Perspectives from the Board's Technical Staff

AP Poloski, S Sircar, MW Dunlevy,

F Bamdad, SA Stokes

June 5, 2012

Outline

- Purpose: Review the values used by DOE contractors for dispersion analysis against DOE directives
- Summary of Staff Complex-wide Review
- Areas of Discussion
  - methods for determining atmospheric stability class;
  - use of extremely stable (G) atmospheric stability class;
  - selection of atmospheric dispersion coefficients;
  - correction for wind speed height;
  - selection of surface roughness;
  - adjusting dispersion coefficients due to surface roughness;
  - method for determining the distance to the site boundary;
  - modeling low wind speed conditions;
  - plume meander;
  - use of wake effects;
- Conclusions

Summary of Staff Complex-wide Review

Site	Defense Nuclear Facility	Atmospheric Stability Method	Dispersion Coefficient	Surface Roughness Correction & Method	*Wind Speed and Direction, Measurement Height*	Plume Meander	Directionally-Dependent Site Boundary Distance	Dispersion Modeling Code	Deposition Velocity
NRC	***n/a***	***ΔT/ΔZ + class G[a]***	***Pasquill - Gifford[b]***	***No***	***10 m[a,b]***	***Yes***	***Yes[b]***	***PAVAN***	***No***
DOE	***EM Facilities[c]***	***ΔT/ΔZ, sigma-azimuth[a]***	***Not specified***	***3 cm[c]***	***10 m[a]***	***No[c]***	***Yes[d]***	***Toolbox Codes[c]***	***DOE-HSS SB 2011-02[f]***
SRS	Tritium Facilities	sigma-azimuth	*Pasquill – Gifford*	Yes	61 m corrected to 10 m	Yes	No	MACCS2	Yes
Y-12	UPF	SRDT		No	10 m	No	Yes	MACCS2	Yes
LANL	Area G	sigma-elevation		Yes, wind prof.	11.5 m	Yes	Yes	MACCS2	Yes
Hanford	Tank Farms	ΔT/ΔZ + class G		n/a	9.1 m	Yes	Yes	GXQ[e]	No
	WTP	ΔT/ΔZ		No		Yes	No	MACCS2[e]	Yes
INL	IWTU	ΔT/ΔZ		Yes	10 m	No	No	MACCS2	Yes
LLNL	B332	Assume class F	Briggs-Urban	n/a	Assume 1 m/sec @ 2 m	No	No	Hotspot	Yes

[a]—NRC Regulatory Guide 1.23, *Meteorological Monitoring Programs for Nuclear Power Plants*
[b]—NRC Regulatory Guide 1.145 Rev 1
[c]—DOE letter dated July 18, 2006 from Dr. Ines R Triay titled "*Interim Guidance on Safety Integration into Early Phases of Nuclear Facility Design*"
[d]—DOE-STD-3009 CN 3, March 2006, *DOE STANDARD—PREPARATION GUIDE FOR U.S. DEPARTMENT OF ENERGY NONREACTOR NUCLEAR FACILITY DOCUMENTED SAFETY ANALYSES*
[e]—Not a toolbox code or version
[f]—DOE Office of Health, Safety and Security (HSS), Safety Bulletin No. 2011-02, "Accident Analysis Parameter Update", May 2011

Atmospheric Stability Class & Dispersion Coefficients

- NRC RG 1.145 defines dispersion coefficients for seven stability classes A-G
  - most DOE facilities consider stability classes A-F, not class G
- NRC RG 1.23 specifies that the preferred method for stability class is the ΔT/ ΔZ method
  - “is an effective indicator of worst-case stability conditions”
  - NRC plume meander equations were based on the ΔT/ ΔZ method
- DOE sites are using several methods for determining stability class
  - Selection of the stability class will bias the overall cumulative distribution of χ/Q and impact the 95% value
- Pairing of stability class methods to dispersion coefficients might be inconsistent with the source experimental data

