9th Conference on Air Quality Modeling – A&WMA AB-3 Comments on Building and Terrain Downwash Issues

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Air & Waste Management Association
Air Pollution Meteorology (AB-3) Committee

Comment Areas

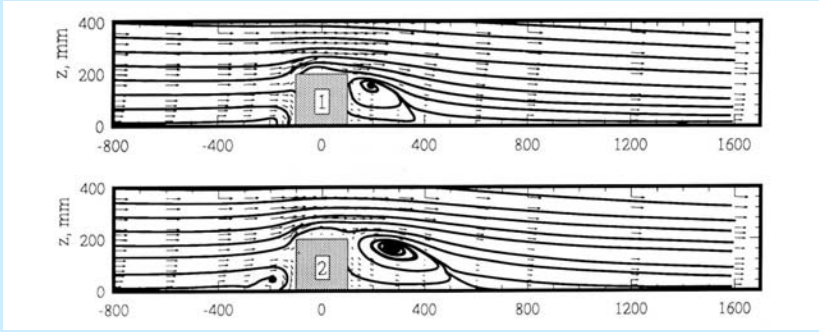
- Problems with BPIP
- AERMOD/PRIME Problem for Short/Large Buildings
- AERMOD/PRIME Underestimation For Corner Vortex
- Terrain Wake Effects

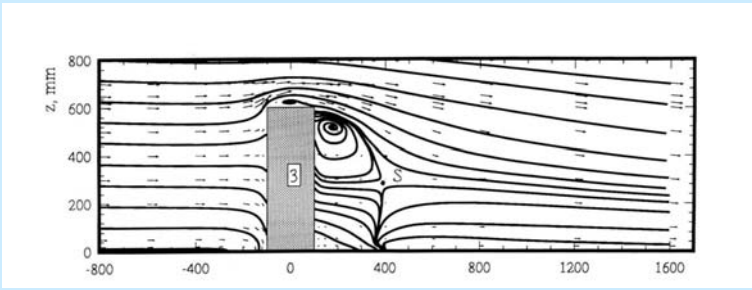
Problems with BPIP

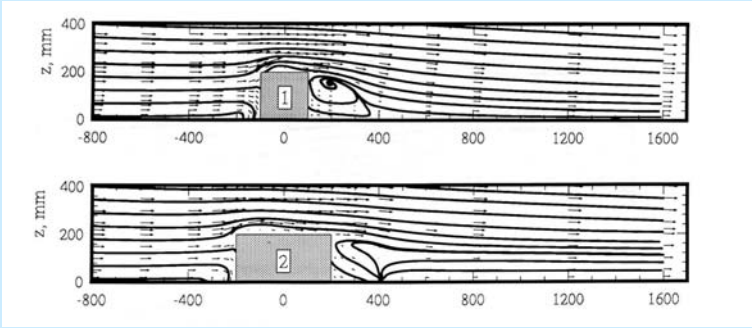
- Cannot accurately account for complex geometries
- May merge two structures into one large structure
- May pick the wrong dominant building
- May place the building at the wrong location to get correct dispersion
- Does not account for lattice or cylindrical structures

Sampling of Snyder Data Base

Ultimately, PRIME Needs the Building Shape and Position that Places Stack in the Correct Snyder/Lawson Data Base Flow Region (i.e., Data Base Used to Develop Downwash Algorithms)





