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MEMO

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From:
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Date:
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ARCADIS Project No.:
NC000239.0017

Subject:
UNC Airport Road Waste Disposal Area
Lecture Bottle Technical Evaluation

Due to the recent discovery of small compressed gas cylinders at the UNC Airport Road Waste Disposal Area, ARCADIS was asked to re-evaluate the site remediation practices and engineering controls to help minimize the potential for impacts to site workers and the surrounding community, including personnel and animals at the Orange County Animal Shelter.

To facilitate this additional evaluation ARCADIS integrated an air monitoring and sampling expert into the project team to review the site practices and conditions. The overall project team reviewed all aspects of the recent cylinder event including discovery, intermediate handling, over-pack application, and finally shipping from the site. Several aspects were noted as having a higher potential to greatly affect capture and dispersion of an emission event from a cylinder. These aspects included:

1- The embossed number on one of the cylinders suggests it could have originally contained one of the following compounds: phosphine, arsine, diborane, nitric oxide, and nitrogen dioxide. The color of an additional cylinder suggests that it could potentially contain phosgene. The evaluation discussed in this memo used arsine and phosgene as a worst-case condition model.

2 - The arrangement of the pit and the tent-like enclosure over the work area allows direct wind only from its open ends. The sides, including the side facing the Animal Shelter, are closed all the way to ground level. The work area is afforded partial protection from the wind, since excavation of waste is taking place 8 to 13 feet below the surrounding grade. The worst-case condition gases being considered are heavier

than air and prone to settling rather than lofting. The sides of the pit effectively form a containment area for heavier-than-air gases.

3 – There are currently three fans used to ventilate air from the immediate work area. Each fan has a nominal flow rate of 2,000 standard cubic feet per minute (scfm). Each fan includes an inlet and an outlet hose of about 12 inch diameter arranged to exhaust about 30 yards away from the work zone, in the opposite direction from the Orange County Animal Shelter. The air extraction system is designed to protect the workers by preventing high concentrations of volatile organic compounds or other chemical vapors from accumulating in the excavation. The hoses are arranged to remove air from the floor of the pit drawing makeup air downward from the surrounding grade. The fan inlet configuration forces dilution at the fan inlet. Additional dilution is provided as air discharges from the outlet of the fan.

4 – During the discovery and handling of the cylinders there are two periods where there is a higher potential for an accidental release. First, when the cylinder is discovered and secondly, when it is moved into the cylinder overpack container.

5 – The worst-case condition assumes that a cylinder is full at the time of discovery. Gas cylinder vendors have confirmed that it is conservative to assume that lecture bottle sized gas cylinders containing the gases of concern have a capacity of no more than 1 pound (lb).

The second and third aspects listed above are crucial modifiers of a potential release from a cylinder.

ALOHA AIR DISPERSION MODEL

The Aerial Location of Hazardous Atmospheres (ALOHA) linear, two-dimensional, air dispersion model was used to evaluate the impacts from a potential cylinder release at the site. ALOHA is an industry-recognized model that is often used by emergency managers, during a spill event, to quickly and easily determine a worst-case impact from a chemical release. When using ALOHA the only variables inputted into the program are: chemical of concern, quantity released, wind direction, wind speed, air temperature, and cloud cover. Additional site specific variables that lessen the actual impacts from a release are not included in the model.

In order to develop a more accurate model of chemical concentrations that could potentially reach the Animal Shelter, still utilizing the conservative ALOHA model, ARCADIS modified the input to the model to more reasonably reflect the dilution that is occurring as a result of forced mechanical dilution afforded by the fans that are used at the site for ventilation.

The modeling assumes the following:

- One pound or arsine or phosgene is released and captured by the ventilation system over the course of one minute

- Initial saturation concentrations of the chemical released is 1,000,000 parts per million (ppm), i.e. the chemical released is pure and not diluted in the cylinder

- 6,000 cubic feet per minute (cfm) of clean air is also captured by the ventilation system over the course of one minute

These reasonable assumptions and the concentrations of the chemical of concern that will exit the ventilation system are shown in Table 1.