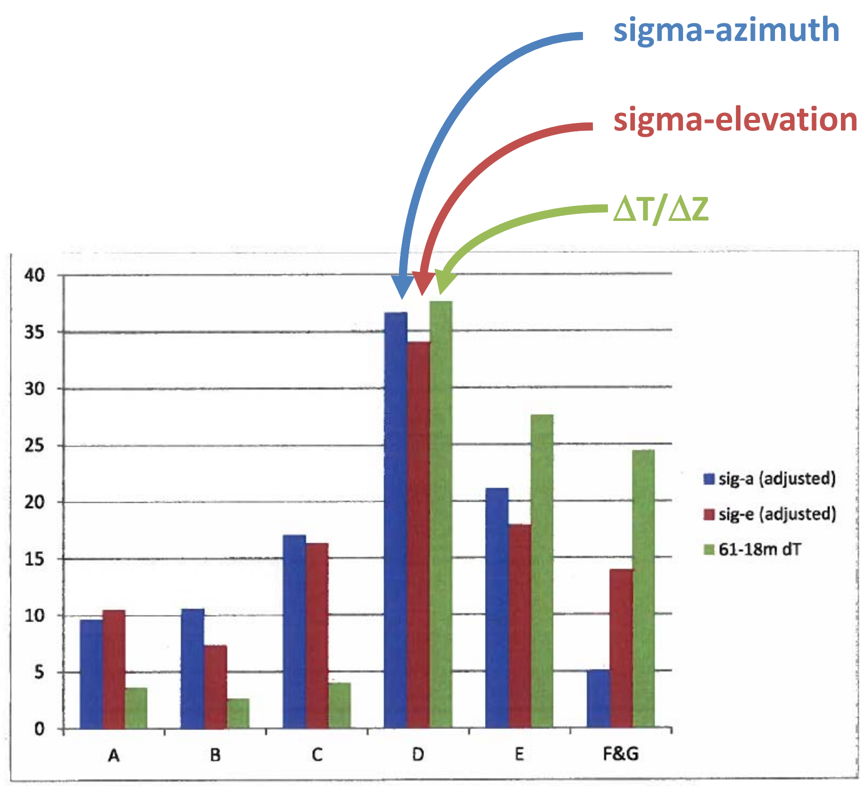


Figure 3-3. Percent Occurrence of Pasquill Stability Class Using σ_a and σ_e Criteria, Adjusted per EPA (2000) Guidance and 18-61m ΔT from Central Climatology.

Source:
Hunter C. H., “A Recommended Pasquill Stability Classification Method for Safety Basis Atmospheric Dispersion Modeling at SRS”, May 2012, SRNL-STI-2012-00055, Rev. 1

Wind Speed Height

- NRC RG 1.23 states that wind speed should be measured at 10 meters in height.
- NRC RG 1.145
  - "The 10 meter level is considered to be representative of the layer through which the plume is mixed when subjected to building wake effects."
- Wind speed profile equations can correct the 10-m wind speed to a receptor height of 1-2 m depending on stability class
  - HOTSPOT, ALOHA, EPIcode can perform height correction
  - MACCS2 cannot perform height correction
- Thoman et al. (2006) presents air concentration predictions for 1-m/s winds at three reference heights (10 m, 2 m, 3 m)

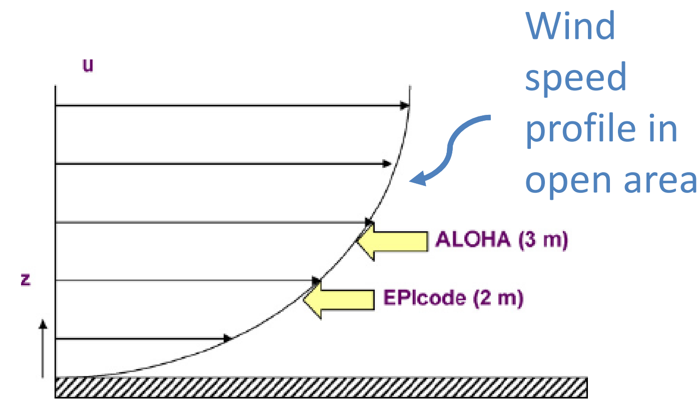


Figure 2. Atmospheric wind speed profile—ALOHA and EPIcode reference heights for atmopsheric transport and dispersion shown.

