure limits for respective time periods (0.030 mg/m³ or 30 µg/m³ for 15-min STEL, 8.9 mg/m³ or 8,900 µg/m³ for 1-hour PAC and 0.025 mg/m³ or 25 µg/m³ for 8-hour TLV).

Results presented in Tables 3-1a and 3-1b are different from the results in Tables 3-2a and 3-2b only due to a single additional receptor added to the top of the West Stack Platform. Results in Tables 3-1a and 3-1b are identical to those presented in Tables 3-2a and 3-2b until the stack heights are raised to 40 ft. Above 40 ft, the maximum receptor value occurs only at the West Stack Platform receptor. The mercury plume from the Tank 31H stack presumably has more turbulent mixing in the environment between the Tank 31H surface and the 3H Evaporator Building, preventing exceedance of either the STEL or TLV standard. Once the Tank 31H stack height lifts the plume away from the surface, the lack of turbulent mixing as well as the more direct path for the mercury cause the values to exceed the STEL (for the 25 mg/m^3 and 50 mg/m^3 release scenarios) and the TLV standards (for the 50 mg/m^3 release scenario).

For the 25 mg/m^3 and 32-ft stack release scenario without the West Stack Platform receptor, the STEL is exceeded on the surface of Tank 31H, in the area between Tank 31H and the 3H Evaporator building, and on Hut H (Figure 3-1a). The pattern in the elongated thin pink contour (above 50% of the STEL standard) is oriented in the northwest to southeast (see Figure 3-1b) which suggests that turbulence created by the 3H Evaporator building, along with the Huts and structures defined on the top of Tank 31H directs mercury plume down to the surface. Figures 3-2a and 3-2b show that the TLV exceedances (at 25-ft) occur only for the tops of the huts (Figure 3-2a) and with northwest to southeast oriented downwash contours (Figure 3-2b), like those in Figure 3-1a and 3-1b.

For the 50 mg/m^3 and 50 ft stack release scenario, the STEL is exceeded along the top of the West Hill surface, near Tank 22H, to the south east of Tank 31H and Tank 32H (Figure 3-3). This is due to the larger source term for mercury being able to overcome the turbulent diffusion in the area around the Tank 31H and being captured by the wake of the West Hill and directed downward. Figures 3-4a and 3-4b show that the TLV exceedances (at 25-ft) are confined to receptors on top of Huts B9, B10 and E2.

No exceedances were observed for the 5th floor entrance, therefore it was not necessary to make additional runs without these receptors.

4.0 Conclusions

The summary of maximum concentrations modeled (Tables 3-1 and 3-2) shows that the PAC standard is not exceeded for either the 25 or 50 mg/m^3 release scenarios. If the West Stack Breathing Platform is included in the modeling domain (Tables 3-1a and 3-1b), the stack height would need to be 92 ft and 95 ft for the 25 mg/m^3 and 50 mg/m^3 modeling scenarios, respectively.

If the West Stack Breathing Platform is excluded from the modeling domain, the stack heights of 35 ft for the 25 mg/m^3 and 52 ft for the 50 mg/m^3 modeling scenarios would prevent exceedances at any receptors from the Tank 31H stack.