Table 1 – Dilution Effects

Gas released	Quantity (lb)	Undiluted Concentration (ppm)	Dilution air at source (cfm)	Diluted concentration (ppm)*
Arsine	1.0	1,000,000	6,000	824
Phosgene	1.0	1,000,000	6,000	648

*Calculation backup is attached.

Diluted concentration at the ventilation discharge is 824 ppm for arsine and 648 ppm for phosgene. The same volume of space that originally contained one pound of gas, at the time that it was initially released, will contain 0.0008 lbs of arsine gas (0.0006 lbs of phosgene gas) once it is diluted by the ventilation system.

A fence that limits access to the site is located over 100 yards south of the work area. The ventilation system discharges approximately 30 yards north of the work area. Therefore, ventilation system discharge is over 130 yards from the southern fence line. The Orange County Animal Shelter is located an additional 10 yards south of the fence line.

Table 2 shows the concentrations of the chemicals of concern at the southern fence line, using the ALOHA model, using the diluted concentrations as a model input. For a period of a few minutes, the concentration could peak at 0.005 ppm for arsine and 0.003 ppm for phosgene. These concentrations are an order of magnitude or lower than the Temporary Emergency Exposure Level (TEEL-0) standard

established by the U.S. Department of Energy (U.S. DOE, 2007) for the chemicals of concern. The concentrations at the southern fence line would quickly fall from the peak values modeled.

Table 2 - Modeled Constituent Concentrations

Constituent	TEEL-0 (ppm)	Modeled Constituent Concentrations 130 Yards from Source (ppm)
Arsine	0.05	0.005
Phosgene	0.1	0.003

The TEEL-0 is a threshold concentration below which most people will experience no appreciable health-threat risk. It is calculated as the peak 15-minute time weighted average concentration below which most people will experience no appreciable health-threat risk. In the definition "most people" refers to the general population which includes sensitive subpopulations such as, infants, children, the elderly.

There are many factors that will lower the likelihood of an exposure concentration as identified in Table 2. Given the size of the cylinders, the short-time duration of a possible release event (five to ten minutes) is shorter than the duration specified by the TEEL-0. Physical features at the site, not accounted for by the ALOHA model, like topography, vegetation, and the presence of the tent will reduce concentrations below the values predicted. If the ventilation system takes longer than one minute to capture the released chemical, the peak concentrations predicted will also be reduced.

As stated earlier, the ALOHA linear two-dimensional model was used to determine a reasonable worst-case concentration given a specified release scenario. ARCADIS is also utilizing a more robust 3-dimensional air dispersion model to confirm the results of the ALOHA screening model discussed in this memo to help ensure that the engineering controls proposed are effective at controlling migration of gases off the site. A report will be prepared upon completion of the 3-dimensional air dispersion model.

Reference

2007. US Department of Energy, Office of Health, Safety, and Security. August. http://www.hss.energy.gov/HealthSafety/WSHP/chem_safety/teel.html (link to database and definitions) - http://www.atlintl.com/DOE/teels/teel.html The **Temporary Emergency Exposure Limit (TEEL)** data set has a new name; it is now called the **Protective Action Criteria (PAC)** dataset. While the PAC dataset continues to present the latest TEEL values (as developed by Subcommittee on Consequence Assessment and Protective Action (SCAPA), the intent of the new name is to emphasize that the data set also includes available Acute Exposure Guideline Level (AEGL) and Emergency Response Planning Guideline (ERPG) values. **Protective Action Criteria (PAC) with AEGLs, ERPGs, & TEELs: Rev. 23 for Chemicals of Concern (08/2007)**

Calculations for Table 1 – Dilution Effects

From Perry's Chemical Engineering Handbook, 6th Edition. Table 1-9 on page 1-18 is the basic gas constant of 0.08205 L atm/ g mole K

For a volume mole constant:
0.08205 atm/ g mole K * 293.15K * 1 atm = 24.05 L/mole

1 mole of an ideal gas occupies 24.05 L/mole at 1 atm and 20 °C based on EPA conditions for standard temperature and pressure.