Reference Height

10 m	2 m	3 m

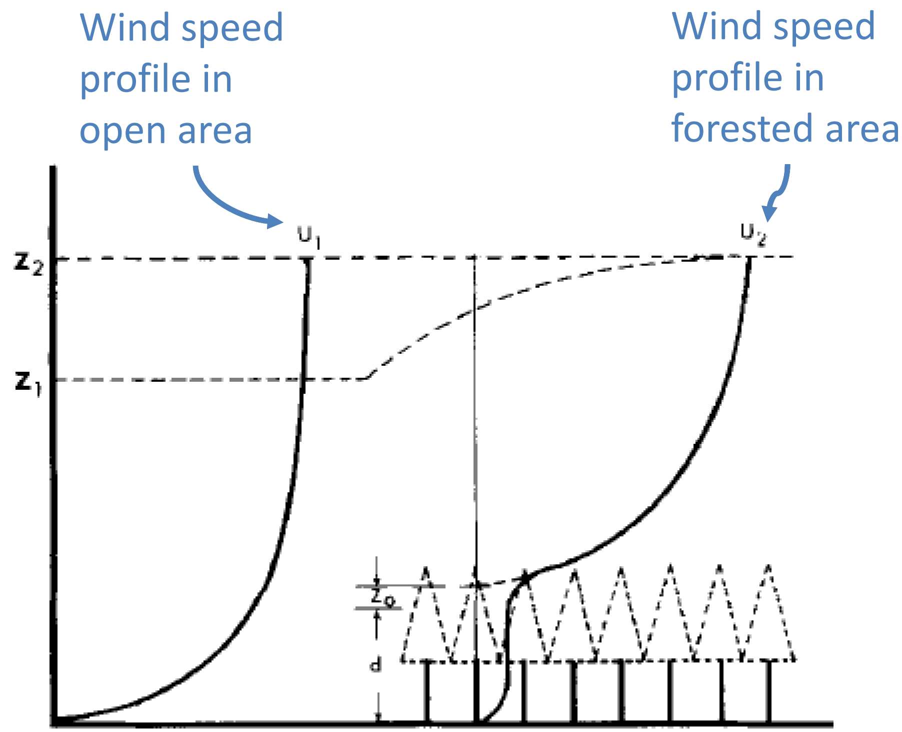
Table 5. Wind speed height sensitivity results for plume concentration (x = 100 m)

Sample Problem Result for Base Case (1 m/s Wind Speed at Reference Height) (mg/m^3)	EPIcode 7.0 Result for 1 m/s Wind Speed at 10 m Height (mg/m^3)	ALOHA 5.2.3 Result for 1 m/s Wind Speed at 10 m Height (mg/m^3)
51	120	84

Source:
D.C. Thoman, K.R. O'Kula, J.C. Laul, M.W. Davis, K.D. Knecht, "Comparison of ALOHA and EPIcode for Safety Analysis Applications", *Journal of Chemical Health & Safety*, November/December 2006

Tree Canopies

- Sites are beginning to account for tree canopies
  - displacement heights in wind speed profile calculations
  - friction velocity for deposition velocity estimation (UPF)
  - surface roughness determination (SRS)
- DOE approach does not model radio-aerosol dispersion at the forest floor
  - Different wind speed profile
  - Use of dispersion coefficients based on prairie grass experiments versus forest with canopy

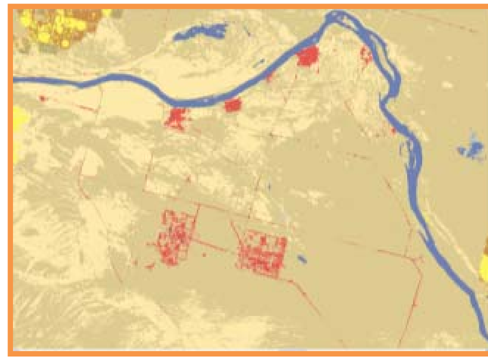


Source:
Lo A.K., "On the Determination of Zero-Plane Displacement and Roughness Length for Flow Over Forest Canopies", *Boundary-Layer Meteorology*, 51: 255-268, 1990.

Surface Roughness

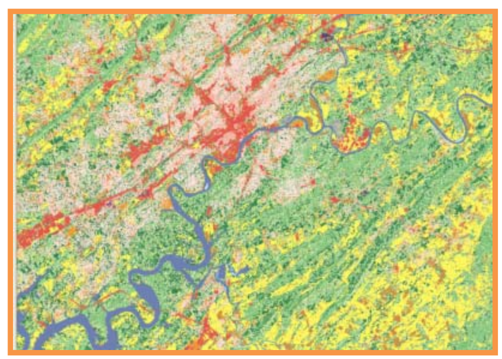
- Surface roughness varies with location and season
- DOE does not provide guidance on how to determine this parameter
- Wind Profiles
- Single-level Gustiness Method
  - Section 6.6.3 of EPA-454/R-99-005
- EPA AERSURFACE Code
  - Uses USGS Land Cover Satellite Data
  - Each pixel color is a land cover type
  - Can be used to determine variations by sector, distance, and season
  - land cover images are not current (1992 satellite images)
- Methods do not account for future site conditions
  - D&D of facilities
  - Wildfires
  - Clear Cutting