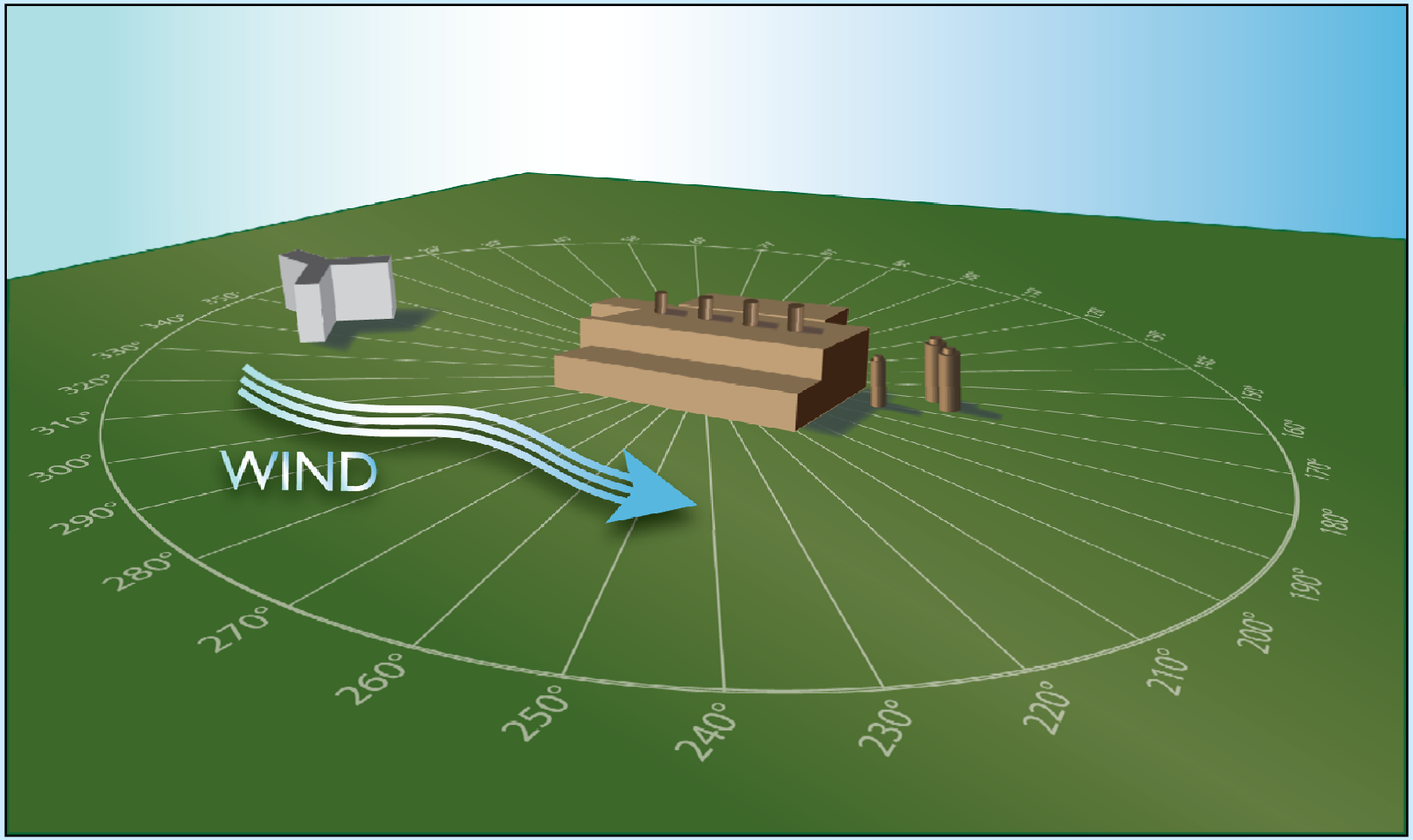


Streamline figures from: Snyder, W.H. and R.E. Lawson, Jr.: Wind Tunnel Measurements of Flow Fields in the Vicinity of Buildings; 8th Joint Conference on Appl. of Air Poll. Met. With A&WMA; AMS, Boston, MA, 1994; pp. 244-250

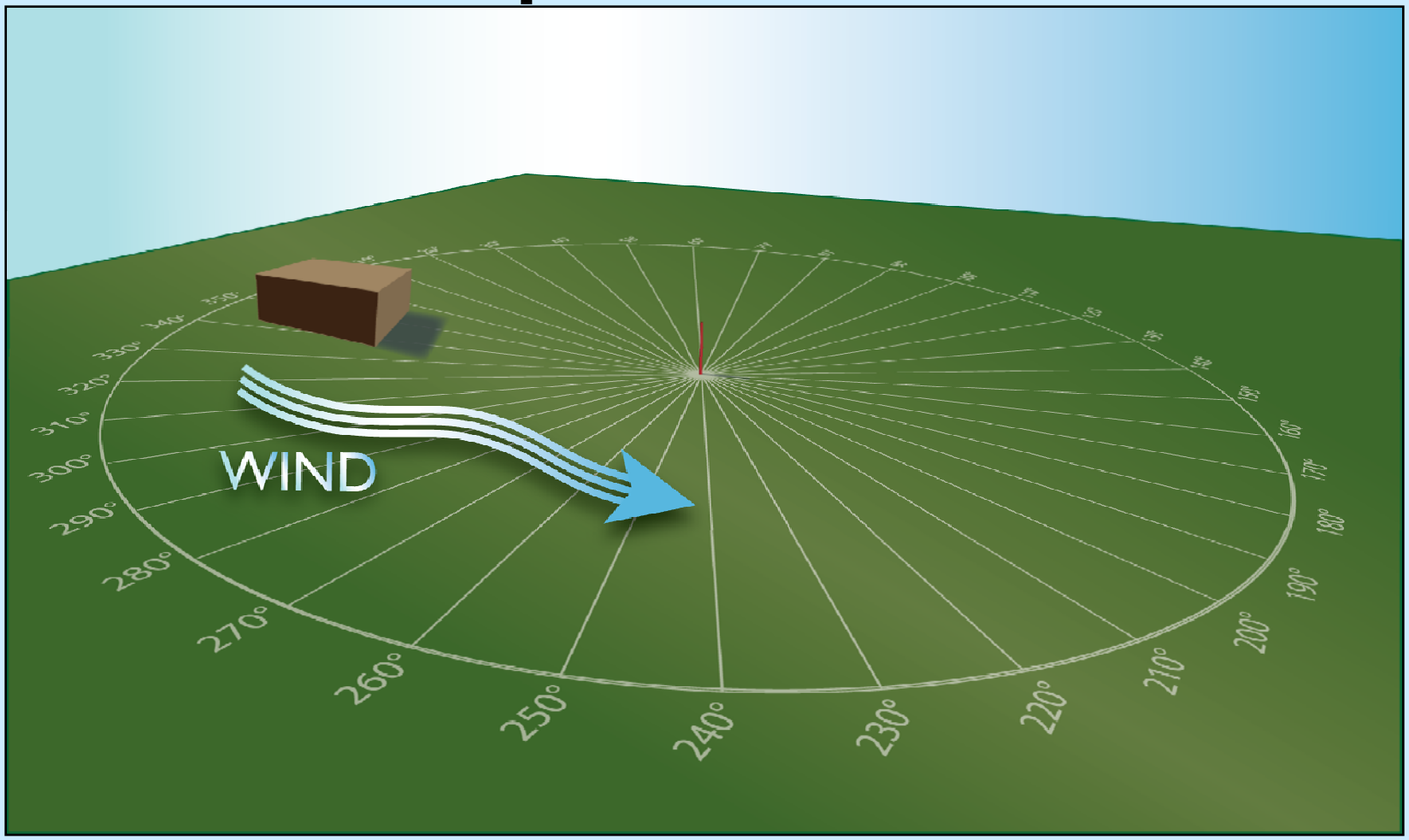
Other considerations

- Building downwash algorithms in AERMOD are designed for simple rectangular buildings.
- Building downwash algorithms in AERMOD only appropriate for certain building aspect ratios
- Use of wind tunnel testing to determine Equivalent Building Dimensions (EBD) has been used to help solve the problem
  - EBD guidance provided in Tikvart July 1994 Memorandum -“Thus, the analysis is viewed as a source characterization study which generally has been considered under the purview of the Regional Offices.”
  - All testing to determine EBD under neutral stratification, similar to assumptions in Prime Algorithms.
  - With AERMOD/PRIME building location is also a variable and new methods may be appropriate and has been used on recent studies.