Units conversion:

453.6 g/lb

28.32 L/ft^3

Phosgene

Example for phosgene (Molecular Weight [MW] of 98.92 g/mole)

$$GasDensity = (MW) * \frac{mole}{24.05L}$$

Gas Density = 98.92÷24.037 = 4.11 g/L

Converted = 4.11g/L÷453.6g/lb*28.32 L/ft^3
=0.257lb/ft^3

Inverted = 3.89ft^3/lb

Assumption was for a 1lb release in one minute.

For dilution by 6000ft^3/min of ambient air in a 1 minute release

3.89/(6000+3.89) = .000648 = 648 ppm - phosgene

Arsine

Example for arsine (MW of 77.95 g/mole)

$$GasDensity = (MW) * \frac{mole}{24.05L}$$

Gas Density = 77.95÷24. 037 = 3.24 g/L

Units Converted = 3.24g/L÷453.6g/lb*28.32 L/ft^3
=0.202lb/ft^3
Inverted = 4.95ft^3/lb

For dilution by 6000ft^3/min of ambient air in one minute release

4.95/(6000+4.95) = .000824 = 824 ppm arsine

Changes in Site Ambient Conditions

Although barometric pressures changes little from the assumed condition of 1atm, site temperatures deviate as much as 32°F from the 20°C (68°F) temperatures used in these calculations. As increased temperature will affect both dilution air and the contaminant gas to the same extent, dilution rates are the same throughout our expected operating range. Ventilation flowrate measurements for the dilution system must be converted to the standards used here (20°C, 1atm) to confirm they meet the minimum of 6,000 scfm regardless of site conditions. Because it is anticipated that safety factors (i.e. greater than 6,000 scfm) will be applied in the final system, actual dilution rates will always be higher than the values shown in Table 1 and downstream concentrations will therefore be lower than values shown in Table 2.

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SITE DATA:
  Location: CHAPEL HILL, NORTH CAROLINA
  Building Air Exchanges Per Hour: 0.62 (unsheltered single storied)
  Time: June 27, 2008  1305 hours EDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: PHOSGENE                 Molecular Weight: 98.92 g/mol
  AEGL-2(60 min): 0.3 ppm   AEGL-3(60 min): 0.75 ppm
  IDLH: 2 ppm
  Ambient Boiling Point: 44.9° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 7 miles/hour from 270° true at 3 meters
  Ground Roughness: urban or forest       Cloud Cover: 10 tenths
  Air Temperature: 70° F                  Stability Class: D
  No Inversion Height                     Relative Humidity: 75%

SOURCE STRENGTH:
  Direct Source: 0.000648 pounds/min      Source Height: 0
  Release Duration: 1 minute
  Release Rate: 1.08e-05 pounds/sec
  Total Amount Released: 6.48e-004 pounds
  Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE: (HEAVY GAS SELECTED)
  Model Run: Heavy Gas
  Red    : 13 yards --- (0.75 ppm = AEGL-3(60 min))
  Note: Threat zone was not drawn because effects of near-field patchiness
    make dispersion predictions less reliable for short distances.
  Orange: 13 yards --- (0.3 ppm = AEGL-2(60 min))
  Note: Threat zone was not drawn because effects of near-field patchiness
    make dispersion predictions less reliable for short distances.
  Yellow: 101 yards --- (0.005 ppm)