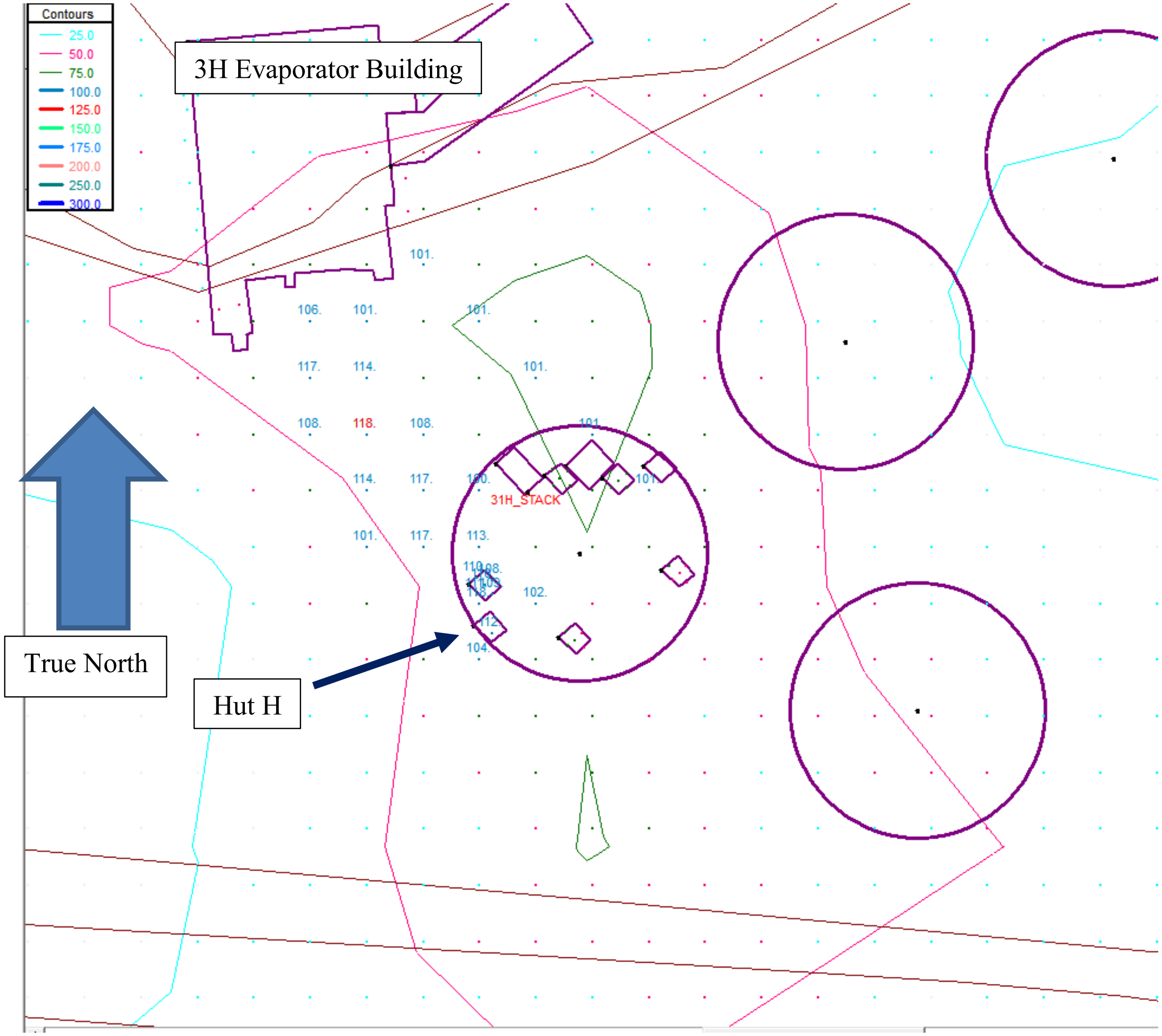

Figure 3-1a. Close up of the STEL Exceedances expressed as percent of standard for Tank 31H with a 32-foot stack and 25 mg/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of STEL (>30 µg/m^3). Contours show values that exceed 25% of STEL. Brown lines are the elevation contours of the hill. Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