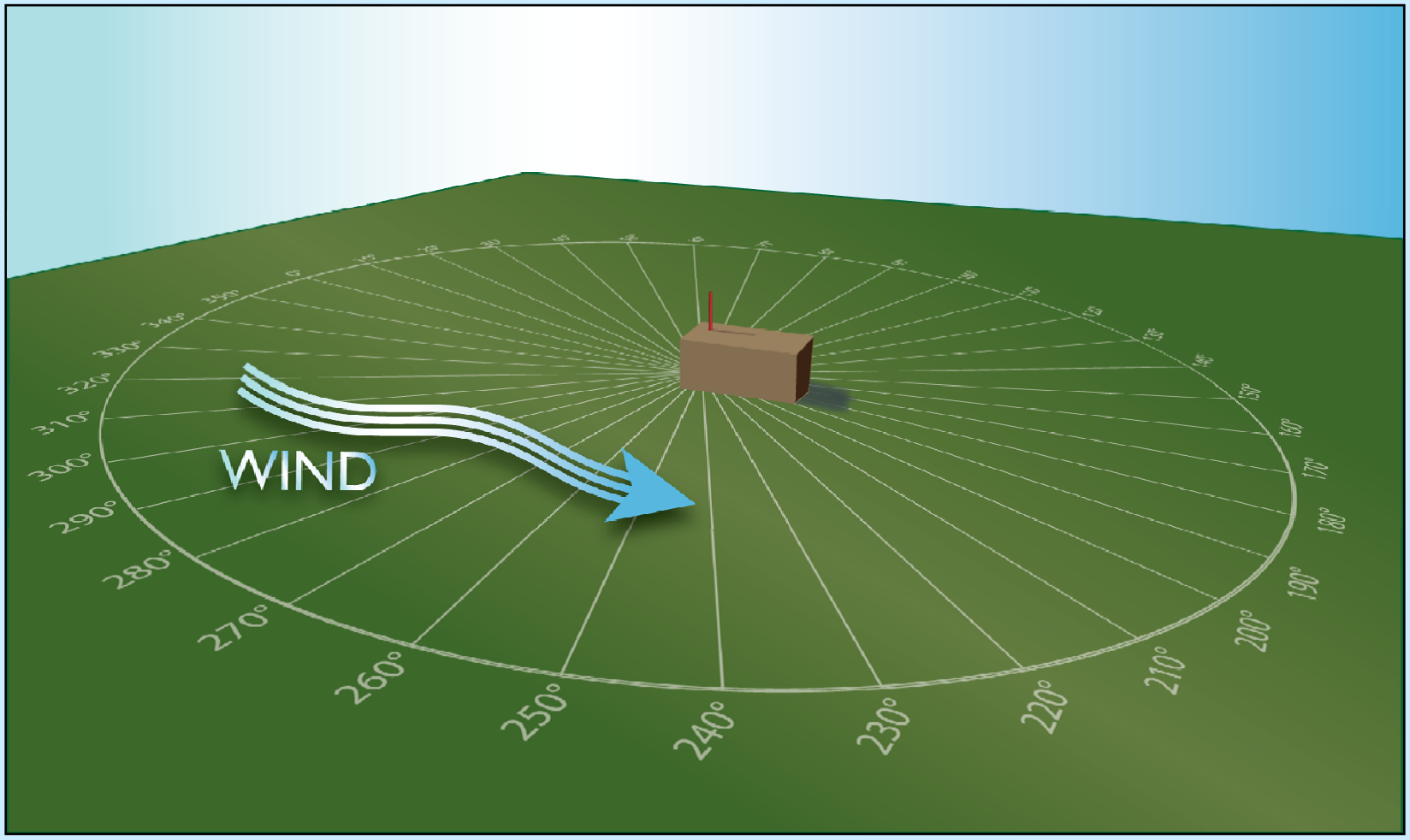
Picking Dominant Structure Example
BPIP Input Information