THREAT AT POINT:
  Concentration Estimates at the point:
  Downwind: 130 yards                     Off Centerline: 0 yards
  Max Concentration:
     Outdoor: 0.00314 ppm
     Indoor:  3.04e-05 ppm
```

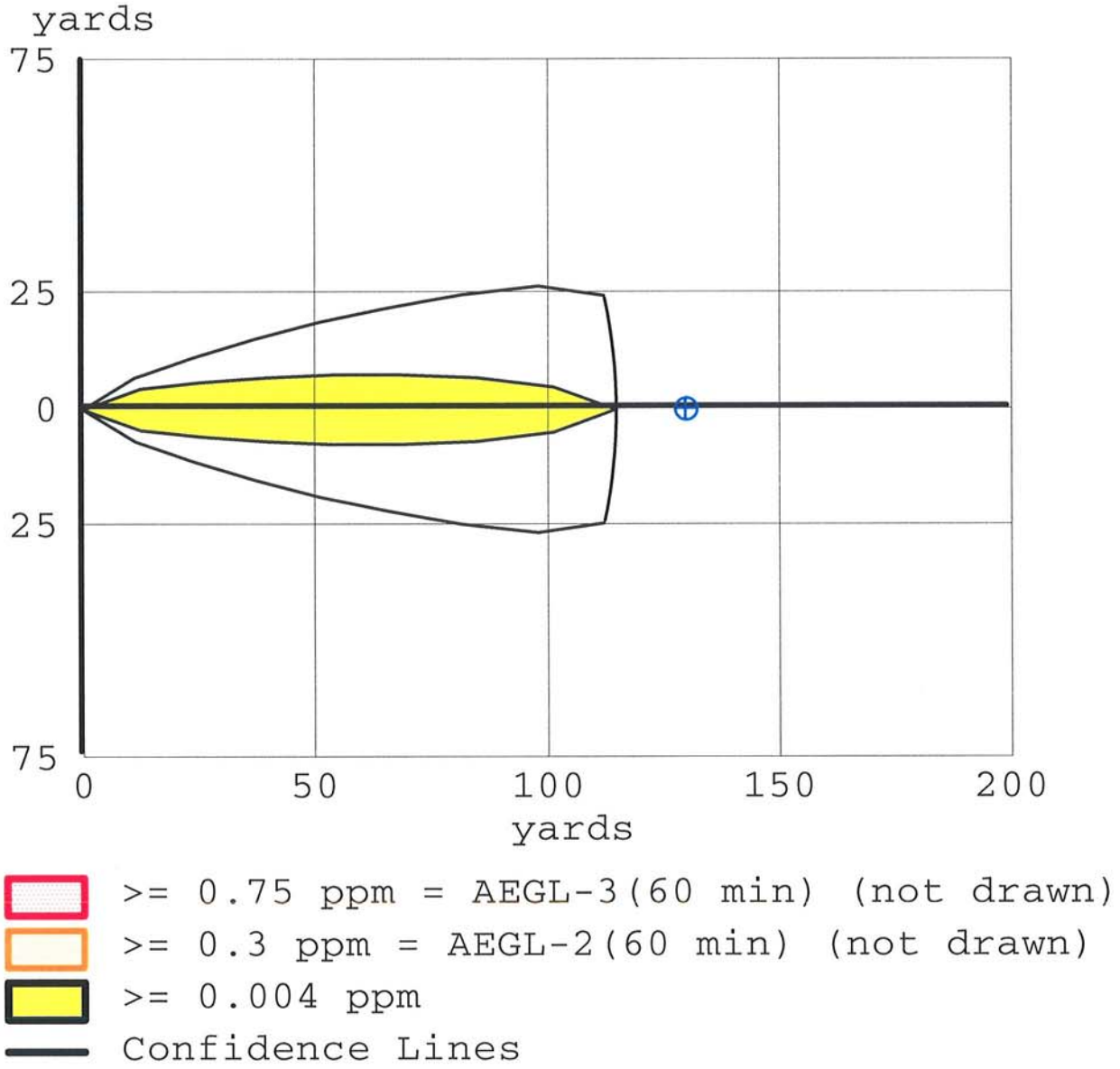
Note: phosgene at an ambient saturation concentration of 1,000,000 ppm or 100% with a discharge rate of 0.0006 pounds and release duration of 1 minute is equivalent to an ambient saturation concentration of 648 ppm with a discharge rate of 1.0 pounds and release duration of 1 minute.

Time: June 27, 2008 1305 hours EDT (using computer's clock)

Chemical Name: PHOSGENE

Wind: 7 miles/hour from 270° true at 3 meters

THREAT ZONE: (HEAVY GAS SELECTED)
Model Run: Heavy Gas
Red : 13 yards --- (0.75 ppm = AEGL-3(60 min))
Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
Orange: 13 yards --- (0.3 ppm = AEGL-2(60 min))
Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
Yellow: 115 yards --- (0.004 ppm)

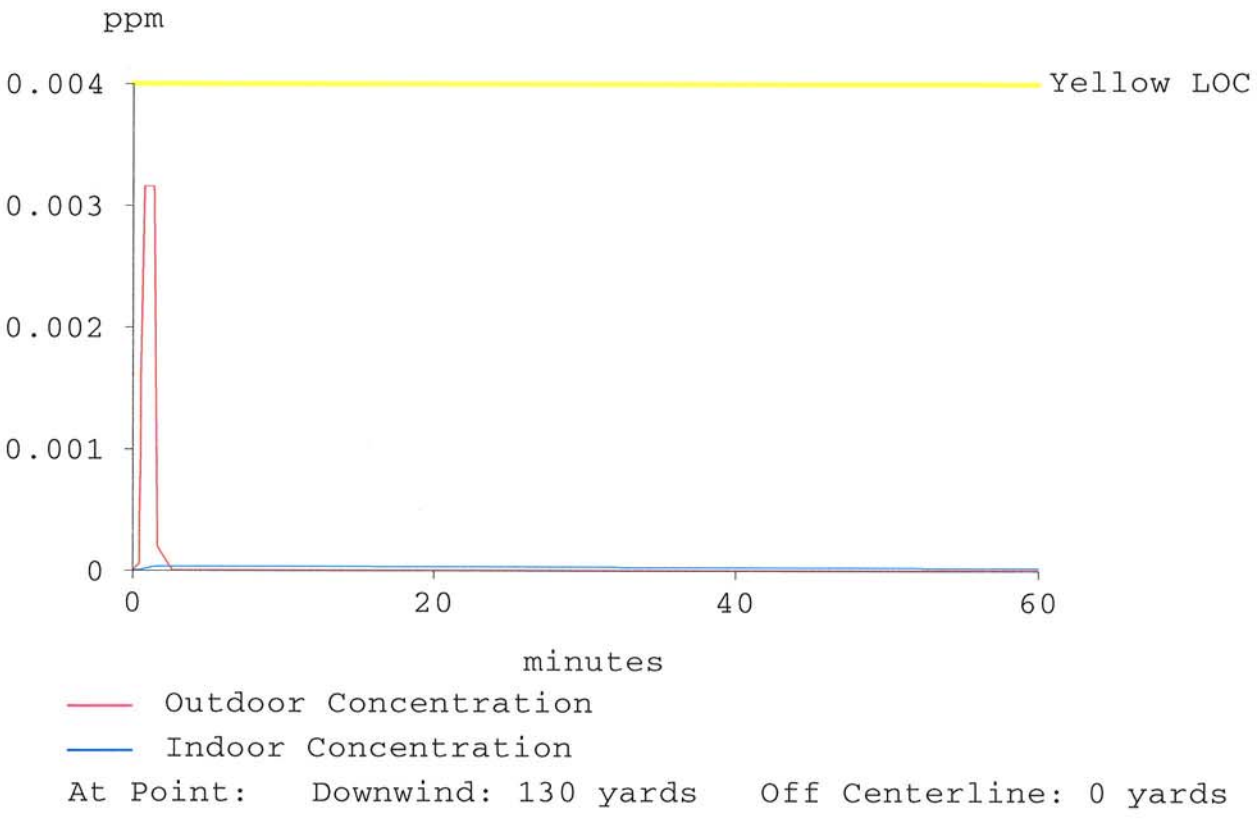