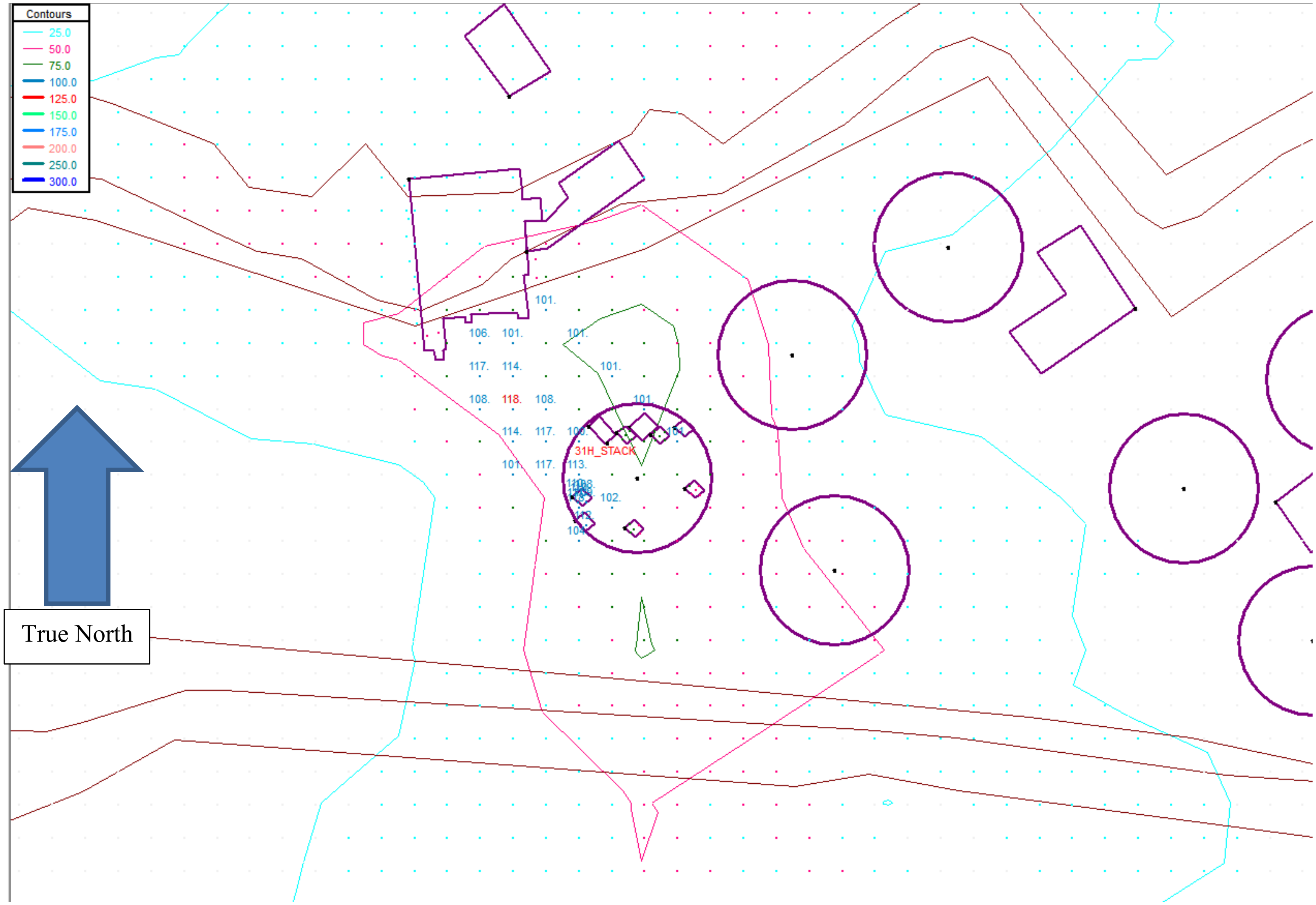

Figure 3-1b. STEL Exceedances expressed as percent of standard for Tank 31H with a 32-foot stack and 25 mg/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of STEL (>30 µg/m^3). Contours show values that exceed 25% of STEL. Brown lines are the elevation contours of the hill. Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