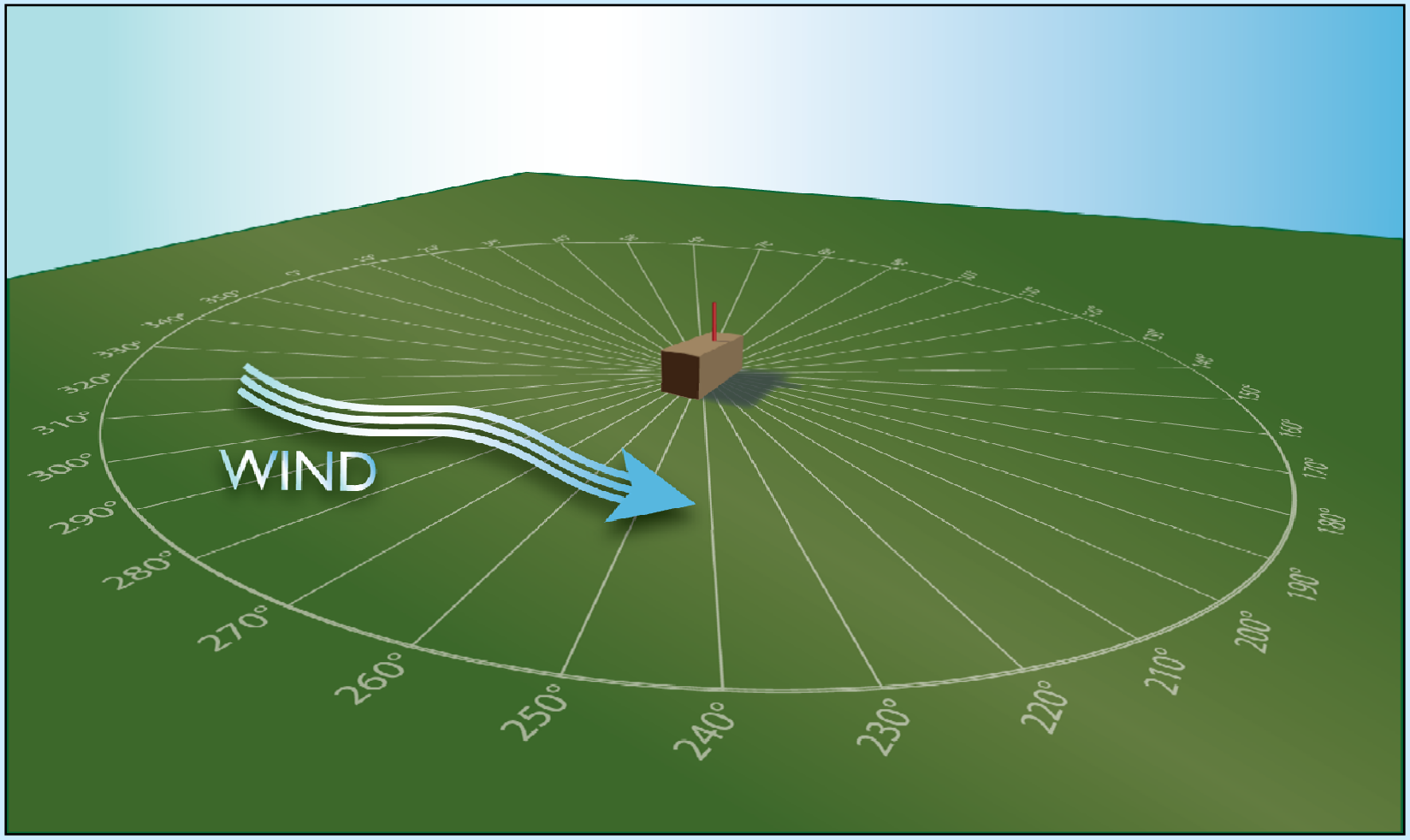
BPIP Input for Entire Site



BPIP Input without upwind Tower



Input needed to model dispersion based on EBD Study



Mirant Power Station – Recent Example

- AERMOD with BPIP predicting high concentrations.
- AERMOD with Equivalent Building Dimensions gave lower concentrations and ones that agreed better with field observations.

- Petersen, R. L., J. Reifschneider, D. Shea, D. Cramer, and L. Labrie, “Improved building Dimension Inputs for AERMOD Modeling of the Mirant Potomac River Generating Station,” 100th Annual A&WMA Conference, Pittsburgh, PA, June 2007
- Shea,D., O. Kostrova, A. MacNutt, R. Paine, D. Cramer, L. Labrie, “ Model Evaluation Study of AERMOD Using Wind Tunnel and Ambient Measurements at Elevated Locations,” 100th Annual A&WMA Conference, Pittsburgh, PA, June 2007.

AERMOD/PRIME Problem for Short/Large Buildings

- The wake algorithms have only been developed/tested for limited building aspect ratios
- Short/large industrial facilities fall outside this range.

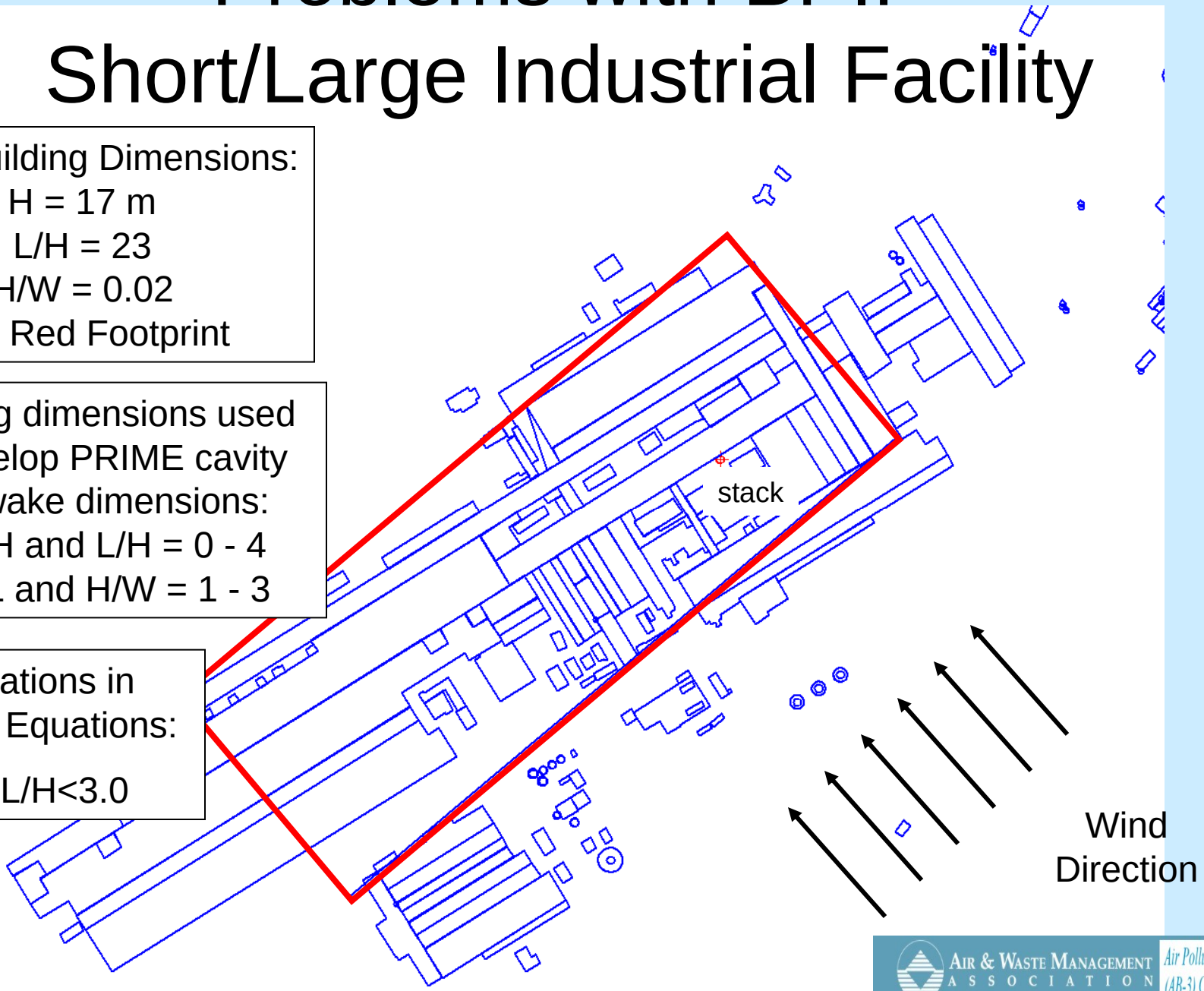
Problems with BPIP
Short/Large Industrial Facility