Hanford Site

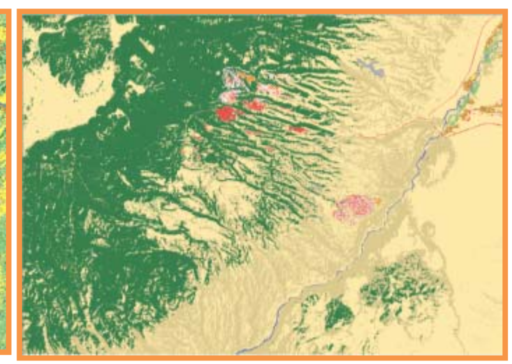


Savannah River Site

Y-12 Site



Los Alamos Site

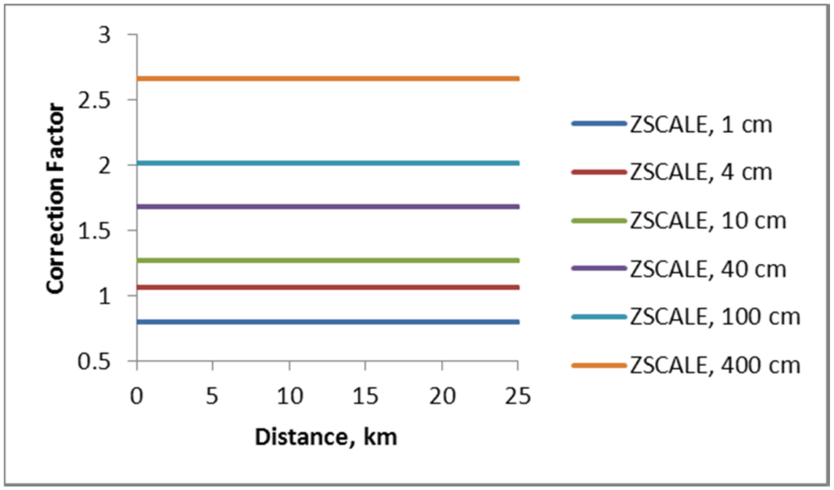


Source:
http://landcover.usgs.gov/natllandcover.php

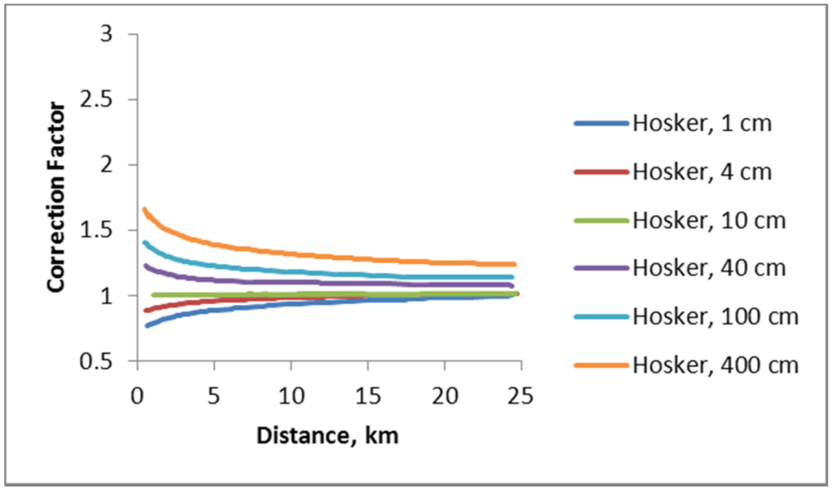
Adjusting Dispersion Coefficients due to Surface Roughness

- DOE Guidance
  - Surface roughness used in correction factor to account for plume dilution from mechanical turbulence
  - $\sigma_z' / \sigma_z = (z_0 / 3\ cm)^{0.2}$
- PNNL recently recommended a new correction for downwind distances beyond 5 km for SRS
  - $\sigma_z' / \sigma_z = (z_0 / 3\ cm)^{0.1}$
- Hosker (1974) provides a continuous function for the surface roughness correction
  - Dispersion coefficient adjusted to 10 cm surface roughness

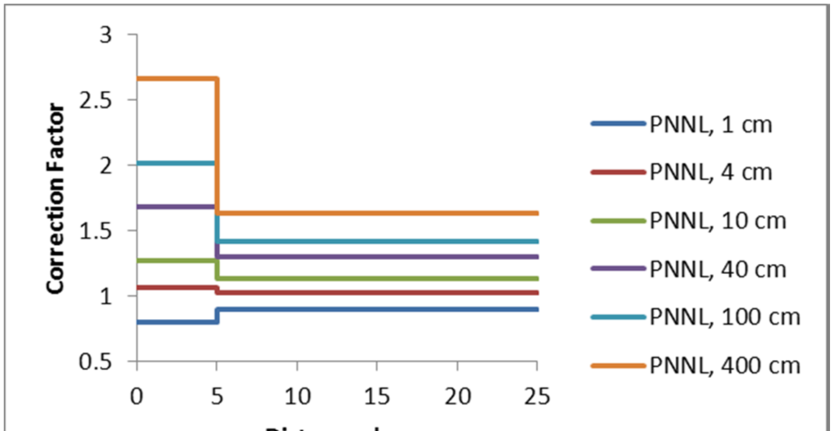
MACCS2



R.P. Hosker, *Estimates for dry deposition and plume depletion over forests and grasslands*, International Atomic Energy Agency, Vienna, 1974.