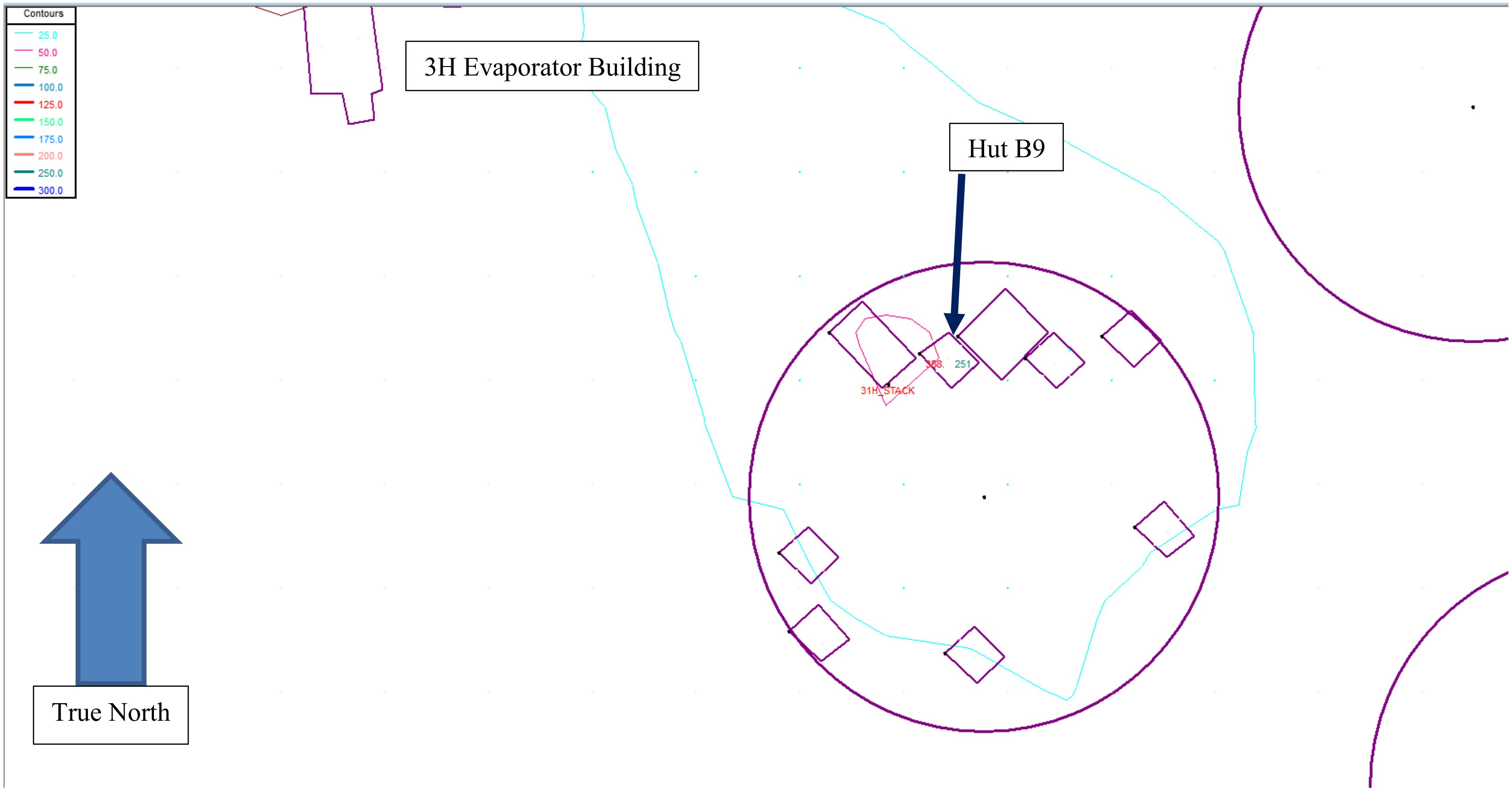

Figure 3-2a. Close up of the TLV Exceedances expressed as a percent of standard for Tank 31H with a 25-foot stack and 25 mg/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of TLV (>25 µg/m^3). Contours show values that exceed 25% of TLV. Brown lines are the elevation contours of the hill, labeled in meters AGL. Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