Time: June 27, 2008 1305 hours EDT (using computer's clock)

Chemical Name: PHOSGENE

Building Air Exchanges Per Hour: 0.62 (unsheltered single storied)

THREAT AT POINT:
Model Run: Heavy Gas
Concentration Estimates at the point:
Downwind: 130 yards Off Centerline: 0 yards
Max Concentration:
Outdoor: 0.00314 ppm
Indoor: 3.04e-05 ppm



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SITE DATA:
  Location: CHAPEL HILL, NORTH CAROLINA
  Building Air Exchanges Per Hour: 0.62 (unsheltered single storied)
  Time: June 27, 2008  1318 hours EDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: ARSINE                  Molecular Weight: 77.95 g/mol
  AEGL-2(60 min): 0.17 ppm   AEGL-3(60 min): 0.5 ppm
  IDLH: 3 ppm        LEL: 510 ppm        UEL: 7800 ppm
  Carcinogenic risk - see CAMEO
  Ambient Boiling Point: -81.0° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 7 miles/hour from 270° true at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 10 tenths
  Air Temperature: 70° F                 Stability Class: D
  No Inversion Height                    Relative Humidity: 75%

SOURCE STRENGTH:
  Direct Source: 0.000824 pounds/min     Source Height: 0
  Release Duration: 1 minute
  Release Rate: 1.37e-05 pounds/sec
  Total Amount Released: 8.24e-004 pounds
  Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE: (HEAVY GAS SELECTED)
  Model Run: Heavy Gas
  Red    : 13 yards --- (0.5 ppm = AEGL-3(60 min))
  Note: Threat zone was not drawn because effects of near-field patchiness
    make dispersion predictions less reliable for short distances.
  Orange: 22 yards --- (0.17 ppm = AEGL-2(60 min))
  Note: Threat zone was not drawn because effects of near-field patchiness
    make dispersion predictions less reliable for short distances.

THREAT AT POINT:
  Concentration Estimates at the point:
  Downwind: 130 yards                    Off Centerline: 0 yards
  Max Concentration:
     Outdoor: 0.00509 ppm
     Indoor:  4.93e-05 ppm
```