BPIP Building Dimensions:
H = 17 m
L/H = 23
H/W = 0.02
See Red Footprint

Building dimensions used to develop PRIME cavity and wake dimensions:
W = H and L/H = 0 - 4
W = L and H/W = 1 - 3

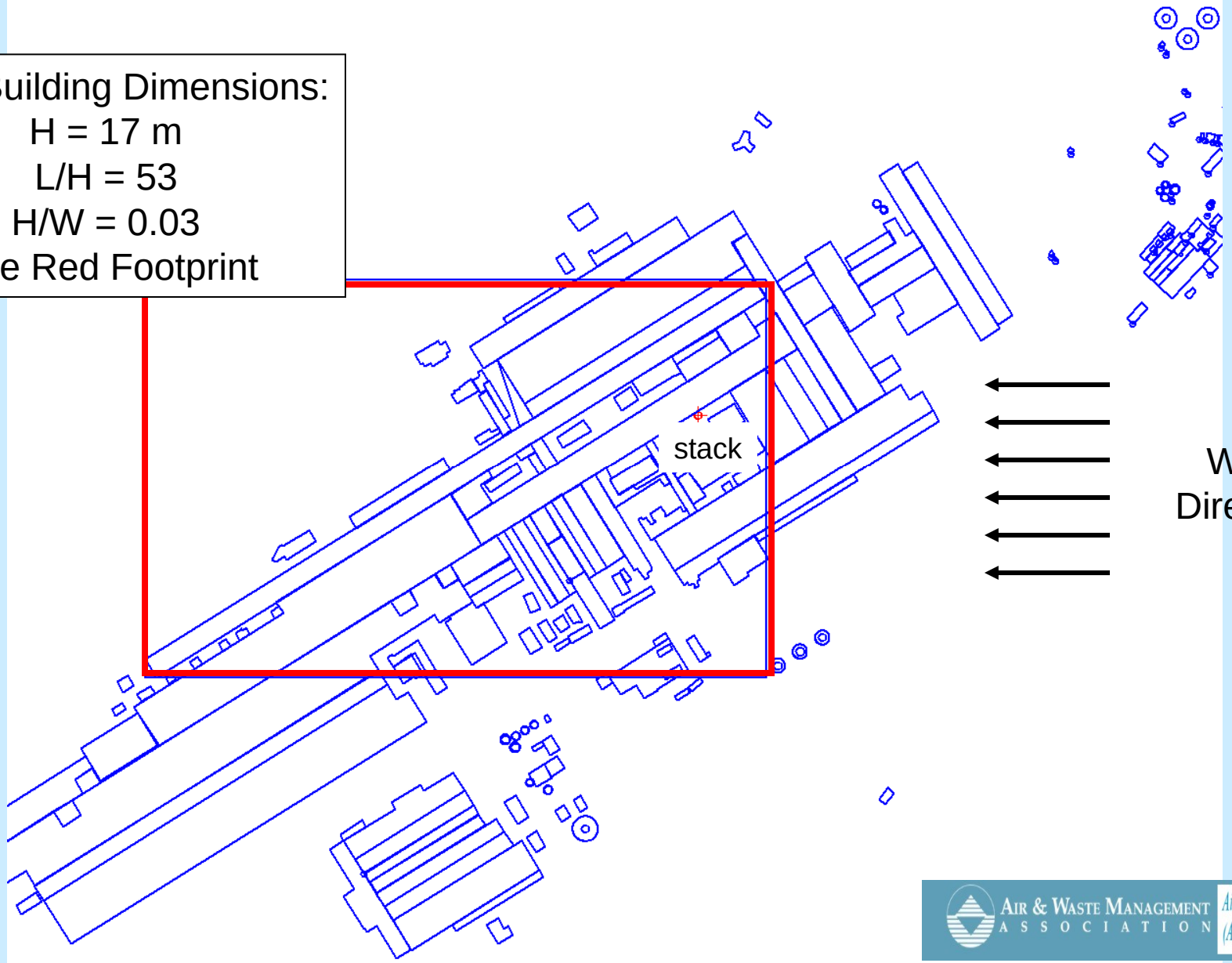
Limitations in PRIME Equations:

0.3<L/H<3.0



Problems with BPIP

BPIP Building Dimensions:
H = 17 m
L/H = 53
H/W = 0.03
See Red Footprint



AERMOD/BPIP Problem for Short/Large Buildings

Source Input Parameters:

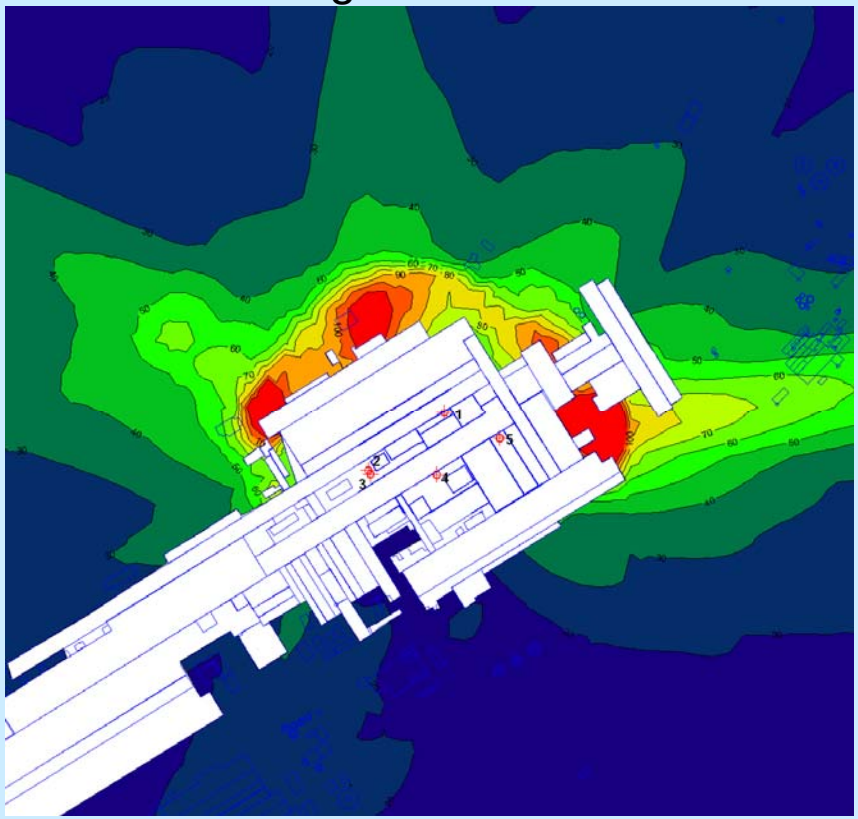
Source Number	Source Height Hs (m)	Stack Inside Diameter d (m)	Stack Exit Velocity V (m/s)	Stack Exit Temperature Ts (K)	Flow Rate (m^3/s)	Emission Rate (g/s)
1	23.16	1.07	17.8	294.1	15.9	0.2
2	26.33	2.74	11.1	315.2	65.7	1.6
3	26.33	2.74	11.4	310.8	67.3	1.6
4	25.91	2.24	17.9	302.4	70.4	1.2
5	21.34	2.46	17.8	310.9	85.0	1.9