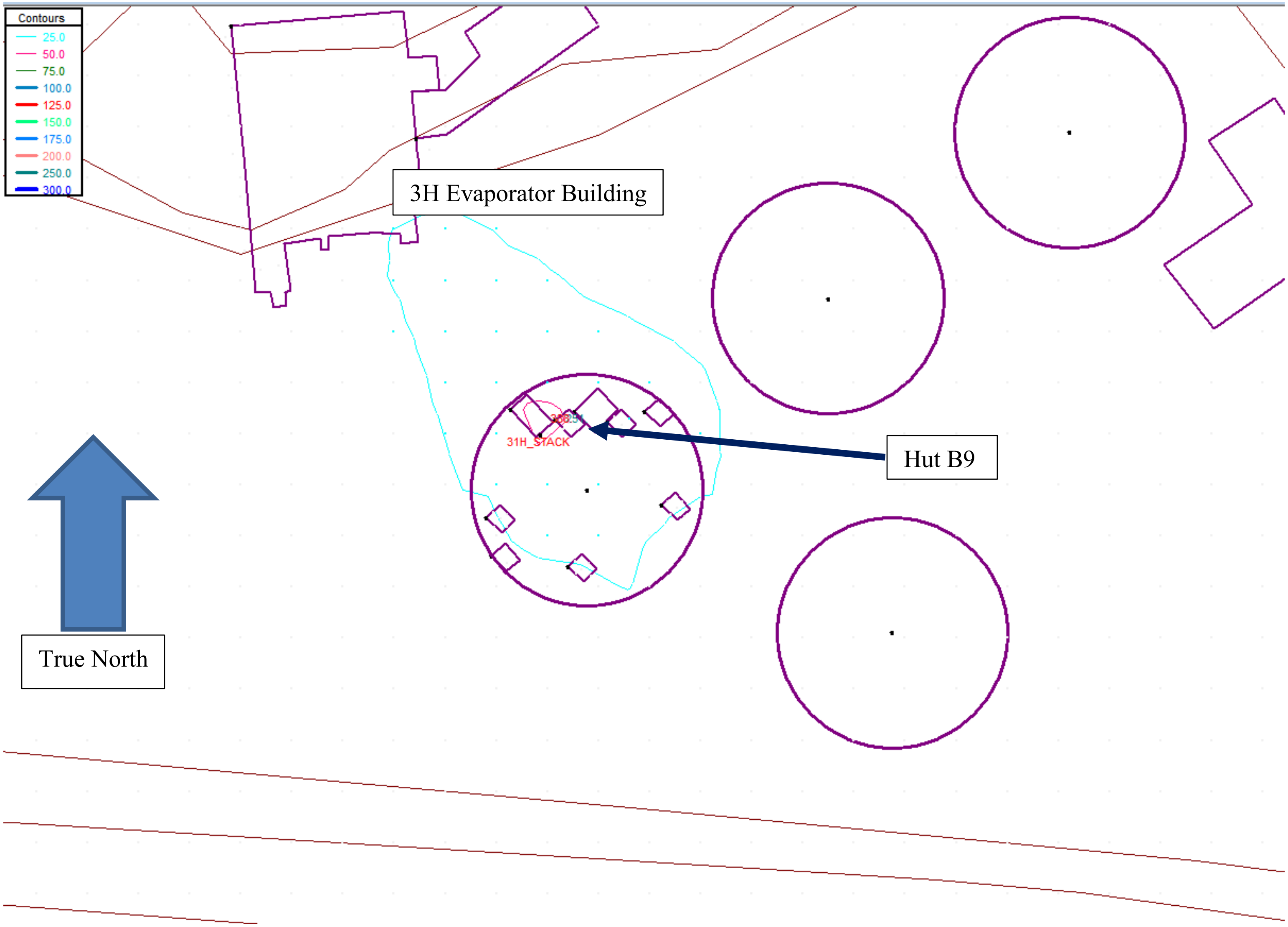

Figure 3-2b. TLV Exceedances expressed as a percent of standard for Tank 31H with a 25-foot stack and 25 mg/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of TLV (>25 μg/m^3). Contours show values that exceed 25% of TLV. Brown lines are the elevation contours of the hill, labeled in meters AGL. Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