PNNL- 20990, *Final Review of Safety Assessment Issues at Savannah River Site, August 2011*



Mixing Layer Height

- MACCS2 code guidance Table 4-1
  - Mixing Layer Height: Apply local site/laboratory recommendations for seasonal and time-of-day estimates for the mixing layer height.
  - MACCS2 allows for morning/afternoon values to be assigned for each season
- HotSpot, GXQ can input a single value for the mixing height
- GENII2 estimates mixing layer height from a correlation
- Mixing layer heights can vary dramatically on an hour-by-hour basis
- Pairing hourly mixing layer heights with wind speed and stability can change the results of a 95% dispersion calculation.
  - Values less than about 100 m can significantly increase χ/Q for stable conditions

TABLE 2.5. Percent Frequency of Occurrence of Mixing-Layer Thickness by Season and Time of Day

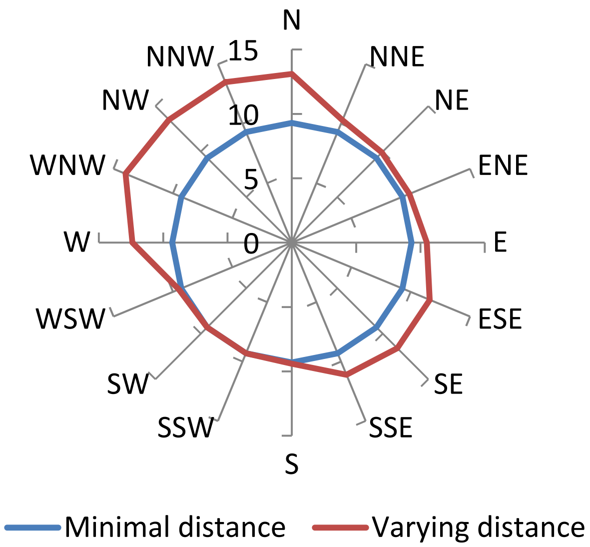
	Winter		Summer	
Mixing Layer, m	Night	Day	Night	Day
Less than 250	65.7	35.0	48.5	1.2
250-500	24.7	39.8	37.1	9.0
More than 500	9.6	25.2	14.4	89.9

Source:
PNL-7668, *Characterization of the Hanford Site and Environs*

Distance to Site Boundary

- DOE uses two major methods
  - Minimal distance—historically used by DOE contractors
  - Varying distance—being adopted by several DOE contractors
- For each method, the DOE χ/Q is determined by compiling an overall cumulative distribution to find 95% value
- Facility Location Scenario
  - a facility close to a boundary
  - prevailing winds away from the nearest boundary
- NRC RG 1.145 addresses this scenario by using maximum of
  - the 99.5% worst sector χ/Q (NRC position 2; not used by DOE)
  - overall 95% χ/Q (NRC position 3 ; used by DOE)
- NRC (NUREG/CR-2260) states that 95% minimal distance method is approximately equal to 99.5% by sector.

Example based on the WTP at Hanford (distances in km)



Low Wind Speeds, Plume Meander, Wake Effects

- Low Wind Speeds
  - Predicted $\chi/Q \rightarrow \infty$ as wind speed $\rightarrow 0$
  - DOE contractors use a substitute with a non-zero lower bound
  - UPF 95% meteorology corresponds to a calm condition
- Plume Meander
  - Draft DOE-STD-3009-2012 states: "*Plume meander shall not be used in the consequences analysis.*"
  - Some DOE contractors use plume meander corrections
- Wake Effects
  - Credits the facility structure
  - Draft DOE-STD-3009-2012 states: "*Wake effect of nearby obstacles shall be ignored in the plume dispersion.*"

Conclusions

- Staff observed inconsistent input parameter selection across the DOE complex
- Currently, there is limited DOE guidance to help a contractor select a reasonably conservative methodology to develop input parameters in atmospheric dispersion calculations.
- Additional DOE guidance on the selection of the dispersion modeling parameters would be prudent as they each have the potential to significantly impact the calculated radiological dose consequence analysis.