Other Model Input:

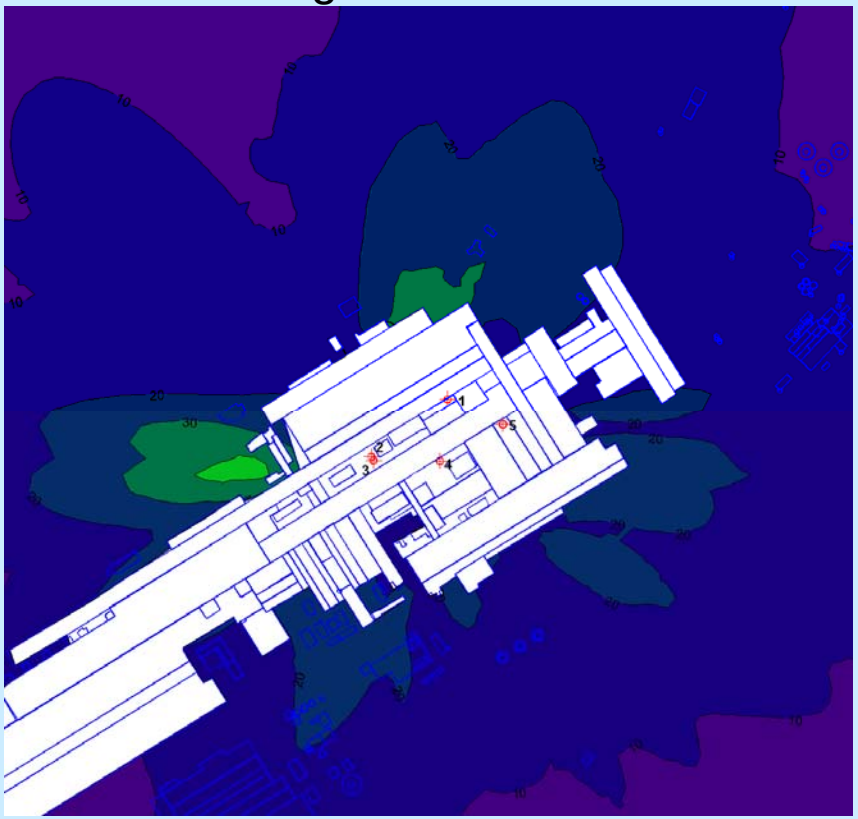
- Meteorology: one year of surface and upper air data from nearby Airport
- Flat terrain
- Uniform Cartesian grid with 3600 receptors
- Regulatory default dispersion options

AERMOD/BPIP Problem for Short/Large Buildings

BPIP
Max = 173.7 ug/m^3



EBD
Max = 43.7 ug/m^3



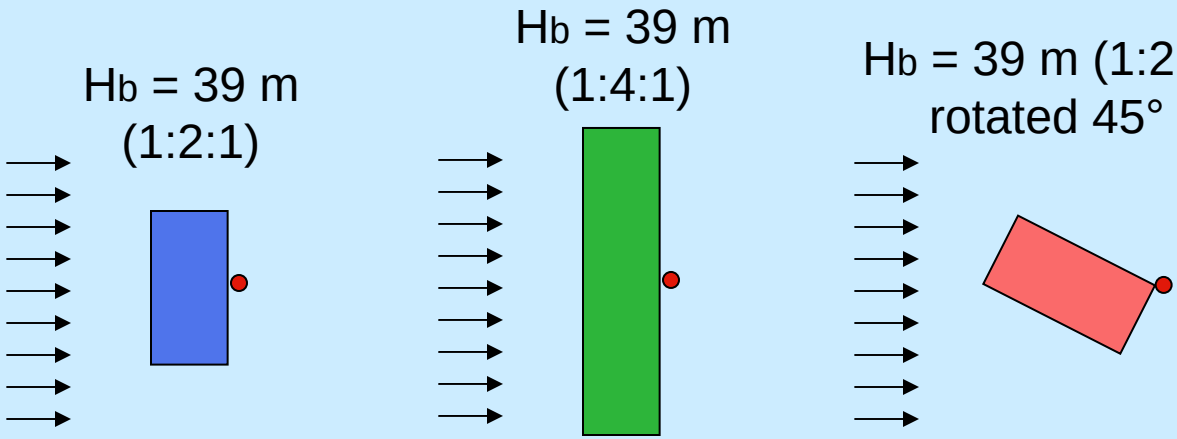
24 hr maximum ground-level concentrations