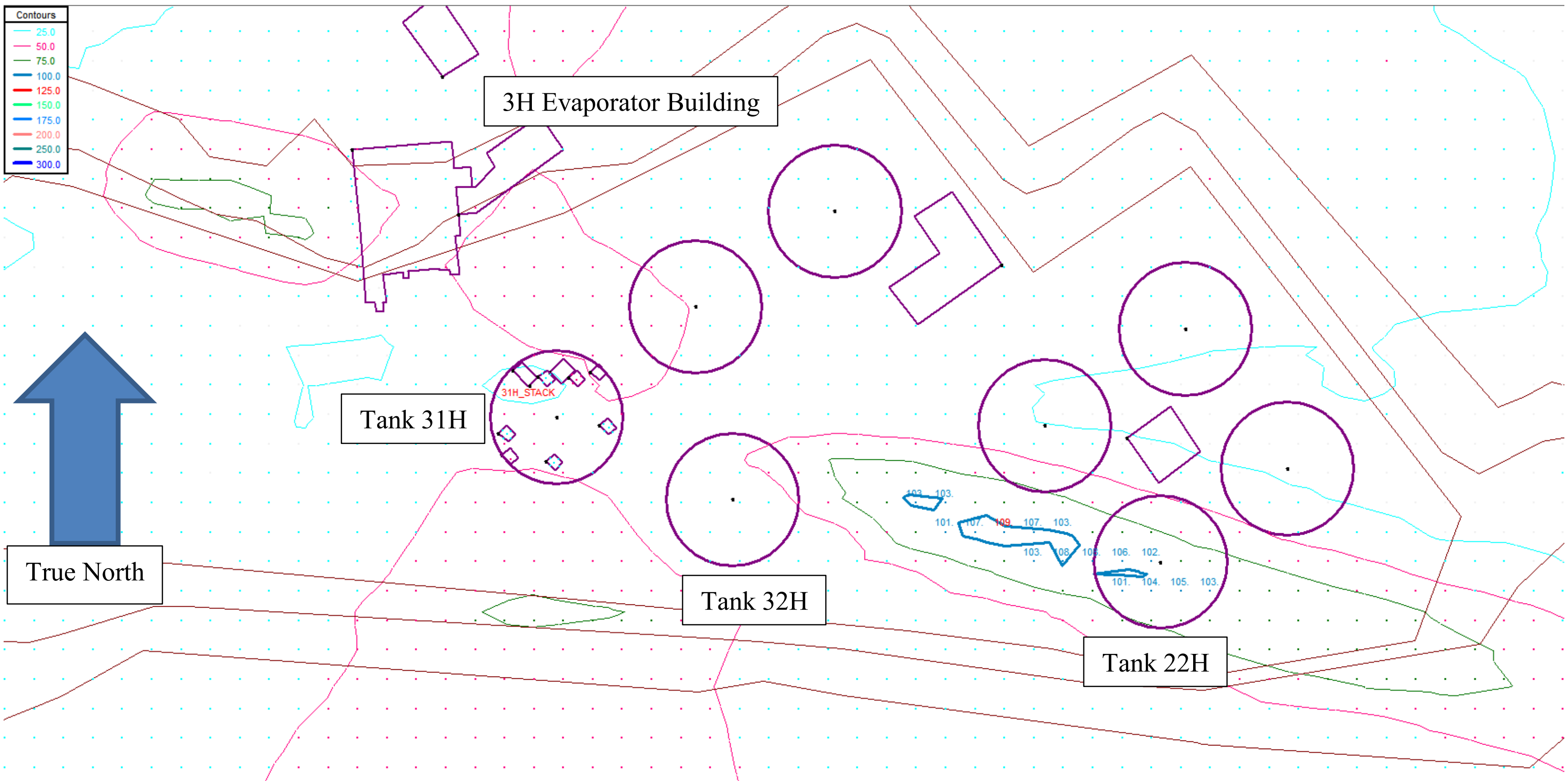

Figure 3-3. STEL Exceedances expressed as a percent of standard for Tank 31H with a 50-foot stack and 50 g/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of STEL (>30 µg/m^3). Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