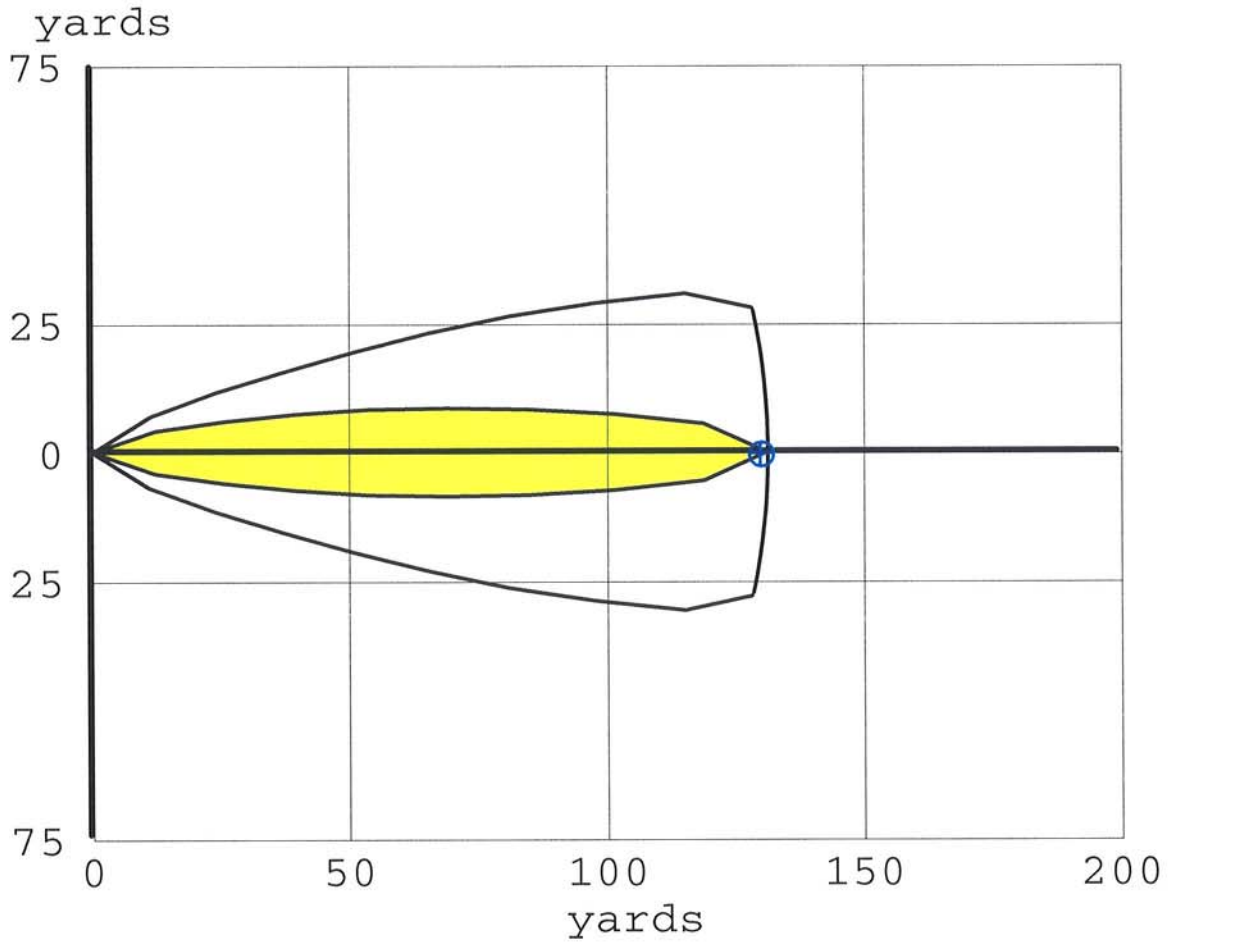
Note: arsine at an ambient saturation concentration of 1,000,000 ppm or 100% with a discharge rate of 0.0008 pounds and release duration of 1 minute is equivalent to an ambient saturation concentration of 824 ppm with a discharge rate of 1.0 pounds and release duration of 1 minute.

Time: June 27, 2008 1318 hours EDT (using computer's clock)

Chemical Name: ARSINE
Carcinogenic risk - see CAMEO

Wind: 7 miles/hour from 270° true at 3 meters

THREAT ZONE: (HEAVY GAS SELECTED)
Model Run: Heavy Gas
Red : 13 yards --- (0.5 ppm = AEGL-3(60 min))
Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
Orange: 22 yards --- (0.17 ppm = AEGL-2(60 min))
Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
Yellow: 131 yards --- (0.005 ppm)



>= 0.5 ppm = AEGL-3(60 min) (not drawn)
>= 0.17 ppm = AEGL-2(60 min) (not drawn)
>= 0.005 ppm
Confidence Lines

Time: June 27, 2008 1318 hours EDT (using computer's clock)

Chemical Name: ARSINE
Carcinogenic risk - see CAMEO

Building Air Exchanges Per Hour: 0.62 (unsheltered single storied)

THREAT AT POINT:
Model Run: Heavy Gas
Concentration Estimates at the point:
Downwind: 130 yards Off Centerline: 0 yards
Max Concentration:
Outdoor: 0.00509 ppm
Indoor: 4.93e-05 ppm