AERMOD Corner Vortex Issue

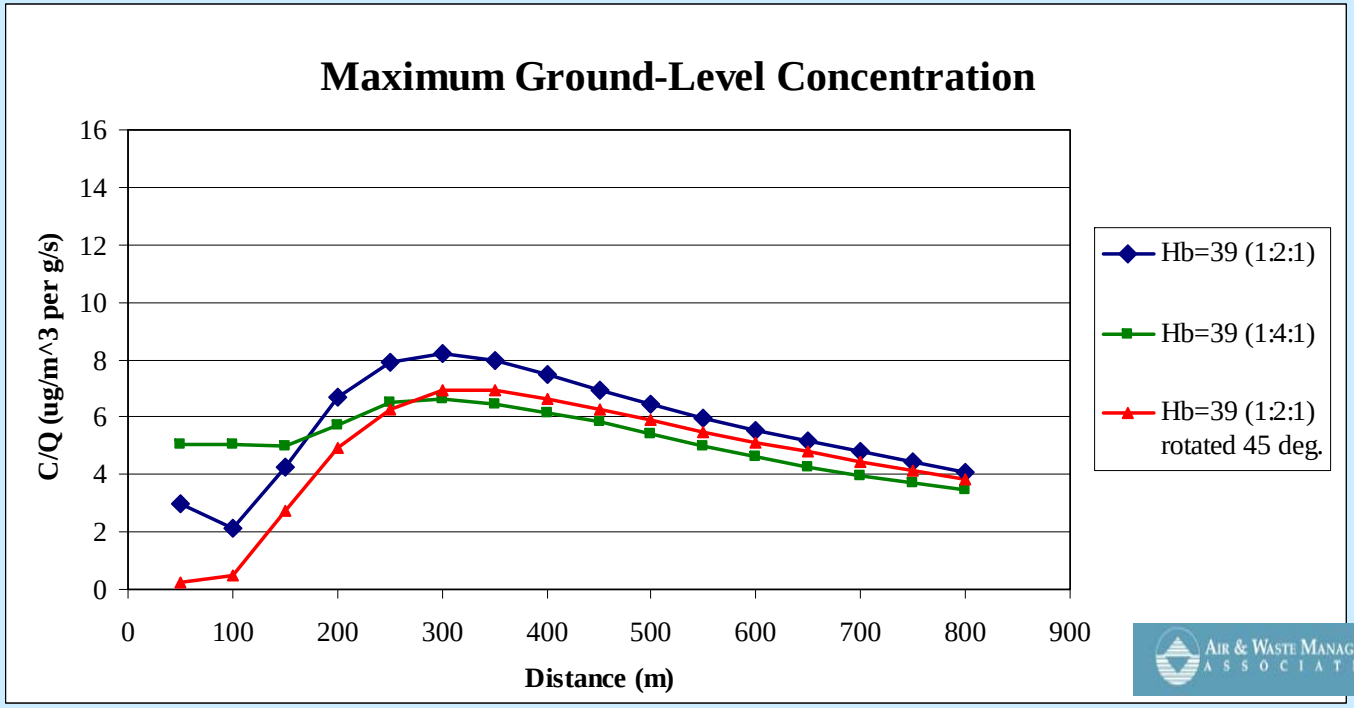
- Current building wake equations do not account for corner vortex
- Corner vortex causes higher concentrations than currently predicted in AERMOD.

Corner Vortex Issue

Stack Height:
  H_s = 48 m
Stack Top Wind Speed:
  U_s = 12.5 m/s
Stack Inside Diameter:
  d = 2.4 m



AERMOD/
PRIME



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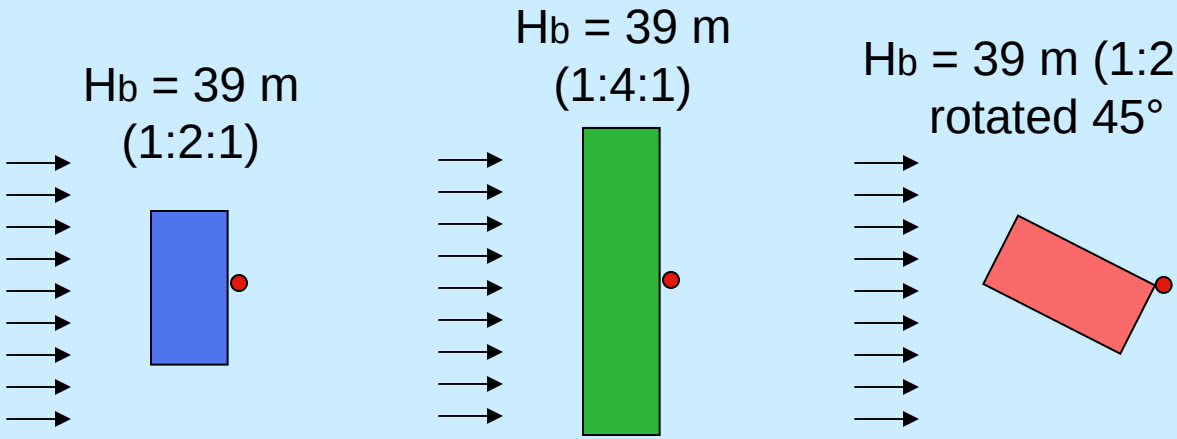
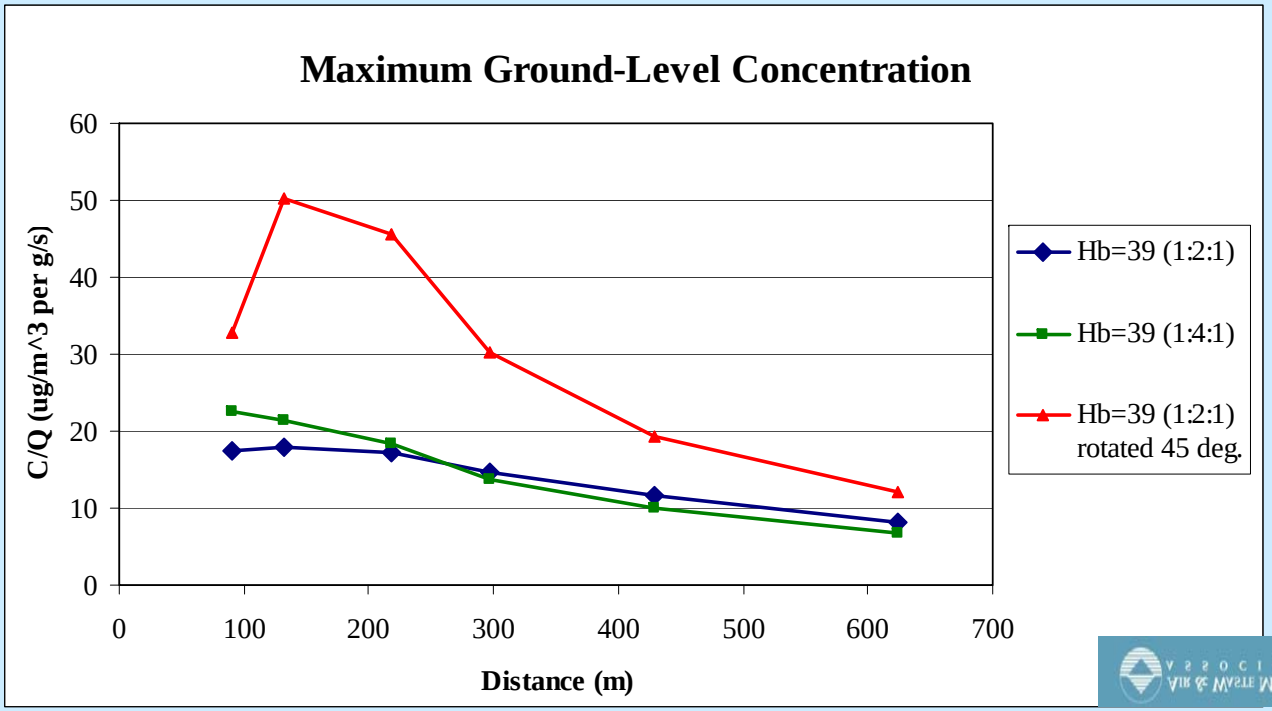