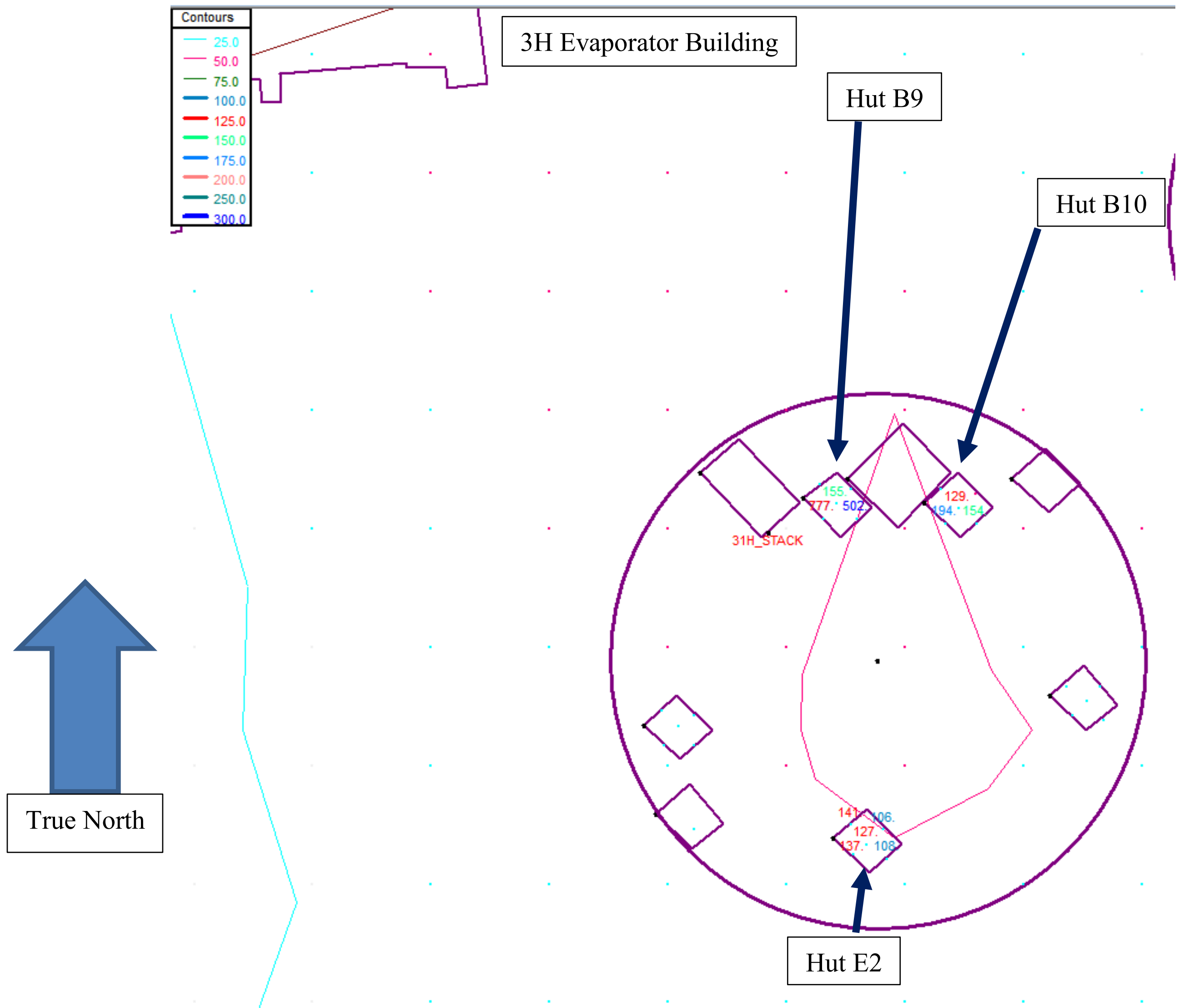

Figure 3-4a. Close-up of the TLV Exceedances expressed as a percent of standard for Tank 31H with a 25-foot stack and 50 mg/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of TLV (>25 µg/m^3). Contours show values that exceed 25% of TLV. Brown lines are the elevation contours of the hill, labeled in meters AGL. Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

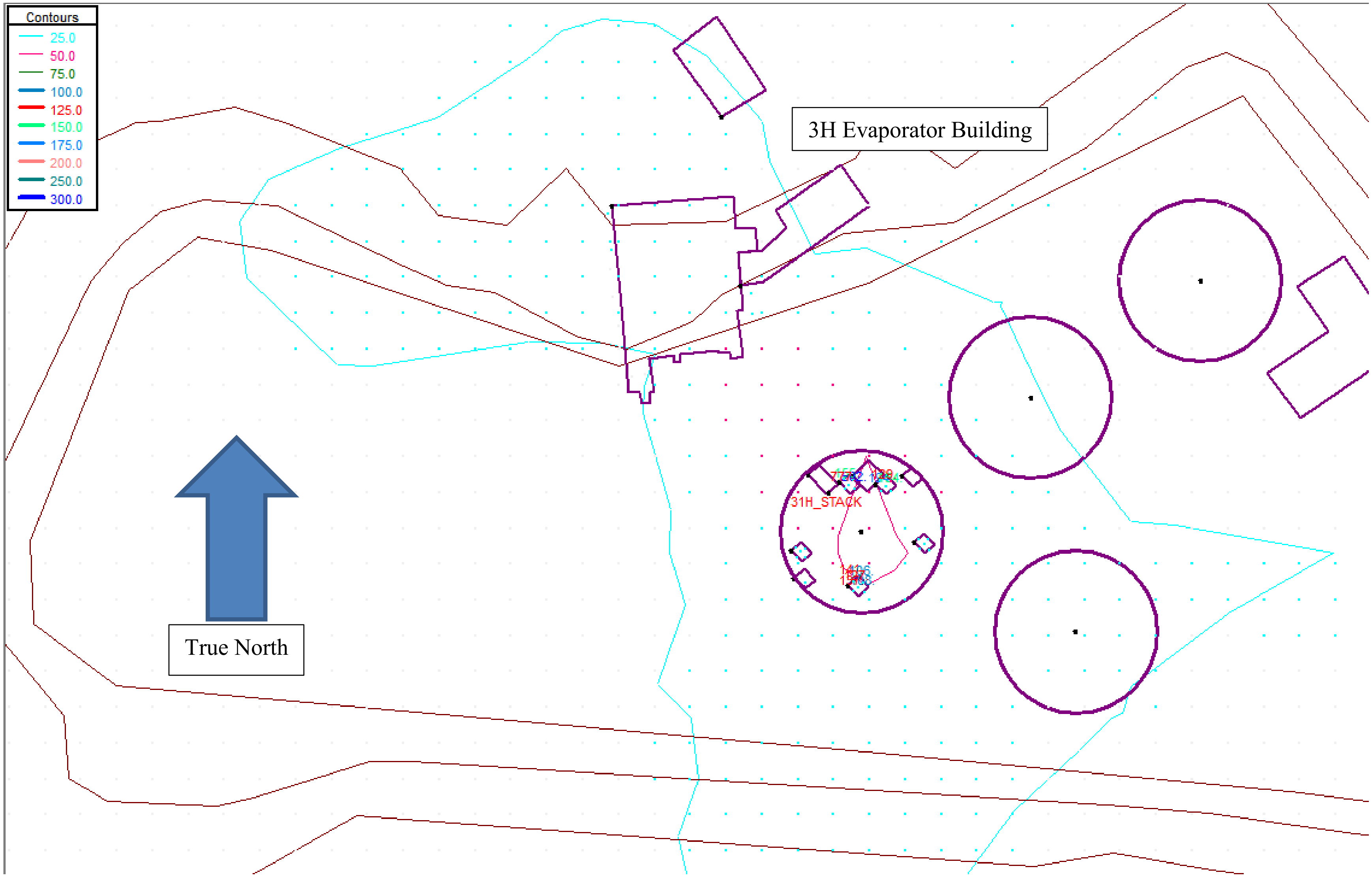

Figure 3-4b. TLV Exceedances expressed as a percent of standard for Tank 31H with a 25-foot stack and 50 mg/m^3 release concentration scenario. Numerical receptor values shown for values above 100 percent of TLV (>25 µg/m^3). Contours show values that exceed 25% of TLV. Brown lines are the elevation contours of the hill, labeled in meters AGL. Purple lines are the outlines of the buildings, huts and tanks. True North is at the top of the page.

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Distribution:

C. H. Hunter	773-A
M. Hubbard	241-162H
J. Tihey	241-162H
W. Lewitus	241-162H
A. T. Brown	704-56H
B. J. Wiedenman	773-42A
M. Schweder	704-56H