Wind Tunnel Measurements



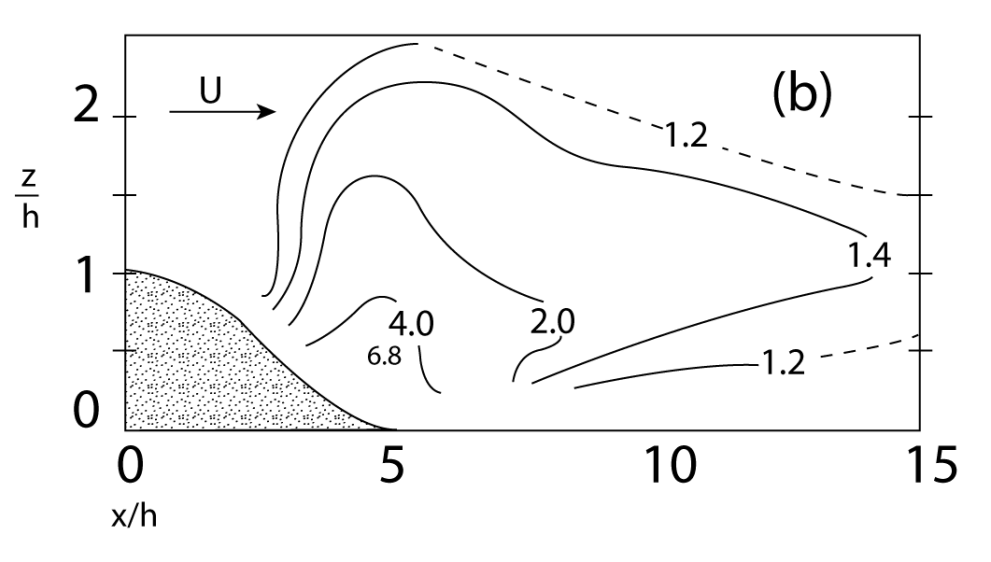
Terrain Wake Effects Neglected

- The GEP stack height regulation defines nearby terrain for the purpose of limiting stack heights.
- Past EPA research shows that the effect of upwind terrain can be significant. Currently this effect is neglected.
- Recent study[1)] showed concentrations increased by a nearly a factor of two when terrain wake effect is accounted for using Equivalent Building Dimensions in AERMOD.
- A method should be developed to determine when upwind terrain wake effects should be considered.

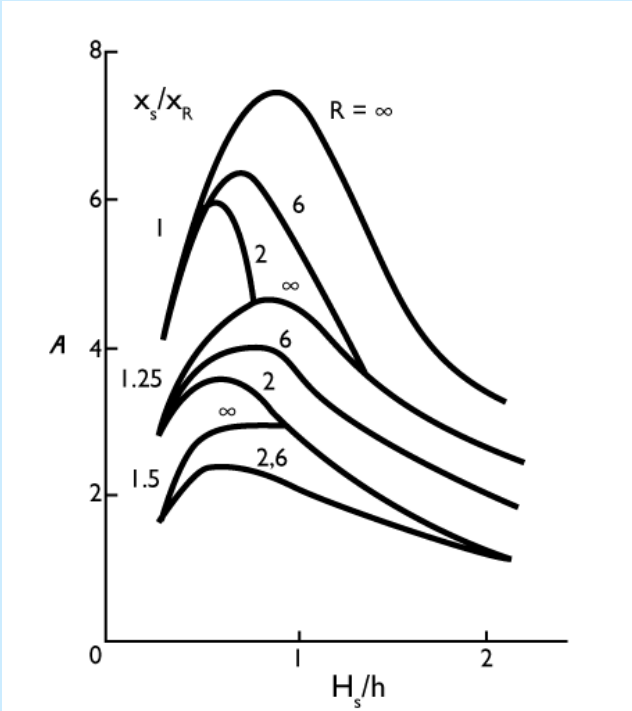
1) Petersen, R., J. Reifschneider, R. Paine, K Schmidt, "Use of Equivalent Building Dimensions (EBD) to Characterize Upwind Terrain Wake Effects for AERMOD," 100th Annual A&WMA Conference, Pittsburgh, PA, June 2007.

Terrain Wake Effects Neglected

EPA Research: Terrain Wake Amplification Factor, A, Ranges from 1.2 to 8.



Contours of constant terrain amplification factors over a two-dimensional ridge (Snyder Atmospheric Environment, Volume 24, 1990)



Variation of terrain amplification factor for sources at or downwind of the reattachment point (Castro, Snyder, and Lawson, (Atmospheric Environment, Volume 22, 1988)

Recommendations

- Continue research on ways to improve BPIP so input dimensions match assumptions in algorithms.
- If needed, update guidance on use of EBD in place of BPIP for AERMOD/PRIME.
- Develop algorithms for the corner vortex situation.
- Develop method for accounting for upwind terrain wake effects.